Risk No.	Rehabilitation Area	Risk	Impacts	Causes	Existing Controls	Inherent Risk					Additional Controls	Residual Risk					Responsible owners /
						Likelihood	Consequence			Severity		Likelihood	Consequence			Severity	
							Safety	Env	Social				Safety	Env	Social		
1	General	Availability of rehabilitation materials	1. Inability to achieve rehabilitation and revegetation to support future land use/s	1. Insufficient growth medium quality and/or quantity recovered from topsoil stockpile for use on WRD and other disturbed areas 2. No clay available on site. Potential clay nearby may not achieve necessary compaction / low permeability	Preplanning for volumes of materials required. Limited skeletal soils available on site. Coarse NAF can be recovered from WRD and haul roads for cover system / rocky mulch (growth media).	Almost certain		Moderate		High	Clay and / or rocky mulch can be sourced off ML (local landowner at additional cost). NAF material utilised as on site source for rocky mulch (crush and screen for fines). Review silty clay appropriateness as growth media	Unlikely		Minor		Low	Senior Environmental Advisor (SEA)
2	Pits	North Pit water storage	1. Formation of pit lake with poor water quality impacting groundwater	1. Overall groundwater sink (evaporation high-no accumulation of storage). 2. Three diversions around pit (creek diversion and levee, east creek diversion and North Pit diversion to be maintained post-closure / assume abandonement bunds / fencing will not intersect diversion) therefore no additional water flowing in. However, review ability to allow clean flow into pits. Minor recharge through soil and sediments, episodic recharge through lineaments aligned with watercourses. Evaporation far exceeds rainfall (minimal recharge from rainfall).	Groundwater monitoring / water balance confirms void is long term groundwater sink for both open cut and underground scenarios	Unlikley		Minor		Low		Unlikely		Minor		Low	SEA
3	Pits	South Pit water storage	1. Formation of pit lake with poor water quality impacting groundwater	1. Overall groundwater sink (evaporation high-no accumulation of storage). 2. Clean water diversion (east diversion drain) around pit (post-closure / cut off by abondonement bund?) therefore no additional water flowing in. Minor recharge through soil and sediments, episodic recharge through lineaments aligned with watercourses. Evaporation far exceeds rainfall (minimal recharge from rainfall).	Groundwater monitoring / water balance confirms void is long term groundwater sink for both open cut and underground scenarios	Unlikley		Minor		Low		Unlikely		Minor		Low	SEA
4	Pits	North Pit water storage	1. Formation of pit lake with poor water quality (unsuitable for stock water)	1. Some understanding of local and regional groundwater to pit lake formation (risk to groundwater considered low, local aquifer confined, groundwater sinks: high evap & low rainfall) 2. Higher than expected mobile contaminants in pit walls (if PAF material exists in walls or as PAF backfill) 3. Overall groundwater sink (evaporation high-no accumulation of storage). Diversion in place around pit therefore no additional water flowing in. Minor recharge through soil and sediments, episodic recharge through lineaments aligned with watercourses. Evaporation far exceeds rainfall (minimal recharge from rainfall). 4. Increased catchment surrounding pit (within safety bund area) resulting in increased inflow if diversion removed (within pit extent of failure)	No PAF material present in walls. Ensure revegetation meets completion criteria to reduce chance of sediment runoff. Direct rainfall to improve water quality (minor dilution). Long term water quality modelling demonstrates livestock water quality	Unlikley		Minor		Low		Unlikely		Minor		Low	SEA
6	Pits	South Pit water storage	1. Formation of pit lake with poor water quality (unsuitable for stock water)	1. Fair understanding of local and regional groundwater to pit lake formation (risk to groundwater considered low, local aquifer confined, groundwater sinks: high evap & low rainfall) 2. Higher than expected mobile contaminants in pit walls (if PAF material exists in walls) 3. Overall groundwater sink (evaporation high-no accumulation of storage). Diversion in place around pit therefore no additional water flowing in. Some fluctuation of groundwater source/levels during wet season. 4. Increased catchment surrounding pit (within safety bund area) resulting in increased inflow	Ensure successful rehabilitation of waste rock dump cap: Rainfall run-off and overland flow from rehabilitated (capped) WRD and ROM to dilute water quality.PAF returned as backfill UG to be saturated with groundwater return. Long term water quality modelling demonstrates livestock water quality	Unlikley		Minor		Low		Unlikely		Minor		Low	SEA
7	Pits	North pit overtopping to receiving environment	1. Downstream release of contaminants 2. Impact on riparian vegetation	1. Fair knowledge and understanding of local and regional groundwater to understand pit lake formation (level and water quality) 2. Higher than expected mobile contaminants in pit walls (if PAF material exists in walls) 3. Overall groundwater sink (evaporation high-no accumulation of storage). Diversion in place around pit therefore no additional water flowing in unless diversion failure(s). Likley inflow from pit walls into pit water is low. 4. Increased catchment surrounding pit (within safety bund area) if diversion removed within extent of pit failure resulting in increased inflow	Any water quality release would be considered to be of good quality. 2024 Water Balance Model : The average water level in North Pit is at the end of the 200-year simulation is 302m AHD, reaching a maximum elevation of 307.6 m AHD (8.4 m below the crest at 316m AHD).	Unlikley		Minor		Low		Unlikely		Minor	Minor	Low	SEA
8	Pits	South Pit overtopping to receiving environment	1. Downstream release of contaminants 2. Impact on riparian vegetation	1. Fair knowledge and understanding of local and regional groundwater to understand pit lake formation (level and water quality) 2. Higher than expected mobile contaminants in pit walls (if PAF material exists in walls) 3. Runoff from WRD may increase contaminants 4. Overall groundwater sink (evaporation high-no accumulation of storage). Diversion in place around pit therefore no additional water flowing in. Some fluctuation of groundwater source/levels during wet season. Likley inflow from pit walls into pit water is low. 5. Increased catchment surrounding pit (within safety bund area) resulting in increased inflow if diversions removed (within extent of pit wall failure).	Water Balance Model (2024): The average water level in the South Pit at the end of the 200-year simulation is 292m AHD, reaching a maximum elevation of 299m AHD (35.3 m below the crest). Water quality is livestock quality.	Rare		Minor		Low		Unlikely		Minor		Low	
9	Pits	Access to Voids	1. Injury or death of a member of the public or livestock	1. Access to steep, unprotected slopes / instability of pit walls / surface subsidence	Long term geotechnical stability assessment completed on open cut and surface subsidence from UG. Construction of abandonement (safety) bunds / gates / barriers / signage located outside maximum extent of pit wall failure.	Rare	Catestrohpic			Medium		Rare	Moderate			Medium	Site Senior Executive (SSE)
10	WRD	Geochemical characteristics of mine waste in WRD	1. Infiltration to encapsulated PAF causing seepage 2. Occurance of poor quality seepage/runoff from WRD impacting groundwater or surface water / riparian vegetation 3. Governance unacceptance of final WRD	Placement of PAF in upper tiers of WRD (5m from surface) and limited compactibility causing potential infiltration oxidation of PAF / leaching 1. Known characteristics of NAF/PAF 2. Known segregation and encapsulation of PAF, reasonable lag time of PAF to oxidise 3. Unknown pad preparation underneath WRD	Encapsualtion of PAF within nominal 5m of NAF within top and edges of dump. Surface of final landform shaped to direct surface run-off to eastern portion of WRD (assumes no cover system).	Likely		Major		High	Cover system to reduce percolation of incidental rainfall and seepage expression from WRD within reasonable timeframe (5 years), to consider erosion potential, technical specification by engineer, as con certification of cover system, followed by verification cover system works. Remove upper level of PAF from WRD and return back underground as backfill, saturated under groundwater return.	Unlikely		Major		Medium	SSE
11	WRD	WRD Landform stability - geotechnical	1. Uncontrolled release of waste material (AMD) to downstream environment 2. Serious injury to humans, native fauna and livestock	1. Exposure of encapsulated PAF	Natural angle of repose: 'Geotechnical Modelling slope stability FOS over 1.5 achieved (FOS 1.83 ATC, 2019).	Rare		Moderate		Low		Rare	Moderate			Low	SSE
12	WRD	WRD Landform stability - erosional	1. Exposure of encapsulated PAF 2. Landform rilling/gullying, sedimentation of landform, drainage lines and downstream environment, etc.	1. Storm event that exceeds design criteria 2. Inadequate cover design 3. Inadequate characterisation of rehabilitation materials 4. Availability of suitable rehabilitation materials 5. Failure of water management measures 6. Inadequate sediment control measures 7. Unmanaged access by people/vehicles/fauna 8. Lack of vegetation growth	Maintain diversions, rainfall shedding landform. Non ersoive material used in rehabilitation. LEM (calibrated WEPP) indicates erosional stability (negligible erosion)	Unlikely		Minor		Low	Designed cover system with non-erosive materials, restricted access by public and livestock until stable/ vegetation established	Unlikely		Minor		Low	SEA
13	General	General landform stability - erosional	1. Erosion and sedimentation of landform and downstream environment, landform rilling/gullying etc.	1. Storm event that exceeds design criteria 2. Failure of water management measures 3. Inadequate sediment control measures 4. Unmanaged access by people/vehicles/fauna 5. Lack of vegetation growth	Erosion & sediment control - silt fences/sediment traps/coir logs until reabilitation is established. Site access security to prevent people/vehicles. Final site contouring for water management. Established vegetation from rehab	Unlikley		Insignificant		Low						Low	SEA

Risk No.	Rehabilitation Area	Risk	Impacts	Causes	Existing Controls	Inherent Risk					Additional Controls	Residual Risk					Responsible owners /
						Likelihood	Consequence			Severity		Likelihood	Consequence			Severity	
							Safety	Env	Social				Safety	Env	Social		
14	Water Infrastructure	Diversions	1. Erosion and sedimentation of diversions and downstream environment etc.2. Inflows to pits	1. Diversions within extent of pit wall failure, in the longer term removed.	Geotech assessments: South Pit diversion / gully located outside pit wall failure extents. Erosion & sediment control - silt fences/sediment traps/coir logs until rehabilitation is established. Maintain culverts at natural drainage lines (landowner agreement)	Unlikley		Minor		Low		Rare		Insignificant		Low	SSE
15	Water Infrastructure	WRD Sed Dam	1. Landowner may not accept at closure 2. Contaminants from sediments and lining impacting surface water quality	1. Removal of dam before WRD rehabilitation complete 2. Depth of in-situ burial adequate	Landowner agreement to take on dam. Currently very little presence of sediments within dam. Maintain dam until WRD rehab is complete/certified	Rare		Minor		Low	Rehabilitating prior to surrender	Rare		Minor		Low	SSE
16	Infrastructure	Residual infrastructure or equipment	1. Minor Injury to livestock and / or public	1. Water infrastructure (polypipe)/groundwater bores (TBC) left behind post closure	Make safe to agreed condition upon leaving. Fencing / bunding of water management infrastructure	Unlikley			Insignificant	Low						Low	SSE
17	Infrastructure	ROM and infrastructure (rehab areas)	1. Soil contamination resulting in reduced soil fertility and land capability 2. Potential contamination of surface water run off 3. Potential groundwater contamination	1. Remediation action was not suitable or successful	Site contmination assessment. Removal of identified contaminants. Recontouring of infrastructure areas for water management. Lack of shallow groundwater aquifers within the area. Decommissioning/demobilising infrastructure	Unlikley		Insignificant		Low						Low	SEA
18	General	Site contamination - Hydrocarbon	1. Soil contamination resulting in reduced soil fertility and land capability 2. Potential contamination of surface water run off 3. Potential groundwater contamination	1. Hydrocarbon area 2. Elevated metals, preventing soil quality screening guidelines from being met 3. Increased salinity	Site contmination assessment. Removal of identified contaminants. Recontouring of infrastructure areas for water management. Lack of shallow groundwater aquifers within the area. Decommissioning/demobilising infrastructure	Unlikley		Insignificant		Low						Low	SEA
19	General	Exploration areas and tracks	1. Erosion and sedimentation of landform and downstream environment, landform rilling/gullying etc.	1. Storm event that exceeds design criteria 2. Failure of water management measures 3. Inadequate sediment control measures 4. Unmanaged access by people/vehicles/fauna 5. Lack of vegetation growth	Maintain tracks in a good condition upon surrender. Landowner agreement in place. Reduce roads down to LV/single lane access. Rehabilitate road verges. Fencing and gates to restrict access.	Likely		Insignificant		Medium	Bed level crossing installed between CP7 & CP9 on Greenback Access Road once haulage finishes, included in landowner agreement.	Unlikely		Insignificant		Low	SEA
20	General	Availablity of seeds/seed quality	1. Inability to achieve rehabilitation and revegetation to support future land use/s/ PMLU	1. Lack of seed availability or poor quality seeds (restricted to endmic species as per EA) 2. Poor seed hygiene and/or storage 3. Seed storage time exceeded	Agreement with landowner of rehabilitation seeds, in accordance with EA conditions (seeds endemic to the area). Purchased from a reputable supplier. Sowing of seeds prior to rainfall events / season, or within two weeks after seeding - watering program as per tender	Unlikley			Insignificant	Low						Low	SEA
21	General	Weed, pests and livestock impacts	1. Weed and pest increase during/following rehabilitation	1. Inadequate weed/pest management program 2. Inadequate monitoring program and poor weed hygiene of introduced machinery	Monitoring program and annual evaluation of weed diversity/abundance. Undertake weed and pest control program as required prior to surrender	Unlikley		Insignificant		Low						Low	SEA
22	General	Fire management	1. Fire kills revegetation 2. Fire damages HDPE liner at WRD Sed Dam	1. Fire management not in place or followed correctly 2.Fire by lightening strike or other natrual cause	Tracks onsite to be considered firebreaks, with maintenance as required (landowner agreement). Grazing by livestock to keep fuel load down. Seeds to be endemic/naturally regenerating. Ensure dam is a good condition for landowner handover	Likely		Minor		Medium	Landowner agreement to maintain firebreaks	Likely		Minor		Medium	SEA
23	General	Cultural heritage	1. Disturbance or impacts to known cultural heritage sites	Aretefacts or sites of significanc are interefered wih / not protected during rehabiltation activities.	All artefacts have been relocated to one area, with limited access/well away from infrastructure. Existing fencing in place to prevent disturbance. Site CHMP to be followed during rehab activities.	Unlikley			Moderate	Medium	Upgrade signage, contractors to be made aware of "no-go" zones during rehabilitation activities	Rare			Moderate	Low	SSE

REPORT

AERIS RESOURCES LIMITED

Barbara Copper Project Progressive Rehabilitation and Closure Planning – Hydraulic Assessment

118131.12.R001
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CONTENTS

1 INTRODUCTION 1

1.1 Background and Purpose 1
1.2 Site Watercourses and Drainage Features 2
1.3 Scope of Work 4
1.4 Methodology 4
1.5 Structure of Report 4

2 HYDROLOGIC ASSESSMENT 6

2.1 General 6
2.2 Probable Maximum Precipitation 6
2.3 Rare Precipitation Estimation 8

3 HYDRAULIC ASSESSMENT 10

3.1 Model Overview 10
3.2 Model Domain 10
3.3 Post-closure Infrastructure Retention 10
3.4 Post-closure Infrastructure Deletion and Remediation ..... **Error! Bookmark not defined.**
3.5 Digital Elevation Model 12
3.5.1 Base Topography 13
3.5.2 Post-Closure Surface Modifications 14
3.5.2.1 WRD 14
3.5.2.2 North Pit 14
3.5.2.3 South Pit 16
3.5.2.4 LIA and ROM 17
3.5.2.5 WRD Sediment Dam 17
3.5.2.6 Haul Road 17
3.6 Grid Size Selection and Time Step 19
3.7 Boundary Conditions 19
3.8 Surface Roughness 20
3.9 Road Crossings 22
3.10 Sensitivity Analysis 22

4 RESULTS 23

4.1 Introduction 23
4.2 North Pit, Diversion Drain and Levee 24
4.3 South Pit and Rehabilitated ROM Pad 26
4.4 WRD Sediment Dam 27
4.5 WRD Sediment Dam Diversion Drain 28
4.6 WRD 30
4.7 Light Infrastructure Area 30
4.8 Unnamed Tributary of Leichardt River 31
4.9 Sensitivity Analyses 32

5 PRCP INPUTS AND DISCUSSION 34

5.1 General 34
5.2 North Pit and South Pit 34
5.3 Unnamed Tributary of Weatherly Creek 34

6 SUMMARY AND CONCLUSIONS 36

REFERENCES 37

TAILINGS.WATER.WASTE.

TABLES

TABLE 1: GSDM FACTORS FOR PMP ESTIMATE 6
TABLE 2: GTSMR FACTORS FOR PMP ESTIMATE 6
TABLE 3: PMP DEPTH ESTIMATE 7
TABLE 4: RARE RAINFALL DEPTH ESTIMATES 8
TABLE 5: HAUL ROAD MODIFICATIONS .....**ERROR! BOOKMARK NOT DEFINED.**
TABLE 6: DIVERSION DRAIN DIMENSION VS GRID SIZE 19
TABLE 7: MANNINGS 'N' ROUGNESS COEFFICIENTS 21
TABLE 8: ROAD CROSSING DETAILS 22
TABLE 9: HYDRAULIC MODELLING RESULTS – LOCATIONS ADJACENT TO THE NORTH PIT . 24
TABLE 10: HYDRAULIC MODELLING RESULTS – ROM PAD AND SOUTH PIT 26
TABLE 11: HYDRAULIC MODELLING RESULTS – WRD SEDIMENT DAM 27
TABLE 12: HYDRAULIC MODELLING RESULTS – WRD SEDIMENT DAM DIVERSION DRAIN 28
TABLE 13: HYDRAULIC MODELLING RESULTS - WRD 30
TABLE 14: HYDRAULIC MODELLING RESULTS - LIA 30
TABLE 15: HYDRAULIC MODELLING RESULTS - UNNAMED TRIBUTARY OF THE LEICHARDT RIVER 31
TABLE 16: SENSITIVITY ANALYSIS RESULTS – 0.1% AEP EVENT 33

DIAGRAMS

DIAGRAM 1: SITE LOCATION 1
DIAGRAM 2: SITE LAYOUT 2
DIAGRAM 3: REGIONAL WATERCOURSES 3
DIAGRAM 4: PMP DEPTH ESTIMATE 7
DIAGRAM 5: TUFLOW MODEL DOMAIN 11
DIAGRAM 6: DIVERSION DRAINS TO BE RETAINED AND REMOVED 12
DIAGRAM 7: TOPOGRAPHICAL INPUTS AND EXTENTS 13
DIAGRAM 8: NORTH PIT BUND ALIGNMENT 15
DIAGRAM 9: SOUTH PIT BUND GULLY 16
DIAGRAM 10: ROM AREA SURFACE TOPOGRAPHY 17
DIAGRAM 11: ROAD CROSSING LOCATIONS 18
DIAGRAM 12: BOUNDARY CONDITION LOCATIONS 20
DIAGRAM 13: MANNINGS ROUGHNESS 21
DIAGRAM 14: RESULTS REPORTING LOCATIONS 23
DIAGRAM 15: PMF DEPTHS ADJACENT TO THE NORTH PIT 25
DIAGRAM 16: PMF DEPTHS ADJACENT TO THE ROM PAD AND SOUTH PIT 27
DIAGRAM 17: PMF DEPTHS AT WRD SEDIMENT DAM DIVERSION DRAIN 29
DIAGRAM 18: FLOOD PROFILE OF THE UNNAMED TRIBUTARY OF THE LEICHARDT RIVER ... 35

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FIGURES

FIGURE 1: PROBABLE MAXIMUM FLOOD – MAXIMUM DEPTH
FIGURE 2: PROBABLE MAXIMUM FLOOD – MAXIMUM VELOCITY
FIGURE 3: 1:1,000 AEP – MAXIMUM DEPTH
FIGURE 4: 1:1,000 AEP – MAXIMUM VELOCITY
FIGURE 5: 1:100 AEP – MAXIMUM DEPTH
FIGURE 6: 1:100 AEP – MAXIMUM VELOCITY

APPENDICES

APPENDIX A: PROBABLE MAXIMUM PRECIPITATION ESTIMATION
APPENDIX B: HAUL ROAD CULVERT PHOTOS

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1 INTRODUCTION

1.1 Background and Purpose

Aeris Resources Limited (Aeris) owns and operates the Barbara Copper Project (BCP), located on mining lease ML90241 within Mt Isa City Council region. The BCP is located approximately 49 km northeast of Mt Isa and is accessed via Lake Julius Road from the Barkly Highway. The BCP is located at the upstream extents of an unnamed tributary of the Leichardt River. The unnamed tributary of Leichardt River and the Leichardt River are located in the Gulf Rivers Basin which discharges into the Gulf of Carpentaria. The location of the BCP relative to Mt Isa and Cloncurry is shown on **DIAGRAM 1**.

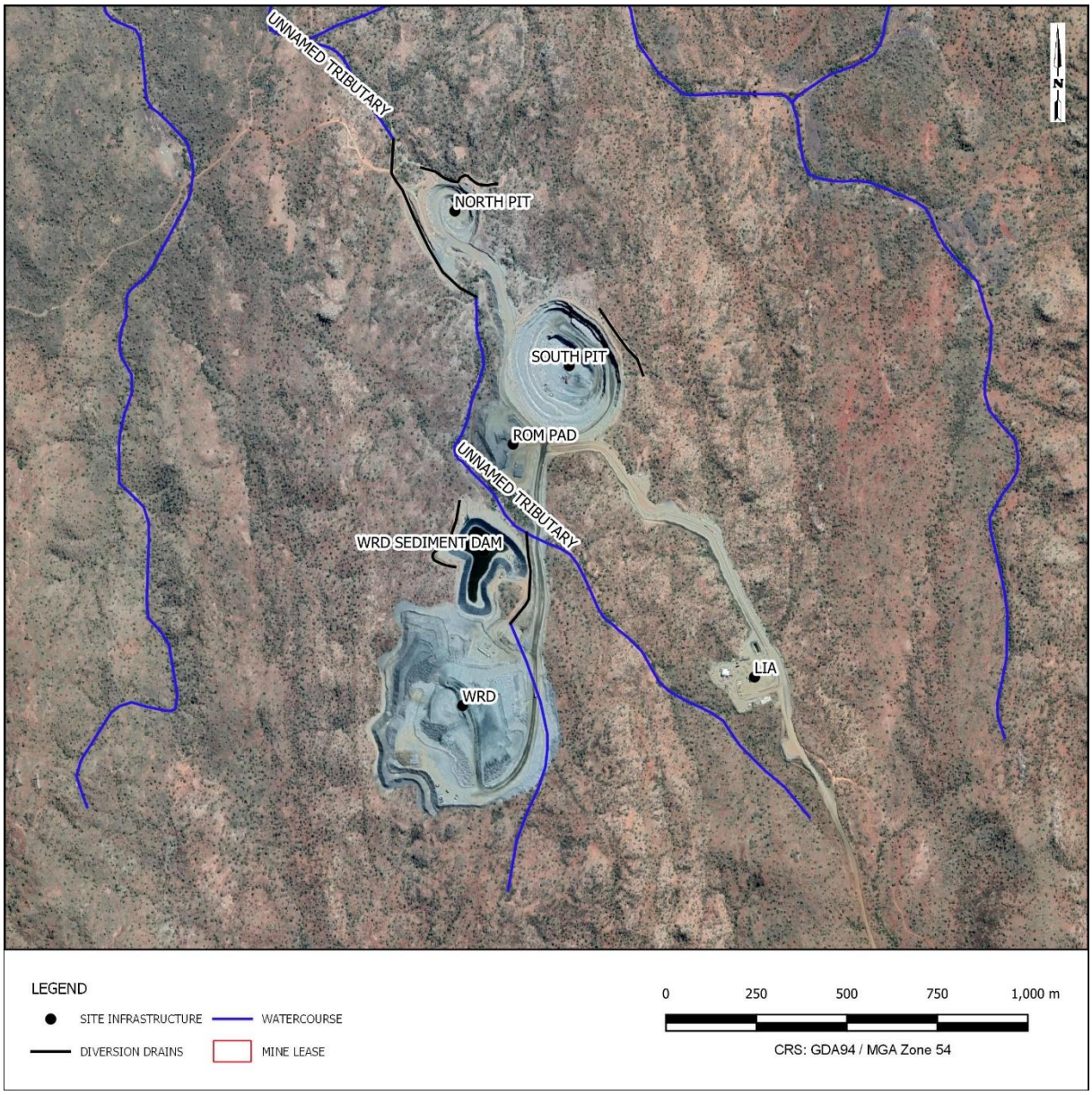
DIAGRAM 1: SITE LOCATION

The purpose of this report is to develop a flood profile for the BCP site as part of the Progressive Rehabilitation and Closure Plan (PRCP) in accordance with the PRCP guidelines **[1]**. The site's flood profile will be developed for the Probable Maximum Flood (PMF), 1:1,000 and 1:100 Annual Exceedance Probability (AEP) design storm events. Additionally, the locations of the North Pit and South Pit relative to the extents of the 1:1,1000 AEP (0.1% AEP) design storm event floodplain will be assessed.

1.2 Site Watercourses and Drainage Features

The BCP is located on the western and eastern banks of an unnamed tributary of the Leichardt River, which runs in an approximate southeast to northwest direction. The route of this unnamed tributary was formalised by the construction of two permanent diversion drains. The most upstream (southerly) diversion is to the east of the WRD Sediment Dam and the most downstream (northerly) diversion is to the west of the North Pit. The two diversion drains and an associated levee at the North Pit were sized to convey flows up to and including the 1:1,000 AEP (0.1% AEP) design storm event. The locations of the exiting site features (including diversion drains) are depicted on **DIAGRAM 2**.

DIAGRAM 2: SITE LAYOUT



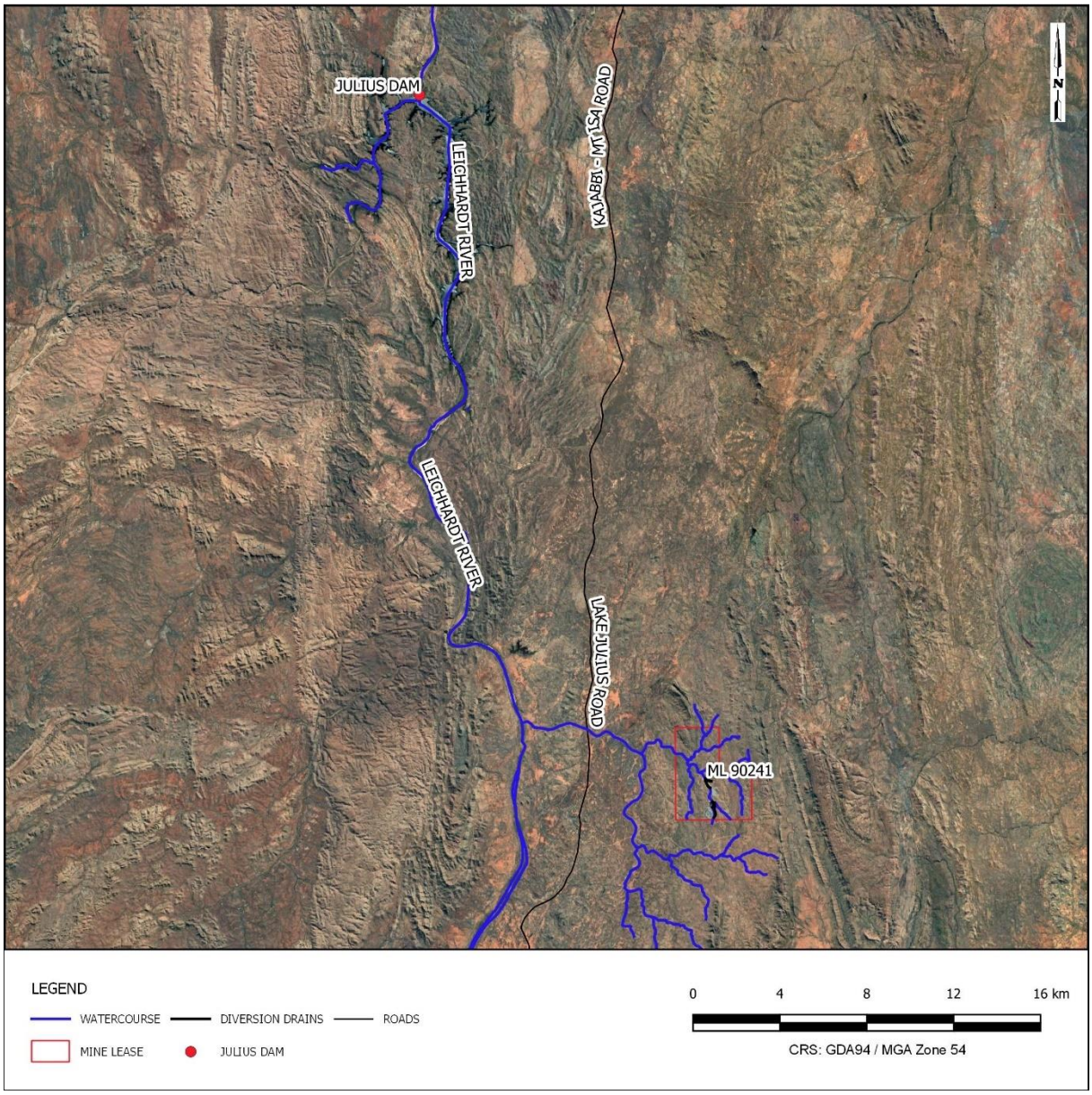
The North Pit, South Pit, rehabilitated Run of Mine (ROM) Pad, rehabilitated Light Infrastructure Area (LIA) (including site offices and workshop area) are located on the eastern bank of the unnamed tributary of the Leichardt River. The WRD and WRD Sediment Dam are located on the western bank of the unnamed tributary of the Leichardt River. The WRD is to be capped with material from the rehabilitated ROM Pad, LIA and roads. The WRD Sediment Dam, North Pit and South Pit are to be retained for stockwater use by the landowner.

The rehabilitation of the ROM Pad includes the removal of all current material to pre-mining conditions, shaping, ripping and revegetation. The rehabilitation of the LIA Pad involves reshaping, ripping and revegetation. The workshop area with the LIA will be stripped of the top 500 mm of material (where possible) or to a depth where no hydrocarbon contamination is present. Following this, the workshop area will be shaped, ripped and revegetated.

The unnamed tributary of the Leichardt River conveys flows to the Leichardt River approximately 9.5 km to the west-northwest of the BCP. All tributaries to the east of the Leichardt River within mine lease 90241 are unnamed. As such, when the unnamed tributary of the Leichardt River is henceforth referred to, it refers to the watercourse that flows through the BCP site and its continuing flow path to the Leichardt River.

Excluding the BCP, there are no dams or engineered structures on the unnamed tributary of the Leichardt River which might impact the characteristics of surface water runoff or flood behaviour. Approximately 35 km north of the confluence of the unnamed tributary of the Leichardt River with the Leichardt River, the Leichardt River is impounded by the Julius Dam. The location of the unnamed tributary of the Leichardt River, the Leichardt River, Julius Dam and the BCP mining lease are depicted on **DIAGRAM 3**.

DIAGRAM 3: REGIONAL WATERCOURSES



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1.3 Scope of Work

The following scope of work is required by Aeris to complete their PRCP submission.

- To provide a flood risk profile for the site under post-closure conditions.
- To provide flood mapping to show water depths and velocities on the final landform design.

The flood risk profiles for the unnamed tributary of the Leichardt River (including diversion drains), North Pit, South Pit, and the ROM Pad at the BCP are required by the PRCP guidelines **[1]**. In consultation with Aeris, it was agreed to model the following events:

- Probable Maximum Flood (PMF) resulting from the Probable Maximum Precipitation (PMP);
- 1:1,000 AEP (0.1% AEP) design storm event; and
- 1:100 AEP (1% AEP) design storm event.

Australian Rainfall and Runoff (ARR) **[2]** was utilised to develop the design rainfall depth estimates for input into a 2D TUFLOW hydraulic model.

1.4 Methodology

The methodology adopted to achieve the scope of works for the PRCP flood study consists of the following three tasks.

- Hydrologic assessment of the site and upstream catchments. This will include:
  - Estimation of PMP; and
  - Estimation of site rainfall for the 0.1% AEP and 1% AEP design events from the Bureau of Meteorology (BoM) datasets.
- Hydraulic modelling of the site and upstream catchments. This will include:
  - Setting up a digital elevation model (DEM) of the site that conceptually represents the post-closure site conditions;
  - Estimation of surface roughness conditions;
  - Undertaking grid size sensitivity testing to establish the most appropriate grid size for modelling;
  - Undertaking model sensitivity testing for rainfall and roughness variations to investigate the impacts of both an increase and decrease in rainfall estimates and surface roughness on model performance and flood behaviour; and
  - Producing mapping of flood depths and velocities for the modelled storm events.
- Preparation of a report to present the results of the modelling for inclusion in Aeris' PRCP submission.

1.5 Structure of Report

The structure of the report, to address the above scope of works, is as follows.

Section 2	Details the hydrologic estimations undertaken for the site. This section includes the inputs and outcomes of the rainfall estimation process for the PMP, 0.1% AEP and 1% AEP design events.
Section 3	Details the development of the TUFLOW hydraulic model utilised to estimate the response of the post-closure surface to the estimated hydrographs from **Section 2.**
Section 4	Presents and discusses the results of the post-closure conditions.

Section 5 Discusses relevant results to inform the PCRP planning and design.

Section 6 Provides a summary of the hydraulic assessment and conclusions drawn from the results.

2 HYDROLOGIC ASSESSMENT

2.1 General

The BCP site is located within the upper extents of the unnamed tributary of the Leichardt River. As such, the unnamed tributary of the Leichardt River has no external upstream catchments from which it may receive inflows. As a consequence, direct rainfall was applied to the hydraulic model grid, which included the upper catchment of the unnamed tributary of the Leichardt River. Due to the location of the BCP within the upper catchment of the unnamed tributary of the Leichardt River, a one dimensional hydrologic model was not required as the direct rainfall approach incorporates the full upstream catchment extents.

2.2 Probable Maximum Precipitation

The PMP for the site was assessed in accordance with ARR **[2]**. The site is located in the generalised tropical storm coastal zone and therefore the Generalised Short Duration Method (GSDM) **[3]** was adopted for event durations between 0.25 hrs and 6 hrs and the Generalised Tropical Storm Method Revised (GTSMR) **[4]** was adopted for event durations between 24 hrs and 120 hrs.

The GSDM and GTSMR require catchment factors to be applied to the initial rainfall depths to estimate the PMP for the site. The site specific values of the catchment factors utilised in deriving the PMP estimates are summarised in TABLE 1 for the GDSM and TABLE 2 for the GTSMR. A summary of the PMP calculations is provided in **Appendix A**.

TABLE 1: GSDM FACTORS FOR PMP ESTIMATE

Parameter	Value
Duration Limit	0.25 - 6 hrs
Proportion Smooth	0.5
Proportion Rough*	0.5
Mean elevation at site (m AHD)	350
Elevation Adjustment Factor (EAF)	1.0
Moisture Adjustment Factor (MAF)	0.9471

*Rough terrain is classified at that in which elevation changes of 50 m or more within horizontal distances of 400 m are common **[3].**

TABLE 2: GTSMR FACTORS FOR PMP ESTIMATE

Parameter	Value
Topographical Adjustment Factor (TAF)	1.01
Decay Amplitude Factor (DAF)	0.9796
Extreme Precipitable Water (Annual)	98.82
Extreme Precipitable Water (Winter)	66.33

The factors in TABLE 1 and TABLE 2 were applied to generate the PMP depths for 0.25 hr to 120 hr durations, as shown on DIAGRAM 4 and in TABLE 3.

DIAGRAM 4: PMP DEPTH ESTIMATE

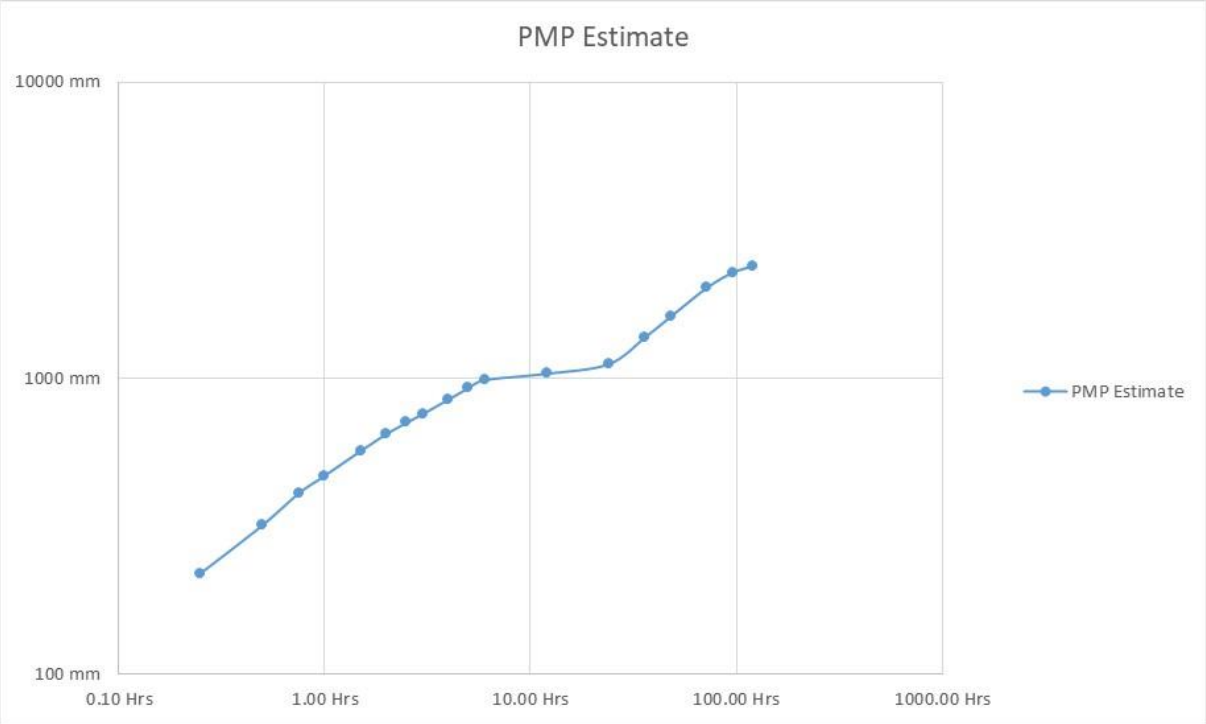

TABLE 3: PMP DEPTH ESTIMATE

Duration (hr)	Total Rainfall Depth (mm)
0.25	220
0.5	320
0.75	410
1.0	470
1.5	570
2.0	650
2.5	710
3.0	760
4.0	850
5.0	930
6.0	990
12.0	1,040
24.0	1,120
36.0	1,380
48.0	1,620
72.0	2,030
96.0	2,280
120.0	2,400

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2.3 Rare Precipitation Estimation

Rare events are defined as events with an AEP equal to or greater than the 5% AEP event. Rainfall estimates for the 1% and 0.1% AEP storm events for the BCP site were obtained from the Bureau of Meteorology's 'Design Rainfall Data System' **[5]**. The rainfall depths for these events are summarised in **TABLE 4**.

TABLE 4: RARE RAINFALL DEPTH ESTIMATES

Duration	Rainfall Depth (mm)	
	1% AEP	0.1% AEP
1 min	3.2	4.7
2 min	6.6	9.6
3 min	10.3	15
4 min	13.8	20.3
5 min	17.3	25.3
10 min	31.3	46.3
15 min	41.7	61.7
20 min	49.7	73.5
25 min	56.3	82.9
30 min	61.8	90.9
45 min	74.1	108.9
1 hour	83.1	121.2
1.5 hour	96.2	139.6
2 hour	105.6	153
3 hour	119.9	174.8
4.5 hour	138.7	203.2
6 hour	154.8	230.7
9 hour	180.5	271.6
12 hour	200.5	301.4
18 hour	232.7	347.1
24 hour	259	382
30 hour	280.9	407.9
36 hour	299.8	431.7
48 hour	331.8	472.3
72 hour	376.8	534.9
96 hour	406.9	579.8
120 hour	428.1	612
144 hour	442.4	636.3
168 hour	452.6	653.7

Each duration event is further divided into an ensemble of ten temporal patterns (TP), as detailed in the Australian Rainfall and Runoff (ARR) Datahub **[6]**. The variations in the temporal patterns account for rainfall patterns not being uniform for their duration, with periods of more intense and less intense rainfall occurring within a single rainfall event. Rainfall estimates from **TABLE 3** and **TABLE 4** were applied directly to the hydraulic model as rain on grid. This is discussed further in **Section 3.7**.

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3 HYDRAULIC ASSESSMENT

3.1 Model Overview

Hydraulic analysis of the study area has been undertaken using the two dimensional (2D) finite difference program TUFLOW, which is an industry accepted software package highly suited to the investigation of flood behaviour in complex flow scenarios. The model can simulate unsteady hydrodynamic flow in two dimensions on a rectilinear grid. The model is based on a robust finite difference solution scheme that can compute both sub-critical and supercritical flow regimes. The selected hydraulic solver for the 2D model was the HPC scheme.

3.2 Model Domain

The TUFLOW model was set up to quantify the impacts of the PMP, 0.1% AEP and 1% AEP design storms on the post-closure site arrangement, as shown on **DIAGRAM 2**. The model domain is depicted on **DIAGRAM 5** and includes the following structures and areas.

- North Pit
- South Pit
- Diversion Drains
- WRD
- WRD Sediment Dam
- Rehabilitated ROM Pad
- Rehabilitated LIA

In conjunction with the site extents, the model domain includes the entire upstream catchment of the unnamed tributary of the Leichardt River to a point to the northwest of the North Pit.

A smaller unnamed tributary of the Leichardt River conveys runoff form the rehabilitated LIA west to the south of the WRD Sediment Dam. The rehabilitation of the LIA area and the ROM Pad is discussed in **Section 1.2**.

3.3 Post-closure Infrastructure Retention

As part of the closure planning and remediation works, the following infrastructure is to be retained:

- North Pit
- South Pit
- Diversion Drain (and Levee) to the west and south of the North Pit
- Diversion Drain to the north of the North Pit
- Diversion Drain to the east of South Pit
- Rehabilitated WRD
- WRD Sediment Dam
- Diversion Drain to the east of the WRD Sediment Dam
- Haul Road pipe crossings (discussed further in **Section 3.5.2.6**)

The diversion drains to be retained are shown in black on **DIAGRAM 6**.

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DIAGRAM 5: TUFLOW MODEL DOMAIN

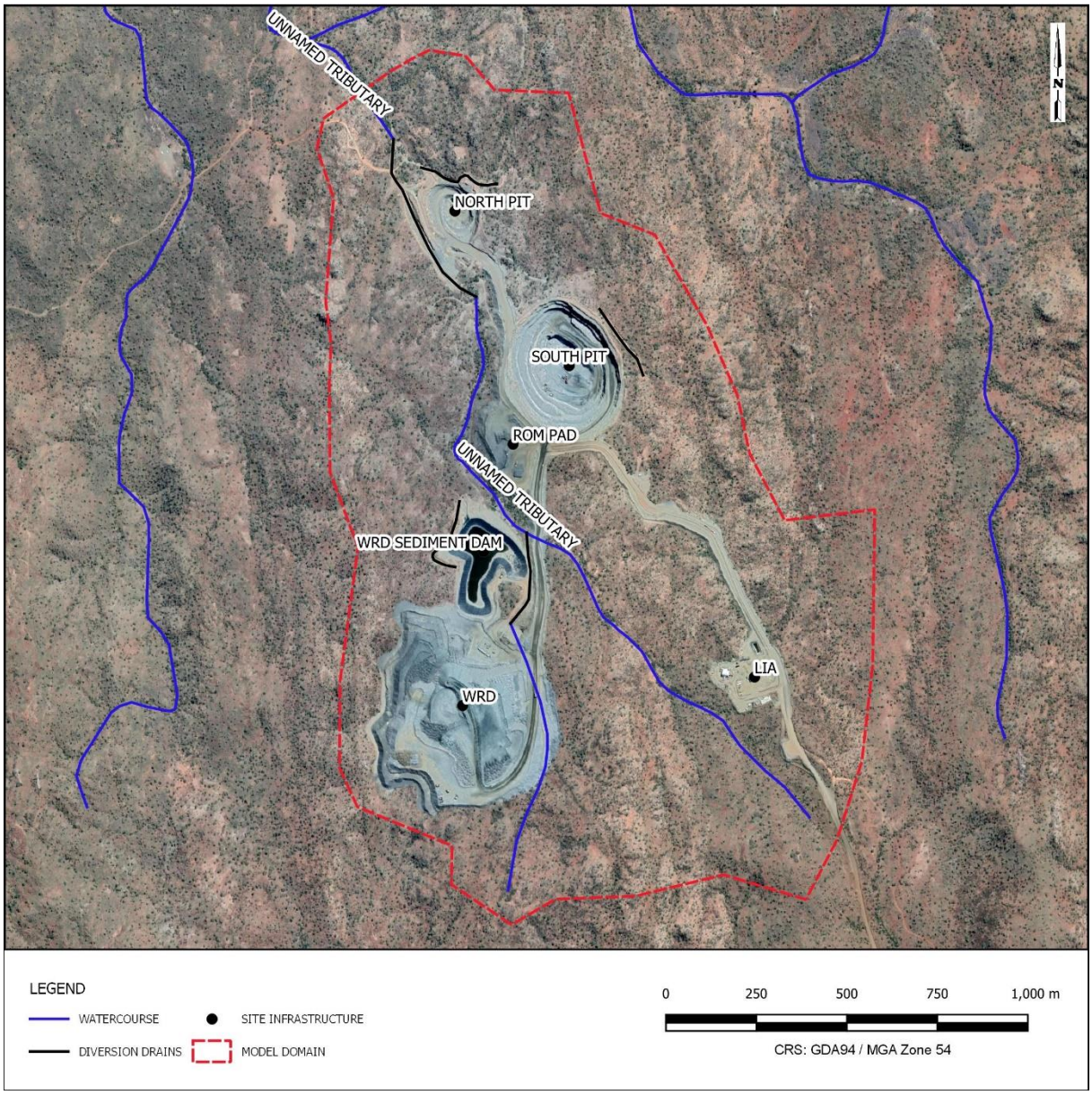

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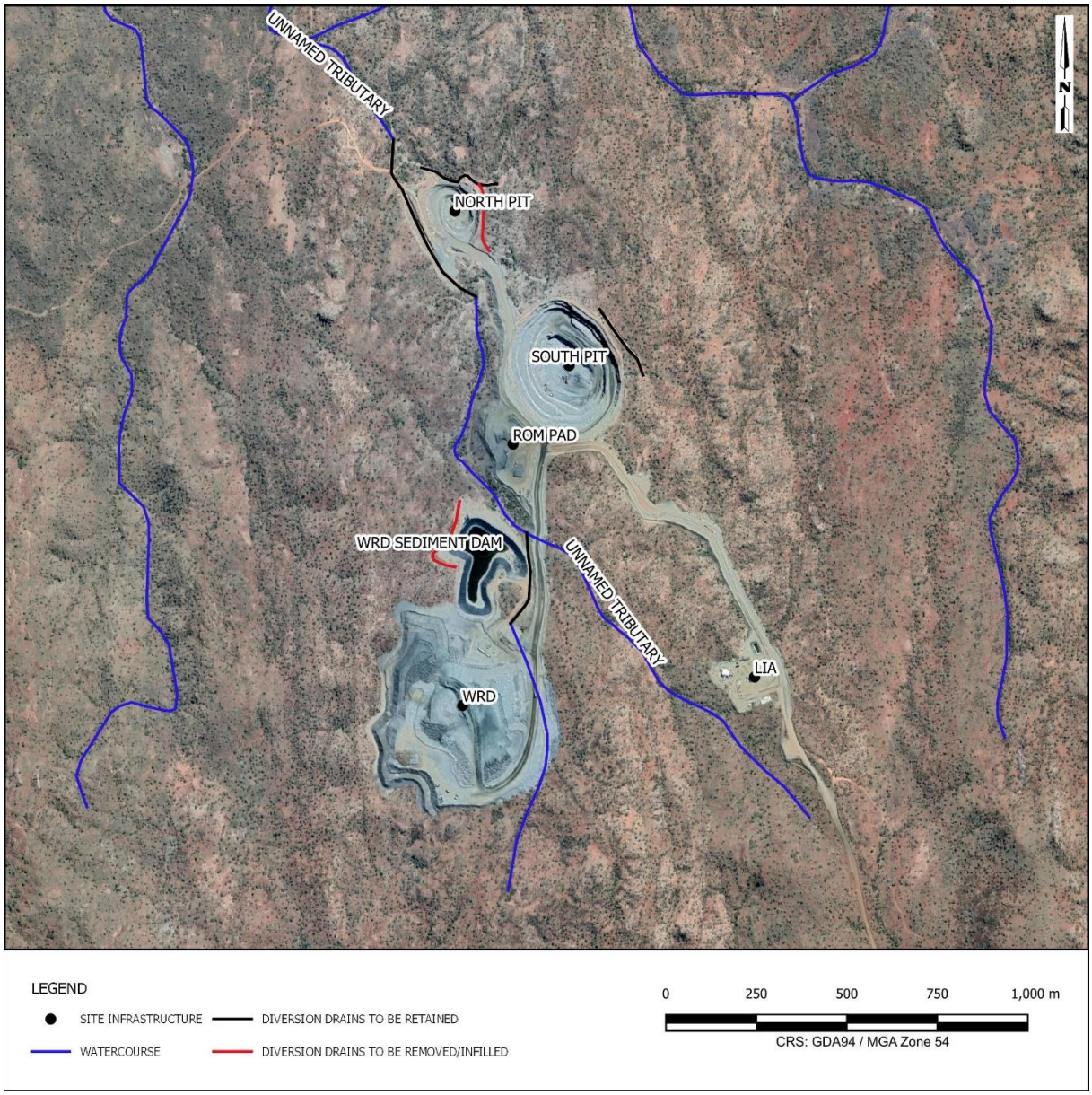
DIAGRAM 6: DIVERSION DRAINS TO BE RETAINED AND REMOVED



3.4 Post-closure Infrastructure Deletion and Remediation

As part of the closure planning and remediation works, the following infrastructure is to be decommissioned, infilled, removed or otherwise remediated:

- ROM Pad
- LIA
- Diversion drain to the east of the North Pit
- Diversion drain to the west of the WRD Sediment Dam

The diversion drains to be removed are shown in red on **DIAGRAM 6**.

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3.5 Digital Elevation Model

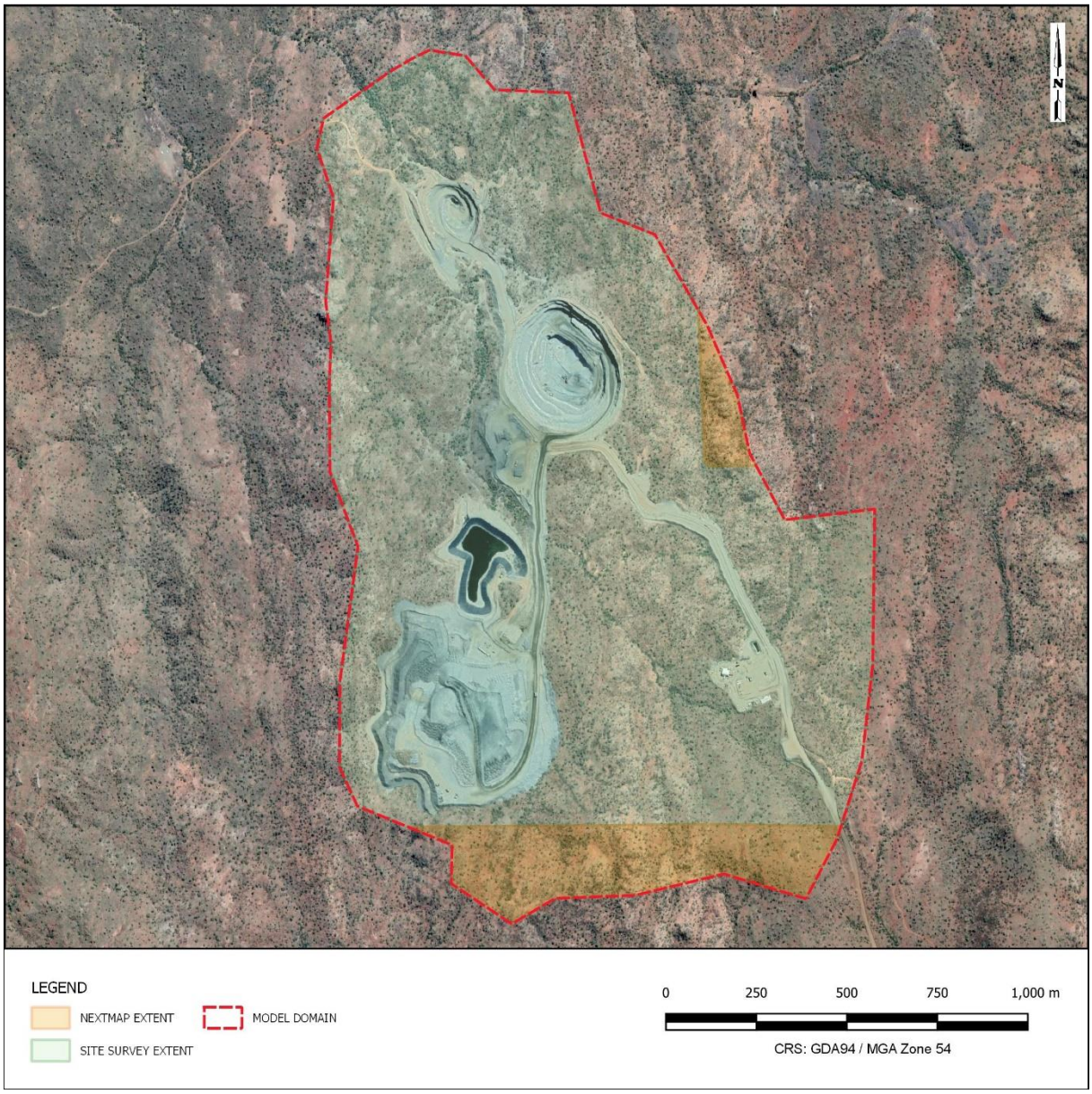
3.5.1 Base Topography

The topographical base for the TUFLOW model was developed from a series of regional survey and site specific survey datasets. The site survey dataset was resampled into a Digital Elevation Model (DEM). The following datasets were input into the topographical model.

- NEXTMap Elevation Data **[7]**
- Site Survey dated 11 September 2021 **[8]**

There were two areas external to the site survey extents **[8]** within the modelling domain for which detailed survey was not available. These areas were to the south of the WRD and east of the South Pit. To ensure appropriate runoff estimation within the upstream catchment extents of the project area, topographical details were derived from the NEXTMap elevation data **[7]**. The extents of the site survey and NEXTMap data sets within the modelling domain are depicted on **DIAGRAM 7**.

DIAGRAM 7: TOPOGRAPHICAL INPUTS AND EXTENTS



An interrogation of the elevations at the interface of the site survey and Nextmap datasets was necessary to ascertain where topographical modifications would be required to create a smooth hydraulic surface, without large, trapped sags or drop offs at the edges. It was observed that the

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NEXTMap elevations were approximately 0.5 m to 1.0 m higher than the site survey elevations. As such, no topographical modifications were made because the transition between the topographical datasets did not result in trapped sags or areas of hydraulic isolation and were far enough from the site infrastructure to not cause any significant hydraulic impacts on the post-closure site.

3.5.2 Post-Closure Surface Modifications

Several changes were made to the site survey to represent the proposed post-closure changes Aeris intend to undertake. These changes are detailed further in the following sub-sections.

3.5.2.1 WRD

The WRD Surface has been modelled with a conceptual cap approximately 1.8 m thick above existing surface levels. The design and configuration of the WRD surface will be confirmed throughout the PRCP design process.

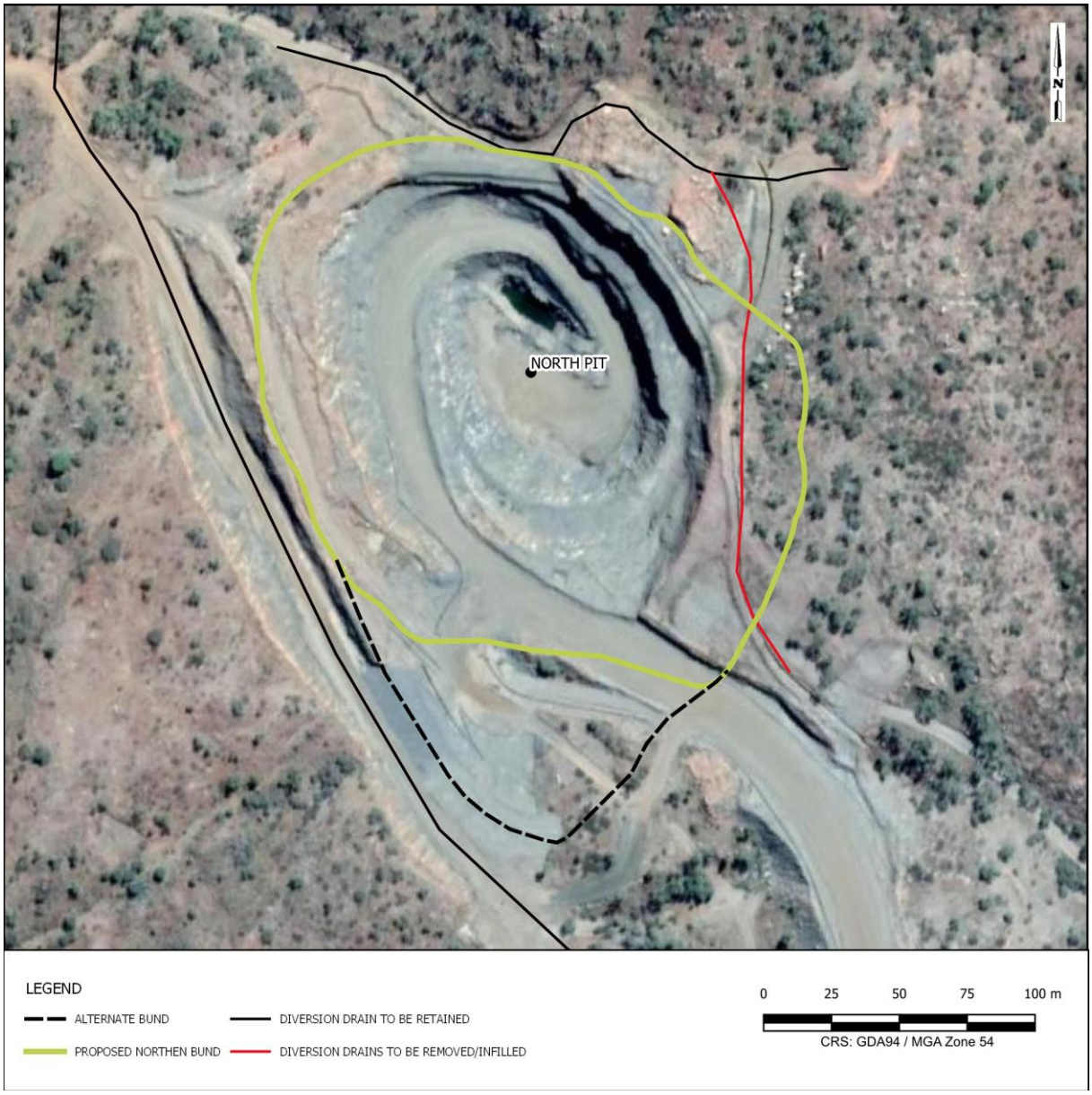
3.5.2.2 North Pit

Aeris provided the alignment of the originally proposed abandonment bund for the North Pit (shown in green on **DIAGRAM 8**). Due to the assessment of the long term instability of the north wall of the North Pit, it was concluded that the abandonment bund at the north of the North Pit would be comprised of a fence due to the limitations of the surrounding topography for access to construction machinery. The final alignment of the fence to the north of the North Pit will be determined by Aeris, but it is understood these fences will intersect the diversion to the north of the North Pit that is to be retained.

Further to this, and in conjunction with the post closure water balance modelling undertake by ATC **[9]**, the north wall of the North Pit is located within a zone of instability. It was assumed in the hydraulic modelling and water balance modelling **[9]** that the engineered north wall would be removed upon closure to increase the clean water catchment area reporting to the North Pit to improve the water quality of stored water in the Pit for use as a stock water supply. As such, the current North Pit crest height will be reduced from approximately 316.0 m AHD to 313 m AHD.

Additionally, the proposed abandonment bund was modified at the southwest corner of the North Pit to incorporate the existing levee by raising it an additional 2.5 m to at least 322.5 m AHD. The originally proposed and alternate bund alignments are shown on **DIAGRAM 8**. The alignment of the proposed abandonment bund on either side of the alternate bund alignment is to be retained.

DIAGRAM 8: NORTH PIT BUND ALIGNMENT



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3.5.2.3 South Pit

To prevent a trapped sag against the eastern side of the South Pit abandonment Bund, a small gully connecting to the existing diversion drain to the east of the South Pit is required. This gully will be approximately 1.5 m deeper than the existing diversion drain. The location of this gully is shown on **DIAGRAM 9**.

DIAGRAM 9: SOUTH PIT BUND GULLY

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3.5.2.4 *LIA and ROM Pad*

Topographic smoothing was applied to the area of the LIA to reflect the removal of the bunds and drains which directed flows to the small sump and to restore pre-mining flow regimes to the unnamed tributary of the Leichardt River which traverses the site. The top 500 mm of surface within the area of the workshop was also removed to reflect the remediated conditions of the LIA.

Within the extents of the ROM Pad, the pre-mining topography was extracted from the NEXTMap elevation data **[7]** and adopted to reflect the remediated site conditions after all surface material has been removed, along with stripping and remediation works being undertaken. The typical pre mining surface, along with the current topography is depicted on **DIAGRAM 10**. The location of the section in shown on the inset of **DIAGRAM 10**. This was undertaken to reflect the remediated conditions of the ROM Pad.

DIAGRAM 10: ROM PAD AREA SURFACE TOPOGRAPHY

3.5.2.5 *WRD Sediment Dam*

The existing diversion drain to the west of the WRD Sediment dam was filled to allow for runoff from the upstream catchment of the remediated WRD and non-mine impacted areas to enter the WRD Sediment Dam, which will be retained post-closure. The diversion drain to the east of the WRD Sediment Dam will be retained post-closure, as shown on **DIAGRAM 6**.

3.5.2.6 *Haul Road*

The haul roads were reduced in level to reflect the removal of material to be used for capping the WRD. The haul roads were modified above the culvert crossings to reduce the extent of upstream ponding within the gullies. The haul roads were modified at the crossing locations shown on **DIAGRAM 11** by the values listed in **TABLE 5**. A minimum of 800 mm cover above the culverts has been maintained. The haul roads were modified to reduce the overtopping depths and velocities for storm events equal to and greater than the 1% AEP.

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DIAGRAM 11: ROAD CROSSING LOCATIONS

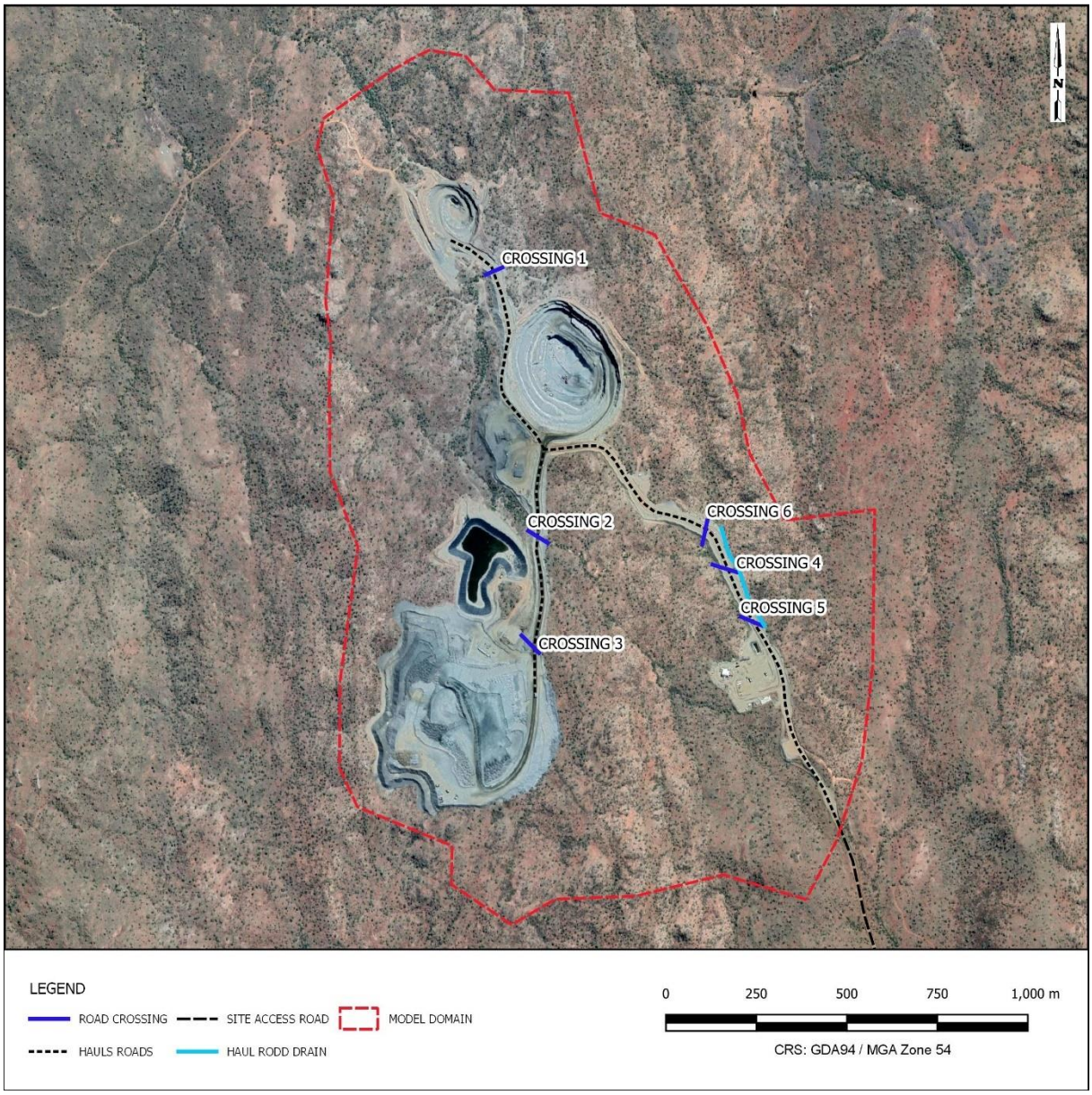

TABLE 5: HAUL ROAD MODIFICATIONS

Crossing	Existing Formation Height (m AD)	Post-closure Formation Height (m AHD)	Change in Formation (m)
1	328.2	326.5	- 1.7
2	341.5	334.0	-7.5
3	345.3	345.3	No Change
4	355.5	355.5	No Change
5	356.4	356.4	No Change
6	354.6	350.5	-4.1

In discussion with Aeris, it was decided to maintain the elevation of Crossing 4 and Crossing 5, while directing runoff from their respective upstream gullies via the construction of a drain towards Crossing 6.

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This will result in a single location, Crossing 6, where flows may overtop the retained haul road. The proposed haul road drain has been modelled with a 5 m base width and 1:2 side batters. Detailed design of this drain will be undertaken further in the rehabilitation and closure stages. The location of this drain is shown on **DIAGRAM 11**. Photos of the culverts are included in **Appendix B.**

3.6 Grid Size Selection and Time Step

The diversion drains within the site form the key hydraulic structures within the hydraulic model. As such, the grid size was selected in accordance with the recommendations of the TUFLOW Manual **[10][9]** and ARR Revision Project 15 Report **[11]** that for flow in a channel, a minimum of five grid elements should be modelled across the channel width.

An interrogation of the diversion drains across the site was undertake and is summarised in **TABLE 6**.

TABLE 6: DIVERSION DRAIN DIMENSION VS GRID SIZE

Diversion Drain	Width (m)	Maximum Grid Size (m)
West of North Pit	18	3.6
East of WRD Dam	14	2.8

As detailed in **TABLE 6**, the maximum grid size recommend for the model domain is 2.8 m. As such, a 2 m grid size was selected. Based upon the grid size of 2 m, an initial time step of 1.0 seconds was selected for the simulation.

3.7 Boundary Conditions

The only input boundary for the model was the direct rainfall over the full extent of the model domain. No other external inflows or point sources exist. The perimeter of the model had an outflow boundary condition applied to allow rainfall to exit the model. This was done to prevent unrealistic ponding of surface runoff or flow in the unnamed tributary at the model boundary. These outflow boundaries are not shown on **DIAGRAM 12** for clarity. The boundary condition at the outflow locations on the unnamed tributary of the Leichardt River incorporates a bed slope of approximately 2.5% based on the topographical survey.

The WRD Sediment Dam was assumed to be full at the commencement of the model simulations to allow for spilling as the result of rainfall and runoff. This is a realistic assumption based on the likelihood of rainfall having occurred prior to a rare, very rare or extreme rainfall event. The WRD Sediment Dam has an emergency spillway on the northwestern corner. The spillway level is 336.8 m AHD, which was the initial water level (IWL) adopted in the storage. IWL's were not applied to the North Pit or South Pit.

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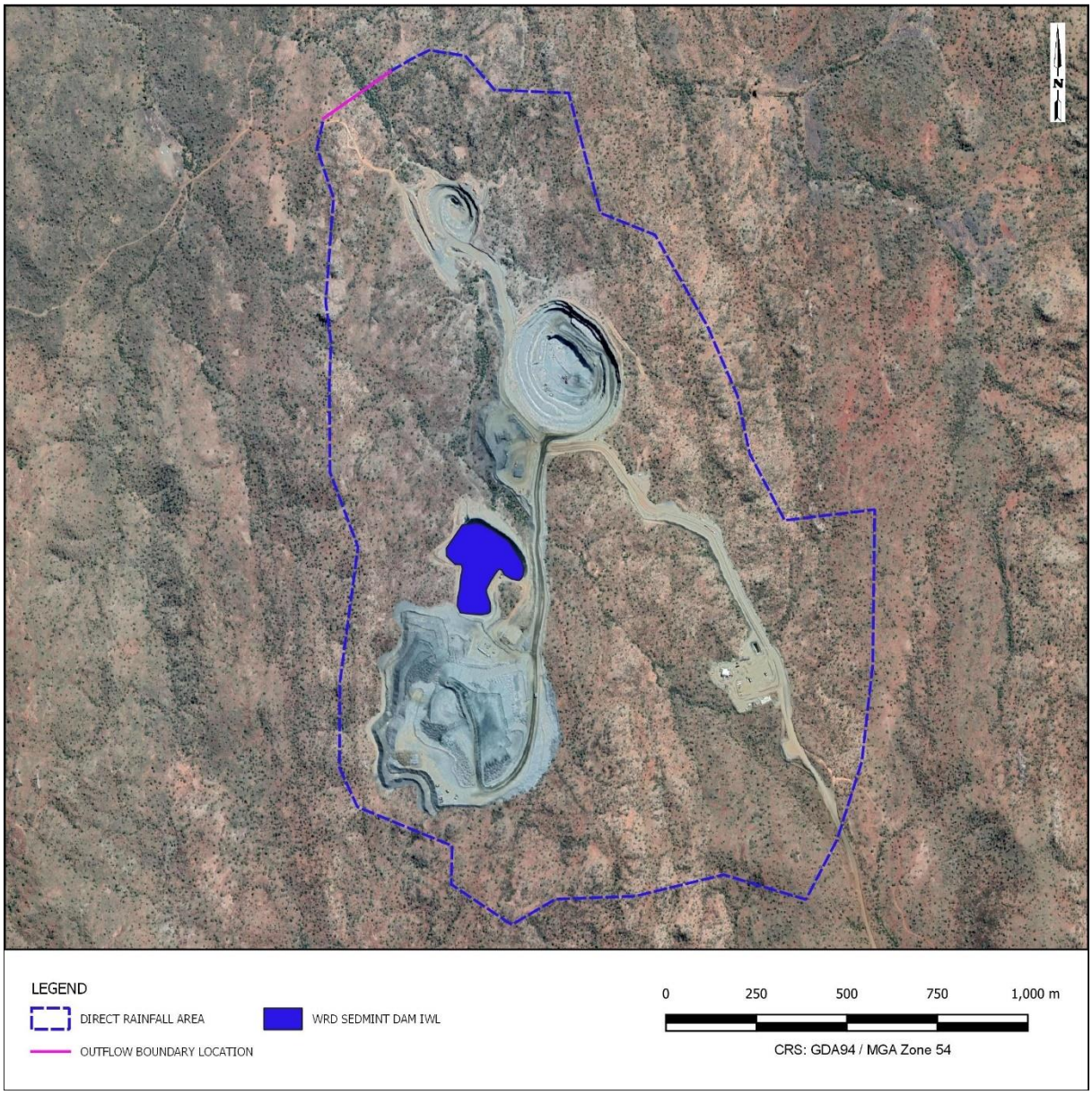
DIAGRAM 12: BOUNDARY CONDITION LOCATIONS



3.8 Surface Roughness

Manning's 'n' surface roughness coefficient was used to describe the surface conditions within the model domain. Manning's 'n' roughness coefficients were assigned to the model domain based on land use type and characteristics, as depicted on **DIAGRAM 13**. Selection of the coefficient values was made considering the apparent roughness of surfaces based upon inspection of available aerial imagery and assumption of the proposed surface conditions post-closure. The reference values detailed in Innovyze (2019) **[12]** were utilised to represent natural channels and post-closure site conditions. The main flow regime in a direct rainfall model is overland flow, which results in higher Manning's 'n' values than in river channels and floodplains. A default surface roughness of n = 0.083 was adopted for non-mine impacted areas. A description of each adopted Manning's 'n' coefficients is provided in **TABLE 7**.

DIAGRAM 13: MANNINGS ROUGHNESS

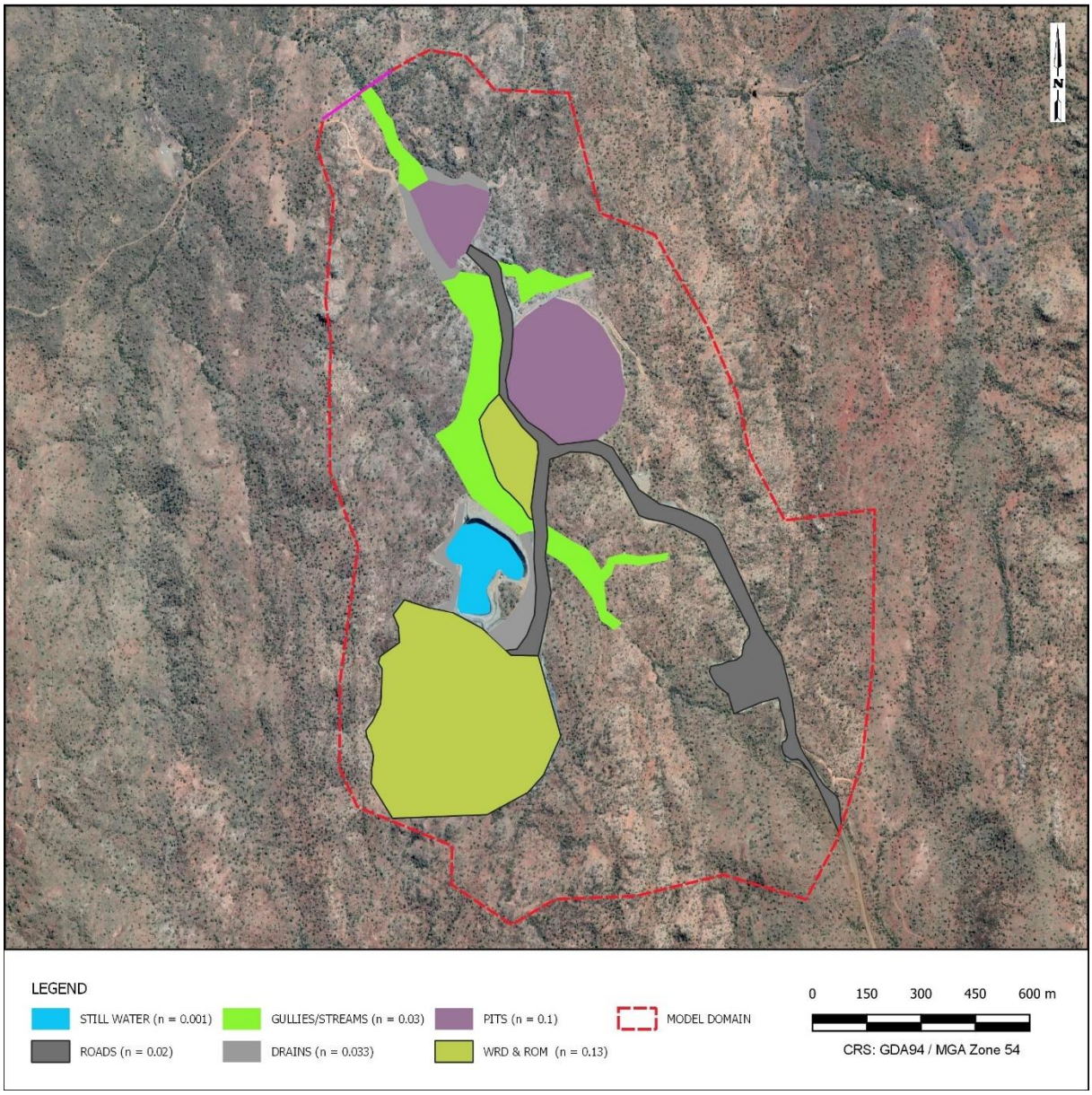


TABLE 7: MANNINGS 'N' ROUGNESS COEFFICIENTS

Mannings 'n' coefficient	Description
0.001	Still water/dams
0.020	Unsealed Roads
0.030	Rocky gullies and streams
0.033	Blasted rock based diversion drains
0.083	Sparse light brush on rocky natural ground
0.100	Pits, vertical walls, angular rocked surfaces
0.130	Rehabilitated WRD - grass and sparse light brush

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3.9 Road Crossings

Within the project area, there are several culverts beneath the existing haul roads. It is understood these culverts are to be retained. The locations of the culverts are depicted on **DIAGRAM 11**. Details of the circular steel pipe (CSP) culverts are summarised in **TABLE 8**. Assumed upstream and downstream invert levels were extracted from the 2021 Site Survey **[8]** as detailed survey of the crossings was not available.

TABLE 8: ROAD CROSSING DETAILS

Culvert Crossing	Configuration	Length (m)	Upstream Invert Level (m AHD)	Downstream Invert Level (m AHD)
1	1 x 500 mm CSP	71	323.8	322.3
2	1 x 1200 mm CSP	63.6	331.9	331.6
3	3 x 1200 mm CSP	67.3	344.5	338.5
4	1 x 500 mm CSP	69.0	351.3	347.0
5	1 x 500 mm CSP	65.0	353.5	353.2
6	1 x 500 mm CSP	67.0	347.5	346.2

3.10 Sensitivity Analysis

A sensitivity analysis was undertaken for the closure conditions to understand the model's response to changes in values of key parameters, such as changes in rainfall estimates and surface roughness. This provided an improved understanding of the potential impacts in the uncertainties in estimation of these parameters. The following sensitivity scenarios were assessed:

- A ± 20% change in rainfall depths to account for the uncertainty in the estimated rainfall and those associated with climate change impacting extreme rainfall events.
- A ± 20% change in assumed Manning's 'n' roughness coefficients. In general, higher roughness coefficients reduce flow velocities and therefore may increase modelled flood depths and extents. Lower roughness coefficients generally have a converse effect.

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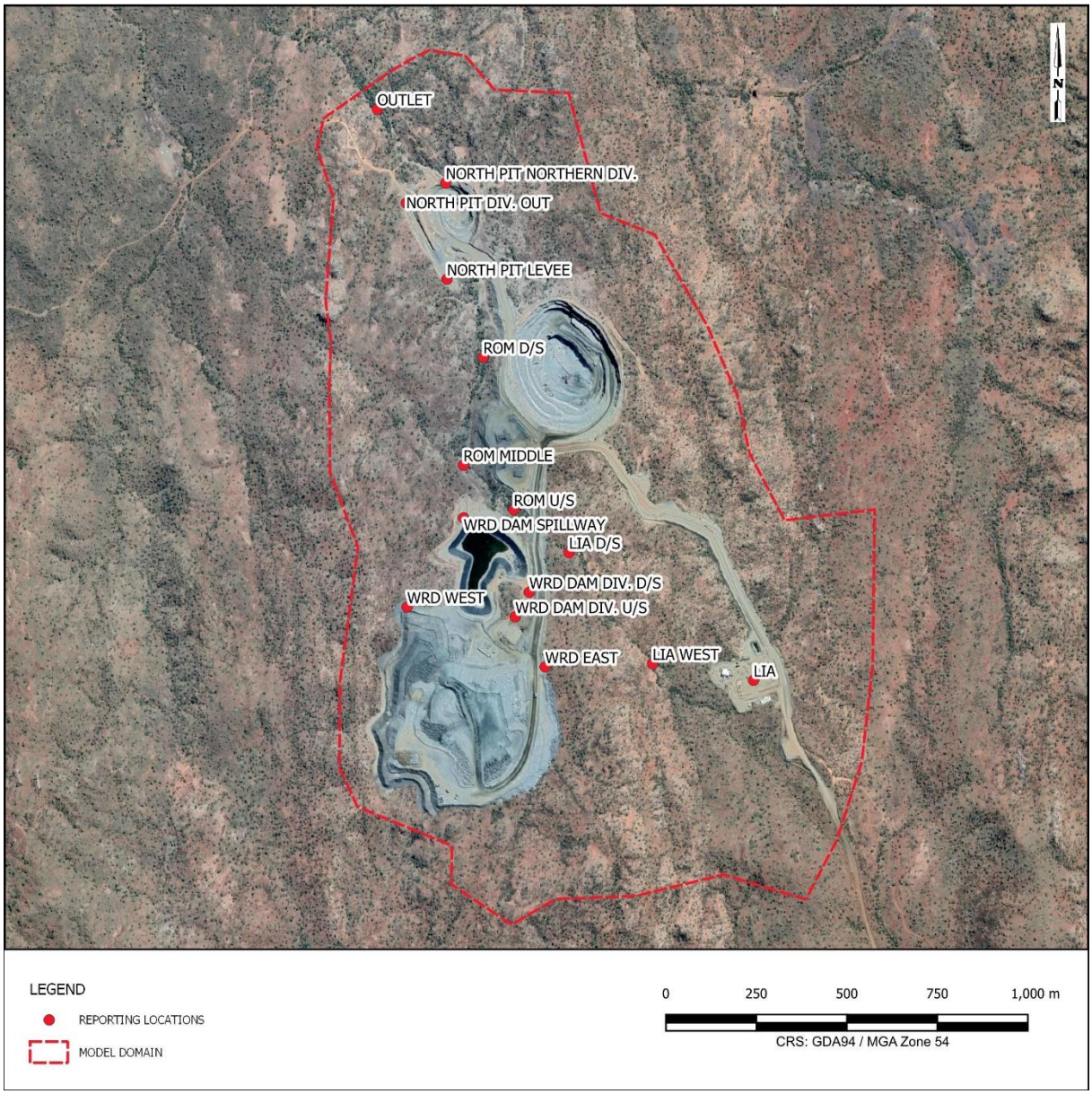
4 RESULTS

4.1 Introduction

The mapped results of the TUFLOW modelling showing maximum water depths and velocities are presented on **Figure 001** to **Figure 006** for the PMP, 0.1% AEP and 1% AEP design storm events. The results of flooding on the post-closure conditions of the North Pit (including Diversion Drain and Levee) South Pit and rehabilitated ROM Pad, WRD Sediment Dam and Diversion Drain, LIA, Haul Roads and the unnamed tributary of the Leichardt are discussed in **Sections 4.2** to **4.8**. The results of the sensitivity analyses are discussed in **Section 4.9**. The locations at which results are reported are depicted on **DIAGRAM 14**.

DIAGRAM 14: RESULTS REPORTING LOCATIONS



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4.2 North Pit, Diversion Drain and Levee

The maximum estimated flow rates, depths, velocities, and freeboard at the Levee, Diversion Drain, and North Drain adjacent to the North Pit are summarised in **TABLE 9**. Peak PMF flood depths adjacent to the North Pit are depicted on **DIAGRAM 15**. The Levee (shown in yellow on **DIAGRAM 15**) prevents the North Pit from receiving inflows from the unnamed tributary of the Leichardt River. The black line on **DIAGRAM 15** is the location of the abandonment bund**.** The North Pit receives inflows from the upstream catchment of the diversion drain to the North. The impacts on long-term water levels in the North Pit and water quality are discussed further in ATCW's 2023 report on the geochemical assessment of residual waters in the pits **[9]**.

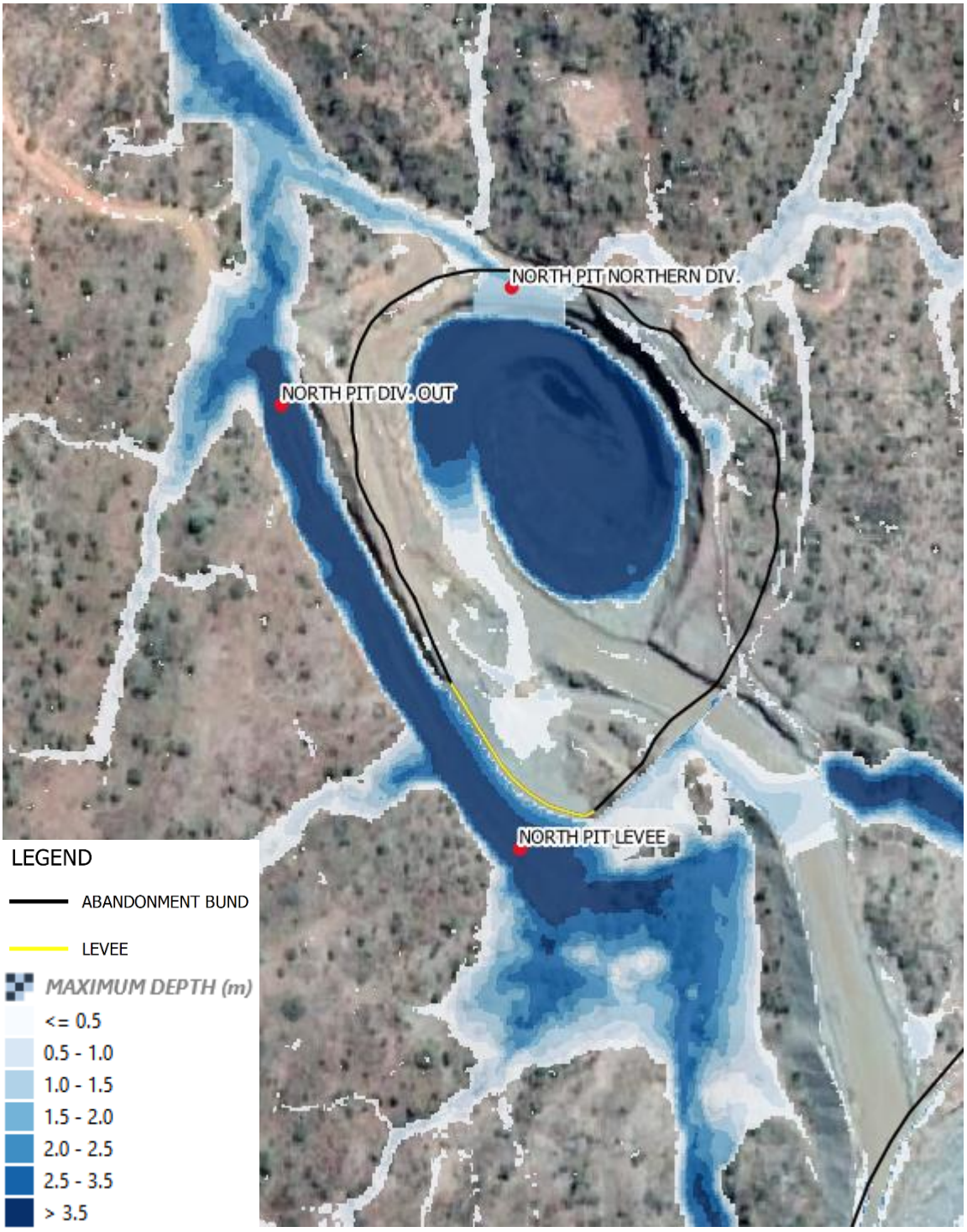
TABLE 9: HYDRAULIC MODELLING RESULTS – LOCATIONS ADJACENT TO THE NORTH PIT

Location	Parameter	PMF	0.1% AEP	1% AEP
North Pit Levee	Peak Flow Rate (m^3/s)	271.7	67.7	43.9
	Ground Elevation Level (m AHD)	317.35	317.35	317.35
	Maximum Water Surface Elevation (m AHD)	322.07	319.11	318.25
	Levee Elevation (m AHD)	322.5	322.5	322.5
	Maximum Flood Depth (m)	4.72	1.76	0.90
	Freeboard below Levee (m)	0.43	3.39	4.25
	Maximum Velocity (m/s)	2.4	2.3	2.3
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	120 min TP02
North Pit Diversion Out	Peak Flow Rate (m^3/s)	279.3	69.5	45.3
	Ground Elevation Level (m AHD)	315.82	315.82	315.82
	Maximum Water Surface Elevation (m AHD)	320.38	318.44	317.72
	Maximum Flood Depth (m)	4.56	2.62	1.90
	Maximum Velocity (m/s)	3.3	1.6	1.0
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	120 min TP02
North Pit Northern Diversion	Ground Elevation Level (m AHD)	312.86	312.86	312.86
	Maximum Water Surface Elevation (m AHD)	314.38	313.48	313.39
	Maximum Flood Depth into Pit (m)	1.52	0.62	0.53
	Peak Flow Rate into the North Pit (m^3/s)	8.9	5.6	3.1
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	120 min TP02

As can been seen in **TABLE 9**, the North Pit Levee has 0.43 m of freeboard above the PMF flows. Flow rates up to 272 m^3/s were recorded adjacent to the Levee.

From the results in **TABLE 9** and the flood extents shown on **Figure 003**, the North Pit is not located within the 0.1% AEP flood plain of the unnamed tributary of the Leichardt River, and so complies with the PRCP guidelines **[1]**.

DIAGRAM 15: PMF DEPTHS ADJACENT TO THE NORTH PIT



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4.3 South Pit and Rehabilitated ROM Pad

The maximum estimated flow rates, depths, velocities, and freeboard adjacent to the South Pit and rehabilitated ROM Pad along the unnamed tributary of the Leichardt River, as depicted on **DIAGRAM** 14, are summarised in **TABLE 10**. The PMF flood depths adjacent to the ROM Pad and South Pit are depicted on **DIAGRAM 16**.

TABLE 10: HYDRAULIC MODELLING RESULTS – ROM PAD AND SOUTH PIT

Location	Parameter	PMF	0.1% AEP	1% AEP
ROM Upstream	Peak Flow Rate (m^3/s)	167.7	42.2	28.0
	Ground Elevation Level (m AHD)	329.76	329.76	329.76
	Maximum Water Surface Elevation (m AHD)	330.89	330.33	330.17
	Pit Crest Elevation (m AHD)	340.22	340.22	340.22
	Maximum Flood Depth (m)	1.13	0.57	0.41
	Freeboard (m)	9.33	9.89	10.05
	Maximum Velocity (m/s)	5.9	3.6	2.6
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	90 min TP10
ROM Middle	Peak Flow Rate (m^3/s)	202.5	49.5	32.1
	Ground Elevation Level (m AHD)	326.18	326.18	326.18
	Maximum Water Surface Elevation (m AHD)	328.20	327.41	327.11
	Pit Crest Elevation (m AHD)	340.22	340.22	340.22
	Freeboard (m)	12.02	12.81	13.11
	Maximum Flood Depth (m)	2.02	1.23	0.93
	Maximum Velocity (m/s)	5.1	3.4	3.0
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	90 min TP10
ROM Downstream	Peak Flow Rate (m^3/s)	227.7	56.0	36.5
	Ground Elevation Level (m AHD)	321.82	321.82	321.82
	Maximum Water Surface Elevation (m AHD)	325.37	323.54	323.07
	Pit Crest Elevation (m AHD)	340.22	340.22	340.22
	Freeboard (m)	14.85	16.68	17.15
	Maximum Flood Depth (m)	3.55	1.72	1.25
	Maximum Velocity (m/s)	3.1	2.1	1.5
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	90 min TP10

As can be seen in **TABLE 10**, no flows enter the South Pit from any external catchment due to the proposed abandonment bund (shown in black on **DIAGRAM 16)**. The South Pit does receive direct rainfall over its extents.

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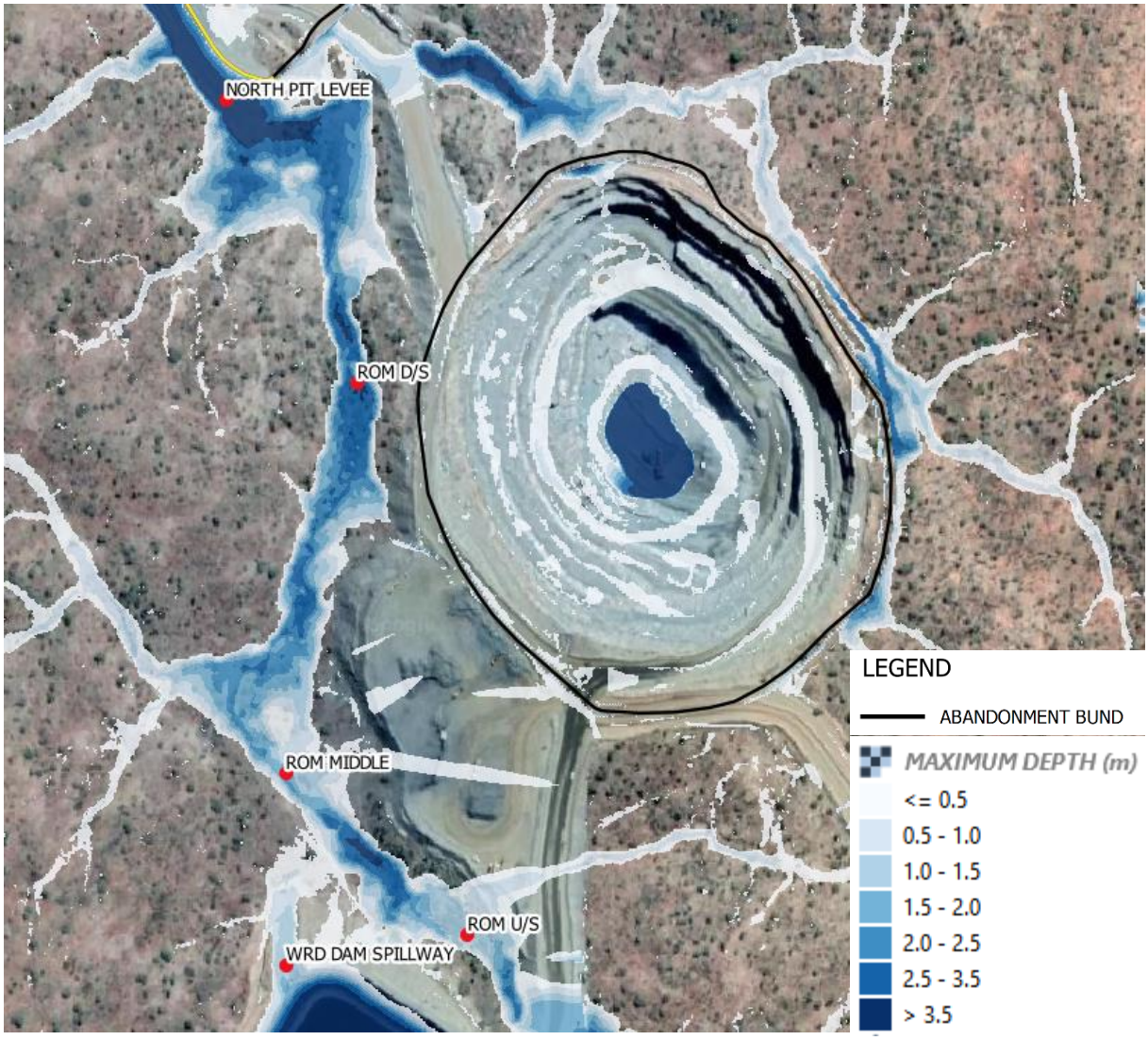
DIAGRAM 16: PMF DEPTHS ADJACENT TO THE ROM PAD AND SOUTH PIT



4.4 WRD Sediment Dam

The maximum estimated flow rates, depths and velocities within the WRD Sediment Dam Spillway, at the location shown on **DIAGRAM 14,** are summarised in **TABLE 11**.

TABLE 11: HYDRAULIC MODELLING RESULTS – WRD SEDIMENT DAM

	PMF	0.1% AEP	1% AEP
Peak Flow Rate (m^3/s)	33.9	4.7	2.1
WRD Spillway Level (m AHD)	336.80	336.80	336.80
WRD Embankment Crest Level (m AHD)	338.60	338.60	338.60
Maximum Water Surface Elevation (m AHD)	338.17	337.35	337.20
Maximum Flood Depth through Spillway (m)	1.37	0.55	0.40
Freeboard to Embankment Crest (m)	0.43	1.25	1.40
Maximum Velocity through Spillway (m/s)	2.0	1.0	0.8
Critical Storm Duration & Temporal Pattern	60 min	120 min TP10	120 min TP06

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The spillway of the WRD has sufficient capacity to convey flows up to and including the PMF without overtopping the embankment. A freeboard of 0.43 m exists above PMF flows.

4.5 WRD Sediment Dam Diversion Drain

The maximum flow rates, depths and velocities within the WRD Sediment Dam Diversion Drain are summarised in **TABLE 12**. The maximum PMF flow depth in the diversion drain is depicted on **DIAGRAM 17**.

TABLE 12: HYDRAULIC MODELLING RESULTS – WRD SEDIMENT DAM DIVERSION DRAIN

Location	Parameter	PMF	0.1% AEP	1% AEP
WRD Dam Diversion Upstream	Peak Flow Rate (m^3/s)	12.9	2.2	1.0
	Ground Elevation Level (m AHD)	337.80	337.80	337.80
	Maximum Water Surface Elevation (m AHD)	339.97	338.98	338.77
	Maximum Flood Depth (m)	2.17	1.18	0.97
	Maximum Velocity (m/s)	0.6	0.3	0.2
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	120 min TP10
WRD Dam Diversion Downstream	Peak Flow Rate (m^3/s)	14.5	2.3	1.0
	Ground Elevation Level (m AHD)	337.60	337.60	337.60
	Maximum Water Surface Elevation (m AHD)	338.73	338.20	338.10
	Maximum Flood Depth (m)	1.13	0.60	0.50
	Maximum Velocity (m/s)	3.5	2.2	1.8
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	120 min TP10

As can be seen in **TABLE 11**, the maximum flow depth within the WRD Sediment Dam Diversion Drain varies between 2.17 m at the upstream end and 1.13 m at the downstream measurement location during the PMF event. The maximum velocities within the drain at the outlet to the unnamed tributary of the Leichardt River are 0.6 m/s during the PMF event.

As can be seen on **DIAGRAM 17**, flows from the eastern edge of the WRD Sediment Dam spill into the diversion drain in the PMF event. This does not occur in the 1% or 0.1% AEP events, as can be seen on **Figures 003** and **005**. Post closure, the WRD Sediment Dam will collect clean water for stock water use and so any spills from the dam will have insignificant impacts on the downstream environment.

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DIAGRAM 17: PMF DEPTHS AT WRD SEDIMENT DAM DIVERSION DRAIN

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4.6 WRD

The maximum estimated flow rates, depths, and velocities at the toe of the WRD at the WRD West and WRD East measuring locations shown on **DIAGRAM 14,** are summarised in **TABLE 13**.

TABLE 13: HYDRAULIC MODELLING RESULTS - WRD

Location	Parameter	PMF	0.1% AEP	1% AEP
WRD West	Peak Flow Rate (m^3/s)	13.1	3.6	1.6
	Ground Elevation Level (m AHD)	347.46	347.46	347.46
	Maximum Water Surface Elevation (m AHD)	348.18	347.77	347.65
	Maximum Flood Depth (m)	0.72	0.31	0.19
	Maximum Velocity (m/s)	1.2	0.8	0.7
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	120 min TP10
WRD East	Peak Flow Rate (m^3/s)	32.9	8.3	5.5
	Ground Elevation Level (m AHD)	344.63	344.63	344.63
	Maximum Water Surface Elevation (m AHD)	347.21	346.05	345.77
	Maximum Flood Depth (m)	2.58	1.42	1.14
	Maximum Velocity (m/s)	1.1	0.6	0.5
	Critical Storm Duration & Temporal Pattern	15 min	90 min TP10	90 min TP10

As can be seen in **TABLE 13**, the maximum PMF flow depth at the toe of the WRD at WRD West and WRD East are 0.72 m and 2.58 m, respectively. The maximum PMF flow velocity over the WRD surface was estimated to occur on the ramp, where the velocity was 0.8 m/s with a flow depth of 0.16 m. The surface of the WRD is to be remediated and the surface will provide sufficient erosion protection for the soils to withstand these flow depths and velocities.

4.7 Light Infrastructure Area

The maximum estimated water surface elevations and velocities at the LIA are summarised in **TABLE** 14.

TABLE 14: HYDRAULIC MODELLING RESULTS - LIA

	PMF	0.1% AEP	1% AEP
Ground Elevation Level (m AHD)	356.29	356.29	356.29
Maximum Water Surface Elevation (m AHD)	357.01	356.86	356.81
Maximum Flood Depth (m)	0.72	0.57	0.52
Maximum Velocity (m/s)	0.9	0.6	0.5
Critical Storm Duration & Temporal Pattern	15 min	45 min TP08	45 min TP08

As shown in **TABLE 14**, the maximum estimated PMF flow depth and velocity within the LIA are 0.72 m and 0.9 m/s respectively during the PMF event. Established vegetation in this area will be able to resist flows of this depth and velocity to prevent surface erosion.

4.8 Unnamed Tributary of Leichardt River

The unnamed tributary of the Leichardt River (including the Diversion Dain to the west of the North Pit) is the key drainage feature on site, to which the majority of surface runoff is directed. The maximum estimated flow rates, depths, and velocities at the measurement locations of LIA West, LIA Downstream, ROM Upstream, ROM Middle, ROM, Downstream, North Pit Levee, North Pt Diversion Out and Outlet are summarised in **TABLE 15**.

TABLE 15: HYDRAULIC MODELLING RESULTS - UNNAMED TRIBUTARY OF THE LEICHARDT RIVER

Location	Parameter	PMF	0.1% AEP	1% AEP
LIA West	Peak Flow Rate (m^3/s)	55.7	13.9	9.4
	Ground Elevation Level (m AHD)	341.75	341.75	341.75
	Maximum Water Surface Elevation (m AHD)	344.48	343.13	342.89
	Maximum Flood Depth (m)	2.73	1.38	1.14
	Maximum Velocity (m/s)	2.1	1.2	1.1
	Critical Storm Duration & Temporal Pattern	15 min	45 min TP08	45 min TP03
LIA Downstream	Peak Flow Rate (m^3/s)	149.8	38.6	26.3
	Ground Elevation Level (m AHD)	332.01	332.01	332.01
	Maximum Water Surface Elevation (m AHD)	339.03	337.92	337.56
	Maximum Flood Depth (m)	7.02	5.91	5.55
	Maximum Velocity (m/s)	0.6	0.2	0.2
	Critical Storm Duration & Temporal Pattern	60 min	45 min TP08	90 min TP10
ROM Upstream	Peak Flow Rate (m^3/s)	167.7	42.2	28.0
	Ground Elevation Level (m AHD)	329.76	329.76	329.76
	Maximum Water Surface Elevation (m AHD)	330.89	330.33	330.17
	Maximum Flood Depth (m)	1.13	0.57	0.41
	Maximum Velocity (m/s)	5.9	3.6	2.6
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	90 min TP10
ROM Middle	Peak Flow Rate (m^3/s)	202.5	49.5	32.1
	Ground Elevation Level (m AHD)	326.18	326.18	326.18
	Maximum Water Surface Elevation (m AHD)	328.20	327.41	327.11
	Maximum Flood Depth (m)	2.02	1.23	0.93
	Maximum Velocity (m/s)	5.1	3.4	3.0
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	90 min TP10
ROM Downstream	Peak Flow Rate (m^3/s)	227.7	56.0	36.5
	Ground Elevation Level (m AHD)	321.82	321.82	321.82
	Maximum Water Surface Elevation (m AHD)	325.37	323.54	323.07
	Maximum Flood Depth (m)	3.55	1.72	1.25
	Maximum Velocity (m/s)	3.1	2.1	1.5
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	90 min TP10
	Peak Flow Rate (m^3/s)	271.7	67.7	43.9

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Location	Parameter	PMF	0.1% AEP	1% AEP
North Pit Levee	Ground Elevation Level (m AHD)	317.35	317.35	317.35
	Maximum Water Surface Elevation (m AHD)	322.07	319.11	318.25
	Maximum Flood Depth (m)	4.72	1.76	0.9
	Maximum Velocity (m/s)	2.4	2.3	2.3
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	120 min TP02
North Pit Diversion Out	Peak Flow Rate (m^3/s)	279.3	69.5	45.3
	Ground Elevation Level (m AHD)	315.82	315.82	315.82
	Maximum Water Surface Elevation (m AHD)	320.38	318.44	317.72
	Maximum Flood Depth (m)	4.56	2.62	1.9
	Maximum Velocity (m/s)	3.3	1.6	1
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	120 min TP02
Outlet	Peak Flow Rate (m^3/s)	294.9	73.0	47.3
	Ground Elevation Level (m AHD)	310.89	310.89	310.89
	Maximum Water Surface Elevation (m AHD)	312.99	311.88	311.54
	Maximum Flood Depth (m)	2.1	0.99	0.65
	Maximum Velocity (m/s)	5.6	3.1	2.1
	Critical Storm Duration & Temporal Pattern	60 min	90 min TP10	120 min TP02

As can be seen in **TABLE 15**, at the LIA Downstream recording location water levels increase and velocities decrease downstream of the LIA West recording location. This is due to the retention effect of the retained haul road at Crossing 2. The unnamed tributary of the Leichardt River and the diversion drain to the west of the North Pit have sufficient capacity to convey flows up to the PMF. Flows from the unnamed tributary of the Leichardt River do not spill into either the North Pit or the South Pit.

4.9 Sensitivity Analyses

Sensitivity analyses were undertaken for the hydraulic model using the surface roughness coefficient and the applied rainfall depth parameters for the 0.1% AEP design event. The main areas of concern in the post-closure condition was flooding to the open voids so the relevant recording locations were in the unnamed tributary of the Leichardt River.

A comparison of peak water surface elevation (WSE), flow rates and velocities at locations ROM Upstream, North Pit Levee and Outlet, as shown on **DIAGRAM 14,** are summarised in **TABLE 16**.

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TABLE 16: SENSITIVITY ANALYSIS RESULTS – 0.1% AEP EVENT

Location	Sensitivity Scenario	Peak WSE (m AHD)	Change in Peak WSE (m AHD)	Peak Flow (m^3/s)	Change in Peak Flow (m^3/s)	Flow Velocity (m/s)	Change in Velocity (m/s)
ROM Upstream	Base Model	330.33	-	42.2	-	3.6	-
	+ 20% Rainfall Depth	330.45	0.12	62.6	20.4	4.1	0.5
	- 20 % Rainfall Depth	330.23	-0.1	25.8	-16.4	2.9	-0.7
	+ 20% Mannings 'n'	330.44	0.11	41.4	-0.8	3	-0.6
	- 20 % Mannings 'n'	330.28	-0.05	43.1	0.9	4.1	0.5
North Pit Levee	Base Model	319.11	-	67.7	-	2.3	-
	+ 20% Rainfall Depth	319.93	0.82	103.1	35.4	2.6	0.3
	- 20 % Rainfall Depth	318.66	-0.45	40.1	-27.6	2.2	-0.1
	+ 20% Mannings 'n'	319.43	0.32	65.9	-1.8	1.9	-0.4
	- 20 % Mannings 'n'	319.09	-0.02	69.6	1.9	2.8	0.5
Outlet	Base Model	311.88	-	73.0	-	3.1	-
	+ 20% Rainfall Depth	312.24	0.36	111.0	38	3.9	0.8
	- 20 % Rainfall Depth	311.71	-0.17	43.2	-29.8	2.7	-0.4
	+ 20% Mannings 'n'	312.04	0.16	71.1	-1.9	2.9	-0.2
	- 20 % Mannings 'n'	311.94	0.06	75	2.0	3.6	0.5

As can be seen in **TABLE 16**, the hydraulic model is sensitive to variations in applied rainfall depth and surface roughness. An increase in rainfall produces higher water surface elevations, flow depths and velocities across the model domain. This modelled increase in rainfall can be indicative of variations due to climate change. This type of climate change may result in the North Pit Levee overtopping in the PMF event, but it would not receive inflows during the 0.1% AEP event.

The climate change impacts of an increase in rainfall depth would mostly be on the diversion drains and haul road crossings. Existing gullies and watercourses have sufficient capacity to convey the modelled increases in rainfall and subsequent runoff.

The South Pit remains unimpacted from increases in rainfall runoff.

From the results, it can be taken that the model is sensitive to changes in both applied rainfall depth- and surface roughness, with the greatest impacts being observed in the +20% rainfall scenario.

5 PRCP INPUTS AND DISCUSSION

5.1 General

With reference to the PRCP guidelines **[1]** a key focus of this flood risk assessment was to identify two aspects of closure planning:

- ensuring that any residual voids are not located wholly or partly in the flood plain (defined as the 0.1% AEP design storm flood extent); and
- assessing the flood risk to any remaining infrastructure.

Discussion of the flood risk profile for the infrastructure on site that is to be retained is provided below. The discussion includes:

- North Pit and South Pit;
- Diversion Drains; and
- WRD.

5.2 North Pit and South Pit

When assessed against the PRCP Guidelines **[1]**, the South Pit void has been shown to be located outside the extents of the PMF and 0.1% AEP flood plain extents of the unnamed tributary of the Leichardt River. The South Pit has no external catchments due to the proposed abandonment bund alignment.

When assessed against the PRCP Guidelines **[1]**, the North Pit void has been shown to be located outside the extents of the 0.1% AEP flood plain extents of the unnamed tributary of the Leichardt River. The North Pit receives flows from a small catchment to the east and the north wall is overtopped in the 1% AEP, 0.1% AEP and PMF design storm events. This is intentional and the addition of the clean water to the pit will bring the stored water to within stock water quality for use by the local farmer. The North Pit is not hydraulically connected to the unnamed tributary of the Leichardt River.

Any rainfall over either the North Pit or South Pit extents will be retained within the voids and will evaporate during the dry season.

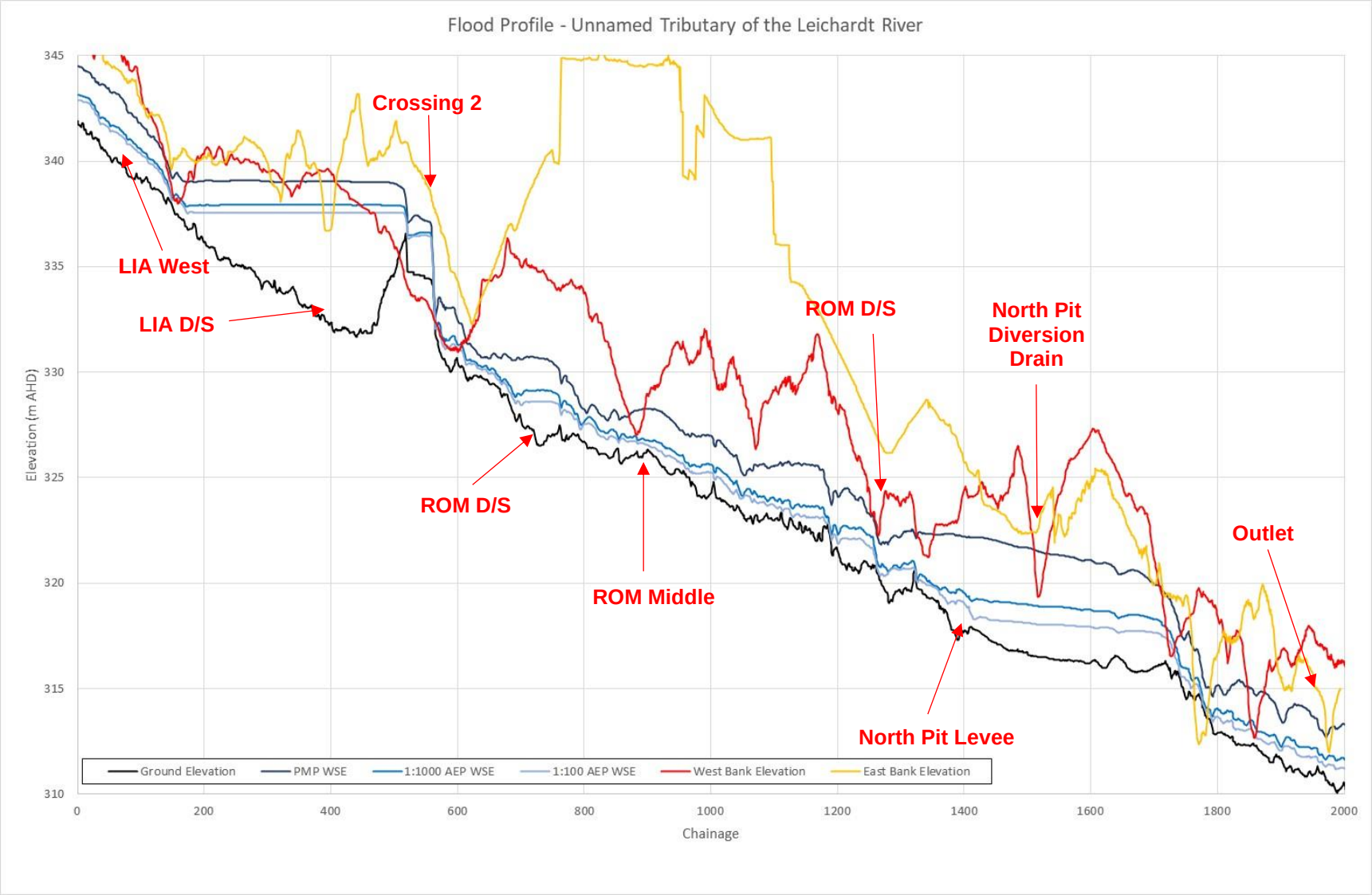
5.3 Unnamed Tributary of Weatherly Creek

The location of Crossing 2 of the Haul Road creates a location of temporary flood retention. The haul road overtops during the 1% AEP, 0.1% AEP and PMF events. Flood water will slowly pass beneath the haul road through the retained 1200 mm CSP culvert during flood events.

The Diversion Drain to the west of the North Pit is to be retained and provides hydraulic connectivity for the unnamed tributary of the Leichardt River to flow to the Leichardt River. The Diversion Drain has sufficient capacity to convey the PMF and 0.1% AEP flows without overtopping and impacting either the North Pit or South Pit.

The flood profile within the unnamed tributary of the Leichardt River is summarised in **TABLE 15** and is depicted on **DIAGRAM 18**. As can be seen on **DIAGRAM 18**, the haul road and Diversion Drain create a temporary retention effect of floodwaters. This retention effect is increased in more extreme events. The eastern and western bank elevations are also depicted on **DIAGRAM 18**. Where the bank elevations are below flood elevations, this indicates locations where small gullies enter the unnamed tributary of the Leichardt River.

DIAGRAM 18: FLOOD PROFILE OF THE UNNAMED TRIBUTARY OF THE LEICHARDT RIVER



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6 SUMMARY AND CONCLUSIONS

ATCW were commissioned by Aeris to prepare a flood risk profile for the BCP site to meet the requirements of the PRCP guidelines at closure. The PRCP requires flood risk assessments for two aspects of closure: to identify whether any mine voids will remain in the floodplain post-closure; and to assess the flood risk to remaining infrastructure.

To prepare the flood risk profile, hydraulic analysis of the site was undertaken using the two dimensional (2D) finite difference program TUFLOW. ARR **[2]** guidelines were utilised to develop the hydrologic inputs as direct rainfall to the hydraulic model.

As a result of the hydraulic analyses, flood risk profiles were developed for key infrastructure that will remain at the BCP site. Flood mapping was generated for maximum flood depths and maximum velocities for the PMF, 0.1% AEP and 1% AEP design storm events.

Hydraulic analysis indicated that neither the North Pit nor the South Pit will be impacted by flows from the unnamed tributary of the Leichardt River. The North Pit retains an external catchment of approximately 10 ha due to the potential long term instability of its north wall. An alternate bund is proposed to divert surface runoff from this external catchment into the North Pit, where it will be used for stockwater. Flows will only enter the North Pit from this catchment in events greater than the 1% AEP design storm event. The diversion drain to the west of the North Pit maintains hydraulic connectivity towards the Leichardt River. As such, the pre-mining hydraulic regime will be maintained post-closure.

The South Pit void is not located within the extents of the 0.1% AEP floodplain.

The retained diversion drain to the west of the North Pit has sufficient capacity to convey flows up to and including the PMF event. The North Pit void is not located within the extents of the 0.1% AEP floodplain of the unnamed tributary of the Leichardt River. The North Pit will receive runoff from the upstream catchment to ensure retained waters meet the requirements on ANZECC for stockwater purposes **[9]**.

The WRD Sediment Dam is to be retained for stockwater use by the landowner. Hydraulic modelling indicates the WRD Sediment Dam spillway has sufficient capacity so that the embankment will not be overtopped in design storm events up to and including the PMF.

All other areas of the site, with the exception of the pit voids, drain freely to the unnamed tributary of the Leichardt River.

A flood profile for the unnamed tributary of the Leichardt River has been derived from the results of the hydraulic modelling for the PMF, 0.1% AEP and 1% AEP design storm events. The flood profile demonstrates that the unnamed tributary of the Leichardt River does not impact any of the retained site infrastructure or the pit voids.

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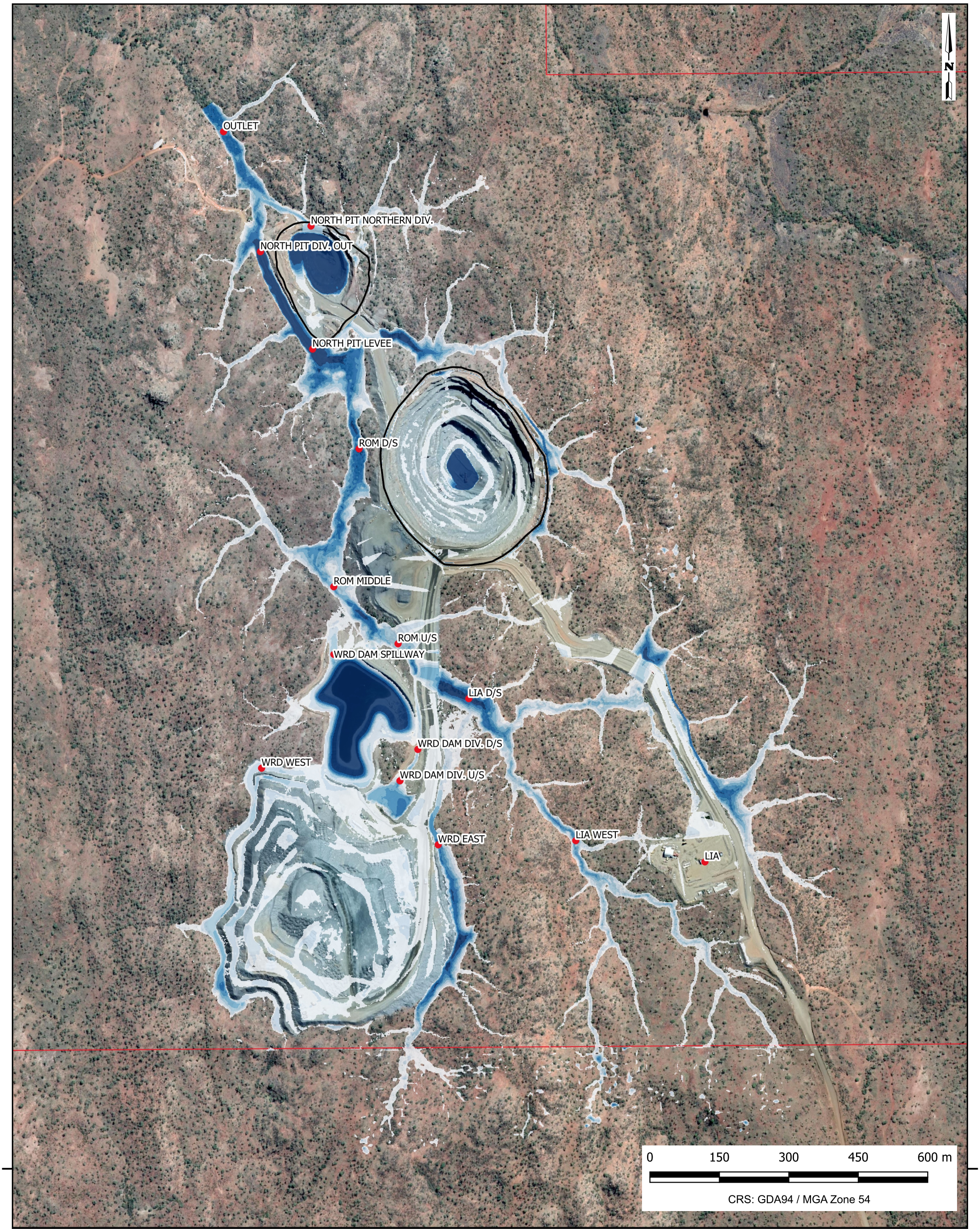
FIGURES



LEGEND

- REPORTING LOCATIONS
- MINE LEASE

MAXIMUM DEPTH (m)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.5
- > 3.5

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PROBABLE MAXIMUM FLOOD - MAXIMUM DEPTH

FIGURE 001

118131-12

DATE: 2023-02-02

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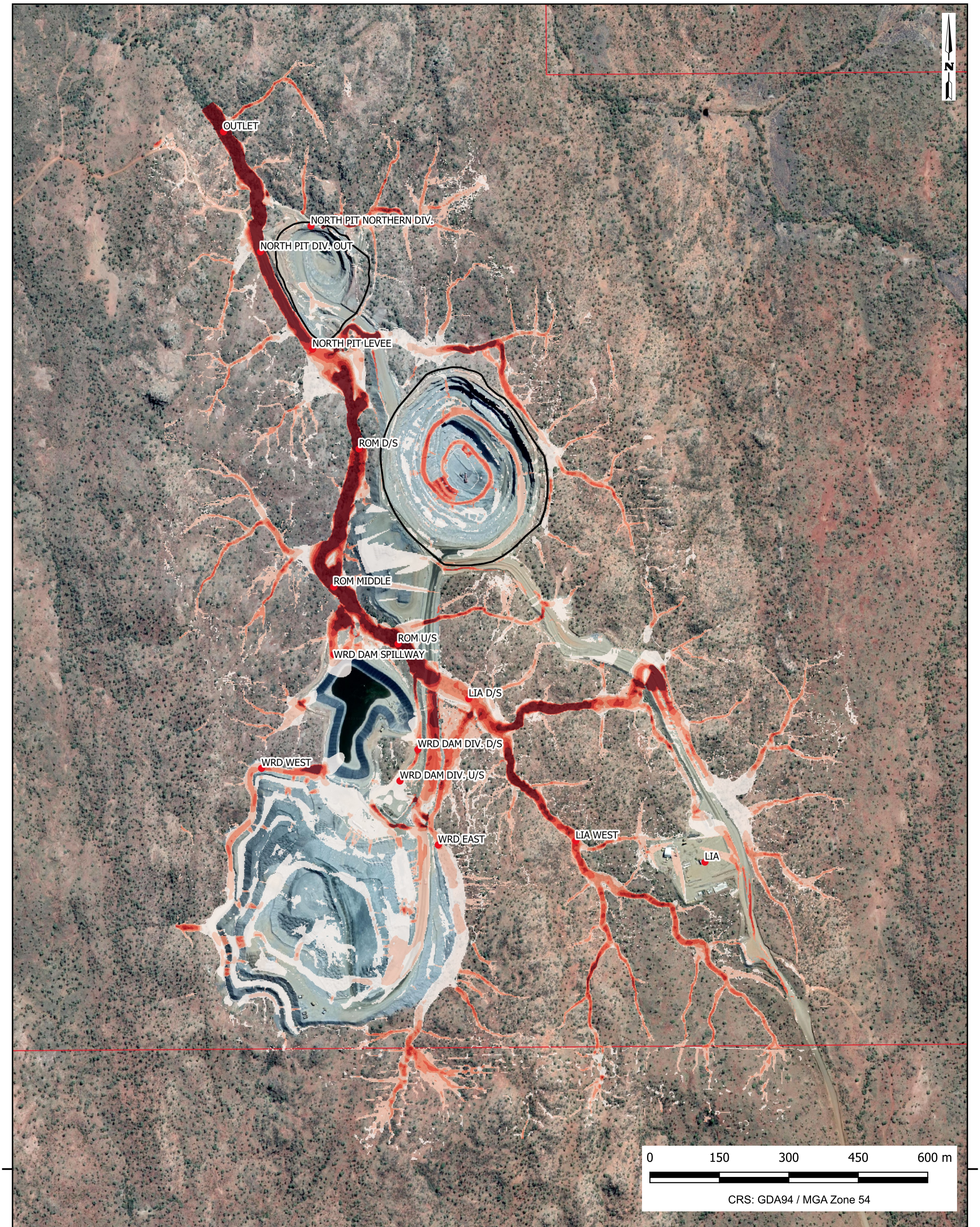

LEGEND

- REPORTING LOCATIONS
- MINE LEASE

MAXIMUM VELOCITY (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- > 2.5

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PROGRESSIVE REHABILITATION AND
CLOSURE PLANNING

PROBABLE MAXIMUM FLOOD - MAXIMUM
VELOCITY

FIGURE 002

118131-12

DATE: 2023-02-02

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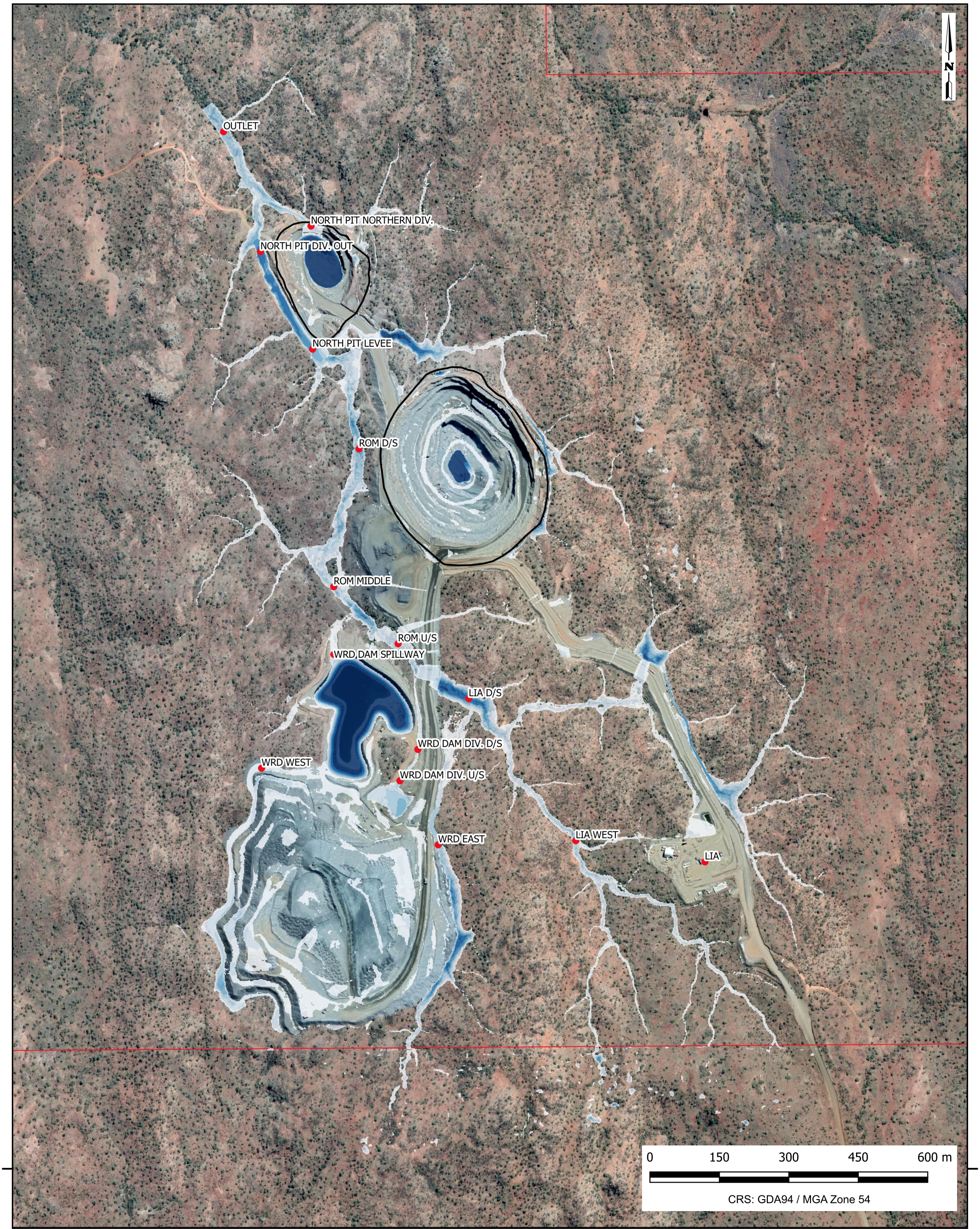

LEGEND

- REPORTING LOCATIONS
- MINE LEASE

MAXIMUM DEPTH (m)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.5
- > 3.5

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PROGRESSIVE REHABILITATION AND
CLOSURE PLANNING

1:1,000 ANNUAL EXCEEDANCE PROBABILITY -
MAXIMUM DEPTH

FIGURE 003

118131-12

DATE: 2023-02-02

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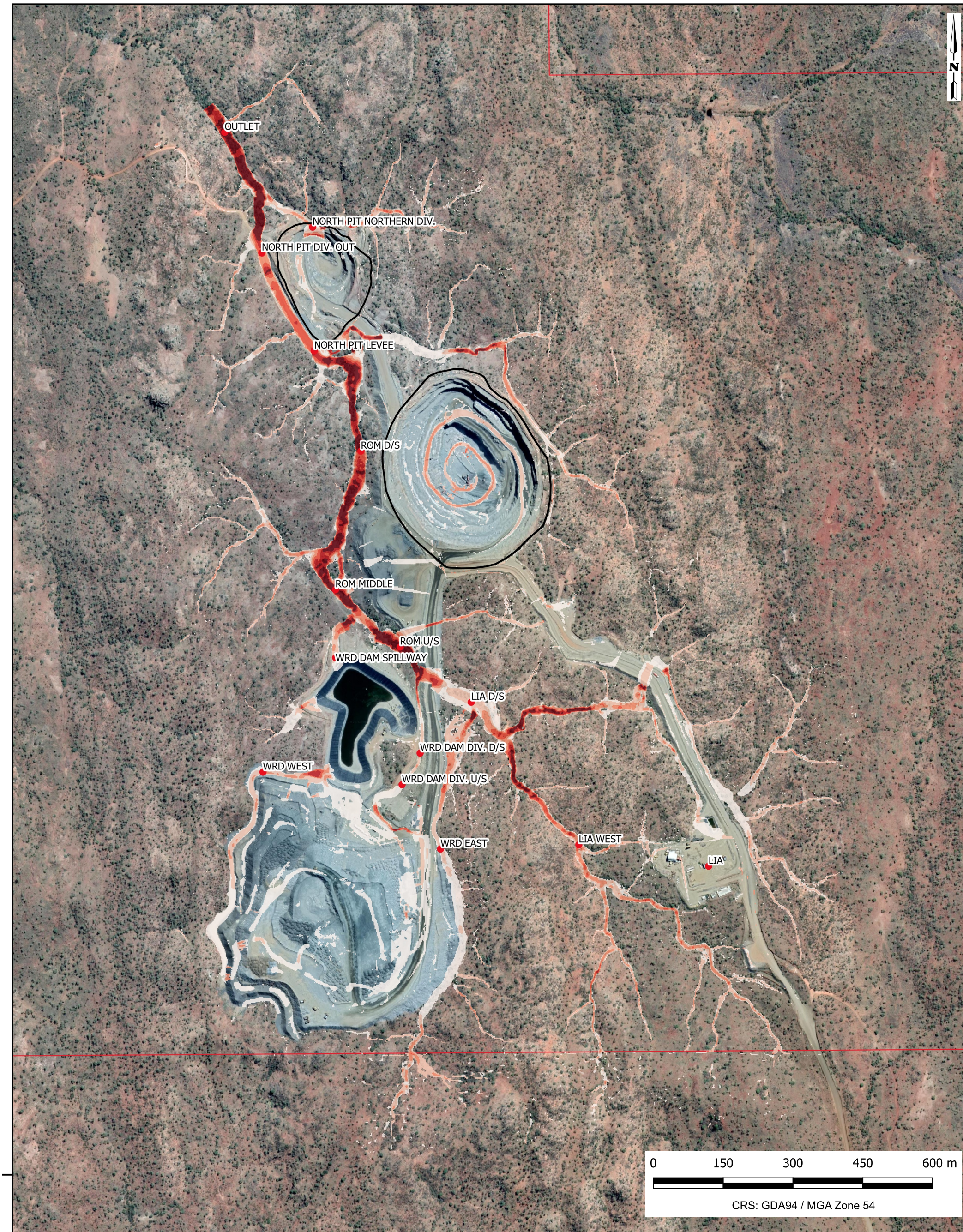

LEGEND

- REPORTING LOCATIONS
- MINE LEASE

MAXIMUM VELOCITY (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- > 2.5

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CLOSURE PLANNING

1:1,000 ANNUAL EXCEEDANCE PROBABILITY -
MAXIMUM VELOCITY

FIGURE 004

118131-12

DATE: 2023-02-02

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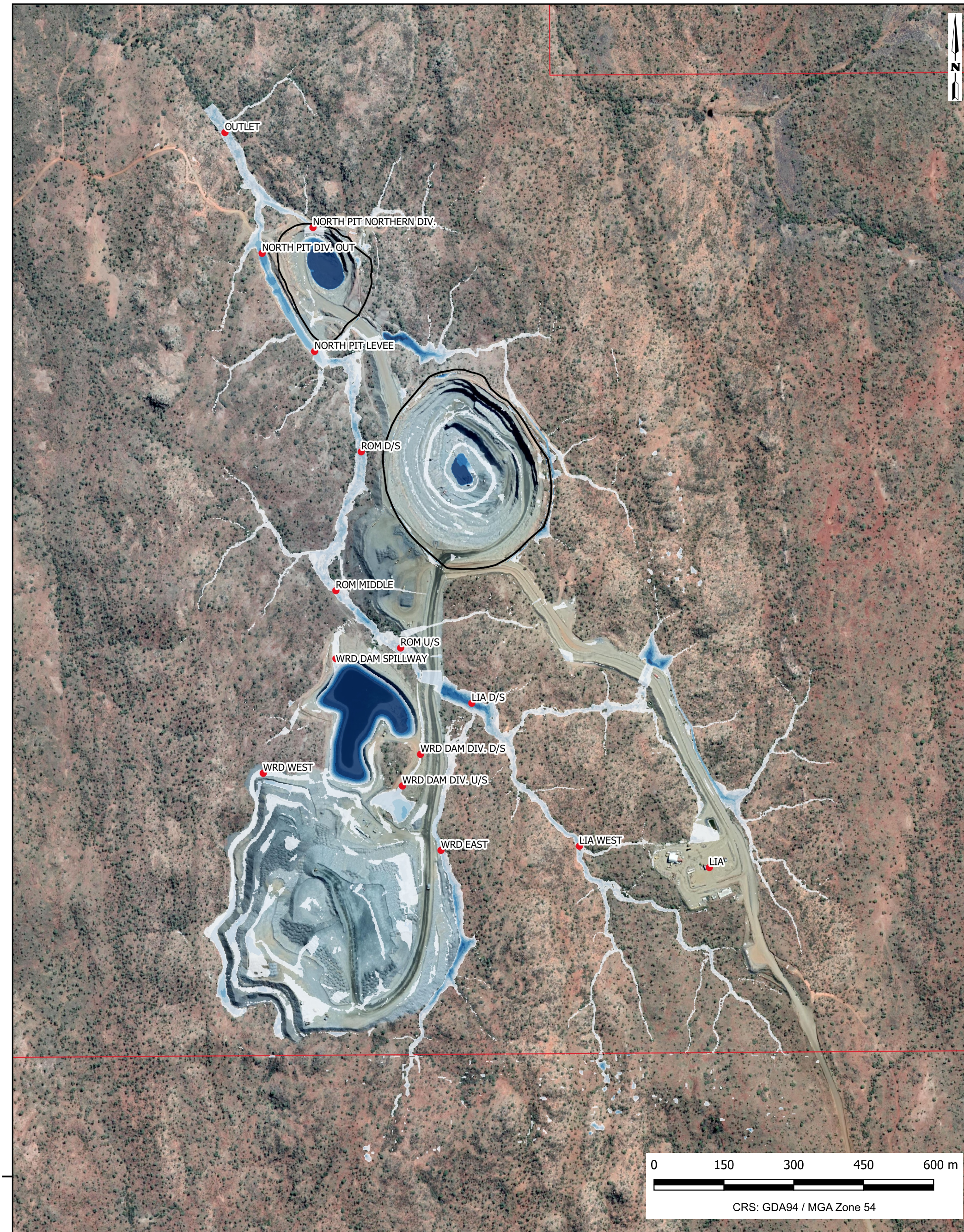

LEGEND

- REPORTING LOCATIONS
- MINE LEASE

MAXIMUM DEPTH (m)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.5
- > 3.5

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CLOSURE PLANNING

1:100 ANNUAL EXCEEDANCE PROBABILITY -
MAXIMUM DEPTH

FIGURE 005

118131-12

DATE: 2023-02-02

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LEGEND

- REPORTING LOCATIONS
- MINE LEASE

MAXIMUM VELOCITY (m/s)

- <= 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- > 2.5

AERIS RESOURCES

BARBARA COPPER PROJECT
PROGRESSIVE REHABILITATION AND
CLOSURE PLANNING

1:100 ANNUAL EXCEEDANCE PROBABILITY -
MAXIMUM VELOCITY

FIGURE 006

118131-12

DATE: 2023-02-02

ATC WILLIAMS

M:\Synergy\Projects\118\118131 Barbara Copper Project\12 PRCP Assistance & Support\Data and Calcs\QGIS\PRCP Figures.qgz

APPENDICES

APPENDIX A – PROBABLE MAXIMUM PRECIPITATIOMN ESTIMATION

Generalised Short-Duration Method (GSDM)

LOCATION INFORMATION

Catchment Name	Barbara Copper Project		*Reference: Generalised Short Duration Method (BOM, 2003)*	
Catchment Area	2.8 km²			
State	Qld			
Latitude	Longitude	Duration Limit	Prop Smooth	Prop Rough
-20.424	139.852	6 Hrs	100%	0%

ELEVATION ADJUSTMENT FACTOR (EAF)

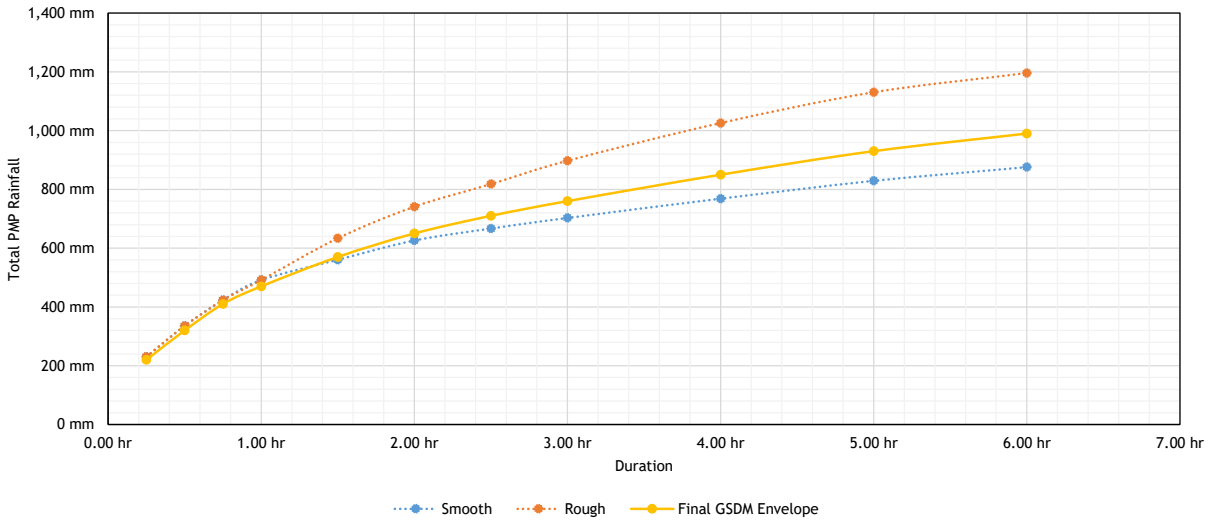
Mean Elevation at Site Location:	350 m	**EAF**	1

MOISTURE ADJUSTMENT FACTOR (MAF)

MAF	0.9471

PMP VALUES (mm)

Duration (hours)	Initial Depth - Smooth (DS)	Initial Depth - Rough (DR)	PMP Estimate = (Ds x S + DR x R) x MAF x EAF	Rounded PMP Estimate (nearest 10 mm)
0.25 hr	230.6 mm	230.6 mm	218.4 mm	220 mm
0.50 hr	335.4 mm	335.4 mm	317.7 mm	320 mm
0.75 hr	423.1 mm	423.1 mm	400.7 mm	410 mm
1.00 hr	491.5 mm	491.5 mm	465.5 mm	470 mm
1.50 hr	560.6 mm	633.6 mm	565.5 mm	570 mm
2.00 hr	626.0 mm	741.0 mm	647.4 mm	650 mm
2.50 hr	666.7 mm	818.0 mm	703.1 mm	710 mm
3.00 hr	702.8 mm	897.3 mm	757.7 mm	760 mm
4.00 hr	768.3 mm	1,025.8 mm	849.6 mm	850 mm
5.00 hr	829.0 mm	1,130.5 mm	927.9 mm	930 mm
6.00 hr	875.7 mm	1,195.8 mm	980.9 mm	990 mm



APPENDIX B – HAUL ROAD CULVERT PHOTOS

A site visit was undertaken to the BCP on 17th September 2022. During the site visit, the locations of the culverts discussed in **Section 3.5.2.6** and **Section 3.9** were examined to ensure the culverts were at the assumed locations and with the assumed geometries.

As can be seen In **Photo 1, Photo 2, Photo 3, Photo 4** and **Photo 5,** the pipe crossing at Crossing 1, Crossing 2, Crossing 3, Crossing 4 and Crossing 5 were all clearly visible and the dimensions were confirmed. **Photo 6** does not clearly show the pipe at Crossing 6. This was due to the steep nature of the adjacent ground levels combined with the dense brush and vegetation at the outlet location. However, the pipe was visually sighted.

It is noted that the culvert at Crossing 1 is completely blocked. It is recommended that all culverts should be inspected regularly and any blockages removed.

PHOTO 1 – CROSSING 1

PHOTO 2 - CROSSING 2

PHOTO 3 - CROSSING 3

PHOTO 4 – CROSSING 4

PHOTO 5 – CROSSING 5

PHOTO 6 - CROSSING 6

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Barbara Copper Project Progressive Rehabilitation and Closure Plan

Water Quality Assessment of North Pit, South Pit and WRD Sediment Dam

Prepared for Round Oak Minerals Pty Limited | 31 March 2023

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Barbara Copper Project Progressive Rehabilitation and Closure Plan

Water Quality Assessment of North Pit, South Pit and WRD Sediment Dam

Client:	Round Oak Minerals Pty Limited
ABN:	64 130 641 691
Suitably Qualified Person	Willy Van Vaerenbergh
Position	Principal Hydrogeologist
Signature	
Date	31/03/2023

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Table of Contents

1 Introduction 1
1.1 Introduction 1
1.2 BCP PRCP status 1
1.3 DES Request for Information 3
1.4 Scope of report 3
2 Applicability of water quality guidelines for livestock watering 4
3 Final void water quality modelling results 8
3.1 Introduction 8
3.2 Water balance model 8
3.3 Water quality model 10
3.3.1 Modelling approach 10
3.3.2 Representative initial water quality conditions 12
3.4 Modelled water quality in final voids and sediment dam 16
3.4.1 Introduction 16
3.4.2 WRD Sediment Dam water quality 16
3.4.3 North Pit water quality 22
3.4.4 South Pit water quality 27
3.5 Summary 35
4 Potential AMD impact on final void water quality 36
4.1 Introduction 36
4.2 Geochemical characterisation results of waste rock and ore 36
4.2.1 Waste rock characterisation 36
4.2.2 Column Leach test of waste rock and ROM oxide 37
4.3 Potential AMD impacts on final void water quality 40
4.3.1 Exposure to PAF material from pit walls 40
4.3.2 Proportion of AMD leachate relative to total inflows in the open pits 42
4.3.3 Solute concentrations within the AMD leachate 42
4.3.4 Potential AMD impacts of open pit water quality 42
5 Preliminary assessment of final void stratification 45
5.1 Introduction 45
5.2 Depth/area ratio assessment 46
5.3 One-dimension GLM model 46
5.3.1 Introduction 46
5.3.2 GLM model setup 47
5.3.3 North Pit GLM model results 47

5.3.4 South Pit GLM model results 49
6 Conclusions 52
7 References 53
8 Limitations 55

Appendices

A Snapshot of water balance model results
B Water quality monitoring results
C ATC Williams "Geochemical assessment of the North Pit, South Pit and the WRD Dam" (2023)
D WRD Sediment Dam modelled long-term water quality
E North Pit modelled long-term water quality
F South Pit modelled long-term water quality
G Kinetic column leach test results

Figures

Figure 1 Project layout and mine features
Figure 2 Schematic BCP water balance model (ATC Williams, February 2023)
Figure 3 Water quality model components for open pit voids
Figure 4 WRD Sediment Dam modelled water quality – pH, TDS, calcium and sulphate
Figure 5 WRD Sediment Dam modelled water quality – arsenic, copper, molybdenum and uranium
Figure 6 North Pit modelled water quality – pH, TDS, calcium and sulphate
Figure 7 North Pit modelled water quality – arsenic, copper, molybdenum and uranium
Figure 8 South Pit (scenario 1) modelled water quality – pH, TDS, calcium and sulphate
Figure 9 South Pit (scenario 1) modelled water quality – arsenic, copper, molybdenum and uranium
Figure 10 South Pit (Scenario 2) modelled water quality – pH, TDS, calcium and sulphate
Figure 11 South Pit (scenario 2) modelled water quality – arsenic, copper, molybdenum and uranium
Figure 12 AMD plot for waste rock and ROM oxide and AMD classification (EGi, 2020)
Figure 13 North Pit waste rock cross-sections (AECOM 2014)
Figure 14 South Pit waste rock cross-sections (AECOM 2014)
Figure 15 Summary of EC values for all rock units within Barbara drill core samples (EGi, 2014)
Figure 16 North Pit GLM model results – temperature (°C) distribution
Figure 17 North Pit GLM model results – density distribution
Figure 18 North Pit GLM model results – salinity (g/L) distribution

Figure 19 South Pit GLM model results – temperature (°C) distribution
Figure 20 South Pit GLM model results – density distribution
Figure 21 North Pit GLM model results – salinity (g/L) distribution

Tables

Table 1 Relevant ANZECC 2000 WQG values for livestock drinking water 5
Table 2 Assessment of initial water quality conditions..... 12
Table 3 Initial concentrations of relevant solutes/parameters 14
Table 4 Long-term modelled (2080) water quality in WRD Sediment Dam..... 18
Table 5 Long-term modelled (Feb-2080) water quality in North Pit 23
Table 6 Long-term modelled (Feb-2080) water quality in South Pit (scenario 1)..... 28
Table 7 Long-term modelled (Feb-2080) water quality in South Pit (scenario 2)..... 31
Table 8 BCP AMD classification (EGi, 2014)..... 36
Table 9 Acid rock drainage samples - acid generation lag time (EGi, 2014)..... 37
Table 10 Descriptions of Barbara waste rock and ROM oxide samples (EGi, 2020)..... 37
Table 11 Summary of leachate analysis from week 4 to 52 (EGi, 2020) 39
Table 12 "*Relative Depth*" of open pits and sediment dam 46

1 Introduction

1.1 Introduction

Aeris Resources (Aeris) owns and operates the Barbara Copper Project (the Project), located within Mining Lease (ML) ML90241 and authorised under Environmental Authority (EA) EPML02840015 for resource activities relevant to mining metals (copper, lead, silver, zinc, gold and iron ore). The Project is an open-cut copper mine that has extracted approximately 772,000 tonnes of ore. The mine operated from June 2019 until March 2021 and was placed on care and maintenance in April 2021.

1.2 BCP PRCP status

On 28 July 2022, an application for a proposed PRPC plan (Round Oak Minerals Pty Limited, July 2022) (i.e. the BCP PRPC v1.0) for the Project was submitted to the Department of Environment and Science (DES) under transitional provisions of the recent rehabilitation reforms and amendments to the *Environmental Protection Act 1994* (EP Act).

The BCP PRPCP v1.0 was prepared in accordance with DES' *Guideline: Progressive rehabilitation and closure plans (PRC plans) (ESR/2019/4964 Version 2.00: March 2021)* (DES, 2021) (referred to herein as the PRCP Guideline). This guideline provides information to assist companies in complying with the amendments to the EP Act and the *Mineral and Energy Resources (Financial Provisioning) Act 2018 (Qld)* (MERFP Act).

As per the BCP PRCP v1.0, the overarching objective of mine rehabilitation and closure is to achieve a safe, stable and non-polluting site that can sustain the agreed post-mining land uses (PMLUs). The current mine features and disturbance areas on the Project site subject to rehabilitation are shown in Figure 1.

The Project site's current land uses include low-intensity cattle grazing and mineral exploration activities. Historically, mining activities and cattle grazing have been the predominant land use.

The following PMLUs are proposed for the site:

- North Pit and South Pit – Water storage for livestock
- Sediment Dam – Water storage for livestock
- Waste Rock Dump – Native ecosystems
- Ancillary infrastructure, ROM pad, roads and exploration – Low-intensity grazing
- Diversion drains – Water management infrastructure

Specific infrastructure items will remain at closure for the landholder as specified in the consultation register (Section 3.2 of the BCP PRPC v1.0). Infrastructure to remain at closure is summarised in Section 4.3.2 of the BCP PRCP v1.0.

The proposed PMLUs for the Project are consistent with the outcomes identified in the consultation plan. The PMLUs support regional landscapes and agriculture production values, which is aligned with objective 2 from the Northwest Regional Plan.

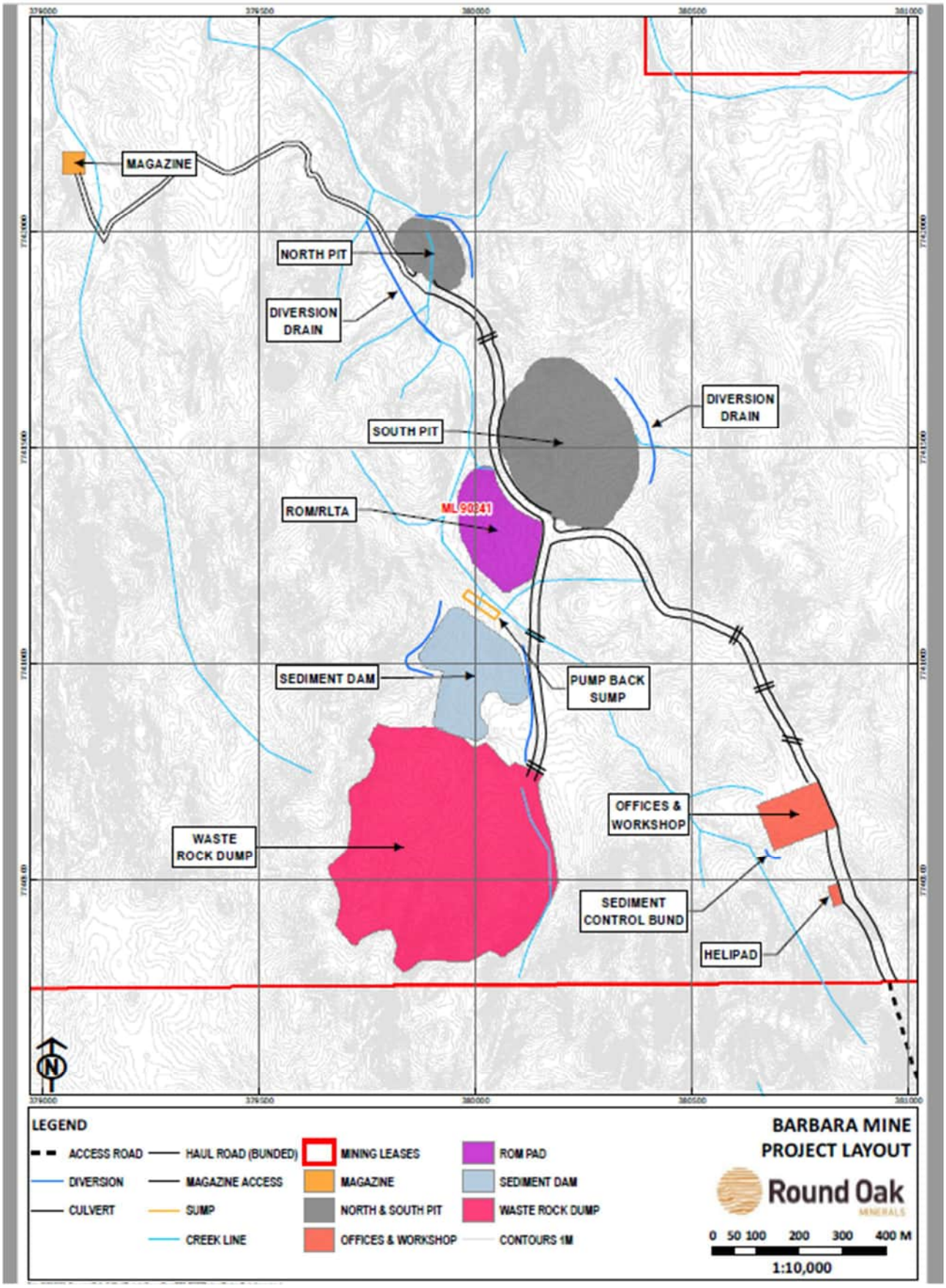

Figure 1 Project layout and mine features

1.3 DES Request for Information

Following receipt and review of the BCP PRPC v1.0, DES issued notice for an information request (DES, September 2022) under section 140 of the *Environmental Protection Act 1994*.

The information requested by DES was outlined in Attachment 1 to the notice. Attachment 1 requested an updated progressive rehabilitation and closure plan (PRC Plan) be provided in response to this information request.

1.4 Scope of report

WMV Environmental Pty Ltd (WMV) prepared this report to address the matters relating to water quality in the North Pit, South Pit and Waster Rock Dump (WRD) Sediment Dam, as raised by DES in the notice. This report takes into consideration data, information and the results of other studies, primarily related to the post closure water management plan and water balance model (WBM) developed by ATC Williams (ATC Williams, February 2023) to assist in determining long-term water levels in the pits and sediment dam.

2 Applicability of water quality guidelines for livestock watering

The proposed PMLUs for the North Pit, South Pit and WRD Sediment Dam are "*water storage for livestock*". Leaving the voids as water storage was considered most suited to the PMLU of low-intensity grazing for the surrounding mining area. Water availability for grazing is limited at the site, and the voids will provide a source of drinking water for livestock. Site access to the pits by the public is restricted by existing infrastructure.

The proposed mine rehabilitation and closure must achieve a safe, stable and non-polluting site that can sustain this PMLU. With respect to the "*non-polluting*" criterion, it must be demonstrated that the water quality in the pits and sediment dam will not exceed the applicable livestock water quality guidelines post-closure.

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) (a.k.a. the *ANZG 2018 Water Quality Guidelines*) provides general guidance for applying the Water Quality Management Framework for the National Water Quality Management Strategy (NWQMS) (https://www.waterquality.gov.au/about/charter).

The objective of the ANZG 2018 Water Quality Guidelines is to provide authoritative guidance on the management of water quality in Australia and New Zealand. This guidance includes setting water quality and sediment quality objectives designed to sustain current or likely future community values for natural and semi-natural water resources.

With respect to livestock drinking water guideline values, ANZG (2018) states that "*the main revision for livestock drinking water guidance in the Water Quality Guidelines is the addition of some weight-of-evidence material. Otherwise, our guidance is structurally the same as the ANZECC & ARMCANZ (2000) guidelines, with minor changes to some of the DGVs*".

However, it is noted that the ANZG has not yet published its "*Primary Industries – Livestock Drinking Water Guidance*" document (https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/primary-industries/stock-water-guidance). Therefore, the guidance provided in the *2000 Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ, 2000) (a.k.a. the ANZECC 2000 WQG) is considered applicable.

The ANZECC 2000 WQG includes trigger levels for livestock drinking water for major ions, total dissolved solids and heavy metals/metalloids, as summarised in Table 1.

It is noted that ANZECC 2000 WQG provides for specific analytes a range of values (e.g. for TDS) based on the adaptability of/potential impact on the livestock or presents different values based on the type of livestock. Where relevant, the range of values has been adopted to assess water quality against the livestock drinking water trigger values.

Table 1 Relevant ANZECC 2000 WQG values for livestock drinking water

Analyte	ANZECC 2000 Livestock WQG Discussion			Adopted value(s) (mg/L)
Major Ions				
Calcium: Stock should tolerate concentrations of calcium in water up to 1000 mg/L, if calcium is the dominant cation and dietary phosphorus levels are adequate.				1,000
Magnesium: Insufficient information is available to set trigger values for magnesium in livestock drinking water.				-
Sulfate: No adverse effects to stock are expected if the concentration of sulfate in drinking water does not exceed 1000 mg/L. Adverse effects may occur at sulfate concentrations between 1000 and 2000 mg/L, especially in young or lactating animals or in dry, hot weather when water intake is high. These effects may be temporary and may cease once stock become accustomed to the water.				1,000 – 2,000
Salinity				
Total dissolved solids (Beef cattle)	No adverse effects on animals expected	Animals may have initial reluctance to drink or there may be some scouring, but stock should adapt without loss of production	Loss of production and a decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually	4,000 – 5,000 – 10,000
	0 – 4,000 mg/L	4,000 – 5,000 mg/L	5,000 – 10,000 mg/L	
Metals/metalloids				
Aluminium: Where aluminium concentrations in water exceed 5 mg/L, stock intake of phosphorus in the diet should be investigated. Animals, particularly ruminants, may tolerate much higher levels of aluminium as long as there is sufficient phosphorus in the diet to compensate for the effects of aluminium.				5
Arsenic: A concentration of total arsenic in drinking water for livestock exceeding 0.5 mg/L may be hazardous to stock health. If arsenic is not provided as a food additive and natural levels of arsenic in the diet are low, a level of 5 mg/L in drinking water may be tolerated.				0.5
Beryllium: There are insufficient data to set trigger values for animal consumption of beryllium in livestock drinking water.				-
Boron: If the concentration of boron in water exceeds 5 mg/L, the total boron content of the livestock diet should be investigated. Higher concentrations in water may be tolerated for short periods of time. For cattle, a trigger value of 7 mg/L has been calculated. Note that a safety factor for possible long-term effects was not included in the calculations because it is considered that there is little likelihood of there being long-term effects due to boron ingestion (NRC 1980).				5
Cadmium: A concentration of total cadmium greater than 0.01 mg/L in drinking water for livestock may be hazardous to animal health.				0.01

Analyte	ANZECC 2000 Livestock WQG Discussion	Adopted value(s) (mg/L)
Chromium:	Levels of total chromium exceeding 1 mg/L in the drinking water of livestock may be hazardous to animal health.	1
Cobalt:	Levels of total cobalt in drinking water for livestock exceeding 1 mg/L may be hazardous to animal health, particularly if cobalt supplements are being used.	1
Copper:	Concentrations of total copper in drinking water for livestock exceeding 0.5 mg/L may be hazardous to the health of sheep. Adverse effects may be experienced in cattle at concentrations above 1 mg/L copper, and in pigs and poultry concentrations exceeding 5 mg/L. If animal diets are high in copper, the levels in drinking water should be revised downwards. Animal intake of sulfur and molybdenum should also be considered in conjunction with copper.	0.5 – 1
Fluoride:	Fluoride concentrations greater than 2 mg/L in drinking water for livestock may be hazardous to animal health. If livestock feed contains fluoride, the trigger value should be reduced to 1.0 mg/L. The trigger value of 2 mg/L is consistent with guidelines developed for fluoride in Canada (CCREM 1987) and South Africa, although the South African guidelines suggest that adverse effects are unlikely to occur in ruminants at concentrations less than 4 mg F/L (DWAF 1996b).	2
Iron:	No guideline has been established for iron in drinking water for livestock as it poses a very low health risk to animals.	-
Lead:	Concentrations of total lead in drinking water for livestock exceeding 0.1 mg/L may be hazardous to animal health. The trigger value of 0.1 mg/L is consistent with guidelines developed for lead in Canada (CCREM 1987) and South Africa, although the latter guidelines suggest that for pigs, no adverse effects are likely to occur at concentrations up to 0.5 mg Pb/L (DWAF 1996b)	0.1
Manganese:	No guideline has been established for manganese in drinking water for livestock.	-
Mercury:	Levels of total mercury exceeding 0.002 mg/L in drinking water for livestock may accumulate in edible animal tissue to a level which may pose a human health risk. The guideline value developed for mercury in Canada is 0.003 mg/L (CCREM 1987) and in South Africa, 0.001 mg/L (DWAF 1996b).	0.002
Molybdenum:	Concentrations of molybdenum in livestock drinking water greater than 0.15 mg/L may cause health problems to stock, depending on total dietary intakes of molybdenum, copper, iron and sulfur. At molybdenum concentrations greater than 0.15 mg/L, the animal diet should be investigated to ensure that copper levels are sufficient to account for the total dietary intake of molybdenum. The guideline recommended in South Africa for molybdenum in livestock drinking water is 0.01 mg/L, with concentrations <0.02 mg/L considered likely to be tolerated provided copper and sulfur intakes are adequate (DWAF 1996b). Canadian guidelines recommend an upper limit of 0.5 mg Mo/L in livestock drinking water (CCREM 1987).	0.15
Nickel:	Concentrations of total nickel in livestock drinking water greater than 1 mg/L may have adverse effects on animal health. The trigger value of 1 mg/L is consistent with guidelines developed for nickel in Canada (CCREM 1987) and South Africa (DWAF 1996b).	1

Analyte	ANZECC 2000 Livestock WQG Discussion	Adopted value(s) (mg/L)
Selenium:	Concentrations of total selenium in drinking water for livestock exceeding 0.02 mg/L may be hazardous to stock health. Recent guidelines developed in Canada (CCREM 1987) and South Africa (DWAF 1996b) recommend an upper limit of 0.05 mg/L.	0.02
Uranium:	Concentrations of uranium less than 0.2 mg/L in livestock drinking water are unlikely to be harmful to animal health.	0.2
Vanadium:	Insufficient information is available to set a trigger value for vanadium in livestock drinking water.	-
Zinc:	Total zinc concentrations in livestock drinking water less than 20 mg/L are unlikely to pose a threat to animal health. The trigger value of 20 mg/L is consistent with guidelines developed for zinc in South Africa (DWAF 1996b); a value of 50 mg/L has been proposed in Canada (CCREM 1987).	20

3 Final void water quality modelling results

3.1 Introduction

In response to DES' Information Request, ATC Williams updated and fine-tuned the existing water balance/water quality model developed for the BCP PRPC project. Detailed descriptions and results of the models are provided in the following reports:

The water balance/water quality model includes the following components:

- A water balance model (WBM) was developed using Goldsim Pro (Goldsim v14). The WBM was used to assess the impact of surface water runoff (mine impacted and non-impacted), evaporation and groundwater in/outflows to the North Pit, South Pit and WRD Sediment Dam. The outcomes of the WBM are presented in ATC William's report "*Aeris Resources - Barbara Copper Project - Progressive Rehabilitation and Closure Planning – Water Management Plan and Water Balance Model. Ref: 118131.12.R03 – dated 17 February 2023*".
- A water quality model (WQM) was developed by linking a PHREEQC (USGS, ver. 3.6.2.15100) geochemical model to the water balance model. PHREEQC is a computer program developed by the United States Geological Survey (USGS) for simulating chemical reactions and transport processes in natural or polluted water, laboratory experiments, or industrial processes. The outcomes of the WQM are presented in ATC William's memo "*Progressive Rehabilitation and Closure Planning – Geochemical assessment of the North Pit, South Pit and the WRD Sediment Dam. Ref: 118131.12.M02 – dated 24 March 2023*".

3.2 Water balance model

GoldSim is a dynamic probabilistic simulation program that allows the modelling of mine water balance systems during operations and post-closure. The program can simulate several relevant processes, such as rainfall runoff, evaporation, groundwater interaction with open pits/voids, void overflows, diversions, etc.

The program uses a range of parameters to represent the catchment surface water system, being routed through a time series of daily rainfall data for an estimated daily runoff.

There are two main types of modelling approaches available in GoldSim i.e.

- a deterministic model in which the input parameters are represented using single values (i.e. they are "determined" or assumed to be known with certainty). The outcome of a model simulation is a unique set of results.
- a stochastic model that uses a probabilistic approach (Monte Carlo analysis). This approach accounts for the input parameters' uncertainty to determine the outcome's likelihood. A Monte Carlo analysis describes the uncertainty of model predictions based on quantifying the input parameter uncertainty (i.e. values selected within realistic parameter bounds). The methodology involves running the models many times (realisations). For each realisation, inputs are sampled randomly and at the end of all model runs, the outputs are aggregated to determine their distribution.

The Goldsim WBM uses the Australian Water Balance Model (AWBM) as the rainfall-runoff model to simulate runoff within catchments based on precipitation and potential evaporation time series. A stochastic model was adopted to represent future climatic conditions (i.e. daily precipitation and evaporation) based on existing historical rainfall data.

Figure 2 presents a schematic of the BCP mine water balance model. A detailed description of the model input data, the modelled processes and the scenarios and modelling results is provided in ATC Williams' report, included as Appendix Q to the main BCP PRPC v2.

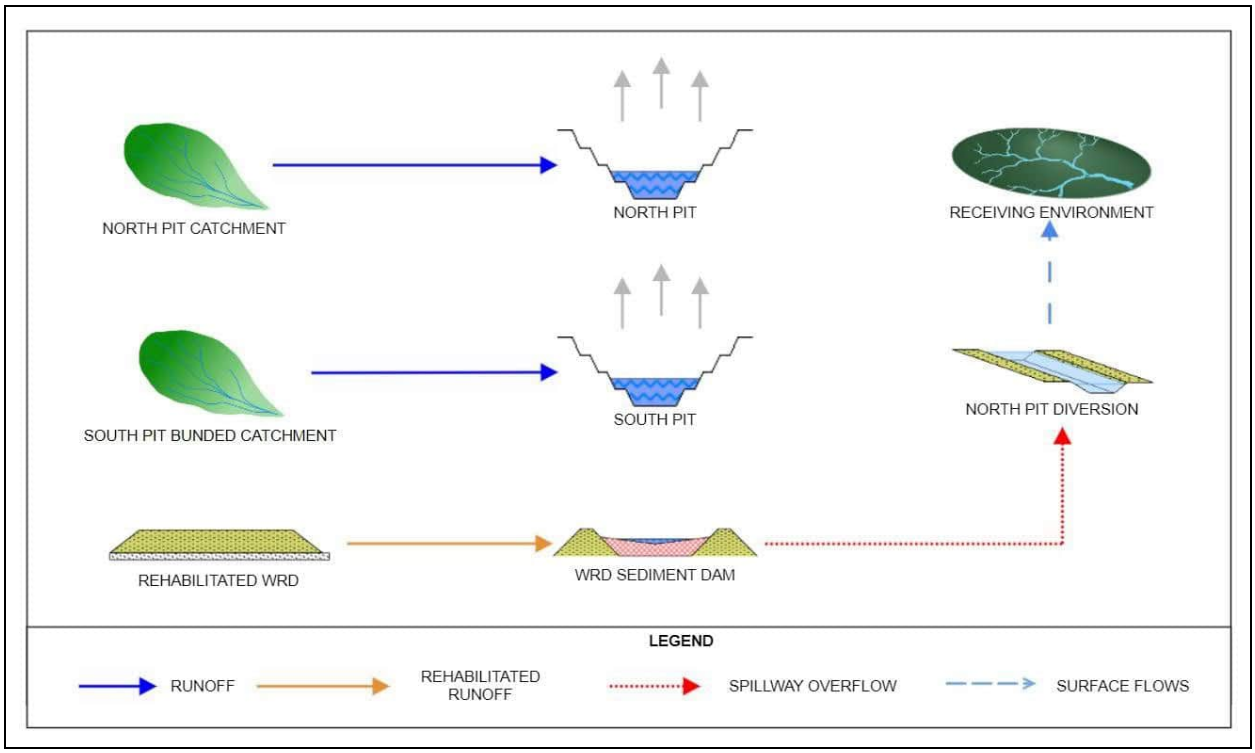

Figure 2 Schematic BCP water balance model (ATC Williams, February 2023)

Concerning the South Pit, two different scenarios were modelled to determine the best configuration of the bund/fence arrangement surrounding the South Pit. The catchment areas for each model area are as follows

- Scenario 1: 14.1 ha
- Scenario 2: 21.7 ha

Appendix A provides a snapshot of the WBM output.

The results of the WBM can be summarised as follows:

- WRD Sediment Dam
  - Rapidly accumulates water to 2027, after which it reaches a state of 'dynamic equilibrium'. The 'dynamic equilibrium' has minor variations throughout the year to account for periods of rainfall and evaporation.
  - The mean (average) water level in the WRD Sediment Dam reaches a level of approximately RL 333 m to RL 334 m.
  - The water level in the WRD Sediment Dam reaches the spillway level of RL 337 m each year, equivalent to rainfall exceeding the 95th percentile.
  - Due to the presence of the HDPE liner on the WRD Sediment Dam, no groundwater inflows or outflows were included or modelled.
- North Pit

- Rapidly accumulates water to 2033/2035, after which it reaches a state of 'dynamic equilibrium'. The 'dynamic equilibrium' has minor variations throughout the year to account for periods of rainfall and evaporation.
- The mean (average) water level in the North Pit reaches a level of approximately RL 308.5 m to RL 309.5 m, with variations throughout the calendar year during periods of rainfall and evaporation. The water level in the North Pit reaches the spill level of RL 313m in years where the rainfall exceeds the 85th percentile.
- In any given year, the spill risk from the North Pit is approximately 9%.
- Whilst the North Pit overtops in events greater than the 85th percentile climate conditions, the pit remains a net groundwater sink most of the time.

- South Pit:
  - Rapidly accumulates water to the year 2040, with the rate of accumulation reducing by 2060 (under Scenario 1) or 2065 under Scenario 2, after which the pit reaches a state of 'dynamic equilibrium'. The 'dynamic equilibrium' has minor variations throughout the year to account for periods of rainfall and evaporation.
  - The mean (average) water level in the South Pit reaches a level of approximately RL 286.5 m to RL 287.5 m (under Scenario 1) or approximately RL 290 m to RL 291 m (under Scenario 2).
  - The water level in the South Pit never reaches the rim level of RL 334 m under both scenarios. As such, there are no modelled spills or overtopping events. This indicates the South Pit achieves long-term containment.
  - The minimum and maximum modelled water levels are approximately RL 295 m and RL 280 m under Scenario 1 and RL 282 m and RL 300 m under Scenario 2. The minimum modelled water level is approximately RL 280 m. These values represent the historically 'wettest' and 'driest' years occurring consecutively through the simulation.
  - The South Pit remains a net groundwater sink.

3.3 Water quality model

3.3.1 Modelling approach

Solutes enter the open pits/sediment dam in rainfall runoff and groundwater inflow and may be removed from the voids in groundwater outflow and through geochemical reactions. The solute concentrations in the pit voids and sediment dam are defined by the fractions and solute concentrations of inflow water (from surface water runoff and groundwater inflow), the existing pit void/sediment dam water volumes and solute concentrations, evaporative processes and the occurring geochemical reactions (Figure 3).

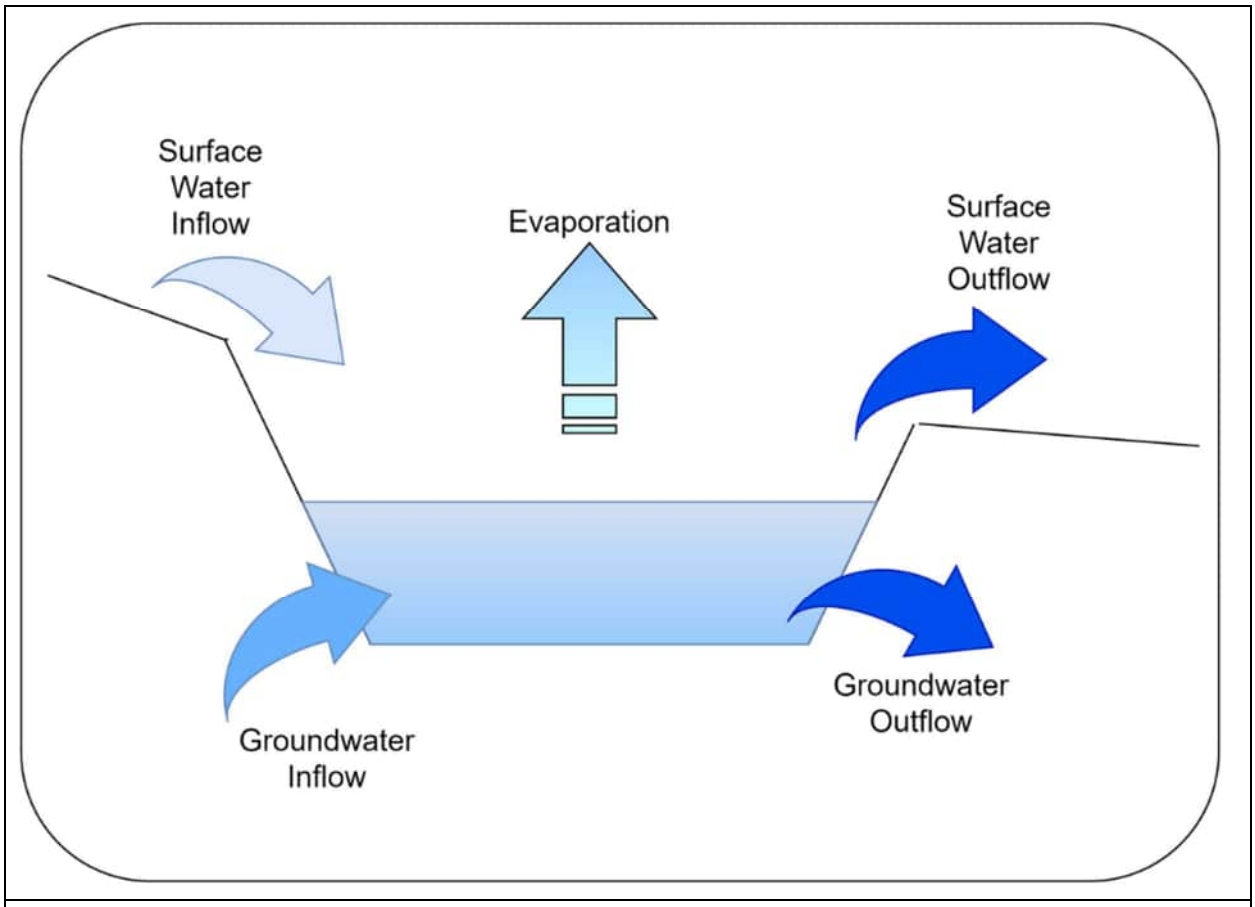

Figure 3 Water quality model components for open pit voids

Water quality models (WQMs) for the final voids and sediment dam were developed by linking the output of the Goldsim WBM with a PHREEQC (USGS, ver. 3.6.2.15100) geochemical model. PHREEQC is based on the equilibrium chemistry of aqueous solutions interacting with minerals, gases, solid solutions, exchangers, and sorption surfaces. The model is designed to perform a wide variety of aqueous geochemical calculations, including speciation, batch-reaction, one-dimensional reactive-transport, and inverse geochemical calculations.

Given the complexity of linking the Goldsim probabilistic output to PHREEQC, only selected scenarios were adopted to model water quality in the voids and sediment dam.

Three different water balance scenarios were evaluated, corresponding with the following Goldsim™ WBM stochastic results:

- The median climatic conditions, corresponding with an occurrence probability of 50% (i.e. 50th percentile or P50).
- Interquartile climatic conditions, corresponding with 25th percentile ant 75th percentile climatic conditions.
- Higher probabilities were not considered since increased rainfall, groundwater discharge into the pit void, and lower evaporation rates would result in improved water quality and represents a lower risk to the downstream environment or closure condition.

With respect to the geochemical process, two main scenarios were considered to evaluate the mixing of the different water types as per Figure 3:

- A first scenario/model that only included mixing of different water types (in terms of volumes and water quality) followed by evaporative processes in the voids/sediment dam. This model is denoted as the "mixing" model.
- A second scenario/model included speciation equilibrium modelling, i.e. the process of precipitation/dissolution of minerals from/into solution when the different water types are mixed. In the first instance, only the mineral phase considered was gypsum, whereby gypsum precipitation could occur if calcium and sulphate concentrations in the mixed water were sufficiently elevated. This model is denoted as the "equilibrium" model.

In the first instance, inflow water is mixed with existing pit voids/sediment dam water and solute concentrations are calculated though a mixing process, before evaporative losses increase the solute concentrations in the pit voids/sediment dams due to a reduction in water content. This mixed solution can be assessed without any equilibrium phases or equilibrated with gypsum. The resulting solution represents the pit void/sediment dam water quality that can outflow to either surface water or groundwater.

Assumptions made in the water quality model include the following (ATC Williams, March 2023):

- In general, surface water inflow into the pit void was equilibrated with standard atmosphere conditions (CO_2(g) -3.2, O_2(g) 0.67)) and groundwater with carbonate (CO_2(g) -1.5) to maintain the pH values of site water quality solutions used in this assessment.
- To reduce the number of parameters in the model and allows for the focus on bulk water chemistry, the models assume that no stratification occurs within the pit void.
- Concerning the equilibrium model, an equilibrium reaction with gypsum was the only parameter considered relevant for the loss of solids from solution in the pit voids and sediment dam.

3.3.2 Representative initial water quality conditions

A review of existing water quality data was undertaken to determine representative water quality input conditions (i.e. solute concentrations) for the different components of the WQM model.

Table 2 summarises the results of this assessment, with detailed analysis results presented in Appendix B. Table 3 presents the adopted input/initial concentrations for solutes.

Table 2 Assessment of initial water quality conditions

WQ Model Component/ Process	Assumptions	Source of water quality data
Rainfall		
Rainfall	Incorporated in the surface water runoff assessment	Surface water monitoring and sampling results (Table B.1)
North Pit		
Initial WQ Condition	Based on monitoring data from North Pit void	North Pit water quality monitoring and sampling results (Table B.2)
Surface Water Runoff from catchment	After rehabilitation, all runoff WQ should be representative of natural, background conditions (i.e. no sources of contamination)	Surface water monitoring and sampling results (Table B.1)
Groundwater Inflow	Based on existing data and results	Groundwater quality monitoring and sampling results from wells/bores in

WQ Model Component/ Process	Assumptions	Source of water quality data
		immediate vicinity of the North Pit (Table B.3)
South Pit		
Initial WQ Condition	Based on existing data and results	South Pit water quality monitoring and sampling results (Table B.4)
Surface Water Runoff from catchment	After rehabilitation, all runoff WQ should be representative of natural, background conditions (i.e. no sources of contamination)	Surface water monitoring and sampling results (Table B.1)
Groundwater Inflow	Based on existing data and results	Groundwater quality monitoring and sampling results from wells/bores in immediate vicinity of the South Pit (Table B.5)
WRD Sediment Dam		
Initial WQ Condition	Based on existing data and results	WRD Sediment Dam water quality monitoring and sampling results (Table B.6)
Surface Water Runoff from WRD	After rehabilitation, all runoff WQ should be representative of natural, background conditions (i.e. no sources of contamination). WRD has been capped.	Surface water monitoring and sampling results (Table B.1)
Groundwater Inflow (if any)	No GW inflow into sediment dam due to presence of HDPE liner.	None

Table 3 Initial concentrations of relevant solutes/parameters

	Included in model?	ANZECC 2000 Livestock WQG	Surface Water Runoff	North Pit		South Pit		WRD Sediment Dam
				Pit Water Quality	Groundwater Inflow	Pit Water Quality	Groundwater Inflow	
Physico-Chemical Parameters								
Electrical Conductivity (µS/cm)	No	-	321	1020	970	1448	2916	1446
pH (-)	Yes	6.5 – 8.5	8.16	8.07	7.60	8.09	7.91	8.09
Total Dissolved Solids (mg/L)	Yes	5,000	455	-	593	-	593	-
Major Ions (mg/L)								
Calcium	Yes	1,000	20.9	81.9	54.3	140.3	54.9	109.7
Magnesium	Yes	-	12.5	31.4	37.3	58.3	81.3	49.4
Sodium	Yes	-	31.4	91.6	123.8	96.0	534.3	114.6
Potassium	Yes	-	10.7	22.6	8.1	27.3	6.5	32.9
Sulphate (as SO4)	Yes	2,000	9.15	337.3	41.3	625.8	446.8	454.2
Chloride	Yes	-	15.5	35.9	27.2	21.5	281.5	37.8
Fluoride	Yes	2	0.41	1.40	0.92	1.20	0.67	1.20
Alkalinity (as CaCO3 mg/L)								
Carbonate Alkalinity	No	-	26.6	<1	4.0	<1	<1	12.7
Hydroxide Alkalinity	No	-	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity	Yes	-	192.4	153.1	479.1	85.5	818.1	61.3
Metals/Metalloids (dissolved) (mg/L)								
Aluminium	No	5	0.0127	NA	0.0180	NA	NA	NA
Arsenic	Yes	0.5	0.0015	0.0021	0.0030	0.0060	0.002	0.0037
Barium	Yes	-	0.03	0.0603	0.19	0.0415	0.05	0.1006
Bismuth	No	-	<0.001	<0.001	<0.001	<0.001	<0.001	NA
Boron	No	5	0.0295	<0.05	0.0926	NA	0.1200	0.0633

	Included in model?	ANZECC 2000 Livestock WQG	Surface Water Runoff	North Pit		South Pit		WRD Sediment Dam
				Pit Water Quality	Groundwater Inflow	Pit Water Quality	Groundwater Inflow	
Cadmium	No	0.01	<0.0001	NA	0.0002	NA	<0.0001	NA
Chromium	Yes	1	-	<0.001	0.0015	<0.001	0.003	<0.001
Cobalt	No	1	-	0.0030	0.0017	0.0085	0.0015	0.0023
Copper	Yes	0.5	0.0106	0.0326	0.0034	0.0163	0.0098	0.0092
Iron	Yes	-			0.537		0.537	
Lead	No	0.1	0.0013	NA	0.0025	NA	<0.001	NA
Manganese	No	-	0.2217	NA	1.5000	NA	0.0070	NA
Mercury	No	0.002	<0.00005	NA	<0.00005	NA	<0.0005	NA
Molybdenum	Yes	0.15	0.0022	0.0130	0.0029	0.0445	0.0068	0.0504
Nickel	Yes	1	0.0026	0.0090	0.0019	0.0190	0.004	0.0057
Selenium	No	0.02	0.0030	0.0180	0.0030	<0.01	0.003	0.0125
Uranium	Yes	0.2	0.0027	0.0053	0.0043	0.0083	0.044	0.0069
Vanadium	No	-	0.0056	<0.01	0.0075	NA	0.0030	<0.01
Zinc	Yes	20	<0.005	NA	0.0143	NA	0.0460	NA

NA: not analysed

3.4 Modelled water quality in final voids and sediment dam

3.4.1 Introduction

The results of the WQM modelling for the WRD Sediment Dam and final voids (North Pit and South Pit) are presented as a time series of modelled concentrations for the following parameters and compounds:

- pH
- salinity: total dissolved solids
- major ions: calcium, magnesium, sodium, potassium, sulphate, chloride and fluoride, bicarbonate alkalinity
- Metals/metalloids: arsenic, barium, chromium, copper, molybdenum, nickel, uranium and zinc

These parameters and compounds have been selected as they represent the post-closure water quality in the voids and sediment dam from a geochemical modelling perspective.

With respect to the two different geochemical processes modelled in PHREEQC:

- The mixing modelling affects levels/concentrations of all selected parameters/solutes, and corresponding time series are presented.
- The speciation equilibrium modelling only affects the results for pH, total dissolved solids, calcium and sulphate, as the precipitation or dissolution of gypsum influences the calcium and sulphate concentrations. Therefore, speciation equilibrium time series are only included for these parameters/solutes The speciation equilibrium modelling does not affect the concentrations of metals, compared to the mixing modelling.

With respect to the modelled water quality:

- Overall, the effect of gypsum precipitation on water quality in the open pits and sediment dam is evident. Concentrations of total dissolved solids, calcium and sulphate in the equilibrium model are markedly less than in the mixing model. Precipitation of gypsum in the final voids is considered likely.
- The long-term temporal changes in solute concentrations generally approximate a power or logarithmic trend, especially once concentrations have stabilised during the initial years. Power and logarithmic trends are characterised by an initial rapid change, which then trails off slowly over time.

3.4.2 WRD Sediment Dam water quality

Detailed time series of the modelled long-term water quality in the WRD Sediment Dam is provided in Appendix D. The following processes govern the long-term water quality in the WRD Sediment Dam:

- Rainfall runoff and evaporation.
- Due to the presence of the HDPE liner on the dam, there is no interaction with the groundwater (i.e. no groundwater in- or outflows).
- The water level in the WRD Sediment Dam reaches the spillway level over several periods. Post-closure, any spillover water will flow into the North Pit diversion and then into the receiving environment.

- The WRD Sediment Dam runs dry over several periods, due to the effect of evaporation exceeding the combined rainfall runoff and available water in storage.

Detailed time series of the modelled long-term water quality in the WRD Sediment Dam are provided in Appendix D. Selected time series are presented in Figure 4 to Figure 5. The maximum and long-term modelled water quality in the WRD Sediment Dam is summarised in Table 4.

Table 4 Long-term modelled (2080) water quality in WRD Sediment Dam

Parameter/ solute	ANZECC 2000 WQG for Livestock Watering	Mixing Model						Speciation Equilibrium Model					
		P25		P50		P75		P25		P50		P75	
Physico-chemical		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
pH	6.5 - 8.5	8.22	7.91	8.22	7.91	8.22	7.91	8.36	8.36	8.36	8.36	8.36	8.36
TDS (mg/L)	4000	3004	2238	2918	2238	3023	2255	1397	162	1002	161	1426	189
Major Ions (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Calcium	1000	712.6	629.3	712.6	629.3	712.6	629.2	153.9	17.8	110.3	17.7	157.1	20.7
Magnesium	-	67.7	7.8	48.6	7.8	69.2	9.1	67.8	7.8	48.6	7.8	69.2	9.1
Sodium	-	159.0	18.4	123.9	18.3	162.3	21.4	159.0	18.4	123.9	18.3	162.4	21.4
Potassium	-	45.4	5.2	32.5	5.2	46.3	6.1	45.4	5.2	32.5	5.2	46.4	6.1
Sulphate	2000	1852.4	1548.2	1754.7	1548.0	1859.6	1554.7	715.2	82.7	512.4	82.3	730.2	96.2
Chloride	-	280.8	19.5	280.8	19.4	280.8	22.6	280.8	19.5	280.8	19.4	280.8	22.7
Fluoride	2	1.7	0.2	1.3	0.2	1.8	0.2	1.7	0.2	1.3	0.2	1.8	0.2
Bicarbonate	-	184.2	9.7	184.2	9.7	184.2	11.3	184.2	10.6	184.2	10.6	184.2	12.3
Metals (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Aluminium	5	0.0130	0.0000	0.0130	0.0000	0.0130	0.0000	0.0130	0.0000	0.0130	0.0000	0.0130	0.0000
Arsenic	0.5	0.0180	0.0006	0.0180	0.0006	0.0180	0.0008	0.0180	0.0006	0.0180	0.0006	0.0180	0.0008
Barium	-	0.0030	0.0002	0.0030	0.0002	0.0030	0.0002	0.0030	0.0002	0.0030	0.0002	0.0030	0.0002
Chromium	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Copper	0.5	0.0140	0.0016	0.0100	0.0016	0.0143	0.0019	0.0140	0.0016	0.0100	0.0016	0.0143	0.0019
Manganese	-	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Molybdenum	0.15	0.0712	0.0082	0.0510	0.0082	0.0727	0.0096	0.0713	0.0082	0.0510	0.0082	0.0727	0.0096
Nickel	1	0.0126	0.0015	0.0090	0.0014	0.0128	0.0017	0.0126	0.0015	0.0090	0.0014	0.0128	0.0017
Uranium	0.2	0.0838	0.0097	0.0601	0.0096	0.0855	0.0113	0.0838	0.0097	0.0601	0.0096	0.0856	0.0113
Zinc	20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

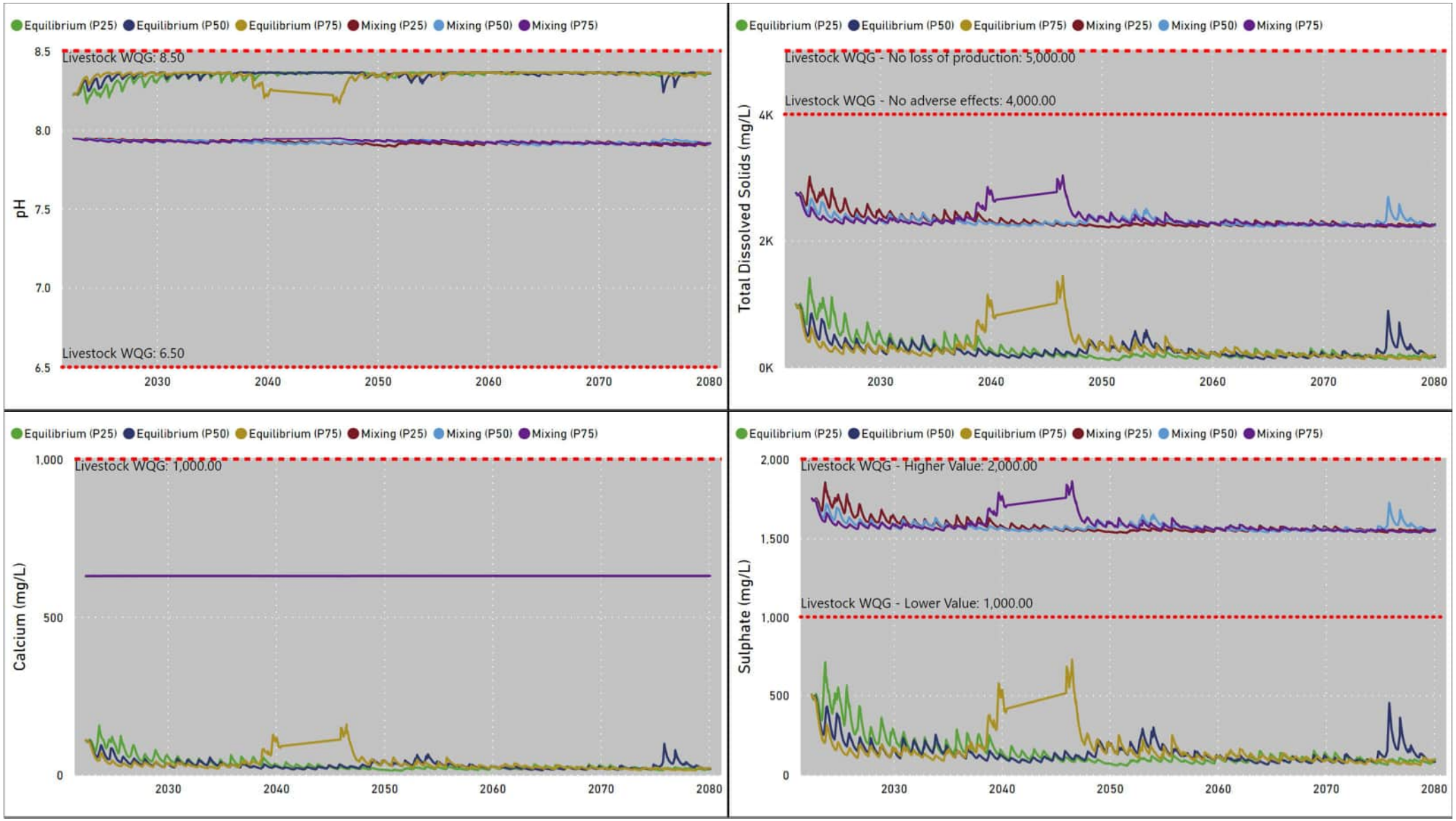

Figure 4 WRD Sediment Dam modelled water quality – pH, TDS, calcium and sulphate

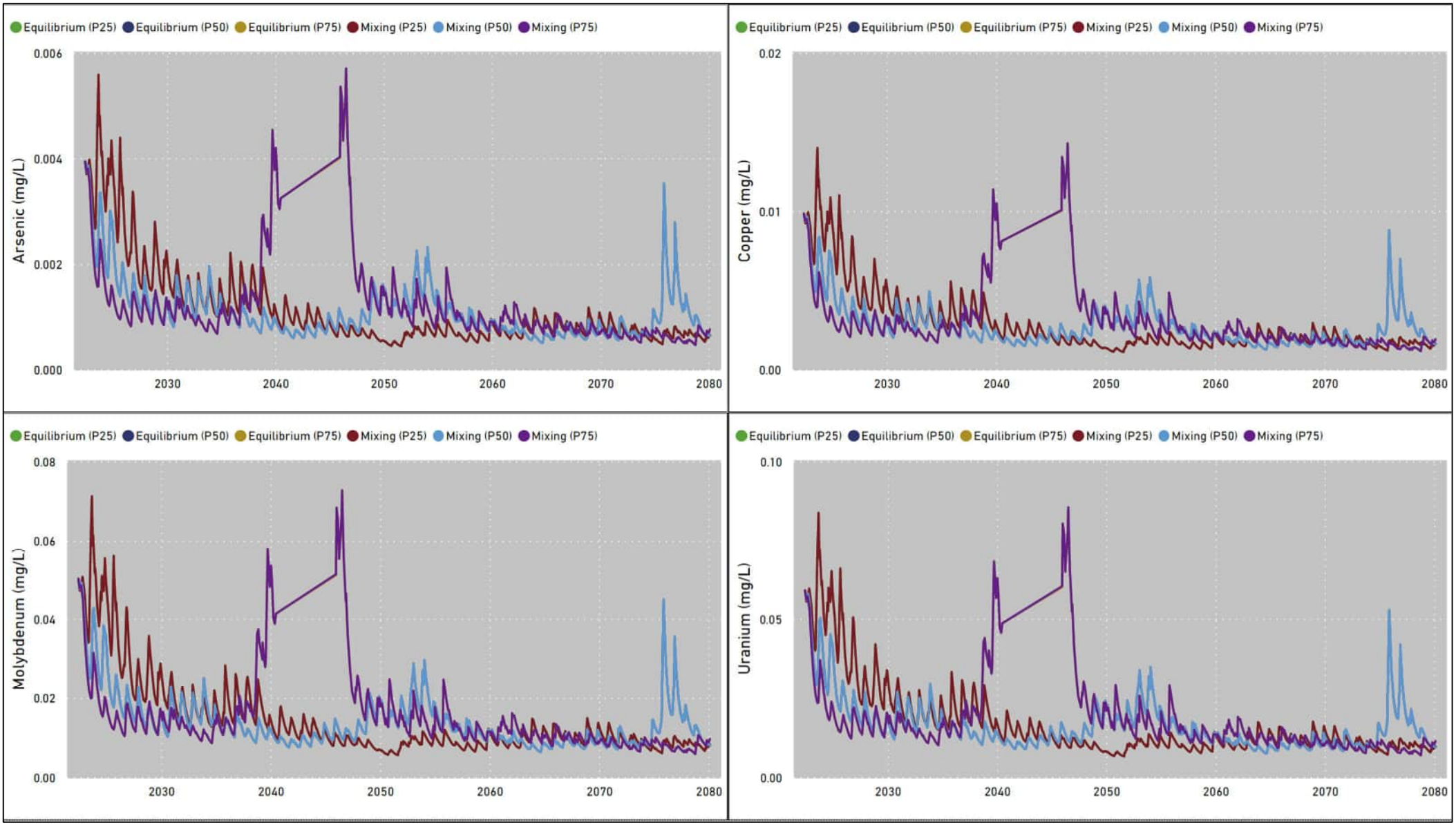

Figure 5 WRD Sediment Dam modelled water quality – arsenic, copper, molybdenum and uranium

The modelled water quality results indicate the following:

- The solute concentrations at all times and for both models (i.e. mixing and equilibrium models) remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.
- The main processes that impact solute levels in the sediment dam are dilution due to rainfall runoff into the pit and concentration due to evaporation from the open pit. Due to the presence of the HDPE liner, groundwater inflow or outflow does not occur. The short-term or seasonal variations in solute concentrations can be correlated with the net balance between rainfall and evaporation.
- Under the 75th percentile climatic conditions, the WRD sediment Dam runs dry between early-2040 and end-2045. This affects the water quality in the WRD Sediment Dam.
- Physico-chemical parameters
  - pH levels: Long-term pH levels in the sediment dam stabilise relatively quickly and trend towards slightly alkaline conditions in the mixing and equilibrium models. pH levels are higher in the equilibrium model due to the geochemical gypsum equilibrium reactions and trend towards the pH of the runoff entering the sediment dam.
  - Total Dissolved Solids: Long-term TDS concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation).
- Major ions:
  - Calcium and sulphate: concentrations differ between the mixing and equilibrium models, with lower concentrations in the latter model due to gypsum equilibrium reactions.
  - Magnesium, sodium, potassium, chloride and fluoride: Gypsum equilibrium reactions do not affect solute concentrations. Concentrations are determined by the concentrations in the inflow water and evaporation from the open pit.
  - Long-term major ion concentrations trend towards stable levels in both models, with short term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation).
- Metals/metalloids
  - Modelled concentrations of meals/metalloids are not affected by gypsum speciation/equilibrium processes.
  - Solute concentrations in the pit are determined by the concentrations in the runoff water and evaporation from the open pit.
  - Long-term concentrations trend towards stable levels in both models, with short term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation).

3.4.3 North Pit water quality

The long-term water quality in the North Pit is governed by the following processes/interactions:

- Rainfall runoff from the pit catchment into the open pit.
- Direct rainfall into and evaporation from the open pit.
- Groundwater inflow into the open pit. Hydrogeological studies indicate that the North Pit will generally remain a groundwater sink.
- Groundwater seepage from the North Pit to the South Pit.
- The results of the WBM indicated that there would be no overflow from the North Pit.

Detailed time series of the modelled long-term water quality in the North Pit is provided in Appendix E. Selected time series are presented in Figure 6 to Figure 7.

The long-term modelled water quality in the North Pit is summarised in Table 5.

Table 5 Long-term modelled (Feb-2080) water quality in North Pit

Parameter/ solute	ANZECC 2000 WQG for Livestock Watering	Mixing Model						Speciation Equilibrium Model					
		P25		P50		P75		P25		P50		P75	
Physico-chemical		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
pH	6.5 - 8.5	8.20	7.71	8.20	7.72	8.20	7.74	8.20	7.88	8.20	7.93	8.20	7.96
TDS (mg/L)	4000	3766	3764	3320	3288	3020	3018	1772	1765	1316	1275	1014	1012
Major Ions (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Calcium	1000	758.2	758.1	717.8	716.5	700.7	690.6	163.7	162.8	122.7	118.6	95.8	95.5
Magnesium	-	88.2	88.0	64.6	62.6	48.8	48.7	88.3	88.0	64.6	62.6	48.9	48.7
Sodium	-	243.5	242.7	179.4	173.6	135.7	135.4	243.6	242.9	179.5	173.7	135.8	135.4
Potassium	-	61.6	61.3	44.8	43.5	34.3	34.3	61.6	61.4	44.8	43.6	34.4	34.3
Sulphate	2000	1768.7	1764.3	1724.0	1708.9	1720.3	1680.3	502.6	337.6	451.6	275.9	444.0	254.1
Chloride	-	458.6	458.3	357.6	312.6	357.6	224.7	458.9	458.5	357.6	312.7	357.6	224.8
Fluoride	2	1.8	1.3	1.5	1.1	1.5	0.9	1.8	1.4	1.5	1.1	1.5	0.9
Bicarbonate	-	391.1	390.8	275.8	270.0	204.8	204.6	413.6	413.3	293.4	287.4	218.9	218.7
Metals (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Aluminium	5	0.0601	0.0601	0.0408	0.0401	0.0286	0.0286	0.0601	0.0601	0.0409	0.0401	0.0286	0.0286
Arsenic	0.5	0.0087	0.0087	0.0062	0.0060	0.0046	0.0046	0.0087	0.0087	0.0062	0.0060	0.0046	0.0046
Barium	-	0.2476	0.2474	0.1902	0.1736	0.1902	0.1302	0.2477	0.2475	0.1902	0.1737	0.1902	0.1303
Chromium	1	0.0007	0.0003	0.0007	0.0002	0.0007	0.0001	0.0007	0.0003	0.0007	0.0002	0.0007	0.0001
Copper	0.5	0.0411	0.0399	0.0353	0.0305	0.0347	0.0263	0.0412	0.0399	0.0353	0.0305	0.0347	0.0263
Manganese	-	1.5012	0.6787	1.5012	0.4676	1.5012	0.3141	1.5012	0.6790	1.5012	0.4678	1.5012	0.3142
Molybdenum	0.15	0.0161	0.0140	0.0139	0.0109	0.0137	0.0095	0.0162	0.0140	0.0139	0.0109	0.0137	0.0095
Nickel	1	0.0108	0.0069	0.0096	0.0057	0.0094	0.0053	0.0108	0.0069	0.0096	0.0057	0.0095	0.0053
Uranium	0.2	0.0152	0.0151	0.0110	0.0107	0.0083	0.0083	0.0152	0.0151	0.0110	0.0107	0.0083	0.0083
Zinc	20	0.0140	0.0063	0.0140	0.0044	0.0140	0.0029	0.0140	0.0063	0.0140	0.0044	0.0140	0.0029

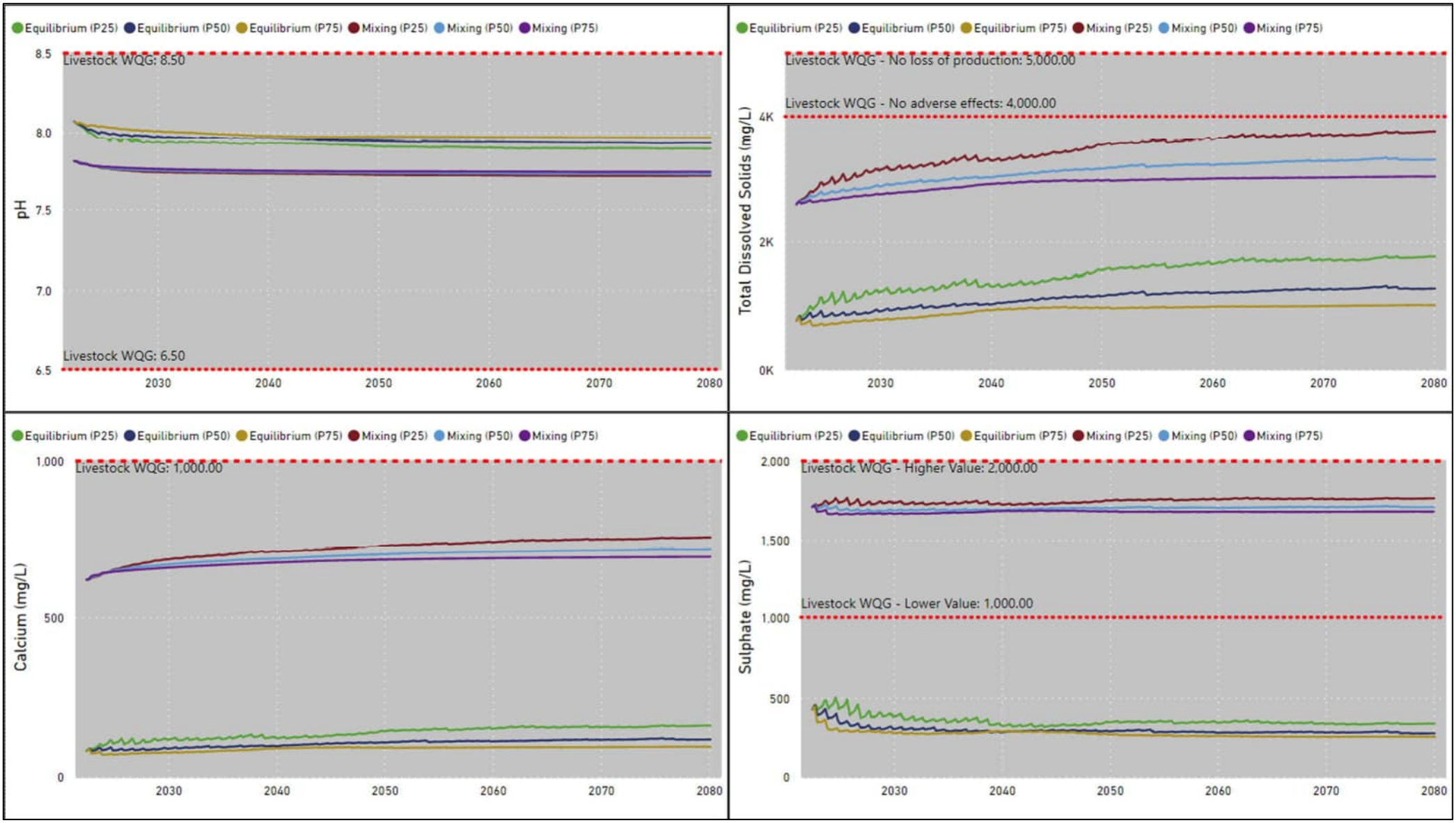

Figure 6 North Pit modelled water quality – pH, TDS, calcium and sulphate

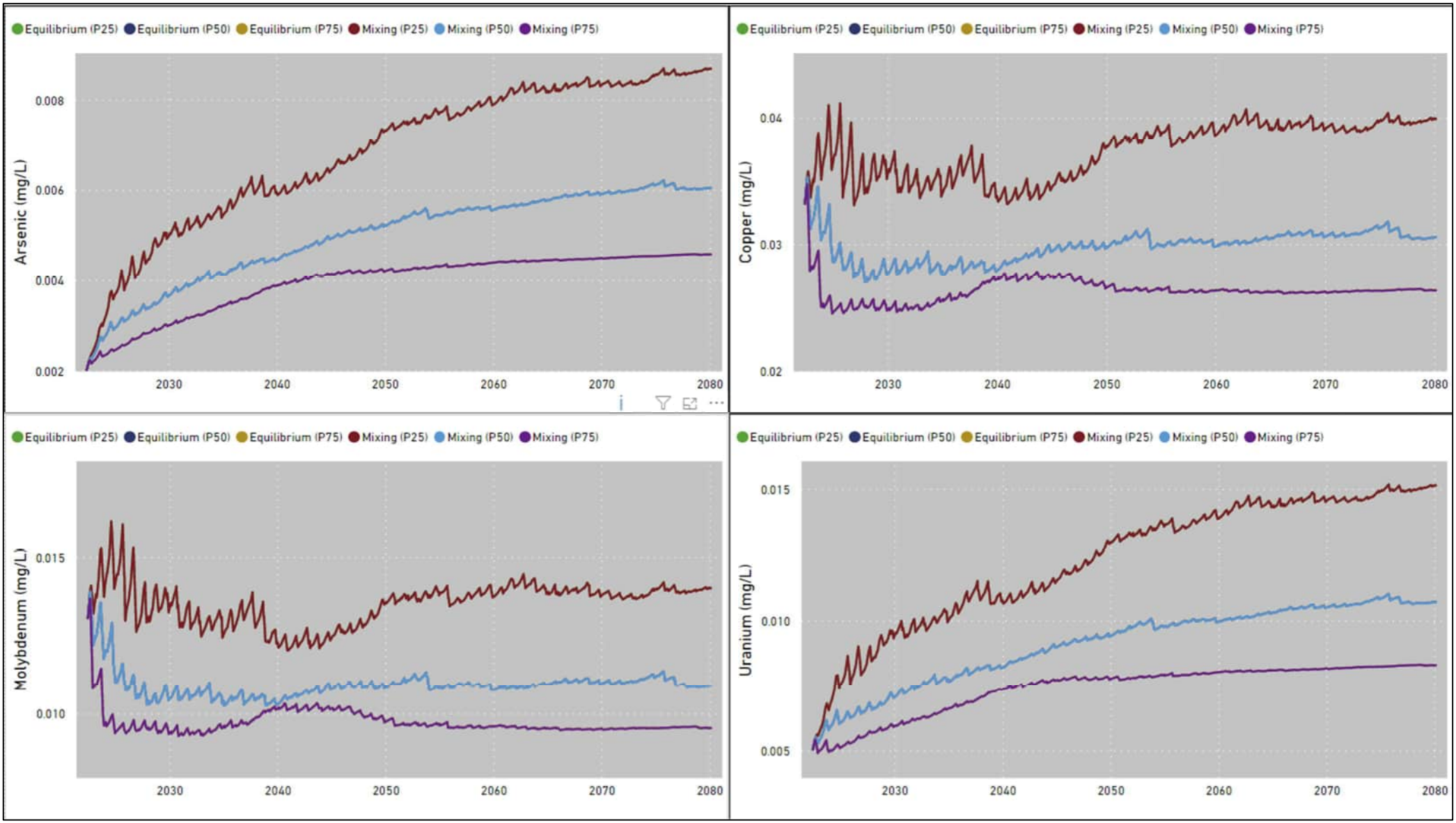

Figure 7 North Pit modelled water quality – arsenic, copper, molybdenum and uranium

The modelled water quality results indicate the following:

- The solute concentrations at all times and for both models (i.e. mixing and equilibrium models) remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.
- The main physical processes that impact solute levels in the open pit are dilution due to rainfall runoff, groundwater inflow into the pit, and concentration due to evaporation from the open pit. Groundwater inflow only plays a minor role, with long-term groundwater inflows comprising only ±10% of total inflows into the open pit. Short-term variations in solute concentrations are related to the net flow balance between inflows and evaporation. Whilst groundwater inflow is only a minor component of pit inflows, it does buffer the effect of evaporation on solute concentrations.
- Physico-chemical parameters
  - pH levels: pH levels stabilise relatively quickly and trend towards near neutral/slightly alkaline conditions in the mixing and equilibrium models. pH levels are higher in the equilibrium model, due to the geochemical gypsum equilibrium reactions and trend towards the pH of the runoff entering the open pit.
  - Total Dissolved Solids: Long-term TDS concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation). The influence of the gypsum equilibrium is evident, with TDS concentrations lower in the equilibrium model than in the mixing model.
- Major ions:
  - Calcium and sulphate: concentrations differ between the mixing and equilibrium models, with lower concentrations in the latter model due to gypsum equilibrium reactions.
  - Magnesium, sodium, potassium, chloride and fluoride: Gypsum equilibrium reactions do not affect solute concentrations. Concentrations are determined by the concentrations in the inflow water and evaporation from the open pit.
  - Long-term major ion concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation) and the effect of evaporation buffered by groundwater inflow.
- Metals/metalloids
  - Modelled concentrations of meals/metalloids are not affected by gypsum speciation/equilibrium processes.
  - Solute concentrations in the pit are determined by the concentrations in the inflow water and evaporation from the open pit.
  - Long-term concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation) and the effect of evaporation buffered by groundwater inflow.

3.4.4 South Pit water quality

The long-term water quality in the South Pit is governed by the following processes/interactions:

- Rainfall runoff from the pit catchment into the open pit.
- Direct rainfall into and evaporation from the open pit.
- Groundwater inflow into the open pit. Hydrogeological studies indicate that the South Pit will generally remain a groundwater sink.
- Groundwater seepage from the North Pit to the South Pit.
- The results of the WBM indicated that there would be no overflow from the North Pit.

Detailed time series of the modelled long-term water quality in the South Pit are provided in Appendix F. Selected time series are presented in Figure 8 to Figure 11. The long-term modelled water quality is summarised in Table 6 and Table 7.

Table 6 Long-term modelled (Feb-2080) water quality in South Pit (scenario 1)

Parameter/ solute	ANZECC 2000 WQG for Livestock Watering	Mixing Model						Speciation Equilibrium Model					
		P25		P50		P75		P25		P50		P75	
Physico-chemical		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
pH	6.5 - 8.5	8.20	7.79	8.20	7.79	8.20	7.79	8.20	8.04	8.20	8.04	8.20	8.05
TDS (mg/L)	4000	4154	3074	4154	2976	4154	2893	1981	1200	1981	1103	1981	1022
Major Ions (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Calcium	1000	696.1	651.7	696.1	648.3	696.1	645.4	140.4	98.0	140.4	94.9	140.4	92.6
Magnesium	-	81.5	57.1	81.5	53.0	81.5	49.7	81.5	57.1	81.5	53.0	81.5	49.7
Sodium	-	535.4	196.9	535.4	171.4	535.4	149.6	535.4	197.0	535.4	171.4	535.4	149.7
Potassium	-	27.3	21.9	27.3	21.4	27.3	21.1	27.3	21.9	27.3	21.4	27.3	21.1
Sulphate	2000	1984.2	1800.9	1984.2	1777.7	1984.2	1758.1	705.3	473.9	702.2	451.5	699.9	433.3
Chloride	-	801.4	244.0	801.4	205.8	801.4	173.2	801.4	244.2	801.4	205.9	801.4	173.3
Fluoride	2	1.2	0.8	1.2	0.7	1.2	0.7	1.2	0.8	1.2	0.7	1.2	0.7
Bicarbonate	-	101.5	101.5	98.2	98.2	95.8	95.8	108.1	108.1	104.6	104.6	102.2	102.2
Metals (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Aluminium	5	0.0130	0.0076	0.0130	0.0075	0.0130	0.0074	0.0130	0.0076	0.0130	0.0075	0.0130	0.0074
Arsenic	0.5	0.0060	0.0045	0.0060	0.0043	0.0060	0.0043	0.0060	0.0045	0.0060	0.0043	0.0060	0.0043
Barium	-	0.0509	0.0509	0.0482	0.0482	0.0481	0.0461	0.0509	0.0509	0.0482	0.0482	0.0481	0.0461
Chromium	1	0.0015	0.0004	0.0015	0.0003	0.0015	0.0002	0.0015	0.0004	0.0015	0.0003	0.0015	0.0002
Copper	0.5	0.0164	0.0132	0.0163	0.0126	0.0163	0.0122	0.0164	0.0132	0.0163	0.0127	0.0163	0.0122
Manganese	-	0.0070	0.0017	0.0070	0.0014	0.0070	0.0011	0.0070	0.0017	0.0070	0.0014	0.0070	0.0011
Molybdenum	0.15	0.0445	0.0253	0.0445	0.0248	0.0445	0.0245	0.0445	0.0253	0.0445	0.0248	0.0445	0.0245
Nickel	1	0.0190	0.0105	0.0190	0.0104	0.0190	0.0102	0.0190	0.0105	0.0190	0.0104	0.0190	0.0102
Uranium	0.2	0.0251	0.0118	0.0251	0.0105	0.0251	0.0095	0.0251	0.0118	0.0251	0.0106	0.0251	0.0095
Zinc	20	0.0461	0.0111	0.0461	0.0089	0.0461	0.0071	0.0461	0.0111	0.0461	0.0089	0.0461	0.0071

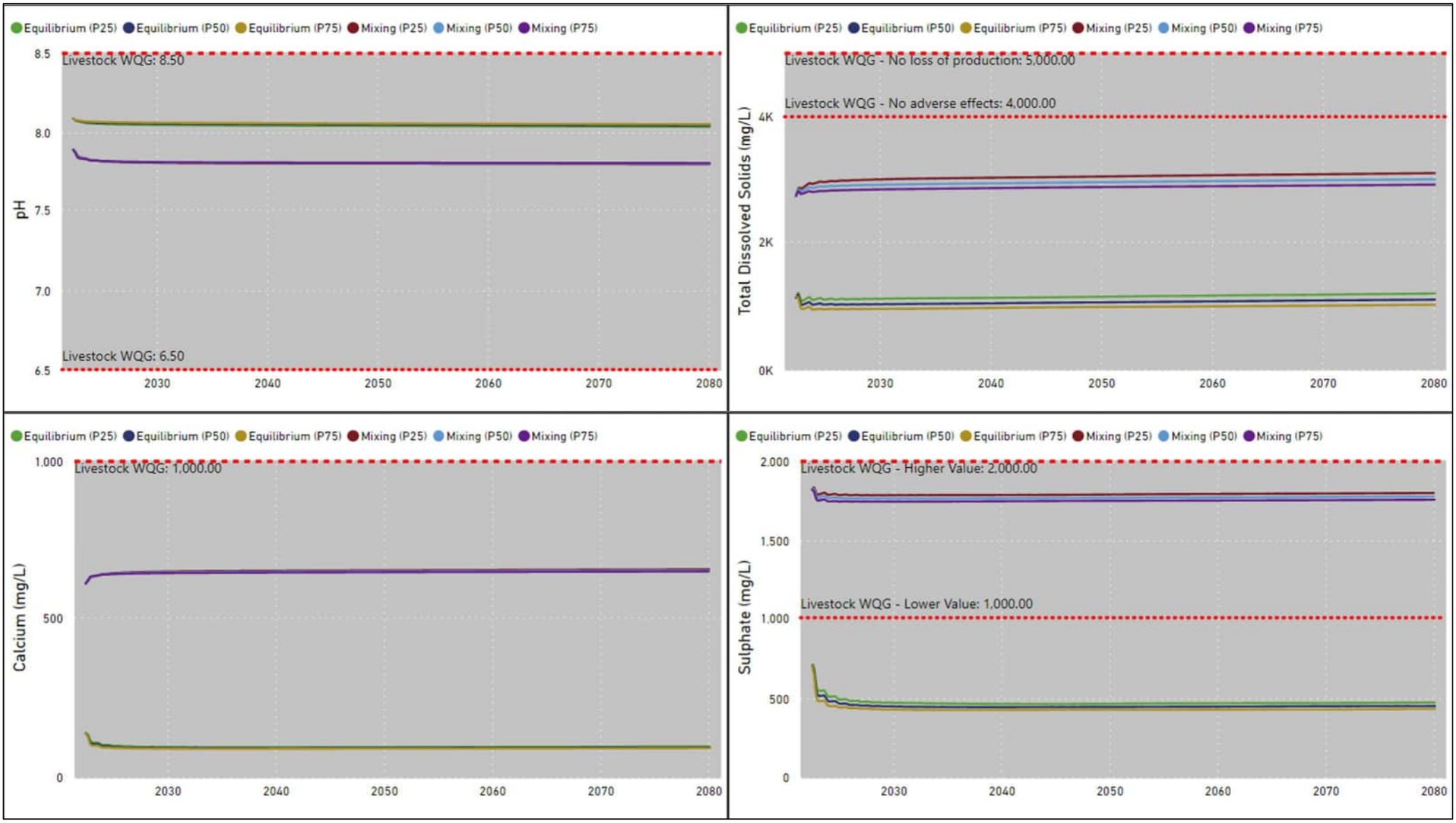

Figure 8 South Pit (scenario 1) modelled water quality – pH, TDS, calcium and sulphate

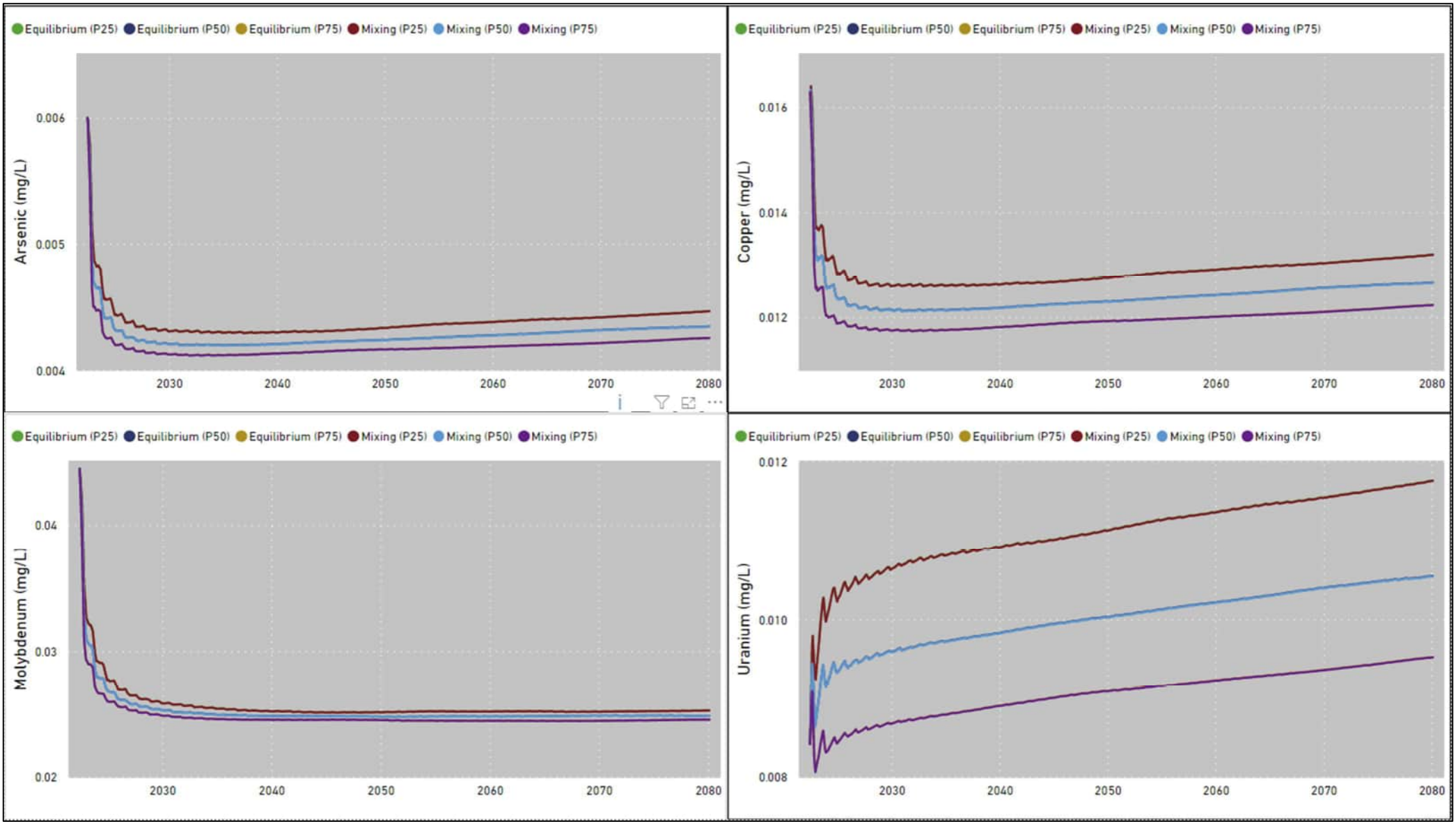

Figure 9 South Pit (scenario 1) modelled water quality – arsenic, copper, molybdenum and uranium

Table 7 Long-term modelled (Feb-2080) water quality in South Pit (scenario 2)

Parameter/ solute	ANZECC 2000 WQG for Livestock Watering	Mixing Model						Speciation Equilibrium Model					
		P25		P50		P75		P25		P50		P75	
Physico-chemical		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
pH	6.5 - 8.5	8.20	7.79	8.20	7.79	8.20	7.79	8.20	8.04	8.20	8.05	8.20	8.06
TDS (mg/L)	4000	4154	3044	4154	2943	4154	2857	1981	1169	1981	1070	1981	986
Major Ions (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Calcium	1000	696.1	650.7	696.1	647.2	696.1	644.1	140.4	96.9	140.4	93.7	140.4	91.2
Magnesium	-	81.5	55.8	81.5	51.6	81.5	48.1	81.5	55.8	81.5	51.6	81.5	48.1
Sodium	-	535.4	189.0	535.4	163.1	535.4	140.5	535.4	189.1	535.4	163.2	535.4	140.6
Potassium	-	27.3	21.7	27.3	21.2	27.3	20.9	27.3	21.7	27.3	21.2	27.3	20.9
Sulphate	2000	1984.2	1793.6	1984.2	1769.9	1984.2	1749.4	705.3	466.4	702.2	443.5	699.9	424.3
Chloride	-	801.4	232.4	801.4	193.5	801.4	159.8	801.4	232.5	801.4	193.6	801.4	159.8
Fluoride	2	1.2	0.8	1.2	0.7	1.2	0.7	1.2	0.8	1.2	0.7	1.2	0.7
Bicarbonate	-	100.3	100.3	96.8	96.8	94.2	94.2	106.8	106.8	103.2	103.2	100.5	100.5
Metals (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Aluminium	5	0.0130	0.0076	0.0130	0.0074	0.0130	0.0073	0.0130	0.0076	0.0130	0.0074	0.0130	0.0073
Arsenic	0.5	0.0060	0.0044	0.0060	0.0043	0.0060	0.0042	0.0060	0.0044	0.0060	0.0043	0.0060	0.0042
Barium	-	0.0500	0.0500	0.0481	0.0472	0.0481	0.0450	0.0500	0.0500	0.0481	0.0473	0.0481	0.0450
Chromium	1	0.0015	0.0003	0.0015	0.0003	0.0015	0.0002	0.0015	0.0003	0.0015	0.0003	0.0015	0.0002
Copper	0.5	0.0164	0.0130	0.0163	0.0124	0.0163	0.0120	0.0164	0.0130	0.0163	0.0125	0.0163	0.0120
Manganese	-	0.0070	0.0016	0.0070	0.0013	0.0070	0.0010	0.0070	0.0016	0.0070	0.0013	0.0070	0.0010
Molybdenum	0.15	0.0445	0.0251	0.0445	0.0246	0.0445	0.0243	0.0445	0.0251	0.0445	0.0246	0.0445	0.0243
Nickel	1	0.0190	0.0105	0.0190	0.0103	0.0190	0.0101	0.0190	0.0105	0.0190	0.0103	0.0190	0.0101
Uranium	0.2	0.0251	0.0114	0.0251	0.0101	0.0251	0.0091	0.0251	0.0114	0.0251	0.0101	0.0251	0.0091
Zinc	20	0.0461	0.0104	0.0461	0.0083	0.0461	0.0063	0.0461	0.0104	0.0461	0.0083	0.0461	0.0063

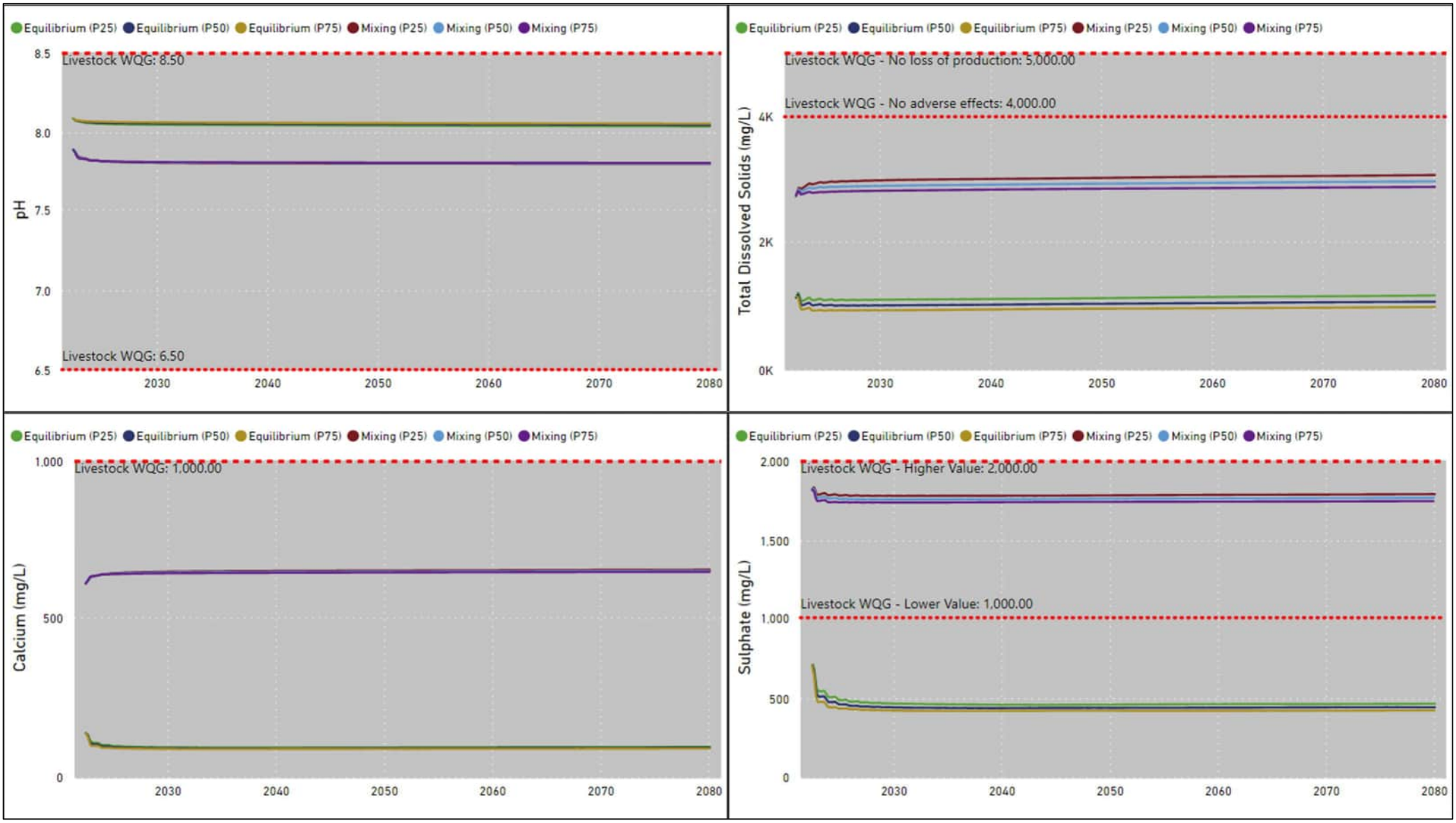

Figure 10 South Pit (Scenario 2) modelled water quality – pH, TDS, calcium and sulphate

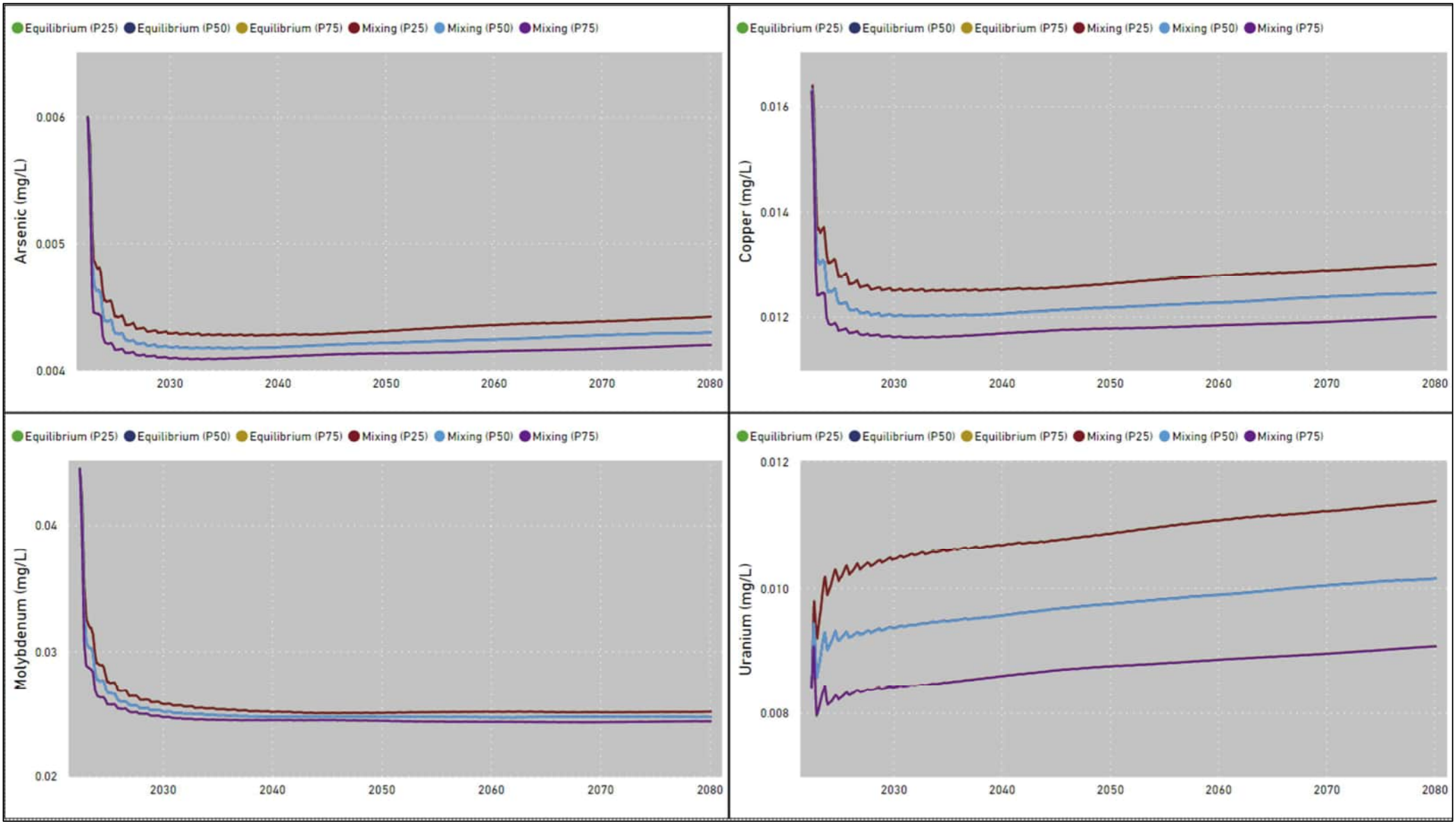

Figure 11 South Pit (scenario 2) modelled water quality – arsenic, copper, molybdenum and uranium

The modelled water quality results indicate the following:

- There is little difference in modelled water quality between both scenarios. Water quality under scenario 2, which includes a larger amount of rainfall runoff from a large catchment area, is better than under scenario 1.
- The solute concentrations at all times and for both models (i.e. mixing and equilibrium models) and scenarios remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.
- The main physical processes that impact solute levels in the open pit are dilution due to rainfall runoff, groundwater inflow into the pit, and concentration due to evaporation from the open pit. Groundwater inflow plays a moderate role, with long-term groundwater inflows (combination of regional inflow and seepage from the North Pit) comprising ±20% of total inflows into the open pit. Short-term variations in solute concentrations are related to the net flow balance between inflows and evaporation. Groundwater inflow buffers the effect of evaporation on solute concentrations.
- Physico-chemical parameters
  - pH levels: pH levels in the South Pit stabilise relatively quickly and trend towards near-neutral/slightly alkaline conditions in the mixing and equilibrium models. pH levels are higher in the mixing model due to the geochemical gypsum equilibrium reactions and trend towards the pH of the runoff entering the open pit.
  - Total Dissolved Solids: Long-term TDS concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation). The influence of the gypsum equilibrium is evident, with TDS concentrations lower in the equilibrium model than in the mixing model.
- Major ions:
  - Calcium and sulphate: concentrations differ between the mixing and equilibrium models, with lower concentrations in the latter model due to gypsum equilibrium reactions.
  - Magnesium, sodium, potassium, chloride and fluoride: Gypsum equilibrium reactions do not affect solute concentrations. Concentrations are determined by the concentrations in the inflow water and evaporation from the open pit.
  - Long-term major ion concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation) and the effect of evaporation buffered by groundwater inflow.
- Metals/metalloids
  - Modelled concentrations of meals/metalloids are not affected by gypsum speciation/equilibrium processes.
  - Solute concentrations in the pit are determined by the concentrations in the inflow water and evaporation from the open pit.
  - Long-term major ion concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation) and the effect of evaporation buffered by groundwater inflow.

3.5 Summary

The water quality modelling indicates that the modelled solute concentrations at all times and for both models (i.e. mixing and equilibrium models) remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.

Long-term water quality in the pits and voids is determined by climatic conditions and geochemical reactions and tends to stabilise. The net flow balance between rainfall runoff plus groundwater inflow and evaporation determines short-term variations.

Based on the WQM results, the North Pit, South Pit and WRD Sediment Dam are considered suitable as PMLUs for livestock watering.

4 Potential AMD impact on final void water quality

4.1 Introduction

The presence of some potentially acid forming (PAF) rock within the open pit shells has potential implications for final void water quality. Some sulphide mineralisation will be exposed on the final pit floor and footwall benches as these final surfaces will be close to ore zones. Direct runoff from the open pit walls that come in contact with PAF rock wall material or groundwater seepage through PAF pit wall material could affect the evolution of final void water quality over time.

The semi-quantitative assessment of potential impacts of AMD on final void water quality presented further below was based on the results of geochemical investigations into the waste rock and oxide ore and the results of the water balance modelling.

4.2 Geochemical characterisation results of waste rock and ore

4.2.1 Waste rock characterisation

A waste rock geochemical assessment has been completed (EGi, 2014) which defines the geochemistry of waste rock materials. The assessment involved the analysis of 121 drill core samples from 14 diamond drill holes, representing the range of waste rock lithologies that were intersected during open pit mining operations across the North and the South Pit footprint. Detailed description of the methodology and results is provided in EGi's report "*Barbara Copper Project – Assessment of Waste Rock Geochemistry*" (EGi, 2014), included as Appendix G of the BCP PRCP Report.

Based upon the analyses undertaken, the samples were classified by EGi (2014) into the following classes:

- Non-acid forming (NAF), the sample is not expected to generate acid in excess of the available acid neutralising capacity (ANC)
- Potentially acid forming (PAF), the sample may form sulphuric acid when in prolonged contact with water and oxygen
- Uncertain (UC), the sample may or may not form acid.

Based upon the acid forming properties of the material, water which remains in contact for medium to long-term durations, may exhibit AMD.

NAPP and NAG characterisation demonstrates most waste rock samples are NAF, while ore samples are distributed between NAF and PAF. An AMD classification plot displaying the concurrence of NAPP and NAG test results is provided in Table 8.

Table 8 BCP AMD classification (EGi, 2014)

Waste/Ore	Classification	Number of Analyte Results	Proportion
Waste Rock (Cu ≤ 0.5% Grade)	PAF	7	7%
	NAF	83	89%
	UC	4	4%
Ore (Cu > 0.5% Grade)	PAF	15	56%
	NAF	12	44%

Additional kinetic NAG analyses were conducted for five samples (three waste, two ore) of PAF rock, to provide an indication of the lag time before significant acid generation occurs. Accordingly, the five samples analysed were PAF samples. The outcomes are presented in Table 9.

Table 9 Acid rock drainage samples - acid generation lag time (EGi, 2014)

Sample	Final pH	Lag Time
Ore #8050	3.1	Weeks to months
Ore #8112	2.7	At least a year to several years
Waste #8066	4.7	At least a year to several years
Waste #8092	3.0	Several years
Waste #8072	6.3	At least a year to several years

Overall, lag times for samples classified as PAF were significant, and likely to exceed a year. Of the two analysed PAF ore samples, one was highly reactive (Ore #8050), with generation of acid expected to occur within weeks of being exposed to atmospheric conditions (water and oxygen).

NAF waste rock materials exhibited limited ANC, consequently blending of NAF and PAF samples may not result in significant changes to acid generation characteristics of the blended material, compared to the PAF material alone.

Additionally, sulphur speciation was conducted on the five samples used in the kinetic NAG analyses to determine the forms of sulphur present in rock. This revealed very minimal sulphate-sulphur present in rock with most sulphur present as sulphide-sulphur.

4.2.2 Column Leach test of waste rock and ROM oxide

A column leach test program involving samples representing waste rock and ROM oxide from the Project commenced on 30 August 2019, with leaching extending over 12 months during which a total of 13 leachate collections were made.

The results and the findings of the program are provided in EGi's report "*Kinetic Column Leach Testing of Waste Rock and ROM Oxide. Final Report - September 2020. Round Oak Mineral. Barbara Copper Project. Ref S4405/J000325/R1382*" (EGi, 2020) , included as Appendix I of the BCP PRCP Report.

The six samples (each sample comprised approximately 10 kg of rock pieces) were collected from the South Pit from various geological units according to geochemical characteristics. One sample was considered PAF, three samples represented NAF waste rock and the remaining two samples represented ROM oxide, as listed in Table 10 (EGi, 2020).

Table 10 Descriptions of Barbara waste rock and ROM oxide samples (EGi, 2020)

Material Class	Location	Northing	Easting	Depth in Pit	Geological Description
PAF1	South Pit	380252	7741437	330 RL	Oxidised sample quartz sericite schist, minor secondary copper.
NAF1	South Pit	380184	7741440	330 RL	Biotite schist
NAF2	South Pit	380122	7741495	325 RL	Biotite schist
NAF3	South Pit	380193	7741549	325 RL	Oxidised sample quartz sericite schist with

Material Class	Location	Northing	Easting	Depth in Pit	Geological Description
(previously PAF2)					secondary copper, malachite and azurite.
NAF4	South Pit	na	na	na	na
ROM Oxide1	South Pit	380298	7741497	325 RL	Sample collected at the southern end of the shear zone and outside the ore zone. Very oxidised samples with minor secondary copper, malachite and azurite.
ROM Oxide2	South Pit	380224	7741519	325 RL	Sample collected from the hanging wall of the shear zone. Mainly oxidised schist, with secondary copper, malachite and azurite.

Chemical characterisation of three of the NAF samples and the two ROM oxide samples indicate NAF characteristics. One NAF sample recorded significant sulphide concentration, although this sample also presented moderate to high ANC which resulted in a negative NAPP test and was subsequently confirmed to be NAF. The PAF sample recorded a positive NAPP result and acidified during the NAG test. The acid forming characteristics of samples are summarised in Figure 12.

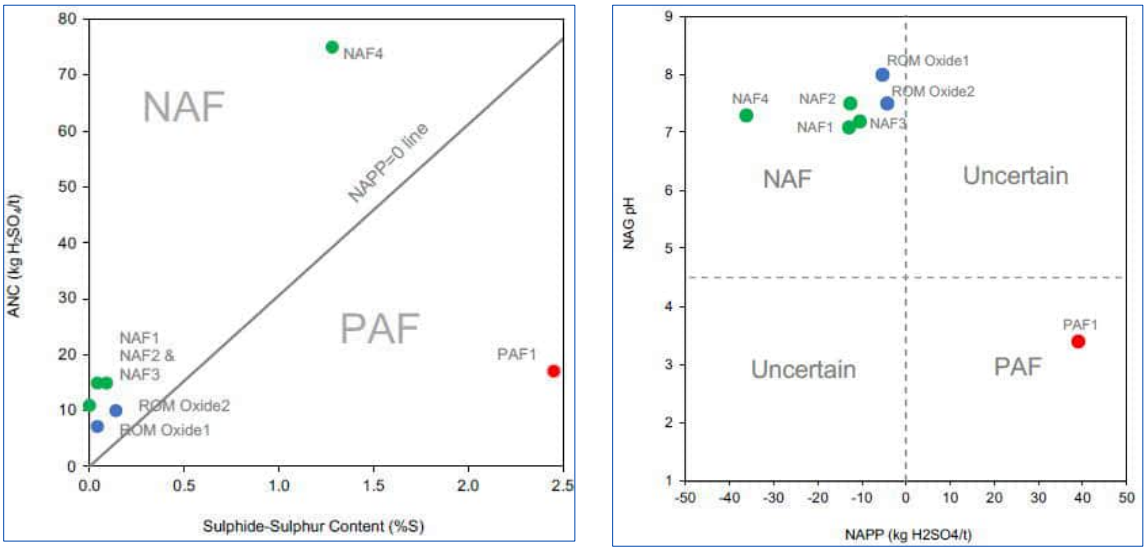

Figure 12 AMD plot for waste rock and ROM oxide and AMD classification (EGi, 2020)

The reactivity of sulphides in the PAF sample was assessed during a monitored NAG test (EGi, 2020). The monitored NAG test revealed an initial lag in acidification, attributed to the acid neutralising capacity of the rock material. After the lag period, pH began to decline while temperature increase as sulphidic material was oxidised. The results of the monitored NAG test indicate the sulphidic mineralisation is reactive, however, the lag period suggests acidification will only occur after many months or years under field conditions.

Two assessments for acid neutralising potential were conducted on samples, namely ANC and carbonate neutralising value (CNV). For all samples, CNVs were below ANC values. This suggests

most acid neutralising capacity in rock is a result of carbonate mineralisation. This is particularly true for sample NAF4 which has the highest ANC. It is anticipated that for samples with very low ANCs, some acid neutralising may be derived from gangue minerals such as silicates.

The column leach test occurred for one year under conditions amenable to sulphide oxidation. The column was flushed every three weeks with the leachate collected for elemental analysis. The first-flush leachate collected from all samples was found to be alkaline, low in soluble salts, contained only trace concentrations of aluminium, iron and manganese. Dissolved metal concentrations were generally below the limits of analytical detection. A summary of chemical characteristics for the leachate produced from each sample for weeks 4-52 is provided in Table 11. Detailed analysis results are provided in Appendix G.

Table 11 Summary of leachate analysis from week 4 to 52 (EGi, 2020)

Sample ID	Leachate Characteristics
PAF1	pH remained circum-neutral signifying the sample was in lag phase. Release of sulphate remained relatively low – ranging between 155 to 334 mg/L which indicates slow rate of sulphide oxidation. No leaching of iron or copper as a result of slow rates of pyrite and chalcopyrite oxidation. Despite significant enrichment of cobalt and selenium and minor enrichment of arsenic and nickel in the sample, arsenic concentration was below detection limits while only trace concentrations of cobalt, nickel and selenium were present in leachate. Only minor leaching of manganese and aluminium were recorded.
NAF 1 and NAF2	pH of leachate remained alkaline. Sulphate concentrations remain very low for the duration of the column leach (NAF1 average of 20 mg/L and NAF2 average of 47 mg/L. Results indicate sulphide oxidation is near non-existent. Calcium was recorded as a major cation in leachate with the average calcium concentration of 11 mg/L and 21 mg/L in NAF1 and NAF2 respectively. Concentration of copper, cobalt and chromium indicates no significant leaching of these metals. NAF2 presented minor leach of arsenic with concentrations in leachate increasing in the first six months before stabilising at 0.03 mg/L.
NAF4	pH of leachate remained slightly alkaline for the duration of the column test. Although leachate remained alkaline, there was a significant release of sulphate during the test with and average sulphate concentration of 452 mg/L at a release rate of 32 mg/kg/week. This corresponds to an IOR of 4.8×10^{-8} kg/O_2/m^3/sec. which is in the moderate range for sulphidic rock. Significant leaching of calcium was detected which reflects the carbonate minerals within sample reacting with the acidity generated by sulphide oxidation. Release of magnesium was also reported, suggesting carbonate mineralisation may have been partially dolomitic. Although the sample had a high copper content, the concentration of copper in leachate was minor at around 0.01 to 0.04 mg/L. It is thought that copper released during oxidation likely reprecipitated as copper oxyhydroxide.

Sample ID	Leachate Characteristics
	No significant leaching of iron, manganese, or any other element of environmental significance was detected.
Oxide ROM1 and ROM2	Both ROM oxide samples remains circum-neutral during the column leach test. Release of sulphate occurred during the first few months of the test, however this decreased thereafter. The copper concentration of leachate indicates some evidence of copper leaching, although results indicate a pH-dependent solubility control for copper release. As such, copper leaching is expected to remain constant as a result of circum-neutral pH. No significant leaching of cobalt or other metals of environmental significance was detected.

4.3 Potential AMD impacts on final void water quality

The potential for AMD to impact on the final void water quality depends on several factors, including:

- the area within the pit shells with exposed PAF material
- the proportion of this leachate water relative to total inflows in the open pits (i.e. the dilution effect)
- the solute concentrations within the leachate water from the exposed material
- the solute concentration and mass balance in the open pits.

4.3.1 Exposure to PAF material from pit walls

Exposure of some PAF rock around the pit shell has implications for pit water quality, especially late in mine life and closure. At closure, some sulphide mineralisation will be exposed on the final pit floor and footwall benches as these final surfaces will be close to ore zones.

Classification of waste rock and ore material undertaken by EGi in 2014 indicates that:

- the majority (89%) of the waste rock from the open pits will have a low sulfur content and will be non-acid forming (NAF). It follows that most exposed waste rock in the pit shells will be NAF.
- whilst most of the ore samples tested had high to very high sulphide content, only ±56% were classified as PAF.

A waste rock and ore block model was developed to provide the basis for initial mine planning, as presented in "*Waste Rock Management Plan*" developed by URS Australia in 2014. This management plan includes several cross-sections through the North Pit and South Pit, depicting the occurrence of PAF waste, NAF waste and ore within the proposed open pits.

These cross-sections (Figure 13 and Figure 14) demonstrate that only a minor part of the pit shell would contain exposed PAF waste or ore.

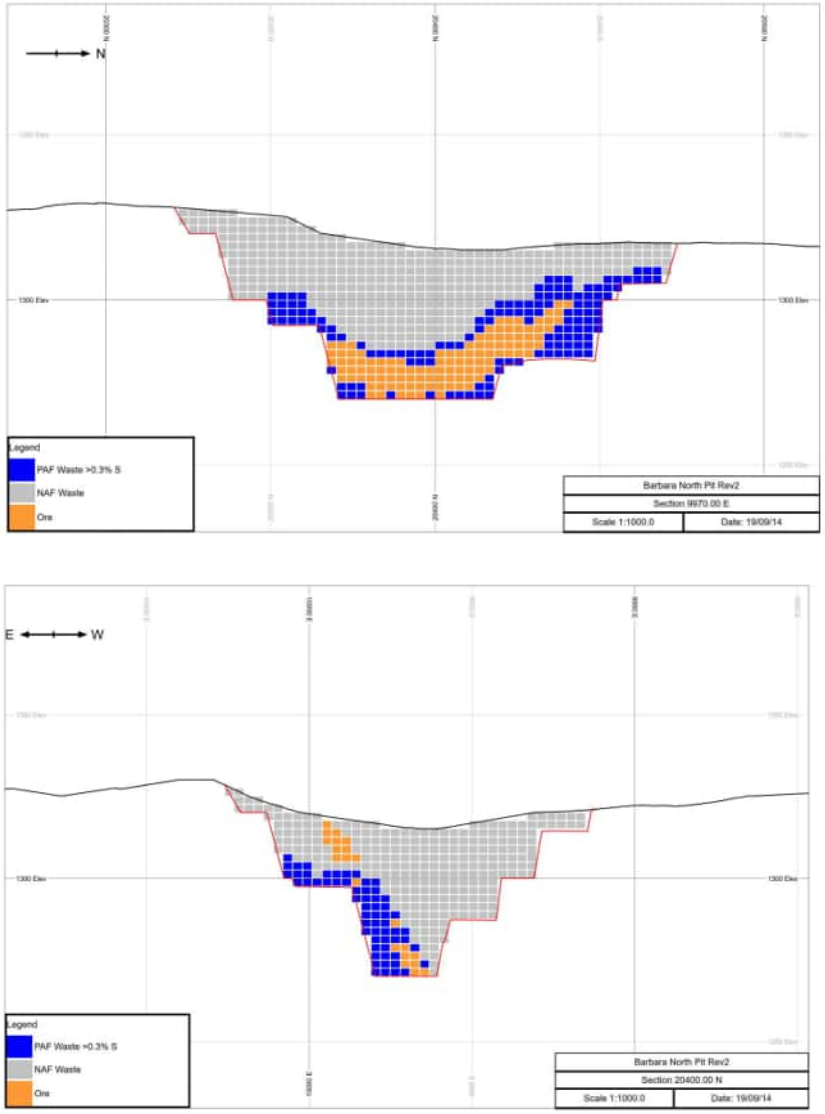

Figure 13 North Pit waste rock cross-sections (AECOM 2014)

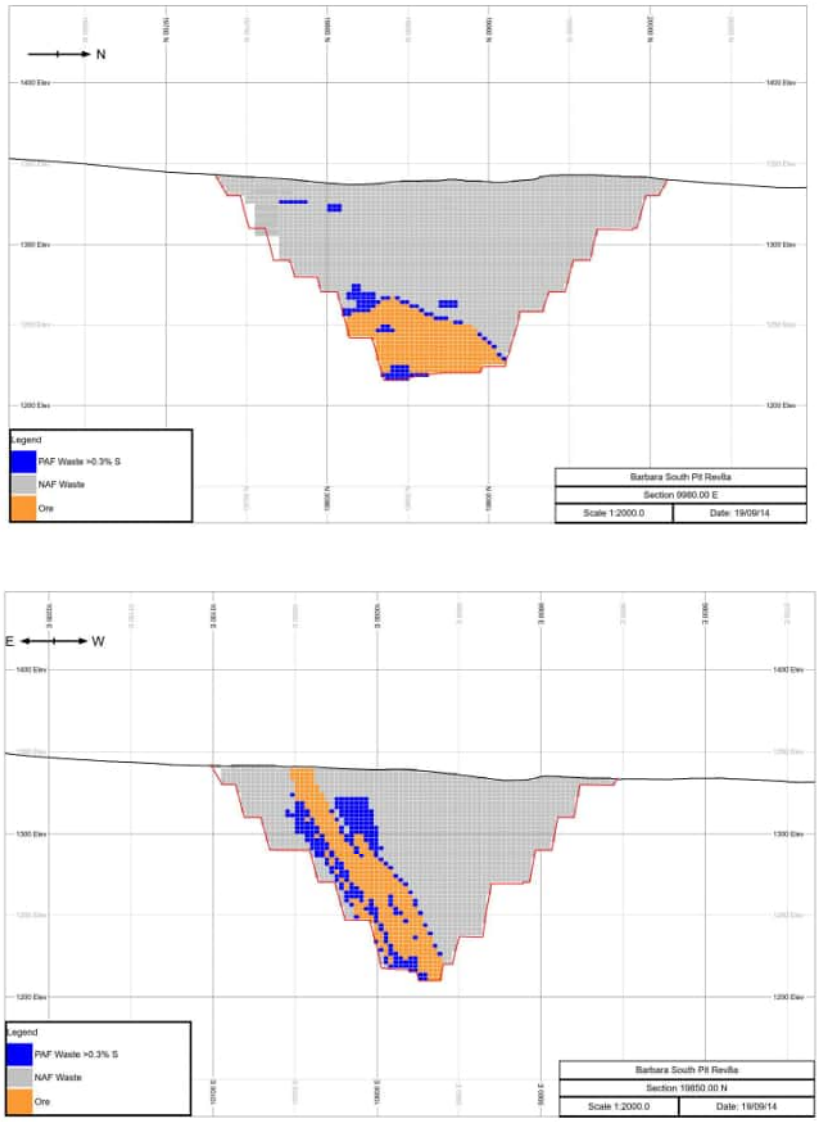

Figure 14 South Pit waste rock cross-sections (AECOM 2014)

4.3.2 Proportion of AMD leachate relative to total inflows in the open pits

Exposed PAF rock may produce localised AMD from seepage of groundwater through the exposed PAF material. If PAF rock represents only a small fraction of total pit wall area then it is likely that any AMD produced would be diluted and neutralised to some extent by the much larger volume of alkaline runoff from NAF rock around the pit and by non-AMD impacted groundwater inflow.

Water balance modelling undertaken by ATC Williams (ATC Williams, 2023) indicate groundwater inflow into the open pits is minor compared to total inflow and existing pit volume. Cumulative groundwater inflow as percentage of total inflow are as follows:

- North Pit: ±10% of the total cumulative inflow (see charts in Appendix A.1)
- South Pit: ±20% of total cumulative inflow (see charts in Appendix A.3)

Assuming that only half of the groundwater inflow would pass through the PAF material in the pit shell, this potentially AMD impacted seepage water would only comprise ±5% and ±10% of total inflow, for North Pit and South Pit respectively. When considering the total inflow from rainfall runoff and the buffering effect of the water volume already present in the open pits, the volume of AMD impacted groundwater seeping into the open pits is sufficiently diluted to alleviate its potential adverse impacts on open pit water quality.

4.3.3 Solute concentrations within the AMD leachate

Representative AMD solute concentrations have been obtained through the kinetic column leach testing undertaken in 2020 (EGi, 2020).

Results of the testing are presented in Appendix G.1. Charts comparing the kinetic column leach test results against he adopted livestock drinking WQG are presented in Appendix G.2, whilst chart comparing the results against the long-term water quality in the open pits are included in Appendix G.2.

The results indicate the following:

- Long-term kinetic column leach results (at week 52 of the test program) are below the adopted livestock drinking WQG values (Appendix G.2).
- Long-term kinetic column leach results (at week 52 of the test program) are below the modelled long-term solute concentrations (average of modelled concentrations/levels after 50 years) in the open pits (Appendix G.3), except for aluminium, arsenic, calcium, chromium and copper in one or more column samples. However, leach results of these solutes are below the livestock drinking WQG (where specified).
- As the AMD impact groundwater inflow constitutes only a minor component of the total inflow into the open pits, the mass load of the AMD solutes will be diluted by rainfall runoff and the pit water volume already in storage.

4.3.4 Potential AMD impacts of open pit water quality

Saline drainage potential

Analyses of EC were performed to provide an indirect measure of the soluble salt content of mined rock and to assess the potential for saline drainage if material is exposed to atmospheric conditions (EGi, 2014). Figure 15 provides a summary of EC values per rock unit.

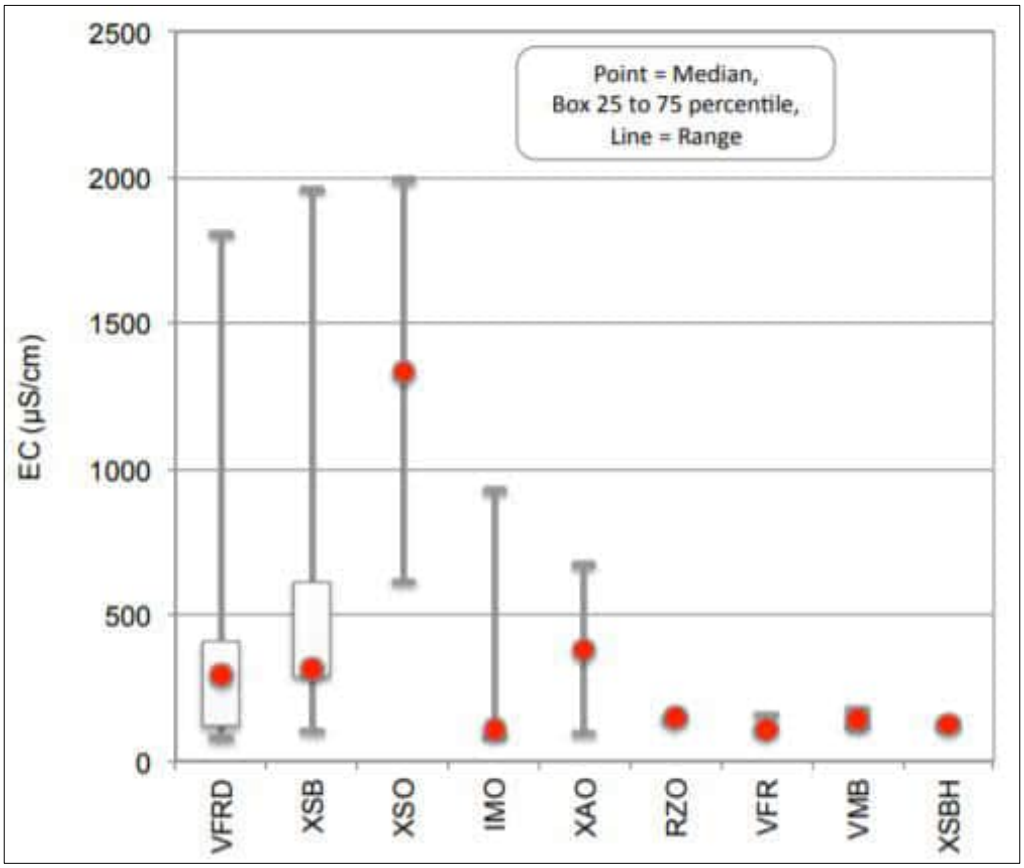

Figure 15 Summary of EC values for all rock units within Barbara drill core samples (EGi, 2014)

From the results presented in Figure , the following outcomes can be determined:

- 72% of the 87 VRFD (the dominant waste unit) analyses - generally comprising of the predominant waste rock unit (Porphyritic Rhyolite), resulted in an EC of less than 400 µS/cm, representative of 'non-saline water'.
- 21% of the 87 VRFD analyses resulted in an EC between 400 and 800 µS/cm, representative of 'slightly saline water'.
- 13 of the 121 drill core analyses conducted were classified indirectly as 'saline' (≥800 µS/cm). It is noted that 12 of the 13 analyses resulting in a 'saline' classification comprised high sulphur ore materials.

Based upon the EGi (2014) results, it is concluded that saline drainage was not considered a significant water quality issue, with respect to waste rock materials.

Metalliferous drainage potential

The elemental characterisation provides an indication of elements enriched in the solid rock material, however, may not be indicative of the potential for metal leaching to water. The leaching potential of ore and waste rock was, therefore, determined using an extraction with deionised water (kinetic column leach testing) (EGi, 2020).

The results indicate the following:

- Long-term kinetic column leach results (at week 52 of the test program) are below the adopted livestock drinking WQG values.

- Long-term kinetic column leach results (at week 52 of the test program) are below the modelled long-term solute concentrations (average of modelled concentrations/levels after 50 years) in the open pits, except for aluminium, arsenic, calcium, chromium and copper in one or more column samples. However, leach results of these solutes are below the livestock drinking WQG (where specified).

As the AMD impact groundwater inflow constitutes only a minor component of the total inflow into the open pits, the mass load of the AMD solutes will be diluted by rainfall runoff and the pit water volume already in storage.

Therefore, it is considered that the seepage of AMD groundwater will not adversely impact the long-term water quality in the open pits.

5 Preliminary assessment of final void stratification

5.1 Introduction

All pit lakes are subject to physical and chemical processes that will determine the water quality of the pit lake, whether the pit lake can support aquatic life and terrestrial food webs, and the impact of the release of water to the receiving environment.

Some processes, such as wind forcing and convective mixing are common to all pit lakes, while other factors (e.g., site-specific geochemistry, hydrology and mine pit morphology) will be specific to the mine pit and its mineralogical character.

Pit lakes undergo annual water temperature cycles due to heat exchange between water and the atmosphere. Heat exchange occurs through longwave radiation, shortwave radiation, conduction and evaporation, as well as through temperature exchanges between the different vertical layers in the lake and the sediments. Temperature gradients in lakes can result in a water column with two or more stratified layers. Some shallow pit lakes may be perpetually mixed by wind and never stratify (Castendyk et al., 2015).

In Northern Australia, where the climate is characterised by a wet and dry season, lake stratification can occur. Stratification of a lake occurs during the summer 'wet' season, where warmer, fresher waters sit atop colder, more saline waters in a lake. With the onset of the winter 'dry' season, the fresher top layer increases in salinity due to evapoconcentration and the water also cools due to a decrease in temperature. This results in denser upper layer water mixing with water below (Boland and Padovan, 2002)

Stratification constrains the mixing of surface and deeper waters, and can minimise replenishment of deep waters with oxygen, and can therefore control redox states, geochemical cycles, and acidification processes.

Based on thermal stratification, three different types of lakes can be defined:

- Holomictic lakes have a uniform density and temperature regardless of depth in a particular period of the year. The layers within a holomictic lake circulate or intermix at least once a year, due to the breakdown of thermal stratification and wind power. Mixing is complete or partial.
- Meromictic lakes have layers of water that do not intermix. These lakes are permanently stratified with a deep-water body of high density, usually because of high salt content in the deepest layer. The waters of meromictic lakes are divided into three layers and the top layer being the mixolimnion while the bottom layer is known as the monimolimnion. The layer between the two is known as the chemocline.
- Amictic lakes have water whose surface is covered with ice throughout the year which prevents the mixing of the waters beneath, and therefore allowing such lakes to exhibit inverse cold water stratification where water temperature increases with the increase in depth. Due to the extreme cold temperatures which characterise amictic lakes, such lakes are only found in the polar regions both in the Arctic as well as in Antarctica.

Pit lakes are especially prone to meromixis (i.e. perennial stratification) owing to their depth, wind sheltering provided by pit walls, and their likelihood of containing elevated solutes that can produce vertical differences in water density (Vandenberg and McCullough, 2017).

5.2 Depth/area ratio assessment

Early studies of stratification in natural and pit mine lakes have focused on simple lake depth/area ratios (e.g., Lyons et al., 1994; Doyle and Runnels, 1997) on the assumption that large area/depth ratios allow more wind mixing and, thus, are less prone to stratification and the development of anoxia (*Jewell, P.W. Stratification controls of pit mine lakes. Mining Engineering, February 2009).*

Mining pit lakes with high depth to width ratio are less apt to undergo complete lake turnover (Doyle and Runnells, 1997). The aspect ratio of a given pit lake can be quantified by Z_r, otherwise known as the "*relative depth*" (Hutchinson 1957):

$$Z_r(\%) = 50\ x\ Z_m\ x\ \frac{\sqrt{\pi}}{\sqrt{A}}$$

where Z_m is the maximum depth, and A is the surface area of the lake.

Using the above equation, the "*relative depth*" for the open pits and sediment dam at BCP are as presented in Table 12.

Table 12 "*Relative Depth*" of open pits and sediment dam

Void	Maximum depth (Z_m [m])	Surface Area (A [m²])	Relative Depth (Z_r [%])
North Pit	16.746	11,639	1376%
South Pit	78.095	29,433	4043%
WRD Sediment Dam	6.795	9,828	367%

In a survey of mining pit lakes around the world, Doyle and Runnells (1997) suggested that most artificial lakes with Z_r > 25% are meromictic. Based on the "relative depth" calculations, there is the potential for the North Pit, South Pit and WRD sediment Dam to become meromictic, i.e. permanently stratified.

Doyle and Runnells (1997) did observe that there were a few lakes with Z_r > 25% that were holomictic and many lakes with Z_r < 25% that were meromictic. There are other factors which dictate whether a given pit lake is permanently stratified.

5.3 One-dimension GLM model

5.3.1 Introduction

A one-dimensional model was developed for the North Pit and south Pit to further assess the potential for stratification, using "*The General Lake Model*" (GLM). GLM has been developed by the Aquatic EcoDynamics Research Group team at the University of Western Australia (http://aed.see.uwa.edu.au) in collaboration with the Lake Ecosystem Restoration research group at the University of Waikato (http://www.lernz.com).

GLM is a 1D lake water balance and vertical stratification model that computes vertical profiles of temperature, salinity and density by accounting for the effect of inflows/outflows, mixing and surface heating and cooling, including the effect of ice cover on heating and mixing of the lake.

GLM incorporates a flexible Lagrangian layer structure similar to the approach of several 1-D lake model designs (Imberger and Patterson 1981; Hamilton and Schladow 1997). The Lagrangian approach was originally introduced in the model DYRESM developed by the Centre for Water Research and allows for layers to change thickness by contracting and expanding in response to inflows, outflows, mixing and surface mass fluxes. When sufficient energy becomes available to overcome density gradients, two layers will merge thus accounting for the process of mixing.

5.3.2 GLM model setup

1D GLM models were developed for the North Pit and South Pit, to assess the potential for stratification to develop in these final voids.

The input data for GLM models were obtained from the following sources:

- Final void/lake geometry, including water depth/surface area relationship, maximum depths, surface length and width, initial void conditions. Relevant information was obtained from the pit geometry developed for the ATCW water balance models.
- Climatic data, including shortwave solar radiation, cloud cover, air temperature, relative humidity, wind speed and rainfall. Information was obtained from the SILO Data Drill Program for the Site Location (https://www.longpaddock.qld.gov.au/silo/gridded-data/).
- Water quality data, including temperature and salinity. Data was obtained from the existing surface water and groundwater monitoring programs.
- Inflow and outflow data, including flow rate, temperature and salinity.

A detailed description of the science and mathematics behind GLM, data input requirements, assumptions and output is provided in "*GLM - General Lake Model: Model overview and user information* "(Hipsey et al., 2014).

A stochastic approach to climate conditions was not adopted as part of this preliminary assessment. Such approach would only be considered warranted if the results of the preliminary assessment indicate stratification in the voids to the extent that this could adversely affect final void water quality.

The GLM models were developed using daily climate data from 1/01/1973 to 19/03/2023 obtained from the SILO Data Drill Program for the BCP site. Adopting a daily timestep for this period is considered adequate to represent long-term climatic conditions, together with short-term variations, for the BCP site.

5.3.3 North Pit GLM model results

GLM model results include detailed water balance results and plots of temperature and density to visually assess the stratification in the open pit with depth and over time.

Modelled depth distributions of temperature, density and salinity over time are presented in Figure 16, Figure 17 and Figure 18, respectively.

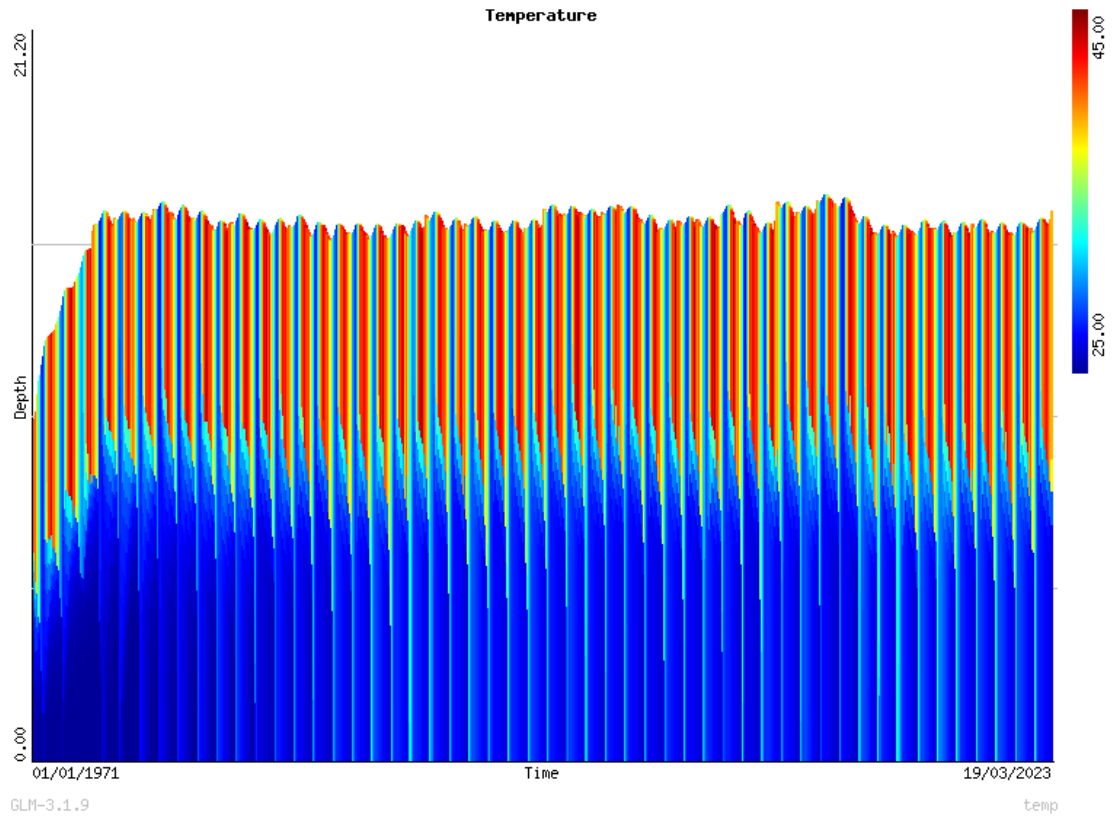

Figure 16 North Pit GLM model results – temperature (°C) distribution

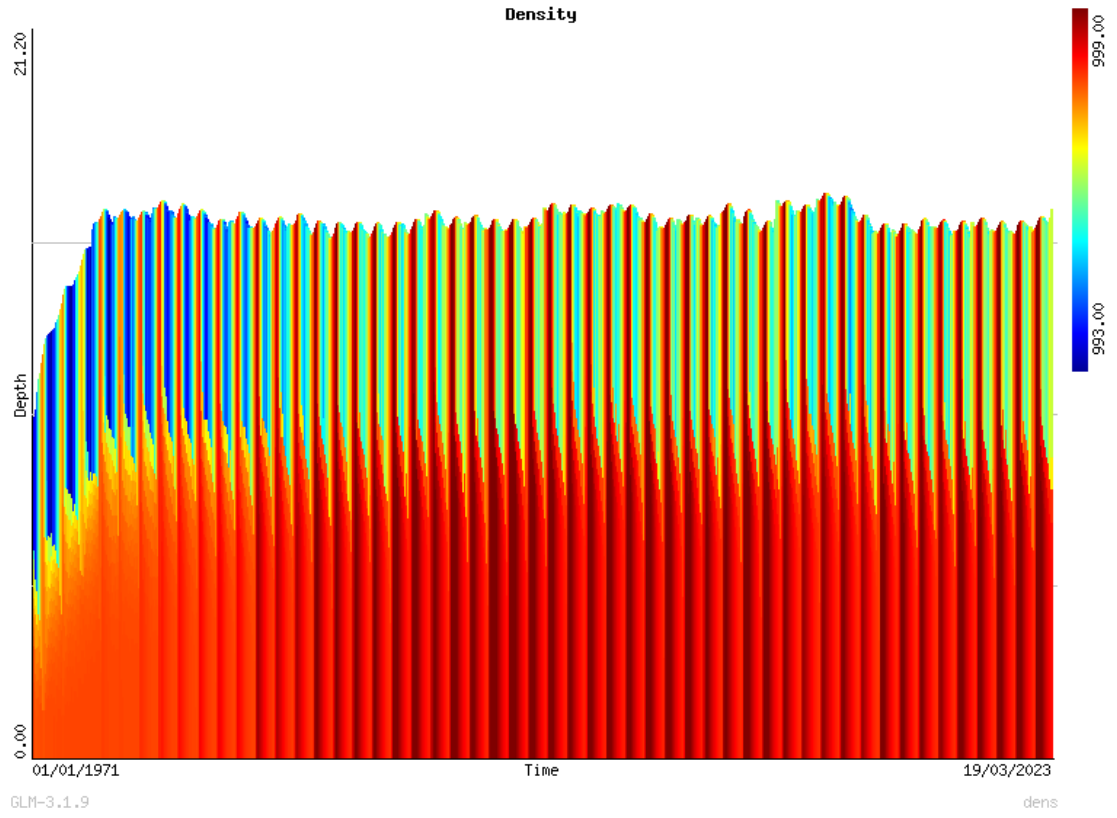

Figure 17 North Pit GLM model results – density distribution

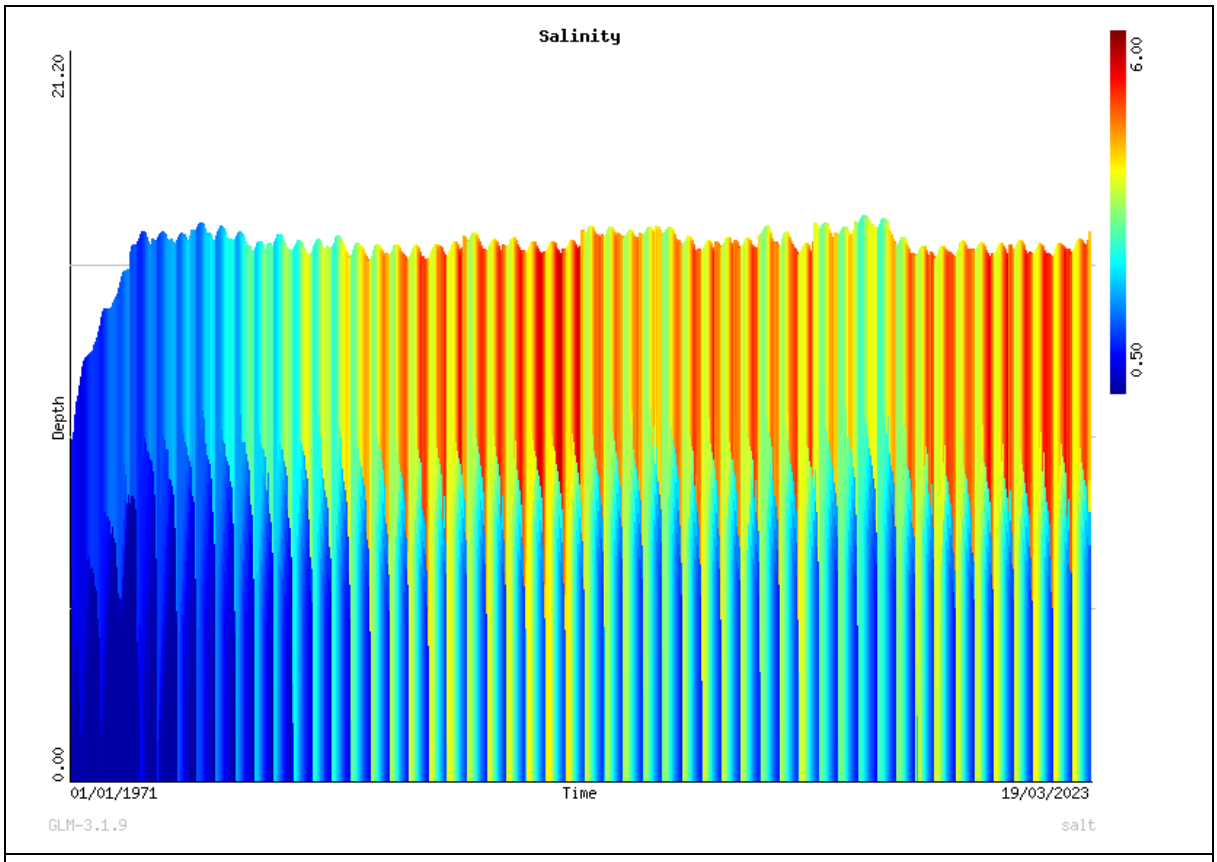

Figure 18 North Pit GLM model results – salinity (g/L) distribution

The preliminary GLM modelling results for the North Pit indicate the following:

- Thermal, density and salinity stratifications may develop over time on a seasonal basis within the North Pit.
- Three stratification zones may develop within the open pit during the dry, hot seasons. However, the stratifications dissipate during the wet season.
- As there is a uniform density and temperature distribution during at least one period of each year, the North Pit lake could be classified as a "holomictic" lake.

As the North Pit generally acts as a terminal groundwater sink, with minimal outflow/seepage towards the South Pit and as the stratification in the pit is seasonal, the PMLU of the pit as "water storage for livestock watering" is not adversely affected by the seasonal stratification.

5.3.4 South Pit GLM model results

GLM model results include detailed water balance results and plots of temperature and density to visually assess the stratification in the open pit with depth and over time.

Modelled depth distributions of temperature, density and salinity over time are presented in Figure 19, Figure 20 and Figure 21, respectively.

The preliminary GLM modelling results for the South Pit indicate the following:

- Thermal, density and salinity stratifications may develop over time on a seasonal basis within the South Pit.

- Three stratification zones may develop within the open pit during the dry, hot seasons. However, the stratifications dissipate during the wet seasons.
- As there is a uniform density and temperature distribution during at least one period of each year, the South Pit lake could be classified as a "holomictic" lake.

As the South Pit generally acts as a terminal groundwater sink and as the stratification in the pit is seasonal, the PMLU of the pit as "water storage for livestock watering" is not adversely affected by the seasonal stratification.

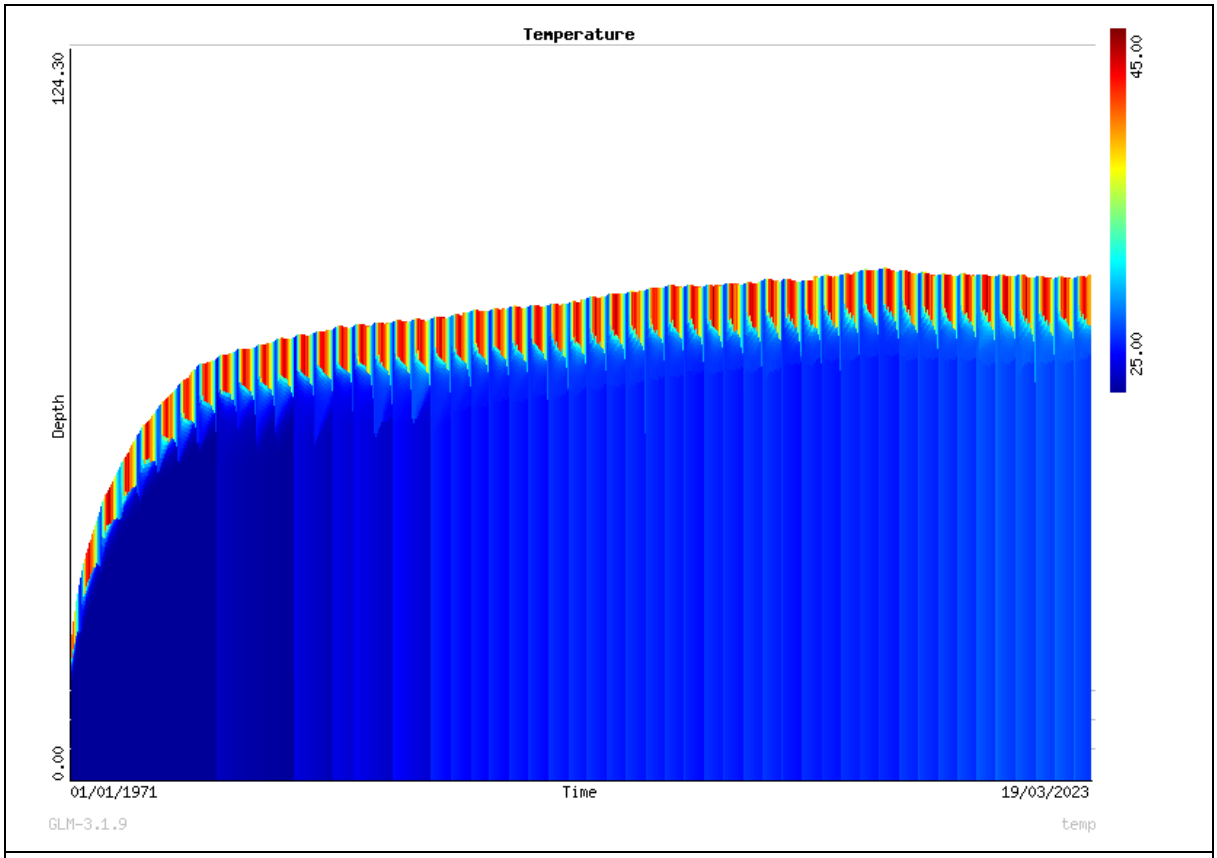

Figure 19 South Pit GLM model results – temperature (°C) distribution

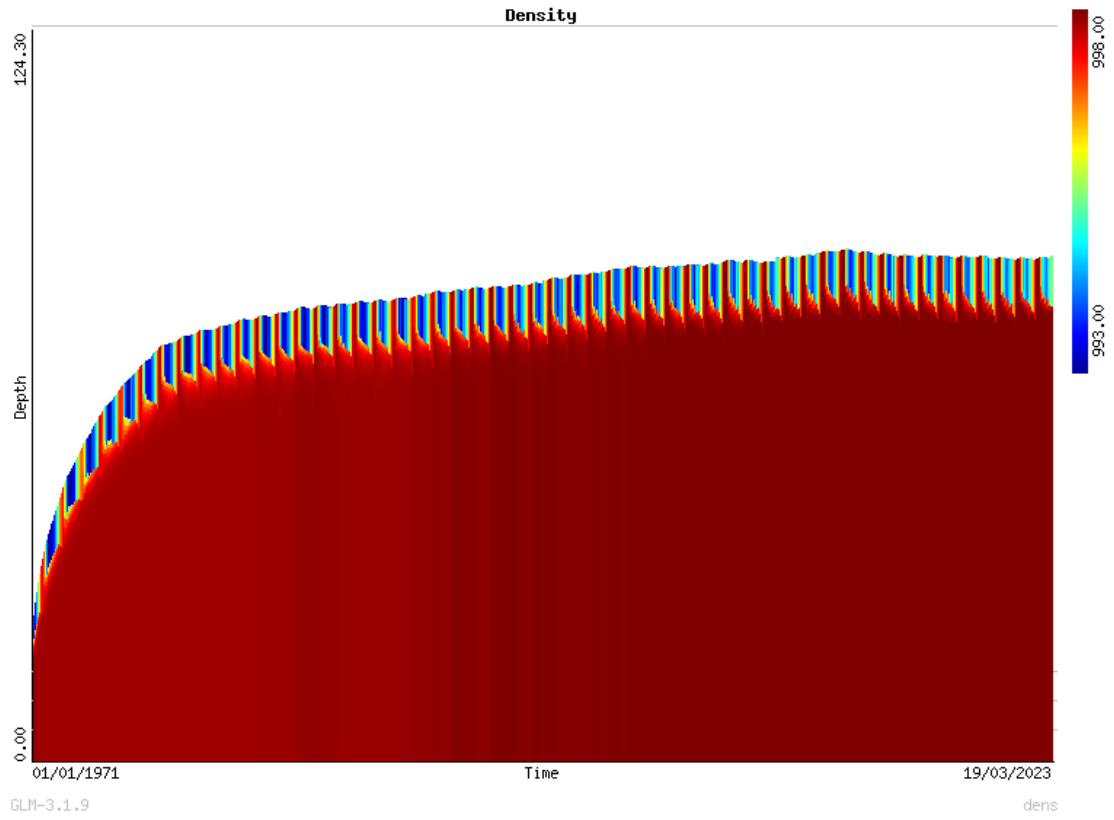

Figure 20 South Pit GLM model results – density distribution

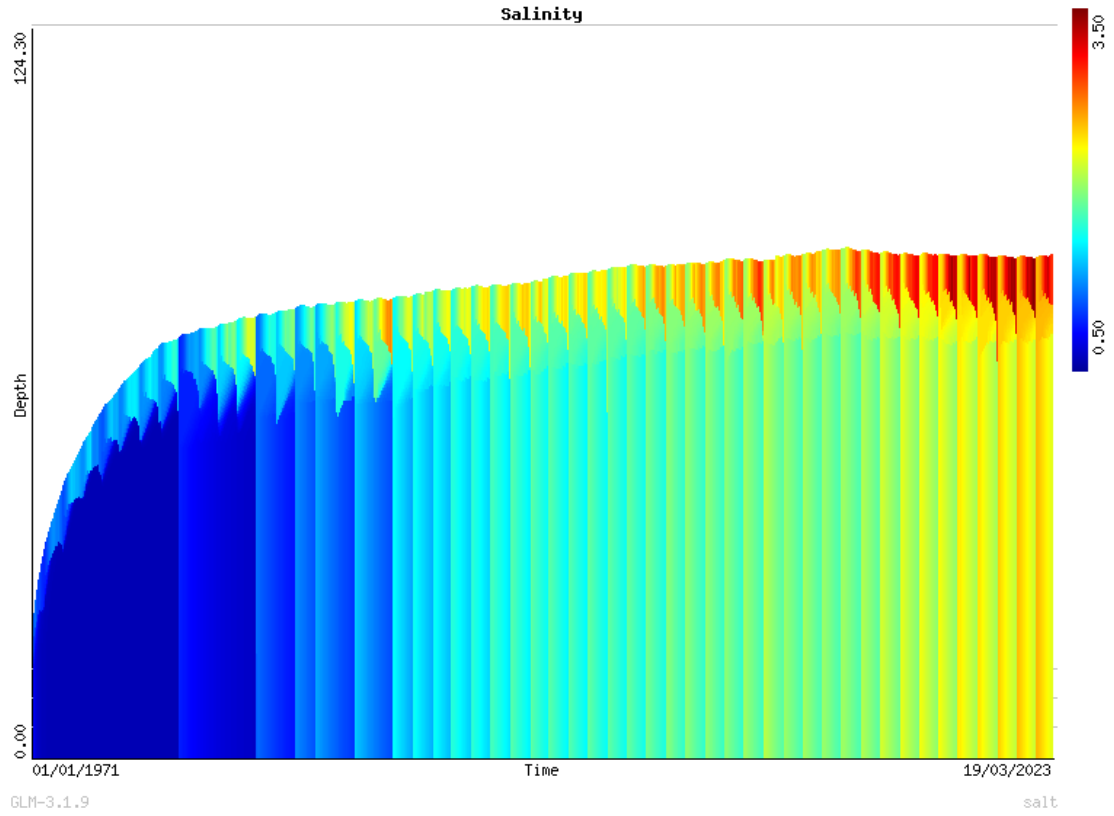

Figure 21 North Pit GLM model results – salinity (g/L) distribution

6 Conclusions

The water balance and water quality modelling, the results of the ongoing groundwater and surface water sampling at BCP, the results of the kinetic column leach testing and the preliminary pit lake stratification modelling conclude the following:

- The WQM indicates that the modelled solute concentrations in the North Pit, South Pit and WRD Sediment Dam remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.
- Regarding potential AMD impact on open pit water quality:
  - Long-term kinetic column leach results (at week 52 of the test program) are below the adopted livestock drinking WQG values
  - Long-term kinetic column leach results (at week 52 of the test program) are below the modelled long-term solute concentrations (average of modelled concentrations/levels after 50 years) in the open pits, except for aluminium, arsenic, calcium, chromium and copper in one or more column samples. However, leach results of these solutes are below the livestock drinking WQG (where specified).
  - As the AMD impact groundwater inflow constitutes only a minor component of the total inflow into the open pits, the mass load of the AMD solutes will be diluted by rainfall runoff and the pit water volume already in storage.
  - Therefore, it is considered that the seepage of AMD groundwater will not adversely impact the long-term water quality in the open pits.
- Preliminary pit lake stratification modelling indicates that, in the north Pit and South Pit:
  - Thermal, density and salinity stratifications may develop over time on a seasonal basis within the North Pit, with three stratification zones developing during the dry, hot seasons. However, the stratifications dissipate during the wet season.
  - As the pits generally acts as a terminal groundwater sink, with minimal outflow/seepage and as the stratification in the pits is seasonal, the PMLU of the pit as "water storage for livestock watering" is not adversely affected by the seasonal stratification.
- Based on the investigation and modelling results, the North Pit, South Pit and WRD Sediment Dam are considered suitable as PMLUs for livestock watering.

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Appendix A

Snapshot of water balance model results

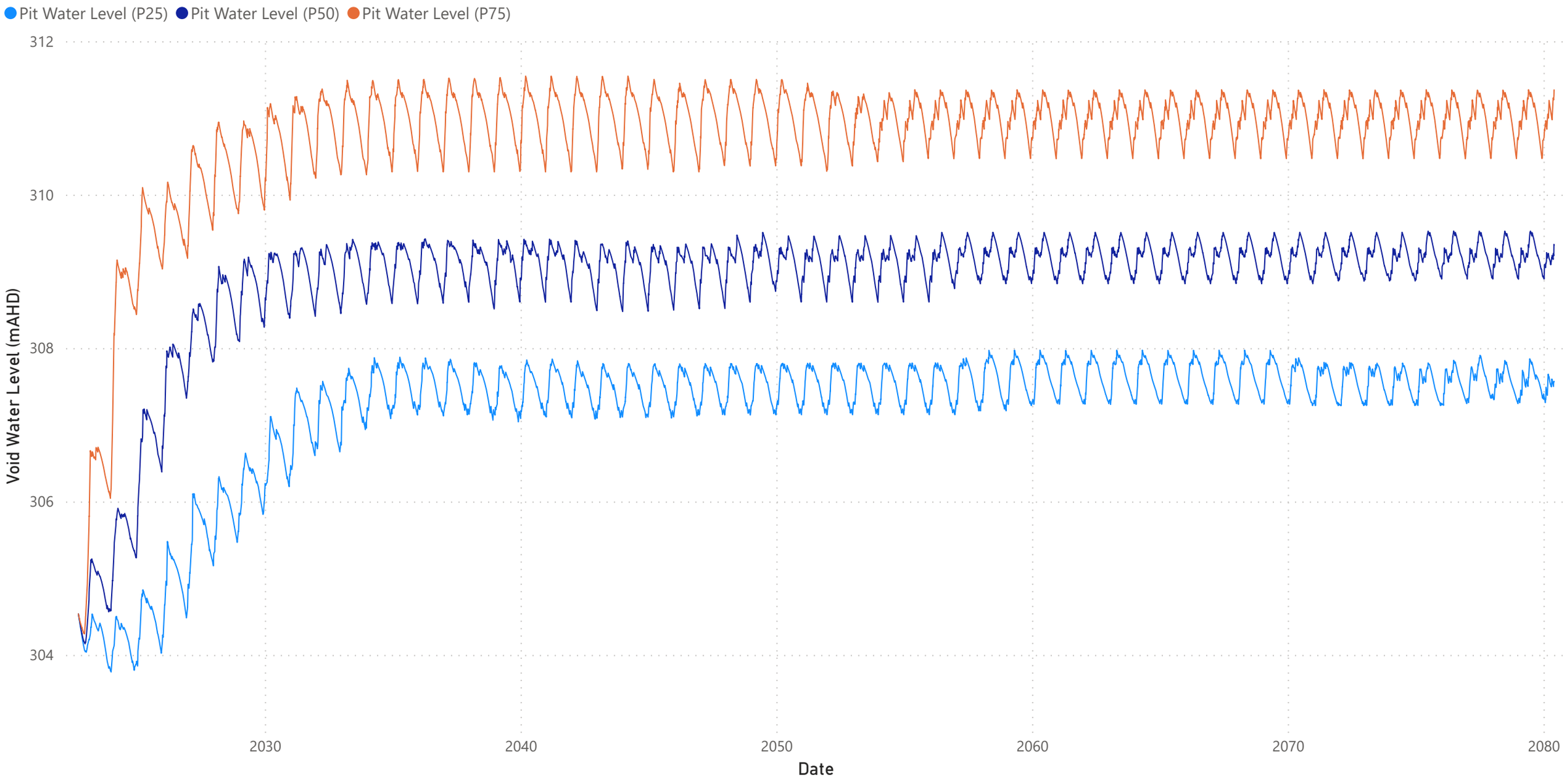
Appendix A.1 North Pit WBM Outputs

Feature

North Pit

4/06/2022 19/02/2080

Modelled water level in pit/void

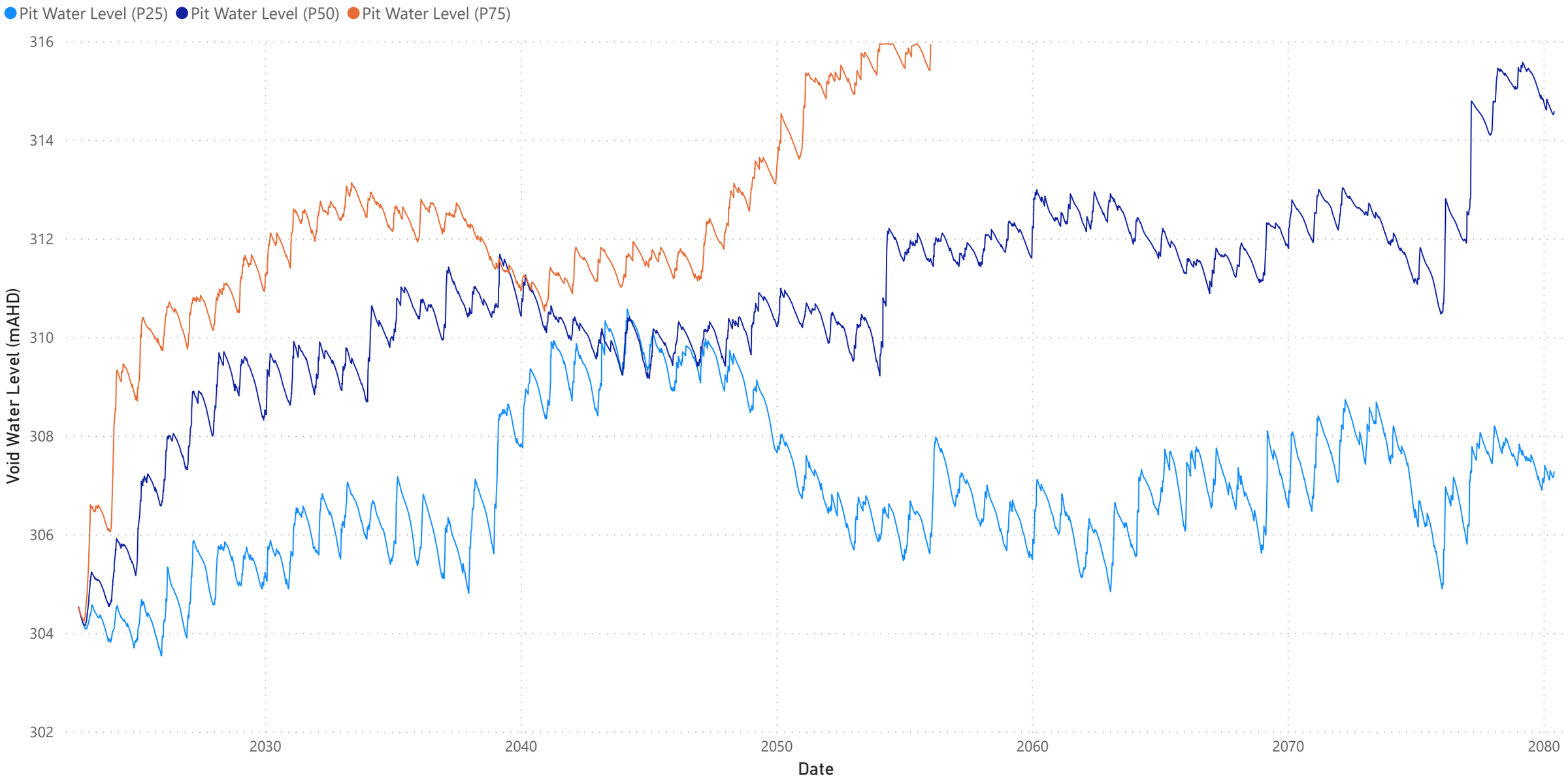


Feature

North Pit

4/06/2022 19/02/2080

Modelled water level in pit/void

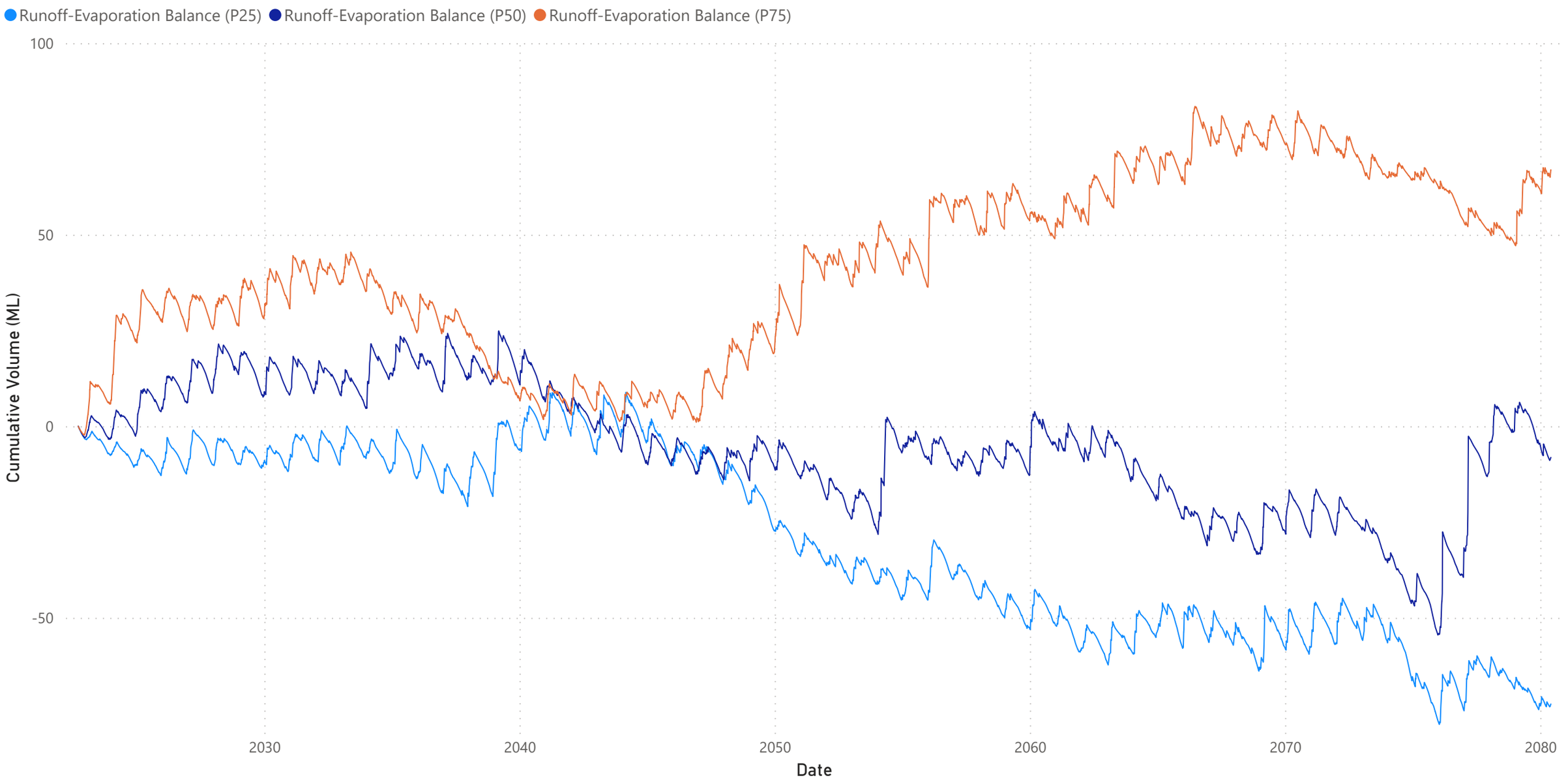


Feature

North Pit

4/06/2022 19/02/2080

Balance between runoff and evaporation

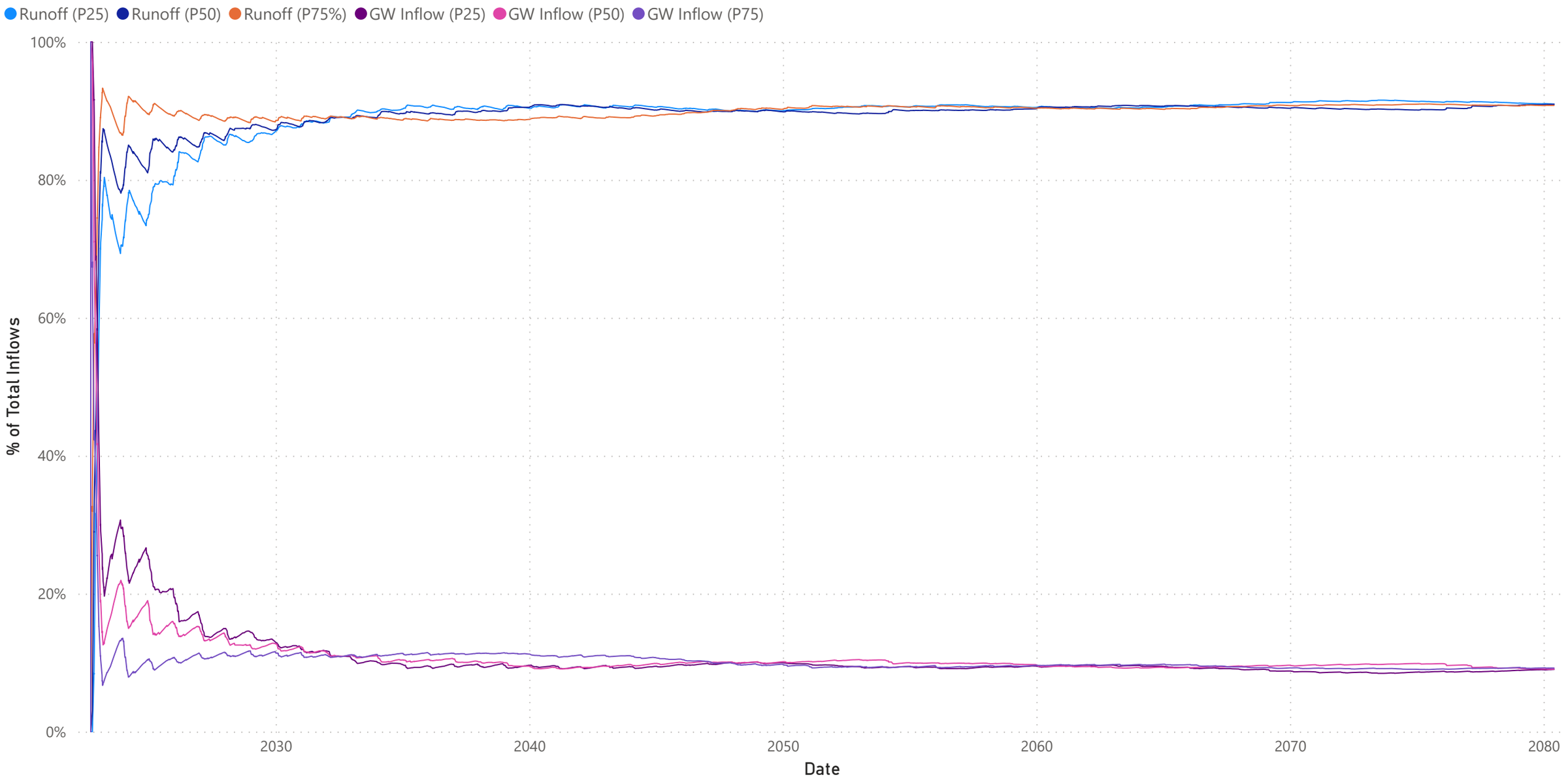


Feature

North Pit

4/06/2022 19/02/2080

Runoff and groundwater inflow as % of total inflow

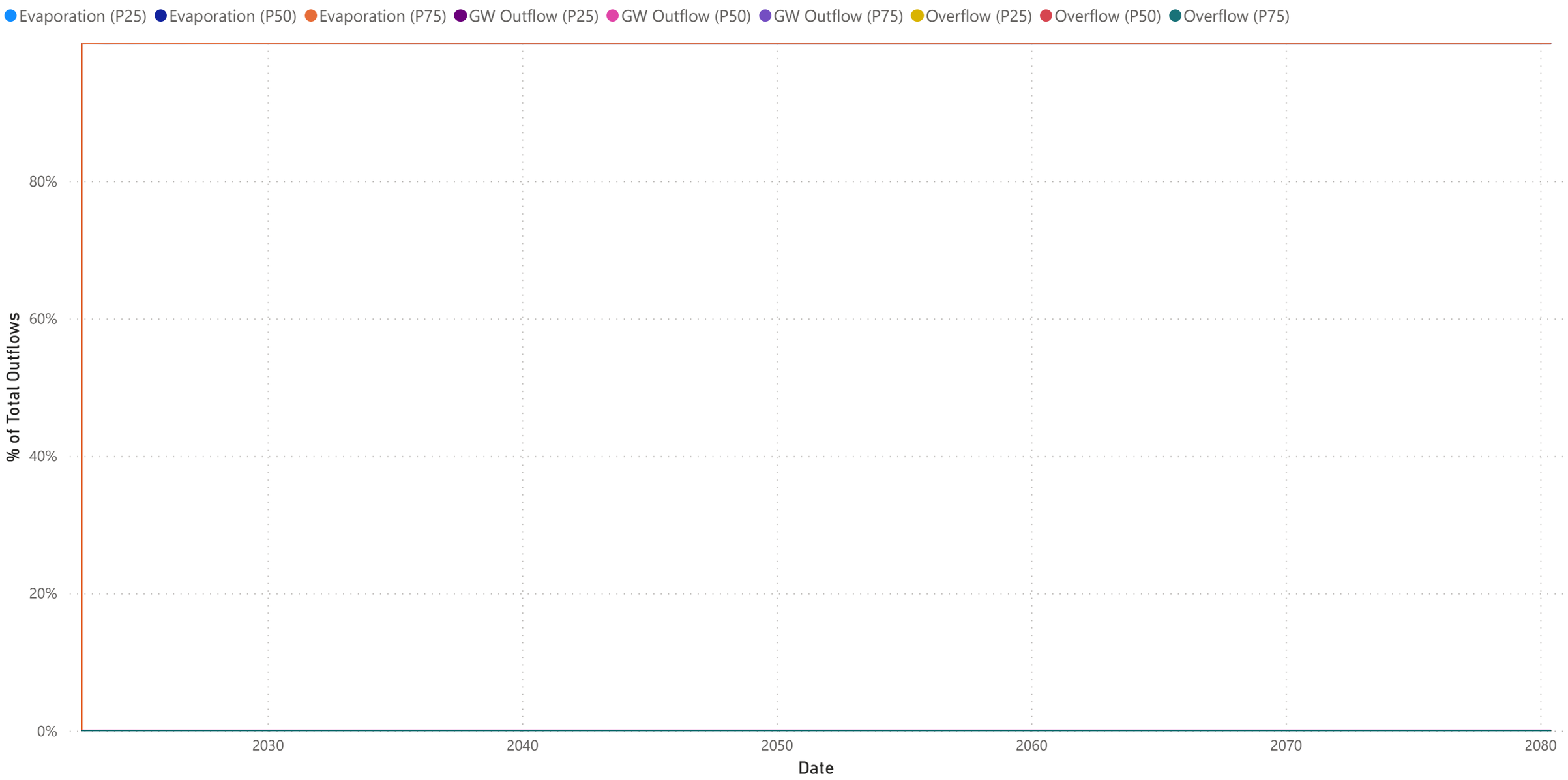


Feature

North Pit

4/06/2022 19/02/2080

Outflow components as % of total outflow

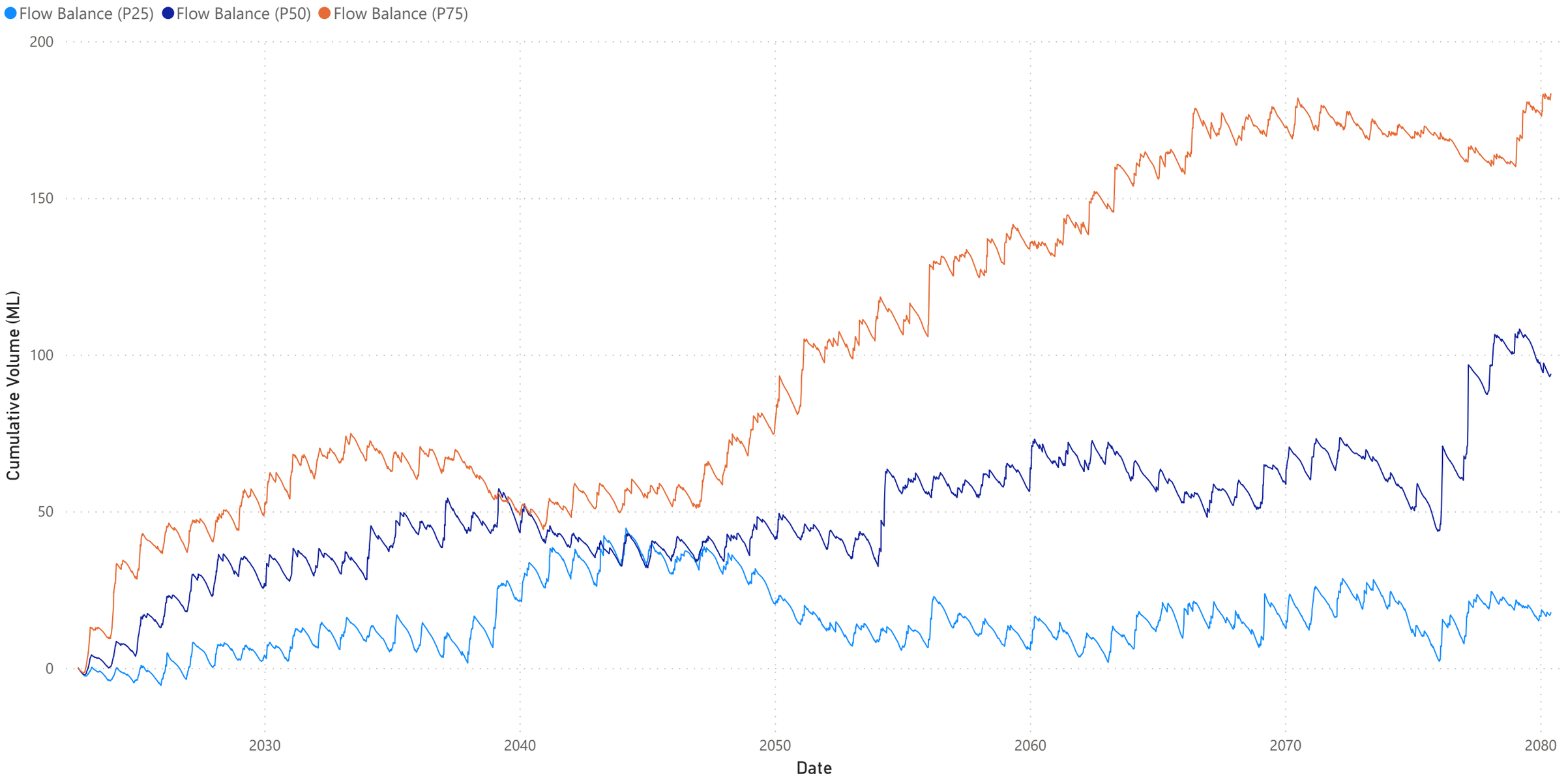


Feature

North Pit

4/06/2022 19/02/2080

Net flow balance (Inflow - Outflow) in pit/void

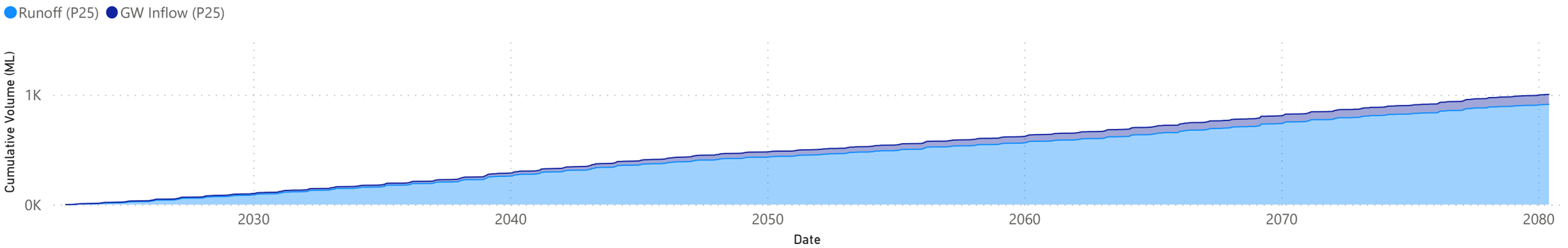


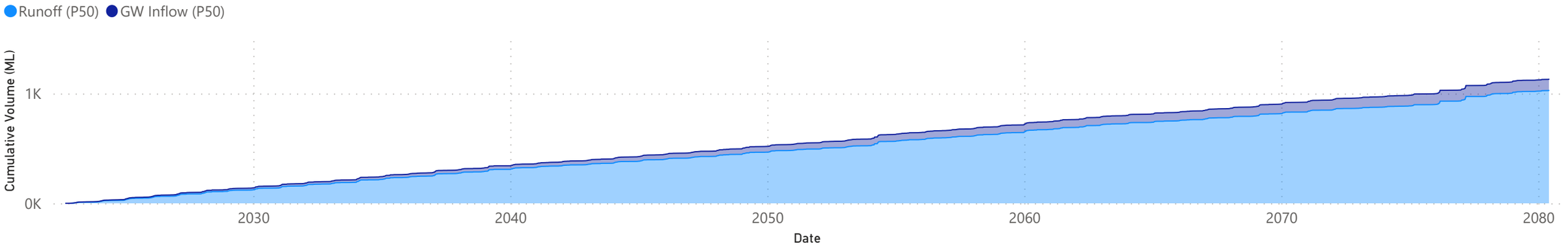
Feature

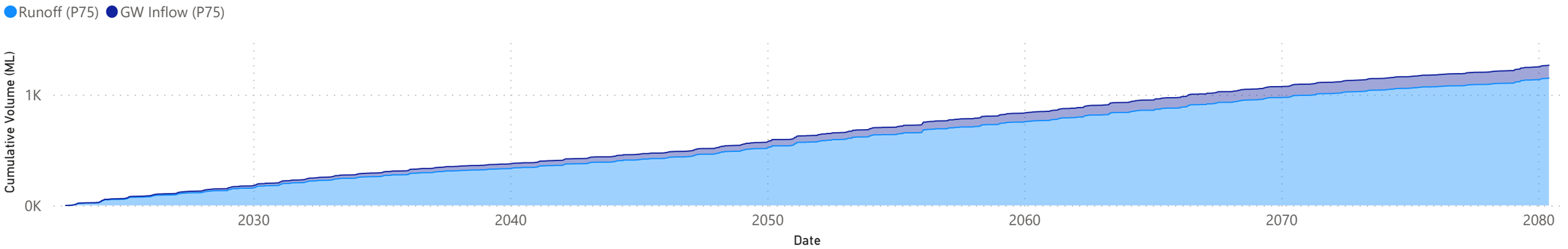
North Pit

4/06/2022 19/02/2080

Cumulative inflows into pit/void





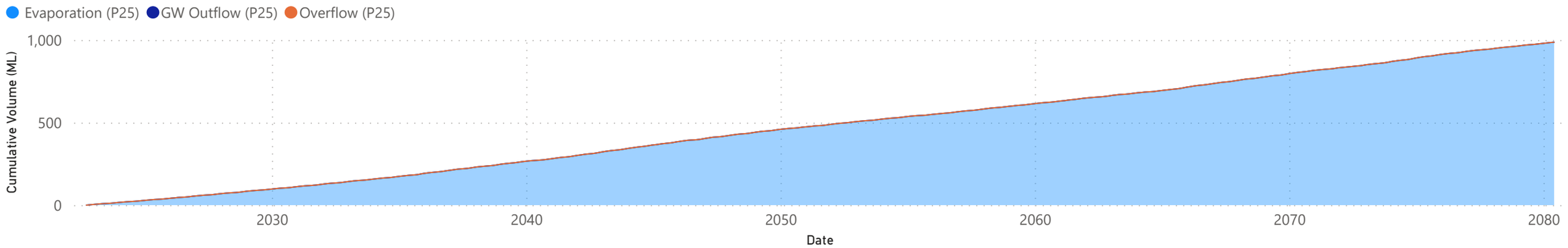


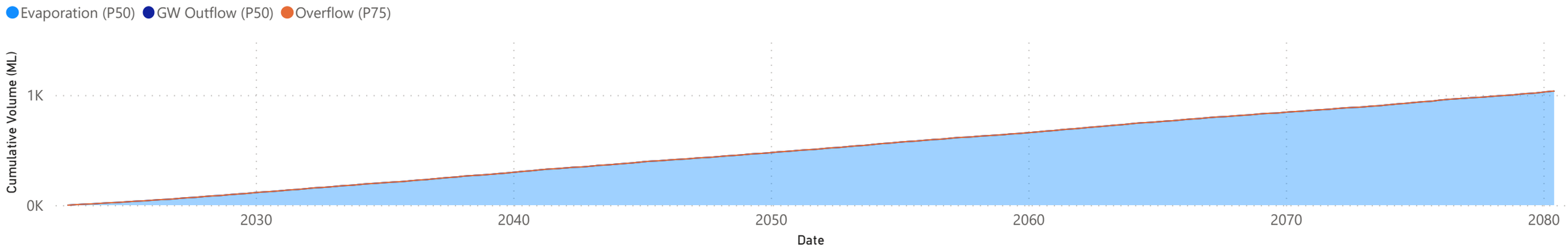
Feature

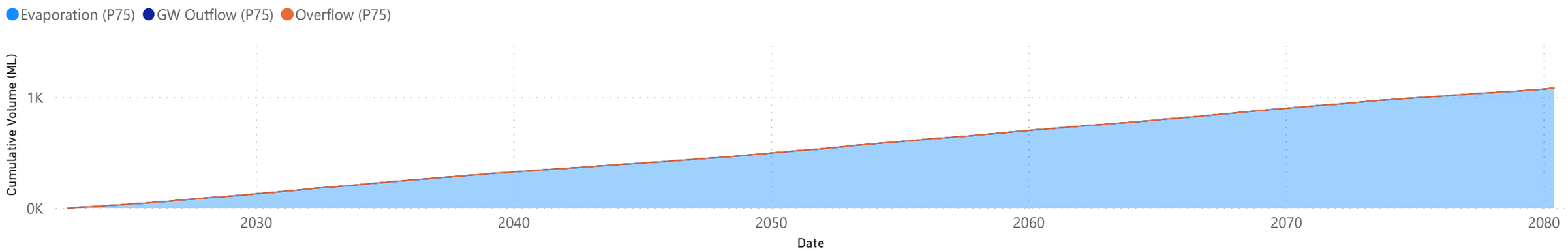
North Pit

4/06/2022 19/02/2080

Cumulative outflows from pit/void







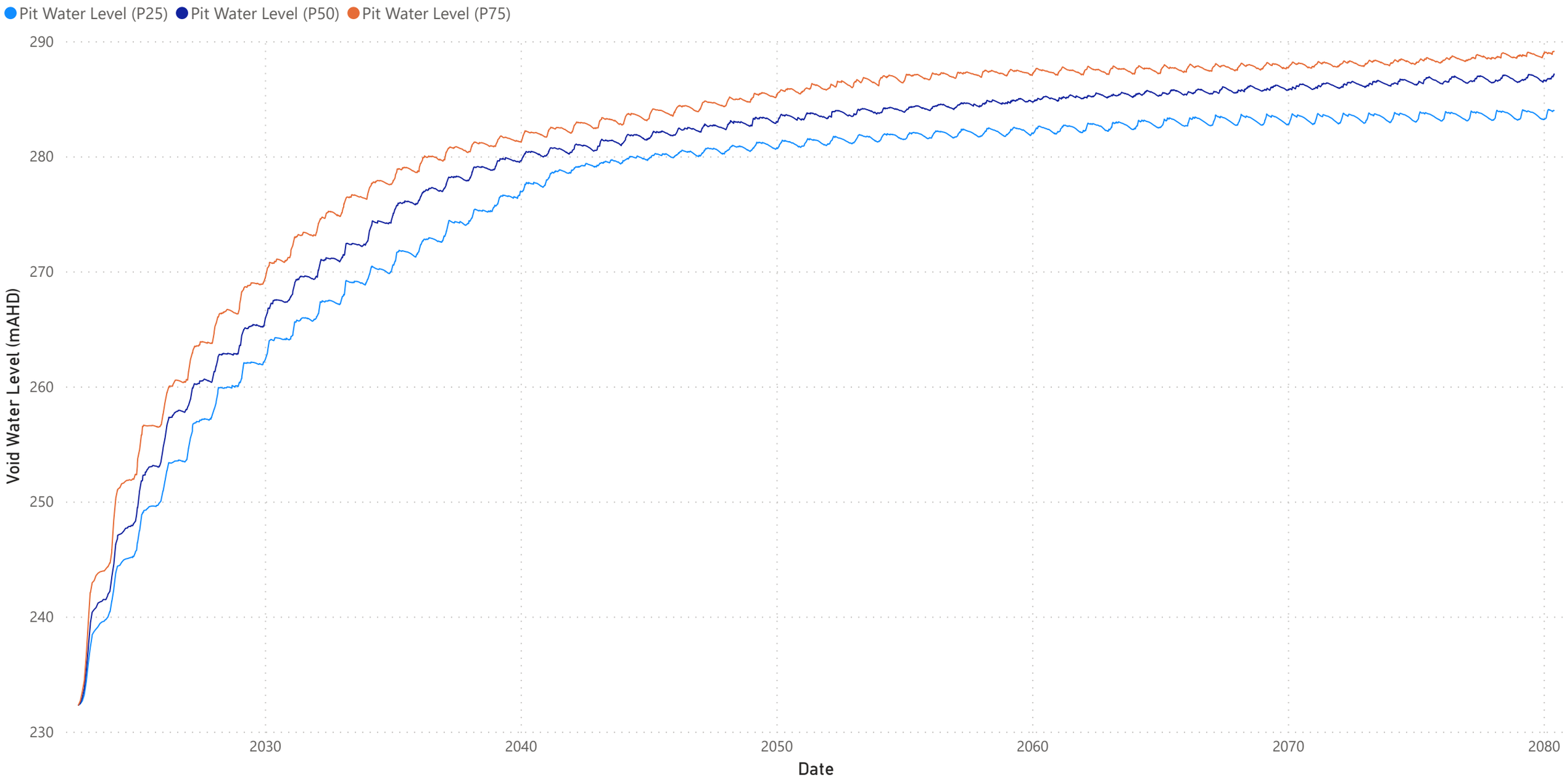
Appendix A.2 South Pit (Scenario 1) WBM Outputs

Feature

South Pit Scenario 1

4/06/2022 19/02/2080

Modelled water level in pit/void

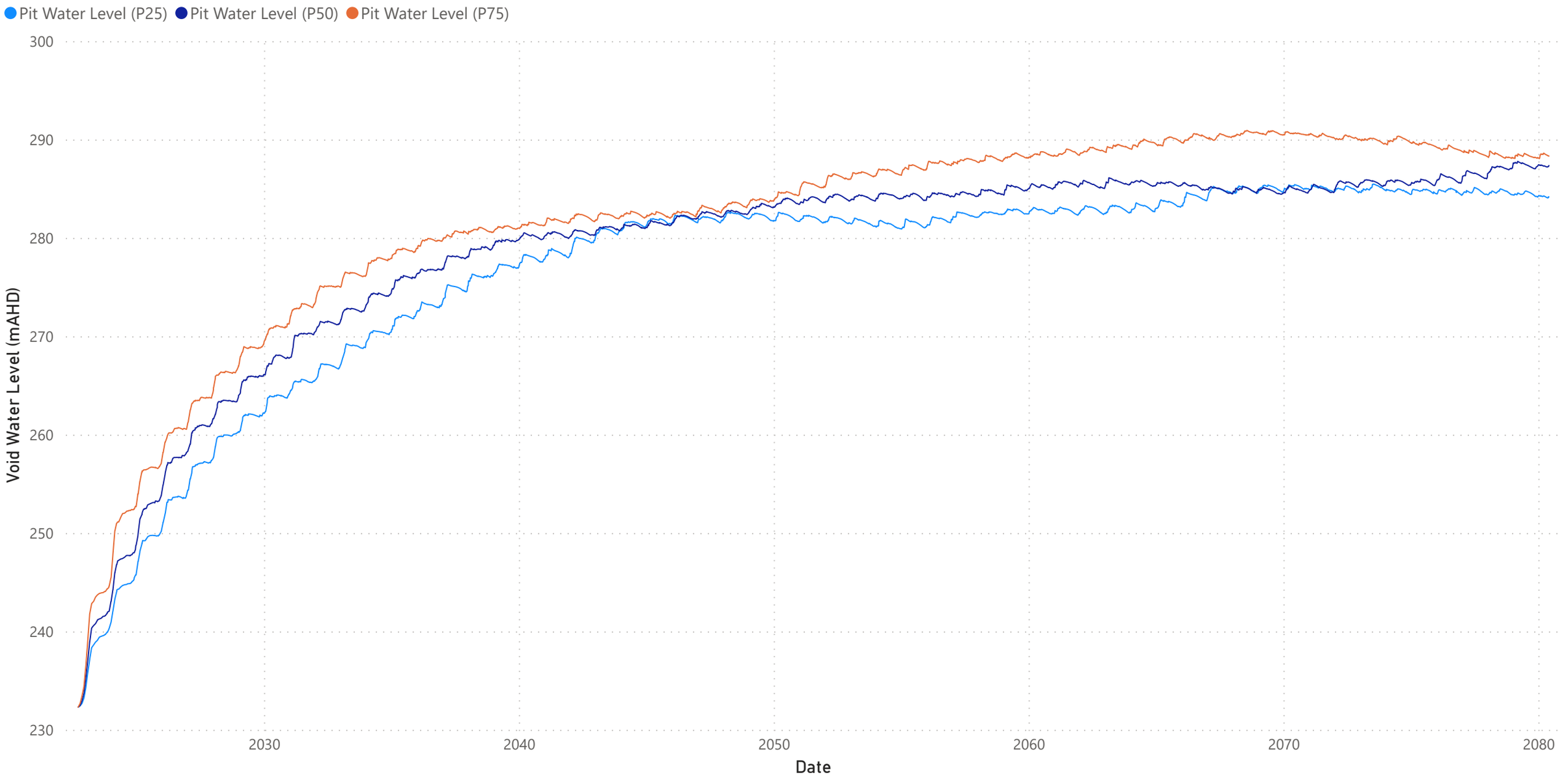


Feature

South Pit Scenario 1

4/06/2022 19/02/2080

Modelled water level in pit/void

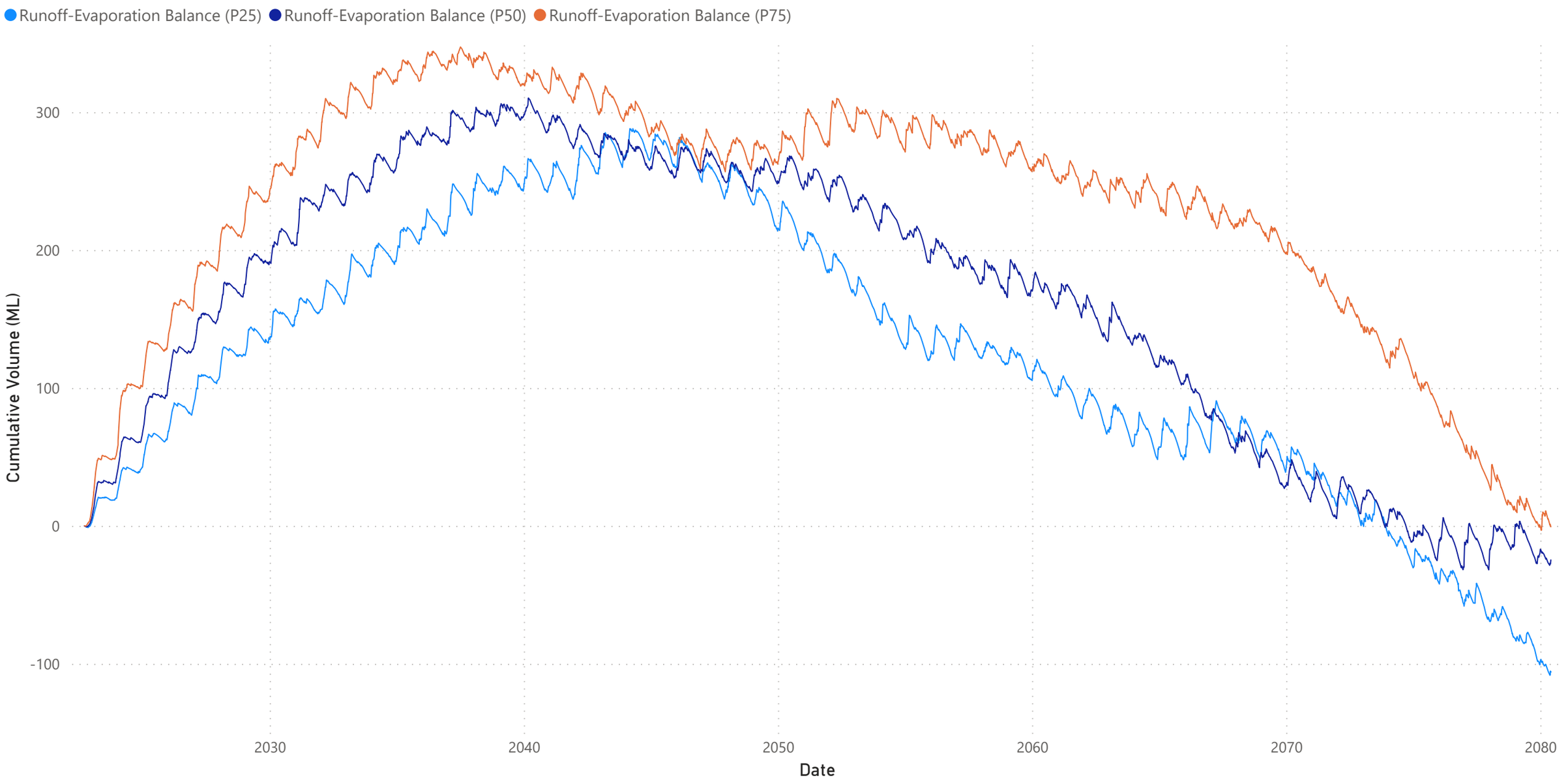


Feature

South Pit Scenario 1

4/06/2022 19/02/2080

Balance between runoff and evaporation

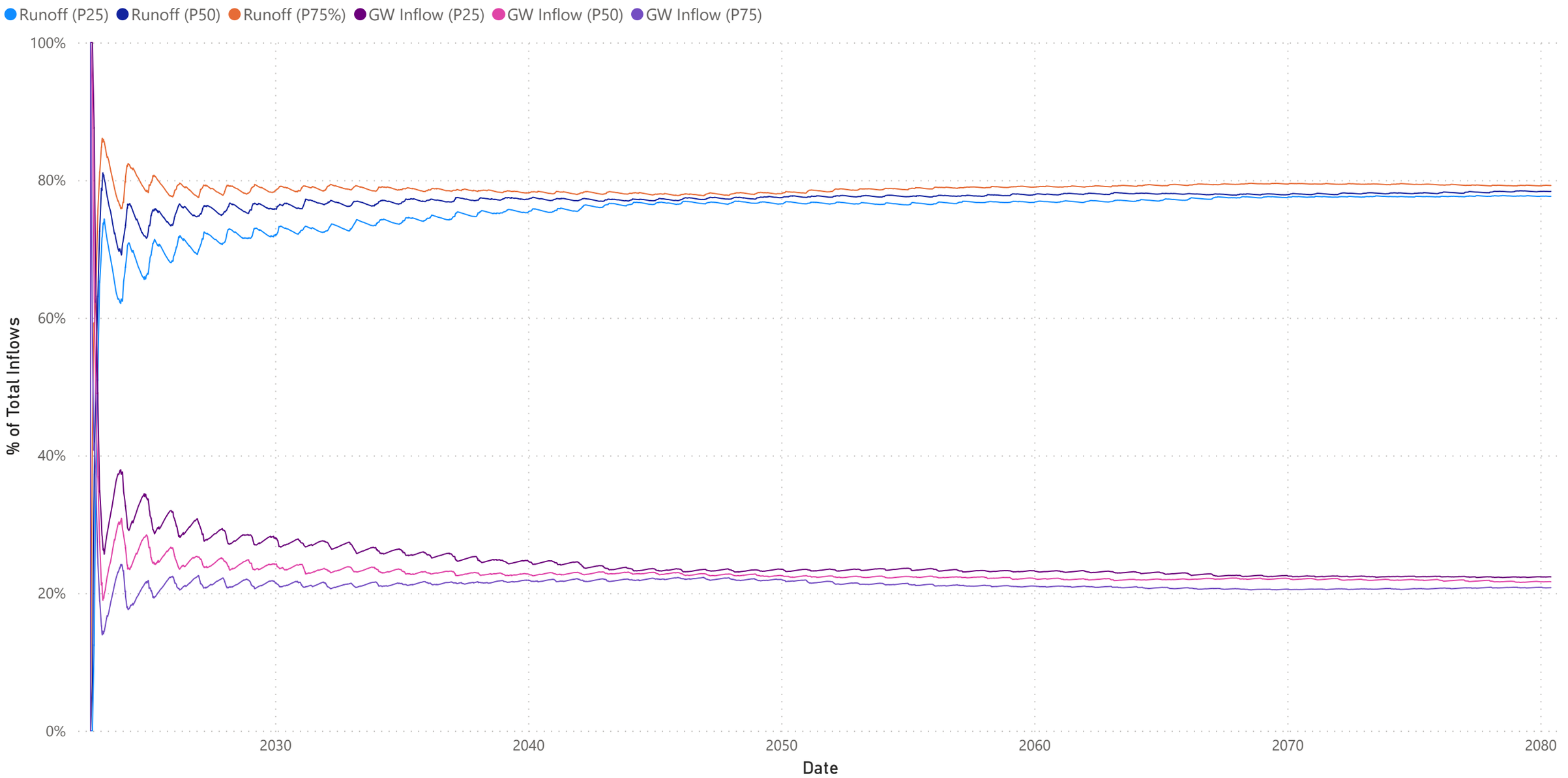


Feature

South Pit Scenario 1

4/06/2022 19/02/2080

Runoff and groundwater inflow as % of total inflow

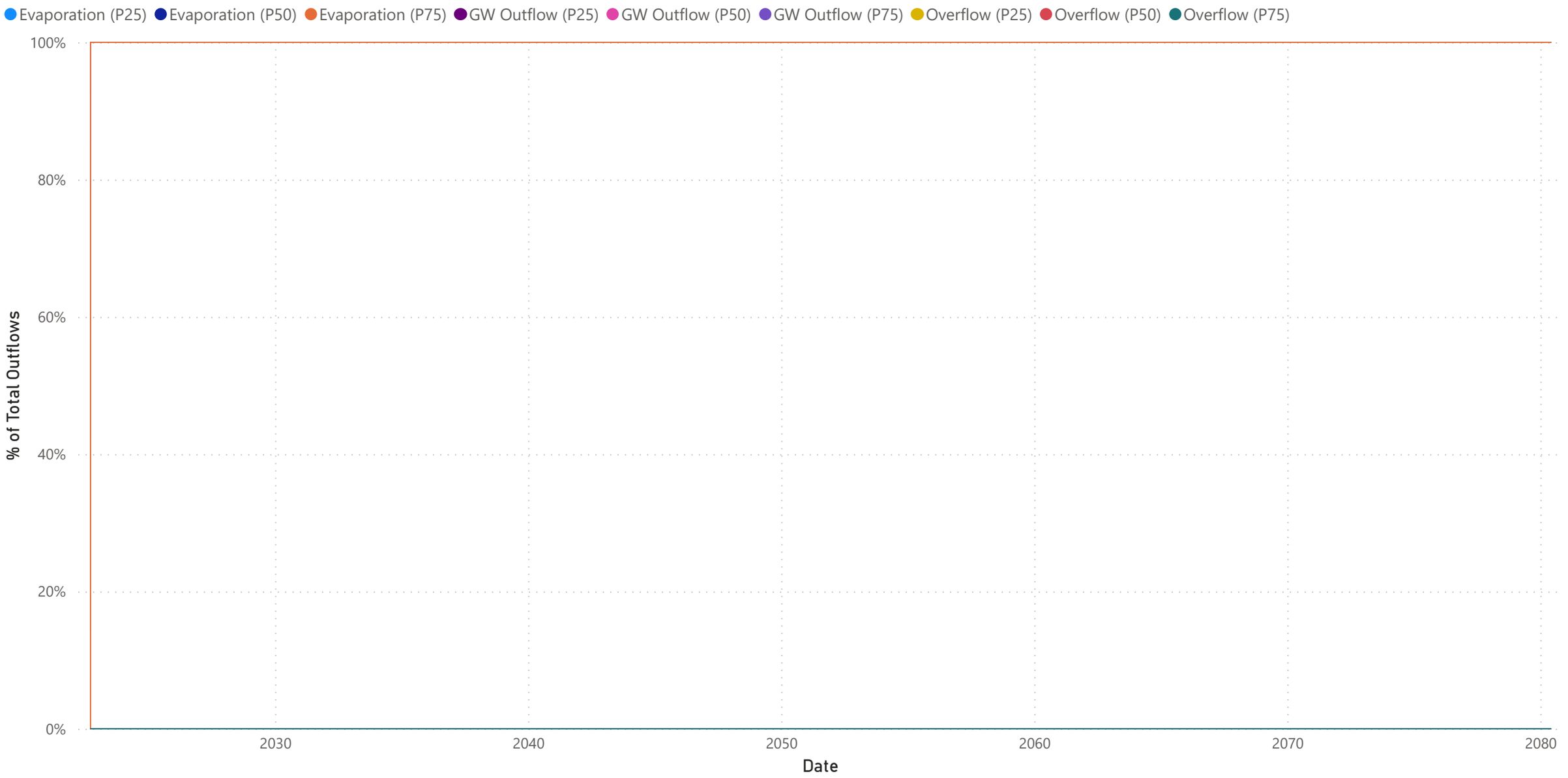


Feature

South Pit Scenario 1

4/06/2022 19/02/2080

Outflow components as % of total outflow

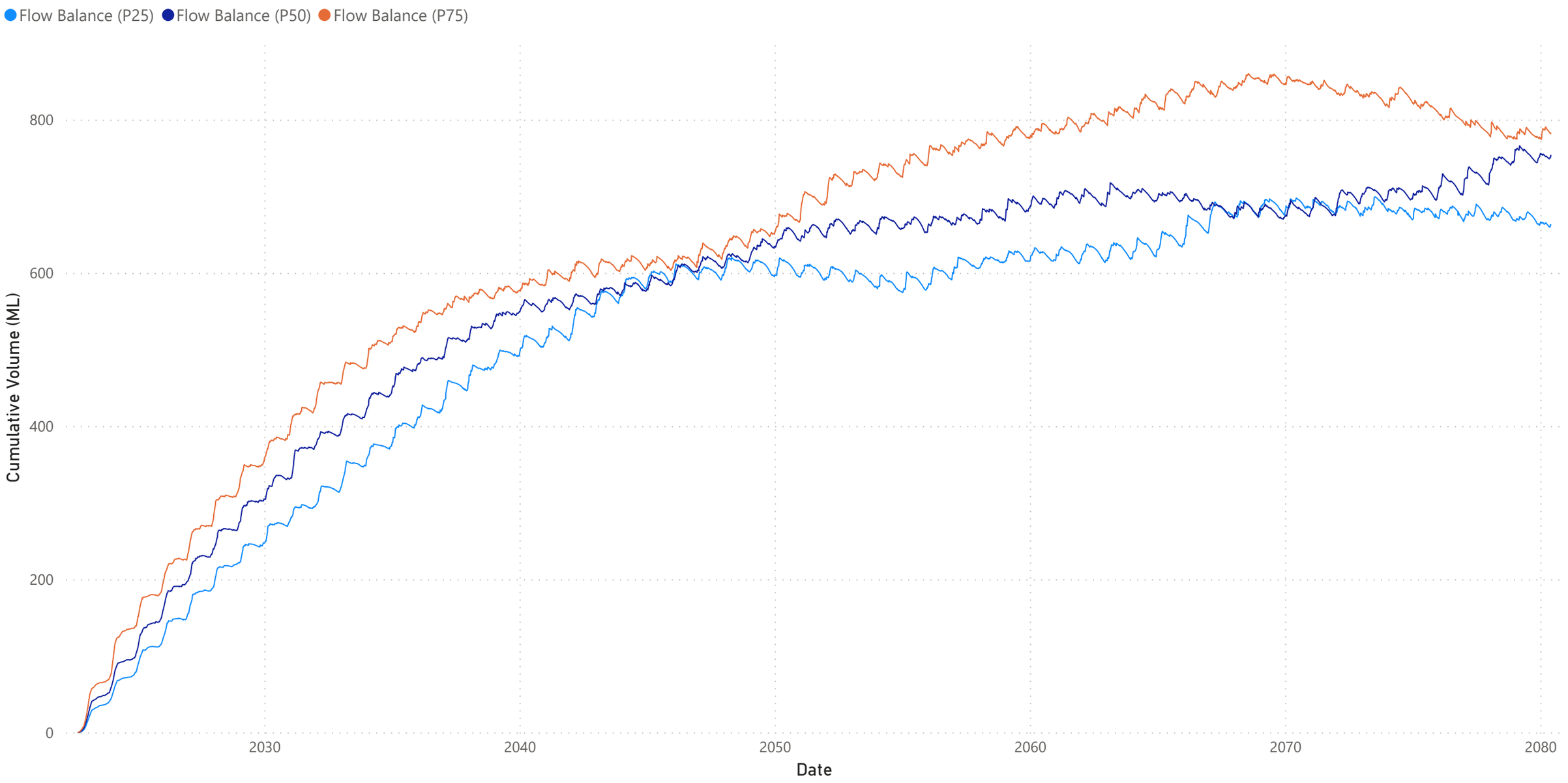


Feature

South Pit Scenario 1

4/06/2022 19/02/2080

Net flow balance (Inflow - Outflow) in pit/void

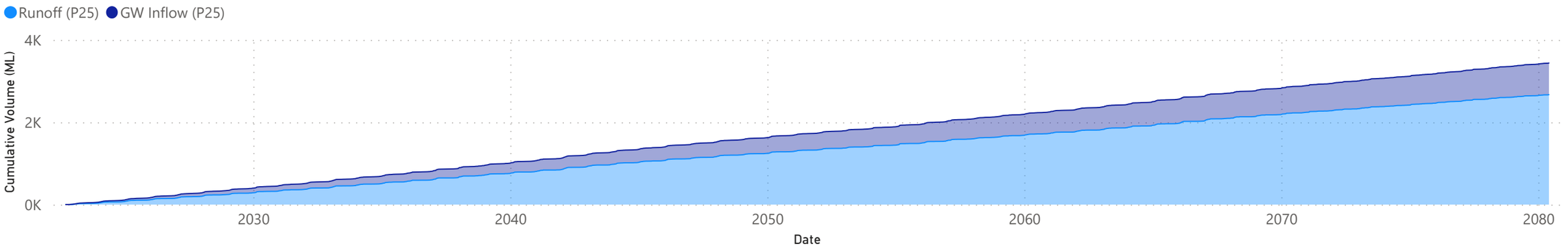


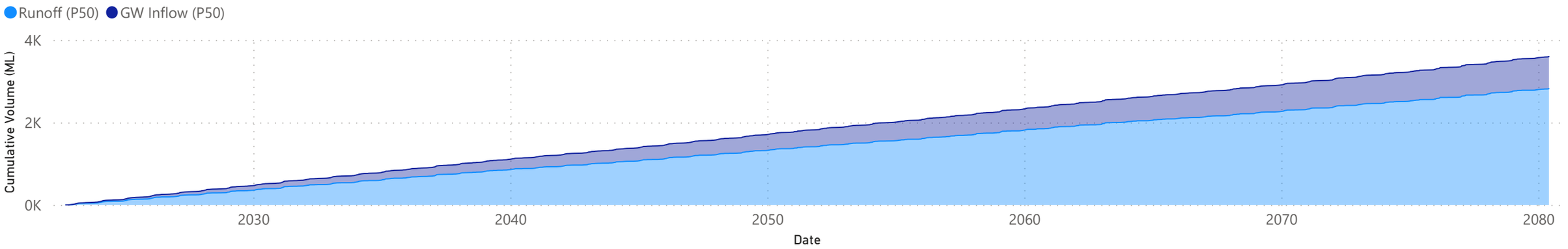
Feature

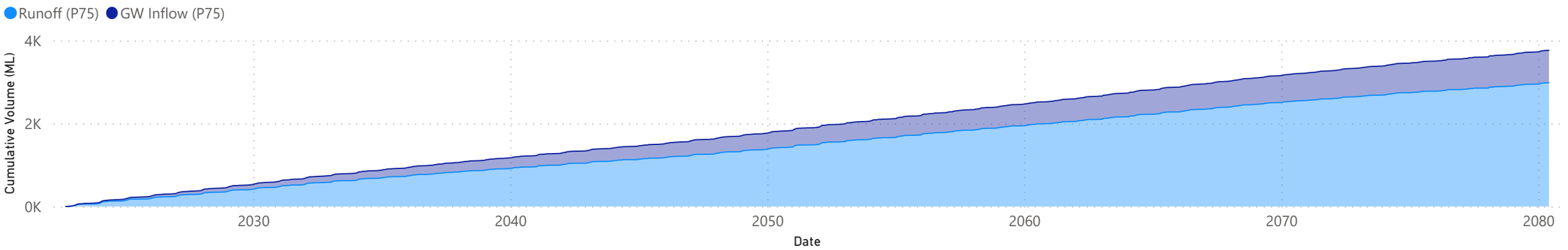
South Pit Scenario 1

4/06/2022 19/02/2080

Cumulative inflows into pit/void





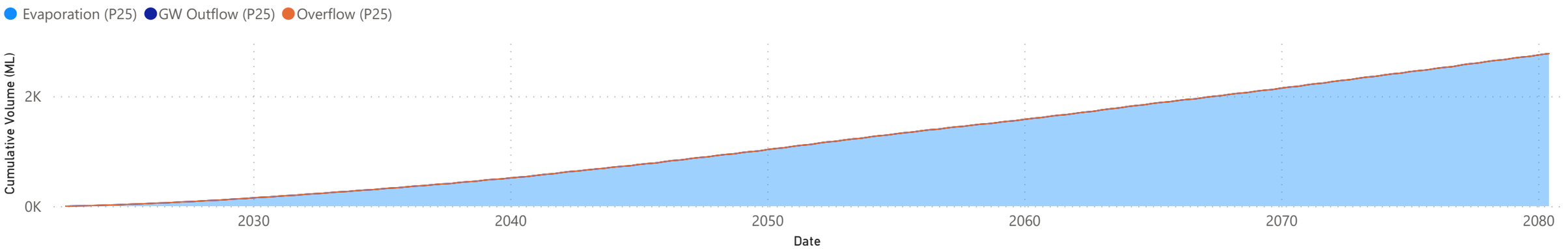


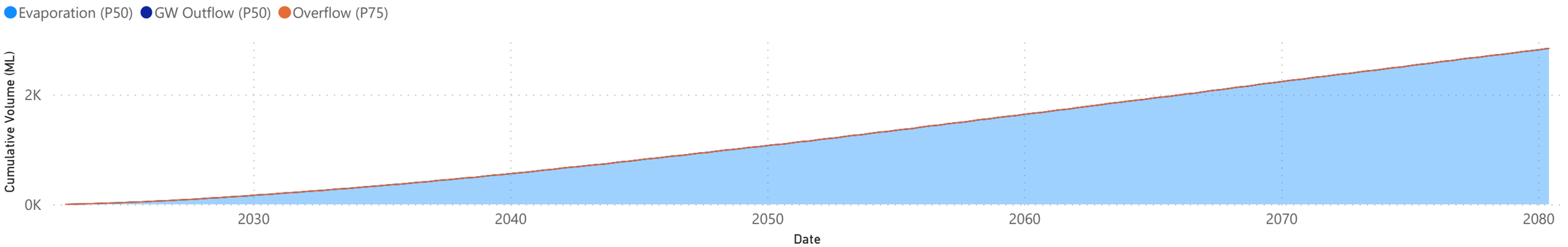
Feature

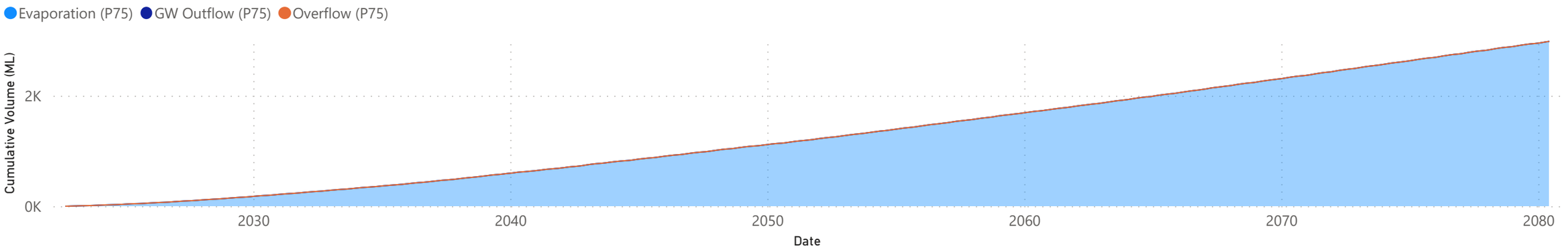
South Pit Scenario 1

4/06/2022 19/02/2080

Cumulative outflows from pit/void







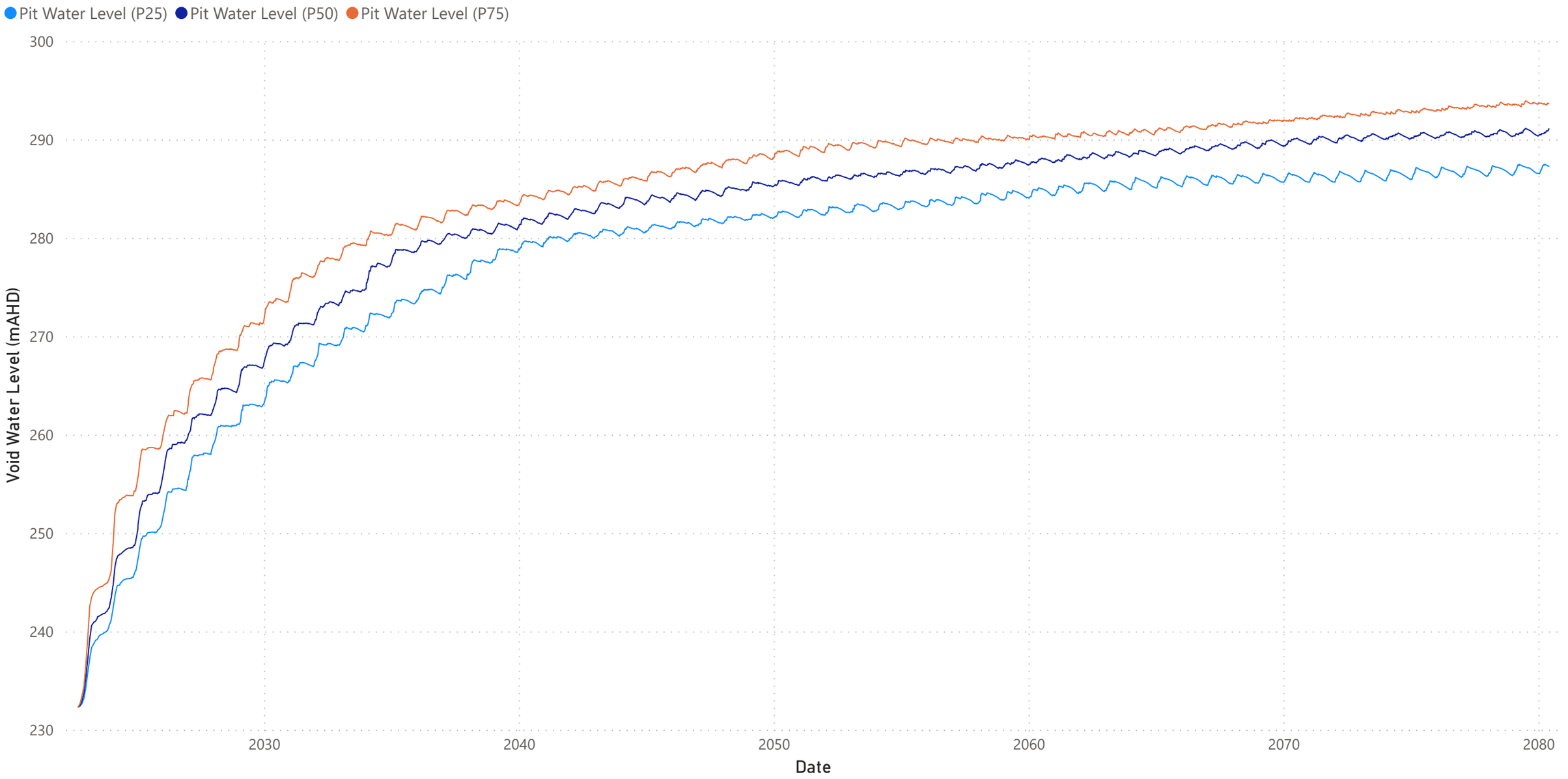
Appendix A.3 South Pit (Scenario 2) WBM Outputs

Feature

South Pit Scenario 2

4/06/2022 19/02/2080

Modelled water level in pit/void

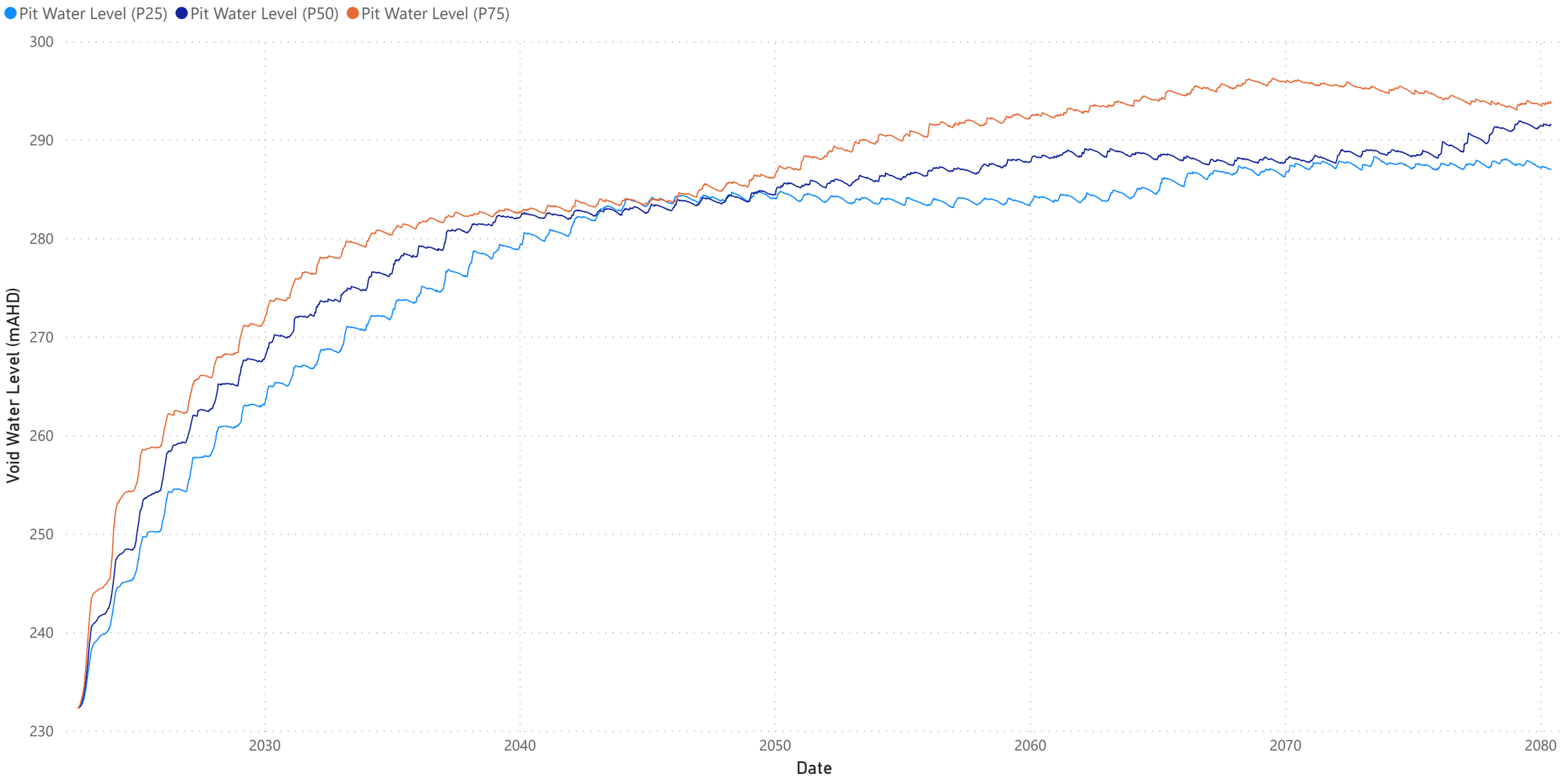


Feature

South Pit Scenario 2

4/06/2022 19/02/2080

Modelled water level in pit/void

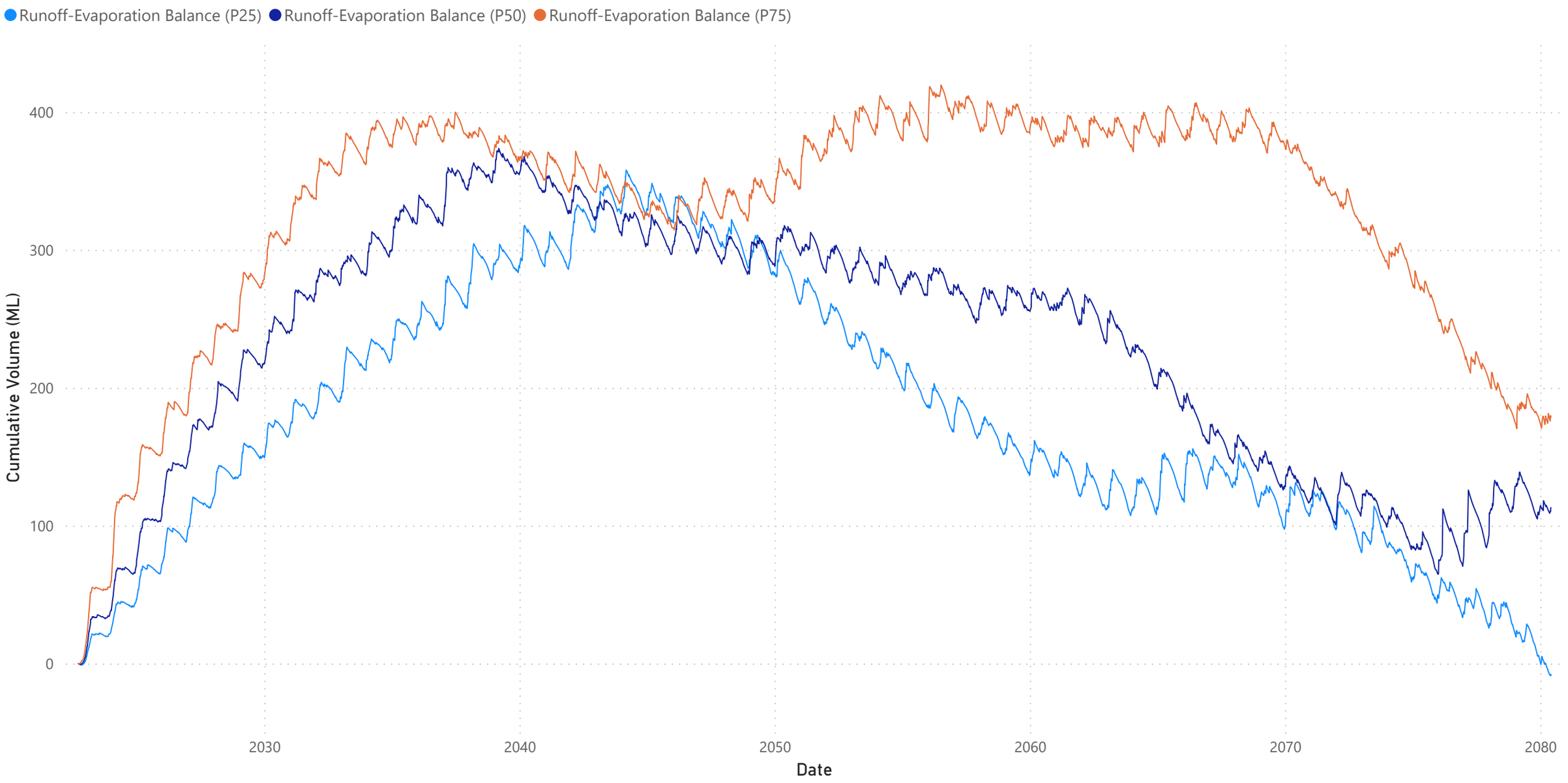


Feature

South Pit Scenario 2

4/06/2022 19/02/2080

Balance between runoff and evaporation

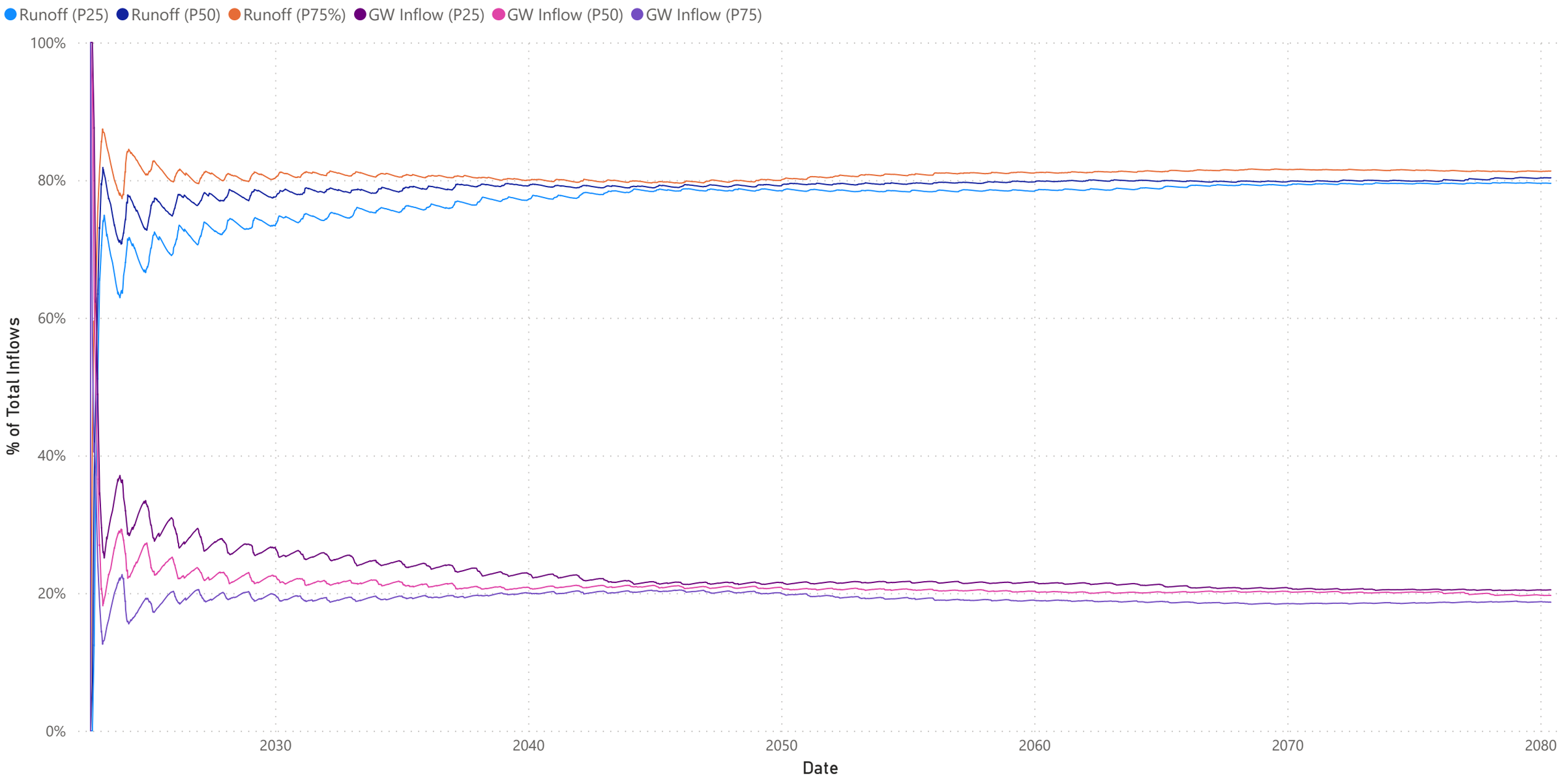


Feature

South Pit Scenario 2

4/06/2022 19/02/2080

Runoff and groundwater inflow as % of total inflow

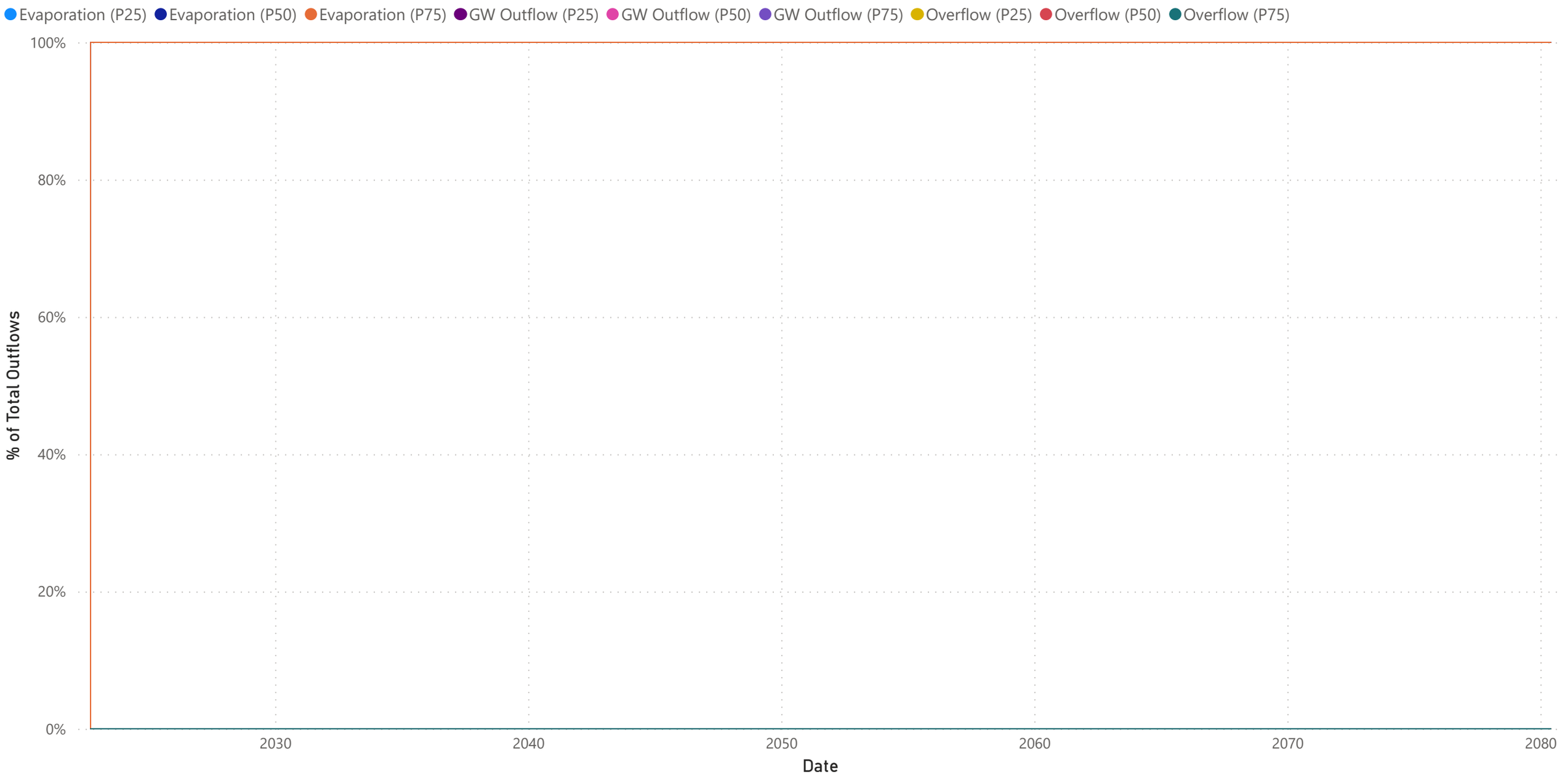


Feature

South Pit Scenario 2

4/06/2022 19/02/2080

Outflow components as % of total outflow

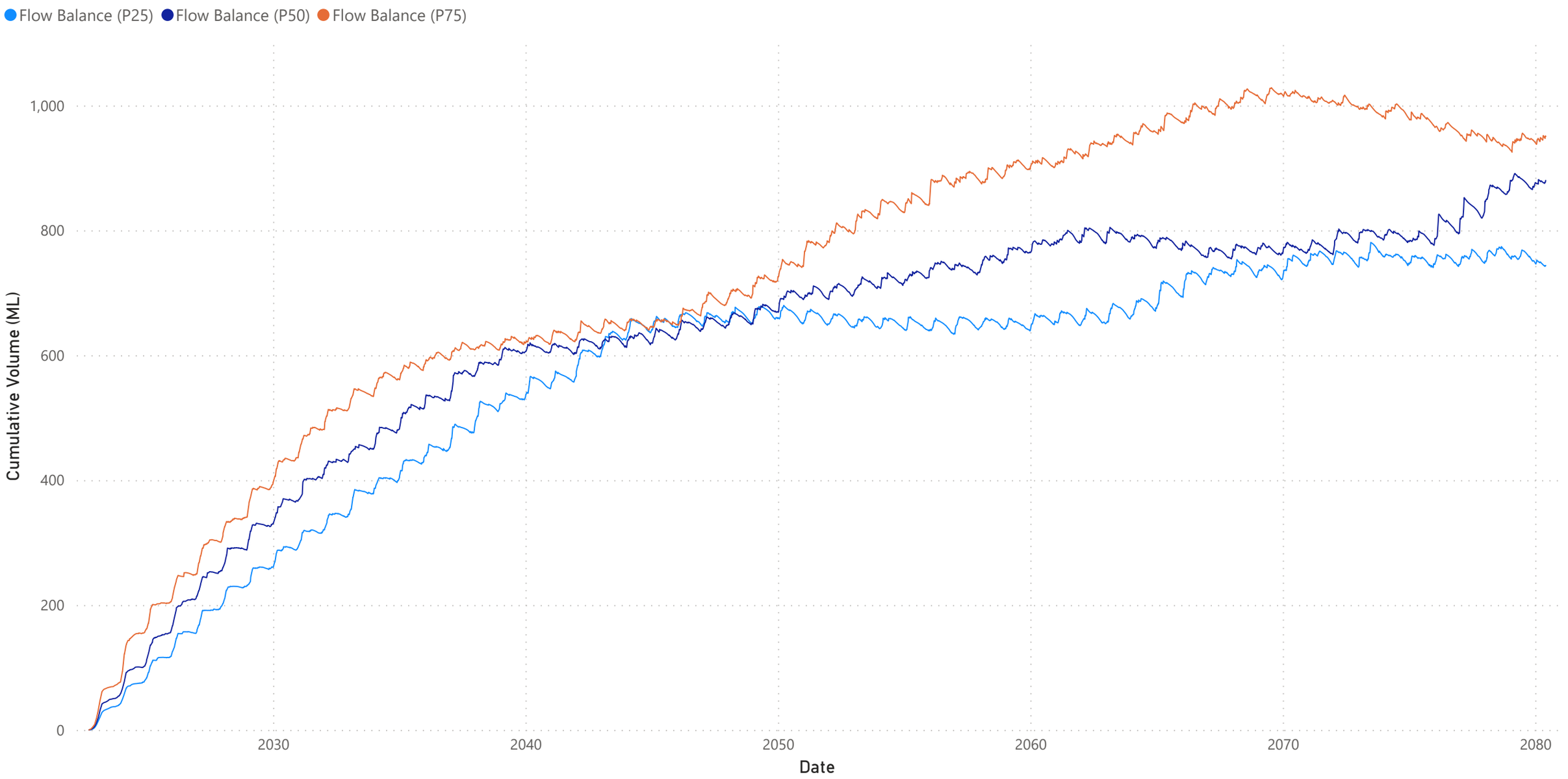


Feature

South Pit Scenario 2

4/06/2022 19/02/2080

Net flow balance (Inflow - Outflow) in pit/void

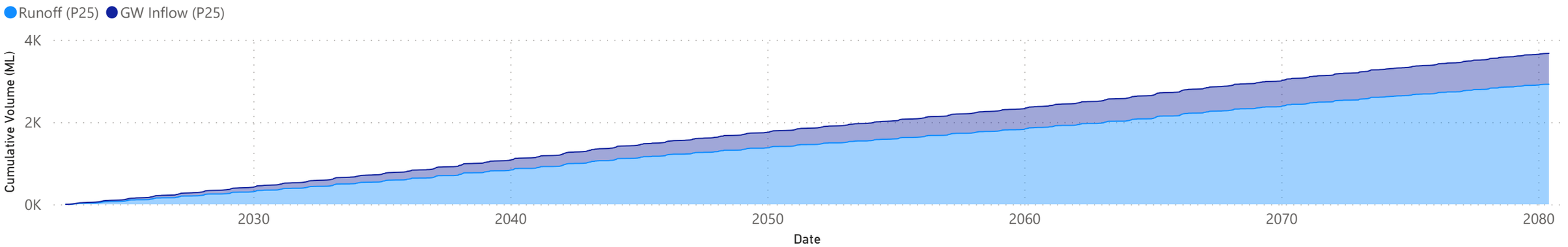


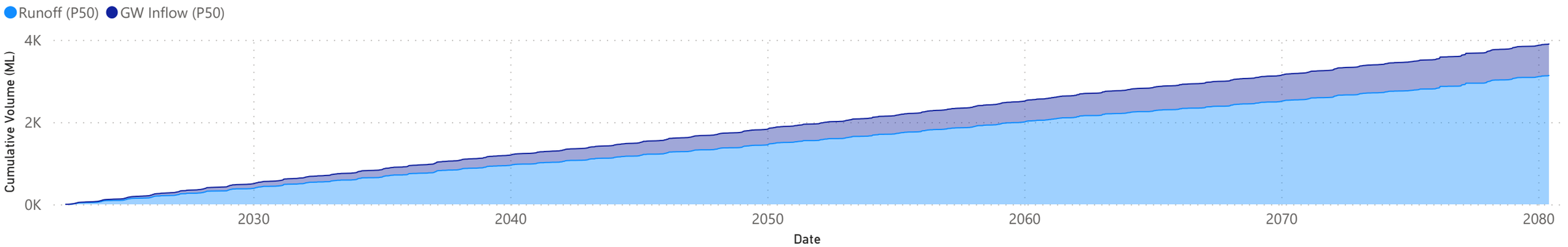
Feature

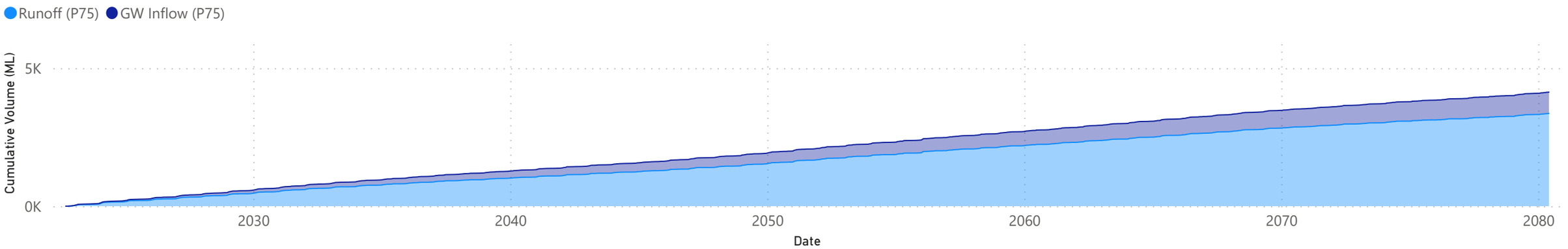
South Pit Scenario 2

4/06/2022 19/02/2080

Cumulative inflows into pit/void





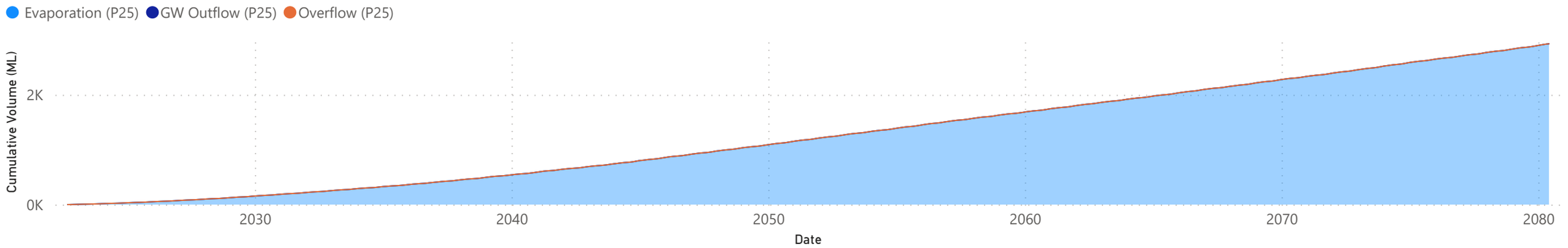


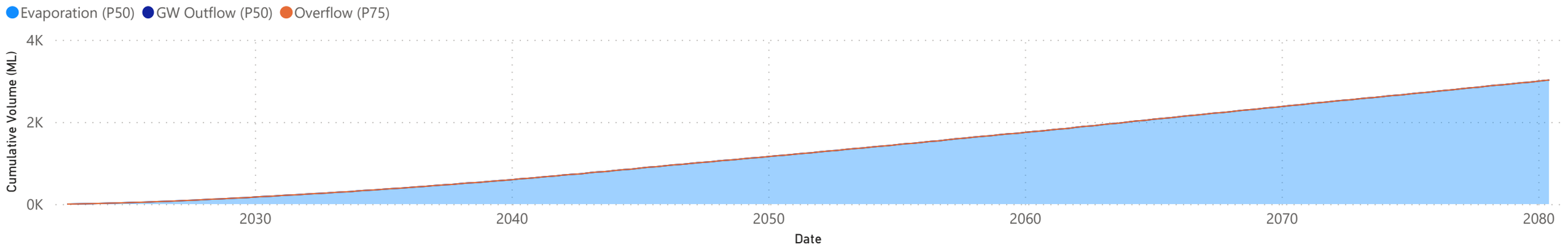
Feature

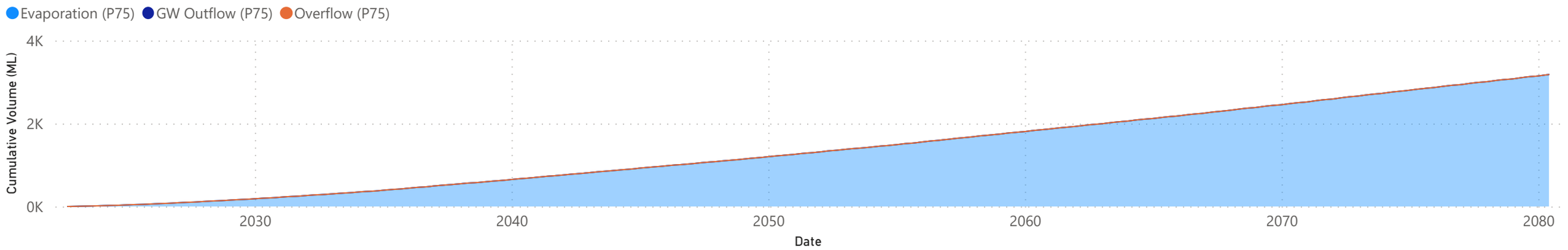
South Pit Scenario 2

4/06/2022 19/02/2080

Cumulative outflows from pit/void







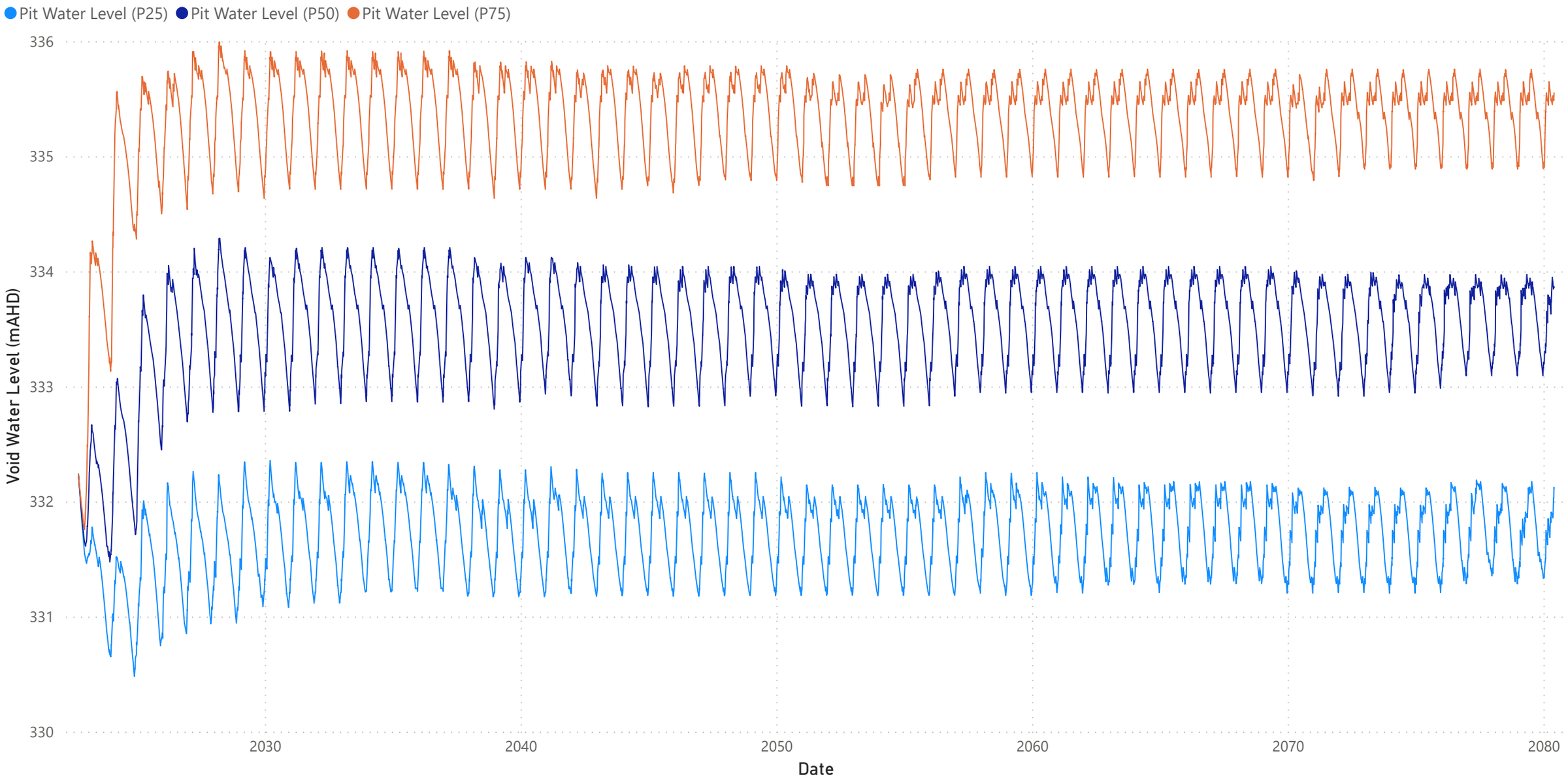
Appendix A.4 WRD Sediment Dam WBM Outputs

Feature

Sediment Dam

4/06/2022 19/02/2080

Modelled water level in pit/void

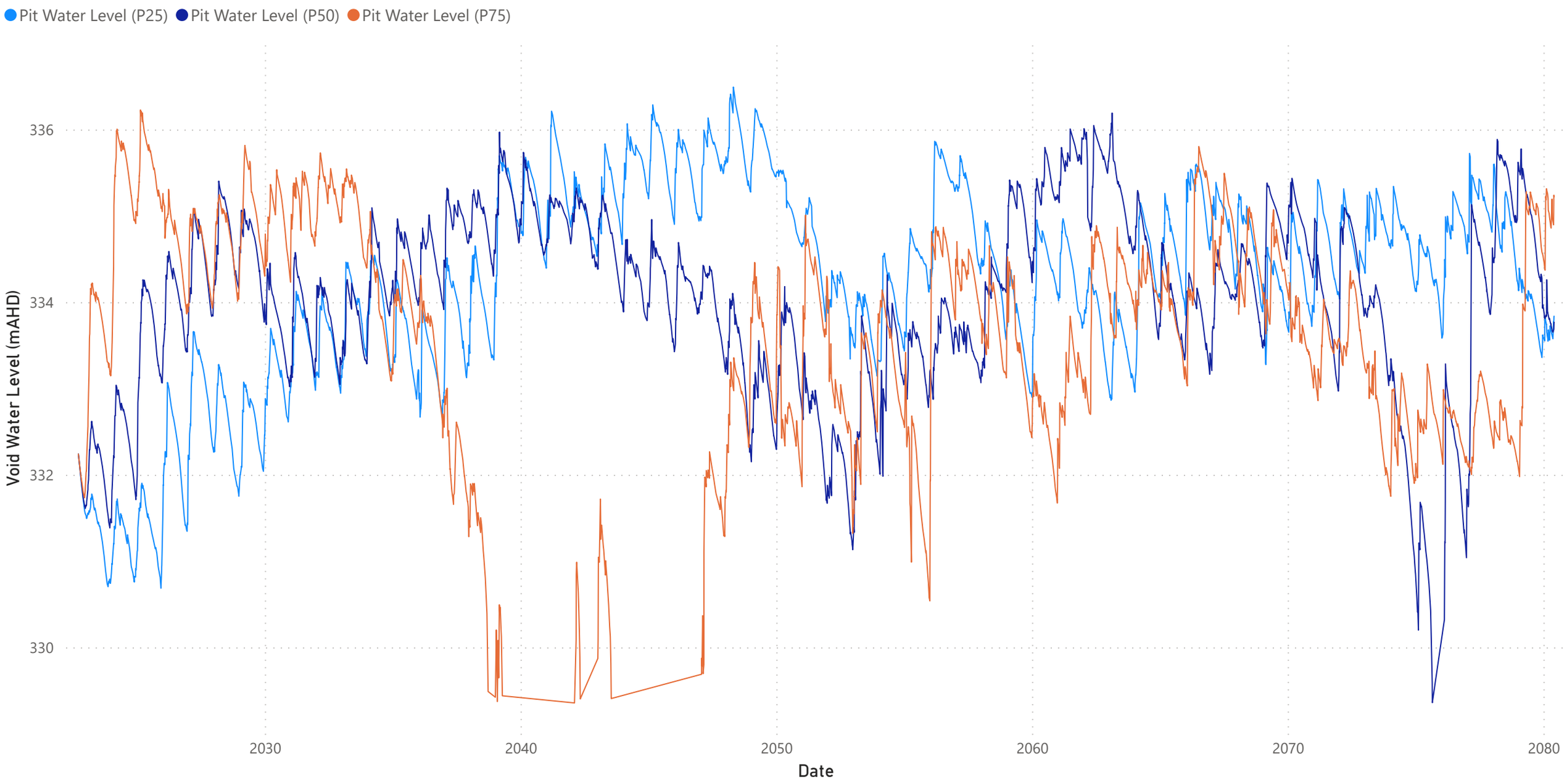


Feature

Sediment Dam

4/06/2022 19/02/2080

Modelled water level in pit/void

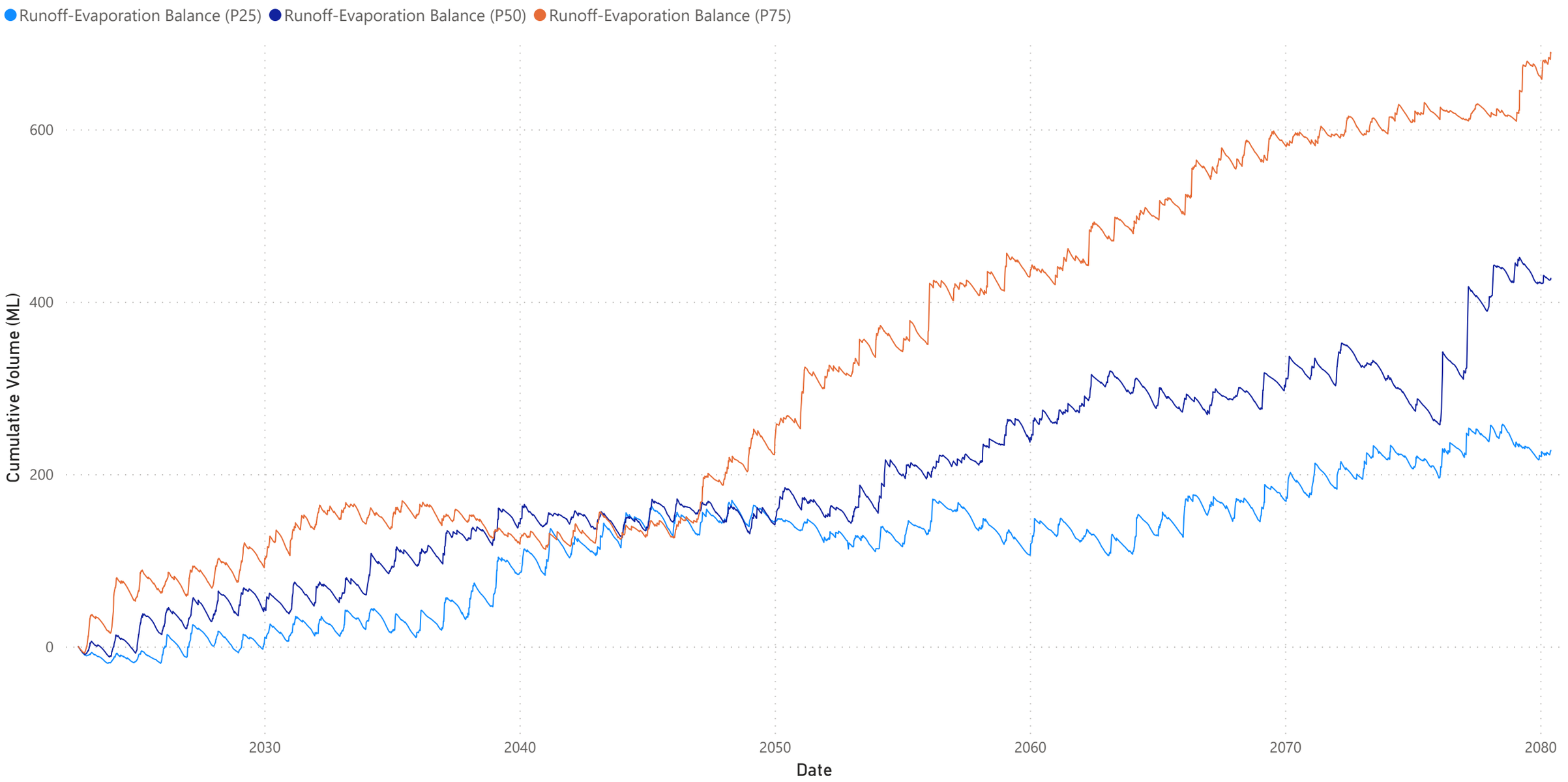


Feature

Sediment Dam

4/06/2022 19/02/2080

Balance between runoff and evaporation

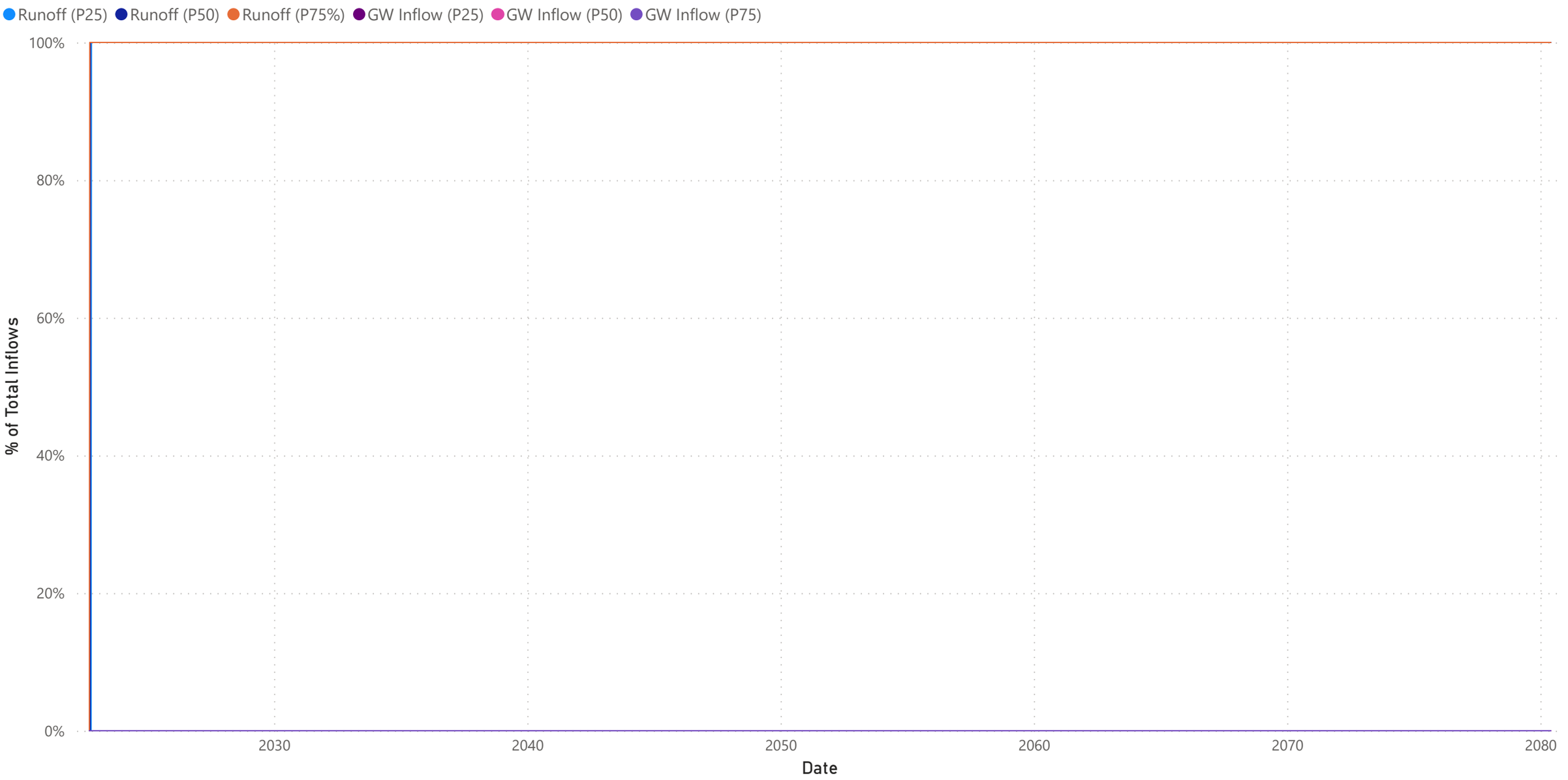


Feature

Sediment Dam

4/06/2022 19/02/2080

Runoff and groundwater inflow as % of total inflow

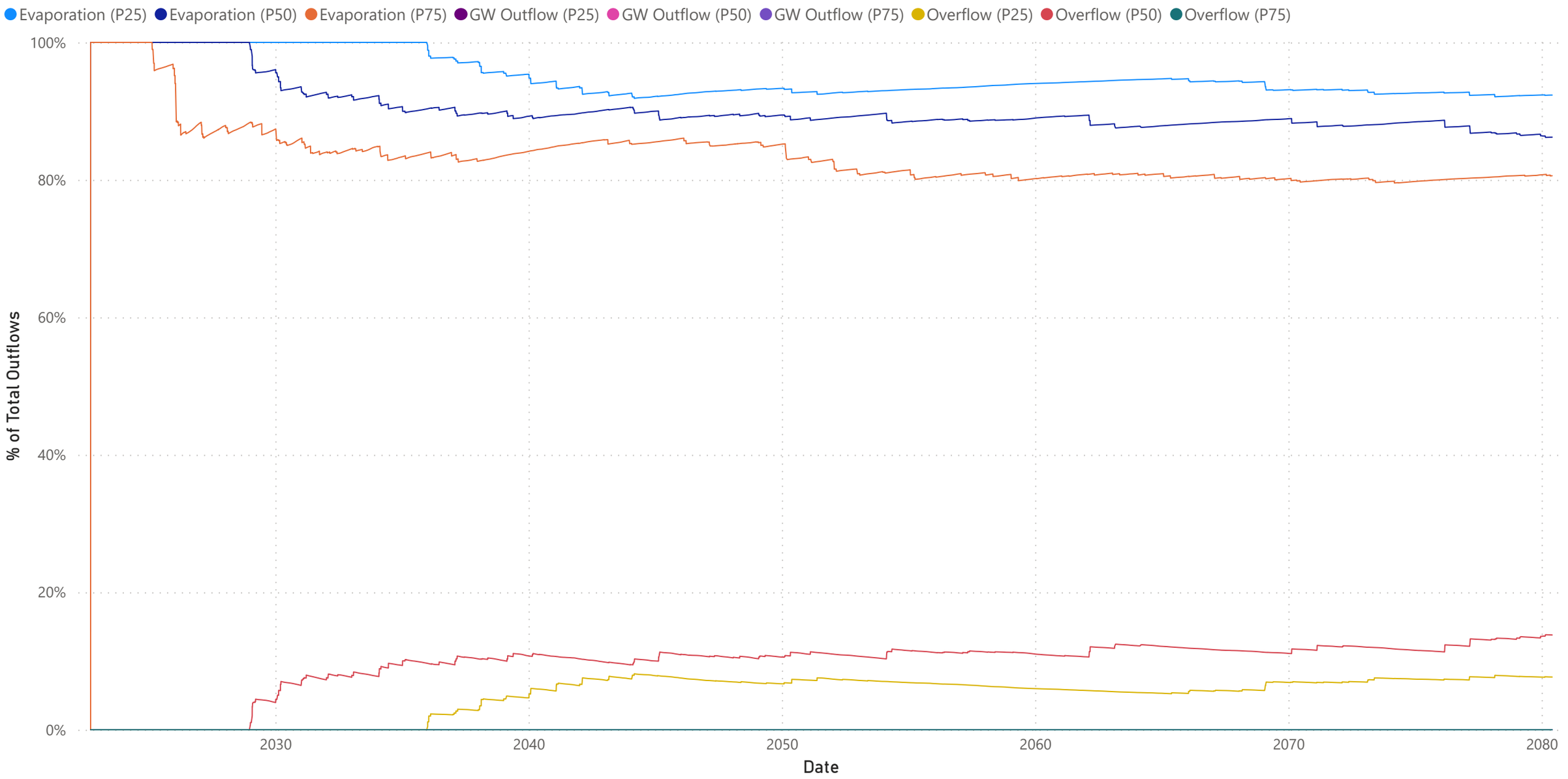


Feature

Sediment Dam

4/06/2022 19/02/2080

Outflow components as % of total outflow

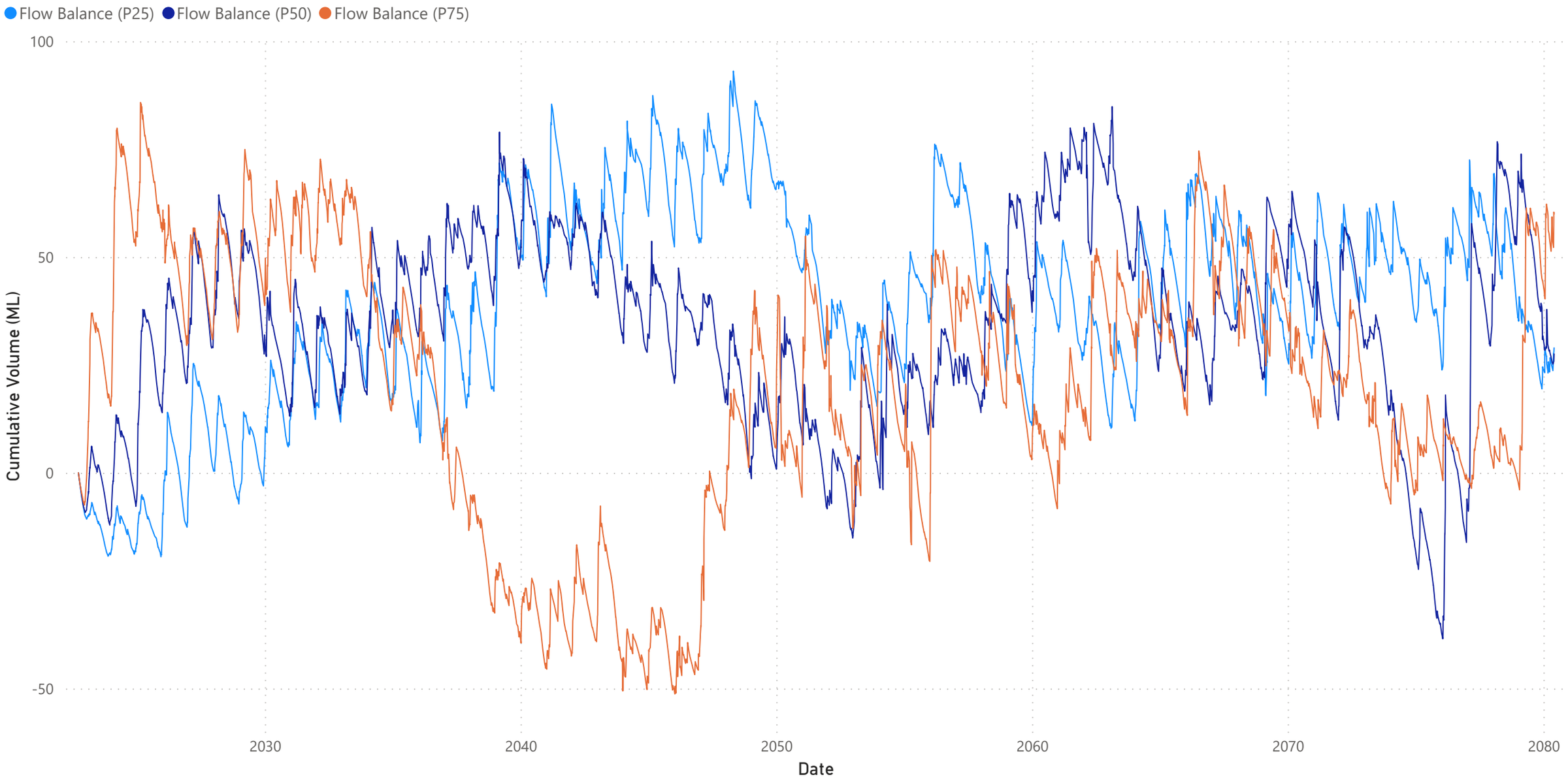


Feature

Sediment Dam

4/06/2022 19/02/2080

Net flow balance (Inflow - Outflow) in pit/void

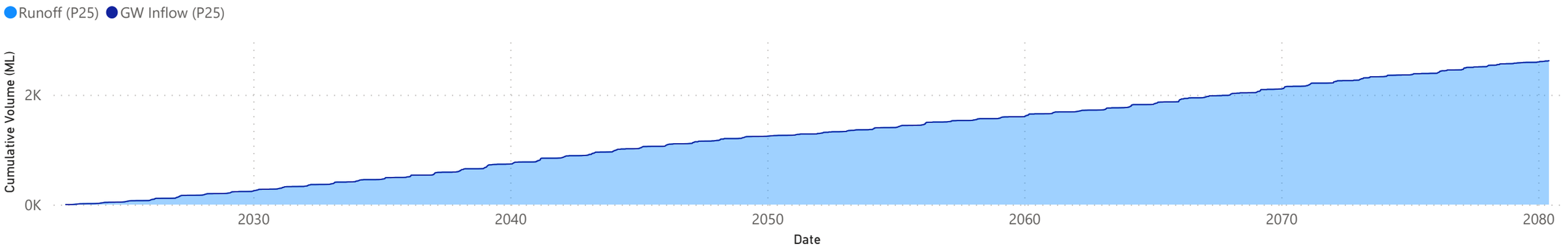


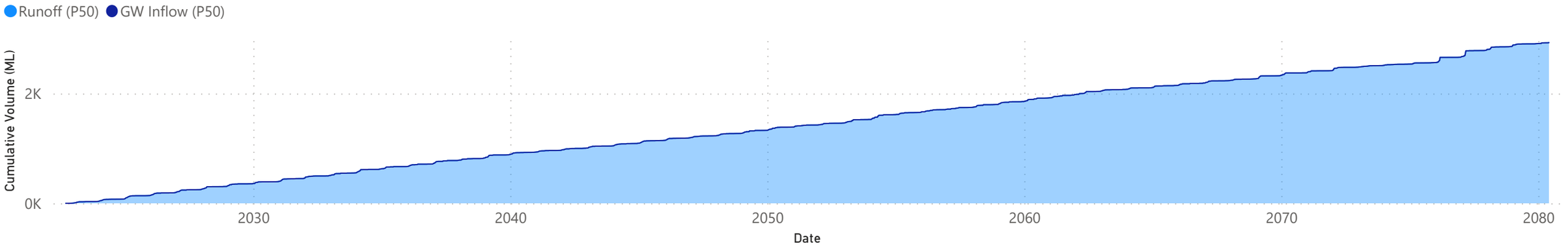
Feature

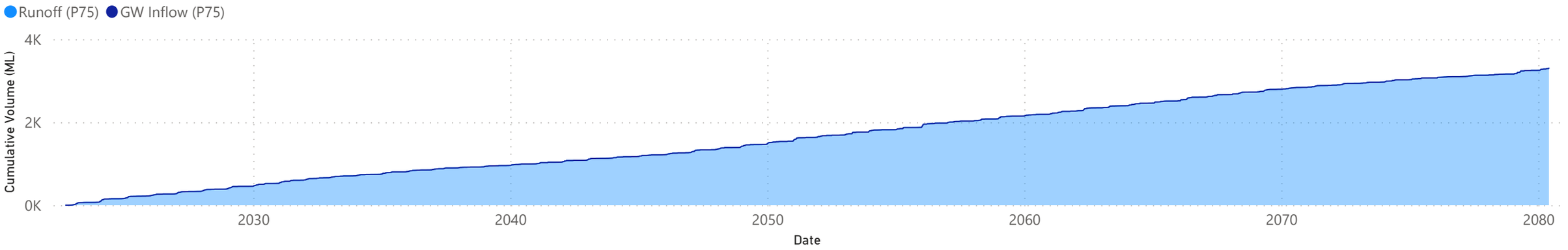
Sediment Dam

4/06/2022 19/02/2080

Cumulative inflows into pit/void





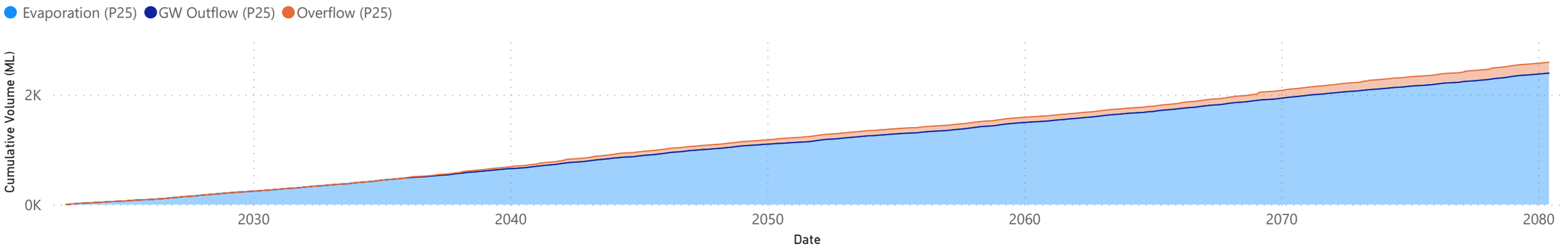


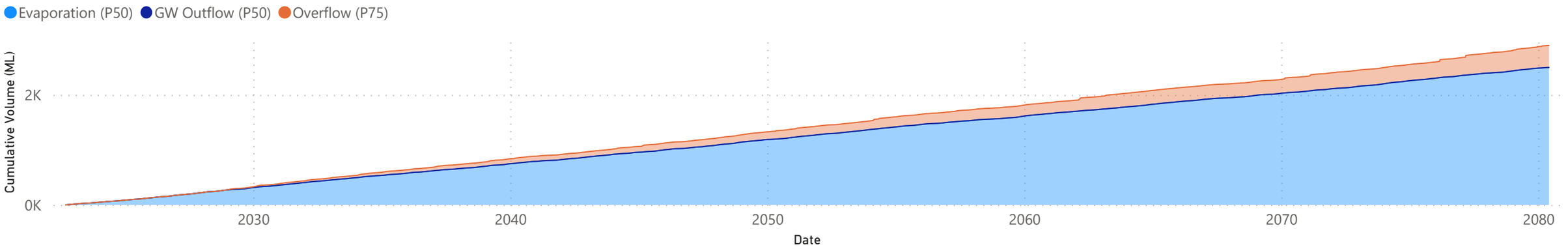
Feature

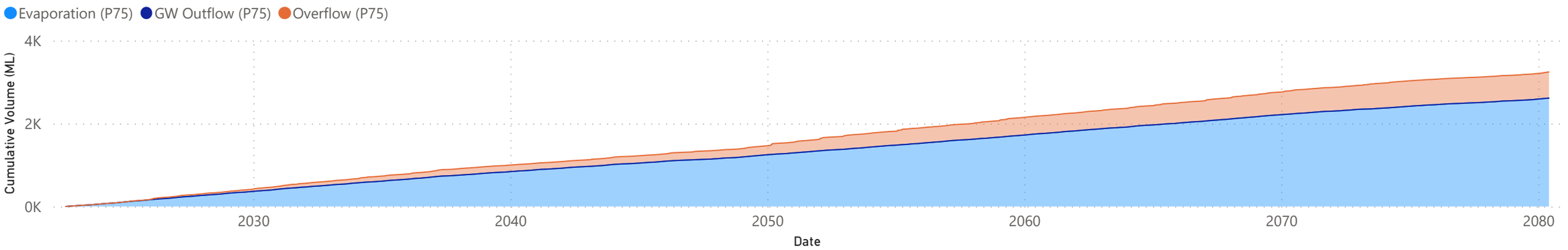
Sediment Dam

4/06/2022 19/02/2080

Cumulative outflows from pit/void







Appendix B

Water quality monitoring results

Table B.1 Surface water monitoring and sampling results

Table B.1: Surface water monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	NA	Background	Downstream
Location ID	BASW01	BASW01	BASW01	BASW01	BASW01	BASW01	BASW01	BASW01	BASW01	BASW01	BASW01	BASW02	BASW03	BASW04
Date	13/01/2019	28/02/2019	19/04/2019	30/11/2019	11/02/2020	22/02/2020	11/01/2021	2/11/2021	16/11/2021	8/02/2022	19/04/2022	19/04/2022	19/04/2022	30/11/2017
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	-	EA Monitoring	EA Monitoring
Physico-Chemical Parameters														
Turbidity (NTU)	50.10	2.00	10.20	37.60	2.80	2.60	4.60	36.50	6.00	1.70	1.00	0.40	0.90	17.30
Biochemical Oxygen Demand (mg/L)														
pH - Lab (pH Units)	6.99	8.21	8.43	6.48	7.47	8.03	7.36	7.15	7.41	7.96	7.80	8.01	8.05	7.52
Electrical Conductivity @ 25°C (µS/cm)	87.00	398.00	573.00	337.00	173.00	319.00	153.00	72.00	100.00	218.00	1170.00	1290.00	996.00	305.00
Total Dissolved Solids (mg/L)														
Total Suspended Solids (mg/L)														
Hardness														
Total Hardness as CaCO3 (mg/L)	35.00	94.00	126.00	72.00	34.00	74.00	41.00	21.00	35.00	43.00	394.00	245.00	224.00	106.00
Major Ions														
Calcium (mg/L)	9.00	18.00	19.00	14.00	7.00	18.00	10.00	5.00	9.00	9.00	44.00	52.00	60.00	21.00
Magnesium (mg/L)	3.00	12.00	19.00	9.00	4.00	7.00	4.00	2.00	3.00	5.00	69.00	28.00	18.00	13.00
Sodium (mg/L)	4.00	55.00	93.00	39.00	29.00	38.00	15.00	6.00	5.00	31.00	118.00	206.00	145.00	11.00
Potassium (mg/L)	6.00	5.00	12.00	21.00	3.00	6.00	4.00	4.00	4.00	4.00	6.00	11.00	11.00	15.00
Chloride (mg/L)	2.00	20.00	30.00	29.00	9.00	14.00	6.00	4.00	4.00	12.00	36.00	44.00	22.00	7.00
Sulphate (as SO4) (mg/L)	<1	16.00	23.00	44.00	6.00	6.00	4.00	<1	<1	11.00	60.00	138.00	49.00	11.00
Fluoride (mg/L)	<0.1	0.20	0.30	0.20	0.10	0.20	0.10	<0.1	<0.1	0.10	1.60	0.80	0.90	
Iodide (mg/L)														
Bromide (mg/L)														
Alkalinity														
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	35.00	163.00	242.00	84.00	72.00	137.00	62.00	26.00	44.00	86.00	550.00	456.00	471.00	139.00
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Alkalinity as CaCO3 (mg/L)	35.00	163.00	242.00	84.00	72.00	137.00	62.00	26.00	44.00	86.00	550.00	456.00	471.00	139.00
Ion Balance														
Ionic Balance (%)		2.94	5.40	3.67		0.36					0.35	3.35	0.06	3.62
Total Anions (meq/L)	0.76	4.15	6.16	3.41	1.82	3.26	1.49	0.63	0.99	2.28	13.20	13.20	11.00	3.20
Total Cations (meq/L)	1.02	4.41	6.86	3.67	2.02	3.28	1.58	0.78	1.02	2.31	13.20	14.10	11.10	2.98
Microbiological														
Escherichia coli (cfu/100ml)														
Nutrients														
Nitrate as N (mg/L)														
Nitrite + Nitrate as N (mg/L)														
Nitrite as N (mg/L)														
Total Kjeldahl Nitrogen as N (mg/L)														
Total Nitrogen as N (mg/L)														
Total Phosphorus as P (mg/L)														
Metals (dissolved)														
Aluminium (mg/L)														
Arsenic (mg/L)	<0.001	<0.001	0.00	0.00	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	0.00	<0.001	<0.001	0.00
Barium (mg/L)	0.02	0.04	0.05	0.07	0.02	0.04	0.02	0.02	0.02	0.02	0.06	0.16	0.12	0.07
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00005	<0.00005	<0.00005	<0.001
Boron (mg/L)														
Cadmium (mg/L)														
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.00	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	0.00	<0.001	<0.001	0.00	<0.001	<0.001	0.01
Copper (mg/L)	0.01	0.00	0.01	0.04	0.00	0.01	0.01	0.01	0.01	0.00	<0.001	<0.001	<0.001	0.03
Lead (mg/L)														
Manganese (mg/L)														
Mercury (mg/L)														
Molybdenum (mg/L)	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	<0.001	0.00	0.00	0.00	0.00
Nickel (mg/L)	<0.001	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	0.01	<0.001	<0.001	<0.001	<0.001	0.00
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium (mg/L)	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	0.00	0.01	<0.001

Table B.1: Surface water monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	NA	Background	Downstream
Location ID	BASW01	BASW01	BASW01	BASW01	BASW01	BASW01	BASW01	BASW01	BASW01	BASW01	BASW01	BASW02	BASW03	BASW04
Date	13/01/2019	28/02/2019	19/04/2019	30/11/2019	11/02/2020	22/02/2020	11/01/2021	2/11/2021	16/11/2021	8/02/2022	19/04/2022	19/04/2022	19/04/2022	30/11/2017
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	-	EA Monitoring	EA Monitoring
Vanadium (mg/L)														
Zinc (mg/L)														
Beryllium (mg/L)														
Silicon (mg/L)														
Iron (mg/L)														
Metals (total)														
Aluminium (mg/L)														
Arsenic (mg/L)	<0.001	<0.001	0.00	0.00	<0.001	0.00	<0.001	0.00	0.00	<0.001	0.00	0.00	0.00	0.00
Barium (mg/L)	0.04	0.04	0.06	0.07	0.02	0.04	0.03	0.02	0.02	0.02	0.07	0.20	0.13	0.07
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00005	<0.00005	<0.00005	<0.001
Boron (mg/L)														
Cadmium (mg/L)														
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.00	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	0.00	<0.001	<0.001	0.00	<0.001	0.00	0.01
Copper (mg/L)	0.00	0.00	0.01	0.05	0.00	0.01	0.01	0.03	0.01	0.01	0.00	0.00	0.00	0.03
Lead (mg/L)														
Manganese (mg/L)														
Mercury (mg/L)														
Molybdenum (mg/L)	<0.001	<0.001	0.00	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.00	0.00	0.00
Nickel (mg/L)	<0.001	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	0.00	0.00	<0.001	<0.001	<0.001	0.00	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium (mg/L)	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	0.01	0.01	<0.001
Vanadium (mg/L)														
Zinc (mg/L)														
Beryllium (mg/L)														
Iron (mg/L)														
Silicon (mg/L)														

Table B.1: Surface water monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream
Location ID	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04
Date	30/11/2017	25/03/2018	17/11/2018	13/01/2019	28/02/2019	24/03/2019	19/04/2019	11/02/2020	22/02/2020	11/01/2021	21/02/2021	2/11/2021	8/02/2022	19/04/2022
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Physico-Chemical Parameters														
Turbidity (NTU)	3.60	8.10	26.60	130.00	2.90	6.40	14.90	13.10	12.10	22.90	6.60	29.00	3.20	14.80
Biochemical Oxygen Demand (mg/L)														
pH - Lab (pH Units)	7.83	8.01	7.17	7.41	8.20	8.58	8.54	7.75	7.75	7.76	7.92	7.23	7.86	8.01
Electrical Conductivity @ 25°C (µS/cm)	790.00	259.00	126.00	129.00	746.00	1040.00	1260.00	274.00	439.00	405.00	265.00	120.00	244.00	876.00
Total Dissolved Solids (mg/L)														
Total Suspended Solids (mg/L)														
Hardness														
Total Hardness as CaCO3 (mg/L)	199.00	62.00	41.00	49.00	264.00	280.00	312.00	76.00	130.00	112.00	60.00	30.00	48.00	238.00
Major Ions														
Calcium (mg/L)	40.00	15.00	10.00	13.00	66.00	48.00	44.00	19.00	34.00	30.00	14.00	7.00	11.00	59.00
Magnesium (mg/L)	24.00	6.00	4.00	4.00	24.00	39.00	49.00	7.00	11.00	9.00	6.00	3.00	5.00	22.00
Sodium (mg/L)	102.00	31.00	10.00	4.00	102.00	145.00	212.00	29.00	38.00	43.00	36.00	14.00	33.00	100.00
Potassium (mg/L)	8.00	5.00	5.00	6.00	7.00	12.00	20.00	5.00	10.00	11.00	5.00	5.00	4.00	6.00
Chloride (mg/L)	24.00	13.00	7.00	4.00	86.00	58.00	83.00	12.00	22.00	20.00	11.00	7.00	14.00	23.00
Sulphate (as SO4) (mg/L)	14.00	3.00	1.00	<1	40.00	51.00	55.00	6.00	<1	24.00	12.00	6.00	9.00	2.00
Fluoride (mg/L)			<0.1	<0.1	1.00	1.60	1.50	0.20	0.20	0.30	0.20	<0.1	0.10	0.50
Iodide (mg/L)														
Bromide (mg/L)														
Alkalinity														
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	22.00	32.00	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	416.00	108.00	49.00	52.00	294.00	439.00	499.00	130.00	200.00	158.00	106.00	40.00	103.00	450.00
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Alkalinity as CaCO3 (mg/L)	416.00	108.00	49.00	52.00	294.00	461.00	531.00	130.00	200.00	158.00	106.00	40.00	103.00	450.00
Ion Balance														
Ionic Balance (%)	3.73				3.95	1.29	6.21	2.46	1.16	1.96				2.24
Total Anions (meq/L)	9.28	2.59	1.20	1.15	9.13	11.90	14.10	3.06	4.62	4.22	2.68	1.12	2.64	9.68
Total Cations (meq/L)	8.61	2.72	1.39	1.30	9.88	12.20	16.00	2.91	4.51	4.39	2.88	1.33	2.50	9.26
Microbiological														
Escherichia coli (cfu/100ml)														
Nutrients														
Nitrate as N (mg/L)														
Nitrite + Nitrate as N (mg/L)		<0.01												
Nitrite as N (mg/L)														
Total Kjeldahl Nitrogen as N (mg/L)		0.90												
Total Nitrogen as N (mg/L)		0.90												
Total Phosphorus as P (mg/L)		0.07												
Metals (dissolved)														
Aluminium (mg/L)														
Arsenic (mg/L)	<0.001	0.00	<0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.001	0.00	<0.001	0.00
Barium (mg/L)	0.24	0.04	0.02	0.04	0.42	0.10	0.12	0.05	0.09	0.07	0.03	0.02	0.02	0.42
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00005
Boron (mg/L)														
Cadmium (mg/L)														
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	<0.001	<0.001	0.00	0.01	0.00	<0.001	0.00	<0.001	0.00	<0.001	<0.001	0.00	<0.001	<0.001
Copper (mg/L)	0.00	0.02	0.01	0.21	<0.001	0.01	0.01	0.01	0.00	0.02	0.01	0.03	0.01	<0.001
Lead (mg/L)														
Manganese (mg/L)														
Mercury (mg/L)														
Molybdenum (mg/L)	0.00	<0.001	<0.001	<0.001	0.00	0.00	0.00	<0.001	0.00	0.00	0.00	<0.001	0.00	0.00
Nickel (mg/L)	<0.001	0.00	0.01	<0.001	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium (mg/L)	0.00	<0.001	<0.001	<0.001	0.00	0.00	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00

Table B.1: Surface water monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream	Downstream
Location ID	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04	BASW04
Date	30/11/2017	25/03/2018	17/11/2018	13/01/2019	28/02/2019	24/03/2019	19/04/2019	11/02/2020	22/02/2020	11/01/2021	21/02/2021	2/11/2021	8/02/2022	19/04/2022
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Vanadium (mg/L)														
Zinc (mg/L)														
Beryllium (mg/L)														
Silicon (mg/L)														
Iron (mg/L)														
Metals (total)														
Aluminium (mg/L)														
Arsenic (mg/L)	<0.001	0.00	<0.001	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	<0.001	0.00
Barium (mg/L)	0.24	0.04	0.03	0.05	0.38	0.10	0.14	0.06	0.10	0.09	0.04	0.03	0.03	0.53
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00005
Boron (mg/L)														
Cadmium (mg/L)														
Chromium (mg/L)	<0.001	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	<0.001	<0.001
Cobalt (mg/L)	<0.001	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	<0.001	0.00	<0.001	<0.001
Copper (mg/L)	0.00	0.03	0.02	0.31	0.01	0.01	0.02	0.02	0.01	0.05	0.02	0.04	0.01	<0.001
Lead (mg/L)														
Manganese (mg/L)														
Mercury (mg/L)														
Molybdenum (mg/L)	0.00	<0.001	<0.001	<0.001	0.00	0.00	0.00	<0.001	0.00	0.00	<0.001	<0.001	<0.001	0.00
Nickel (mg/L)	<0.001	<0.001	0.00	0.00	0.00	<0.001	0.00	<0.001	<0.001	0.00	<0.001	0.00	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium (mg/L)	0.00	<0.001	<0.001	<0.001	0.00	0.00	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00
Vanadium (mg/L)														
Zinc (mg/L)														
Beryllium (mg/L)														
Iron (mg/L)														
Silicon (mg/L)														

Table B.1: Surface water monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	Background	Background	Background	Background	Background	Background	Background	NA	NA	NA	NA	NA	NA	NA
Location ID	BASW05	BASW05	BASW05	BASW05	BASW05	BASW05	BASW05	BASW09	BASW09	BASW09	BASW09	BASW09	BASW09	BASW09
Date	17/05/2019	14/06/2019	30/11/2019	22/02/2020	11/01/2021	8/02/2022	19/04/2022	13/01/2019	4/03/2019	19/04/2019	17/05/2019	14/06/2019	10/08/2019	22/02/2020
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Physico-Chemical Parameters														
Turbidity (NTU)	68.30	37.90	205.00	16.50	62.90	4.20	12.50	14.50	3.90	6.30	32.00	69.60	129.00	4.70
Biochemical Oxygen Demand (mg/L)														
pH - Lab (pH Units)	8.07	7.55	6.47	7.36	7.14	7.33	8.13	7.29	8.60	8.65	8.97	8.94	8.04	7.64
Electrical Conductivity @ 25°C (µS/cm)	541.00	666.00	58.00	260.00	103.00	77.00	966.00	85.00	703.00	838.00	957.00	1040.00	1710.00	246.00
Total Dissolved Solids (mg/L)														
Total Suspended Solids (mg/L)														
Hardness														
Total Hardness as CaCO3 (mg/L)	158.00	165.00	18.00	60.00	45.00	28.00	264.00	25.00	181.00	211.00	230.00	232.00	402.00	82.00
Major Ions														
Calcium (mg/L)	37.00	33.00	4.00	14.00	13.00	8.00	43.00	5.00	23.00	25.00	23.00	17.00	44.00	18.00
Magnesium (mg/L)	16.00	20.00	2.00	6.00	3.00	2.00	38.00	3.00	30.00	36.00	42.00	46.00	71.00	9.00
Sodium (mg/L)	45.00	51.00	6.00	24.00	2.00	3.00	88.00	2.00	94.00	127.00	147.00	163.00	225.00	17.00
Potassium (mg/L)	38.00	55.00	6.00	12.00	3.00	2.00	19.00	6.00	9.00	13.00	24.00	28.00	67.00	7.00
Chloride (mg/L)	20.00	27.00	3.00	21.00	<1	2.00	22.00	3.00	43.00	52.00	59.00	74.00	111.00	8.00
Sulphate (as SO4) (mg/L)	<1	2.00	<1	2.00	<1	1.00	40.00	<1	30.00	20.00	21.00	20.00	20.00	<1
Fluoride (mg/L)	0.20	0.20	<0.1	0.10	<0.1	<0.1	0.50	<0.1	0.40	0.50	0.50	0.50	0.40	0.20
Iodide (mg/L)														
Bromide (mg/L)														
Alkalinity														
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	15.00	30.00	64.00	81.00	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	259.00	295.00	23.00	103.00	48.00	38.00	458.00	34.00	273.00	343.00	372.00	390.00	824.00	116.00
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Alkalinity as CaCO3 (mg/L)	259.00	295.00	23.00	103.00	48.00	38.00	458.00	34.00	288.00	373.00	436.00	471.00	824.00	116.00
Ion Balance														
Ionic Balance (%)	2.99	1.62		2.84			5.04		2.21	3.77	3.56	2.16	1.19	0.28
Total Anions (meq/L)	5.74	6.70	0.54	2.69	0.96	0.84	10.60	0.76	7.59	9.34	10.80	11.90	20.00	2.54
Total Cations (meq/L)	6.09	6.92	0.78	2.54	1.06	0.74	9.59	0.74	7.94	10.10	11.60	12.40	19.50	2.56
Microbiological														
Escherichia coli (cfu/100ml)														
Nutrients														
Nitrate as N (mg/L)														
Nitrite + Nitrate as N (mg/L)														
Nitrite as N (mg/L)														
Total Kjeldahl Nitrogen as N (mg/L)														
Total Nitrogen as N (mg/L)														
Total Phosphorus as P (mg/L)														
Metals (dissolved)														
Aluminium (mg/L)														
Arsenic (mg/L)	0.00	0.00	<0.001	0.00	<0.001	0.00	0.00	<0.001	<0.001	0.00	0.00	0.00	0.00	0.00
Barium (mg/L)	0.13	0.18	0.04	0.05	0.02	0.02	0.28	0.02	0.03	0.04	0.05	0.18	0.08	0.04
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)														
Cadmium (mg/L)														
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.00	0.00	0.00	0.00	<0.001	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	0.00	0.00	<0.001
Copper (mg/L)	0.00	0.00	0.02	0.00	0.00	0.00	<0.001	<0.001	0.00	0.00	0.01	0.00	0.00	<0.001
Lead (mg/L)														
Manganese (mg/L)														
Mercury (mg/L)														
Molybdenum (mg/L)	0.00	0.00	<0.001	<0.001	<0.001	<0.001	0.01	<0.001	0.00	0.00	0.00	0.00	0.00	<0.001
Nickel (mg/L)	0.00	0.00	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium (mg/L)	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	0.00	<0.001	0.00	0.00	0.00	0.00	0.01	<0.001

Table B.1: Surface water monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	Background	Background	Background	Background	Background	Background	Background	NA	NA	NA	NA	NA	NA	NA
Location ID	BASW05	BASW05	BASW05	BASW05	BASW05	BASW05	BASW05	BASW09	BASW09	BASW09	BASW09	BASW09	BASW09	BASW09
Date	17/05/2019	14/06/2019	30/11/2019	22/02/2020	11/01/2021	8/02/2022	19/04/2022	13/01/2019	4/03/2019	19/04/2019	17/05/2019	14/06/2019	10/08/2019	22/02/2020
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Vanadium (mg/L)														
Zinc (mg/L)														
Beryllium (mg/L)														
Silicon (mg/L)														
Iron (mg/L)														
Metals (total)														
Aluminium (mg/L)														
Arsenic (mg/L)	0.00	0.00	<0.001	0.00	0.00	0.00	0.00	<0.001	<0.001	0.00	0.00	0.00	0.00	0.00
Barium (mg/L)	0.18	0.22	0.06	0.07	0.04	0.06	0.37	0.03	0.04	0.05	0.06	0.20	0.32	0.05
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)														
Cadmium (mg/L)														
Chromium (mg/L)	<0.001	<0.001	0.00	<0.001	<0.001	0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	<0.001
Cobalt (mg/L)	0.00	0.01	0.01	0.00	<0.001	0.00	<0.001	0.00	<0.001	<0.001	0.00	0.00	0.01	0.00
Copper (mg/L)	0.00	0.01	0.03	0.00	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.01	0.01	<0.001
Lead (mg/L)														
Manganese (mg/L)														
Mercury (mg/L)														
Molybdenum (mg/L)	0.00	0.00	<0.001	<0.001	<0.001	<0.001	0.01	<0.001	0.00	0.00	0.00	0.00	0.00	<0.001
Nickel (mg/L)	0.00	0.00	0.00	<0.001	<0.001	0.01	0.00	<0.001	<0.001	<0.001	<0.001	0.00	0.00	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium (mg/L)	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	0.00	<0.001	0.00	0.00	0.00	0.01	0.01	<0.001
Vanadium (mg/L)														
Zinc (mg/L)														
Beryllium (mg/L)														
Iron (mg/L)														
Silicon (mg/L)														

Table B.1: Surface water monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	NA	NA	NA	Background	Background	Background	Background	Background	Background	Background	Background	Background	Background	Background
Location ID	BASW09	BASW09	BASW09	BASW11	BASW11	BASW11	BASW11	BASW11	BASW11	BASW11	BASW11	BASW11	BASW11	BASW11
Date	11/01/2021	21/02/2021	8/02/2022	13/01/2019	28/02/2019	19/04/2019	17/05/2019	14/06/2019	10/08/2019	7/09/2019	30/11/2019	11/02/2020	22/02/2020	11/01/2021
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Physico-Chemical Parameters														
Turbidity (NTU)	1.40	13.50	1.10	11.80	1.60	9.00	10.80	15.60	21.30	58.30	22.90	10.80	5.30	1.90
Biochemical Oxygen Demand (mg/L)														
pH - Lab (pH Units)	7.51	7.63	7.80	8.04	8.19	8.44	8.69	8.36	8.55	7.82	6.68	7.32	7.51	7.45
Electrical Conductivity @ 25°C (µS/cm)	139.00	166.00	171.00	203.00	347.00	412.00	467.00	514.00	704.00	963.00	241.00	80.00	136.00	182.00
Total Dissolved Solids (mg/L)														
Total Suspended Solids (mg/L)														
Hardness														
Total Hardness as CaCO3 (mg/L)	48.00	50.00	56.00	55.00	81.00	89.00	109.00	111.00	140.00	226.00	44.00	18.00	36.00	41.00
Major Ions														
Calcium (mg/L)	11.00	10.00	11.00	12.00	16.00	16.00	19.00	18.00	20.00	36.00	11.00	4.00	8.00	10.00
Magnesium (mg/L)	5.00	6.00	7.00	6.00	10.00	12.00	15.00	16.00	22.00	33.00	4.00	2.00	4.00	4.00
Sodium (mg/L)	8.00	16.00	14.00	10.00	46.00	61.00	67.00	71.00	99.00	145.00	19.00	9.00	13.00	21.00
Potassium (mg/L)	5.00	4.00	4.00	12.00	4.00	6.00	7.00	8.00	15.00	32.00	17.00	2.00	4.00	4.00
Chloride (mg/L)	4.00	5.00	7.00	9.00	25.00	28.00	28.00	36.00	44.00	70.00	24.00	4.00	6.00	8.00
Sulphate (as SO4) (mg/L)	2.00	2.00	3.00	<1	12.00	13.00	14.00	15.00	25.00	27.00	25.00	2.00	2.00	4.00
Fluoride (mg/L)	0.10	0.20	<0.1	<0.1	0.20	0.40	0.40	0.40	0.50	0.60	0.10	<0.1	<0.1	0.10
Iodide (mg/L)														
Bromide (mg/L)														
Alkalinity														
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	3.00	13.00	4.00	18.00	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	62.00	74.00	78.00	82.00	128.00	165.00	170.00	194.00	272.00	407.00	37.00	37.00	58.00	75.00
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Alkalinity as CaCO3 (mg/L)	62.00	74.00	78.00	82.00	128.00	168.00	182.00	199.00	290.00	407.00	37.00	37.00	58.00	75.00
Ion Balance														
Ionic Balance (%)					2.93	1.95	5.59	1.89	0.38	4.34			0.96	
Total Anions (meq/L)	1.39	1.66	1.82	1.89	3.51	4.42	4.72	5.30	7.56	10.70	1.94	0.89	1.37	1.81
Total Cations (meq/L)	1.44	1.79	1.84	1.83	3.72	4.59	5.28	5.51	7.50	11.60	2.14	0.81	1.40	1.84
Microbiological														
Escherichia coli (cfu/100ml)														
Nutrients														
Nitrate as N (mg/L)														
Nitrite + Nitrate as N (mg/L)														
Nitrite as N (mg/L)														
Total Kjeldahl Nitrogen as N (mg/L)														
Total Nitrogen as N (mg/L)														
Total Phosphorus as P (mg/L)														
Metals (dissolved)														
Aluminium (mg/L)														
Arsenic (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	<0.001	0.00	<0.001	<0.001	<0.001	<0.001
Barium (mg/L)	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.13	0.05	0.02	0.02	0.02
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)														
Cadmium (mg/L)														
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.00	<0.001	<0.001	<0.001
Copper (mg/L)	0.00	0.00	<0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00
Lead (mg/L)														
Manganese (mg/L)														
Mercury (mg/L)														
Molybdenum (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.00	0.00	0.00	<0.001	<0.001	<0.001	<0.001
Nickel (mg/L)	<0.001	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.00	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.00	0.00	<0.001	<0.001	<0.001	<0.001

Table B.1: Surface water monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	NA	NA	NA	Background	Background	Background	Background	Background	Background	Background	Background	Background	Background	Background
Location ID	BASW09	BASW09	BASW09	BASW11	BASW11	BASW11	BASW11	BASW11	BASW11	BASW11	BASW11	BASW11	BASW11	BASW11
Date	11/01/2021	21/02/2021	8/02/2022	13/01/2019	28/02/2019	19/04/2019	17/05/2019	14/06/2019	10/08/2019	7/09/2019	30/11/2019	11/02/2020	22/02/2020	11/01/2021
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Vanadium (mg/L)														
Zinc (mg/L)														
Beryllium (mg/L)														
Silicon (mg/L)														
Iron (mg/L)														
Metals (total)														
Aluminium (mg/L)														
Arsenic (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.00	0.00	0.00	<0.001	<0.001	<0.001	<0.001
Barium (mg/L)	0.02	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.07	0.16	0.05	0.01	0.02	0.03
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)														
Cadmium (mg/L)														
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.00	<0.001	<0.001	<0.001
Copper (mg/L)	0.00	0.00	0.00	<0.001	0.00	0.00	0.00	0.01	0.02	0.01	0.02	0.00	0.00	0.00
Lead (mg/L)														
Manganese (mg/L)														
Mercury (mg/L)														
Molybdenum (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.00	0.00	0.00	<0.001	<0.001	<0.001	<0.001
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.00	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.00	0.00	<0.001	<0.001	<0.001	<0.001
Vanadium (mg/L)														
Zinc (mg/L)														
Beryllium (mg/L)														
Iron (mg/L)														
Silicon (mg/L)														

Table B.1: Surface water monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	Background	Background	Background	Background	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP
Location ID	BASW11	BASW11	BASW11	BASW11	B1	B3	B3	B3	B3	B3	B3	B3	B3	B4
Date	2/11/2021	16/11/2021	8/02/2022	27/06/2022	20/03/2019	29/08/2018	20/03/2019	28/08/2019	3/03/2020	23/08/2020	22/08/2021	Mar-22	8/03/2021	20/03/2019
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP
Physico-Chemical Parameters														
Turbidity (NTU)	29.90	18.30	3.70	11.30	25.50	78.70	14.40	97.00	9.70	399.00	13.00	15.80	6.00	26.60
Biochemical Oxygen Demand (mg/L)														
pH - Lab (pH Units)	7.17	7.28	7.80	8.19	8.10	8.10	8.40	8.30		7.80	7.60		7.40	8.50
Electrical Conductivity @ 25°C (µS/cm)	57.00	93.00	157.00	303.00	1500.00	450.00	370.00	450.00		450.00	180.00		130.00	960.00
Total Dissolved Solids (mg/L)					950.00	330.00	240.00							660.00
Total Suspended Solids (mg/L)														
Hardness														
Total Hardness as CaCO3 (mg/L)	18.00	26.00	31.00	70.00	290.00	86.00	62.00	170.00	39.00	100.00	45.00	38.00	26.00	250.00
Major Ions														
Calcium (mg/L)	4.00	7.00	6.00	15.00	36.00	18.00	14.00	25.00	9.50	21.00	11.00		6.00	47.00
Magnesium (mg/L)	2.00	2.00	4.00	8.00	49.00	9.80	6.90	26.00	3.80	12.00	4.50		2.70	33.00
Sodium (mg/L)	3.00	3.00	22.00	44.00				110.00	14.00	33.00	16.00		15.00	
Potassium (mg/L)	4.00	5.00	3.00	8.00				23.00	4.40	38.00	7.70		3.80	
Chloride (mg/L)	3.00	5.00	9.00	12.00				65.00	8.00	21.00	8.00		7.00	
Sulphate (as SO4) (mg/L)	<1	<1	4.00	2.00	38.00	4.60	8.00	25.00	2.30	3.50	1.90	4.10	2.20	51.00
Fluoride (mg/L)	<0.1	<0.1	0.10	0.30				0.6	0.1	0.2	<0.1	0.1	0.1	
Iodide (mg/L)														
Bromide (mg/L)														
Alkalinity														
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<5	<5	6.00	<5	<5	<5	<5		<5	36.00
Bicarbonate Alkalinity as CaCO3 (mg/L)	27.00	39.00	64.00	136.00	730.00	200.00	150.00	180.00	69.00	210.00	86.00		74.00	390.00
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<5	<5	<5	<5	<5	<5	<5		<5	<5
Total Alkalinity as CaCO3 (mg/L)	27.00	39.00	64.00	136.00	730.00	200.00	150.00	180.00	69.00	210.00	86.00		74.00	420.00
Ion Balance														
Ionic Balance (%)				6.46				19.00	-3.50	-4.10	-6.00			
Total Anions (meq/L)	0.62	0.92	1.62	3.10				5.86	1.61	4.79	2.00	2.16	1.72	
Total Cations (meq/L)	0.60	0.77	1.66	3.52				8.70	1.50	4.41	1.77	1.83	1.47	
Microbiological														
Escherichia coli (cfu/100ml)														
Nutrients														
Nitrate as N (mg/L)														
Nitrite + Nitrate as N (mg/L)														
Nitrite as N (mg/L)														
Total Kjeldahl Nitrogen as N (mg/L)														
Total Nitrogen as N (mg/L)														
Total Phosphorus as P (mg/L)														
Metals (dissolved)														
Aluminium (mg/L)					<0.005	0.026	<0.005	0.016	<0.02	0.01	0.01		0.03	<0.005
Arsenic (mg/L)	<0.001	<0.001	<0.001	<0.001	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.001	<0.001	<0.003
Barium (mg/L)	0.02	0.03	0.02	0.03				0.094	0.020	0.088	0.03	0.02	0.02	
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001				<0.0005	<0.001	<0.001	<0.001	<0.0005	<0.001	
Boron (mg/L)					0.042	0.038	0.013							0.042
Cadmium (mg/L)					<0.0001	<0.0001	<0.0001	<0.0001						<0.0001
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001
Cobalt (mg/L)	<0.001	0.00	<0.001	<0.001	<0.001	0.001	<0.001	0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.001
Copper (mg/L)	0.01	0.01	0.00	0.00	<0.001	0.003	0.001	0.006	0.003	0.003	0.00	0.00	0.00	0.013
Lead (mg/L)					<0.001	<0.001	0.001	<0.001						0.001
Manganese (mg/L)					0.20	0.016	<0.005	0.31						0.014
Mercury (mg/L)					<0.00005	<0.00005	<0.00005	<0.00005						<0.00005
Molybdenum (mg/L)	<0.001	<0.001	<0.001	<0.001	0.002	0.006	<0.001	0.002	<0.0005	0.0012	<0.0005	<0.001	<0.001	0.003
Nickel (mg/L)	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.003	<0.003	<0.003	<0.003	<0.002	0.003	<0.002	<0.001	<0.001	<0.003
Uranium (mg/L)	<0.001	<0.001	<0.001	<0.001	0.01	<0.001	<0.001	0.0021	<0.001	<0.001	<0.001	<0.0005	<0.001	0.00

Table B.1: Surface water monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	Background	Background	Background	Background	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP
Location ID	BASW11	BASW11	BASW11	BASW11	B1	B3	B3	B3	B3	B3	B3	B3	B3	B4
Date	2/11/2021	16/11/2021	8/02/2022	27/06/2022	20/03/2019	29/08/2018	20/03/2019	28/08/2019	3/03/2020	23/08/2020	22/08/2021	Mar-22	8/03/2021	20/03/2019
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP
Vanadium (mg/L)					0.005	<0.005	0.004							0.011
Zinc (mg/L)					<0.005	<0.005	<0.005	<0.005						<0.005
Beryllium (mg/L)														
Silicon (mg/L)														
Iron (mg/L)														
Metals (total)														
Aluminium (mg/L)					0.030	0.29	0.018	0.58	0.03	0.22	0.33		0.55	0.027
Arsenic (mg/L)	<0.001	<0.001	<0.001	<0.001	0.003	<0.003	<0.003	<0.003	<0.003	0.004	<0.003	<0.001	<0.001	<0.003
Barium (mg/L)	0.02	0.03	0.02	0.03				0.11	0.022	0.26	0.03	21.00	0.02	
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001				<0.0005	<0.001	<0.001	<0.001	<0.0005	<0.001	
Boron (mg/L)					0.038	0.039	0.016							0.038
Cadmium (mg/L)					<0.0001	<0.0001	<0.0001	<0.0001						<0.0001
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.00	0.00	<0.001	<0.001	<0.001	0.002	<0.001	0.002	<0.001	0.006	<0.001	<0.001	<0.001	0.001
Copper (mg/L)	0.01	0.01	0.00	0.00	<0.001	0.005	0.002	0.016	0.003	0.006	0.01	0.00	0.00	0.015
Lead (mg/L)					<0.001	0.002	<0.001	<0.001						<0.001
Manganese (mg/L)					0.21	0.34	0.024	0.48						0.10
Mercury (mg/L)					<0.00005	<0.00005	<0.00005	<0.00005						<0.00005
Molybdenum (mg/L)	<0.001	<0.001	<0.001	<0.001	0.002	0.007	<0.001	0.001	<0.0005	0.0009	<0.0005	<0.001	<0.001	0.003
Nickel (mg/L)	<0.001	0.00	<0.001	<0.001	<0.001	0.002	<0.001	0.002	<0.001	0.002	<0.001	<0.001	<0.001	0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	0.003	<0.003	<0.003	<0.003	<0.002	0.002	<0.002	<0.001	<0.001	<0.003
Uranium (mg/L)	<0.001	<0.001	<0.001	<0.001	0.01	<0.001	<0.001	0.0022	<0.001	<0.001	<0.001	<0.0005	<0.001	0.00
Vanadium (mg/L)					0.005	0.007	0.005							0.010
Zinc (mg/L)					<0.005	<0.005	<0.005	<0.005						<0.005
Beryllium (mg/L)														
Iron (mg/L)														
Silicon (mg/L)														

Table B.1: Surface water monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP
Location ID	B6	B6	B6	B6	B7	B7	B7	B7	B8	B8	B8	B8	B9	B9
Date	20/03/2019	3/03/2020	Mar-22	8/03/2021	20/03/2019	3/03/2020	Mar-22	8/03/2021	29/08/2018	20/03/2019	8/03/2021	Mar-22	3/03/2020	8/03/2021
Purpose	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP
Physico-Chemical Parameters														
Turbidity (NTU)	24.80	5.20	11.50		16.90	32.60	84.90	22.00	114.00	25.40	11.00	26.40	40.40	15.00
Biochemical Oxygen Demand (mg/L)														
pH - Lab (pH Units)	8.10			8.00	8.80			8.40	8.00	8.20	7.50			7.80
Electrical Conductivity @ 25°C (µS/cm)	460.00			230.00	430.00			280.00	930.00	420.00	200.00			260.00
Total Dissolved Solids (mg/L)	210.00				280.00				690.00	280.00				
Total Suspended Solids (mg/L)														
Hardness														
Total Hardness as CaCO3 (mg/L)	82.00	79.00	100.00	55.00	87.00	79.00	77.00	62.00	200.00	100.00	57.00	71.00	120.00	82.00
Major Ions														
Calcium (mg/L)	20.00	18.00		12.00	15.00	18.00		15.00	52.00	22.00	15.00		25.00	19.00
Magnesium (mg/L)	7.70	8.50		5.70	12.00	8.10		6.10	17.00	12.00	4.90		13.00	8.50
Sodium (mg/L)		29.00		24.00		39.00		32.00			17.00		29.00	19.00
Potassium (mg/L)		5.30		4.10		7.20		5.80			7.00		13.00	8.70
Chloride (mg/L)		12.00		10.00		15.00		12.00			7.00		14.00	7.00
Sulphate (as SO4) (mg/L)	1.40	3.40	1.20	3.40	17.00	5.90	12.00	8.90	4.40	10.00	5.20	2.60	1.70	2.00
Fluoride (mg/L)		0.1	0.1	0.1		0.2	0.3	0.2			0.2	0.1	0.1	0.1
Iodide (mg/L)														
Bromide (mg/L)														
Alkalinity														
Carbonate Alkalinity as CaCO3 (mg/L)	<5	<5		<5	30.00	<5		19.00	<5	<5	<5		<5	<5
Bicarbonate Alkalinity as CaCO3 (mg/L)	220.00	150.00		130.00	150.00	170.00		130.00	420.00	190.00	100.00		190.00	160.00
Hydroxide Alkalinity as CaCO3 (mg/L)	<5	<5		<5	<5	<5		<5	<5	<5	<5		<5	<5
Total Alkalinity as CaCO3 (mg/L)	220.00	150.00		130.00	180.00	170.00		150.00	420.00	190.00	100.00		190.00	160.00
Ion Balance														
Ionic Balance (%)		-7.00		-8.90		-5.90							-4.80	-9.60
Total Anions (meq/L)		3.43	3.68	2.91		3.89	4.61	3.47			2.37	3.18	4.33	3.36
Total Cations (meq/L)		2.96	3.13	2.44		3.46	4.26	2.89			2.17	2.68	3.93	2.76
Microbiological														
Escherichia coli (cfu/100ml)														
Nutrients														
Nitrate as N (mg/L)														
Nitrite + Nitrate as N (mg/L)														
Nitrite as N (mg/L)														
Total Kjeldahl Nitrogen as N (mg/L)														
Total Nitrogen as N (mg/L)														
Total Phosphorus as P (mg/L)														
Metals (dissolved)														
Aluminium (mg/L)	<0.005	<0.02		0.02	<0.005	<0.02		0.01	0.021	<0.005	0.01		<0.02	0.01
Arsenic (mg/L)	<0.003	<0.003	0.00	<0.001	<0.003	<0.003	0.00	0.00	0.008	<0.003	0.00	<0.001	<0.003	<0.001
Barium (mg/L)		0.022	0.04	0.03		0.044	0.04	0.03			0.03	0.04	0.036	0.04
Bismuth (mg/L)		<0.001	<0.0005	<0.001		<0.001	<0.0005	<0.001			<0.001	<0.0005	<0.001	<0.001
Boron (mg/L)	0.007				0.014				0.064	0.016				
Cadmium (mg/L)	<0.0001				<0.0001				<0.0001	<0.0001				
Chromium (mg/L)	<0.001	<0.0005	<0.001	<0.001	<0.001	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.001
Cobalt (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	<0.001	0.001	<0.001	0.00	0.005	0.009	0.01	0.01	0.002	0.002	0.00	0.00	0.001	0.00
Lead (mg/L)	0.001				<0.001				0.002	<0.001				
Manganese (mg/L)	0.27				<0.005				0.52	<0.005				
Mercury (mg/L)	<0.00005				<0.00005				<0.00005	<0.00005				
Molybdenum (mg/L)	<0.001	0.0008	<0.001	<0.001	0.001	0.0010	0.00	0.00	<0.005	<0.001	<0.001	0.00	0.0012	<0.001
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.003	0.003	<0.001	<0.001	0.003	<0.002	<0.001	<0.001	<0.003	0.003	<0.001	<0.001	0.003	<0.001
Uranium (mg/L)	<0.001	<0.001	<0.0005	<0.001	0.00	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.001	<0.001

Table B.1: Surface water monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP
Location ID	B6	B6	B6	B6	B7	B7	B7	B7	B8	B8	B8	B8	B9	B9
Date	20/03/2019	3/03/2020	Mar-22	8/03/2021	20/03/2019	3/03/2020	Mar-22	8/03/2021	29/08/2018	20/03/2019	8/03/2021	Mar-22	3/03/2020	8/03/2021
Purpose	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP	REMP
Vanadium (mg/L)	<0.001				0.006				<0.005	0.002				
Zinc (mg/L)	<0.005				<0.005				<0.005	<0.005				
Beryllium (mg/L)														
Silicon (mg/L)														
Iron (mg/L)														
Metals (total)														
Aluminium (mg/L)	<0.005	<0.02		0.02	0.041	0.10		0.04	0.67	0.014	0.08		0.10	0.07
Arsenic (mg/L)	<0.003	<0.003	0.00	<0.001	<0.003	<0.003	0.00	0.00	0.007	<0.003	0.00	<0.001	<0.003	<0.001
Barium (mg/L)		0.024	51.00	0.03		0.048	54.00	0.03			0.04	49.00	0.044	0.04
Bismuth (mg/L)		<0.001	<0.0005	<0.001		<0.001	<0.0005	<0.001			<0.001	<0.0005	<0.001	<0.001
Boron (mg/L)	0.016				0.014				0.069	0.022				
Cadmium (mg/L)	<0.0001				<0.0001				0.0002	<0.0001				
Chromium (mg/L)	<0.001	<0.0005	<0.001	<0.001	<0.001	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.001
Cobalt (mg/L)	0.001	<0.001	0.00	<0.001	<0.001	<0.001	0.00	<0.001	0.005	<0.001	<0.001	<0.001	0.001	<0.001
Copper (mg/L)	<0.001	0.001	0.00	0.00	0.006	0.012	0.01	0.01	0.008	0.003	0.01	0.00	0.002	0.00
Lead (mg/L)	0.002				<0.001				0.003	<0.001				
Manganese (mg/L)	0.41				0.025				0.64	0.068				
Mercury (mg/L)	<0.00005				<0.00005				<0.00005	<0.00005				
Molybdenum (mg/L)	<0.001	0.0008	<0.001	<0.001	0.001	0.0011	0.00	0.00	<0.005	0.001	<0.001	0.00	0.0012	<0.001
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.003	<0.002	<0.001	<0.001	<0.003	<0.002	<0.001	<0.001	<0.003	<0.003	<0.001	<0.001	<0.002	<0.001
Uranium (mg/L)	<0.001	<0.001	<0.0005	<0.001	0.00	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.001	<0.001
Vanadium (mg/L)	<0.001				0.007				0.009	0.004				
Zinc (mg/L)	0.022				<0.005				0.009	<0.005				
Beryllium (mg/L)														
Iron (mg/L)														
Silicon (mg/L)														

Table B.2 North Pit water quality monitoring and sampling results

Table B.2: North Pit water quality monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BCP North Pit	BCP North Pit	BCP North Pit	BCP North Pit	BCP North Pit	BCP North Pit	BCP North Pit	BCP North Pit	BCP North Pit
Date	11/02/2020	22/02/2020	5/10/2020	24/01/2021	18/04/2021	18/07/2021	2/11/2021	28/03/2022	12/06/2022
Purpose	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM
Physico-Chemical Parameters									
Turbidity (NTU)	1.3	0.8	0.6	3.4	1.1	0.3	0.7	0.6	0.2
Biochemical Oxygen Demand (mg/L)									
Electrical Conductivity @ 25°C (µS/cm)	556	761	1240	850	1100	1260	1360	996	1060
pH - Lab (pH Units)	8.07	8.09	8.13	7.85	8	8.13	8.14	8.16	8.06
Total Dissolved Solids (mg/L)									
Total Suspended Solids (mg/L)									
Hardness									
Total Hardness as CaCO3 (mg/L)	157	210		249					
Major Ions									
Calcium (mg/L)	38	51	72	57	98	127	128	79	87
Magnesium (mg/L)	15	20	40	26	33	42	43	30	34
Sodium (mg/L)	54	75	156	81	82	101	111	74	90
Potassium (mg/L)	9	16	23	15	27	32	33	22	26
Chloride (mg/L)	22	153	42	16	17	19	21	17	16
Sulphate (as SO4) (mg/L)	142	153	218	277	410	495	583	359	399
Fluoride (mg/L)	1	1.2	1.9	1	1.5	1.6	1.6	1.4	1.4
Iodide (mg/L)								<0.05	
Bromide (mg/L)								0.12	
Alkalinity									
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1			<1	<1	<1
Carbonate Alkalinity as CO3 (mg/L)									
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1			<1	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	98	131	382	125			130	104	102
Total Alkalinity as CaCO3 (mg/L)	98	131	382	125			130	104	102
Ion Balance									
Ionic Balance (%)	1.55	12.5	3.27	0.99			0.87	0.79	4.1
Total Anions (meq/L)	5.54	10.1	13.4	8.72			15.3	10	10.8
Total Cations (meq/L)	5.71	7.86	14.2	8.89			15.6	10.2	11.7
Microbiological									
Escherichia coli (cfu/100ml)									
Nutrients									
Nitrate as N (mg/L)								0.09	
Nitrite + Nitrate as N (mg/L)								0.09	
Nitrite as N (mg/L)								<0.01	
Total Kjeldahl Nitrogen as N (mg/L)									
Total Nitrogen as N (mg/L)									
Total Phosphorus as P (mg/L)									
Metals (dissolved)									
Aluminium (mg/L)									
Arsenic (mg/L)	0.001	<0.001	<0.001	0.001	0.003	0.003	0.003	0.002	0.002
Barium (mg/L)	0.078	0.054	0.08	0.093	0.053	0.042	0.041	0.057	0.045
Beryllium (mg/L)								<0.001	
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)								<0.05	
Cadmium (mg/L)									
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.002	0.001	0.002	<0.001	0.005	0.004	0.004	<0.001	<0.001
Copper (mg/L)	0.033	0.027	0.054	0.015	0.04	0.041	0.041	0.018	0.024
Iron (mg/L)								<0.05	
Lead (mg/L)									
Manganese (mg/L)									
Mercury (mg/L)									
Molybdenum (mg/L)	0.007	0.006	0.011	0.006	0.014	0.019	0.02	0.016	0.018

Table B.2: North Pit water quality monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BCP North Pit	BCP North Pit	BCP North Pit	BCP North Pit	BCP North Pit	BCP North Pit	BCP North Pit	BCP North Pit	BCP North Pit
Date	11/02/2020	22/02/2020	5/10/2020	24/01/2021	18/04/2021	18/07/2021	2/11/2021	28/03/2022	12/06/2022
Purpose	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM
Nickel (mg/L)	0.008	0.005	0.018	0.011	0.009	0.01	0.01	0.005	0.005
Selenium (mg/L)	0.03	0.02	0.01	0.02	0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)									
Uranium (mg/L)	0.003	0.002	0.014	0.004	0.003	0.006	0.007	0.004	0.005
Vanadium (mg/L)								<0.01	
Zinc (mg/L)									
Metals (total)									
Aluminium (mg/L)									
Arsenic (mg/L)	0.001	0.001	0.001	0.001	0.003	0.003	0.003	0.002	0.003
Barium (mg/L)	0.078	0.087	0.084	0.088	0.053	0.041	0.035	0.06	0.049
Beryllium (mg/L)								<0.001	
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)								<0.05	
Cadmium (mg/L)									
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.003	0.003	0.002	0.003	0.007	0.004	0.004	<0.001	<0.001
Copper (mg/L)	0.038	0.047	0.065	0.034	0.054	0.049	0.041	0.024	0.028
Iron (mg/L)								<0.05	
Lead (mg/L)									
Manganese (mg/L)									
Mercury (mg/L)									
Molybdenum (mg/L)	0.009	0.012	0.012	0.007	0.017	0.021	0.021	0.017	0.021
Nickel (mg/L)	0.008	0.008	0.017	0.012	0.01	0.012	0.01	0.005	0.005
Selenium (mg/L)	0.02	0.03	<0.01	0.02	0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)									
Uranium (mg/L)	0.003	0.004	0.016	0.005	0.004	0.006	0.006	0.004	0.005
Vanadium (mg/L)								<0.01	
Zinc (mg/L)									

Table B.3 North Pit groundwater quality monitoring and sampling results

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BARC071	BARC071	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01
Date	28/10/2014	25/11/2014	26/08/2014	29/09/2014	28/10/2014	25/11/2014	24/02/2015	8/04/2015	30/04/2015	3/11/2015	10/09/2016	16/11/2016	3/01/2017	5/04/2017	30/11/2017
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Physico-Chemical Parameters															
Turbidity (NTU)															0.8
Biochemical Oxygen Demand (mg/L)															
Electrical Conductivity @ 25°C (µS/cm)															1120
pH - Lab (pH Units)											7.8	7.7	7.8	7.8	7.73
Total Dissolved Solids (mg/L)													750		
Total Suspended Solids (mg/L)															
Hardness															
Total Hardness as CaCO3 (mg/L)											410	380	440	390	364
Major Ions															
Calcium (mg/L)	39	41	54	51	50	50	50	44	47	39	47	36	51	46	22
Magnesium (mg/L)	15	15	75	63	68	66	67	59	67	52	70	71	76	67	75
Sodium (mg/L)	153	150	122	158	160	145	141	131	135	139	110	110	110	110	119
Potassium (mg/L)	9	10	8	9	7	9	8	6	8	6	8.2	9.6	7.9	9.3	7
Chloride (mg/L)	32	36	28	36	34	33	30	34	35	36	34	33	33	35	29
Sulphate (as SO4) (mg/L)	48	52	57	68	63	65	64	71	63	76	59	58	57	55	63
Fluoride (mg/L)															
Iodide (mg/L)															
Bromide (mg/L)															
Alkalinity															
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<5	<5	<5	<5	<1
Carbonate Alkalinity as CO3 (mg/L)													<5		
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<5	<5	<5	<5	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	404	406	562	663	622	633	654	608	631	609	570	570	530	520	558
Total Alkalinity as CaCO3 (mg/L)	404	406	562	663	622	633	654	608	631	609	570	570	530	520	558
Ion Balance															
Ionic Balance (%)	0.42	0.77	4.22	2.81	1.74	1.62	3.07	6.15	3.4	8.64	<1.4	<3.3	4.6	1.1	2.52
Total Anions (meq/L)	9.97	10.2	13.2	15.7	14.7	14.9	15.2	14.6	14.9	14.8	13.5	13.6	12.7	12.5	13.3
Total Cations (meq/L)	10.1	10.1	14.4	14.8	15.2	14.5	14.3	12.9	13.9	12.4	13.1	12.7	13.9	12.8	12.6
Microbiological															
Escherichia coli (cfu/100ml)															
Nutrients															
Nitrate as N (mg/L)															
Nitrite + Nitrate as N (mg/L)															
Nitrite as N (mg/L)															
Total Kjeldahl Nitrogen as N (mg/L)															
Total Nitrogen as N (mg/L)															
Total Phosphorus as P (mg/L)															
Metals (dissolved)															
Aluminium (mg/L)													<0.02	0.012	
Arsenic (mg/L)	0.01	0.009	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	<0.003	0.003	<0.003	0.003	0.002
Barium (mg/L)	0.06	0.053	0.094	0.11	0.135	0.101	0.091	0.091	0.101	0.096	0.068	0.061	0.073		0.037
Beryllium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.0001		
Bismuth (mg/L)															<0.001
Boron (mg/L)	0.19	0.24	0.06	0.12	0.26	0.07	0.06	0.05	0.05	0.07	0.034	0.037	0.039		
Cadmium (mg/L)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	<0.001	<0.001	0.001	0.002	0.002	0.002	0.002	0.001	0.001	0.001	<0.001	0.001	0.001	0.002	<0.001
Copper (mg/L)	0.004	0.002	0.001	0.001	0.004	0.002	0.001	0.002	0.005	0.002	0.003	0.003	<0.001	0.003	0.004
Iron (mg/L)													<0.005		
Lead (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001	
Manganese (mg/L)	0.137	0.131	0.879	1.29	1.5	1.12	1.16	0.969	0.993	0.92	0.098	0.19	0.38	0.23	
Mercury (mg/L)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00005	<0.00005	<0.00005	<0.00005	
Molybdenum (mg/L)															0.004

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BARC071	BARC071	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01
Date	28/10/2014	25/11/2014	26/08/2014	29/09/2014	28/10/2014	25/11/2014	24/02/2015	8/04/2015	30/04/2015	3/11/2015	10/09/2016	16/11/2016	3/01/2017	5/04/2017	30/11/2017
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Nickel (mg/L)	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.003	<0.003	<0.003		<0.01
Silicon (mg/L)													28		
Uranium (mg/L)															0.006
Vanadium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.009	0.01	0.008		
Zinc (mg/L)	0.012	0.014	<0.005	0.016	0.02	0.017	0.007	0.014	0.014	0.018	0.01	0.012	<0.005	0.008	
Metals (total)															
Aluminium (mg/L)													0.03	0.021	
Arsenic (mg/L)	0.011	0.011	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	<0.003	0.003	<0.003	<0.003	0.002
Barium (mg/L)	0.06	0.064	0.094	0.128	0.127	0.109	0.108	0.101	0.104	0.101	0.066	0.073	0.073		0.036
Beryllium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.0001		
Bismuth (mg/L)															<0.001
Boron (mg/L)	0.2	0.24	0.08	0.09	0.18	0.07	<0.05	0.08	<0.05	0.06	0.03	0.036	0.041		
Cadmium (mg/L)	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	<0.001	0.002	0.002	0.002	0.002	0.003	0.003	0.002	0.001	0.002	0.001	0.001	0.001	0.001	<0.001
Copper (mg/L)	0.006	0.013	0.001	0.002	0.008	0.006	0.007	0.004	0.002	0.006	0.003	0.003	0.001	0.003	0.003
Iron (mg/L)													0.14		
Lead (mg/L)	0.003	0.002	<0.001	0.002	<0.001	0.003	0.002	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	
Manganese (mg/L)	0.138	0.159	0.902	1.38	1.49	1.17	1.27	1.06	0.999	0.956	0.12	0.2	0.37	0.2	
Mercury (mg/L)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00005	<0.00005	<0.00005	<0.00005	
Molybdenum (mg/L)															0.004
Nickel (mg/L)	0.001	0.001	<0.001	0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.003	<0.003	<0.003		<0.01
Silicon (mg/L)													29		
Uranium (mg/L)															0.007
Vanadium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.011	0.011	0.01		
Zinc (mg/L)	0.017	0.022	<0.005	0.021	0.022	0.024	0.022	0.013	0.006	0.013	0.01	0.011	0.006	0.008	

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01
Date	17/01/2018	25/03/2018	14/06/2018	30/07/2018	14/08/2018	20/09/2018	17/11/2018	13/01/2019	4/03/2019	24/03/2019	19/04/2019	17/05/2019	14/06/2019	13/07/2019	10/08/2019
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Physico-Chemical Parameters															
Turbidity (NTU)	11.4	1.6	8	1.1	10.2	9.7	14.6	17	32.9	1.9	5.7	5.4	4.1	17.9	9.2
Biochemical Oxygen Demand (mg/L)															
Electrical Conductivity @ 25°C (µS/cm)	1260	1220	1110	1140	1200	1230	1240	1560	1410	1200	1330	1340	1290	1390	1260
pH - Lab (pH Units)	7.07	7.56	7.31	7.32	7.41	7.51	7.33	7.37	7.25	7.22	7.16	7.58	7.18	7.13	6.98
Total Dissolved Solids (mg/L)															
Total Suspended Solids (mg/L)															
Hardness															
Total Hardness as CaCO3 (mg/L)	401	391	425	396	364	421	388	278	369	384	394	400	404	375	396
Major Ions															
Calcium (mg/L)	50	38	53	45	47	55	50	39	44	45	49	48	43	48	45
Magnesium (mg/L)	67	72	71	69	60	69	64	44	63	66	66	68	72	62	69
Sodium (mg/L)	145	118	157	115	151	177	157	221	167	136	214	213	140	211	160
Potassium (mg/L)	8	7	8	7	8	9	8	7	8	7	9	8	7	8	8
Chloride (mg/L)	36	34	40	36	39	40	44	65	53	38	37	40	38	45	21
Sulphate (as SO4) (mg/L)	56	60	65	56	60	64	66	104	84	42	74	72	76	86	68
Fluoride (mg/L)			1.5	1.7	1.6	0.7	0.7	1.1	1.4	1.6	1.6	1.6	1.6	1.3	1.6
Iodide (mg/L)															
Bromide (mg/L)															
Alkalinity															
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CO3 (mg/L)															
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	657	542	567	526	562	609	554	620	602	589	645	654	590	684	633
Total Alkalinity as CaCO3 (mg/L)	657	542	567	526	562	609	554	620	602	589	645	654	590	684	633
Ion Balance															
Ionic Balance (%)	2.64	0.37	5.84	1.61	1.73	5.56	3.9	3.24	1.4	0.21	5.91	5.33	0.36	0.46	1.46
Total Anions (meq/L)	15.3	13	13.8	12.7	13.6	14.6	13.7	16.4	15.3	13.7	15.5	15.7	14.4	16.7	14.6
Total Cations (meq/L)	14.5	13.1	15.5	13.1	14	16.4	14.8	15.4	14.8	13.8	17.4	17.5	14.3	16.9	15.1
Microbiological															
Escherichia coli (cfu/100ml)															
Nutrients															
Nitrate as N (mg/L)															
Nitrite + Nitrate as N (mg/L)	0.03	0.14	0.18												
Nitrite as N (mg/L)															
Total Kjeldahl Nitrogen as N (mg/L)	0.1	0.1	0.1												
Total Nitrogen as N (mg/L)	0.1	0.2	0.3												
Total Phosphorus as P (mg/L)	0.06	0.02	0.04												
Metals (dissolved)															
Aluminium (mg/L)															
Arsenic (mg/L)	0.002	0.001	0.002	<0.001	0.002	0.002	0.002	0.001	0.001	0.001	0.002	0.002	0.001	0.002	0.001
Barium (mg/L)	0.216	0.058	0.157	0.074	0.134	0.151	0.206	0.146	0.114	0.125	0.168	0.176	0.112	0.177	0.154
Beryllium (mg/L)															
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)															
Cadmium (mg/L)															
Chromium (mg/L)	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Cobalt (mg/L)	0.002	<0.001	0.002	<0.001	0.002	0.001	0.002	<0.001	0.001	0.002	0.004	0.002	0.001	0.002	0.002
Copper (mg/L)	0.002	0.005	0.002	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron (mg/L)															
Lead (mg/L)															
Manganese (mg/L)															
Mercury (mg/L)															
Molybdenum (mg/L)	0.003	0.003	0.004	0.002	0.004	0.005	0.003	0.004	0.004	0.004	0.004	0.005	0.004	0.004	0.004

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01
Date	17/01/2018	25/03/2018	14/06/2018	30/07/2018	14/08/2018	20/09/2018	17/11/2018	13/01/2019	4/03/2019	24/03/2019	19/04/2019	17/05/2019	14/06/2019	13/07/2019	10/08/2019
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Nickel (mg/L)	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)															
Uranium (mg/L)	0.003	0.006	0.005	0.007	0.004	0.004	0.003	0.003	0.006	0.006	0.006	0.006	0.007	0.006	0.005
Vanadium (mg/L)															
Zinc (mg/L)															
Metals (total)															
Aluminium (mg/L)															
Arsenic (mg/L)	0.002	0.001	0.002	<0.001	0.002	<0.001	0.002	0.002	0.002	0.001	0.001	0.002	0.001	0.002	0.002
Barium (mg/L)	0.253	0.056	0.14	0.066	0.122	0.127	0.208	0.151	0.135	0.125	0.128	0.165	0.128	0.172	0.16
Beryllium (mg/L)															
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)															
Cadmium (mg/L)															
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.002	<0.001	0.001	<0.001	0.001	0.001	0.003	0.003	0.007	0.002	0.002	0.002	0.002	0.004	0.002
Copper (mg/L)	<0.001	0.004	<0.001	<0.001	0.002	<0.001	0.004	0.003	0.009	0.004	0.003	0.002	0.003	0.006	0.005
Iron (mg/L)															
Lead (mg/L)															
Manganese (mg/L)															
Mercury (mg/L)															
Molybdenum (mg/L)	0.004	0.004	0.004	0.002	0.005	0.005	0.005	0.006	0.005	0.004	0.004	0.005	0.004	0.005	0.004
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)															
Uranium (mg/L)	0.003	0.007	0.004	0.006	0.004	0.004	0.004	0.005	0.006	0.007	0.006	0.006	0.007	0.006	0.005
Vanadium (mg/L)															
Zinc (mg/L)															

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01
Date	7/09/2019	19/10/2019	2/11/2019	30/11/2019	17/07/2020	9/08/2020	1/11/2020	10/01/2021	8/02/2021	5/04/2021	18/07/2021	2/11/2021	16/11/2021	4/03/2022	7/07/2022
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Physico-Chemical Parameters															
Turbidity (NTU)	6.2	8	7.1	2.9	0.1	0.7	2.5	1.2	5.2	0.4	1.4	0.2	5.8	0.9	0.2
Biochemical Oxygen Demand (mg/L)															
Electrical Conductivity @ 25°C (µS/cm)	1340	1350	1450	1160	389	1110	1230	1140	1170	1130	1150	1160	965	1140	1110
pH - Lab (pH Units)	7.5	7.31	7.15	7.2	7.85	7.88	7.84	7.67	7.75	7.58	8.06	7.63	7.61	7.84	7.54
Total Dissolved Solids (mg/L)															
Total Suspended Solids (mg/L)															
Hardness															
Total Hardness as CaCO3 (mg/L)	374	351	325	424	112	400	379	424	358	403	420	406	300	386	374
Major Ions															
Calcium (mg/L)	41	40	41	51	30	38	48	48	46	46	48	47	36	44	41
Magnesium (mg/L)	66	61	54	72	9	74	63	74	59	70	73	70	51	67	66
Sodium (mg/L)	186	224	242	125	32	118	143	127	152	114	121	122	84	119	114
Potassium (mg/L)	8	8	8	8	5	7	8	7	8	7	8	7	5	7	7
Chloride (mg/L)	38	44	49	26	7	35	32	30	32	28	33	28	26	34	29
Sulphate (as SO4) (mg/L)	74	87	85	67	17	62	61	55	58	58	58	62	47	61	52
Fluoride (mg/L)	1.6	1.4	1.4	1.7	0.3	1.6	1.6	1.7	1.3	1.7	1.7	1.8	1.4	1.7	1.8
Iodide (mg/L)															
Bromide (mg/L)															
Alkalinity															
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CO3 (mg/L)															
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	688	655	695	581	163	518	556	534	535	512	502	536	450	525	513
Total Alkalinity as CaCO3 (mg/L)	688	655	695	581	163	518	556	534	535	512	502	536	450	525	513
Ion Balance															
Ionic Balance (%)	1.82	2.49	0.53	1.35	0.67	2.59	2.65	5.69	4.36	3.8	6.54	3.04	4.53	1.34	1.88
Total Anions (meq/L)	16.4	16.1	17	13.7	3.81	12.6	13.3	12.7	12.8	12.2	12.2	12.8	10.7	12.7	12.2
Total Cations (meq/L)	15.8	17	17.2	14.1	3.76	13.3	14	14.2	14	13.2	13.9	13.6	9.78	13.1	12.6
Microbiological															
Escherichia coli (cfu/100ml)															
Nutrients															
Nitrate as N (mg/L)															
Nitrite + Nitrate as N (mg/L)															
Nitrite as N (mg/L)															
Total Kjeldahl Nitrogen as N (mg/L)															
Total Nitrogen as N (mg/L)															
Total Phosphorus as P (mg/L)															
Metals (dissolved)															
Aluminium (mg/L)															
Arsenic (mg/L)	0.002	0.002	0.002	0.001	<0.001	0.001	0.001	0.002	0.002	0.001	<0.001	0.001	<0.001	0.001	<0.001
Barium (mg/L)	0.156	0.156	0.169	0.151	0.047	0.06	0.144	0.071	0.17	0.056	0.058	0.071	0.051	0.059	0.066
Beryllium (mg/L)															
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Boron (mg/L)															
Cadmium (mg/L)															
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.003	0.001	0.002	0.005	<0.001	<0.001	0.002	0.002	0.002	0.001	<0.001	0.001	0.001	0.001	0.002
Copper (mg/L)	<0.001	<0.001	<0.001	0.002	0.018	0.002	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.001	<0.001
Iron (mg/L)															
Lead (mg/L)															
Manganese (mg/L)															
Mercury (mg/L)															
Molybdenum (mg/L)	0.009	0.004	0.006	0.003	<0.001	0.003	0.003	0.003	0.004	0.003	0.002	0.003	0.002	0.003	0.003

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01	BAWB01
Date	7/09/2019	19/10/2019	2/11/2019	30/11/2019	17/07/2020	9/08/2020	1/11/2020	10/01/2021	8/02/2021	5/04/2021	18/07/2021	2/11/2021	16/11/2021	4/03/2022	7/07/2022
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)															
Uranium (mg/L)	0.005	0.005	0.005	0.005	0.001	0.006	0.005	0.004	0.004	0.006	0.004	0.006	0.004	0.006	0.006
Vanadium (mg/L)															
Zinc (mg/L)															
Metals (total)															
Aluminium (mg/L)															
Arsenic (mg/L)	0.002	0.002	0.002	0.001	<0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002	0.002	0.001
Barium (mg/L)	0.167	0.153	0.17	0.138	0.054	0.063	0.143	0.077	0.183	0.059	0.062	0.07	0.061	0.062	0.075
Beryllium (mg/L)															
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Boron (mg/L)															
Cadmium (mg/L)															
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.002	0.002	0.002	0.003	<0.001	<0.001	0.002	0.002	0.002	0.002	0.001	<0.001	0.001	0.001	0.002
Copper (mg/L)	0.002	0.007	0.005	0.001	0.034	0.003	0.001	0.002	<0.001	0.003	0.002	0.002	0.004	0.001	0.003
Iron (mg/L)															
Lead (mg/L)															
Manganese (mg/L)															
Mercury (mg/L)															
Molybdenum (mg/L)	0.004	0.005	0.006	0.003	0.001	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)															
Uranium (mg/L)	0.006	0.006	0.005	0.005	0.002	0.007	0.005	0.006	0.004	0.007	0.006	0.006	0.006	0.007	0.007
Vanadium (mg/L)															
Zinc (mg/L)															

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB01	BAWB01	BAWB01	BAWB01	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03
Date	26/07/2022	14/10/2022	30/11/2022	21/01/2023	3/01/2017	17/01/2018	25/03/2018	16/06/2018	30/07/2018	14/08/2018	20/09/2018	17/11/2018	13/01/2019	4/03/2019	24/03/2019
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Physico-Chemical Parameters															
Turbidity (NTU)	0.6	8.4	1.5	0.6		0.6	0.7	1.1	0.6	0.6	1.6	0.3	2.2	0.8	2
Biochemical Oxygen Demand (mg/L)															
Electrical Conductivity @ 25°C (µS/cm)	1150	1200	929	1140		740	707	731	668	717	820	717	1020	807	911
pH - Lab (pH Units)	7.3	7.33	7.45	7.55	8.2	7.54	8.09	7.7	7.91	7.69	7.71	7.62	7.39	7.36	7.37
Total Dissolved Solids (mg/L)					470										
Total Suspended Solids (mg/L)															
Hardness															
Total Hardness as CaCO3 (mg/L)	413	413	302	416	210	197	176	231	178	199	295	204	216	226	233
Major Ions															
Calcium (mg/L)	45	50	37	48	57	51	44	58	45	50	77	52	57	59	62
Magnesium (mg/L)	73	70	51	72	17	17	16	21	16	18	25	18	18	19	19
Sodium (mg/L)	127	135	84	123	78	88	88	98	83	86	113	89	131	88	122
Potassium (mg/L)	8	8	4	7	9.7	9	8	10	9	9	12	9	10	10	11
Chloride (mg/L)	33	39	23	33	13	13	15	20	12	14	11	12	23	13	16
Sulphate (as SO4) (mg/L)	48	59	45	65	43	44	42	46	49	44	43	45	55	36	52
Fluoride (mg/L)	1.3	1.7	1.5	1.5				0.8	0.9	0.9	0.3	0.4	0.7	0.7	0.8
Iodide (mg/L)															
Bromide (mg/L)															
Alkalinity															
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CO3 (mg/L)					<5										
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	655	558	417	583	290	345	295	351	268	316	403	313	455	365	464
Total Alkalinity as CaCO3 (mg/L)	655	558	417	583	290	345	295	351	268	316	403	313	455	365	464
Ion Balance															
Ionic Balance (%)	3.57	3.08	0.6	0.3	5.4	1.07	2.4	3.43	4.88	2.07	9.15	4.13	2.86	1.07	2.66
Total Anions (meq/L)	15	13.5	9.92	13.9	7.1	8.18	7.19	8.53	6.71	7.62	9.26	7.53	10.9	8.41	10.8
Total Cations (meq/L)	14	14.3	9.8	13.8	7.91	8	7.54	9.14	7.4	7.95	11.1	8.18	10.3	8.59	10.2
Microbiological															
Escherichia coli (cfu/100ml)															
Nutrients															
Nitrate as N (mg/L)															
Nitrite + Nitrate as N (mg/L)						2.44	2.56	0.89							
Nitrite as N (mg/L)															
Total Kjeldahl Nitrogen as N (mg/L)						0.4	0.4	0.1							
Total Nitrogen as N (mg/L)						2.8	3	1							
Total Phosphorus as P (mg/L)						0.03	0.02	0.02							
Metals (dissolved)															
Aluminium (mg/L)					0.03										
Arsenic (mg/L)	0.001	0.002	0.001	<0.001	<0.003	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium (mg/L)	0.068	0.146	0.043	0.07	0.067	0.068	0.057	0.092	0.069	0.074	0.136	0.078	0.096	0.089	0.116
Beryllium (mg/L)					<0.0001										
Bismuth (mg/L)	<0.00005	<0.00005	<0.00005	<0.00005		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)					0.15										
Cadmium (mg/L)					<0.0001										
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.001	0.002	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	<0.001	<0.001	0.002	<0.001	0.002	0.003	0.012	0.004	0.002	0.002	<0.001	0.002	<0.001	<0.001	<0.001
Iron (mg/L)					<0.005										
Lead (mg/L)					<0.001										
Manganese (mg/L)					<0.005										
Mercury (mg/L)					<0.00005										
Molybdenum (mg/L)	0.003	0.003	0.002	0.002		0.002	0.002	0.004	0.002	0.002	0.003	0.002	0.001	0.002	0.002

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB01	BAWB01	BAWB01	BAWB01	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03
Date	26/07/2022	14/10/2022	30/11/2022	21/01/2023	3/01/2017	17/01/2018	25/03/2018	16/06/2018	30/07/2018	14/08/2018	20/09/2018	17/11/2018	13/01/2019	4/03/2019	24/03/2019
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.002	0.004	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.003	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)					15										
Uranium (mg/L)	0.006	0.005	0.004	0.006		0.006	0.005	0.008	0.005	0.005	0.007	0.005	0.006	0.005	0.007
Vanadium (mg/L)					0.003										
Zinc (mg/L)					0.06										
Metals (total)															
Aluminium (mg/L)					0.09										
Arsenic (mg/L)	0.001	0.002	0.002	<0.001	<0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium (mg/L)	0.071	0.164	0.044	0.078	0.069	0.076	0.06	0.078	0.058	0.066	0.093	0.063	0.099	0.096	0.104
Beryllium (mg/L)					<0.0001										
Bismuth (mg/L)	<0.00005	<0.00005	<0.00005	<0.00005		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)					0.15										
Cadmium (mg/L)					<0.0001										
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.001	0.002	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001
Copper (mg/L)	0.004	0.002	0.002	0.004	0.003	0.002	0.004	0.002	0.002	0.003	0.002	0.002	<0.001	<0.001	<0.001
Iron (mg/L)					0.071										
Lead (mg/L)					<0.001										
Manganese (mg/L)					0.007										
Mercury (mg/L)					<0.00005										
Molybdenum (mg/L)	0.003	0.004	0.003	0.003		0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.001	0.002	0.002
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.003	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)					15										
Uranium (mg/L)	0.006	0.005	0.004	0.007		0.005	0.005	0.006	0.005	0.005	0.006	0.006	0.006	0.005	0.007
Vanadium (mg/L)					0.003										
Zinc (mg/L)					0.074										

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03
Date	19/04/2019	17/05/2019	14/06/2019	13/07/2019	10/08/2019	7/09/2019	19/10/2019	2/11/2019	30/11/2019	8/04/2020	17/07/2020	1/11/2020	10/01/2021	5/04/2021	18/07/2021
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Physico-Chemical Parameters															
Turbidity (NTU)	2.4	1.3	3.1	2.2	2.8	4.5	1.9	1.7	1.9	41.4	0.4	1	0.6	0.7	1
Biochemical Oxygen Demand (mg/L)															
Electrical Conductivity @ 25°C (µS/cm)	1040	741	999	927	862	1130	818	246	926	484	734	942	906	1010	972
pH - Lab (pH Units)	7.34	7.94	7.37	7.25	7.27	7.69	7.49	7.24	7.44	8.2	7.81	7.93	7.87	7.82	7.86
Total Dissolved Solids (mg/L)															
Total Suspended Solids (mg/L)															
Hardness															
Total Hardness as CaCO3 (mg/L)	260	260	249	247	232	238	279	63	265	87	250	238	244	243	238
Major Ions															
Calcium (mg/L)	68	71	65	66	60	59	72	17	70	15	67	64	68	66	64
Magnesium (mg/L)	22	20	21	20	20	22	24	5	22	12	20	19	18	19	19
Sodium (mg/L)	141	114	126	99	114	123	144	29	137	92	76	112	124	130	133
Potassium (mg/L)	13	14	12	10	11	12	14	4	12	8	11	12	12	12	13
Chloride (mg/L)	18	12	17	17	14	17	14	7	15	12	11	15	17	17	18
Sulphate (as SO4) (mg/L)	53	39	56	53	46	51	42	14	48	40	36	48	52	53	48
Fluoride (mg/L)	0.5	0.6	0.7	0.6	0.5	0.3	0.5	0.3	0.7	0.9	0.6	0.8	0.9	0.8	2.4
Iodide (mg/L)															
Bromide (mg/L)															
Alkalinity															
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CO3 (mg/L)															
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	508	349	473	470	416	546	397	108	459	257	337	433	413	452	453
Total Alkalinity as CaCO3 (mg/L)	508	349	473	470	416	546	397	108	459	257	337	433	413	452	453
Ion Balance															
Ionic Balance (%)	0.39	12.8	1.54	7.19	1.1	8.92	14		4.4	2.97	4.78	0.69	3.73	0.96	1.48
Total Anions (meq/L)	11.8	8.12	11.1	11	9.66	12.4	9.2	2.65	10.6	6.31	7.79	10.1	9.81	10.6	10.6
Total Cations (meq/L)	11.7	10.5	10.8	9.5	9.88	10.4	12.2	2.62	11.6	5.94	8.58	9.94	10.6	10.8	10.9
Microbiological															
Escherichia coli (cfu/100ml)															
Nutrients															
Nitrate as N (mg/L)															
Nitrite + Nitrate as N (mg/L)															
Nitrite as N (mg/L)															
Total Kjeldahl Nitrogen as N (mg/L)															
Total Nitrogen as N (mg/L)															
Total Phosphorus as P (mg/L)															
Metals (dissolved)															
Aluminium (mg/L)															
Arsenic (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Barium (mg/L)	0.126	0.126	0.122	0.108	0.107	0.144	0.169	0.086	0.124	0.094	0.094	0.106	0.094	0.119	0.12
Beryllium (mg/L)															
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Boron (mg/L)															
Cadmium (mg/L)															
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.002	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.001	0.001
Copper (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.001	0.003	<0.001	<0.001	<0.001	<0.001
Iron (mg/L)															
Lead (mg/L)															
Manganese (mg/L)															
Mercury (mg/L)															
Molybdenum (mg/L)	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03
Date	19/04/2019	17/05/2019	14/06/2019	13/07/2019	10/08/2019	7/09/2019	19/10/2019	2/11/2019	30/11/2019	8/04/2020	17/07/2020	1/11/2020	10/01/2021	5/04/2021	18/07/2021
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.002	0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)															
Uranium (mg/L)	0.006	0.007	0.006	0.005	0.004	0.005	0.006	0.006	0.006	0.005	0.004	0.005	0.004	0.006	0.005
Vanadium (mg/L)															
Zinc (mg/L)															
Metals (total)															
Aluminium (mg/L)															
Arsenic (mg/L)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium (mg/L)	0.18	0.123	0.114	0.114	0.112	0.113	0.183	0.09	0.106	0.102	0.104	0.103	0.102	0.132	0.126
Beryllium (mg/L)															
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Boron (mg/L)															
Cadmium (mg/L)															
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Copper (mg/L)	<0.001	0.003	0.001	0.006	0.003	0.009	0.012	0.005	0.003	0.005	0.004	0.004	0.002	0.002	<0.001
Iron (mg/L)															
Lead (mg/L)															
Manganese (mg/L)															
Mercury (mg/L)															
Molybdenum (mg/L)	0.003	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.003	0.002	0.002	0.003	0.002
Nickel (mg/L)	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)															
Uranium (mg/L)	0.007	0.007	0.007	0.005	0.005	0.004	0.007	0.005	0.006	0.006	0.004	0.005	0.007	0.007	0.006
Vanadium (mg/L)															
Zinc (mg/L)															

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04
Date	2/11/2021	4/03/2022	12/07/2022	14/10/2022	21/01/2023	26/08/2014	29/09/2014	28/10/2014	25/11/2014	8/04/2015	30/04/2015	3/11/2015	10/09/2016	16/11/2016	3/01/2017
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Physico-Chemical Parameters															
Turbidity (NTU)	0.9	0.9	1	0.9	0.5										
Biochemical Oxygen Demand (mg/L)															
Electrical Conductivity @ 25°C (µS/cm)	1010	996	985	969	951										
pH - Lab (pH Units)	7.84	8.04	7.8	7.65	7.61								7.9	8.1	8.1
Total Dissolved Solids (mg/L)															560
Total Suspended Solids (mg/L)															
Hardness															
Total Hardness as CaCO3 (mg/L)	234	220	220	242	279								280	270	280
Major Ions															
Calcium (mg/L)	64	60	57	64	74	42	51	56	74	75	79	61	70	68	71
Magnesium (mg/L)	18	17	19	20	23	19	22	25	28	26	31	21	26	25	26
Sodium (mg/L)	150	142	136	136	119	168	156	145	116	102	107	94	95	93	95
Potassium (mg/L)	12	12	12	14	14	10	9	7	9	7	8	6	8.5	11	8.2
Chloride (mg/L)	19	19	16	17	14	28	26	23	20	27	23	19	22	22	21
Sulphate (as SO4) (mg/L)	48	48	46	47	47	<1	8	8	13	21	19	19	21	15	12
Fluoride (mg/L)	0.8	0.9	0.8	0.9	0.5										
Iodide (mg/L)															
Bromide (mg/L)															
Alkalinity															
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<5	<5	<5
Carbonate Alkalinity as CO3 (mg/L)															<5
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<5	<5	<5
Bicarbonate Alkalinity as CaCO3 (mg/L)	473	451	452	431	448	484	562	532	530	550	601	490	470	390	420
Total Alkalinity as CaCO3 (mg/L)	473	451	452	431	448	484	562	532	530	550	601	490	470	390	420
Ion Balance															
Ionic Balance (%)	2.31	1.54	0.9	4.93	3.71	3.48	3.26	0.5	0.69	7.46	6.98	8.67	<2.6	5.1	3.9
Total Anions (meq/L)	11	10.5	10.4	10.1	10.3	10.5	12.1	11.4	11.4	12.2	13	10.7	10.5	8.77	9.25
Total Cations (meq/L)	11.5	10.9	10.6	11.1	11.1	11.2	11.4	11.3	11.3	10.5	11.4	9.01	9.93	9.72	9.99
Microbiological															
Escherichia coli (cfu/100ml)															
Nutrients															
Nitrate as N (mg/L)															
Nitrite + Nitrate as N (mg/L)															
Nitrite as N (mg/L)															
Total Kjeldahl Nitrogen as N (mg/L)															
Total Nitrogen as N (mg/L)															
Total Phosphorus as P (mg/L)															
Metals (dissolved)															
Aluminium (mg/L)															<0.02
Arsenic (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.004	0.003	0.001	0.002	<0.001	<0.003	<0.003	<0.003
Barium (mg/L)	0.121	0.117	0.126	0.121	0.123	0.084	0.177	0.268	0.284	0.256	0.315	0.254	0.32	0.3	0.34
Beryllium (mg/L)						<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.0001
Bismuth (mg/L)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005										
Boron (mg/L)						0.12	0.13	0.1	0.1	0.06	0.08	0.07	0.07	0.081	0.084
Cadmium (mg/L)						<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.001	0.002	0.003	0.003	0.003	0.002	0.003	0.003	0.001
Iron (mg/L)															<0.005
Lead (mg/L)						<0.001	0.003	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese (mg/L)						0.684	2.94	3.7	4.04	3.29	4.06	3.22	3.6	3	3.8
Mercury (mg/L)						<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00005	<0.00005	<0.00005
Molybdenum (mg/L)	0.002	0.002	0.002	0.003	0.005										

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB03	BAWB03	BAWB03	BAWB03	BAWB03	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04
Date	2/11/2021	4/03/2022	12/07/2022	14/10/2022	21/01/2023	26/08/2014	29/09/2014	28/10/2014	25/11/2014	8/04/2015	30/04/2015	3/11/2015	10/09/2016	16/11/2016	3/01/2017
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.003	0.003	<0.003
Silicon (mg/L)															18
Uranium (mg/L)	0.006	0.005	0.002	0.005	0.005										
Vanadium (mg/L)						<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.001	<0.001	<0.001
Zinc (mg/L)						<0.005	0.011	0.014	0.024	0.011	0.023	0.014	0.017	0.007	<0.005
Metals (total)															
Aluminium (mg/L)															0.03
Arsenic (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.004	0.004	0.002	0.002	<0.001	<0.003	<0.003	<0.003
Barium (mg/L)	0.121	0.123	0.129	0.131	0.13	0.087	0.206	0.26	0.31	0.334	0.342	0.288	0.34	0.31	0.35
Beryllium (mg/L)						<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.0001
Bismuth (mg/L)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005										
Boron (mg/L)						0.09	0.08	0.13	0.12	0.07	<0.05	0.06	0.07	0.081	0.087
Cadmium (mg/L)						<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	<0.0001	<0.0001
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.002	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.002	0.004	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	0.002	0.001	<0.001	<0.001	0.002	0.001	0.002	0.019	0.004	0.204	0.369	0.012	0.003	0.007	0.006
Iron (mg/L)															1.4
Lead (mg/L)						<0.001	<0.001	0.003	<0.001	<0.001	<0.001	0.002	<0.001	0.001	<0.001
Manganese (mg/L)						0.696	2.88	3.66	4.35	4.05	4.24	3.52	3.7	3.3	3.7
Mercury (mg/L)						<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00005	<0.00005	<0.00005
Molybdenum (mg/L)	0.003	0.003	0.003	0.003	0.003										
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.003	<0.001	0.002	0.003	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.003	0.003	<0.003
Silicon (mg/L)															18
Uranium (mg/L)	0.006	0.006	0.006	0.005	0.005										
Vanadium (mg/L)						<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.001	<0.001	<0.001
Zinc (mg/L)						0.017	0.013	0.038	0.025	0.019	0.017	0.018	0.017	0.007	0.007

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04
Date	5/04/2017	17/01/2018	25/03/2018	16/06/2018	30/07/2018	14/08/2018	20/09/2018	17/11/2018	13/01/2019	4/03/2019	24/03/2019	19/04/2019	17/05/2019	14/06/2019	13/07/2019
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Physico-Chemical Parameters															
Turbidity (NTU)		16.5	1.1	23.3	7.2	23.8	16.7	22.2	28.4	18.4	15.1	17.1	24.3	22.1	24.2
Biochemical Oxygen Demand (mg/L)															
Electrical Conductivity @ 25°C (µS/cm)		891	798	810	841	868	862	868	890	840	798	848	860	844	832
pH - Lab (pH Units)	7.9	7.32	7.77	7.51	7.39	7.63	7.75	7.38	7.5	7.47	7.43	7.39	7.79	7.47	7.28
Total Dissolved Solids (mg/L)															
Total Suspended Solids (mg/L)															
Hardness															
Total Hardness as CaCO3 (mg/L)	250	262	226	288	259	263	258	282	231	259	240	284	274	265	285
Major Ions															
Calcium (mg/L)	57	62	51	69	64	64	62	70	58	64	60	71	67	65	73
Magnesium (mg/L)	26	26	24	28	24	25	25	26	21	24	22	26	26	25	25
Sodium (mg/L)	94	102	99	110	98	100	101	103	94	101	92	113	104	100	107
Potassium (mg/L)	8.8	7	7	8	7	7	7	7	5	6	6	7	7	6	6
Chloride (mg/L)	24	26	23	27	26	24	25	25	26	20	19	21	19	20	20
Sulphate (as SO4) (mg/L)	16	11	15	11	10	8	9	6	5	8	7	7	6	7	7
Fluoride (mg/L)				0.4	0.4	0.4	0.2	0.2	0.4	0.4	0.5	0.4	0.4	0.4	0.4
Iodide (mg/L)															
Bromide (mg/L)															
Alkalinity															
Carbonate Alkalinity as CaCO3 (mg/L)	<5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CO3 (mg/L)															
Hydroxide Alkalinity as CaCO3 (mg/L)	<5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	420	473	373	455	428	434	466	435	429	430	433	468	458	424	451
Total Alkalinity as CaCO3 (mg/L)	420	473	373	455	428	434	466	435	429	430	433	468	458	424	451
Ion Balance															
Ionic Balance (%)	<0.7	2.78	3.4	3.15	0.62	1.37	2.41	3.89	3.12	2.07	2.04	3.3	1.87	3.28	3.89
Total Anions (meq/L)	9.4	10.4	8.41	10.1	9.49	9.51	10.2	9.52	9.41	9.32	9.33	10.1	9.81	9.18	9.72
Total Cations (meq/L)	9.27	9.85	9	10.7	9.61	9.78	9.72	10.3	8.84	9.72	8.96	10.8	10.2	9.8	10.5
Microbiological															
Escherichia coli (cfu/100ml)															
Nutrients															
Nitrate as N (mg/L)															
Nitrite + Nitrate as N (mg/L)		<0.01	0.28	<0.01											
Nitrite as N (mg/L)															
Total Kjeldahl Nitrogen as N (mg/L)		0.3	0.2	0.2											
Total Nitrogen as N (mg/L)		0.3	0.5	0.2											
Total Phosphorus as P (mg/L)		0.08	0.03	0.07											
Metals (dissolved)															
Aluminium (mg/L)	0.012														
Arsenic (mg/L)	<0.003	<0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001	0.001	0.001	0.001	0.001	<0.001	<0.001	0.001
Barium (mg/L)		0.355	0.26	0.404	0.346	0.411	0.387	0.432	0.365	0.06	0.415	0.457	0.406	0.475	0.486
Beryllium (mg/L)															
Bismuth (mg/L)		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)															
Cadmium (mg/L)	<0.0001														
Chromium (mg/L)	<0.001	<0.001	<0.001	0.002	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001
Copper (mg/L)	0.006	0.002	0.007	0.002	0.001	0.003	<0.001	<0.001	<0.001	0.008	<0.001	<0.001	<0.001	<0.001	<0.001
Iron (mg/L)															
Lead (mg/L)	<0.001														
Manganese (mg/L)	2.6														
Mercury (mg/L)	<0.00005														
Molybdenum (mg/L)		0.003	0.005	0.003	0.003	0.003	0.004	0.002	0.003	0.002	0.003	0.003	0.004	0.003	0.002

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04
Date	5/04/2017	17/01/2018	25/03/2018	16/06/2018	30/07/2018	14/08/2018	20/09/2018	17/11/2018	13/01/2019	4/03/2019	24/03/2019	19/04/2019	17/05/2019	14/06/2019	13/07/2019
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Nickel (mg/L)	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)															
Uranium (mg/L)		0.003	0.002	0.003	0.003	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Vanadium (mg/L)															
Zinc (mg/L)	0.009														
Metals (total)															
Aluminium (mg/L)	0.039														
Arsenic (mg/L)	<0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.002	0.002	<0.001	0.002	0.002
Barium (mg/L)		0.441	0.272	0.36	0.371	0.425	0.408	0.437	0.372	0.068	0.413	0.493	0.43	0.457	0.51
Beryllium (mg/L)															
Bismuth (mg/L)		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)															
Cadmium (mg/L)	<0.0001														
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
Copper (mg/L)	0.008	0.006	0.007	0.011	0.009	0.012	0.014	0.012	<0.001	0.012	0.006	0.004	0.002	0.003	0.002
Iron (mg/L)															
Lead (mg/L)	0.001														
Manganese (mg/L)	2.9														
Mercury (mg/L)	<0.00005														
Molybdenum (mg/L)		0.003	0.005	0.003	0.003	0.003	0.004	0.003	0.002	0.002	0.003	0.004	0.003	0.003	0.003
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)															
Uranium (mg/L)		0.003	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Vanadium (mg/L)															
Zinc (mg/L)	0.008														

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04
Date	10/08/2019	19/10/2019	2/11/2019	30/11/2019	8/04/2020	21/05/2020	17/07/2020	1/11/2020	10/01/2021	5/04/2021	3/05/2021	18/07/2021	10/08/2021	2/11/2021	16/11/2021
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Physico-Chemical Parameters															
Turbidity (NTU)	23.8	26.1	20.7	17.9	50.7	8.3	3.9	8.8	4.5	18.2	25.5	26.3	6.6	21.5	3.2
Biochemical Oxygen Demand (mg/L)															
Electrical Conductivity @ 25°C (µS/cm)	857	847	828	817	233	840	785	850	829	864	908	848	877	884	690
pH - Lab (pH Units)	7.25	7.57	7.33	7.61	8.33	7.71	7.82	7.97	7.89	7.81	7.77	7.96	7.88	7.9	7.78
Total Dissolved Solids (mg/L)															
Total Suspended Solids (mg/L)															
Hardness															
Total Hardness as CaCO3 (mg/L)	259	278	251	268	69	237	259	252	253	254	247	243	217	264	213
Major Ions															
Calcium (mg/L)	64	70	61	66	11	57	64	63	60	64	61	61	49	68	54
Magnesium (mg/L)	24	25	24	25	10	23	24	23	25	23	23	22	23	23	19
Sodium (mg/L)	101	106	104	103	37	92	104	97	104	99	98	100	118	104	81
Potassium (mg/L)	6	7	6	7	2	6	7	7	7	6	6	6	5	6	5
Chloride (mg/L)	19	20	18	19	7	31	28	18	21	19	20	20	67	21	16
Sulphate (as SO4) (mg/L)	6	6	7	7	3	6	6	5	6	4	4	4	39	3	3
Fluoride (mg/L)	0.4	0.5	0.4	0.5	0.4	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.4
Iodide (mg/L)															
Bromide (mg/L)															
Alkalinity															
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	4	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CO3 (mg/L)															
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	464	464	460	448	166	414	407	428	419	433	429	441	329	433	361
Total Alkalinity as CaCO3 (mg/L)	464	464	460	448	170	414	407	428	419	433	429	441	329	433	361
Ion Balance															
Ionic Balance (%)	1.1	1.87	0.76	1.92	9.33	2.08	4.36	1.46	3.53	1.46	0.72	0.54	1.71	3.41	1.17
Total Anions (meq/L)	9.93	9.96	9.84	9.63	3.66	9.27	9.05	9.16	9.09	9.27	9.22	9.46	9.28	9.31	7.73
Total Cations (meq/L)	9.72	10.3	9.7	10	3.03	8.89	9.87	9.43	9.75	9.55	9.35	9.36	9.6	9.96	7.91
Microbiological															
Escherichia coli (cfu/100ml)															
Nutrients															
Nitrate as N (mg/L)															
Nitrite + Nitrate as N (mg/L)															
Nitrite as N (mg/L)															
Total Kjeldahl Nitrogen as N (mg/L)															
Total Nitrogen as N (mg/L)															
Total Phosphorus as P (mg/L)															
Metals (dissolved)															
Aluminium (mg/L)						<0.01									
Arsenic (mg/L)	<0.001	0.001	0.001	0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001	0.001	0.001	<0.001	0.001	<0.001
Barium (mg/L)	0.433	0.455	0.427	0.491	0.465	0.391	0.368	0.404	0.384	0.43	0.439	0.41	0.325	0.475	0.306
Beryllium (mg/L)															
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Boron (mg/L)						0.09									
Cadmium (mg/L)						<0.0001									
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	<0.001	0.002	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.004	<0.001	0.002
Iron (mg/L)															
Lead (mg/L)						<0.001									
Manganese (mg/L)						2.63									
Mercury (mg/L)															
Molybdenum (mg/L)	0.003	0.003	0.003	0.002	0.003	0.003	0.003	0.002	0.003	0.003	0.003	0.002	0.002	0.002	0.002

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04
Date	10/08/2019	19/10/2019	2/11/2019	30/11/2019	8/04/2020	21/05/2020	17/07/2020	1/11/2020	10/01/2021	5/04/2021	3/05/2021	18/07/2021	10/08/2021	2/11/2021	16/11/2021
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.004	<0.001	0.002	<0.001	0.004	<0.001	0.003
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)															
Uranium (mg/L)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001
Vanadium (mg/L)															
Zinc (mg/L)						<0.005									
Metals (total)															
Aluminium (mg/L)						0.02									
Arsenic (mg/L)	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.001
Barium (mg/L)	0.425	0.46	0.468	0.433	0.49	0.39	0.386	0.417	0.514	0.495	0.48	0.417	0.314	0.48	0.375
Beryllium (mg/L)															
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Boron (mg/L)						0.07									
Cadmium (mg/L)						<0.0001									
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.006	<0.001	<0.001	<0.001
Cobalt (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	0.003	0.004	0.006	0.001	0.002	0.005	<0.001	0.003	0.002	0.002	0.002	<0.001	0.005	<0.001	0.002
Iron (mg/L)															
Lead (mg/L)						<0.001									
Manganese (mg/L)						2.55									
Mercury (mg/L)															
Molybdenum (mg/L)	0.003	0.003	0.003	0.003	<0.001	0.004	0.003	0.003	0.004	0.003	0.003	0.004	0.002	0.003	0.003
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	0.002
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)															
Uranium (mg/L)	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002
Vanadium (mg/L)															
Zinc (mg/L)						<0.005									

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB07	BAWB07	BAWB07	BAWB07	BAWB07	BAWB07	BAWB07	BAWB07	BAWB07
Date	4/03/2022	12/07/2022	26/07/2022	14/10/2022	30/11/2022	21/01/2023	26/08/2014	30/09/2014	28/10/2014	25/11/2014	8/04/2015	30/04/2015	16/06/2018	30/07/2018	14/08/2018
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Physico-Chemical Parameters															
Turbidity (NTU)	17.7	14.9	6.1	7.7	2.7	0.4							1.3	1.3	6.2
Biochemical Oxygen Demand (mg/L)															
Electrical Conductivity @ 25°C (µS/cm)	881	863	887	855	668	841							951	1060	1120
pH - Lab (pH Units)	8.03	7.68	7.7	7.51	7.7	7.64							7.71	7.43	7.45
Total Dissolved Solids (mg/L)															
Total Suspended Solids (mg/L)															
Hardness															
Total Hardness as CaCO3 (mg/L)	222	259	254	268	203	269							258	259	273
Major Ions															
Calcium (mg/L)	56	64	62	66	50	68	56	55	50	53	44	56	44	51	55
Magnesium (mg/L)	20	24	24	25	19	24	34	34	34	32	26	37	36	32	33
Sodium (mg/L)	97	106	106	109	79	103	154	158	173	150	117	139	170	153	152
Potassium (mg/L)	6	6	6	7	4	9	8	7	7	8	5	7	8	7	7
Chloride (mg/L)	22	18	21	20	15	23	40	39	40	44	36	42	49	47	43
Sulphate (as SO4) (mg/L)	2	1	2	<1	1	7	39	44	43	45	52	47	59	56	66
Fluoride (mg/L)	0.6	0.5	0.4	0.6	0.5	0.4							1.5	1.6	1.7
Iodide (mg/L)															
Bromide (mg/L)															
Alkalinity															
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CO3 (mg/L)															
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	439	444	474	442	338	448	492	554	531	537	465	547	419	449	479
Total Alkalinity as CaCO3 (mg/L)	439	444	474	442	338	448	492	554	531	537	465	547	419	449	479
Ion Balance															
Ionic Balance (%)	3.4	2.76	1.36	4.45	2.7	1.68	2.96	1.94	1.38	3.64	8.8	4.11	7.48	2.34	0.38
Total Anions (meq/L)	9.43	9.4	10.1	9.4	7.2	9.74	11.8	13.1	12.6	12.9	11.4	13.1	11	11.5	12.2
Total Cations (meq/L)	8.81	9.93	9.83	10.3	7.6	10.1	12.5	12.6	13	12	9.55	12.1	12.8	12	12.2
Microbiological															
Escherichia coli (cfu/100ml)															
Nutrients															
Nitrate as N (mg/L)															
Nitrite + Nitrate as N (mg/L)													0.39		
Nitrite as N (mg/L)															
Total Kjeldahl Nitrogen as N (mg/L)													0.1		
Total Nitrogen as N (mg/L)													0.5		
Total Phosphorus as P (mg/L)													0.04		
Metals (dissolved)															
Aluminium (mg/L)															
Arsenic (mg/L)	0.001	<0.001	0.001	<0.001	<0.001	0.001	0.018	0.018	0.018	0.017	0.008	0.01	0.015	0.005	0.003
Barium (mg/L)	0.42	0.468	0.487	0.487	0.321	0.394	0.078	0.071	0.087	0.078	0.055	0.054	0.074	0.089	0.122
Beryllium (mg/L)							<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			
Bismuth (mg/L)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005							<0.001	<0.001	<0.001
Boron (mg/L)							0.05	0.07	<0.05	0.07	<0.05	0.08			
Cadmium (mg/L)							<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001			
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.002	<0.001
Cobalt (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	<0.001	<0.001	<0.001	<0.001	0.002	0.02	<0.001	<0.001	<0.001	0.001	0.001	0.012	0.015	0.002	0.001
Iron (mg/L)															
Lead (mg/L)							<0.001	0.006	0.001	<0.001	<0.001	<0.001			
Manganese (mg/L)							0.073	0.081	0.086	0.081	0.061	0.058			
Mercury (mg/L)							<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001			
Molybdenum (mg/L)	0.003	0.002	0.002	0.003	0.002	0.003							0.005	0.004	0.003

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB04	BAWB07	BAWB07	BAWB07	BAWB07	BAWB07	BAWB07	BAWB07	BAWB07	BAWB07
Date	4/03/2022	12/07/2022	26/07/2022	14/10/2022	30/11/2022	21/01/2023	26/08/2014	30/09/2014	28/10/2014	25/11/2014	8/04/2015	30/04/2015	16/06/2018	30/07/2018	14/08/2018
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Nickel (mg/L)	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)															
Uranium (mg/L)	0.002	0.002	0.002	0.002	0.001	0.002							0.004	0.005	0.004
Vanadium (mg/L)							<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			
Zinc (mg/L)							<0.005	0.008	0.008	0.006	0.005	0.007			
Metals (total)															
Aluminium (mg/L)															
Arsenic (mg/L)	0.002	0.002	0.001	0.001	0.001	0.001	0.019	0.018	0.018	0.017	0.011	0.006	0.014	0.006	0.003
Barium (mg/L)	0.508	0.508	0.462	0.509	0.297	0.421	0.079	0.08	0.086	0.086	0.081	0.093	0.066	0.084	0.103
Beryllium (mg/L)							<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			
Bismuth (mg/L)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005							<0.001	<0.001	<0.001
Boron (mg/L)							0.07	0.05	<0.05	0.09	0.08	<0.05			
Cadmium (mg/L)							<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001			
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	0.001	0.002	0.002	<0.001	0.002	0.003	0.002	0.003	0.003	0.003	0.008	0.022	0.02	0.006	0.017
Iron (mg/L)															
Lead (mg/L)							<0.001	0.002	0.019	<0.001	<0.001	0.001			
Manganese (mg/L)							0.074	0.074	0.08	0.086	0.08	0.116			
Mercury (mg/L)							<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001			
Molybdenum (mg/L)	0.003	0.003	0.003	0.003	0.002	0.004							0.005	0.004	0.004
Nickel (mg/L)	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)															
Uranium (mg/L)	0.002	0.002	0.002	0.002	0.002	0.002							0.004	0.004	0.004
Vanadium (mg/L)							<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			
Zinc (mg/L)							<0.005	0.021	0.021	0.011	0.028	<0.005			

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB07	BAWB07	BAWB07	BAWB07	BAWB07	BAWB07
Date	20/09/2018	17/11/2018	13/01/2019	28/02/2019	24/03/2019	19/04/2019
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Physico-Chemical Parameters						
Turbidity (NTU)	5.8	4.6	16.2	1.7	0.8	0.3
Biochemical Oxygen Demand (mg/L)						
Electrical Conductivity @ 25°C (µS/cm)	1120	1100	1130	1060	1040	1100
pH - Lab (pH Units)	7.7	7.34	7.31	7.32	7.45	7.35
Total Dissolved Solids (mg/L)						
Total Suspended Solids (mg/L)						
Hardness						
Total Hardness as CaCO3 (mg/L)	285	271	236	269	264	307
Major Ions						
Calcium (mg/L)	58	54	50	55	53	62
Magnesium (mg/L)	34	33	27	32	32	37
Sodium (mg/L)	161	158	143	162	153	169
Potassium (mg/L)	8	8	6	8	8	10
Chloride (mg/L)	45	47	44	41	36	37
Sulphate (as SO4) (mg/L)	66	66	61	70	70	75
Fluoride (mg/L)	0.8	0.8	1.6	1.7	1.5	1.7
Iodide (mg/L)						
Bromide (mg/L)						
Alkalinity						
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CO3 (mg/L)						
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	497	462	457	464	476	492
Total Alkalinity as CaCO3 (mg/L)	497	462	457	464	476	492
Ion Balance						
Ionic Balance (%)	1.28	2.28	2.42	3.04	0.64	5
Total Anions (meq/L)	12.6	11.9	11.6	11.9	12	12.4
Total Cations (meq/L)	12.9	12.5	11.1	12.6	12.1	13.7
Microbiological						
Escherichia coli (cfu/100ml)						
Nutrients						
Nitrate as N (mg/L)						
Nitrite + Nitrate as N (mg/L)						
Nitrite as N (mg/L)						
Total Kjeldahl Nitrogen as N (mg/L)						
Total Nitrogen as N (mg/L)						
Total Phosphorus as P (mg/L)						
Metals (dissolved)						
Aluminium (mg/L)						
Arsenic (mg/L)	0.002	0.003	0.002	0.003	0.004	0.003
Barium (mg/L)	0.152	0.093	0.073	0.084	0.1	0.119
Beryllium (mg/L)						
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)						
Cadmium (mg/L)						
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Copper (mg/L)	<0.001	0.001	<0.001	0.001	0.002	0.009
Iron (mg/L)						
Lead (mg/L)						
Manganese (mg/L)						
Mercury (mg/L)						
Molybdenum (mg/L)	0.004	0.003	0.004	0.003	0.004	0.005

Table B.3: North Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	North Pit	North Pit	North Pit	North Pit	North Pit	North Pit
Location ID	BAWB07	BAWB07	BAWB07	BAWB07	BAWB07	BAWB07
Date	20/09/2018	17/11/2018	13/01/2019	28/02/2019	24/03/2019	19/04/2019
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Nickel (mg/L)	<0.001	0.004	<0.001	<0.001	<0.001	0.004
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)						
Uranium (mg/L)	0.004	0.004	0.004	0.004	0.004	0.005
Vanadium (mg/L)						
Zinc (mg/L)						
Metals (total)						
Aluminium (mg/L)						
Arsenic (mg/L)	0.005	0.003	0.002	0.003	0.003	0.004
Barium (mg/L)	0.105	0.098	0.076	0.092	0.098	0.104
Beryllium (mg/L)						
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)						
Cadmium (mg/L)						
Chromium (mg/L)	0.001	<0.001	0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	0.029	0.007	<0.001	0.006	0.004	0.005
Iron (mg/L)						
Lead (mg/L)						
Manganese (mg/L)						
Mercury (mg/L)						
Molybdenum (mg/L)	0.004	0.004	0.003	0.004	0.004	0.005
Nickel (mg/L)	0.001	<0.001	0.001	0.001	<0.001	0.002
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)						
Uranium (mg/L)	0.004	0.004	0.003	0.004	0.004	0.005
Vanadium (mg/L)						
Zinc (mg/L)						

Table B.4 South Pit water quality monitoring and sampling results

Table B.4: South Pit water quality monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	South Pit	South Pit	South Pit	South Pit
Location ID	BCP South Pit	BCP South Pit	BCP South Pit	BCP South Pit
Date	18/04/2021	18/07/2021	2/11/2021	12/06/2022
Purpose	ROM	ROM	ROM	ROM
Physico-Chemical Parameters				
Turbidity (NTU)	0.7	0.8	1	0.2
Biochemical Oxygen Demand (mg/L)				
Electrical Conductivity @ 25°C (µS/cm)	1380	1630	1520	1260
pH - Lab (pH Units)	8.11	8.1	8.09	8.06
Total Dissolved Solids (mg/L)				
Total Suspended Solids (mg/L)				
Hardness				
Total Hardness as CaCO3 (mg/L)				
Major Ions				
Calcium (mg/L)	125	169	153	114
Magnesium (mg/L)	52	66	60	55
Sodium (mg/L)	93	114	101	76
Potassium (mg/L)	31	32	25	21
Chloride (mg/L)	23	27	22	14
Sulphate (as SO4) (mg/L)	580	683	713	527
Fluoride (mg/L)	1.4	1.3	1.1	1
Iodide (mg/L)				
Bromide (mg/L)				
Alkalinity				
Carbonate Alkalinity as CaCO3 (mg/L)			<1	<1
Carbonate Alkalinity as CO3 (mg/L)				
Hydroxide Alkalinity as CaCO3 (mg/L)			<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)			93	78
Total Alkalinity as CaCO3 (mg/L)			93	78
Ion Balance				
Ionic Balance (%)			0.81	4.2
Total Anions (meq/L)			17.3	12.9
Total Cations (meq/L)			17.6	14
Microbiological				
Escherichia coli (cfu/100ml)				
Nutrients				
Nitrate as N (mg/L)				
Nitrite + Nitrate as N (mg/L)				
Nitrite as N (mg/L)				
Total Kjeldahl Nitrogen as N (mg/L)				
Total Nitrogen as N (mg/L)				
Total Phosphorus as P (mg/L)				
Metals (dissolved)				
Aluminium (mg/L)				
Arsenic (mg/L)	0.004	0.007	0.006	0.007
Barium (mg/L)	0.045	0.04	0.04	0.041
Beryllium (mg/L)				
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)				
Cadmium (mg/L)				
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.005	0.016	0.012	0.001
Copper (mg/L)	0.023	0.018	0.012	0.012
Iron (mg/L)				
Lead (mg/L)				
Manganese (mg/L)				
Mercury (mg/L)				
Molybdenum (mg/L)	0.047	0.054	0.043	0.034

Table B.4: South Pit water quality monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	South Pit	South Pit	South Pit	South Pit
Location ID	BCP South Pit	BCP South Pit	BCP South Pit	BCP South Pit
Date	18/04/2021	18/07/2021	2/11/2021	12/06/2022
Purpose	ROM	ROM	ROM	ROM
Nickel (mg/L)	0.013	0.031	0.024	0.008
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)				
Uranium (mg/L)	0.008	0.01	0.008	0.007
Vanadium (mg/L)				
Zinc (mg/L)				
Metals (total)				
Aluminium (mg/L)				
Arsenic (mg/L)	0.004	0.007	0.007	0.008
Barium (mg/L)	0.05	0.039	0.037	0.046
Beryllium (mg/L)				
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)				
Cadmium (mg/L)				
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.009	0.021	0.015	0.002
Copper (mg/L)	0.04	0.035	0.026	0.015
Iron (mg/L)				
Lead (mg/L)				
Manganese (mg/L)				
Mercury (mg/L)				
Molybdenum (mg/L)	0.059	0.059	0.051	0.036
Nickel (mg/L)	0.014	0.034	0.025	0.008
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)				
Uranium (mg/L)	0.009	0.01	0.008	0.008
Vanadium (mg/L)				
Zinc (mg/L)				

Table B.5 South Pit groundwater quality monitoring and sampling results

Table B.5: South Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	South Pit	South Pit	South Pit	South Pit	South Pit	South Pit	South Pit	South Pit
Location ID	BAWBR2	BAWBR2	BAWBR2	BAWBR2	BAWBR2	BAWBR3	BAWBR3	BAWBR3
Date	10/01/2021	5/04/2021	7/07/2022	26/07/2022	24/01/2023	10/09/2016	24/03/2019	24/01/2023
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Physico-Chemical Parameters								
Turbidity (NTU)	4.9	3.6	3.1	1.9	20		16.1	0.6
Biochemical Oxygen Demand (mg/L)								
Electrical Conductivity @ 25°C (µS/cm)	883	1600	6590	7280	1190		1250	1620
pH - Lab (pH Units)	7.95	8.07	7.97	7.92	7.46	8.2	7.71	7.98
Total Dissolved Solids (mg/L)								
Total Suspended Solids (mg/L)								
Hardness								
Total Hardness as CaCO3 (mg/L)	119	238	1280	1300	80	210	114	433
Major Ions								
Calcium (mg/L)	23	46	90	74	17	54	26	109
Magnesium (mg/L)	15	30	257	271	9	17	12	39
Sodium (mg/L)	170	280	1520	1570	205	72	252	205
Potassium (mg/L)	3	4	5	5	12	12	5	6
Chloride (mg/L)	58	128	908	950	89	16	43	60
Sulphate (as SO4) (mg/L)	80	176	1290	1290	143	47	93	455
Fluoride (mg/L)	0.8	0.6	1	0.8	0.3		1	0.2
Iodide (mg/L)								
Bromide (mg/L)								
Alkalinity								
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<5	<1	<1
Carbonate Alkalinity as CO3 (mg/L)								
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1	<1	<5	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	290	469	2200	2140	352	320	519	255
Total Alkalinity as CaCO3 (mg/L)	290	469	2200	2140	352	320	519	255
Ion Balance								
Ionic Balance (%)	4	1.19	2.41	1.05	7.32	<2.3	0.54	4.29
Total Anions (meq/L)	9.1	16.6	96.4	96.4	12.5	7.93	13.5	16.3
Total Cations (meq/L)	9.85	17	91.9	94.4	10.8	7.57	13.4	17.7
Microbiological								
Escherichia coli (cfu/100ml)								
Nutrients								
Nitrate as N (mg/L)								
Nitrite + Nitrate as N (mg/L)								
Nitrite as N (mg/L)								
Total Kjeldahl Nitrogen as N (mg/L)								
Total Nitrogen as N (mg/L)								
Total Phosphorus as P (mg/L)								
Metals (dissolved)								
Aluminium (mg/L)								
Arsenic (mg/L)	0.001	0.001	<0.001	0.003	0.002	<0.003	0.002	0.002
Barium (mg/L)	0.054	0.096	0.003	0.03	0.057	0.068	0.043	0.031
Beryllium (mg/L)						<0.0001		
Bismuth (mg/L)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005		<0.001	<0.00005
Boron (mg/L)						0.12		
Cadmium (mg/L)						<0.0001		
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.003	0.006
Cobalt (mg/L)	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.001
Copper (mg/L)	0.006	0.005	<0.001	0.008	0.034	0.005	0.007	0.004
Iron (mg/L)								
Lead (mg/L)						<0.001		
Manganese (mg/L)						0.007		
Mercury (mg/L)						<0.00005		
Molybdenum (mg/L)	0.003	0.004	<0.001	0.018	<0.001		0.006	0.003

Table B.5: South Pit groundwater quality monitoring and sampling results

Location Type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Sub Area	South Pit	South Pit	South Pit	South Pit	South Pit	South Pit	South Pit	South Pit
Location ID	BAWBR2	BAWBR2	BAWBR2	BAWBR2	BAWBR2	BAWBR3	BAWBR3	BAWBR3
Date	10/01/2021	5/04/2021	7/07/2022	26/07/2022	24/01/2023	10/09/2016	24/03/2019	24/01/2023
Purpose	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring	EA Monitoring
Nickel (mg/L)	0.002	<0.001	<0.001	0.002	0.006	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.003	<0.01	<0.01
Silicon (mg/L)								
Uranium (mg/L)	0.003	0.012	0.008	0.143	0.003		0.002	0.004
Vanadium (mg/L)						0.003		
Zinc (mg/L)						0.046		
Metals (total)								
Aluminium (mg/L)								
Arsenic (mg/L)	0.002	0.001	0.002	0.003	0.006	<0.003	0.002	0.002
Barium (mg/L)	0.067	0.101	0.114	0.134	0.069	0.068	0.068	0.031
Beryllium (mg/L)						<0.0001		
Bismuth (mg/L)	<0.00005	<0.00005	<0.00005	<0.00005	0.0002		<0.001	<0.00005
Boron (mg/L)						0.12		
Cadmium (mg/L)						0.0002		
Chromium (mg/L)	0.001	<0.001	<0.001	0.001	0.002	<0.001	0.006	0.005
Cobalt (mg/L)	0.002	<0.001	0.001	<0.001	0.003	<0.001	0.002	0.002
Copper (mg/L)	0.015	0.009	0.011	0.034	0.22	0.009	0.022	0.006
Iron (mg/L)								
Lead (mg/L)						<0.001		
Manganese (mg/L)						0.006		
Mercury (mg/L)						<0.00005		
Molybdenum (mg/L)	0.004	0.004	0.016	0.017	0.001		0.007	0.004
Nickel (mg/L)	0.004	0.001	0.002	0.007	0.008	<0.001	0.002	<0.001
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.003	<0.01	<0.01
Silicon (mg/L)								
Uranium (mg/L)	0.004	0.013	0.126	0.156	0.007		0.003	0.005
Vanadium (mg/L)						0.003		
Zinc (mg/L)						0.061		

Table B.6 WRD Sediment Dam water quality monitoring and sampling results

Table B.6: WRD Sediment Dam water quality monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam
Location ID	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam
Date	11/02/2020	22/02/2020	5/10/2020	24/01/2021	18/04/2021	18/07/2021	19/08/2021	19/09/2021	5/10/2021	2/11/2021	8/02/2022	28/03/2022	12/06/2022	20/08/2022
Purpose	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM
Physico-Chemical Parameters														
Turbidity (NTU)	1.9	0.5	1.3	1.5	0.4	0.6	1	0.6	0.7	1.4	1.4	1.3	0.6	1
Biochemical Oxygen Demand (mg/L)														
Electrical Conductivity @ 25°C (µS/cm)	739	1060	3310	990	1080	1350	1610	1500	1720	1610	1080	1270	1470	1460
pH - Lab (pH Units)	8	8.03	7.93	7.55	7.86	8.12	8.6	7.6	8.65	8.15	7.83	8.52	8.17	8.26
Total Dissolved Solids (mg/L)														
Total Suspended Solids (mg/L)														
Hardness														
Total Hardness as CaCO3 (mg/L)	215	268		311			514	517						
Major Ions														
Calcium (mg/L)	50	61	290	75	86	127	125	123	131	124	80	78	90	96
Magnesium (mg/L)	22	28	124	30	35	48	49	51	54	54	40	43	55	59
Sodium (mg/L)	48	59	252	67	76	104	108	115	130	132	92	106	148	167
Potassium (mg/L)	16	24	84	23	23	30	32	39	40	36	24	24	32	34
Chloride (mg/L)	15	26	100	26	24	35	39	36	44	40	27	34	39	44
Sulphate (as SO4) (mg/L)	168	183	729	247	361	440	590	538	521	603	396	423	521	639
Fluoride (mg/L)	0.6	0.8	2.6	0.7	0.9	1.2	1.5	1.3	1.6	1.4	0.7	1	1.2	1.3
Iodide (mg/L)											<0.05	<0.1		
Bromide (mg/L)											0.11	0.21		
Alkalinity														
Carbonate Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1			14	<1	14	<1	<1	10	<1	<1
Carbonate Alkalinity as CO3 (mg/L)														
Hydroxide Alkalinity as CaCO3 (mg/L)	<1	<1	<1	<1			<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3 (mg/L)	70	70	67	50			38	62	42	52	53	63	78	90
Total Alkalinity as CaCO3 (mg/L)	70	70	67	50			52	62	56	52	53	73	78	90
Ion Balance														
Ionic Balance (%)	12.2	17.9	32.3	17.1			4.51	9.66	14.4	8.03	8.35	5.99	9.29	4.21
Total Anions (meq/L)	5.32	5.94	19.3	6.88			14.4	13.4	13.2	14.7	10.1	11.2	13.5	16.3
Total Cations (meq/L)	6.8	8.53	37.8	9.71			15.8	16.3	17.6	17.3	11.9	12.6	16.3	17.8
Microbiological														
Escherichia coli (cfu/100ml)														
Nutrients														
Nitrate as N (mg/L)							34.6	33.6			17.3	18.8		
Nitrite + Nitrate as N (mg/L)							35.3	34.1			17.6	19.3		
Nitrite as N (mg/L)							0.65	0.46			0.29	0.55		
Total Kjeldahl Nitrogen as N (mg/L)														
Total Nitrogen as N (mg/L)														
Total Phosphorus as P (mg/L)														
Metals (dissolved)														
Aluminium (mg/L)														
Arsenic (mg/L)	0.003	0.003	0.005	0.002	0.004	0.004	0.004	0.006	0.004	0.004	0.004	0.003	0.003	0.003
Barium (mg/L)	0.079	0.107	0.139	0.082	0.081	0.105	0.102	0.094	0.11	0.1	0.089	0.101	0.11	0.11
Beryllium (mg/L)							<0.001	<0.001				<0.001		
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)							0.06	0.07				0.06		
Cadmium (mg/L)														
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	0.004	0.008	0.023	0.006	0.008	0.007	0.009	0.013	0.009	0.012	0.006	0.008	0.008	0.008
Iron (mg/L)							<0.05	<0.05				<0.05		
Lead (mg/L)														
Manganese (mg/L)														
Mercury (mg/L)														
Molybdenum (mg/L)	0.022	0.034	0.146	0.032	0.033	0.047	0.05	0.058	0.061	0.054	0.034	0.037	0.047	0.05

Table B.6: WRD Sediment Dam water quality monitoring and sampling results

Location Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Sub Area	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam
Location ID	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam	Sediment Dam
Date	11/02/2020	22/02/2020	5/10/2020	24/01/2021	18/04/2021	18/07/2021	19/08/2021	19/09/2021	5/10/2021	2/11/2021	8/02/2022	28/03/2022	12/06/2022	20/08/2022
Purpose	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM	ROM
Nickel (mg/L)	0.003	0.003	0.003	0.002	<0.001	<0.001	0.001	0.027	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	0.01	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)														
Uranium (mg/L)	0.004	0.006	0.021	0.005	0.005	0.007	0.007	0.002	0.008	0.007	0.005	0.005	0.007	0.008
Vanadium (mg/L)							<0.01	<0.01				<0.01		
Zinc (mg/L)														
Metals (total)														
Aluminium (mg/L)														
Arsenic (mg/L)	0.002	0.003	0.005	0.002	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.003	0.004	0.003
Barium (mg/L)	0.077	0.103	0.142	0.08	0.074	0.098	0.104	0.106	0.113	0.099	0.088	0.108	0.13	0.12
Beryllium (mg/L)							<0.001	<0.001				<0.001		
Bismuth (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)							0.07	0.07				0.07		
Cadmium (mg/L)														
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (mg/L)	0.002	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	0.013	0.008	0.036	0.013	0.008	0.011	0.01	0.01	0.011	0.017	0.009	0.01	0.01	0.017
Iron (mg/L)							<0.05	<0.05				<0.05		
Lead (mg/L)														
Manganese (mg/L)														
Mercury (mg/L)														
Molybdenum (mg/L)	0.023	0.039	0.156	0.039	0.037	0.05	0.057	0.063	0.069	0.063	0.039	0.042	0.054	0.06
Nickel (mg/L)	0.004	0.002	0.003	0.002	<0.001	0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.01	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon (mg/L)														
Uranium (mg/L)	0.004	0.006	0.023	0.005	0.005	0.007	0.008	0.008	0.008	0.007	0.005	0.006	0.008	0.009
Vanadium (mg/L)							<0.01	<0.01				<0.01		
Zinc (mg/L)														

Appendix C

ATC Williams “Geochemical assessment of the North Pit, South Pit and the WRD Dam” (2023)

MEMORANDUM

TO	Gemma Brown	**COMPANY**	Aeris Resources
FROM	James Parker	**OFFICE**	Brisbane
EMAIL	jamesp@atcwilliams.com.au	**PHONE**	(07) 3352 7222
PROJECT TITLE	Barbara Copper Project		
SUBJECT	Progressive Rehabilitation and Closure Planning - Geochemical assessment of the North Pit, South Pit and the WRD Sediment Dam		
DATE	4 April 2023	**OUR REF**	118131.12.M02

1 BACKGROUND AND SCOPE

1.1 Background

This memorandum is to be read in conjunction with ATCW (2023) **[1]** which details the inputs and results of the post closure water balance model for Barbara Copper Project (the Project).

This technical memorandum details the inputs and results of the geochemical modelling to calculate the expected long term water quality within the North Pit, South Pit and WRD Sediment Dam at the Project.

Results will include:

- Combining the outcomes of the WBM with the results of historical surface water and groundwater quality at the Project.
- Undertake a geochemical assessment to determine the long-term water quality levels in the North Pit, South Pit and WRD Sediment Dam.

Additional commentary and analysis will be undertaken by others to determine if the North Pit, South Pit and the WRD Sediment Dam will be suitable for a post mining land use (PMLU) for stockwater drinking water use or will need to remain as non-use management areas (NUMAs). This commentary and analysis are provided under separate cover.

1.2 Input Data and Reference Guidelines

The following data inputs and reference guidelines were used in the preparation of this assessment:

- Department of Environment and Science (2021), 'Guideline Progressive rehabilitation and closure plans (PRC plans)', ESR/2019/4964, March 2021, version 2.00 **[2]**.
- Department of the Environment and Science (2020), Environmental Authority EPML00715513 (Effective Date 3 February 2020), Queensland Government **[3]**.
- ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia **[4]**.
- Aeris Resources (2022), 'BCP Void Results vs ANZECC Stock Water_2020 – current.xls', 26 April 2022 **[5]**.
- WMV Environmental (2019), 'Barbara Copper Project – Groundwater Characterisation' **[6]**.
- SLR (2021a), 'Barbara Copper Project – Receiving Environment Monitoring Program – Annual Report 2021' **[7]**.
- SLR (2021b), 'Receiving Environment Monitoring Program Barbara – Wet Season 2021' **[8]**.
- SLR (2022), 'Receiving Environment Monitoring Program Barbara – Wet Season 2022' **[9]**.

2 WATER QUALITY INPUTS

2.1 Stored Water Quality

Water quality sampling within the North Pit **[5],** South Pit **[5]** and WRD Sediment Dam **[5]** has been undertaken up to ten (10) times between 2020 and 2022. Sampling was undertaken within each structure, with the North Pit being sampled nine (9) times, the South Pit four (4) times and WRD Sediment Dam sampled fourteen (14) times.

A review of sampling data found the following:

- North Pit
  - All sampled analytes were within the ANZECC stock water limits.
- South Pit
  - All sampled analytes were within the ANZECC stock water limits.
- WRD Sediment Dam
  - With the exception of October 2020, all sampled analytes were within the ANZECC stock water limits.
  - The October 2020 sample indicated an EC level of 3,310 µs/cm, exceeding the ANZECC stockwater limit of 2,680 µs/cm. Since that time however, EC levels have varied between 990 µs/cm and 1,720 µs/cm and the 3,310 µs/cm is likely to represent an anomaly **[4]**.
  - The October 2020 sample indicated a fluoride level of 2.6 mg/L, exceeding the ANZECC stockwater limit of 2.0 mg/L. Since that time however, fluoride levels have varied between 0.7 mg/L and 1.6 mg/L, and the 2.6 mg/L is likely to represent an anomaly **[4]**.
  - As part of the closure and rehabilitation, the capping of the WRD will result in an expected improvement in water quality outcomes. Additionally, the WRD Sediment Dam will be emptied of mine impacted waters prior to handover to the landowner.

A summary of the sampled data from October 2020 to March 2022 for the North Pit, South Pit and WRD Sediment Dam are summarised in **TABLE 1**, **TABLE 2** and **TABLE 3**, respectively. These results have been summarised in **TABLE 4** as the initial conditions for the geochemical modelling undertaken.

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TABLE 1: NORTH PIT WATER QUALITY DATA

Quality Parameter	Unit	ANZECC Stock Water Limit	Sampling Date					
			5/10/20	24/01/21	18/04/21	18/07/21	02/11/21	28/03/22
pH Value	pH Unit	5.0 - 9.0	8.13	7.85	8	8.13	8.14	8.16
EC	µS/cm	2,680	1,240	850	1,100	12,60	1,360	1,720
Turbidity	NTU	N/A	0.6	3.4	1.1	0.3	0.7	0.6
Sulfate as SO_4	mg/L	1,000	218	277	410	495	583	359
Chloride	mg/L	N/A	42	16	17	19	21	0.002
Dissolved Major Cations								
Calcium	mg/L	1,000	72	57	98	127	128	79
Magnesium	mg/L	N/A	40	26	33	42	43	30
Sodium	mg/L	N/A	156	81	82	101	111	74
Potassium	mg/L	N/A	23	15	27	32	33	22
Dissolved Metals								
Arsenic	mg/L	0.5	<0.001	0.001	0.003	0.003	0.003	<0.001
Barium	mg/L	N/A	0.08	0.093	0.053	0.042	0.041	0.057
Beryllium	mg/L	N/A	-	-	-	-	-	<0.001
Bismuth	mg/L	N/A	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	mg/L	1	<0.001	<0.001	<0.001	<0.001	<0.001	0.018
Cobalt	mg/L	1	0.002	<0.001	0.005	0.004	0.004	0.016
Copper	mg/L	1	0.054	0.015	0.04	0.041	0.041	0.005
Molybdenum	mg/L	0.15	0.011	0.006	0.014	0.019	0.02	<0.01
Nickel	mg/L	1	0.018	0.011	0.009	0.01	0.01	0.004
Selenium	mg/L	0.02	0.01	0.02	0.01	<0.01	<0.01	<0.01
Uranium	mg/L	0.2						<0.05
Vanadium	mg/L	N/A	0.014	0.004	0.003	0.006	0.007	<0.05
Boron	mg/L	5	-	-	-	-	-	-
Iron	mg/L	N/A	-	-	-	-	-	-
Other								
Fluoride	mg/L	2	1.9	1	1.5	1.6	1.6	1.4
Nitrite as N	mg/L	30	-	-	-	-	-	<0.01
Nitrate as N	mg/L	400	-	-	-	-	-	0.09

TABLE 2: SOUTH PIT WATER QUALITY DATA

Quality Parameter	Unit	ANZECC Stock Water Limit	Sampling Date		
			18/04/2021	18/07/2021	02/11/2021
pH Value	pH Unit	5.0 - 9.0	8.11	8.1	8.09
EC	µS/cm	2,680	1,380	1,630	1,520
Turbidity	NTU	N/A	0.7	0.8	1
Sulfate as SO_4	mg/L	1,000	580	683	713
Chloride	mg/L	N/A	23	27	22
Dissolved Major Cations					
Calcium	mg/L	1,000	125	169	153
Magnesium	mg/L	N/A	52	66	60
Sodium	mg/L	N/A	93	114	101
Potassium	mg/L	N/A	31	32	25
Dissolved Metals					
Arsenic	mg/L	0.5	0.004	0.007	0.006
Barium	mg/L	N/A	0.045	0.04	0.04
Beryllium	mg/L	N/A	-	-	-
Bismuth	mg/L	N/A	<0.001	<0.001	<0.001
Chromium	mg/L	1	<0.001	<0.001	<0.001
Cobalt	mg/L	1	0.005	0.016	0.012
Copper	mg/L	1	0.023	0.018	0.012
Molybdenum	mg/L	0.15	0.047	0.054	0.043
Nickel	mg/L	1	0.013	0.031	0.024
Selenium	mg/L	0.02	<0.01	<0.01	<0.01
Uranium	mg/L	0.2	-	-	-
Vanadium	mg/L	N/A	0.008	0.01	0.008
Boron	mg/L	5	-	-	-
Iron	mg/L	N/A	-	-	-
Other					
Fluoride	mg/L	2	1.4	1.3	1.1
Nitrite as N	mg/L	30	-	-	-
Nitrate as N	mg/L	400	-	-	-

TABLE 3: WRD SEDIMENT WATER QUALITY DATA

Quality Parameter	Unit	ANZECC Stock Water Limit	Sampling Date									
			5/10/2020	24/01/2021	18/04/2021	18/07/2021	19/08/2021	19/09/2021	05/10/2021	02/11/2021	08/02/2022	28/03/2022
pH Value	pH Unit	5.0 - 9.0	7.93	7.55	7.86	8.12	8.6	7.6	8.65	8.15	7.83	8.52
EC	µS/cm	2,680	3,310	990	1,080	1,350	1,610	1,500	1,720	1,610	1,080	1,720
Turbidity	NTU	N/A	1.3	1.5	0.4	0.6	1	0.6	0.7	1.4	1.4	1.3
Sulfate as SO_4	mg/L	1,000	729	247	361	440	590	538	521	603	396	423
Chloride	mg/L	N/A	100	26	24	35	39	36	44	40	27	0.003
Dissolved Major Cations												
Calcium	mg/L	1,000	290	75	86	127	125	123	131	124	80	78
Magnesium	mg/L	N/A	124	30	35	48	49	51	54	54	40	43
Sodium	mg/L	N/A	252	67	76	104	108	115	130	132	92	106
Potassium	mg/L	N/A	84	23	23	30	32	39	40	36	24	24
Dissolved Metals												
Arsenic	mg/L	0.5	0.005	0.002	0.004	0.004	0.004	0.006	0.004	0.004	0.004	<0.001
Barium	mg/L	N/A	0.139	0.082	0.081	0.105	0.102	0.094	0.11	0.1	0.089	0.101
Beryllium	mg/L	N/A	-	-	-	-	-	-	-	-	-	<0.001
Bismuth	mg/L	N/A	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	mg/L	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.008
Cobalt	mg/L	1	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	0.037
Copper	mg/L	1	0.023	0.006	0.008	0.007	0.009	0.013	0.009	0.012	0.006	<0.001
Molybdenum	mg/L	0.15	0.146	0.032	0.033	0.047	0.05	0.058	0.061	0.054	0.034	<0.01
Nickel	mg/L	1	0.003	0.002	<0.001	<0.001	0.001	0.027	<0.001	<0.001	0.001	0.005
Selenium	mg/L	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Uranium	mg/L	0.2	-	-	-	-	-	-	-	-	-	0.06

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Quality Parameter	Unit	ANZECC Stock Water Limit	Sampling Date									
			5/10/2020	24/01/2021	18/04/2021	18/07/2021	19/08/2021	19/09/2021	05/10/2021	02/11/2021	08/02/2022	28/03/2022
Vanadium	mg/L	N/A	0.021	0.005	0.005	0.007	0.007	0.002	0.008	0.007	0.005	<0.05
Boron	mg/L	5	-	-	-	-	-	-	-	-	-	-
Iron	mg/L	N/A	-	-	-	-	-	-	-	-	-	-
Other												
Fluoride	mg/L	2	2.6	0.7	0.9	1.2	1.5	1.3	1.6	1.4	0.7	1
Nitrite as N	mg/L	30	-	-	-	-	0.65	0.46	-	-	0.29	0.55
Nitrate as N	mg/L	400	-	-	-	-	34.6	33.6	-	-	17.3	18.8

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TABLE 1: INITIAL WATER QUALITY VALUES

Quality Parameter	Unit	North Pit	South Pit	WRD Sediment Dam
pH Value	pH Unit	8.07	8.09	8.22
EC	µS/cm	1020.3	1447.5	1540.0
Turbidity	NTU	1.0	0.68	1.06
Sulfate as SO_4	mg/L	337.3	625.8	511.8
Chloride	mg/L	35.9	21.5	31.0
Dissolved Major Cations				
Calcium	mg/L	81.89	140.25	110.16
Magnesium	mg/L	31.44	58.25	48.50
Sodium	mg/L	91.56	96.00	113.83
Potassium	mg/L	22.56	27.25	32.50
Dissolved Metals				
Arsenic	mg/L	0.002	0.006	0.004
Barium	mg/L	-	-	-
Beryllium	mg/L	-	-	-
Bismuth	mg/L	-	-	-
Chromium	mg/L	<0.001	<0.001	0.008
Cobalt	mg/L	0.003	0.009	0.020
Copper	mg/L	0.042	0.029	0.010
Molybdenum	mg/L	0.015	0.051	0.051
Nickel	mg/L	0.010	0.020	0.009
Selenium	mg/L	0.02	-	0.01
Uranium	mg/L	0.006	0.009	0.060
Vanadium	mg/L	-	-	0.006
Boron	mg/L	-	-	-
Iron	mg/L	-	-	-
Other				
Fluoride	mg/L	1.50	1.45	1.25
Nitrite as N	mg/L	-	-	0.49
Nitrate as N	mg/L	-	-	26.07

2.2 Groundwater Quality

Based on the monitoring and analysis results obtained from the groundwater monitoring program undertaken in accordance with the EA requirements **[6]**,**[8]**,**[9],** the analyte inputs for the groundwater into the North Pit and South Pit are detailed in **TABLE 5**.

TABLE 5: GROUNDWATER QUALITY INPUTS

Quality Parameter	Unit	North Pit	South Pit
pH Value	pH Unit	7.6	7.9
EC	µS/cm	969.5	2916.1
Turbidity	NTU	8.26	7.17
Sulfate as SO_4	mg/L	41.27	446.75
Chloride	mg/L	27.2	281.5
Dissolved Major Cations			
Calcium	mg/L	54.28	54.88
Magnesium	mg/L	37.26	81.25
Sodium	mg/L	123.81	534.25
Potassium	mg/L	8.08	6.50
Dissolved Metals			
Arsenic	mg/L	0.018	-
Barium	mg/L	0.003	0.002
Beryllium	mg/L	0.190	0.048
Bismuth	mg/L	-	-
Chromium	mg/L	0.002	0.003
Cobalt	mg/L	0.002	0.002
Copper	mg/L	0.003	0.010
Molybdenum	mg/L	0.003	0.007
Nickel	mg/L	0.002	0.003
Selenium	mg/L	0.003	-
Uranium	mg/L	0.004	0.025
Vanadium	mg/L	0.008	0.003
Boron	mg/L	0.093	0.120
Iron	mg/L	-	-
Other			
Fluoride	mg/L	0.924	0.671
Nitrate as N	mg/L	-	-

2.3 Surface Water Quality

Based on monitoring and analysis results obtained from the surface monitoring program undertaken in accordance with the EA requirements and with the Receiving Environment Monitoring Program **[6]**,**[8]**,**[9]**, the analyte inputs for the surface water runoff into the North Pit and South Pit are detailed in **TABLE 6**.

TABLE 6: SURFACE WATER QUALITY INPUTS

Quality Parameter	Unit	Value
pH Value	pH Unit	8.17
EC	µS/cm	321.57
Turbidity	NTU	46.49
Sulfate as SO_4	mg/L	9.15
Chloride	mg/L	15.50
Dissolved Major Cations		
Calcium	mg/L	54.28
Magnesium	mg/L	37.26
Sodium	mg/L	123.81
Potassium	mg/L	8.08
Dissolved Metals		
Arsenic	mg/L	0.018
Barium	mg/L	0.003
Beryllium	mg/L	0.190
Bismuth	mg/L	-
Chromium	mg/L	0.002
Cobalt	mg/L	0.002
Copper	mg/L	0.003
Molybdenum	mg/L	0.003
Nickel	mg/L	0.002
Selenium	mg/L	0.003
Uranium	mg/L	0.004
Vanadium	mg/L	0.008
Boron	mg/L	0.093
Iron	mg/L	-
Other		
Fluoride	mg/L	0.924
Nitrite as N	mg/L	-
Nitrate as N	mg/L	-

3 WATER QUALITY ASSESSMENT

ATCW undertook geochemical assessment based upon sampled water quality results and the WBM detailed in ATCW (2023) **[1].** This was undertaken to inform the consequence assessment on the potential for contamination of waters accumulating in the North Pit, South Pit and WRD Sediment Dam and potential impact to groundwater and surface water.

3.1 Model Setup

A Phreeqc (USGS, ver. 3.6.2.15100) geochemical model (Llnl database) was linked to the water balance simulation to evaluate the mixing of different water types from **DIAGRAM 1**. Two main scenarios were considered in which equilibrium of the water chemistry with the mineral phase (gypsum) was either included or not in the simulation. As a consequence, if calcium and sulphate concentrations are sufficiently elevated, precipitation of gypsum could occur, and this was included in one of the simulations. No additional gypsum was applied within the model to induce precipitation. Due to the linking of the geochemical model to the water balance simulation, three probabilities were evaluated: the median inflow and outflow conditions, and the interquartile range of probabilities at 25% and 75%. These ranges were selected to illustrate the variation in pit void geochemistry. Higher probabilities for the site were not considered since increased rainfall and groundwater discharge into the pit void and lower evaporation rates would result in an improved water quality and represents a lower risk to the downstream environment or closure condition.

A geochemical model is beneficial in simulating the potential pit void chemistry and allows for the investigation of different options. To simplify the assessment, an equilibrium reaction with gypsum was the only parameter considered relevant for loss of solids from solution in the pit void

In general, surface water inflow into the pit void was equilibrated with standard atmosphere conditions (CO_2(g) -3.2, O_2(g) 0.67)) and groundwater with carbonate (CO_2(g) -1.5) to maintain the pH values of site water quality solutions used in this assessment.

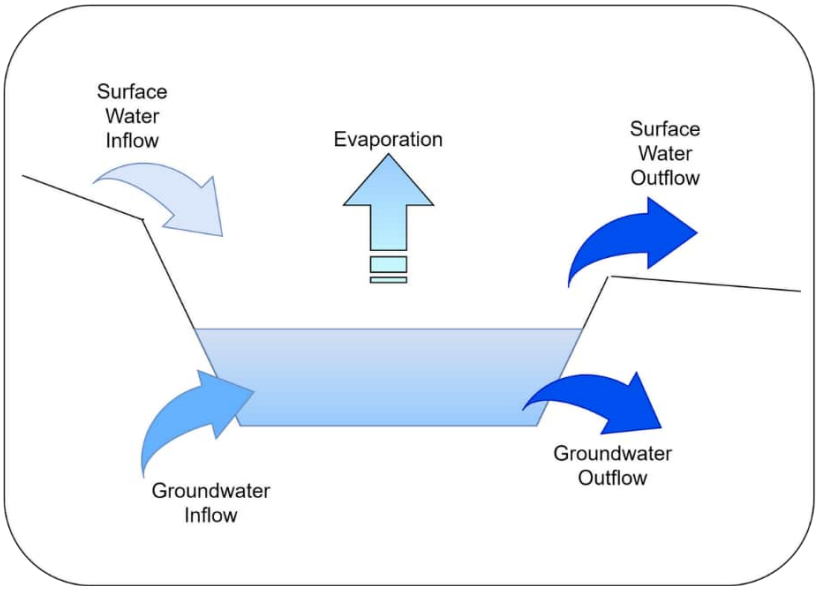
The model assumes that no stratification occurs within the pit void, this simplified the assessment and reduced the number of parameters to consider in the model. The results generated are reflective of bulk water chemistry. Bulk water chemistry in the pit directly relates to the potential outflow water quality to either groundwater or surface water receptors at each step for the model. Assessment of potential stratification in the open pits has been undertaken by WMV Environmental **[10]** and found there was seasonal stratification potential.

The concentration values of the pit void solution are defined by the fractions of inflow water from surface water, groundwater, and resident pit void water components. Mixing of these solutions is completed before concentration due to evaporative losses is completed, effectively concentrating the solution due to a reduction in water content. The mixed solution can either be assessed with or without equilibrium phases that include gypsum. The resulting solution represents the pit void water quality that can outflow to either surface water or groundwater.

3.2 Pit Chemistry and Mass Loading

The water balance model output was evaluated using a total mixing model for the North Pit and South Pit Voids and for the WRD Sediment Dam. It included assigning average water quality parameters for surface water inflow and groundwater. The concentration value for the pit void solution was obtained by considering the mass gained from inflows as well as evaporative losses, as shown on **DIAGRAM 1**. Mass loss in the mass balance model included outflows into the surface water and groundwater aquifer system. It is noted that groundwater inflow/outflow is not considered for the WRD sediment Dam, due to the presence of the HDPE liner.

DIAGRAM 1: WATER BALANCE MODEL AND GEOCHEMICAL PROCESS DIAGRAM



3.2.1 Geochemical Model and Parameters

Geochemical parameters for the inflowing surface water and groundwater were obtained from site sampling **[5]**. Runoff from rainfall is the primary input to the accumulation of waters and analytes in the North Pit, South Pit and WRD Sediment Dam. General chemical parameters are listed in **TABLE 7**.

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TABLE 7: SUMMARY OF PARAMETERS FOR GEOCHEMICAL MODEL

Analyte	Unit	Groundwater		Surface Water
		North Pit	South Pit	All Structures
pH	pH unit	7.60	7.91	8.16
EC	µS/cm	969.6	2,916.1	321.6
TDS	mg/L	593.3	593.3	455
SO_4	mg/L	41.3	446.8	9.15
Chloride	mg/L	27.2	281.5	15.5
Calcium	mg/L	54.3	54.9	20.9
Magnesium	mg/L	37.3	81.3	12.5
Sodium	mg/L	123.8	534.25	31.4
Potassium	mg/L	8.1	6.5	10.7
Arsenic	mg/L	0.003	0.002	0.0015
Barium	mg/L	0.19	0.05	0.03
Chromium	mg/L	0.0015	0.003	-
Cobalt	mg/L	0.0017	0.0015	-
Copper	mg/L	0.0034	0.0098	0.004
Molybdenum	mg/L	0.0029	0.0068	0.001
Nickel	mg/L	0.0019	0.004	-
Selenium	mg/L	0.003	0.003	-
Uranium	mg/L	0.0043	0.044	0.002
Iron	mg/L	0.537	0.537	-

3.3 Model Results and Summary – North Pit

To evaluate the geochemistry, the general water balance for the North Pit is presented in **DIAGRAM 2A**. The total groundwater flux is illustrated in **DIAGRAM 2B**, while the total surface water flux is presented in **DIAGRAM 2C** with a downward trend beyond 2035. The surface water flux dominates the water balance in the pit void. Groundwater outflows are included; however, the annual volumes

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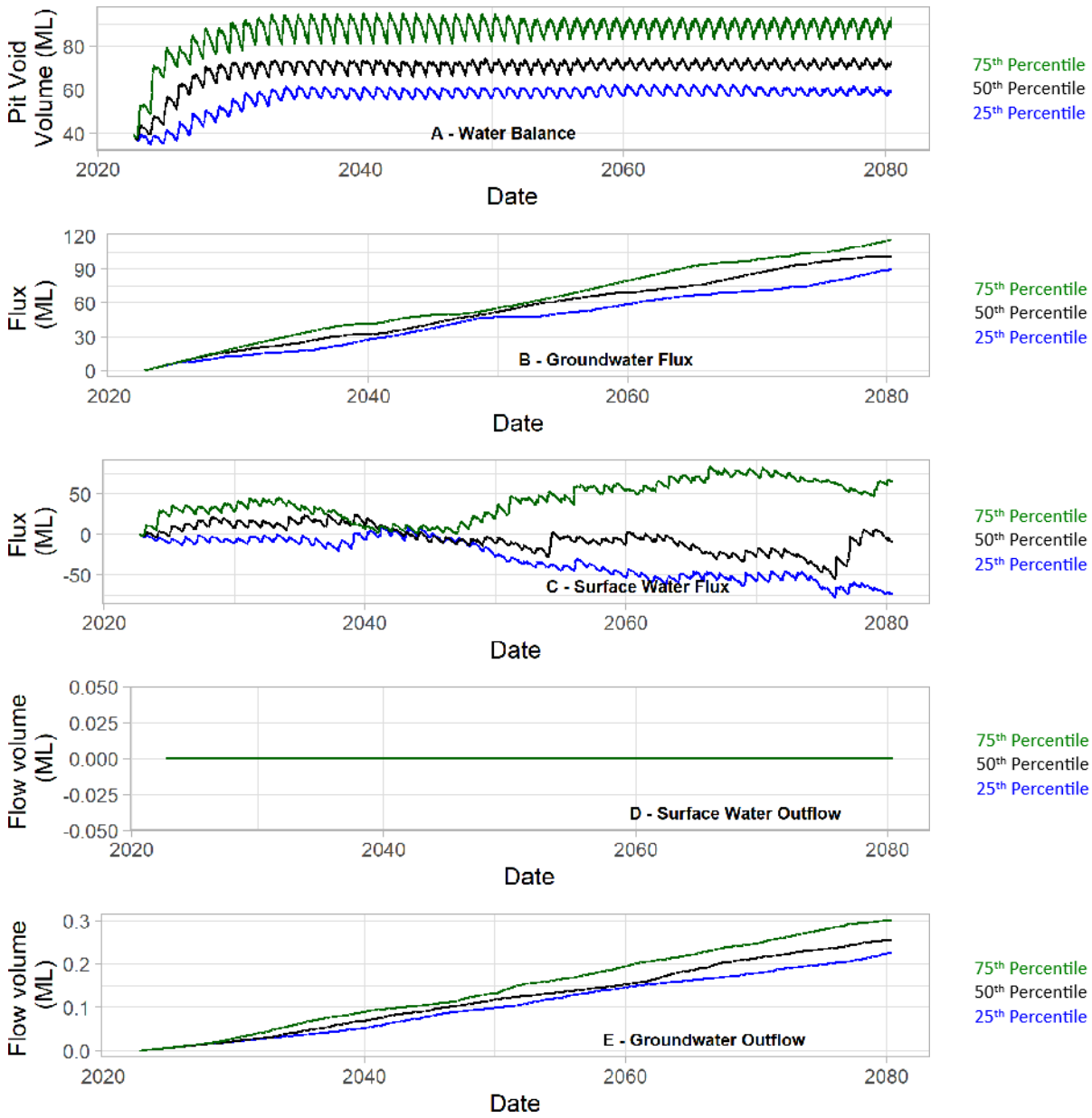
are less than 0.004 ML. Outflows for surface water were run, for the 25th, 50th and 75th percentiles, totaling 0.2 ML, 0.25 and 0.3 ML for the P25, P50 and P75 scenarios at the year 2083.

The geochemical model was developed in association with the water balance model and limited influence of water chemistry was observed. The equilibrium with gypsum influenced the concentration values. It is expected that precipitation of gypsum within the pit void is likely. The pit water quality is influenced by evaporative losses and connectivity with either surface water or groundwater sources. Long term behaviour of the pit void is expected to reflect slightly elevated concentration values compared to the groundwater water quality but can range from surface water to groundwater quality ranges with reduced evaporation potential.

DIAGRAM 2: NORTH PIT BALANCE OVER TIME



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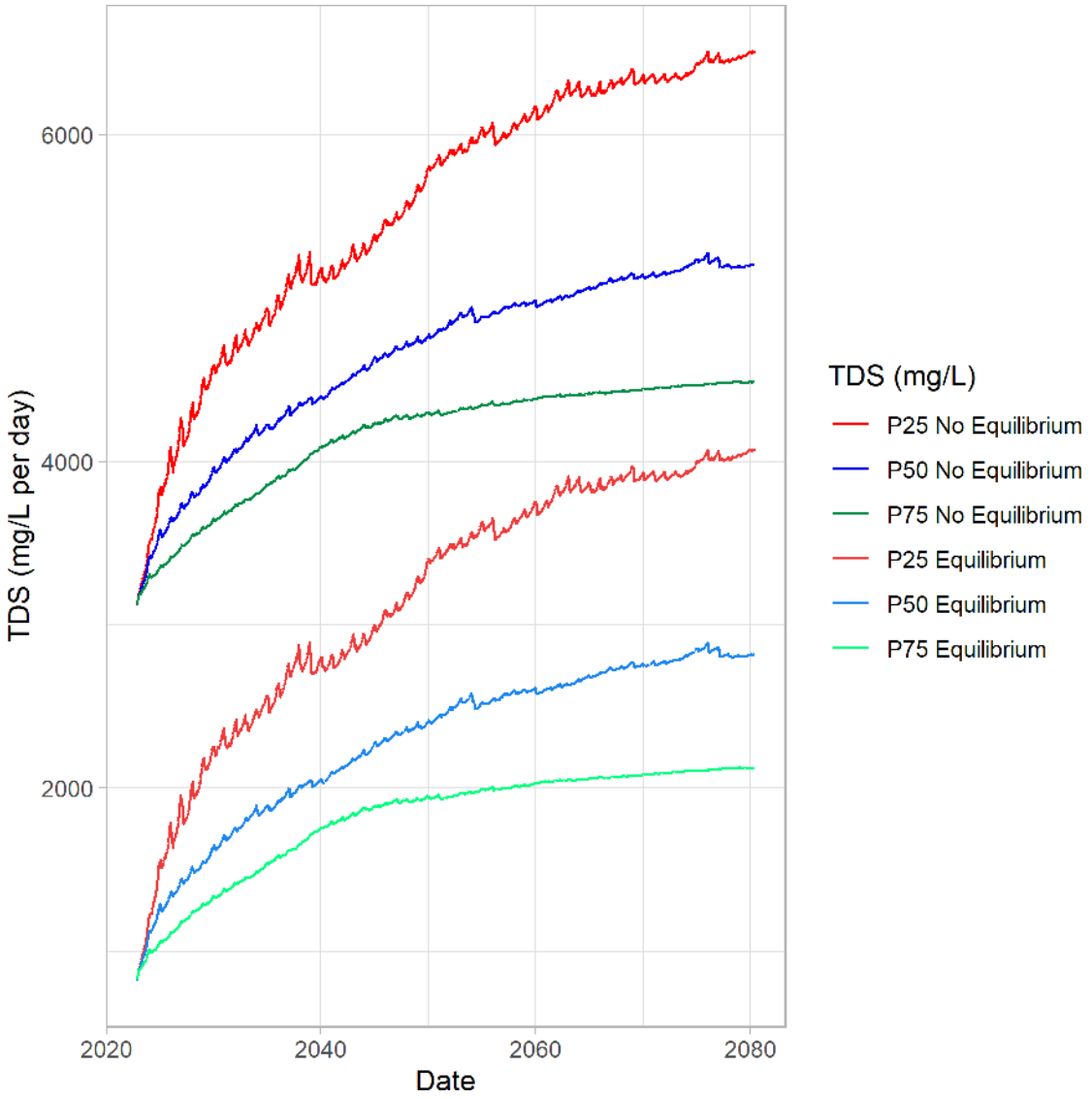
3.3.1 Total Dissolved Solids

The total dissolved solids (TDS) content was evaluated, and the results are illustrated in **DIAGRAM 3**.

The influence of the gypsum equilibrium is evident with an average water quality for the non-equilibrated solution in the order of 4,200 mg/L to 6,300 mg/L for all probability scenarios at 2085. In general, high rainfall periods equate to a reduction in TDS, in this process the gypsum equilibrium does not influence water quality, but the influx of surface water can be observed as a reduction in TDS while extended dry spells result in an increase in the TDS.

With the addition of the gypsum equilibrating in solution, a reduction of the average water quality is in the order of 2,100 mg/L to 4,100 mg/L at 2085. The range is reflective of the anticipated pit water quality and would indicate that the geochemical process controls the upper TDS limit in the surrounding aquifer.

DIAGRAM 3: TOTAL DISSOLVED SOLIDS (MG/L) CONTENT FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE



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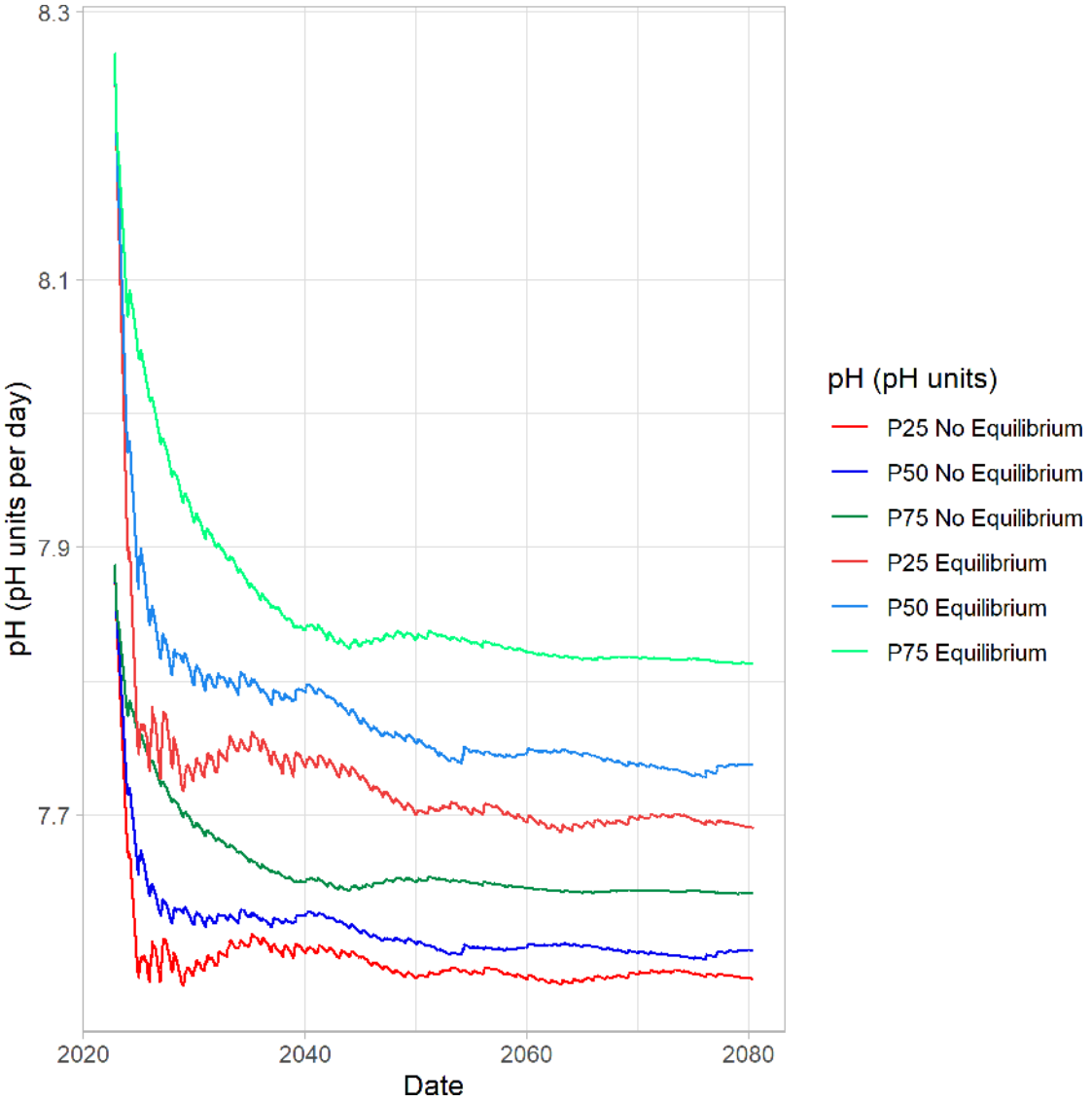
3.3.2 pH Influence

Open pit water quality is alkaline to circum-neutral in both the equilibrated and non-equilibrium scenarios. In the equilibrated scenarios water quality pH values tend toward the surface water quality pH with the non- equilibrated scenarios lagging, but with the same trend as shown on **DIAGRAM 4**.

DIAGRAM 4: pH OF WATER BALANCE MODEL FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE



3.3.3 Macrochemical Components

Macrochemical composition of pit void water is dominated by calcium and sulphate components as shown on **DIAGRAM 5**, with observed changes in concentration a result of the equilibrium with gypsum. The distinct variation is however not reflected in the sodium, potassium, or magnesium cation composition as shown on **DIAGRAM 6.** There is limited potential to form halite ($NaCl$),

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magnesite ($MgCO_3$) or bischofite ($MgCl_2$). The potential for secondary mineral formation is further suppressed by the flow through mechanism in the pit void. Concentrations slowly increase towards 2060 before stabilising.

DIAGRAM 5: CALCIUM AND SULPHATE CONCENTRATION VALUES (mg/L) FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE.

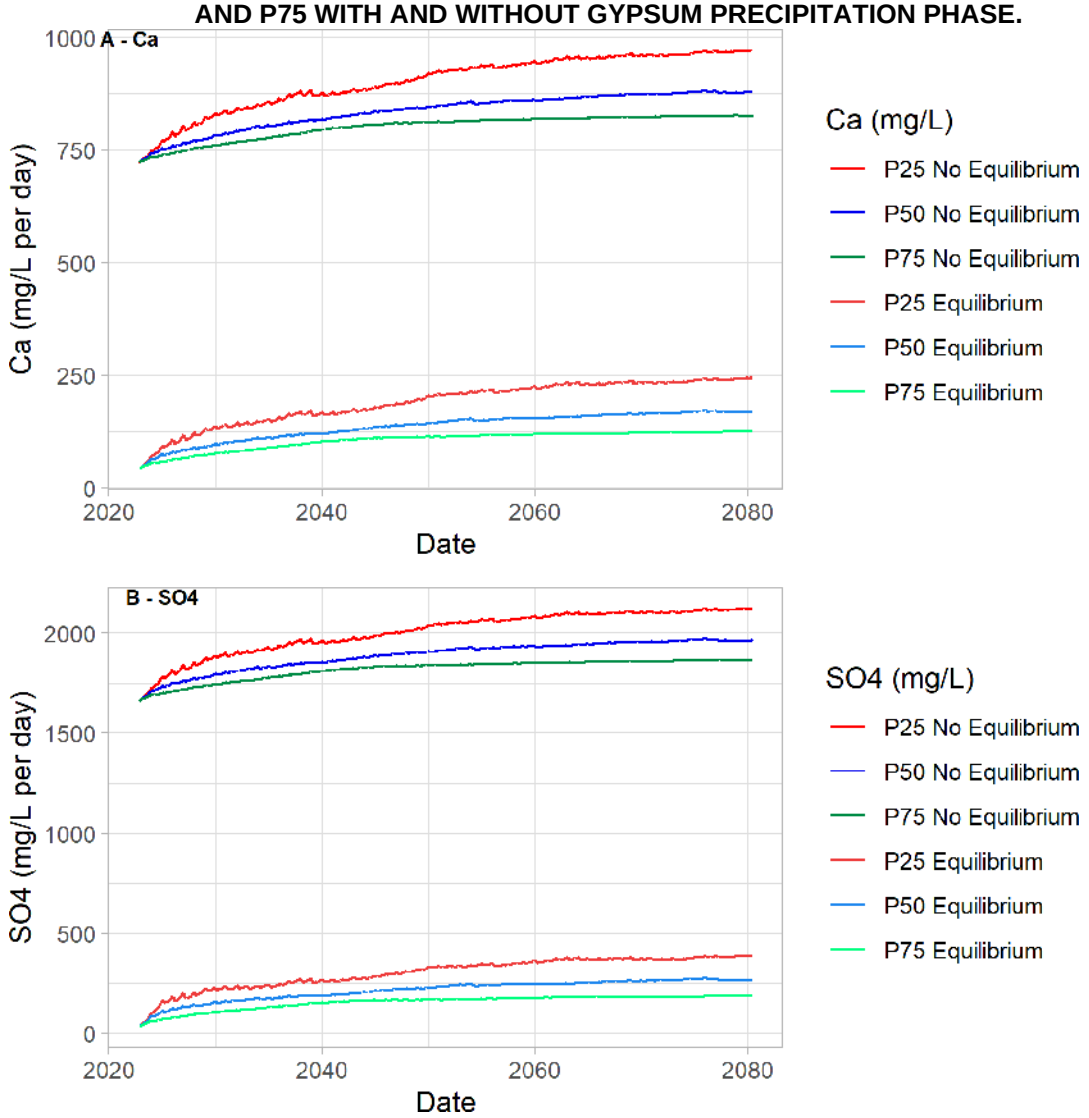

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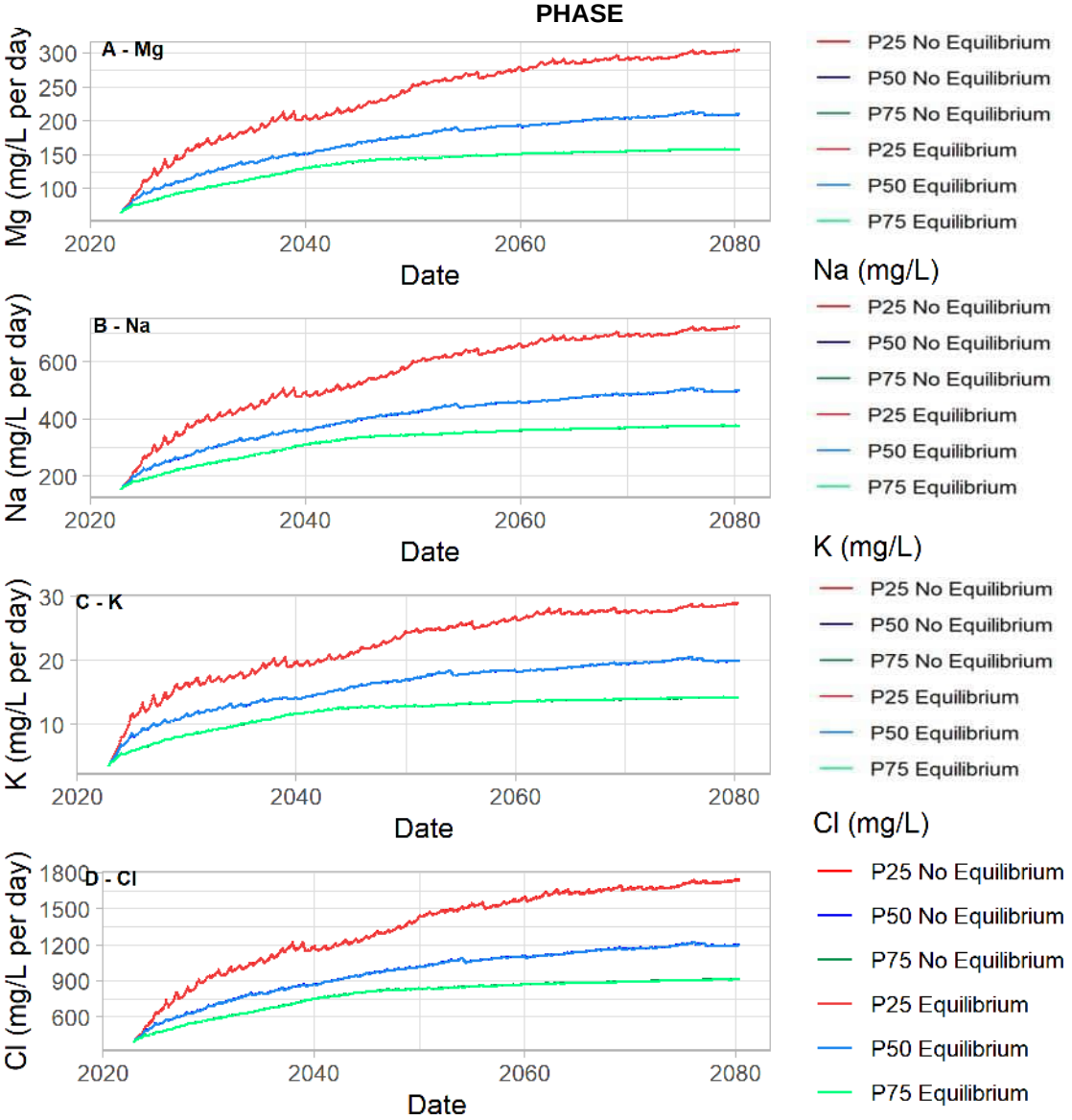
DIAGRAM 6: MAGNESIUM, SODIUM, POTASSIUM AND CHLORINE CONCENTRATION VALUES (mg/L) FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE



3.3.4 Metal(loid) Components

The metal(loid) solubility mimics that of the macrochemical species in that concentration levels within the simulated period varies with inflow and evaporation effects as shown on **DIAGRAM 7**. As no surface adsorption or inclusion of metal(loid)s with gypsum mineral formation has been modelled, limited variation in concentration values can be observed in both models. In general, the pit void solution is undersaturated with these components and advection from groundwater inflows is a major factor in controlling concentration ranges.

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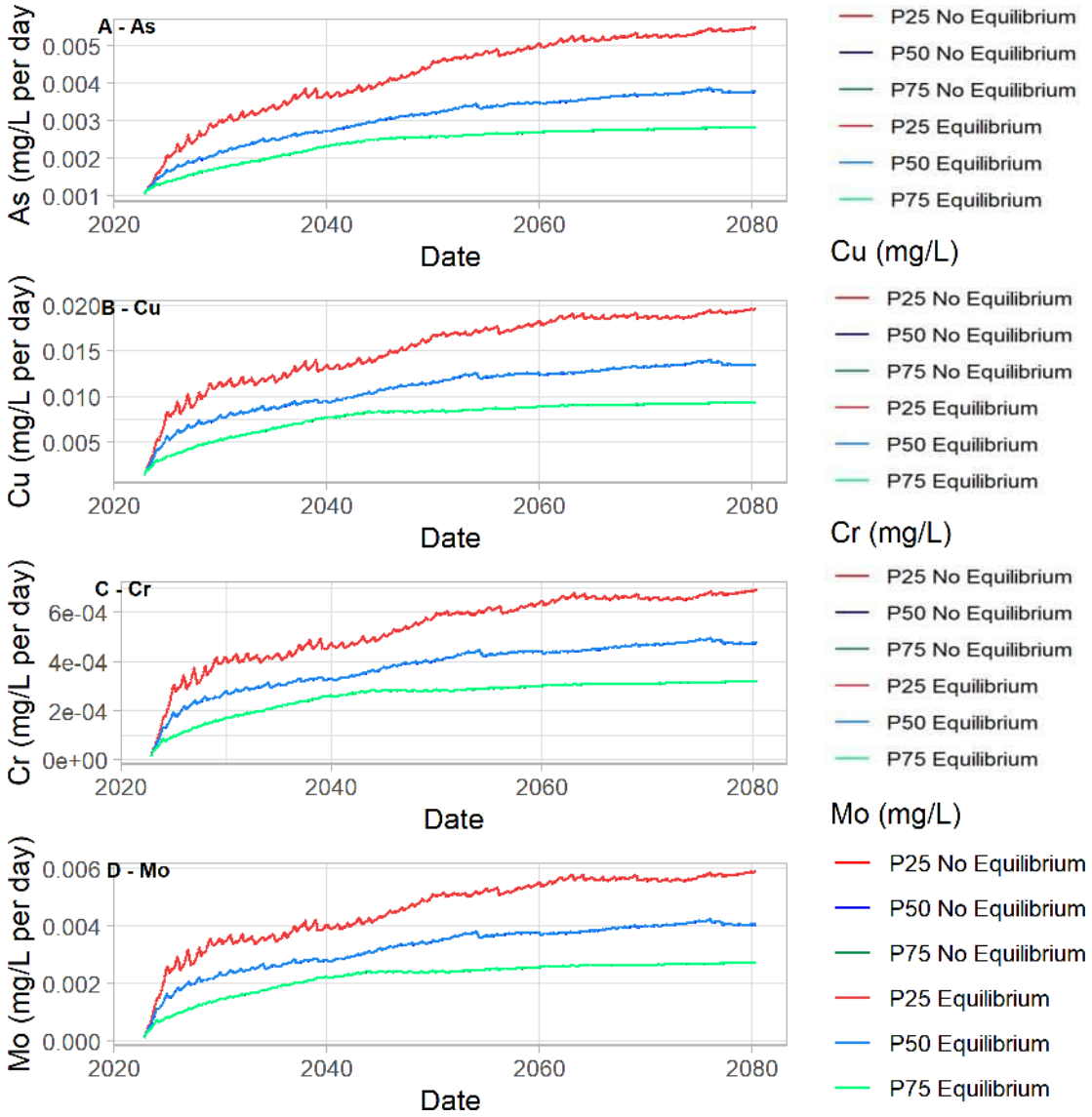
DIAGRAM 7: ARSENIC, COPPER, CHROMIUM AND MOLYBDENUM CONCENTRATION VALUES (mg/L) FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE



3.3.5 Conclusion

The geochemical model was developed in association with the water balance model. The equilibrium with gypsum influenced the concentration values. Precipitation of gypsum within the pit void is considered likely. The pit water quality is influenced by evaporative losses and connectivity with either the surface water or groundwater source depending on probability distribution applied. Long term behaviour of the pit void is expected to reflect an increase in concentration values compared to the groundwater water quality but can range from surface water, groundwater and elevated saline water quality with reduced evaporation potential.

3.4 Model Results and Summary – South Pit – Scenario 1

To evaluate the geochemistry, the general water balance for the South Pit is presented in **DIAGRAM 8A**. The total groundwater flux is illustrated in **DIAGRAM 8B**, while the total surface water flux is presented in **DIAGRAM 8C** with a downward trend beyond 2035. The surface water flux dominates the water balance in the pit void. Outflows for surface water and groundwater are included; however, for the 25th, 50th and 75th percentiles, the values equal zero.

The geochemical model was developed in association with the water balance model and limited influence of water chemistry was observed. The equilibrium with gypsum influenced the concentration values. Precipitation of gypsum within the pit void is considered likely. The pit water quality is influenced by evaporative losses and connectivity with either surface water or groundwater sources. Long term behaviour of the pit void is expected to reflect slightly elevated concentration values compared to the groundwater water quality but can range from surface water to groundwater quality ranges with reduced evaporation potential.

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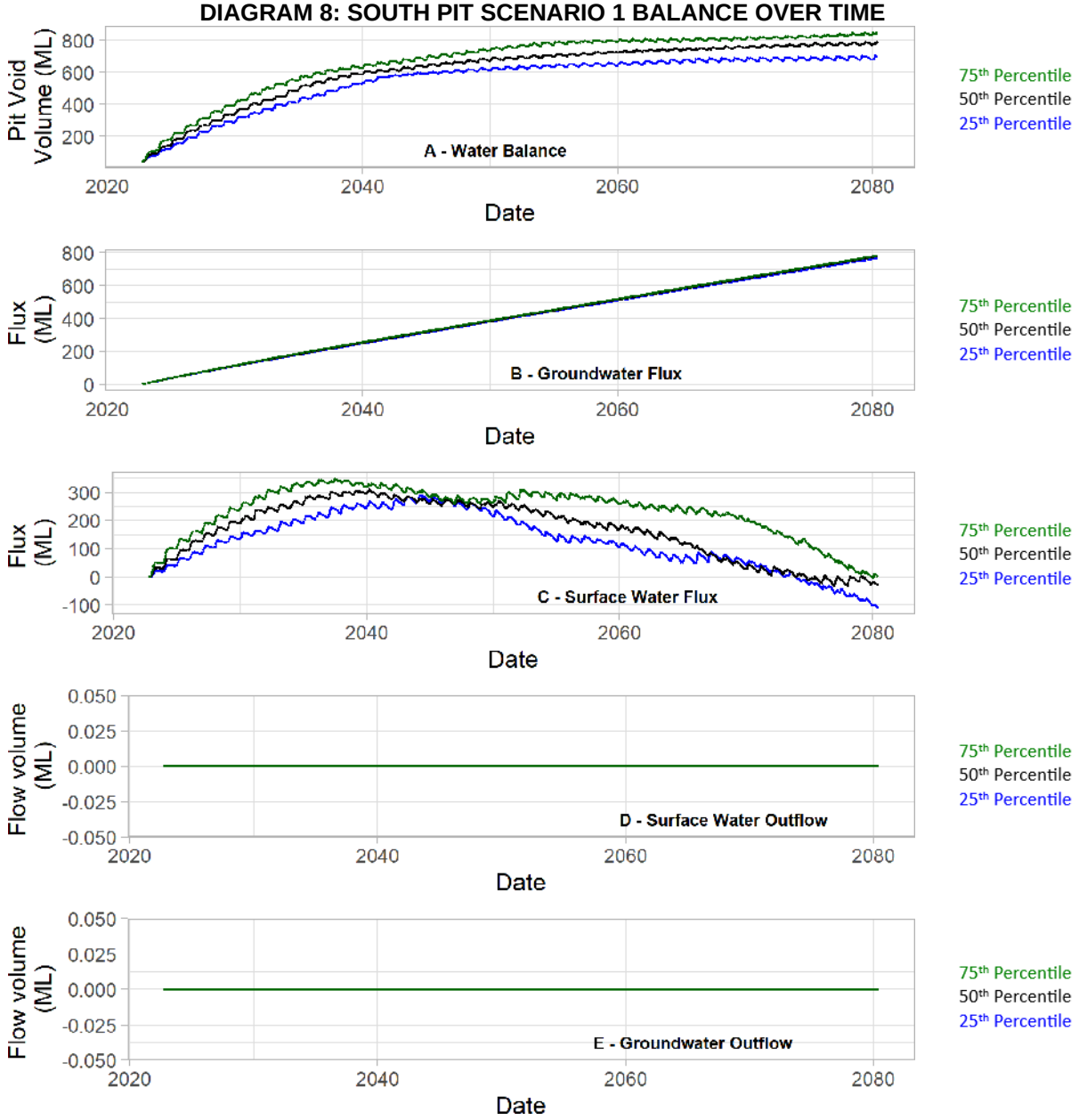
DIAGRAM 8: SOUTH PIT SCENARIO 1 BALANCE OVER TIME



3.4.1 Total Dissolved Solids

The total dissolved solids (TDS) content was evaluated, and the results are illustrated in DIAGRAM 9.

The influence of the gypsum equilibrium is clearly evident with an average water quality for the non-equilibrated solution in the order of approximately 3,500 mg/L to 3,700 mg/L for all probability scenarios at 2085. In general, high rainfall periods equate to a reduction in TDS. In this process the gypsum equilibrium does not influence water quality, but the influx of surface water can be observed as a reduction in TDS while extended dry spells result in an increase in the TDS.

With the addition of the gypsum equilibrating in solution a reduction of the average water quality is in

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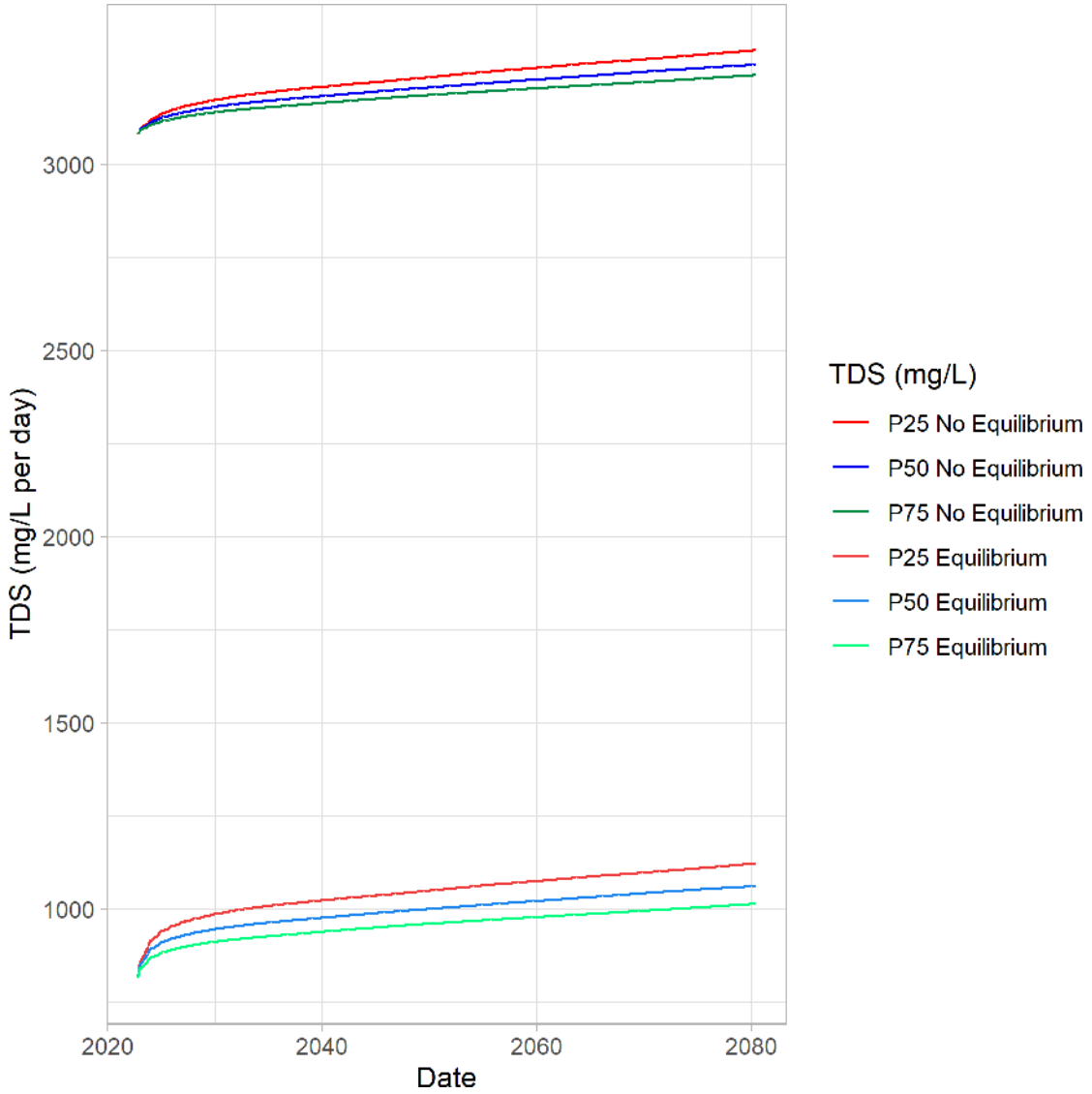
the order of approximately 1,000 mg/L to 1,300 mg/L at 2085. The range is reflective of the anticipated pit water quality and would indicate that the geochemical process control the upper TDS limit in the surrounding aquifer.

DIAGRAM 9: TOTAL DISSOLVED SOLIDS (mg/L) CONTENT FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE



3.4.2 pH Influence

Open pit water quality is alkaline to circum-neutral in both the equilibrated and non-equilibrium scenarios.. In the equilibrated scenarios water quality pH values tend toward the surface water quality pH with the non- equilibrated scenarios lagging but with the same trend as shown on **DIAGRAM 10**.

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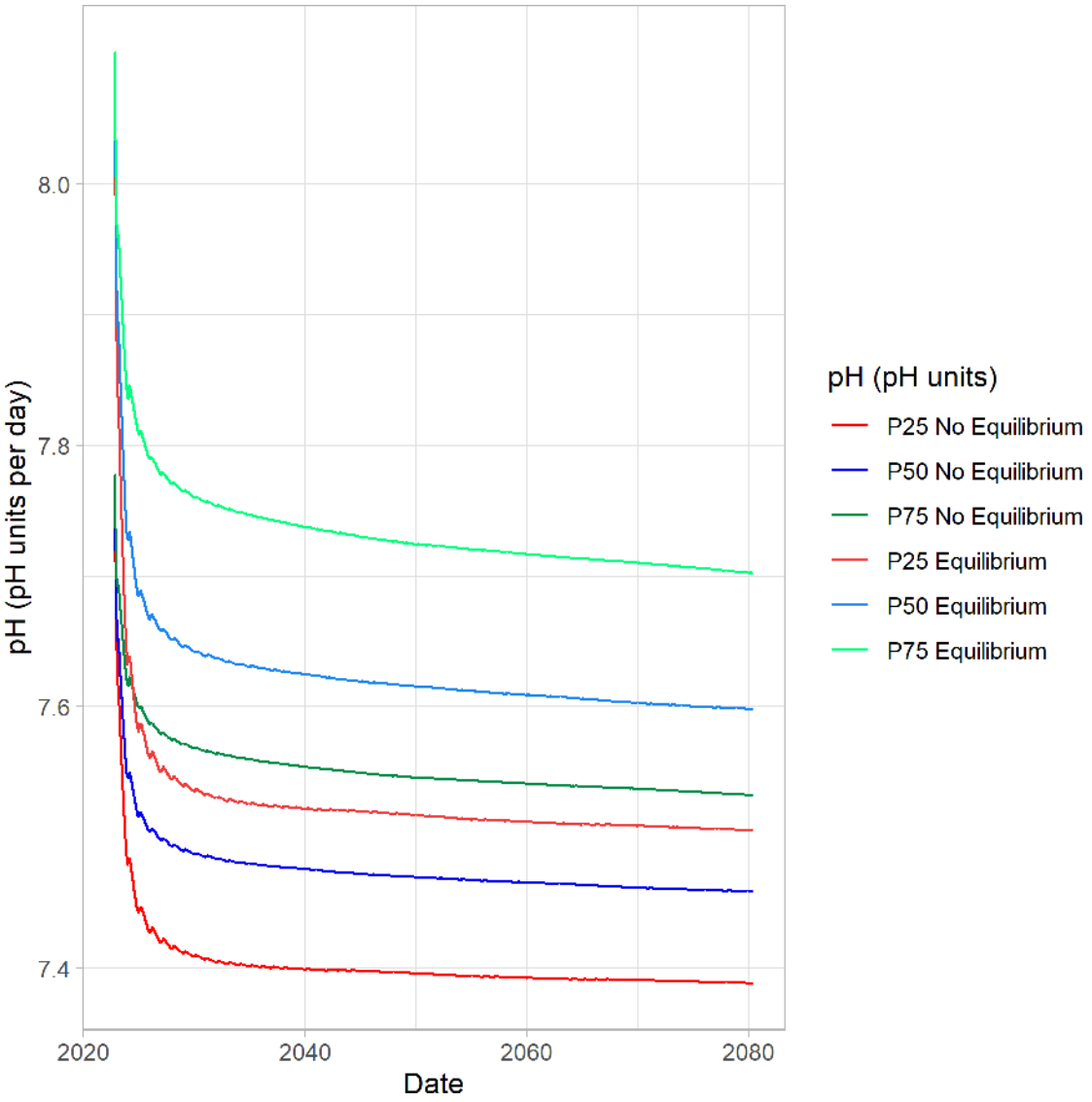
DIAGRAM 10: pH OF WATER BALANCE MODEL FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE



3.4.3 Macrochemical Components

Macrochemical composition of pit void water is dominated by calcium and sulphate components as shown on **DIAGRAM 11**, with observed changes in concentration a result of the equilibrium with gypsum. The distinct variation is however not reflected in the sodium, potassium, or magnesium cation composition as shown on **DIAGRAM 12**. There is limited potential to form halite ($NaCl$), magnesite ($MgCO_3$) or bischofite ($MgCl_2$). The potential for secondary mineral formation is further suppressed by the flow through mechanism functioning in the pit void.

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DIAGRAM 11: CALCIUM AND SULPHATE CONCENTRATION VALUES (mg/L) FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE

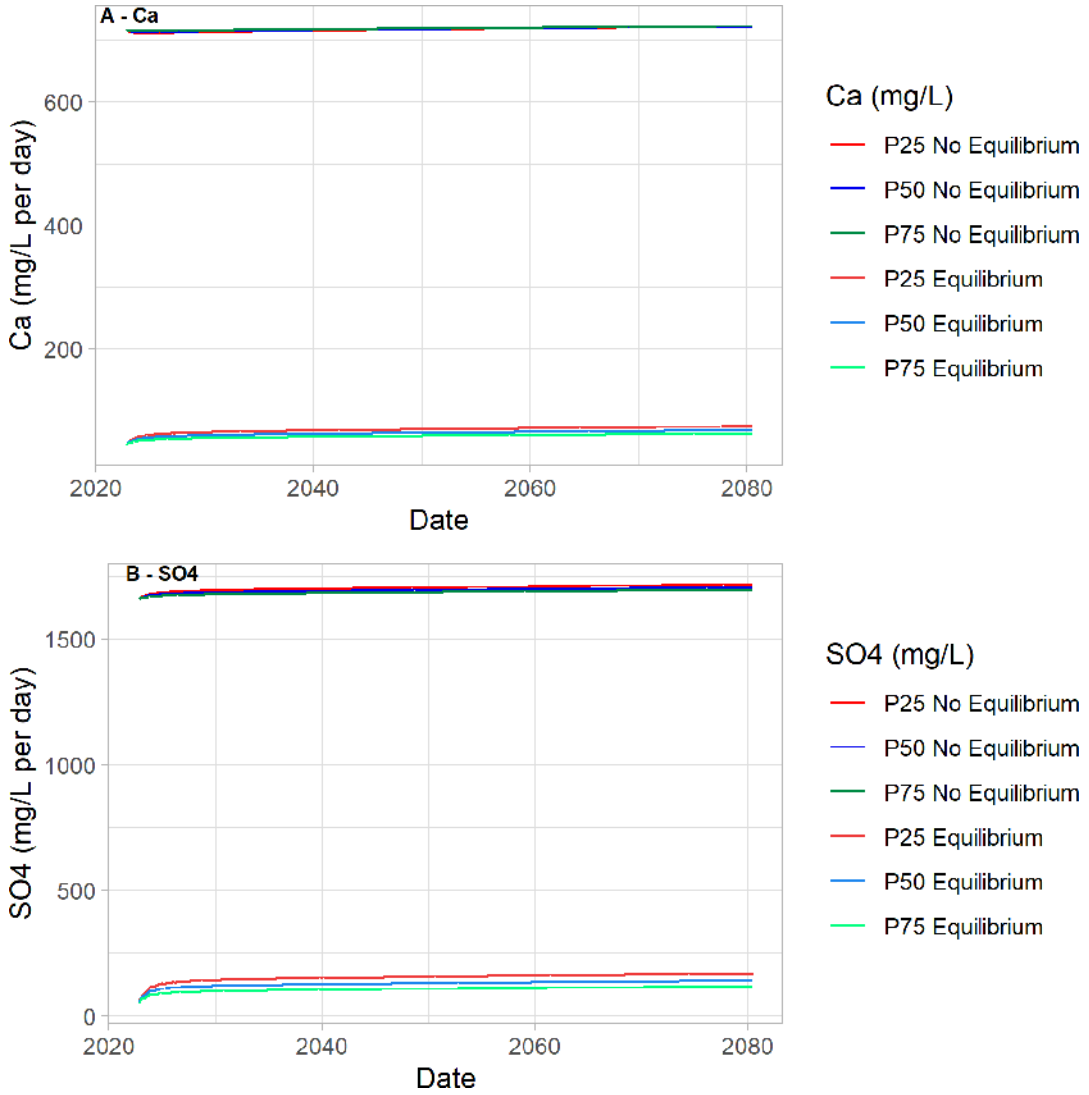

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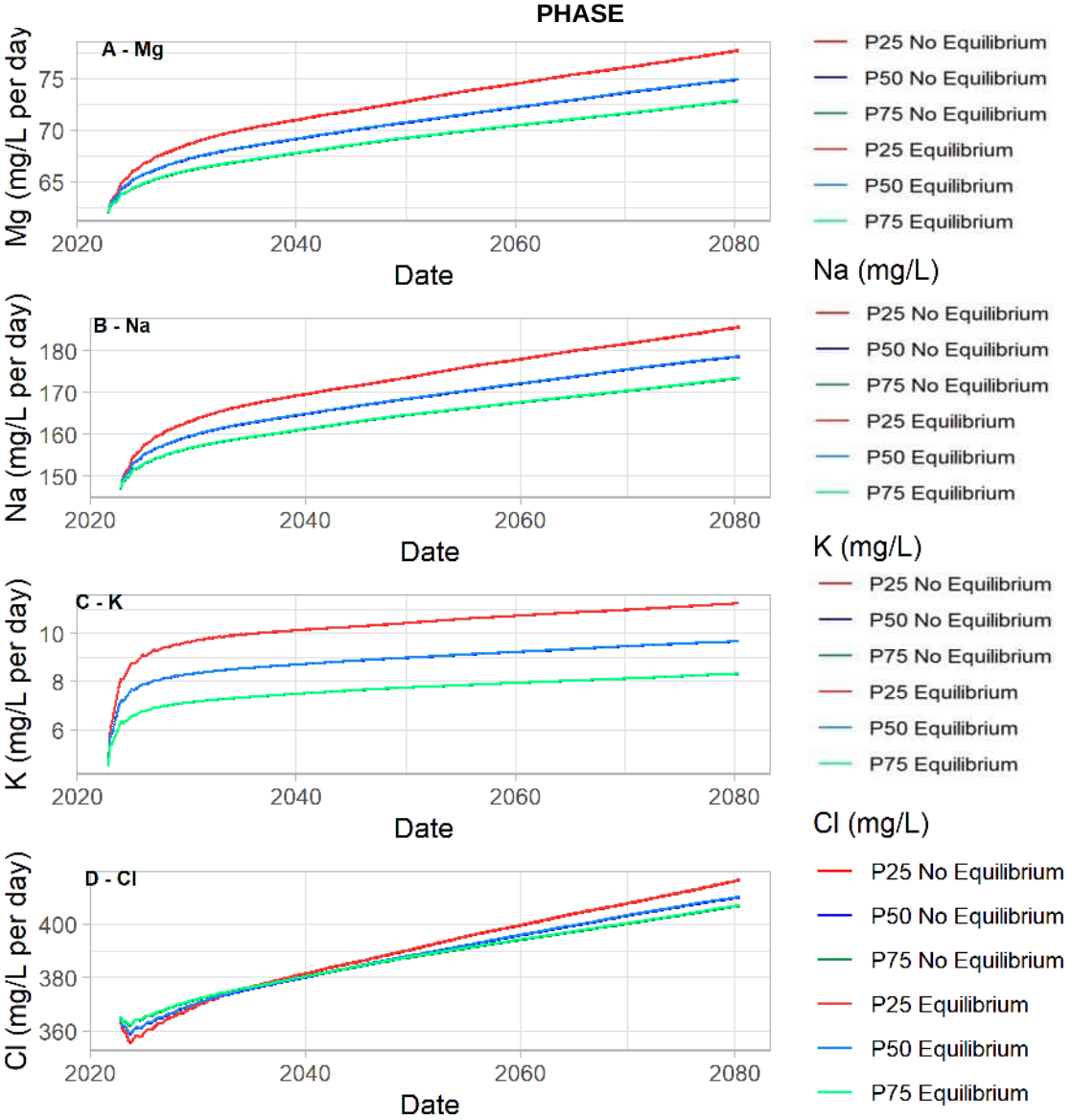
DIAGRAM 12: MAGNESIUM, SODIUM, POTASSIUM AND CHLORINE CONCENTRATION VALUES (mg/L) FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE



3.4.4 Metal(loid) Components

The metal(loid) solubility mimics that of the macrochemical species in that concentration gradients within the simulated period varies with inflow and evaporation effects as shown on **DIAGRAM 13**. As no surface adsorption or inclusion of metal(loid)s with gypsum mineral formation has been modelled limited variation in concentration values can be observed in both models. . In general, the pit void solution is undersaturated with these components and advection from groundwater inflows is a major factor in controlling concentration ranges.

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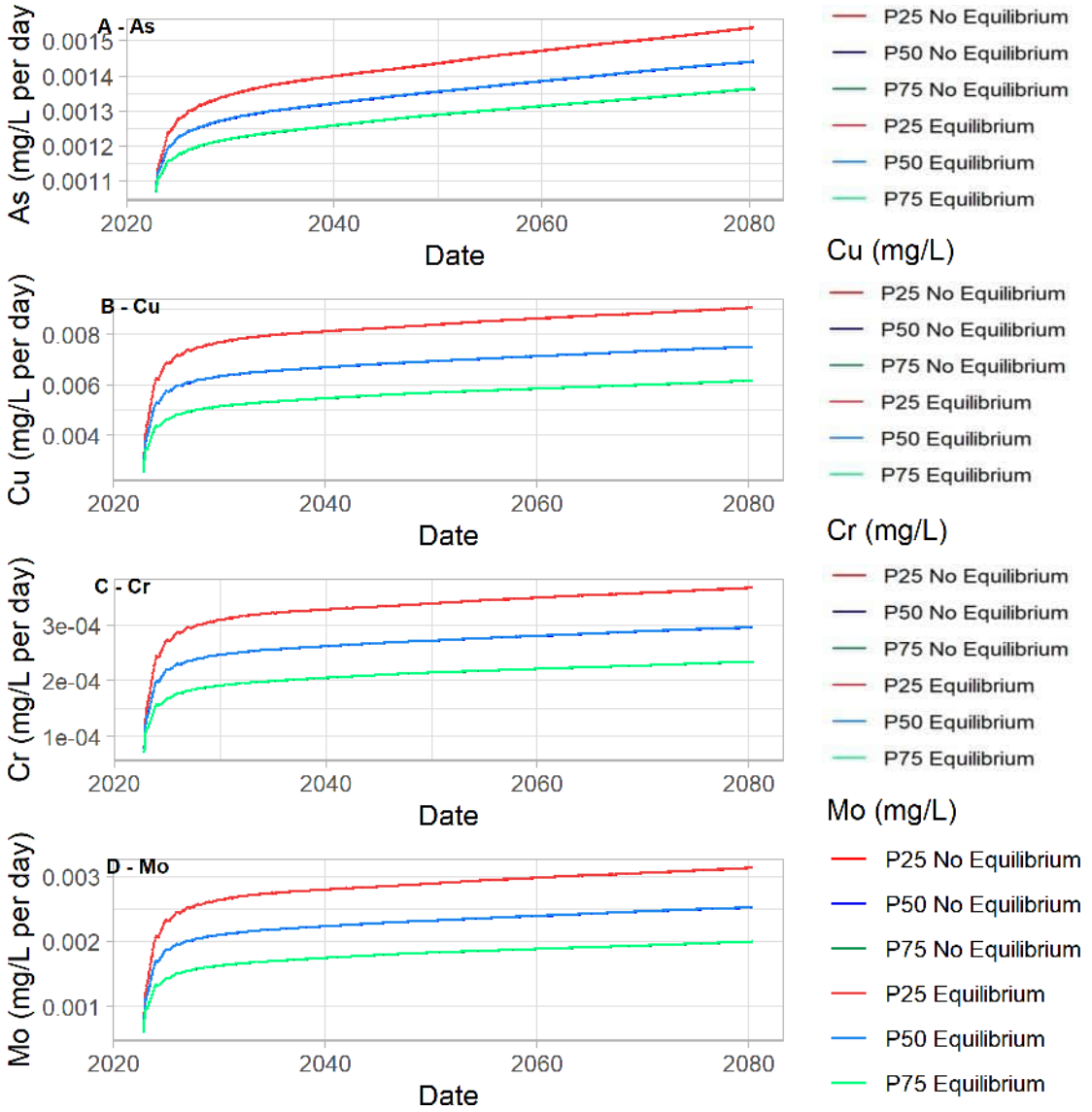
DIAGRAM 13: ARSENIC, COPPER, CHROMIUM AND MOLYBDENUM CONCENTRATION VALUES (mg/L) FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE



3.4.5 Conclusion

The geochemical model for the South Pit Scenario 1 was developed in association with the water balance model. The equilibrium with gypsum influenced the concentration values. Precipitation of gypsum within the pit void is considered likely. The pit water quality is influenced by evaporative losses and connectivity with either the surface water or groundwater source depending on probability distribution applied. Long term behaviour of the pit void is expected to reflect an increase in concentration values compared to the groundwater water quality but can range from surface water, groundwater and elevated saline water quality with reduced evaporation potential.

3.5 Model Results and Summary – South Pit – Scenario 2

To evaluate the geochemistry, the general water balance for the South Pit is presented in **DIAGRAM 14A**. The total groundwater flux is illustrated in **DIAGRAM 14B**, while the total surface water flux is presented in **DIAGRAM 14C** with a downward trend beyond 2035. The surface water flux dominates the water balance in the pit void. Outflows for surface water and groundwater are included, however for the 25th, 50th and 75th percentiles, the values equal zero.

The geochemical model was developed in association with the water balance model and limited influence of water chemistry was observed. The equilibrium with gypsum influenced concentration values. It is expected that precipitation of gypsum within the pit void is likely. The pit water quality is influenced by evaporative losses and connectivity with either surface water or groundwater sources. Long term behaviour of the pit void is expected to reflect slightly elevated concentration values compared to the groundwater water quality but can range from surface water to groundwater quality ranges with reduced evaporation potential.

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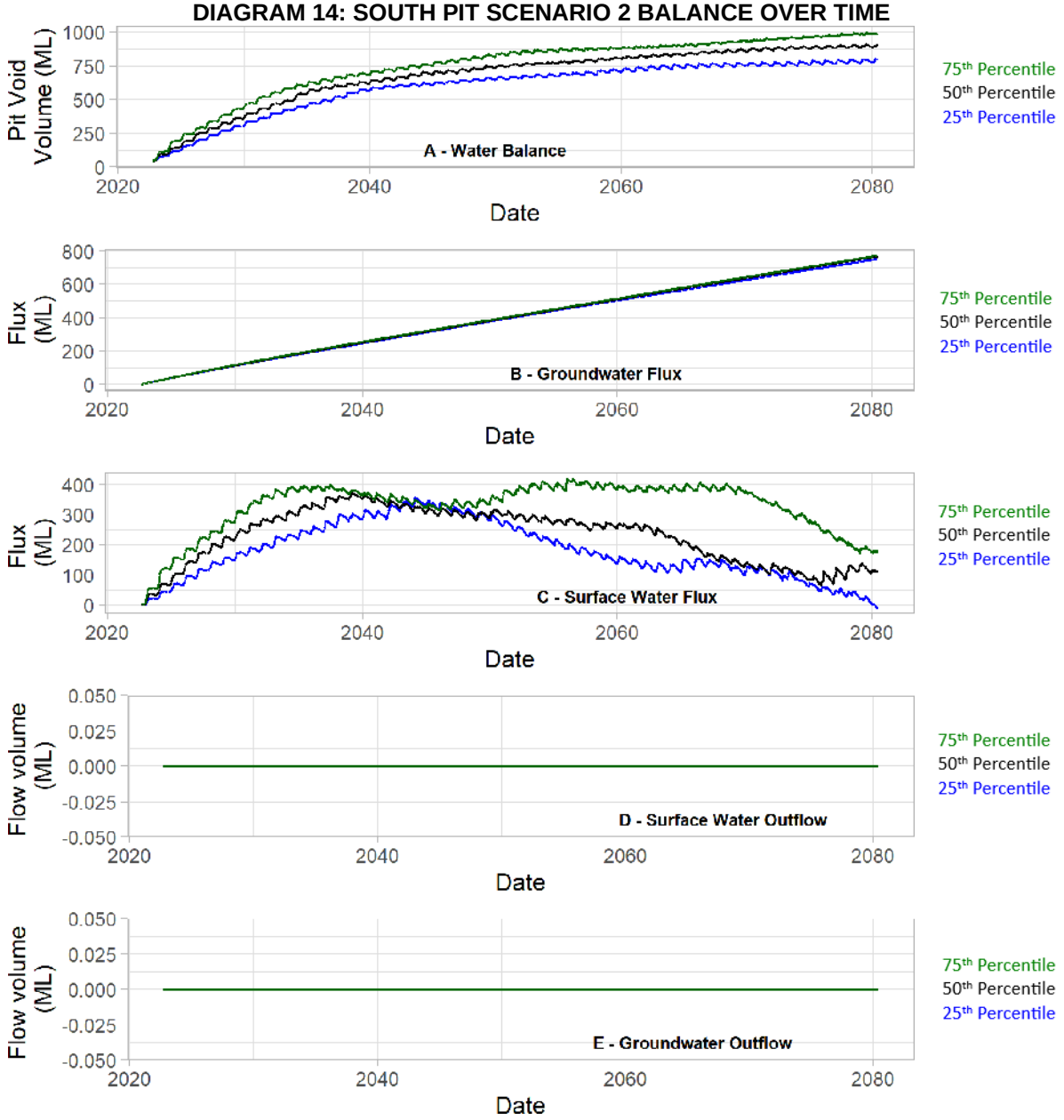
DIAGRAM 14: SOUTH PIT SCENARIO 2 BALANCE OVER TIME



3.5.1 Total Dissolved Solids

The total dissolved solids (TDS) content was evaluated, and the results are illustrated in **DIAGRAM 15**.

The influence of the gypsum equilibrium is clearly evident with an average water quality for the non-equilibrated solution in the order of approximately 3,400 mg/L to 3,600 mg/L for all probability scenarios at 2085. In general, high rainfall periods equate to a reduction in TDS, in this process the gypsum equilibrium does not influence water quality, but the influx of surface water can be observed as a reduction in TDS while extended dry spells result in an increase in the TDS.

With the addition of the gypsum equilibrating in solution a reduction of the average water quality is in the order of approximately 950 mg/L to 1,250 mg/L at 2085. The range is reflective of the anticipated pit water quality and would indicate that the geochemical process controls the upper TDS limit in the surrounding aquifer

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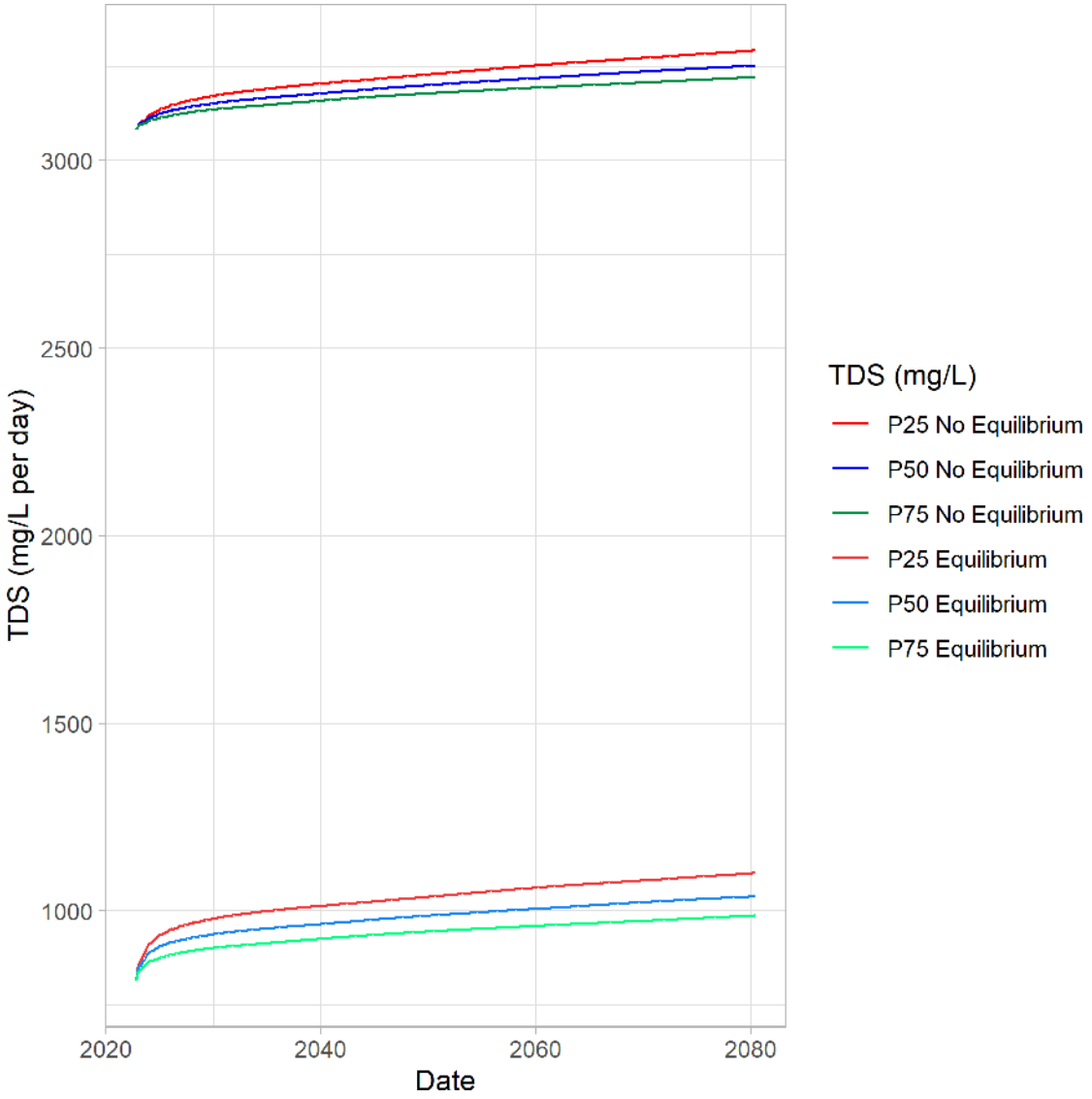
DIAGRAM 15: TOTAL DISSOLVED SOLIDS (mg/L) CONTENT FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE



3.5.2 pH Influence

Influent water quality is alkaline to circum-neutral in both the equilibrated and non-equilibrium scenarios. In the equilibrated scenarios water quality pH values tend toward the surface water quality pH with the non- equilibrated scenarios lagging but with the same trend as shown on **DIAGRAM 16**.

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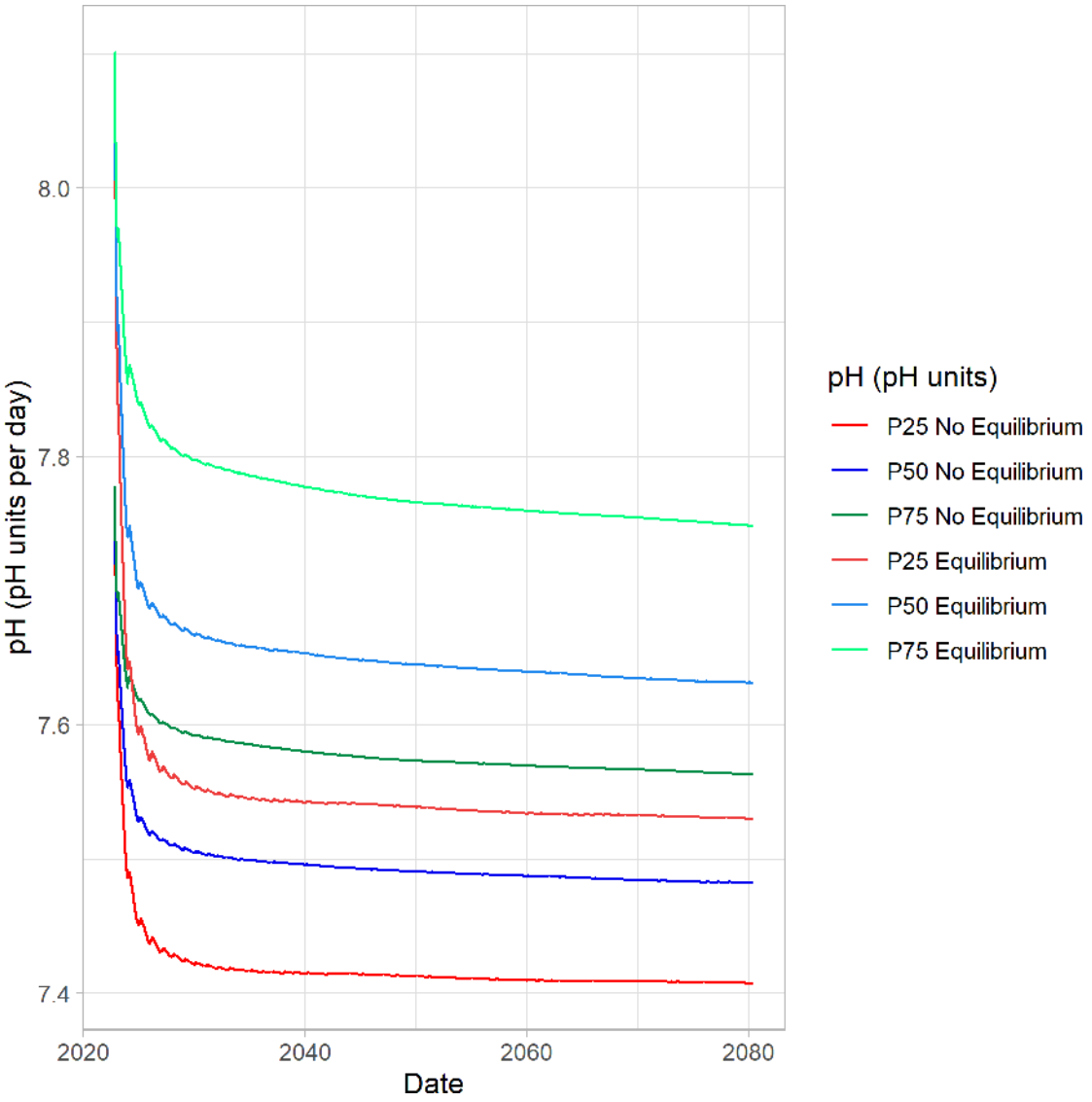
DIAGRAM 16: pH OF WATER BALANCE MODEL FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE



3.5.3 Macrochemical Components

Macrochemical composition of pit void water is dominated by calcium and sulphate components as shown on **DIAGRAM 17**, with observed changes in concentration a result of the equilibrium with gypsum. The distinct variation is however not reflected in the sodium, potassium, or magnesium cation composition as shown on **DIAGRAM 18**, which can be either ascribed to nominal concentration values or limited potential for mineral formation. Limited potential to form halite ($NaCl$), magnesite ($MgCO_3$) or bischofite ($MgCl_2$). The potential for secondary mineral formation is further supressed by the flow through mechanism functioning in the pit void, resulting in a water quality that represents the environmental input water quality.

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DIAGRAM 17: CALCIUM AND SULPHATE CONCENTRATION VALUES (mg/L) FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE

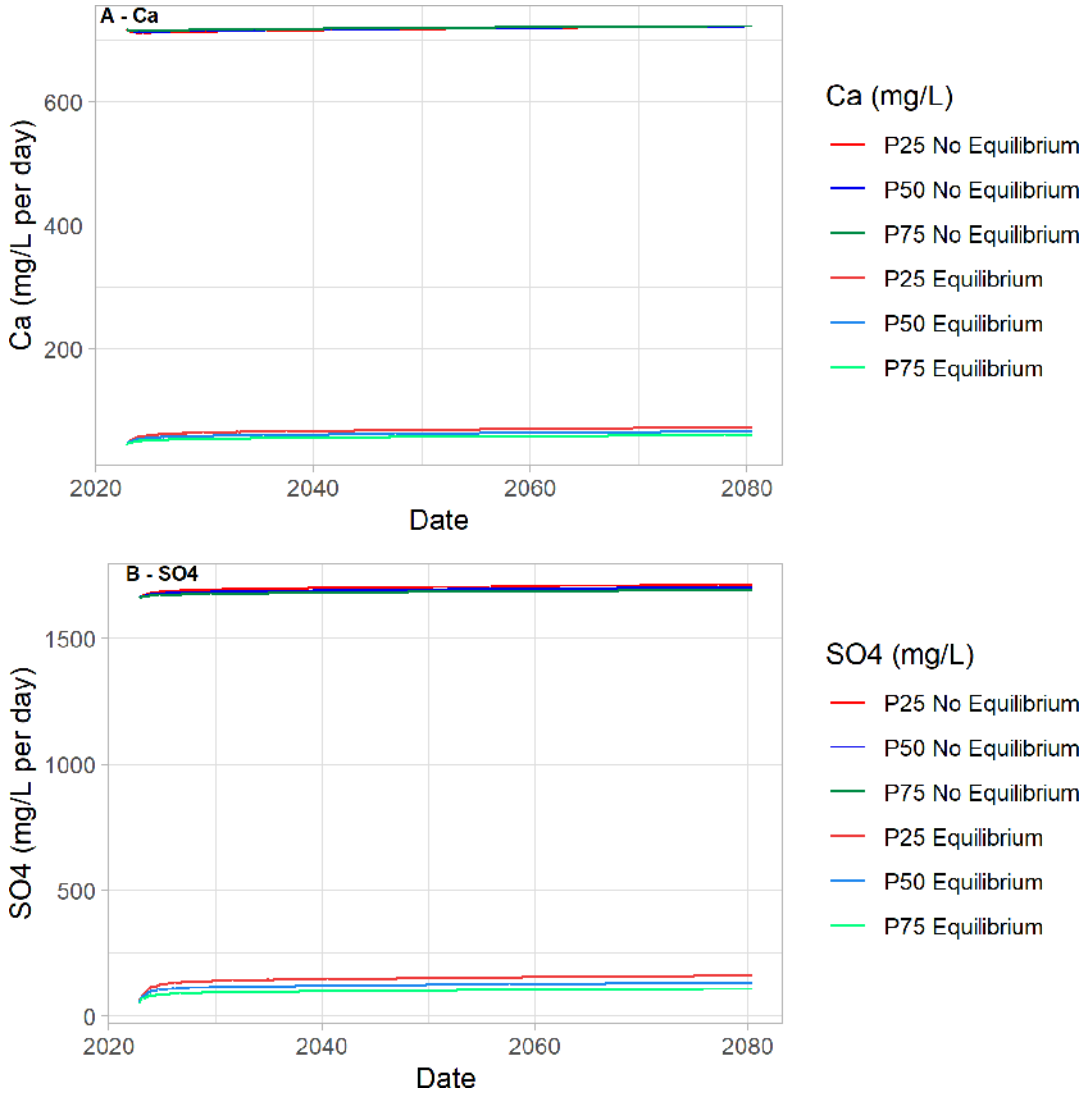

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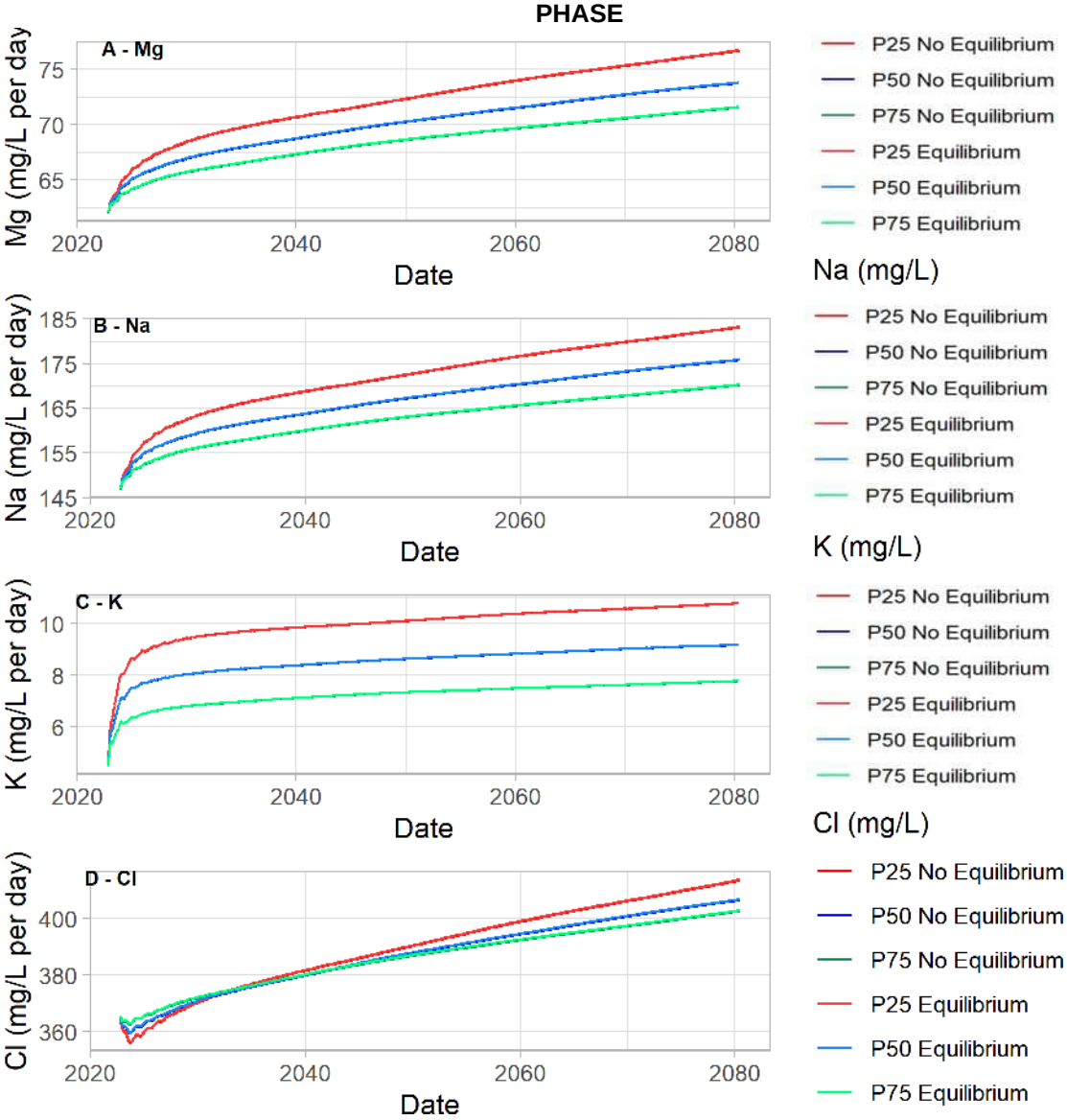
DIAGRAM 18: MAGNESIUM, SODIUM, POTASSIUM AND CHLORINE CONCENTRATION VALUES (mg/L) FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE



3.5.4 Metal(loid) Components

The metal(loid) solubility mimics that of the macrochemical species in that concentration gradients within the simulated period varies with inflow and evaporation effects as shown on **DIAGRAM 19**. As no surface adsorption or inclusion of metal(loid)s with gypsum mineral formation has been modelled limited variation in concentration values can be observed between either equilibrium phase. In general, the pit void solution is undersaturated with these components and advection from groundwater inflows is a major factor in controlling concentration ranges.

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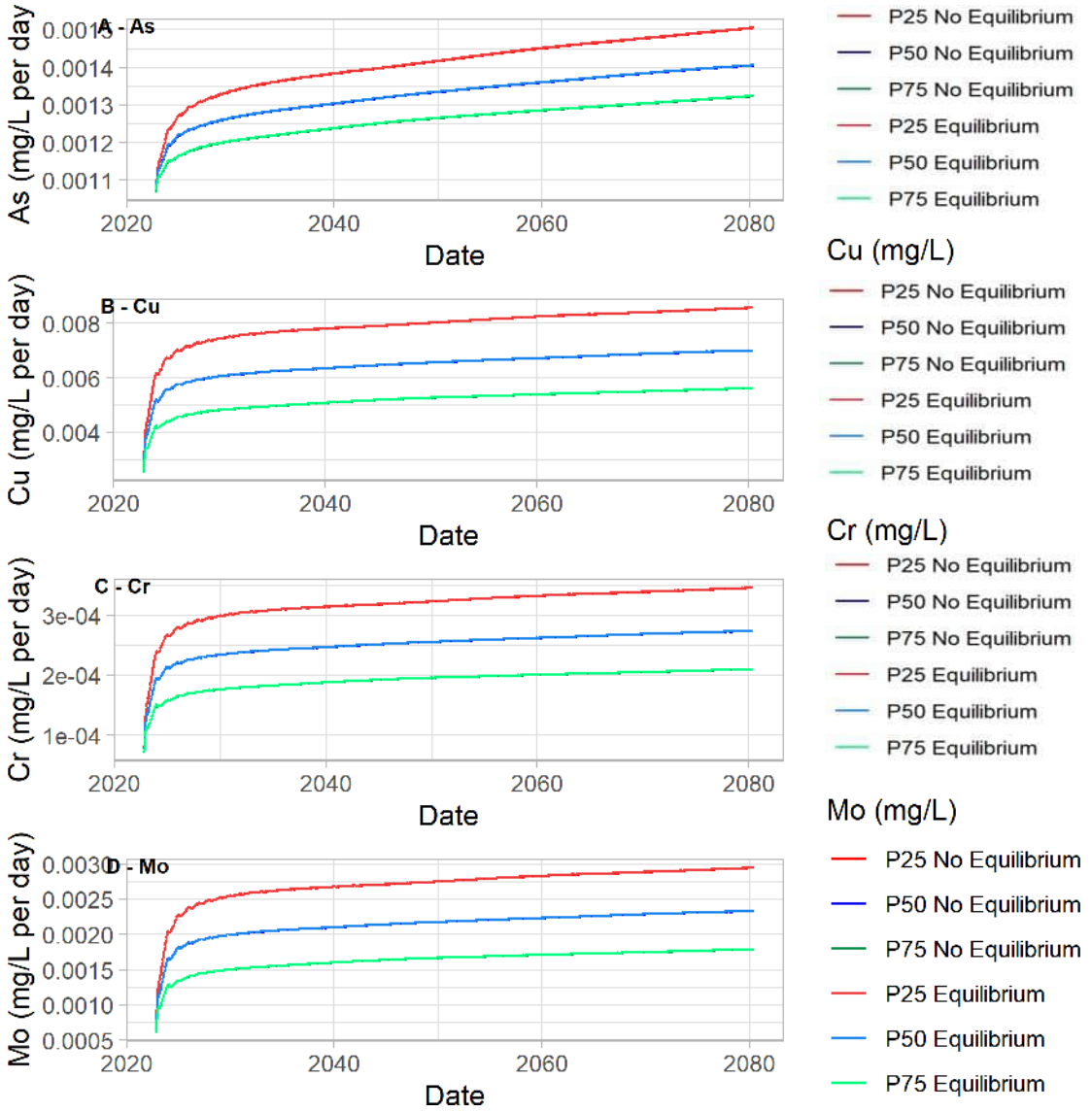
DIAGRAM 19: ARSENIC, COPPER, CHROMIUM AND MOLYBDENUM CONCENTRATION VALUES (mg/L) FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE



3.5.5 Conclusion

The geochemical model for the South Pit Scenario 2 was developed in association with the water balance model. The equilibrium with gypsum influenced concentration values. Precipitation of gypsum within the pit void is considered likely. The pit water quality is influenced by evaporative losses and connectivity with either the surface water or groundwater source depending on probability distribution applied. Long term behaviour of the pit void is expected to reflect an increase in concentration values compared to the groundwater water quality but can range from surface water, groundwater and elevated saline water quality with reduced evaporation potential.

Overall, when compared to Scenario 1, the inclusion of additional catchment area results in lower concentrates of TDS, pH, macrochemical and metalloid concentrations. As such, it is recommended to adopt the Scenario 2 bund and fence conditions for the South Pit.

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3.6 Model Results and Summary – WRD Sediment Dam

To evaluate the geochemistry, the general water balance for the South Pit is presented in **DIAGRAM 20A**. The total groundwater flux is illustrated in **DIAGRAM 20B**, while the total surface water flux is presented in **DIAGRAM 20C** with a downward trend beyond 2035. The surface water flux dominates the water balance in the pit void. Outflows for the groundwater are included, however for the 25th, 50th and 75th percentiles, the values equal zero.

The geochemical model was developed in association with the water balance model and limited influence of water chemistry was observed. The equilibrium with gypsum influenced concentration values. Precipitation of gypsum within the pit void is considered likely. The dam water quality is influenced by evaporative losses and connectivity with surface water. Long term behaviour of the dam is expected to reflect slightly elevated concentration values compared to the surface water quality.

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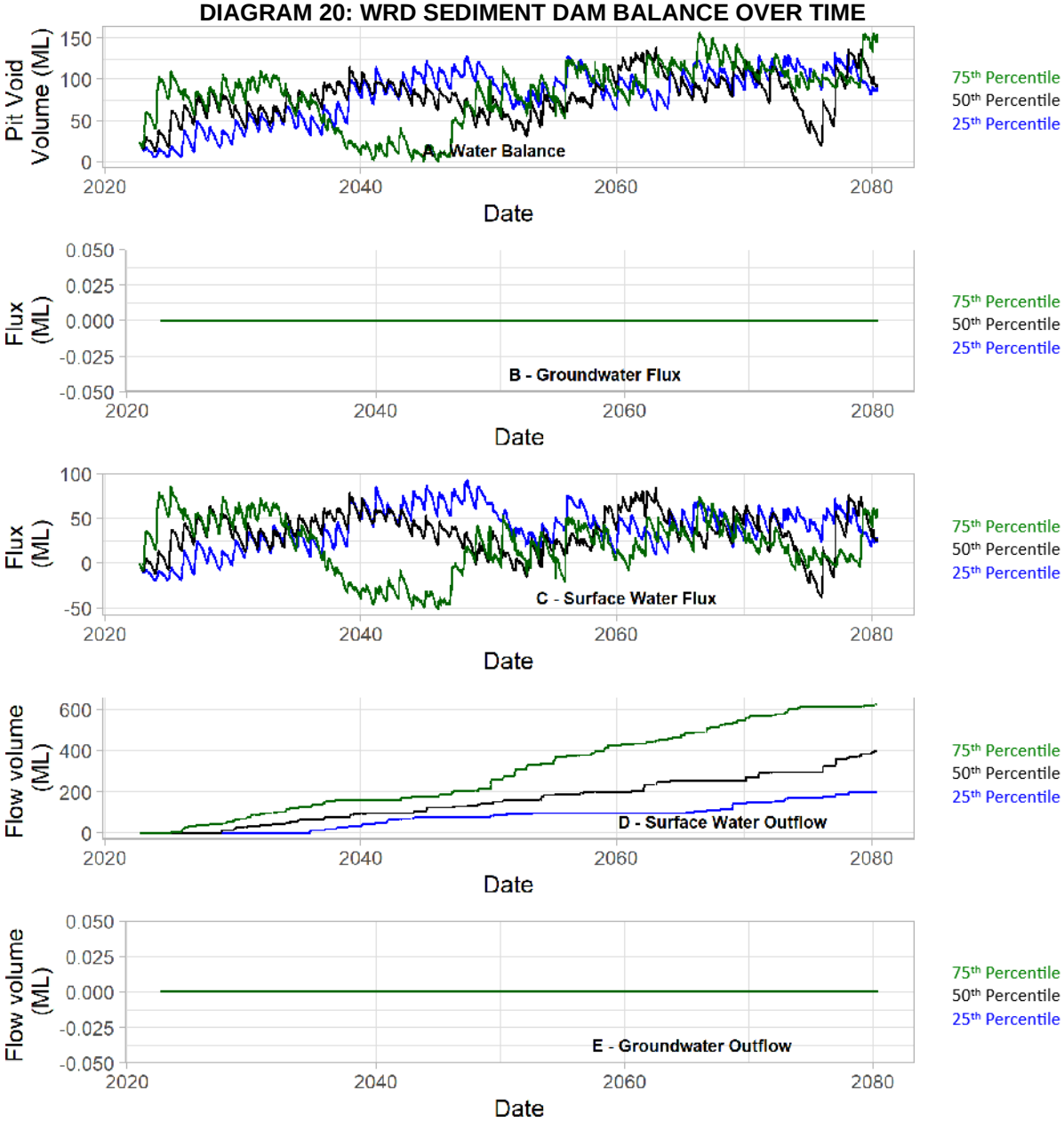
DIAGRAM 20: WRD SEDIMENT DAM BALANCE OVER TIME



3.6.1 Total Dissolved Solids

The total dissolved solids (TDS) content was evaluated, and the results are illustrated in **DIAGRAM 21** and **DIAGRAM 22.**

The influence of the gypsum equilibrium is clearly evident with an average water quality for the equilibrated solution in the order of approximately 200 mg/L to 1,000 mg/L for all probability scenarios at 2085. In general, high rainfall periods equate to a reduction in TDS, in this process the gypsum equilibrium does not influence water quality, but the influx of surface water can be observed as a reduction in TDS while extended dry spells result in an increase in the TDS.

With the addition of the gypsum equilibrating in solution a reduction of the average water quality is in the order of approximately 2,200 mg/L to 3,000 mg/L at 2085. The range is reflective of the anticipated pit water quality and would indicate that the geochemical process controls the upper TDS limit in the surrounding aquifer. Between 2035 and 2050, concentrations increase as the WRD Sediment Dam ‘’dries out’ in the P75 scenarios

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DIAGRAM 21: TOTAL DISSOLVED SOLIDS (mg/L) CONTENT FOR P25, P50 AND P75 WITH GYPSUM PRECIPITATION PHASE

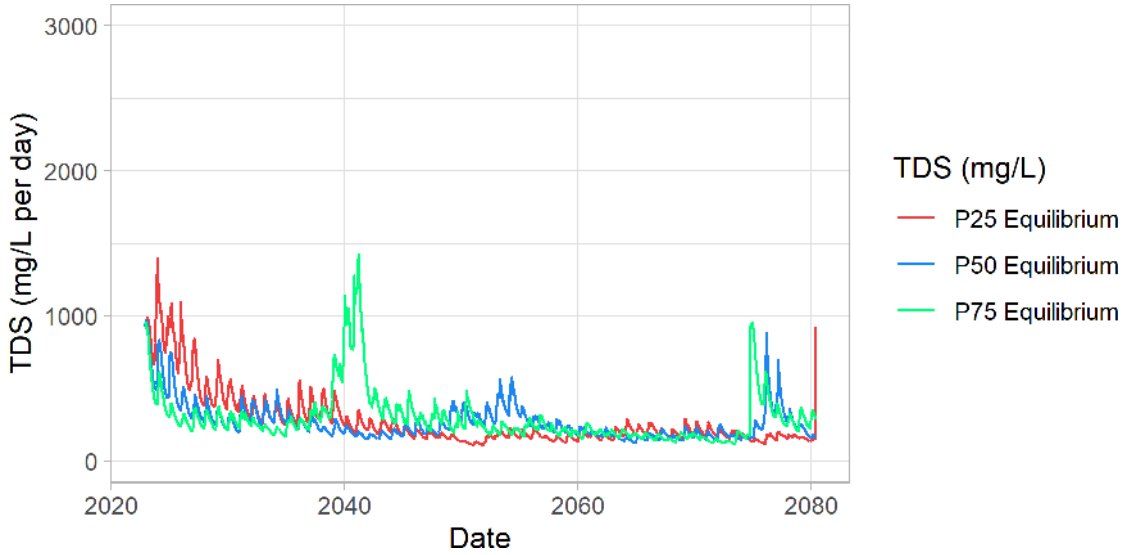
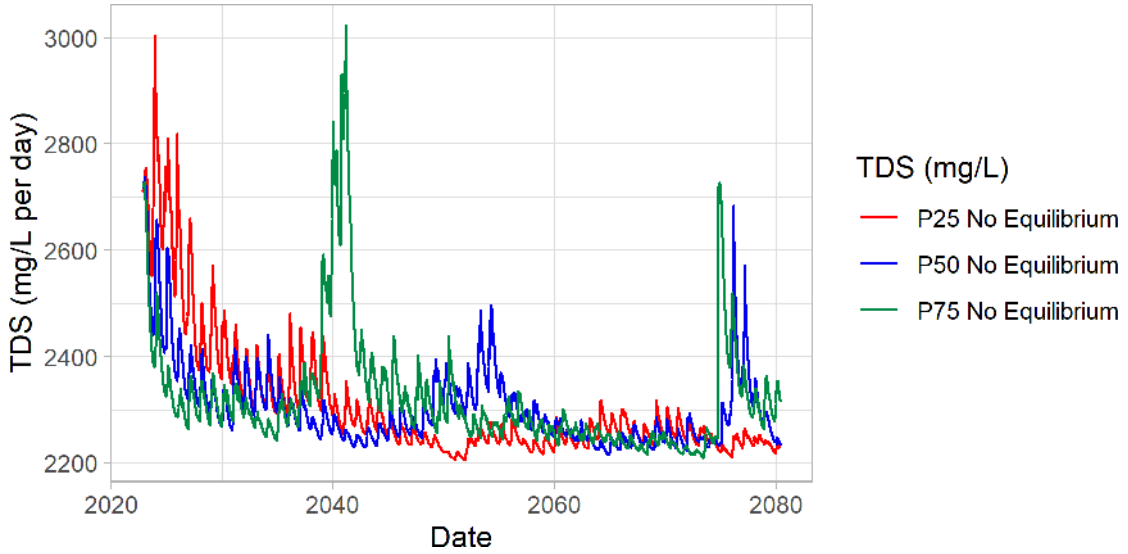


DIAGRAM 22: TOTAL DISSOLVED SOLIDS (mg/L) CONTENT FOR P25, P50 AND P75 WITHOUT GYPSUM PRECIPITATION PHASE



3.6.2 pH Influence

Influent water quality is alkaline to circum-neutral in both the equilibrated and non-equilibrium scenarios. In the equilibrated scenarios water quality pH values tend toward the surface water quality pH with the non- equilibrated scenarios lagging behind but with the same trend as shown on **DIAGRAM 23** and **DIAGRAM 24**.

Between 2035 and 2050, pH levels reduce in the gypsum precipitation model for the P25 scenario at the WRD Sediment Dam 'dries out''.

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DIAGRAM 23: pH OF WATER BALANCE MODEL FOR P25, P50 AND P75 WITH GYPSUM PRECIPITATION PHASE

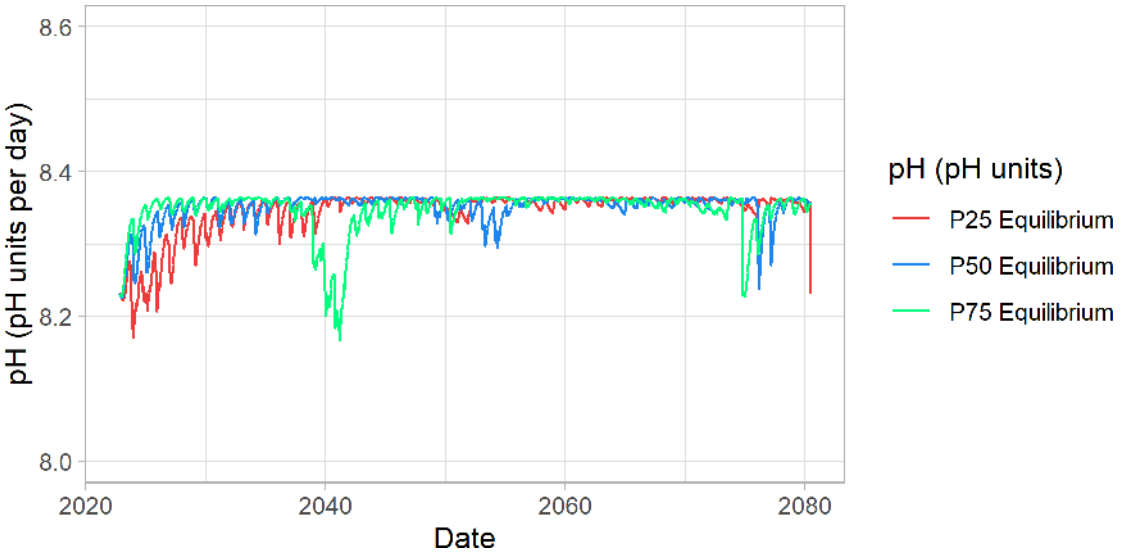
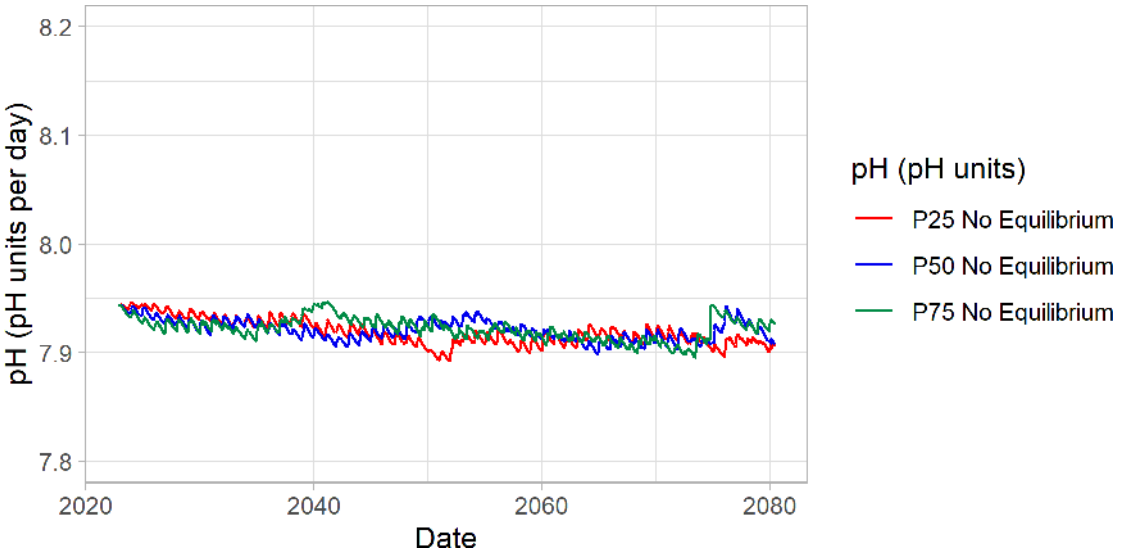


DIAGRAM 24: pH OF WATER BALANCE MODEL FOR P25, P50 AND P75 WITHOUT GYPSUM PRECIPITATION PHASE



3.6.3 Macrochemical Components

Macrochemical composition of pit void water is dominated by calcium and sulphate components as shown on **DIAGRAM 25**, with observed changes in concentration a result of the equilibrium with gypsum. The distinct variation is however not reflected in the sodium, potassium, or magnesium cation composition as shown on **DIAGRAM 26**. There is limited potential to form halite ($NaCl$), magnesite ($MgCO_3$) or bischofite ($MgCl_2$). The potential for secondary mineral formation is further suppressed by the flow through mechanism functioning in the pit void, resulting in a water quality that represents the environmental input water quality.

DIAGRAM 25: CALCIUM AND SULPHATE CONCENTRATION VALUES (mg/L) FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE.

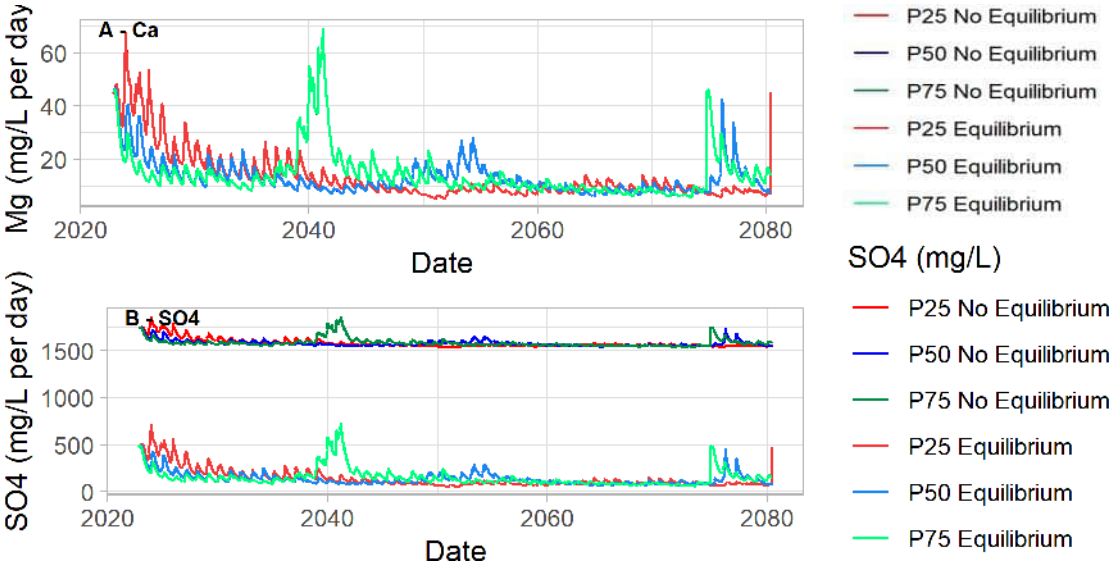


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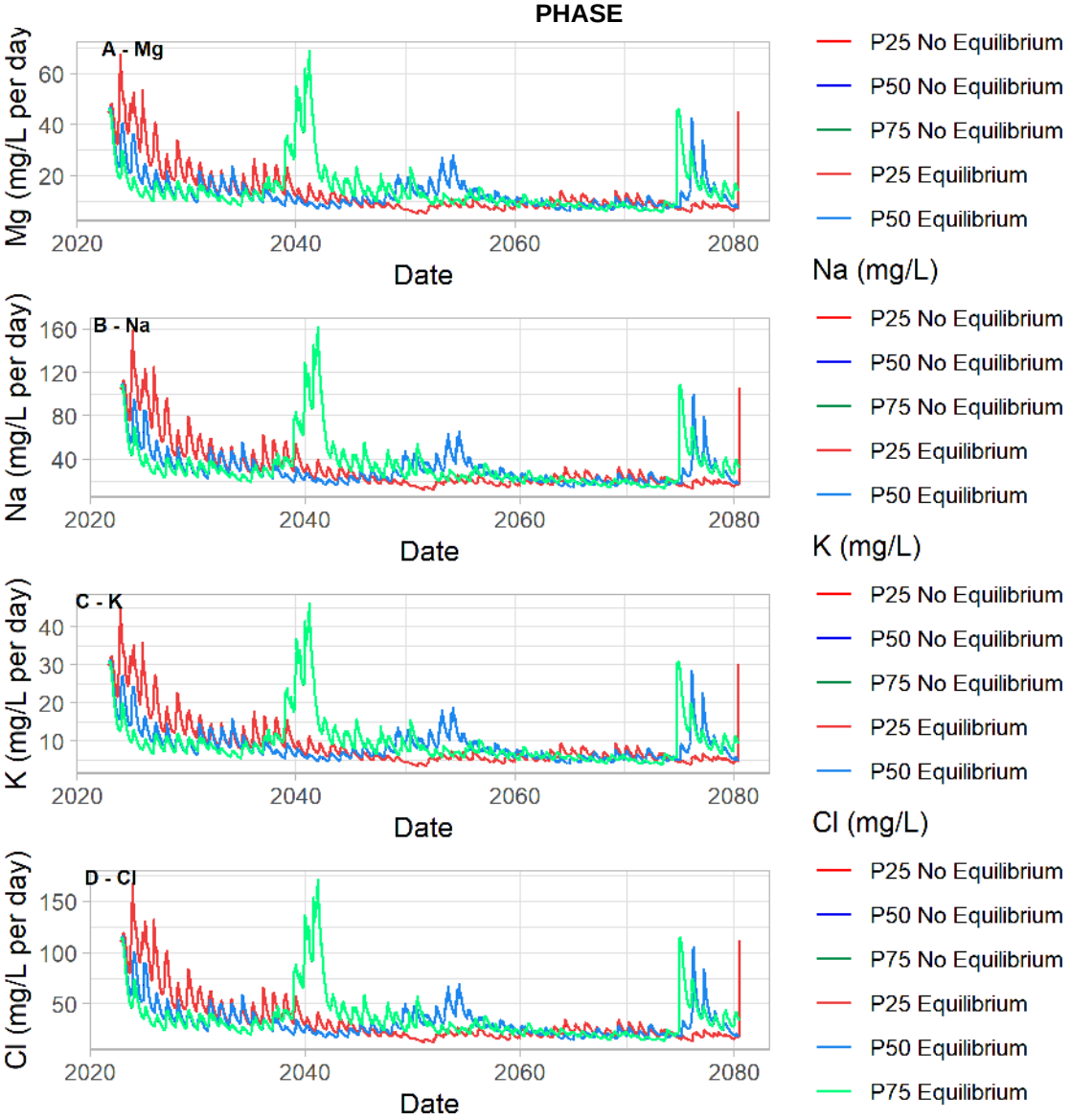
DIAGRAM 26: MAGNESIUM, SODIUM, POTASSIUM AND CHLORINE CONCENTRATION VALUES (mg/L) FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE



3.6.4 Metal(loid) Components

The metal(loid) solubility mimics that of the macrochemical species in that concentration gradients within the simulated period varies with inflow and evaporation effects as shown on **DIAGRAM 27**. As no surface adsorption or inclusion of metal(loid)s with gypsum mineral formation has been modelled limited variation in concentration values can be observed between either equilibrium phase. In general, the pit void solution is undersaturated with these components and surface water inflow is a major factor in controlling concentration ranges.

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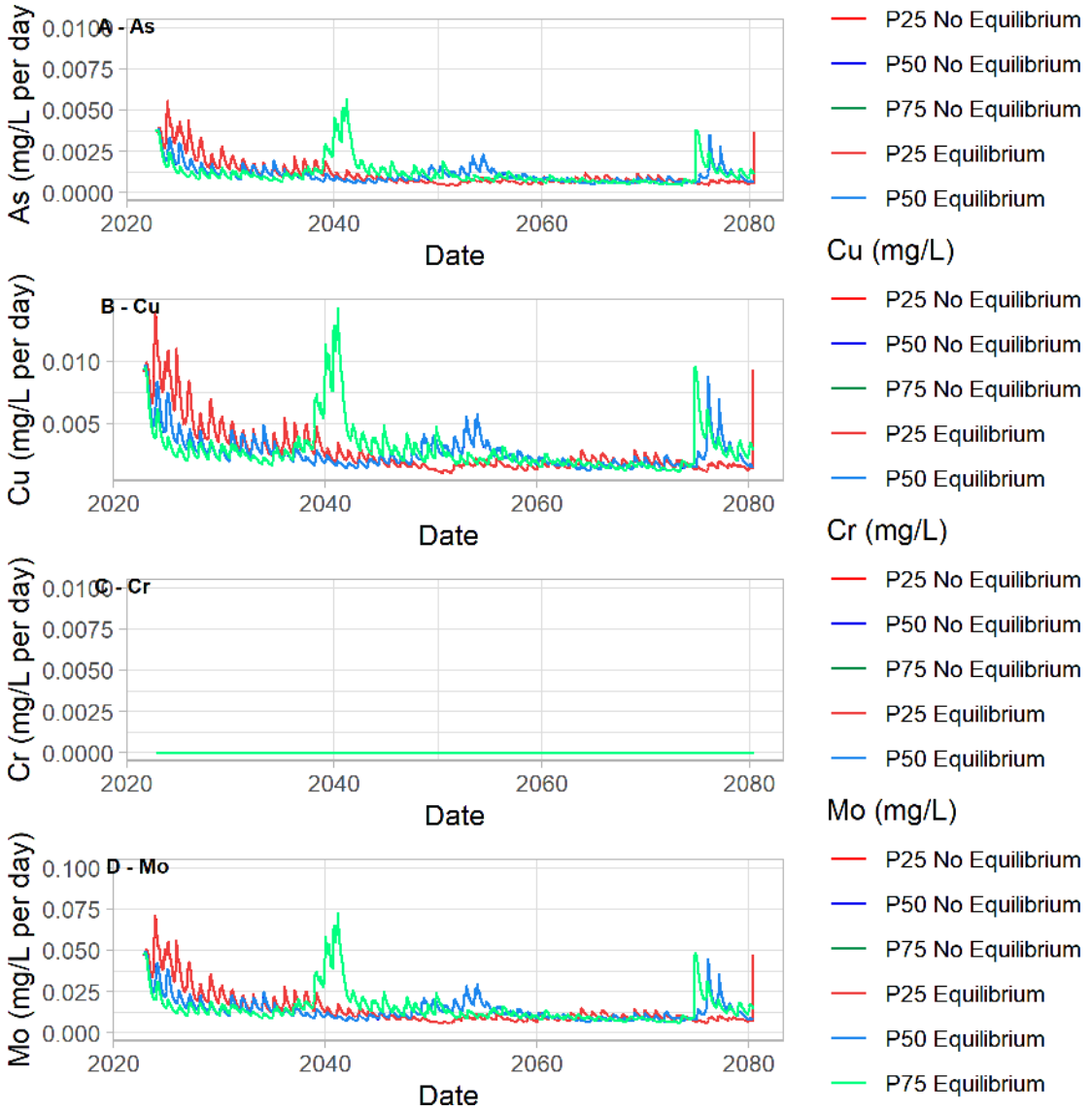
DIAGRAM 27: ARSENIC, COPPER, CHROMIUM AND MOLYBDENUM CONCENTRATION VALUES (mg/L) FOR P25, P50 AND P75 WITH AND WITHOUT GYPSUM PRECIPITATION PHASE



3.6.5 Conclusion

The geochemical model for the WRD Sediment Dam was developed in association with the water balance model. The equilibrium with gypsum influenced concentration values. Precipitation of gypsum within the sediment dam is considered likely. The P75 scenario indicates the WRD Sediment Dam 'Dries out' between 2035 and 2050, which influences concentrations of analytes. The water quality is influenced by evaporative losses and connectivity with the surface water source. Long term behaviour of the WRD Sediment Dam is expected to reflect an increase in concentration values compared to the surface water due to evapo-concentration processes.

REFERENCES

[1] ATC Williams (2023), 'Aeris Resources - Barbara Copper Project - Progressive Rehabilitation and Closure Planning – Water Management Plan and Water Balance Model', Ref: 118131.12.R03 – dated 17 February 2023.

[2] Department of Environment and Science (2021), 'Guideline Progressive rehabilitation and closure plans (PRC plans)', ESR/2019/4964, March 2021, version 2.00.

[3] Department of the Environment and Science (2020), Environmental Authority EPML00715513 (Effective Date 3 February 2020), Queensland Government.

[4] ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia

[5] Aeris Resources (2022), 'BCP Void Results vs ANZECC Stock Water_2020 – current.xls', 26 April 2022.

[6] WMV Environmental (2019), 'Barbara Copper Project – Groundwater Characterisation', Ref:J19008-Barbara Groundwater Characterisation (v1.00 – 2019_05_29), dated 29 May 2019.

[7] SLR (2021a), 'Barbara Copper Project – Receiving Environment Monitoring Program – Annual Report 2021', Ref: 623.20018.21221-R01, Version V2.0, dated 16 December 2021.

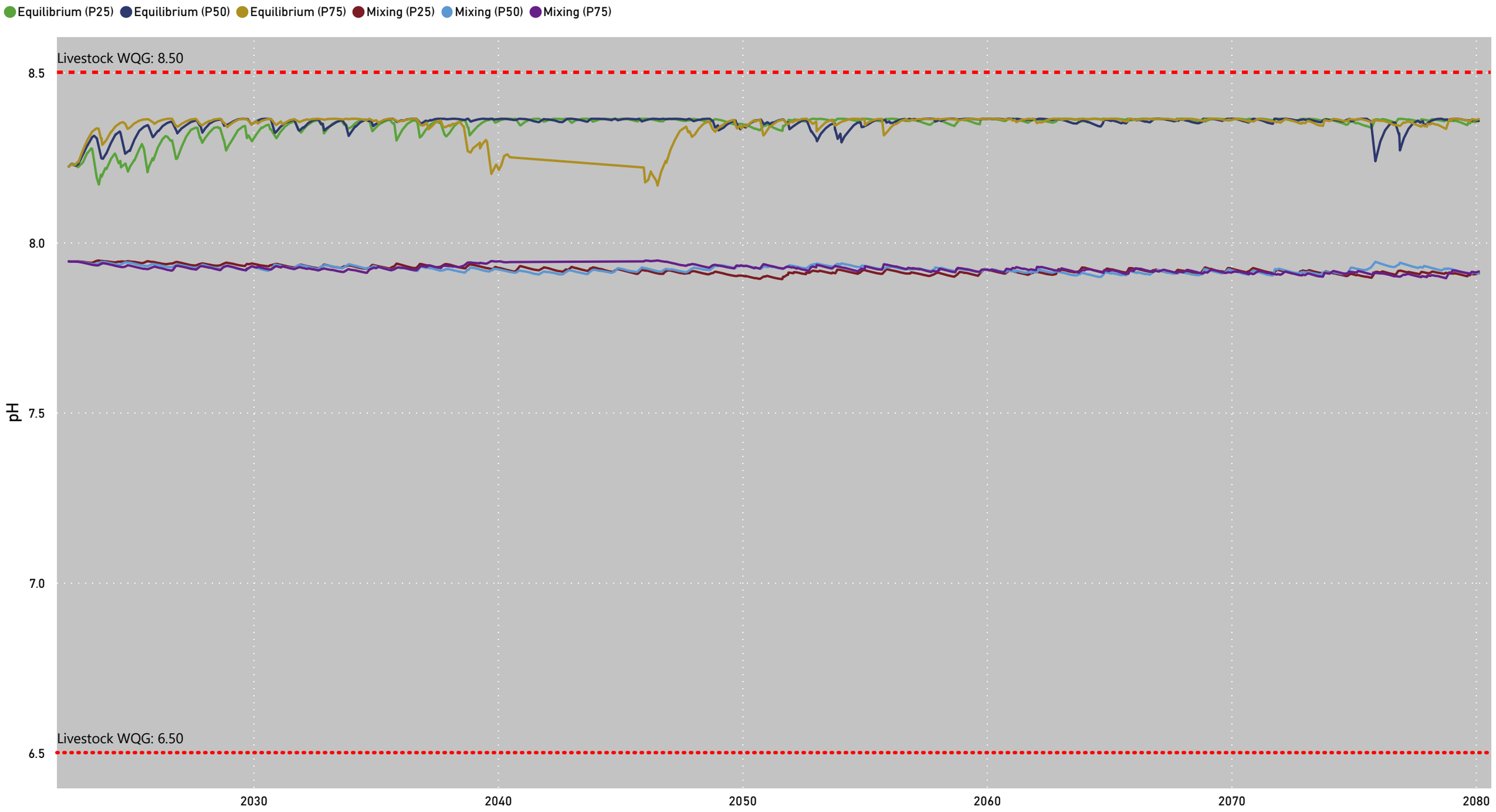
[8] SLR (2021b), 'Receiving Environment Monitoring Program Barbara – Wet Season 2021', Ref: 623.20018.20211-M01-v1.020210602, dated 2 June 2021.

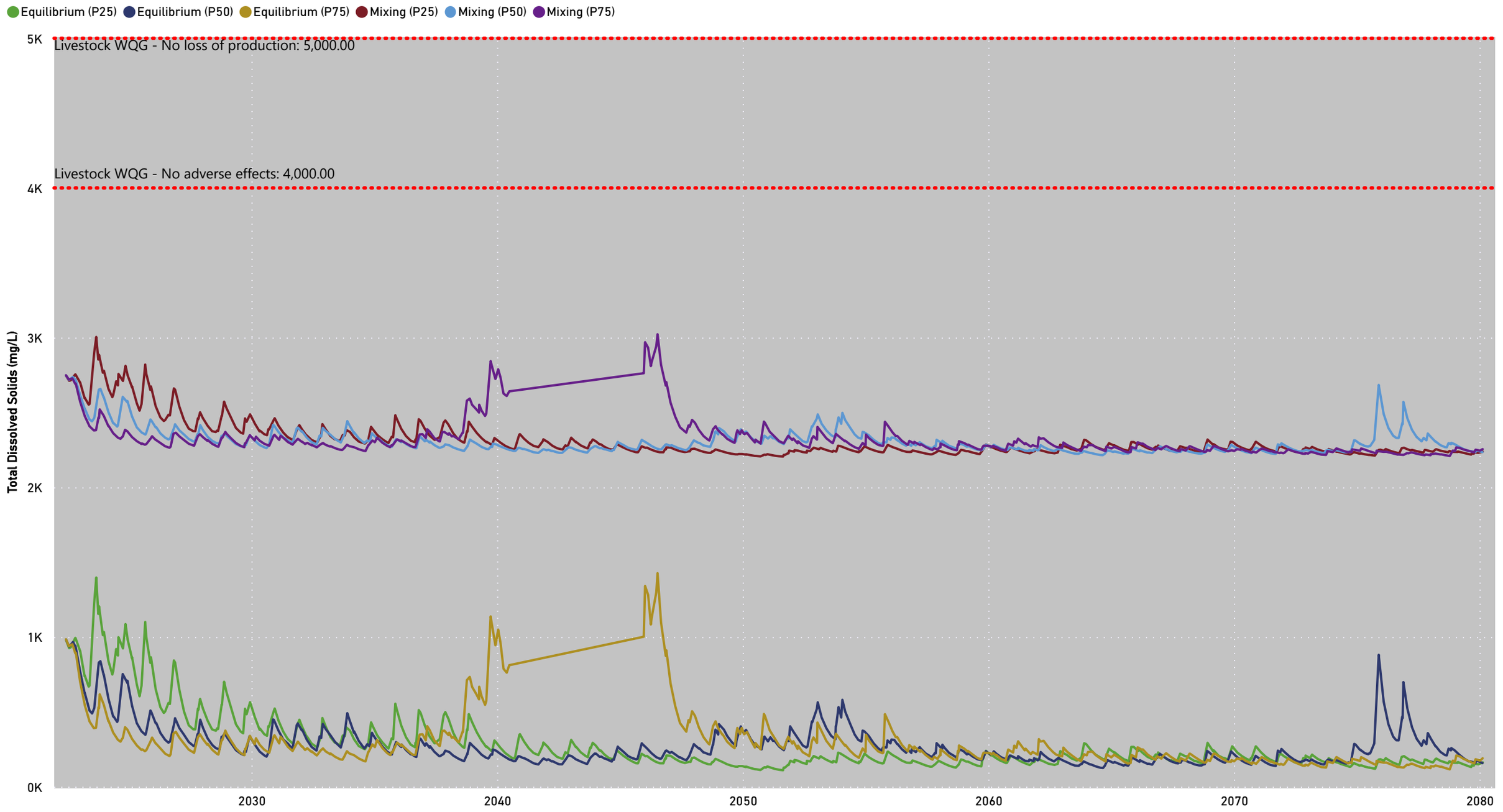
[9] SLR (2022), 'Receiving Environment Monitoring Program Barbara – Wet Season 2022', Ref: 623.20018.2022-M01-V2.0-20220614, dated 14 June 2022.

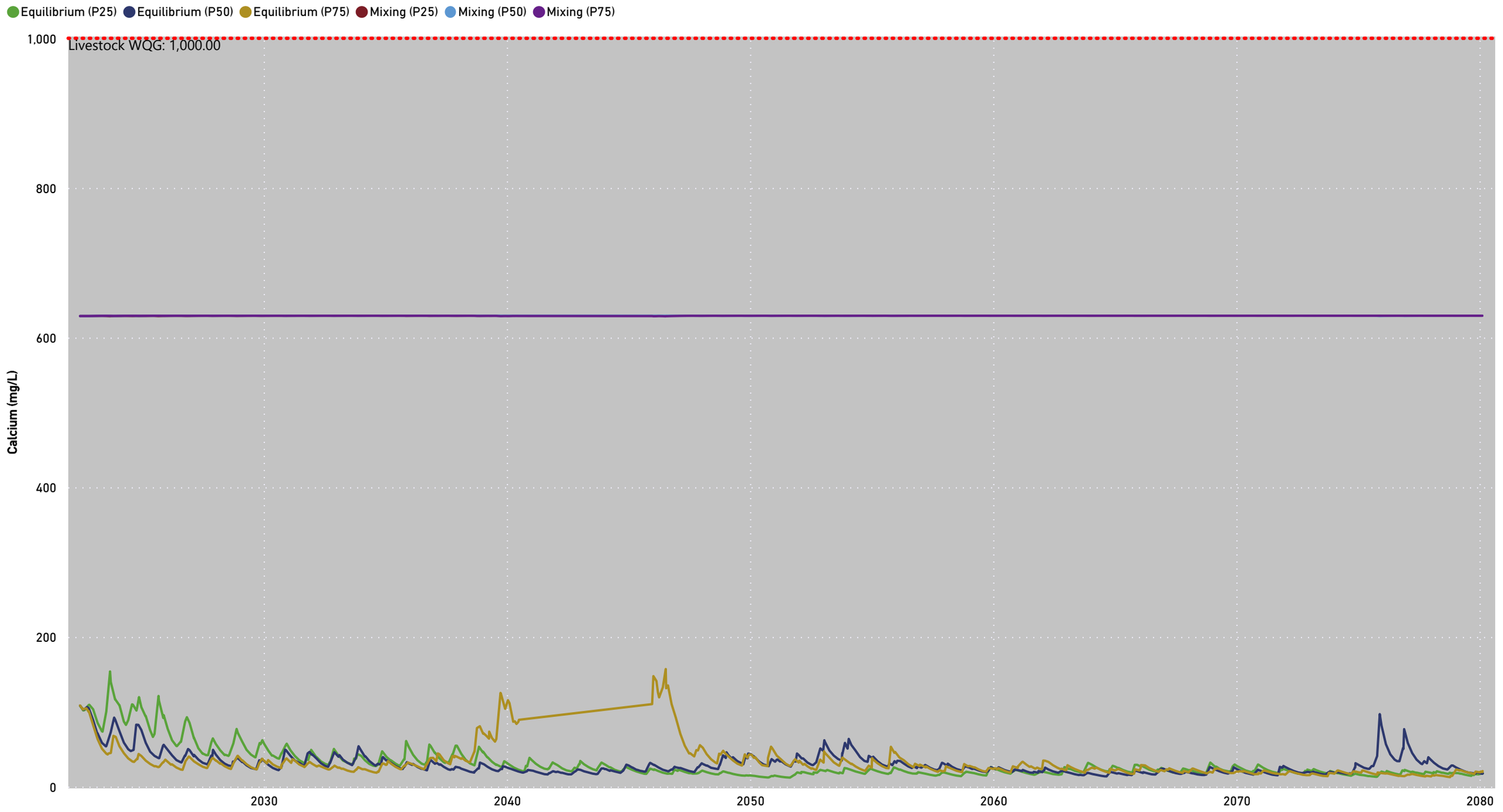
[10] WMV Environmental (2019), 'Barbara Copper Project Progressive Rehabiliattion and Closure Plan. Water Quality Assessment of North Pit, South Pit and WRD Sediment Dam', Ref:J22020-RP01, dated 31 March 2023.

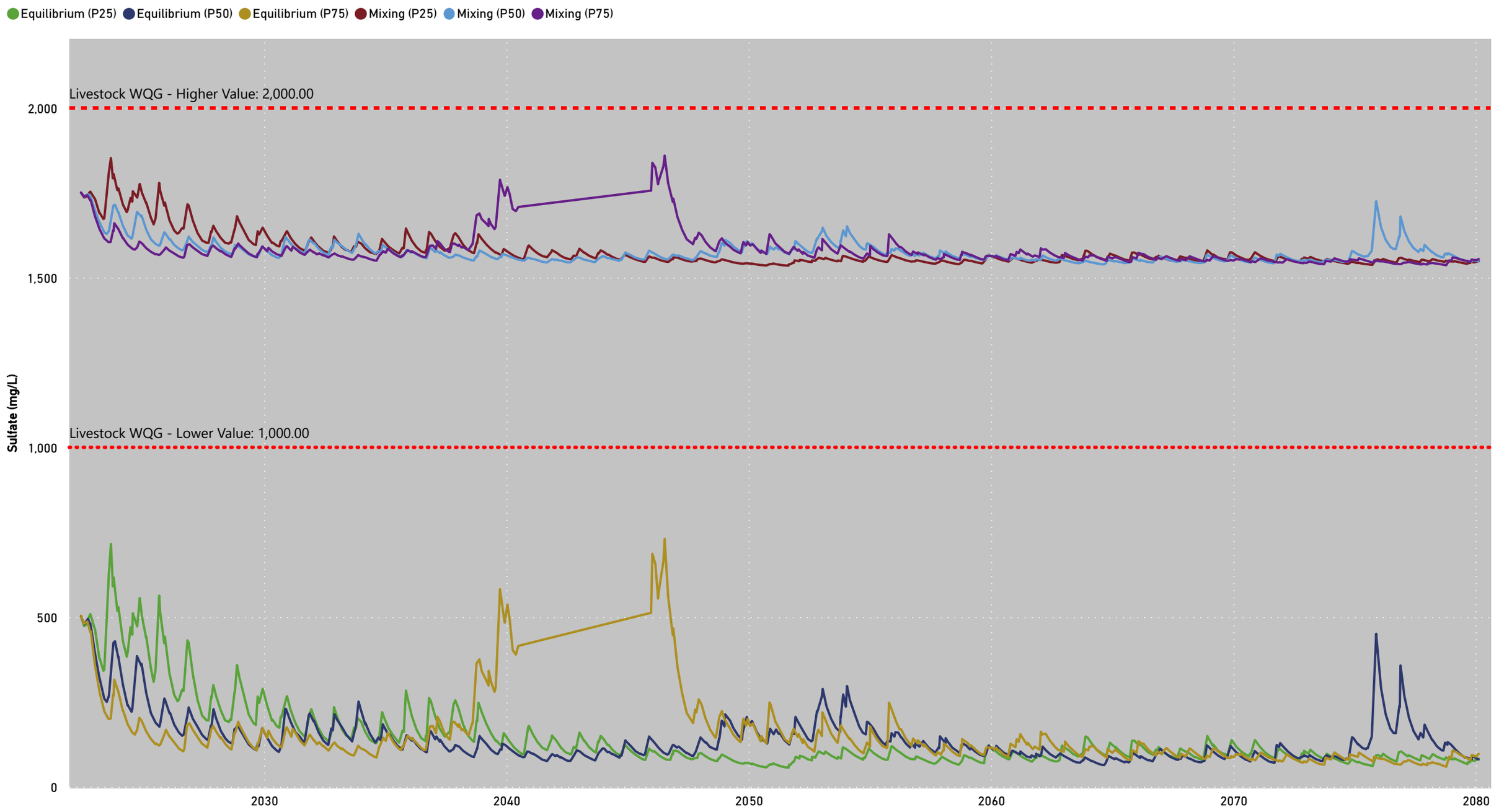
Appendix D

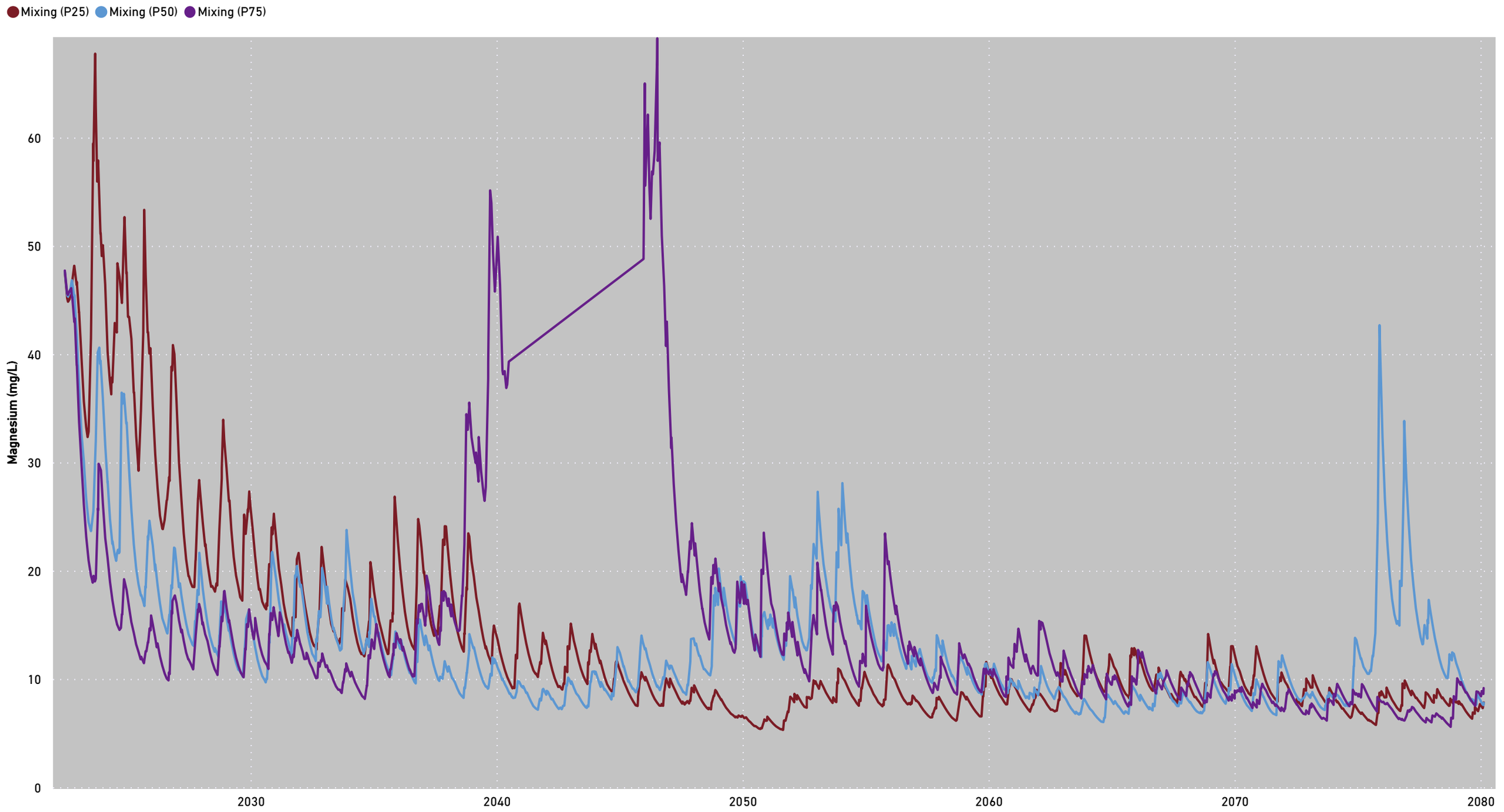
WRD Sediment Dam modelled long-term water quality

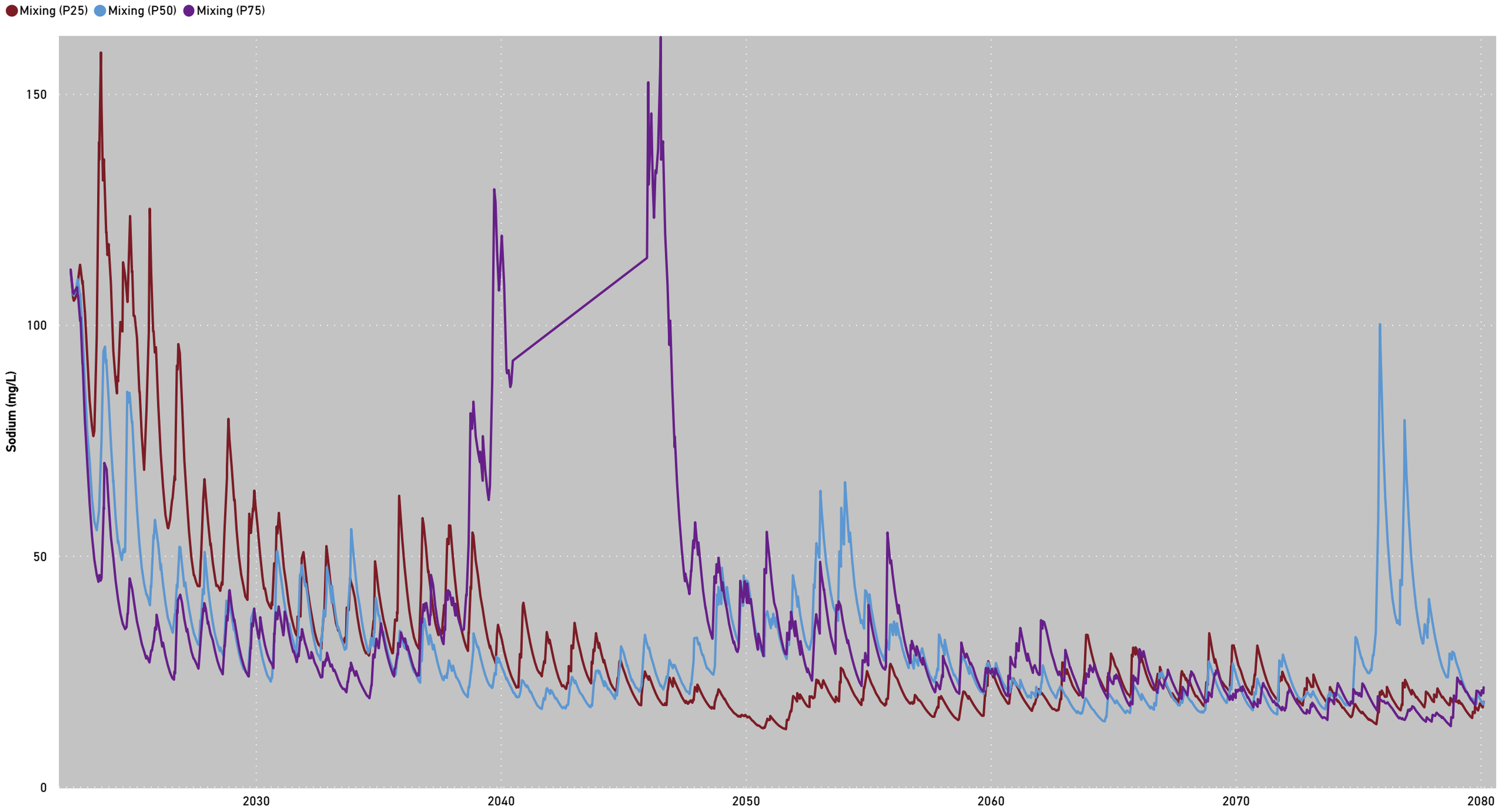

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 8.50
Livestock WQG: 6.50
pH
8.5
8.0
7.5
7.0
6.5
2030
2040
2050
2060
2070
2080

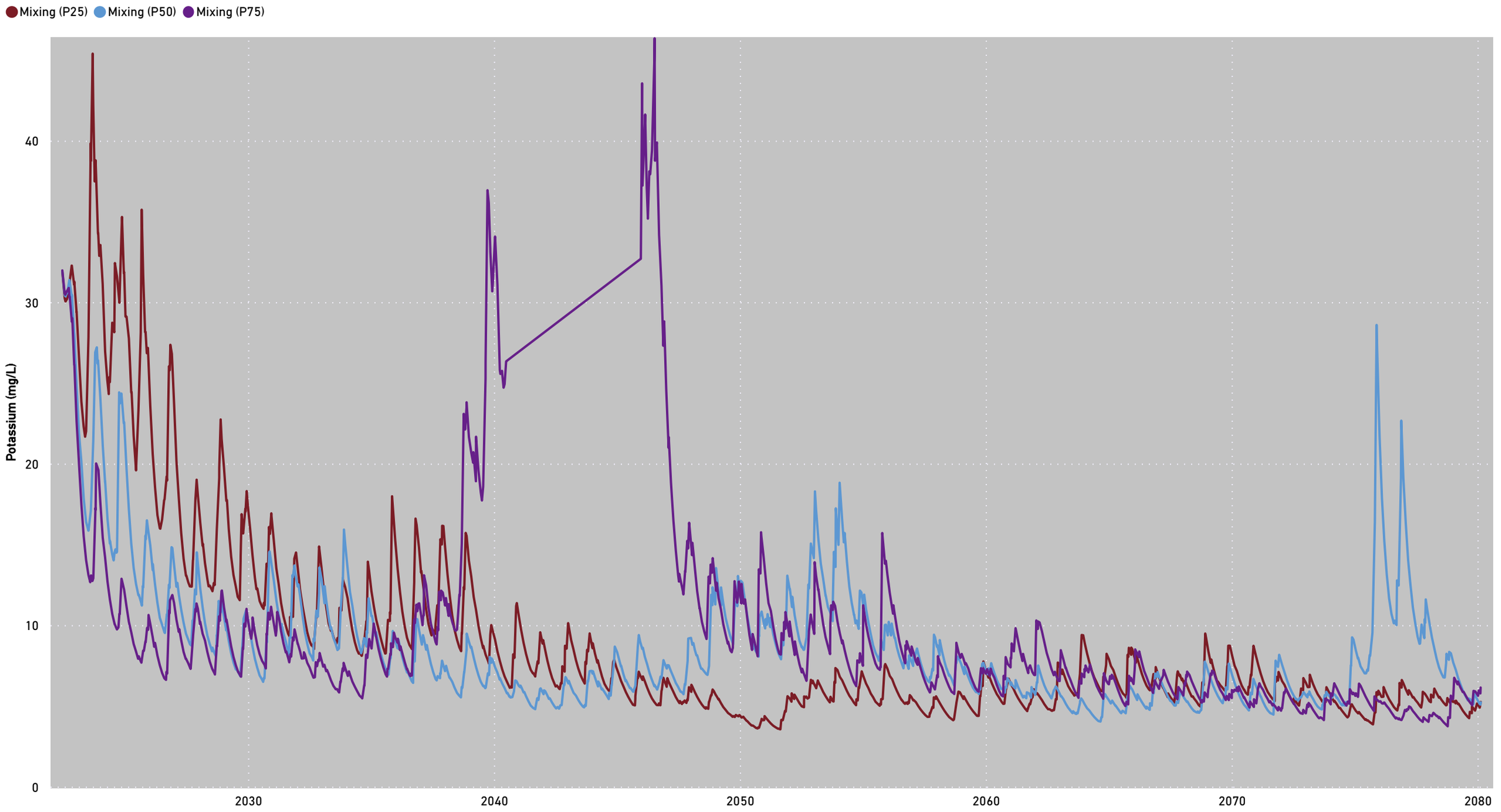

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - No loss of production: 5,000.00
Livestock WQG - No adverse effects: 4,000.00
Total Dissolved Solids (mg/L)
5K
4K
3K
2K
1K
0K
2030
2040
2050
2060
2070
2080

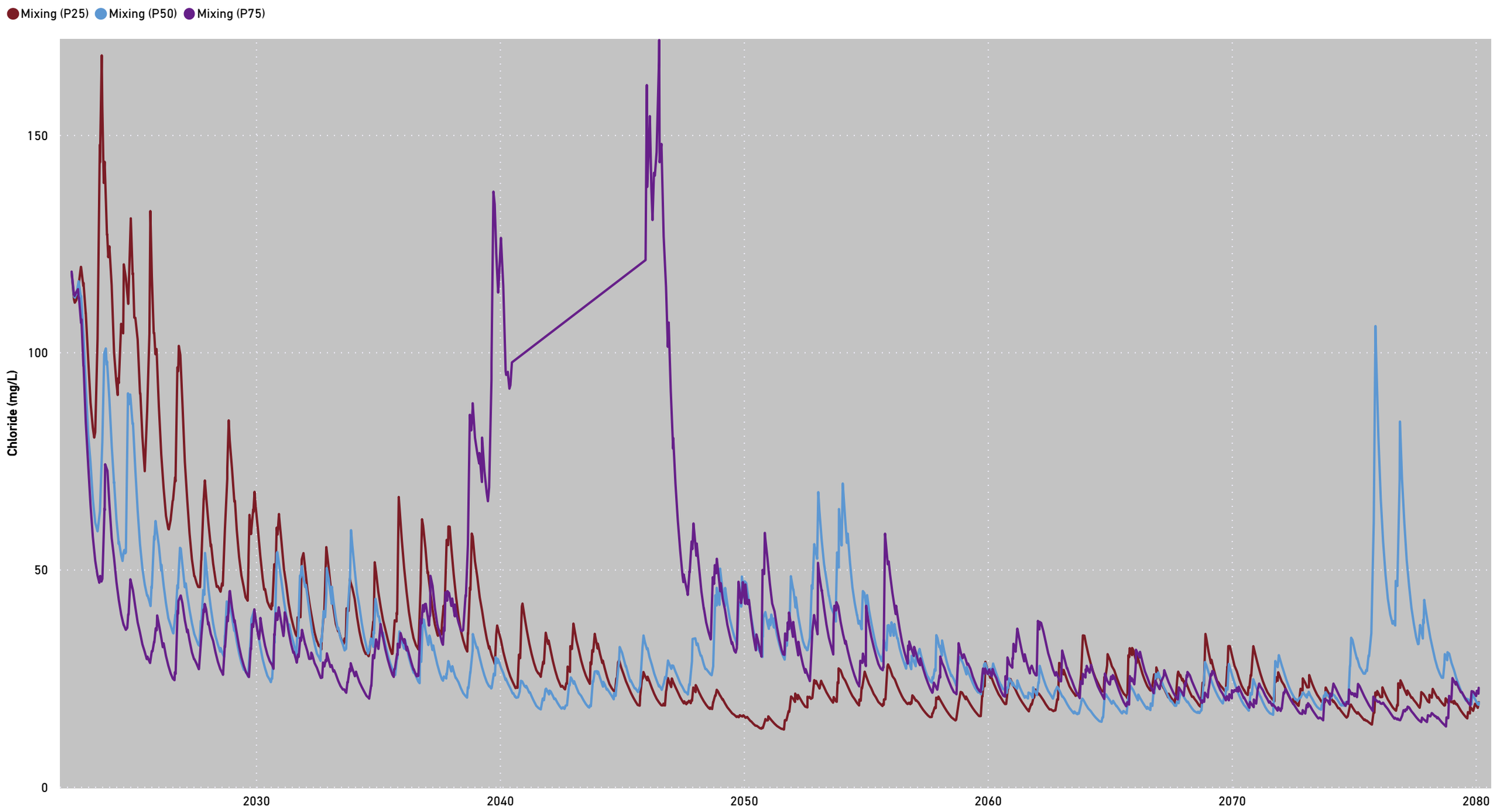

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 1,000.00
Calcium (mg/L)
1,000
800
600
400
200
0
2030
2040
2050
2060
2070
2080

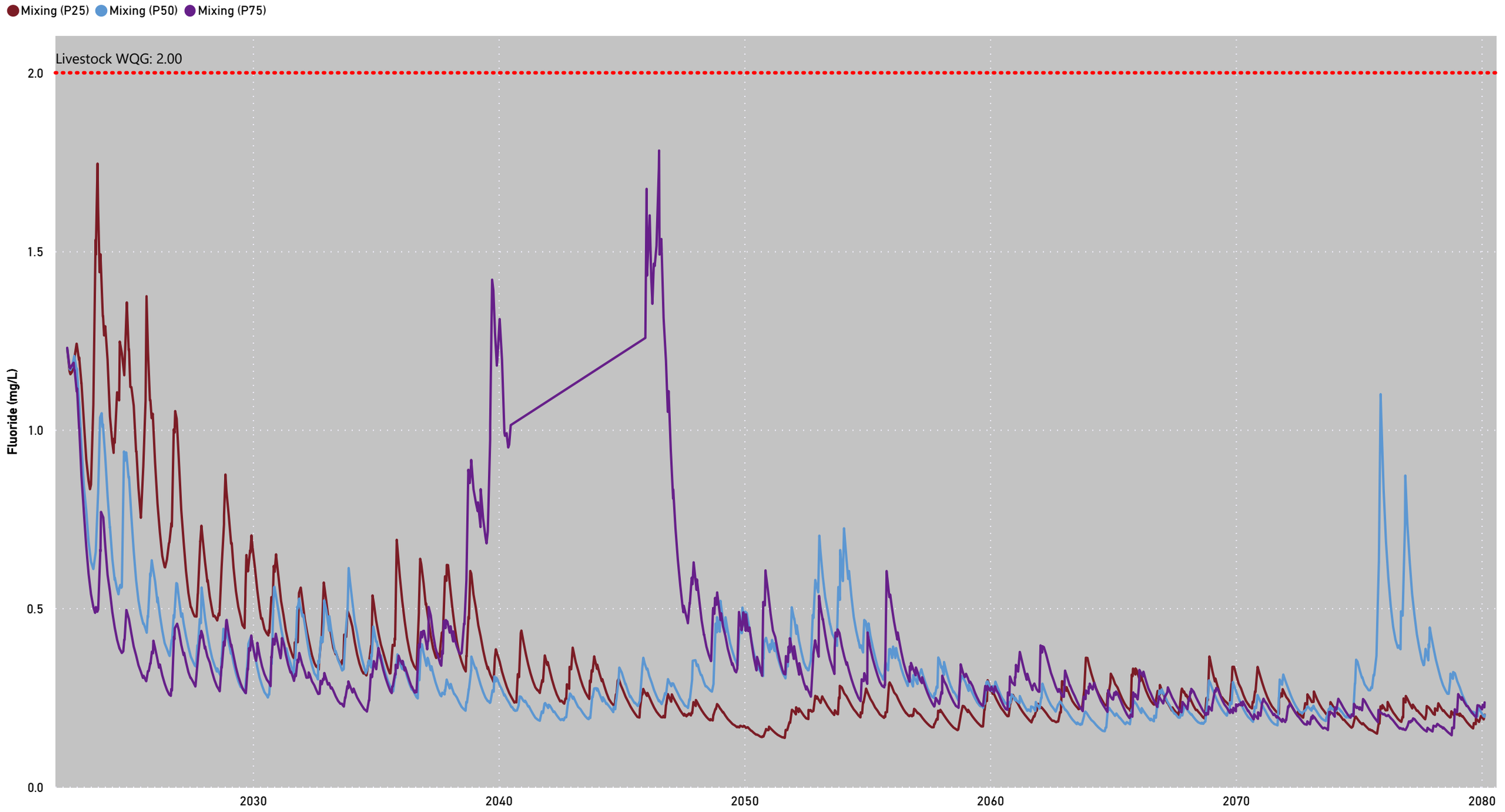

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - Higher Value: 2,000.00
Livestock WQG - Lower Value: 1,000.00
Sulfate (mg/L)
2,000
1,500
1,000
500
0
2030
2040
2050
2060
2070
2080

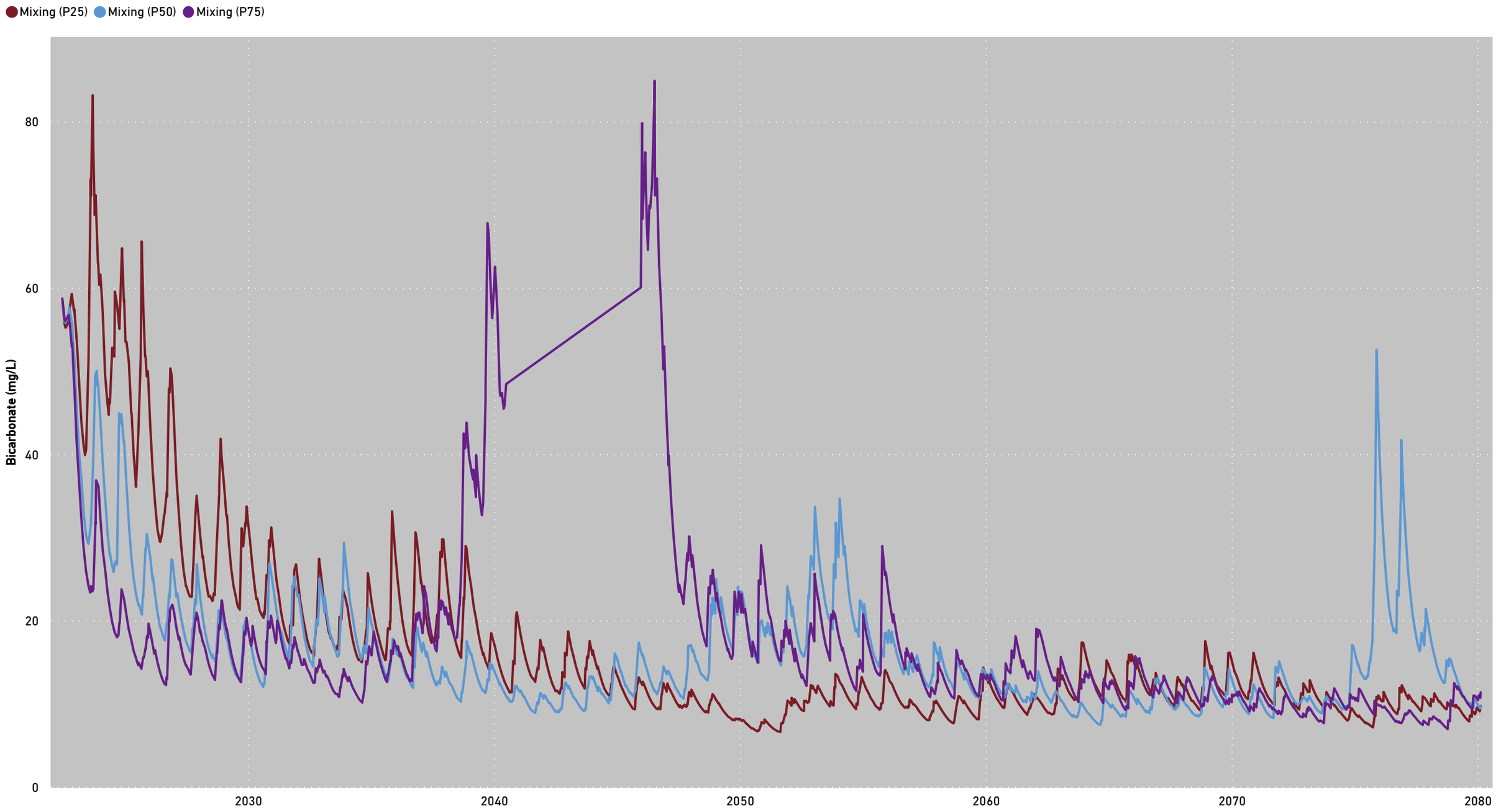

Mixing (P25)
Mixing (P50)
Mixing (P75)
Magnesium (mg/L)
0
10
20
30
40
50
60
2030
2040
2050
2060
2070
2080

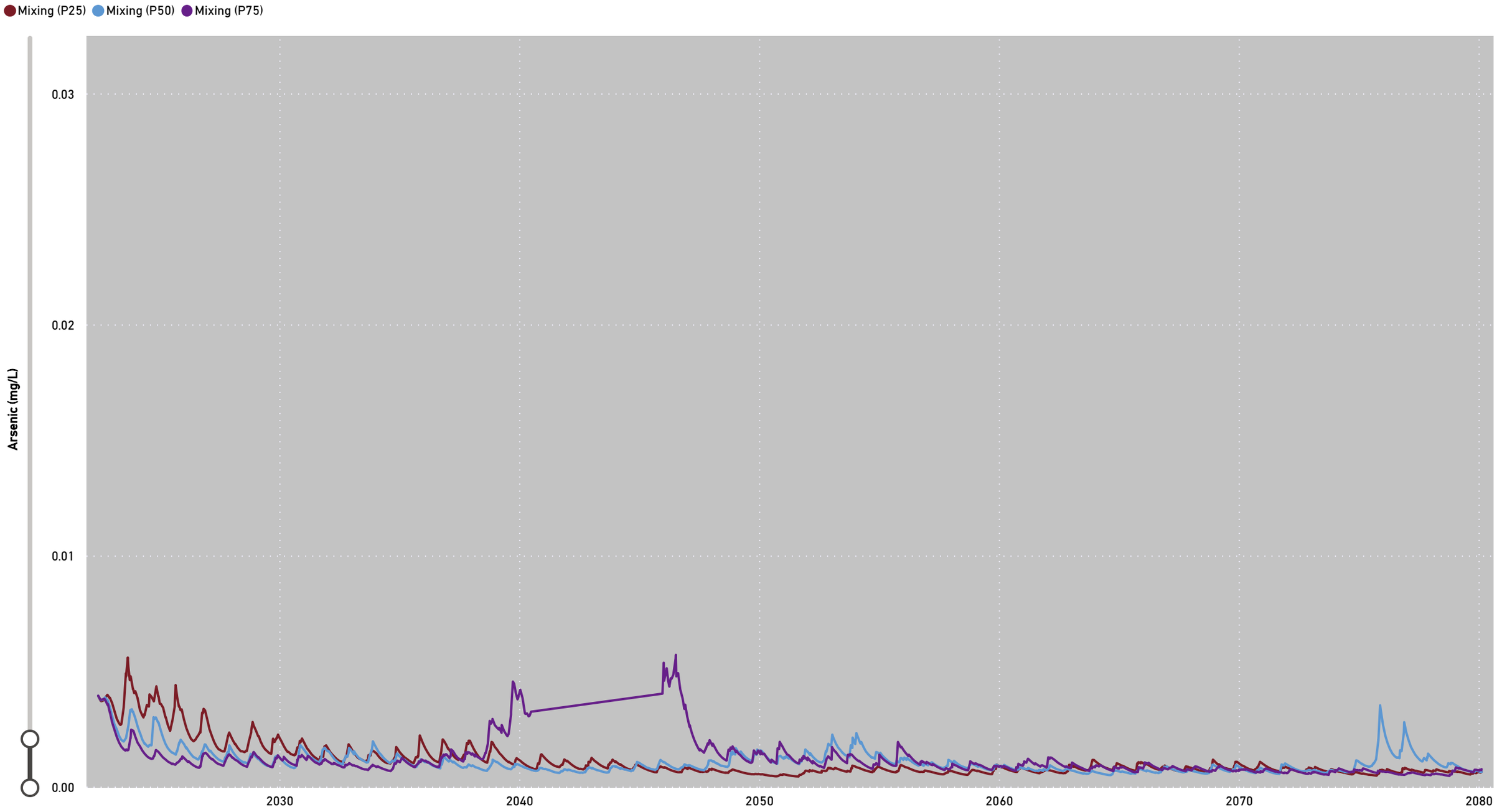

Mixing (P25)
Mixing (P50)
Mixing (P75)
Sodium (mg/L)
150
100
50
0
2030
2040
2050
2060
2070
2080

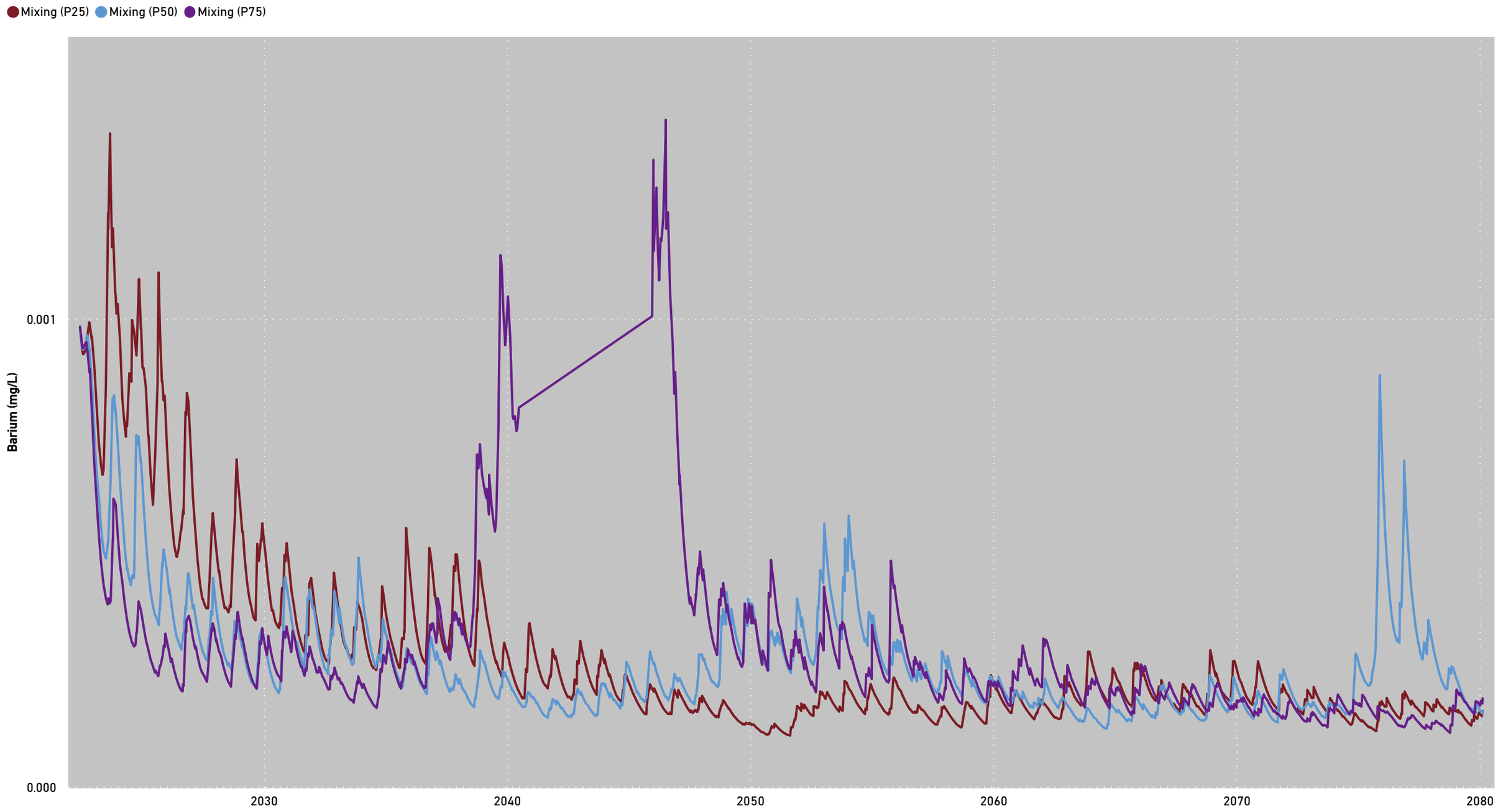

Mixing (P25)
Mixing (P50)
Mixing (P75)
Potassium (mg/L)
0
10
20
30
40
2030
2040
2050
2060
2070
2080

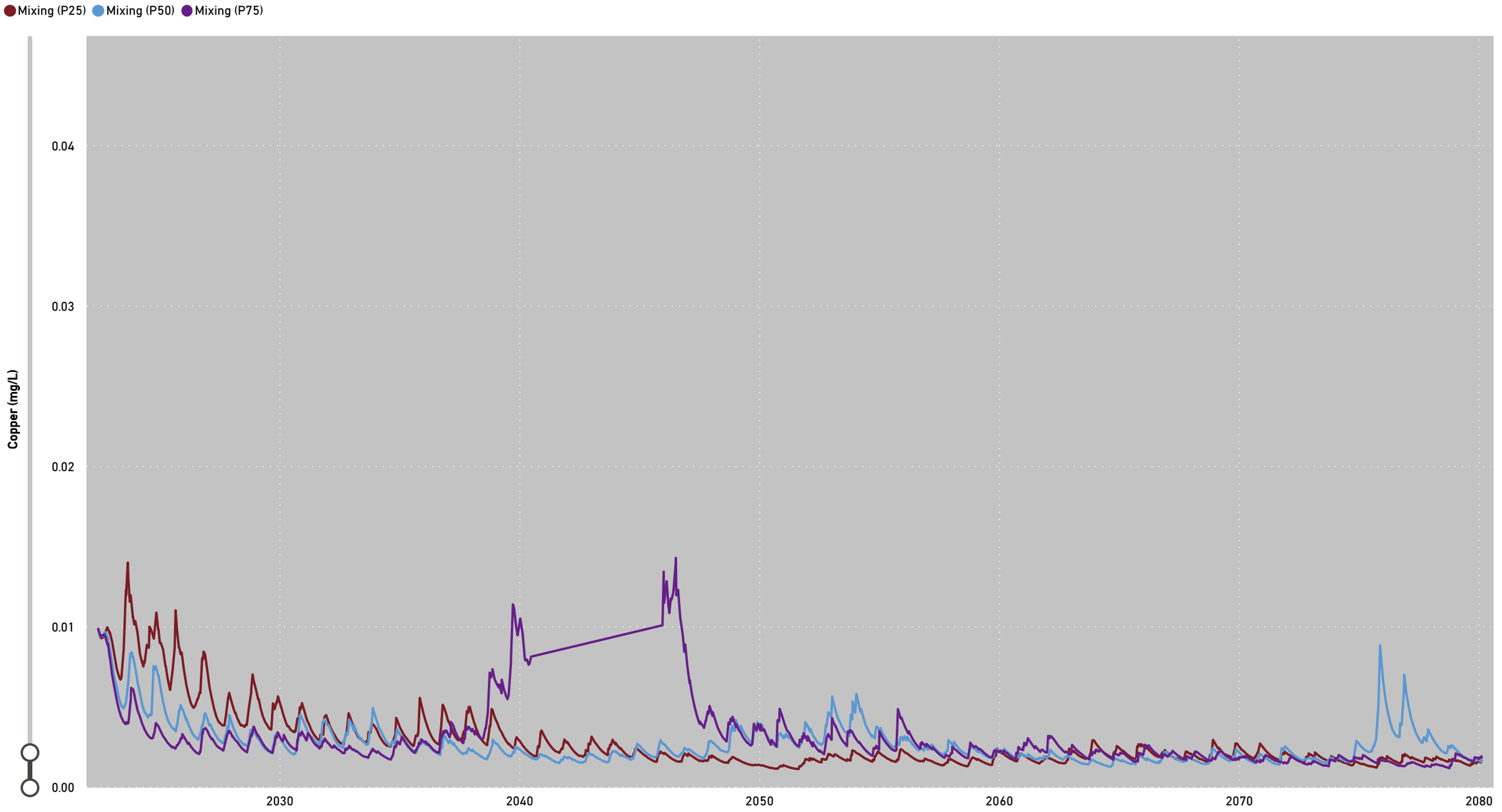

Mixing (P25)
Mixing (P50)
Mixing (P75)
Chloride (mg/L)
150
100
50
0
2030
2040
2050
2060
2070
2080

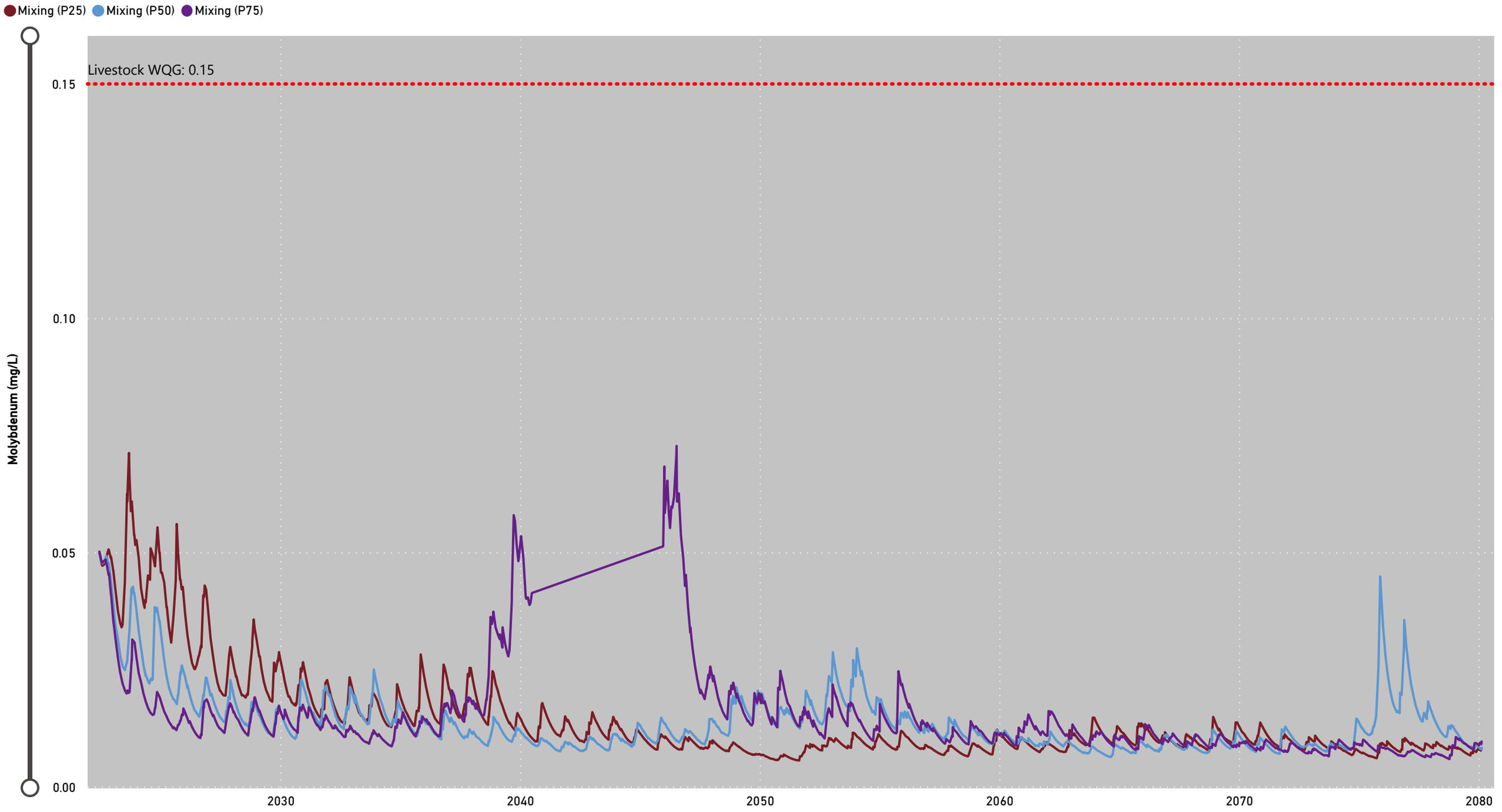

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 2.00
Fluoride (mg/L)
2.0
1.5
1.0
0.5
0.0
2030
2040
2050
2060
2070
2080

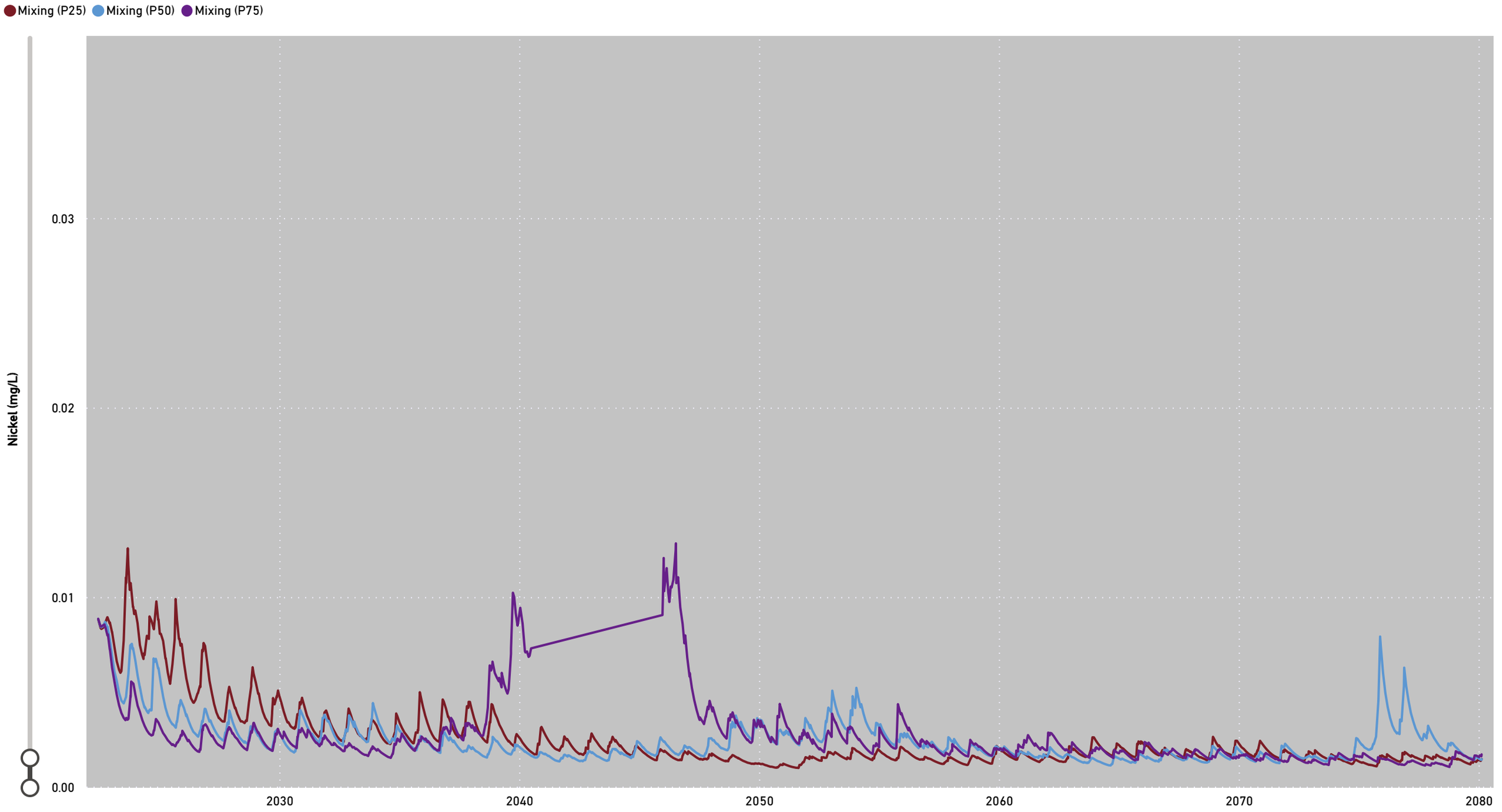

Mixing (P25)
Mixing (P50)
Mixing (P75)
Bicarbonate (mg/L)
0
20
40
60
80
2030
2040
2050
2060
2070
2080

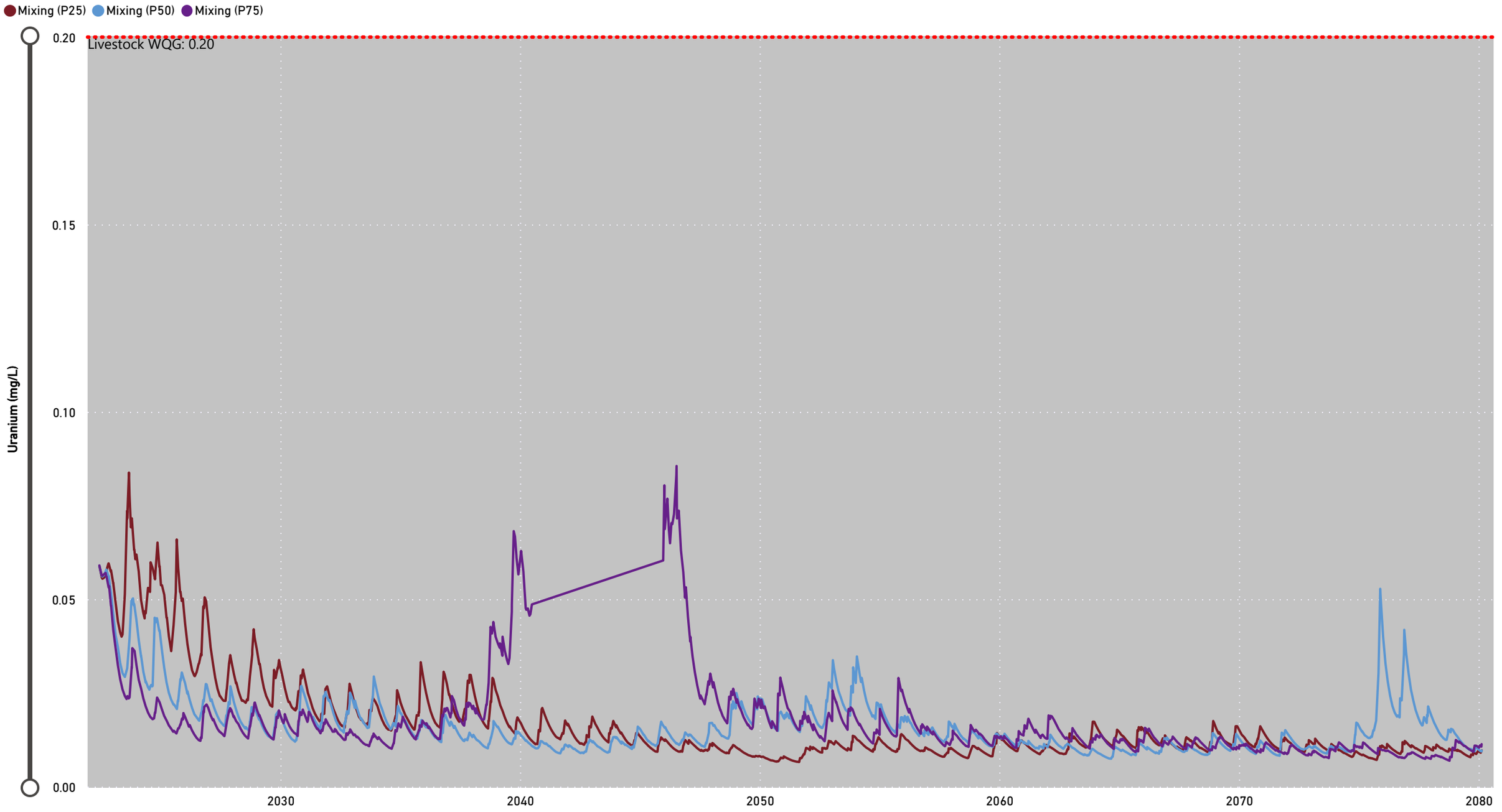

Mixing (P25)
Mixing (P50)
Mixing (P75)
Arsenic (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Barium (mg/L)
0.001
0.000
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Copper (mg/L)
0.04
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

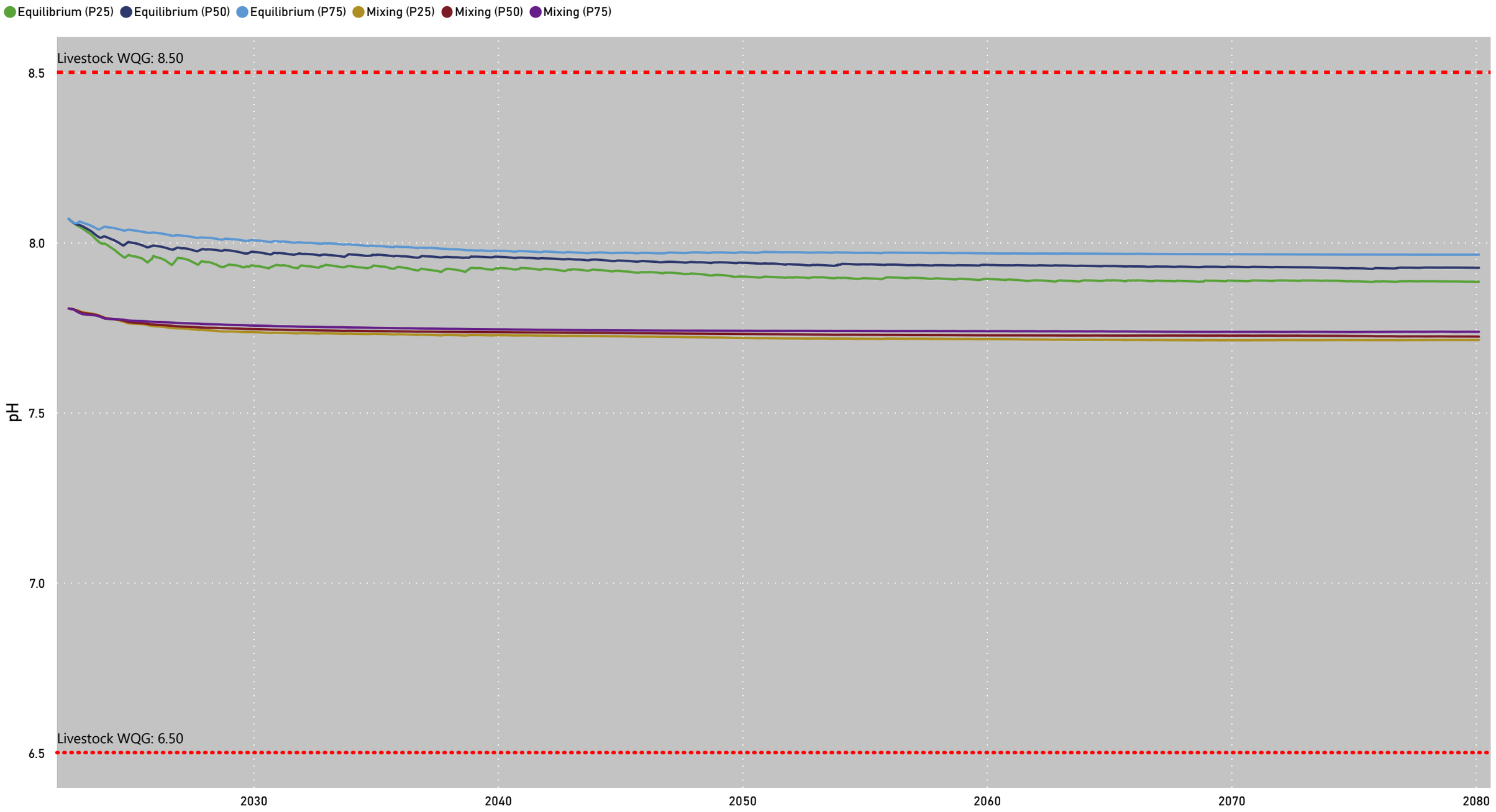

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 0.15
Molybdenum (mg/L)
0.15
0.10
0.05
0.00
2030
2040
2050
2060
2070
2080

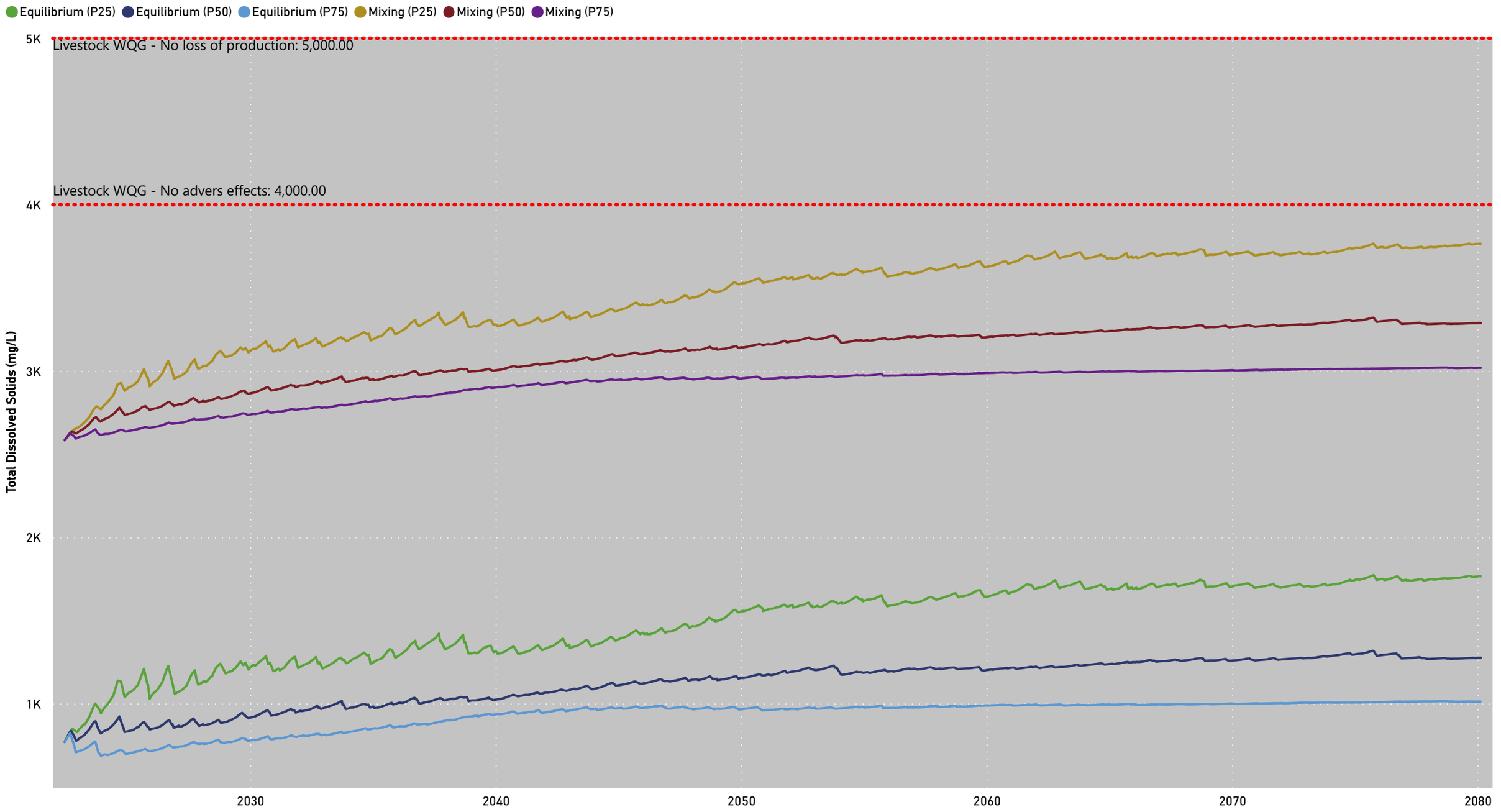

Mixing (P25)
Mixing (P50)
Mixing (P75)
Nickel (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

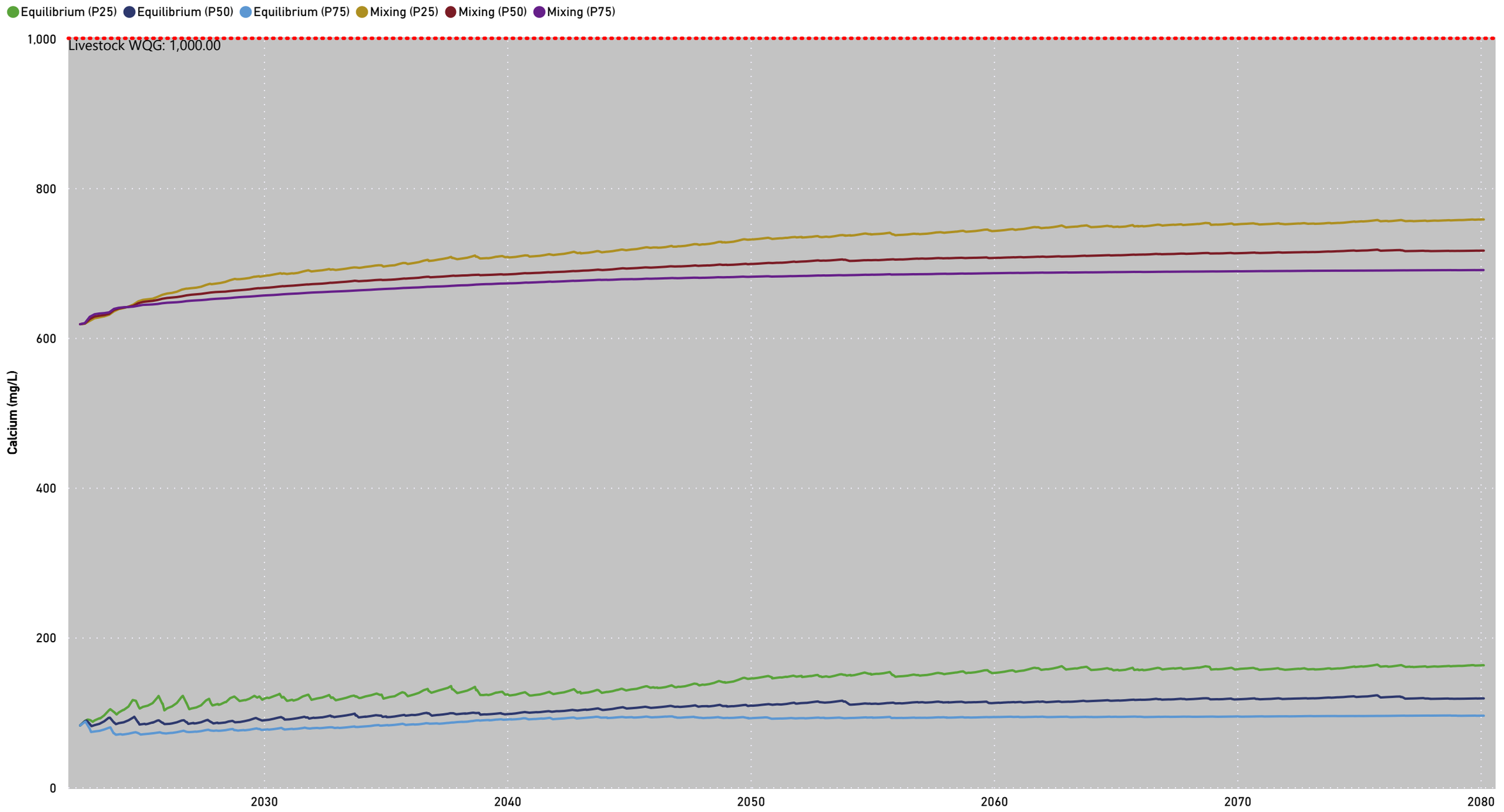

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 0.20
Uranium (mg/L)
0.20
0.15
0.10
0.05
0.00
2030
2040
2050
2060
2070
2080

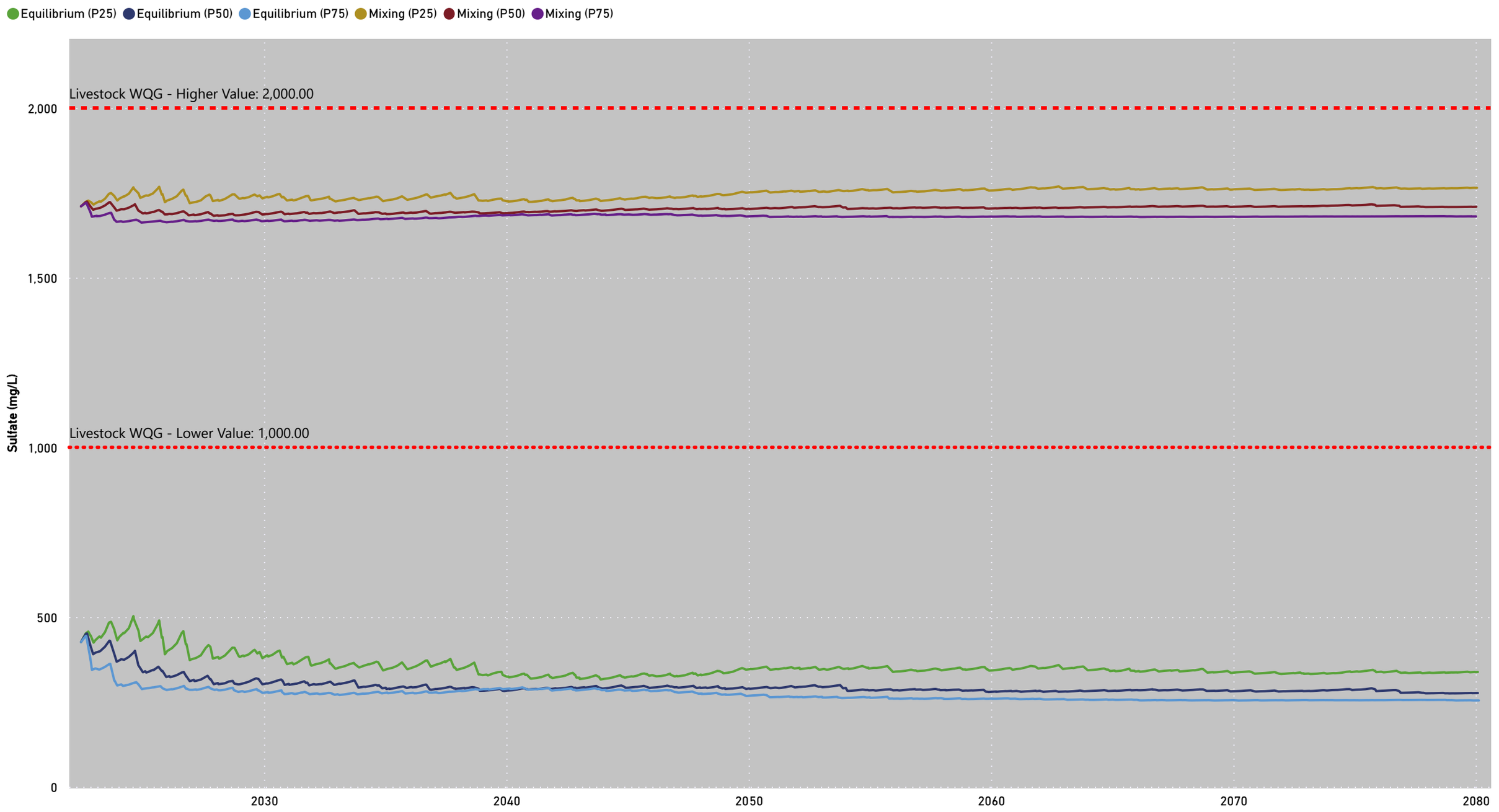
Appendix E

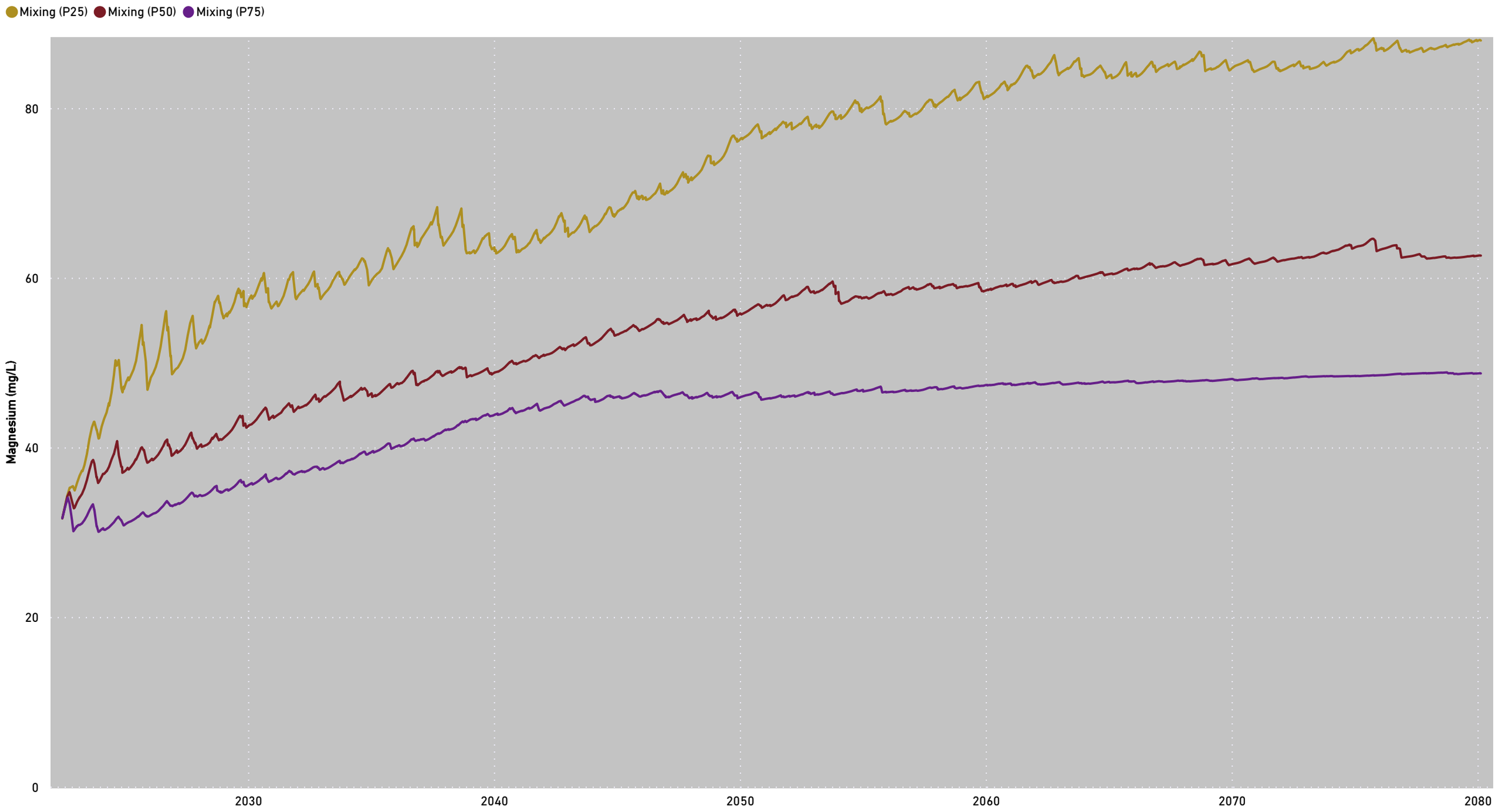
North Pit modelled long-term water quality

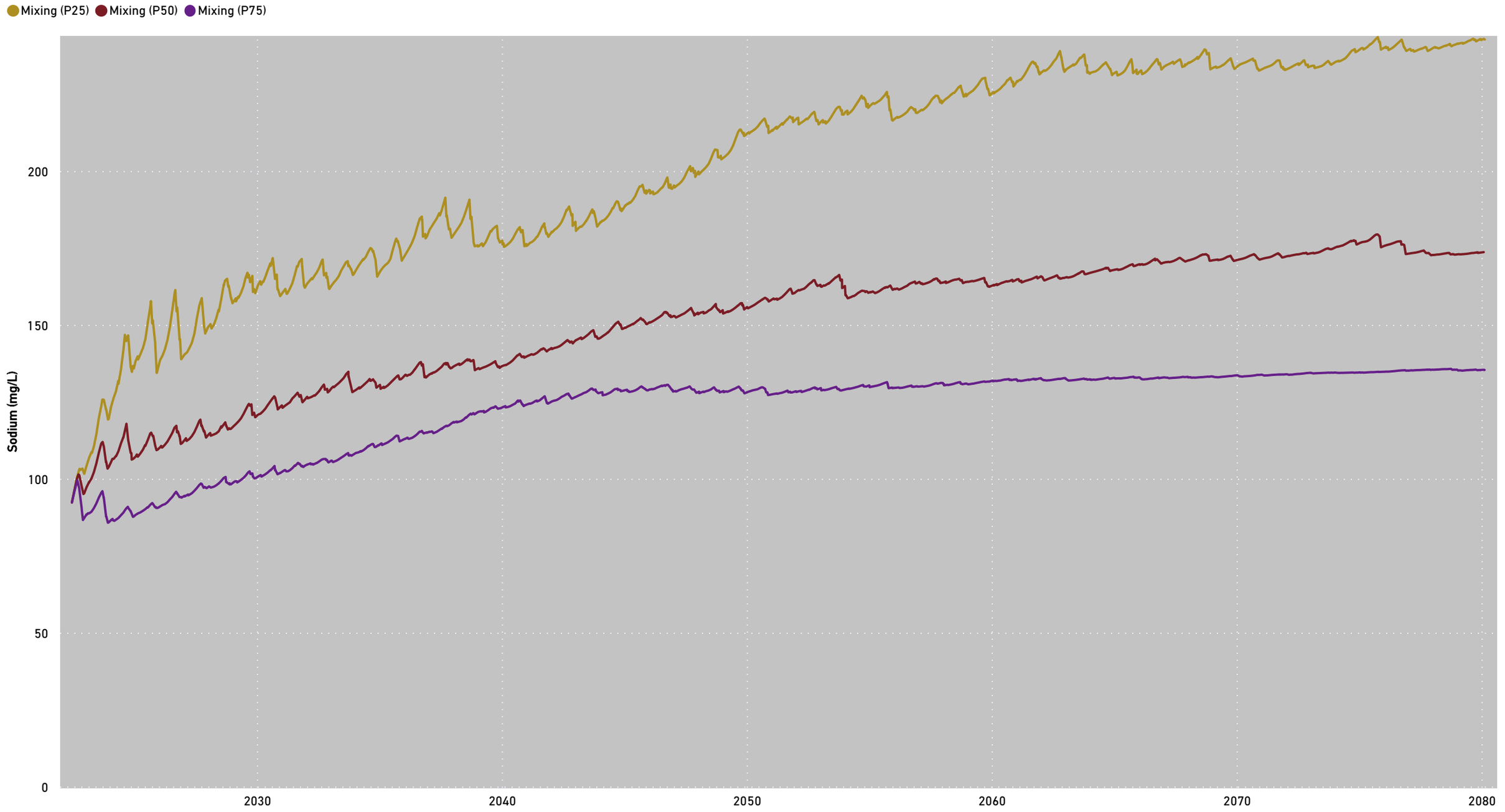

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 8.50
Livestock WQG: 6.50
pH
8.5
8.0
7.5
7.0
6.5
2030
2040
2050
2060
2070
2080

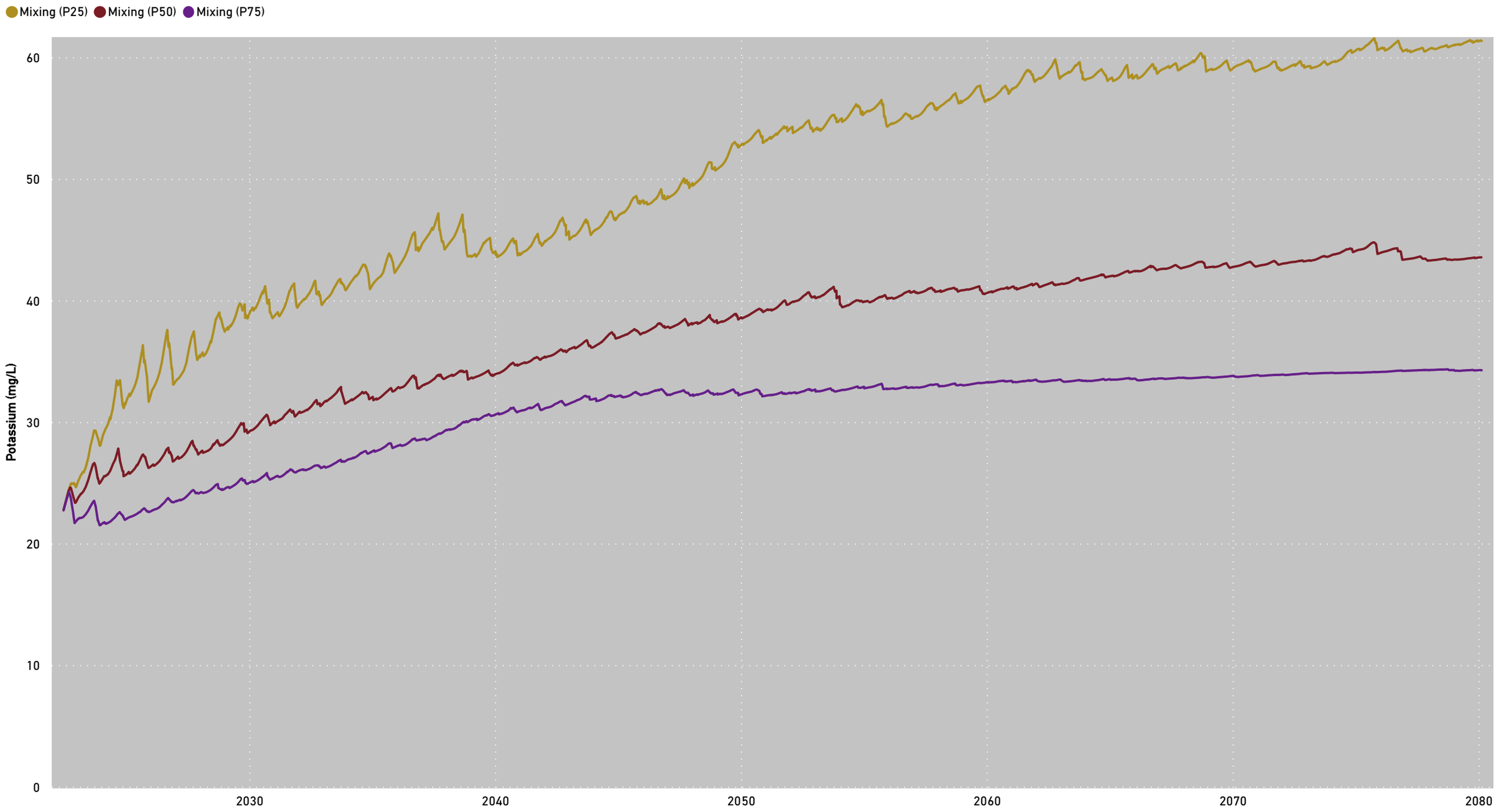

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - No loss of production: 5,000.00
Livestock WQG - No advers effects: 4,000.00
Total Dissolved Solids (mg/L)
5K
4K
3K
2K
1K
2030
2040
2050
2060
2070
2080

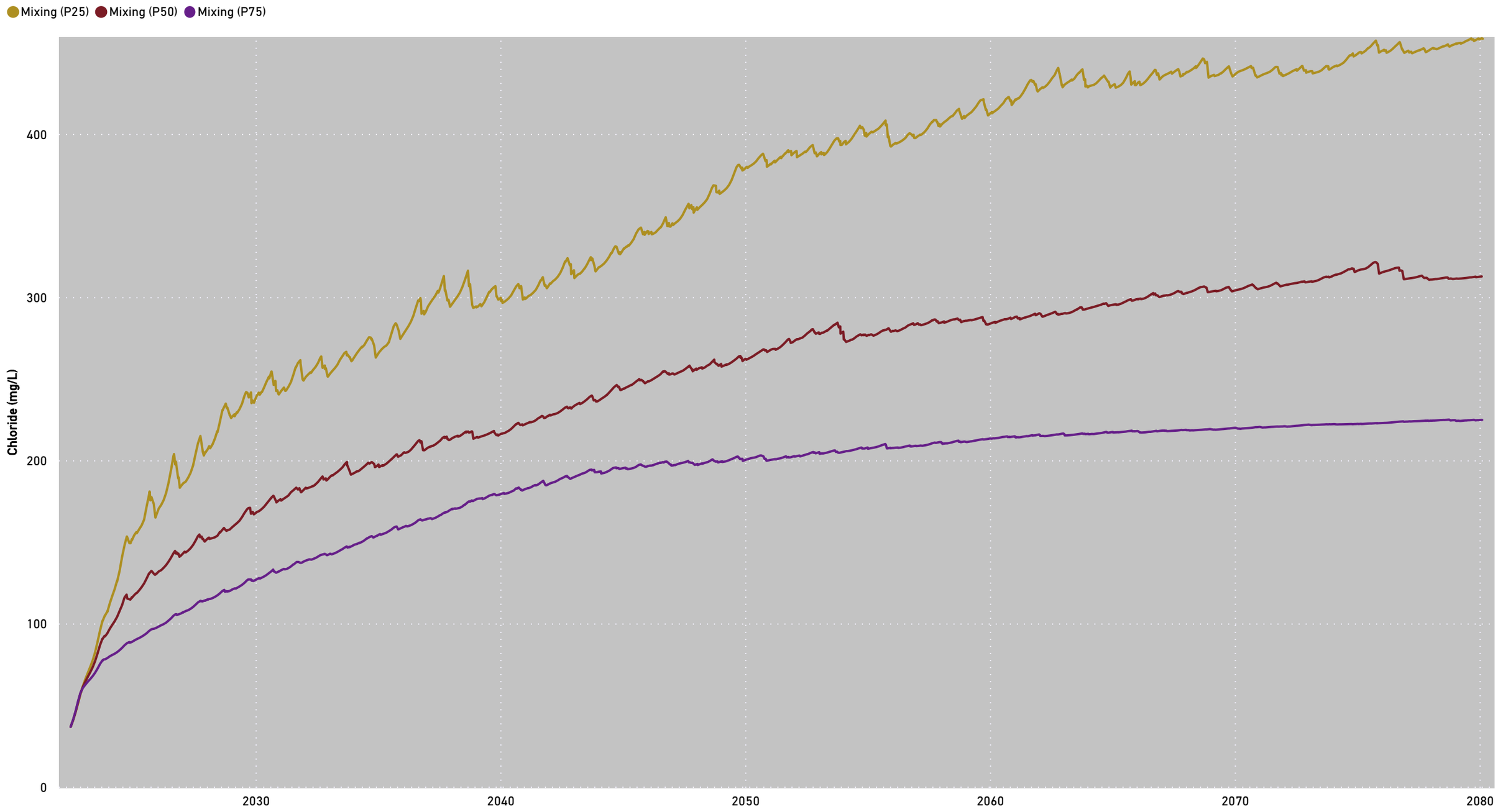

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 1,000.00
Calcium (mg/L)
1,000
800
600
400
200
0
2030
2040
2050
2060
2070
2080

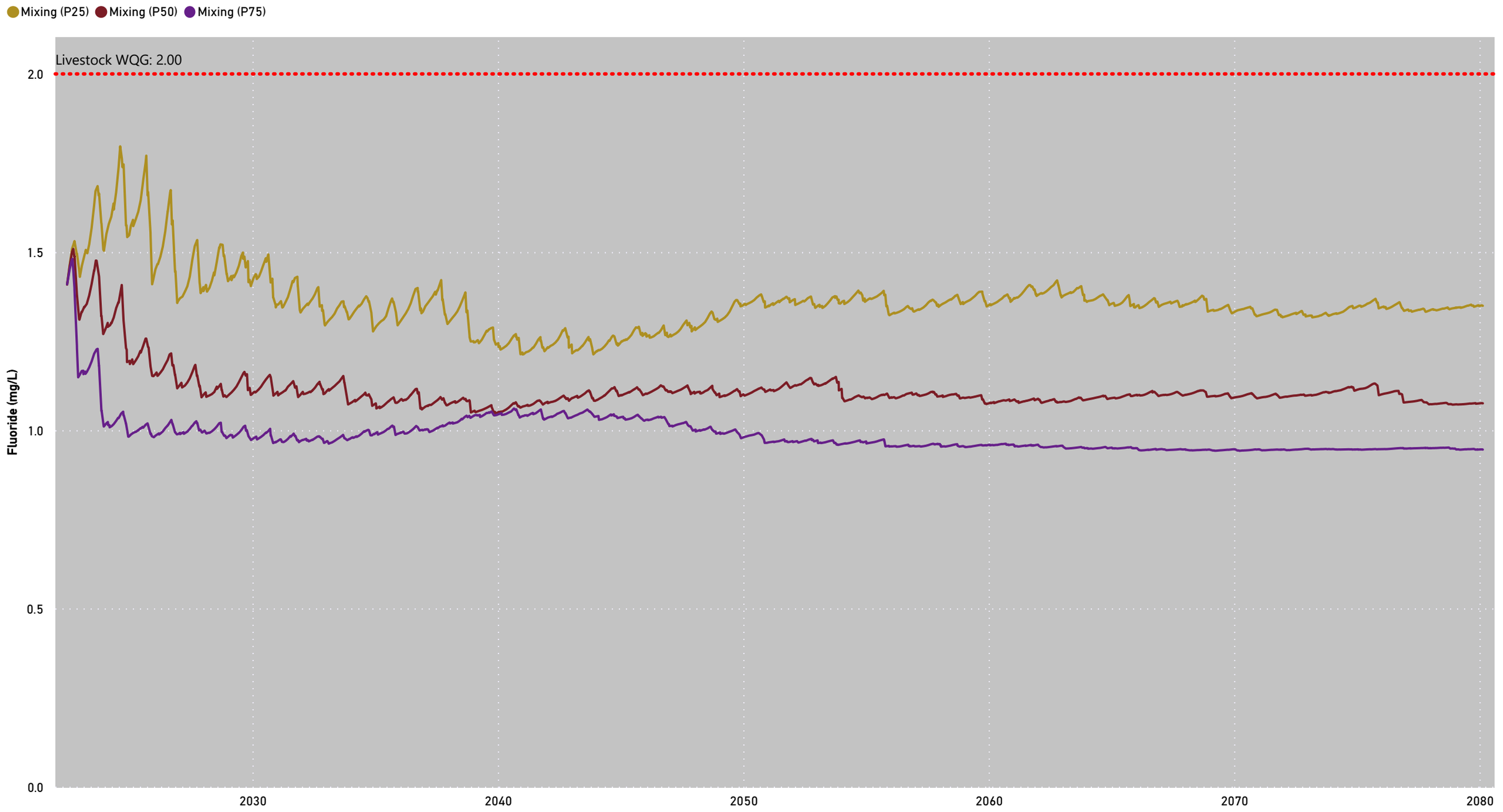

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - Higher Value: 2,000.00
Livestock WQG - Lower Value: 1,000.00
Sulfate (mg/L)
2,000
1,500
1,000
500
0
2030
2040
2050
2060
2070
2080

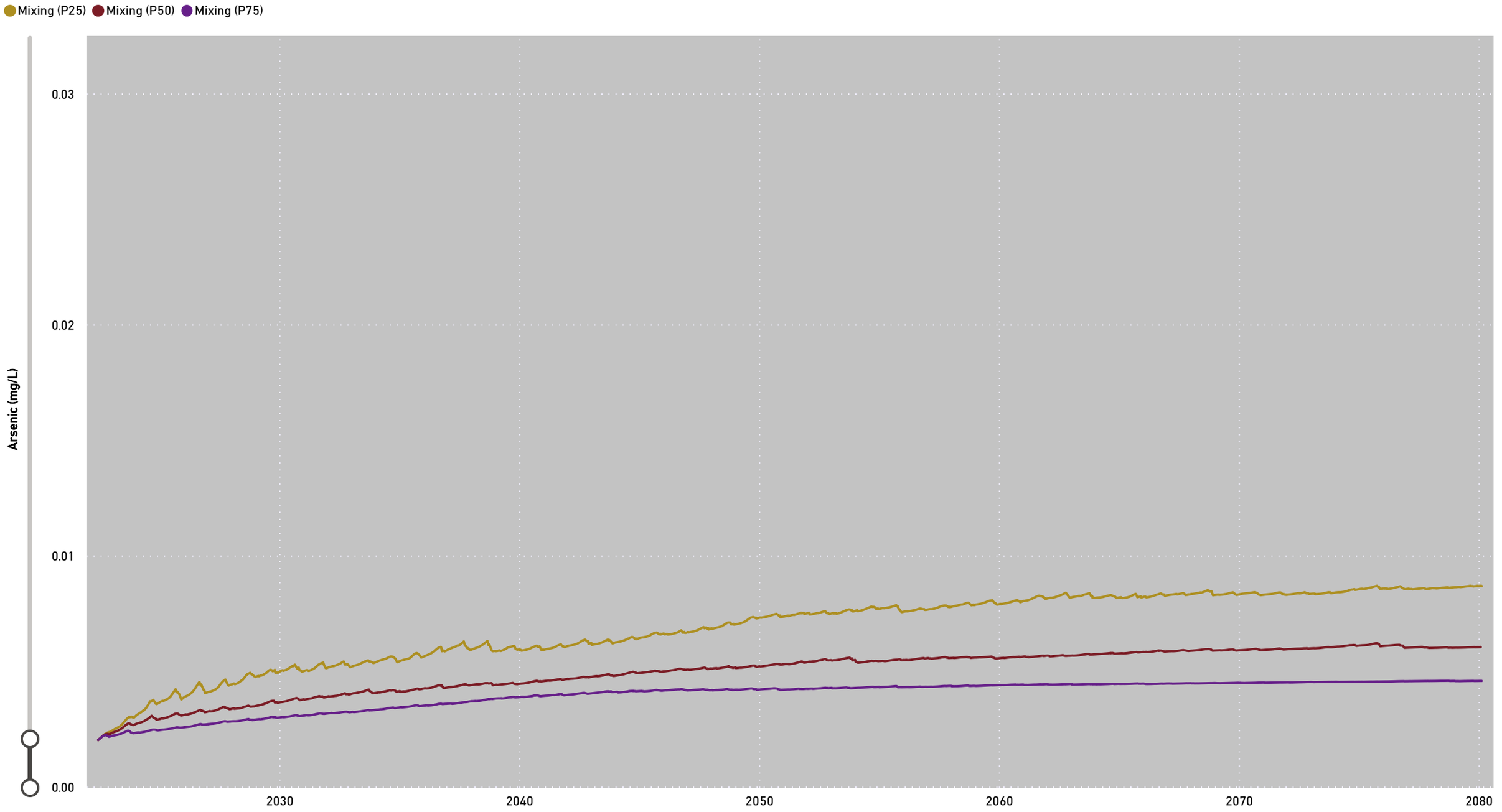

Mixing (P25)
Mixing (P50)
Mixing (P75)
Magnesium (mg/L)
0
20
40
60
80
2030
2040
2050
2060
2070
2080

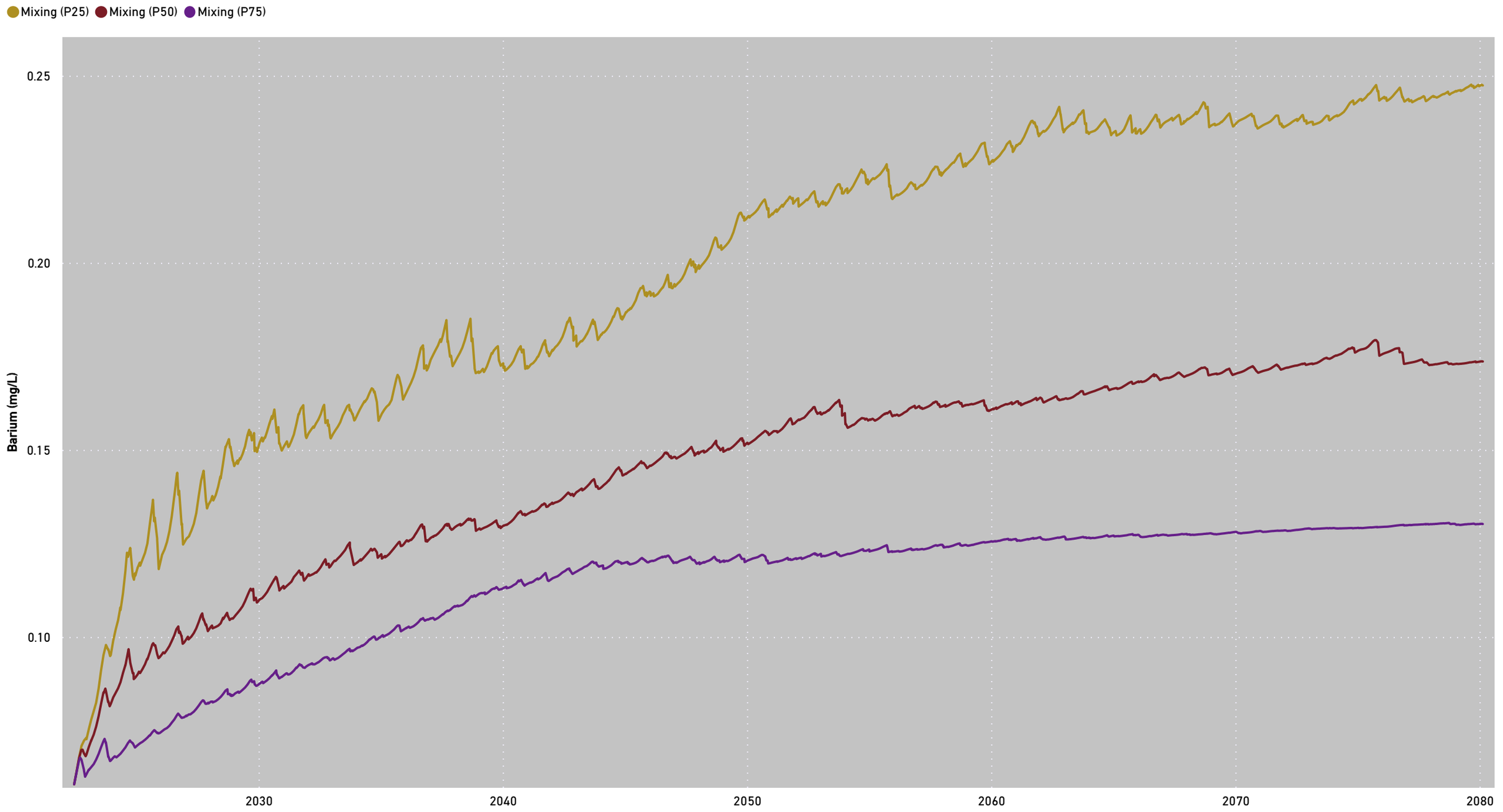

Mixing (P25)
Mixing (P50)
Mixing (P75)
Sodium (mg/L)
0
50
100
150
200
2030
2040
2050
2060
2070
2080

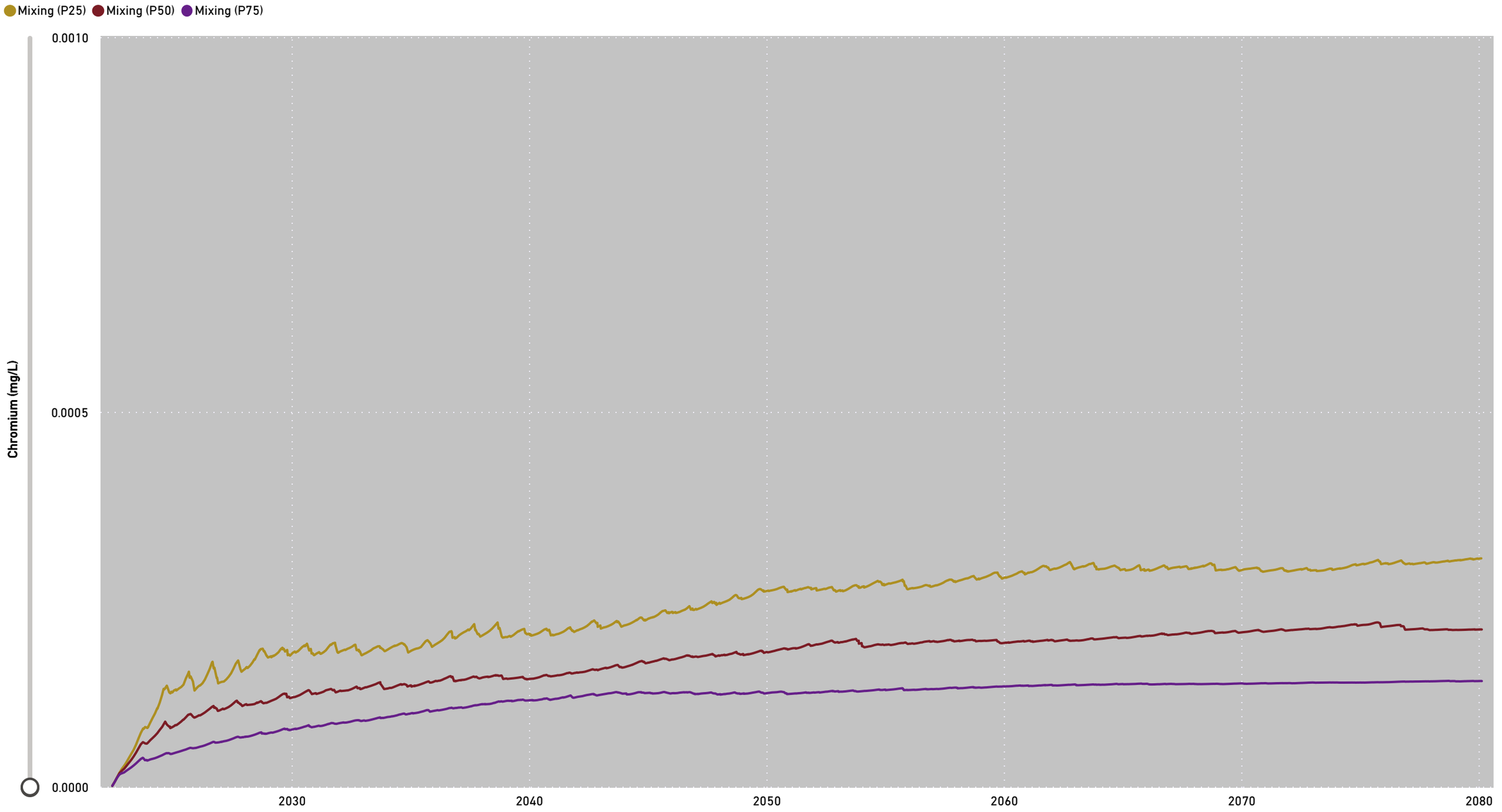

Mixing (P25)
Mixing (P50)
Mixing (P75)
Potassium (mg/L)
0
10
20
30
40
50
60
2030
2040
2050
2060
2070
2080

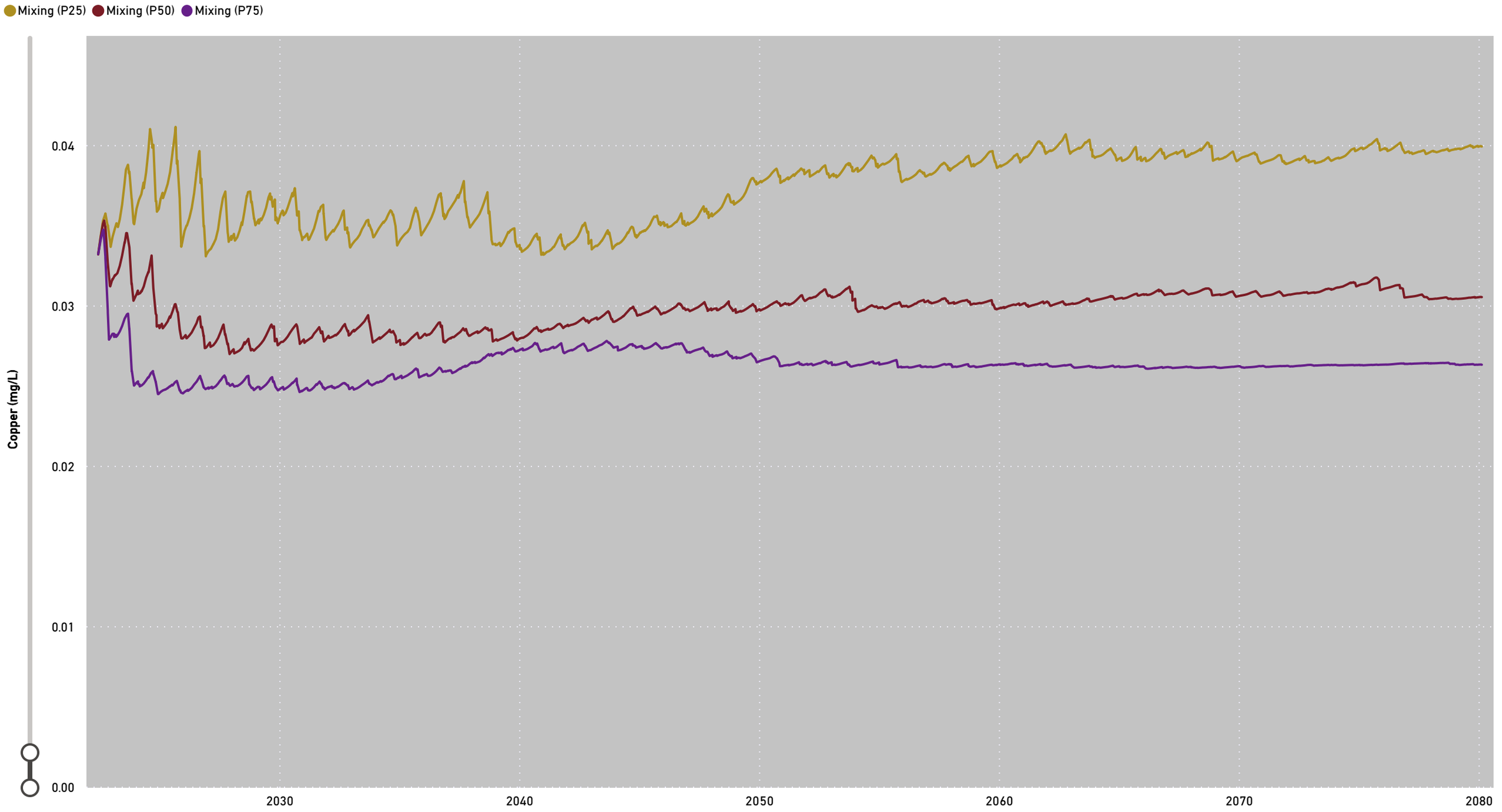

Mixing (P25)
Mixing (P50)
Mixing (P75)
Chloride (mg/L)
0
100
200
300
400
2030
2040
2050
2060
2070
2080

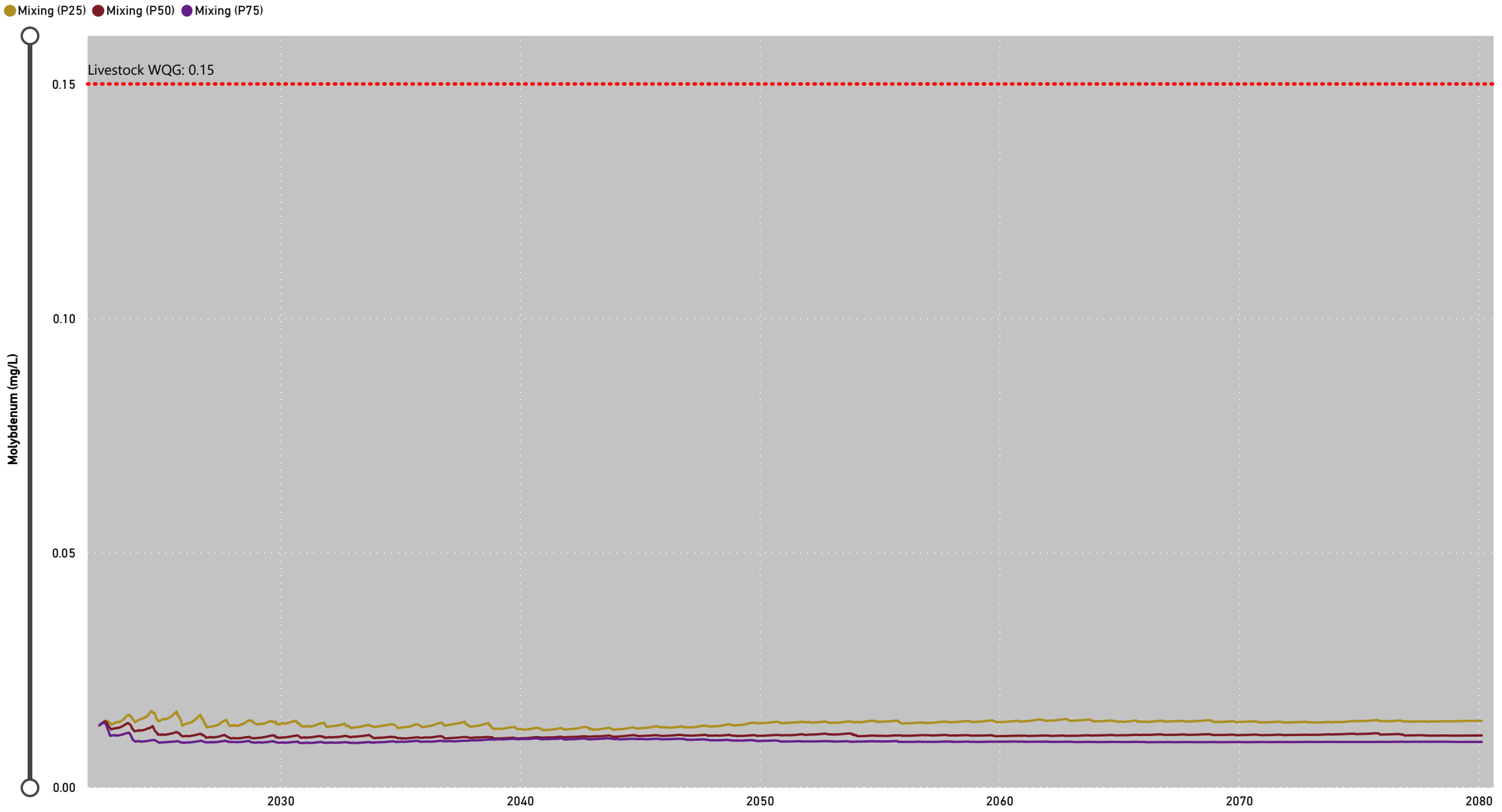

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 2.00
Fluoride (mg/L)
2.0
1.5
1.0
0.5
0.0
2030
2040
2050
2060
2070
2080

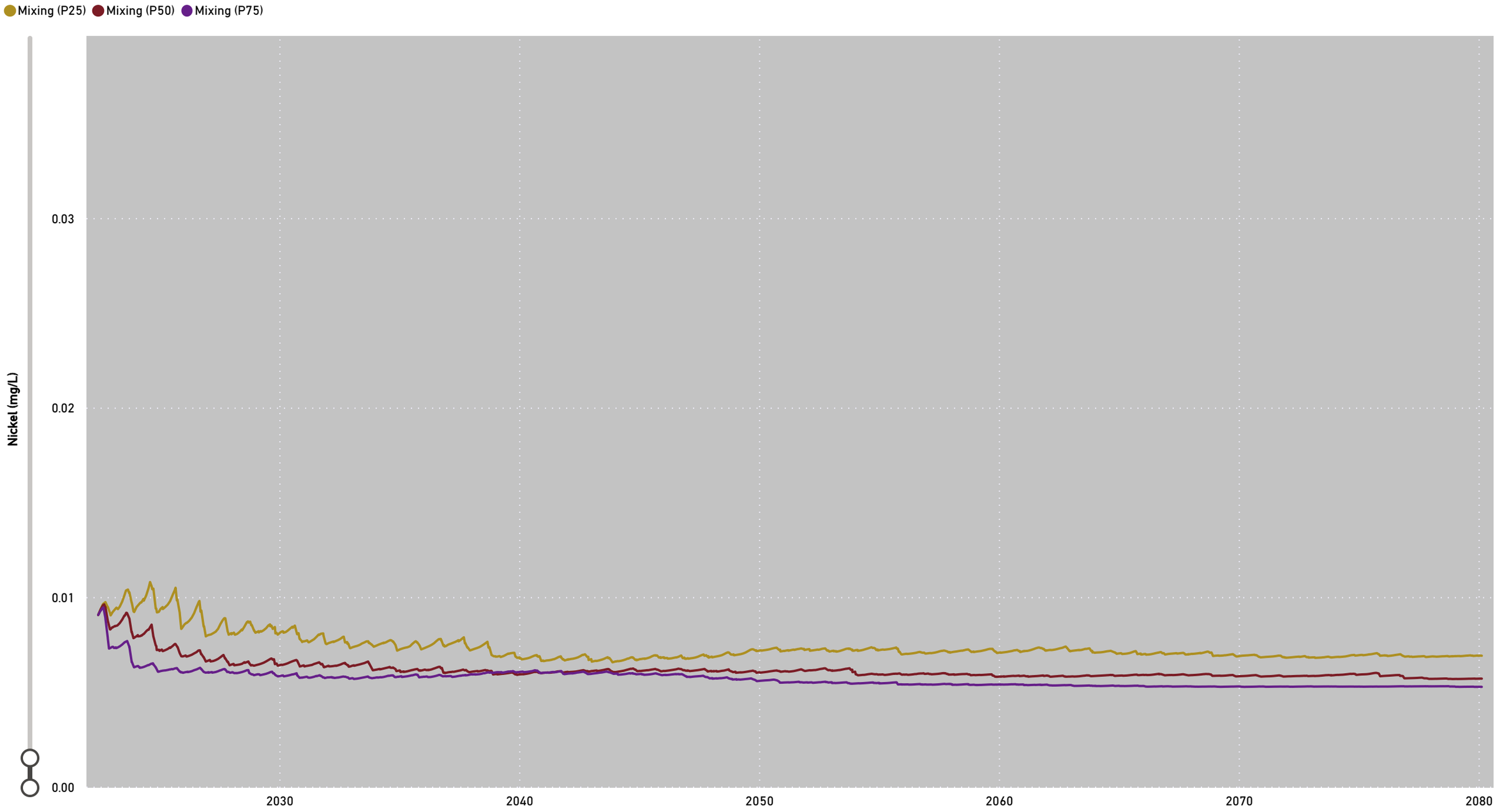

Mixing (P25)
Mixing (P50)
Mixing (P75)
Arsenic (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

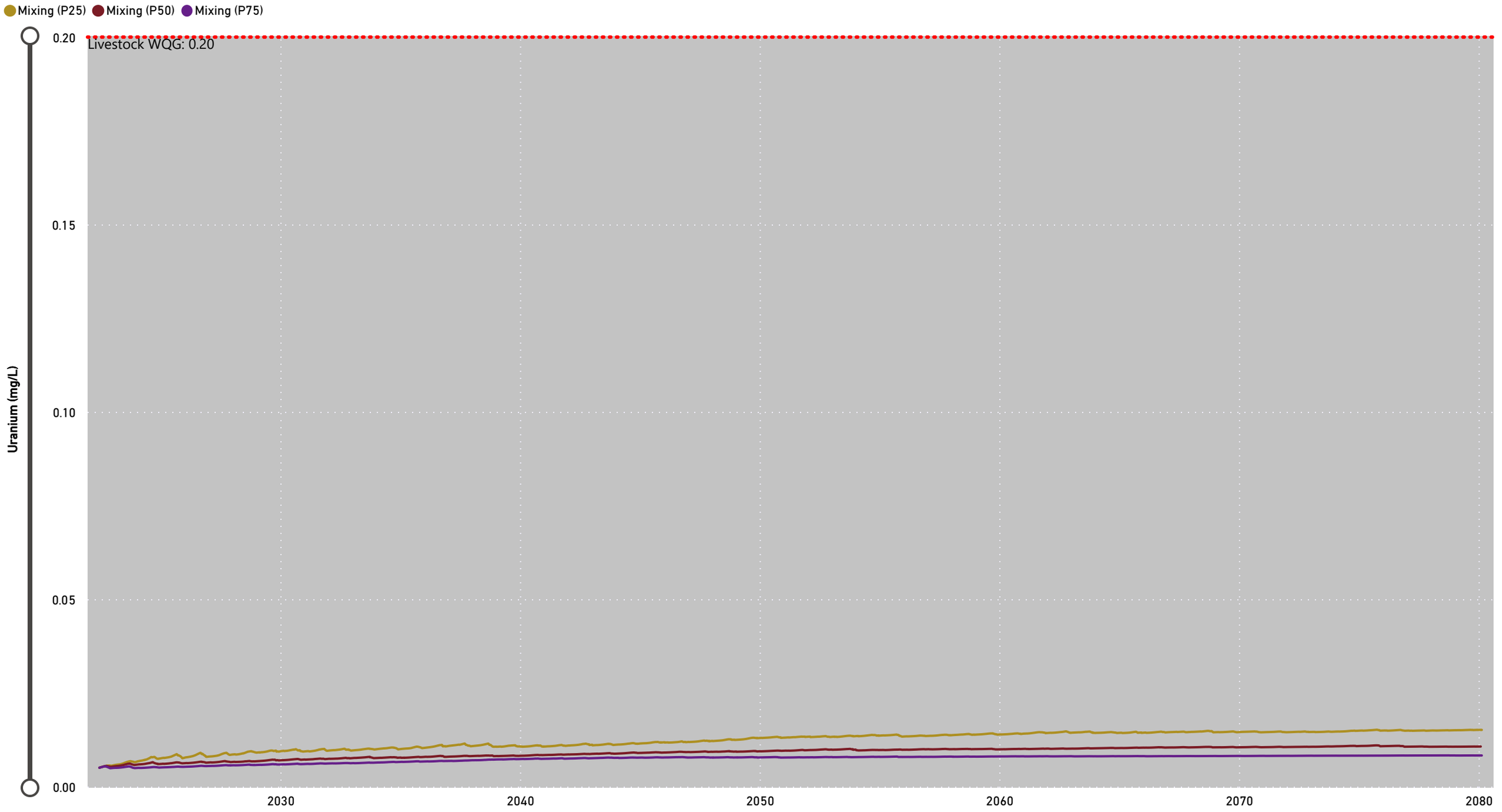

Mixing (P25)
Mixing (P50)
Mixing (P75)
Barium (mg/L)
0.25
0.20
0.15
0.10
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Chromium (mg/L)
0.0010
0.0005
0.0000
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Copper (mg/L)
0.04
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 0.15
Molybdenum (mg/L)
0.15
0.10
0.05
0.00
2030
2040
2050
2060
2070
2080

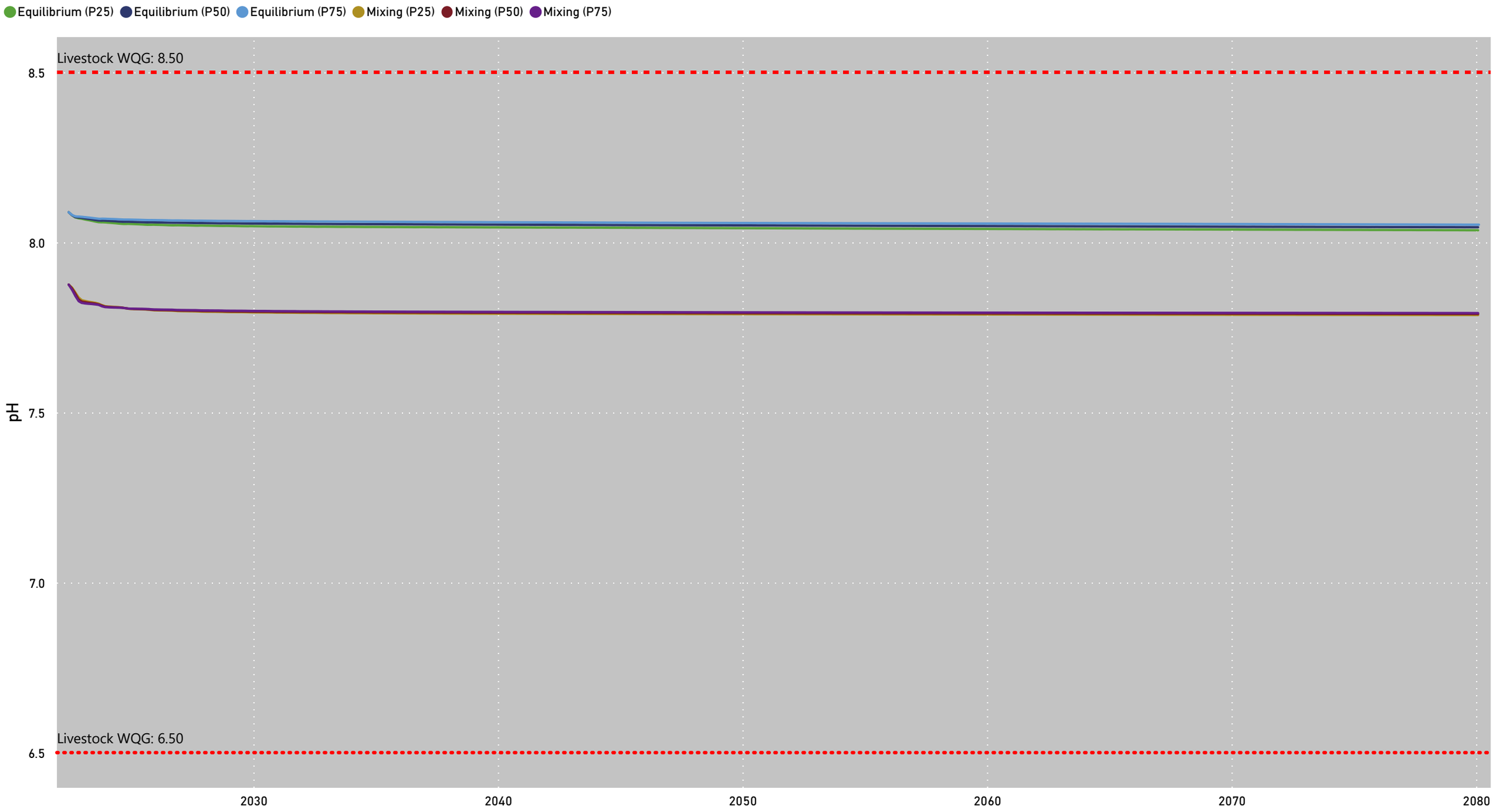

Mixing (P25)
Mixing (P50)
Mixing (P75)
Nickel (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

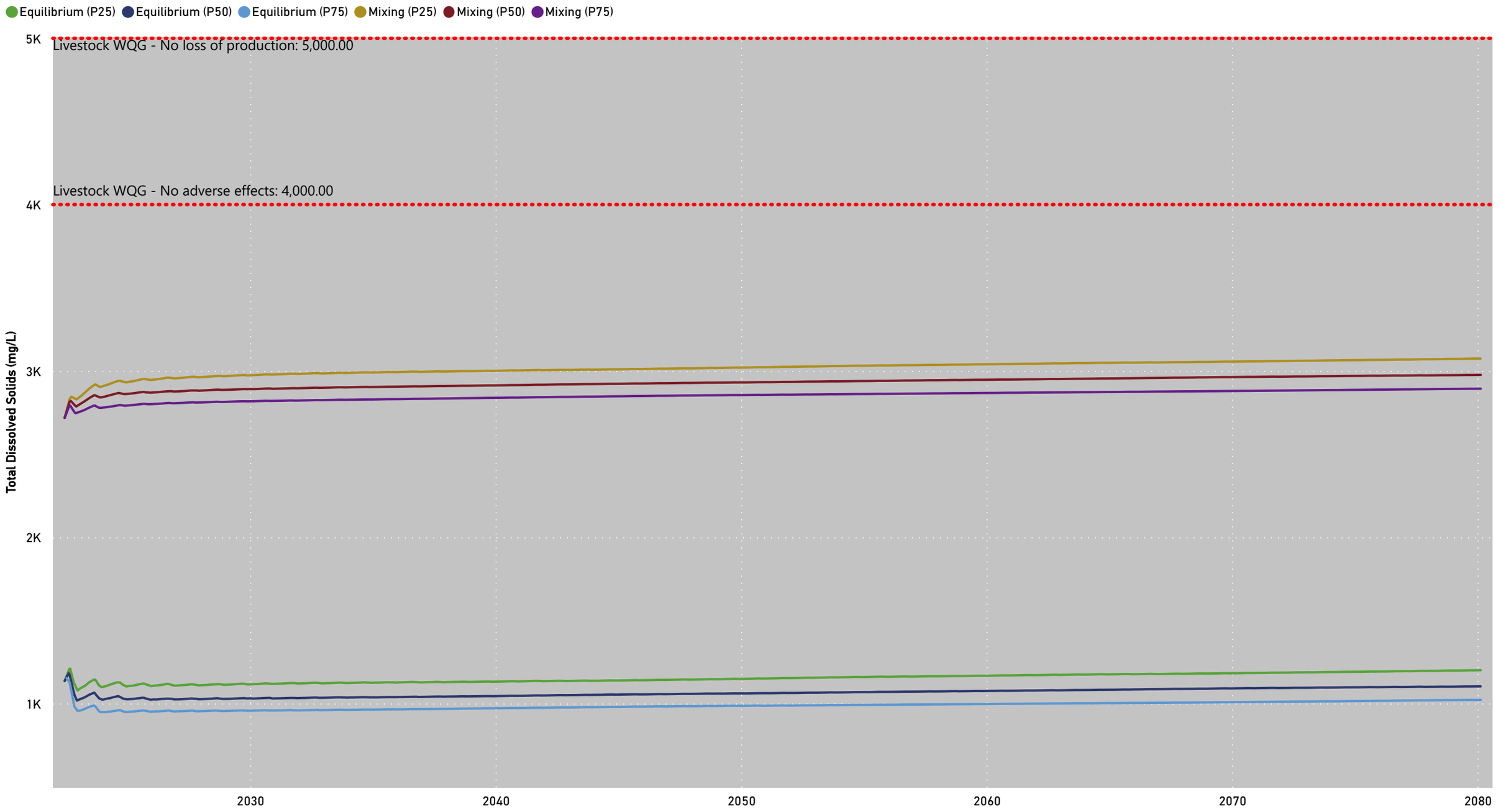

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 0.20
Uranium (mg/L)
0.20
0.15
0.10
0.05
0.00
2030
2040
2050
2060
2070
2080

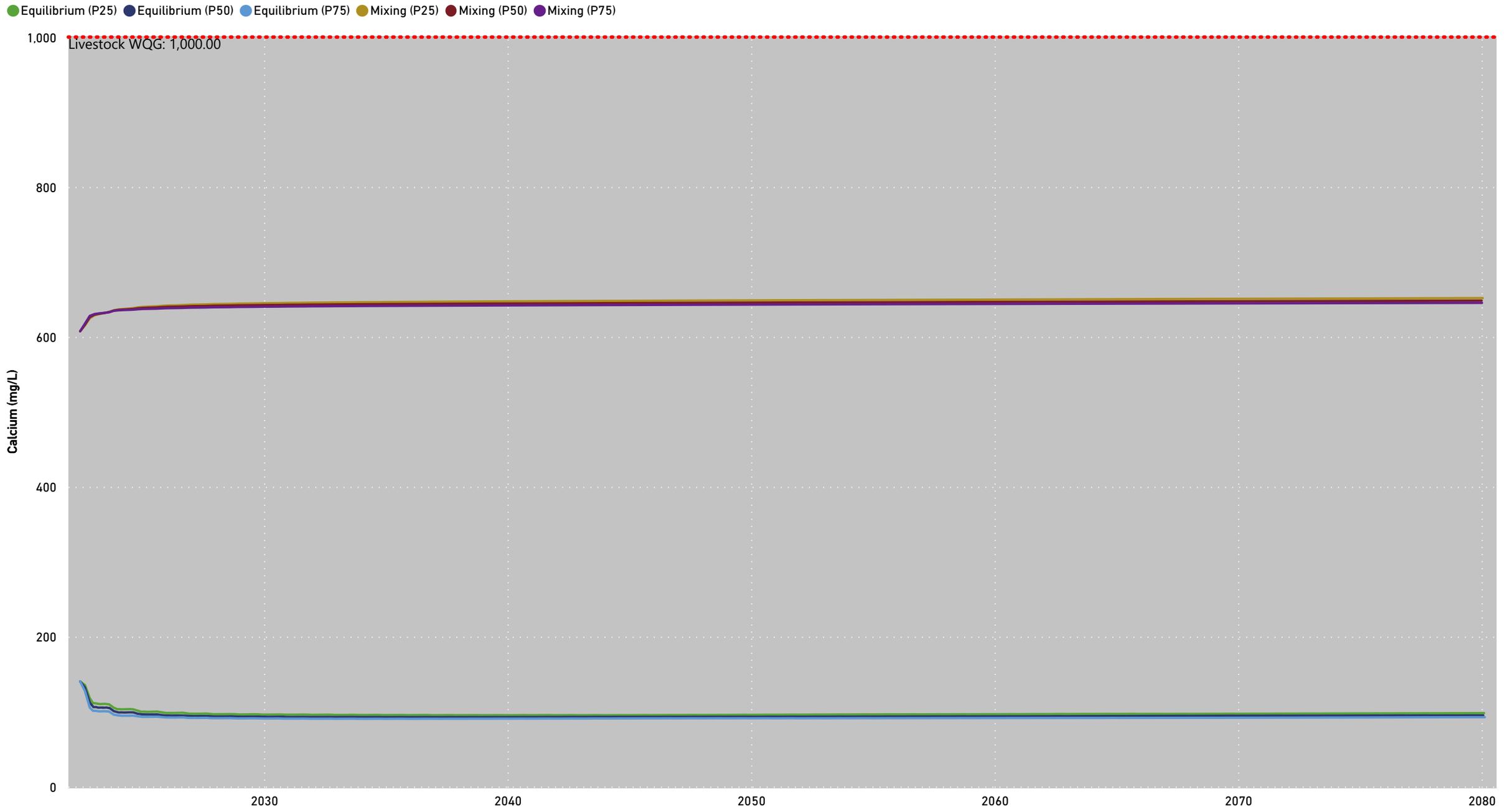
Appendix F

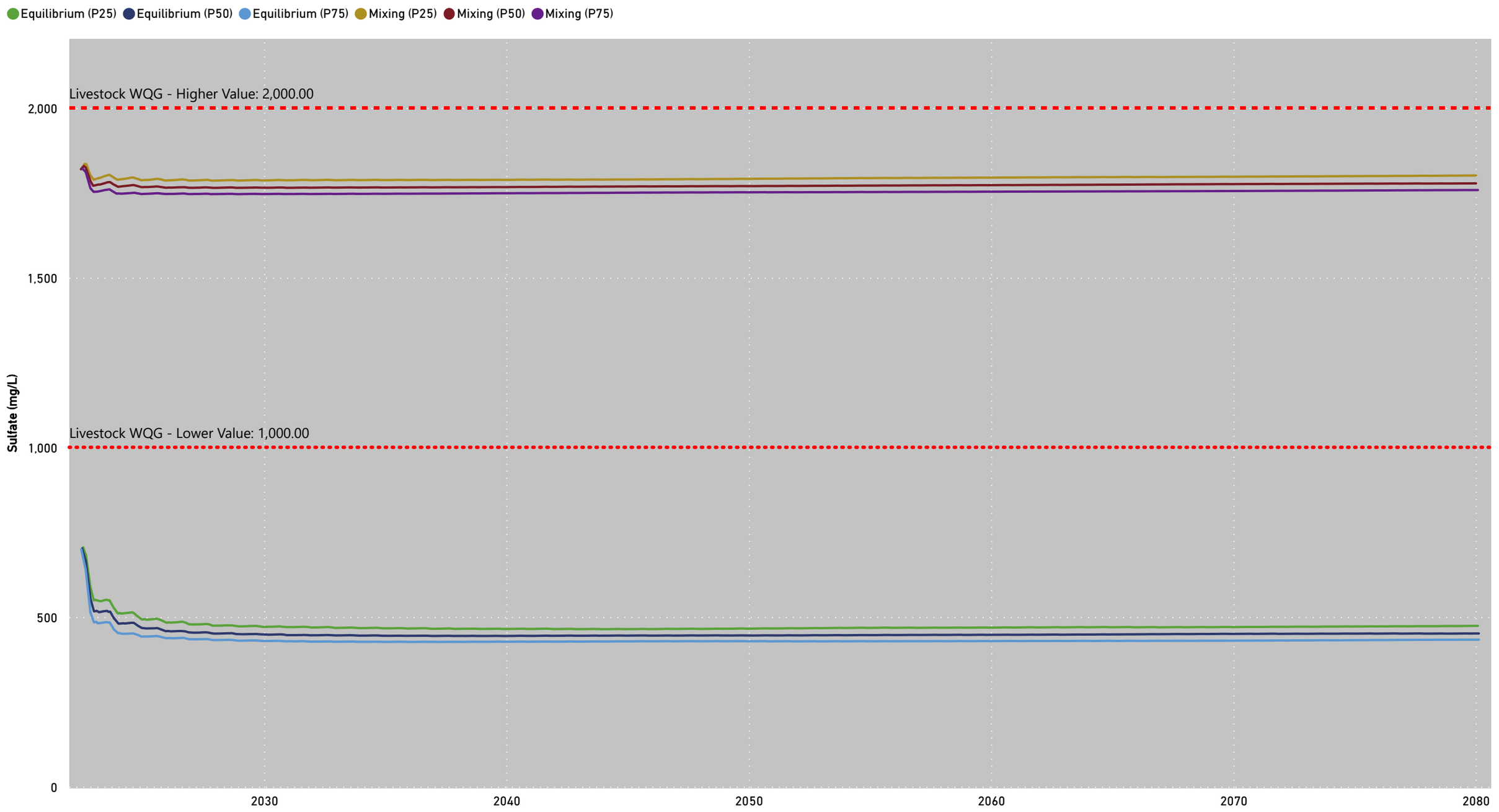
South Pit modelled long-term water quality

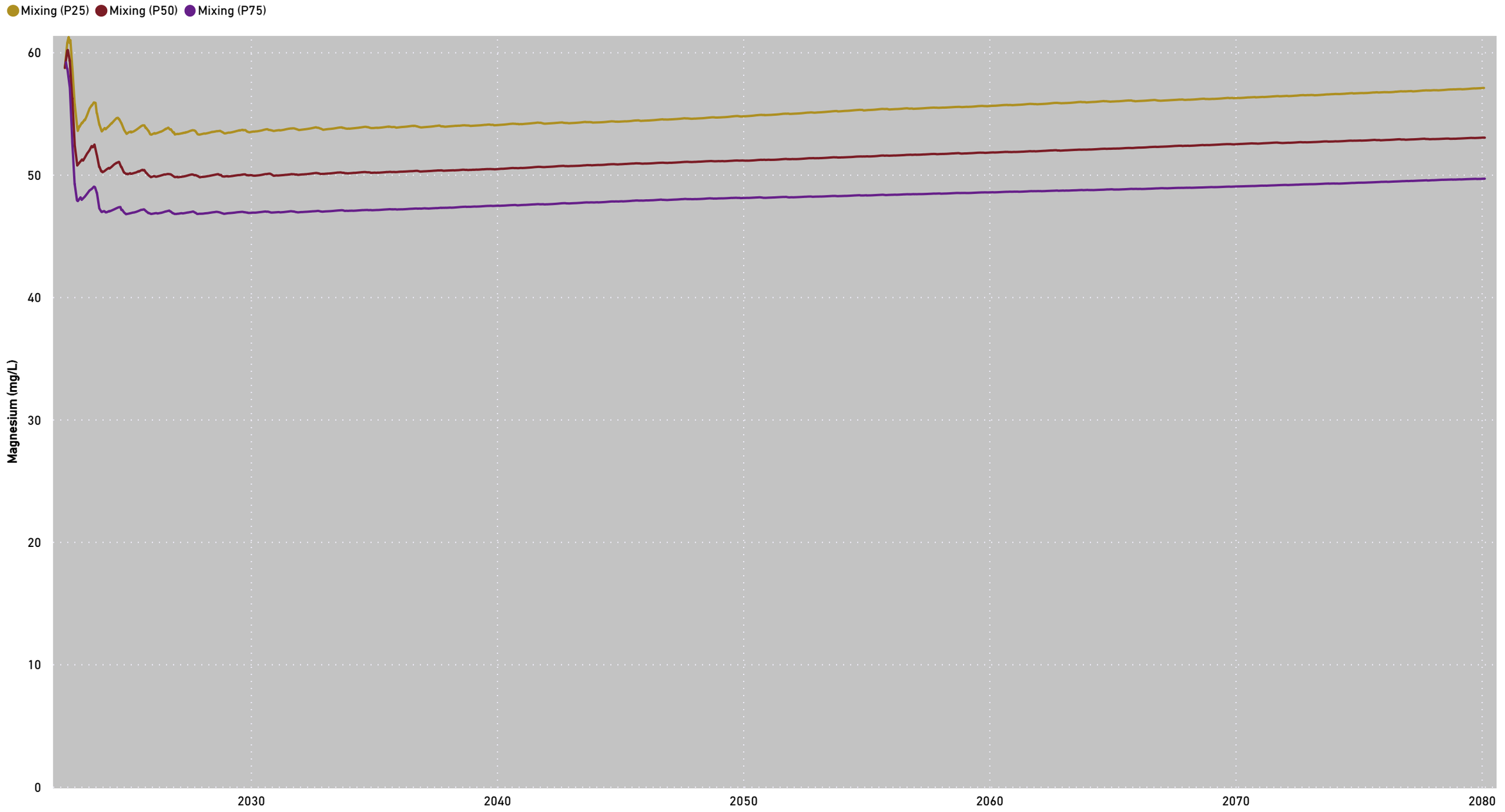
Appendix F.1 South Pit (Scenario 1) modelled long-term water quality

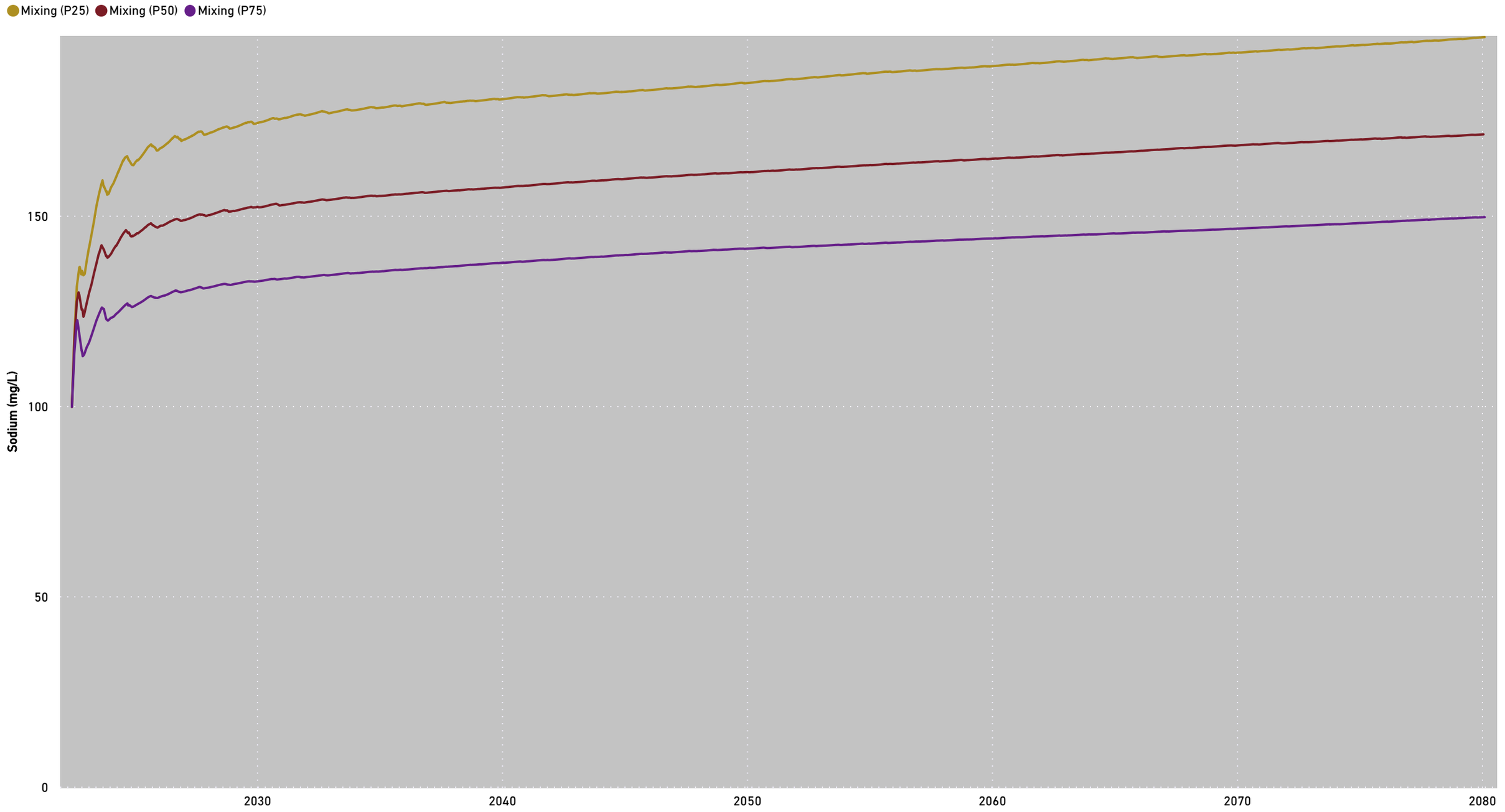

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 8.50
Livestock WQG: 6.50
pH
8.5
8.0
7.5
7.0
6.5
2030
2040
2050
2060
2070
2080

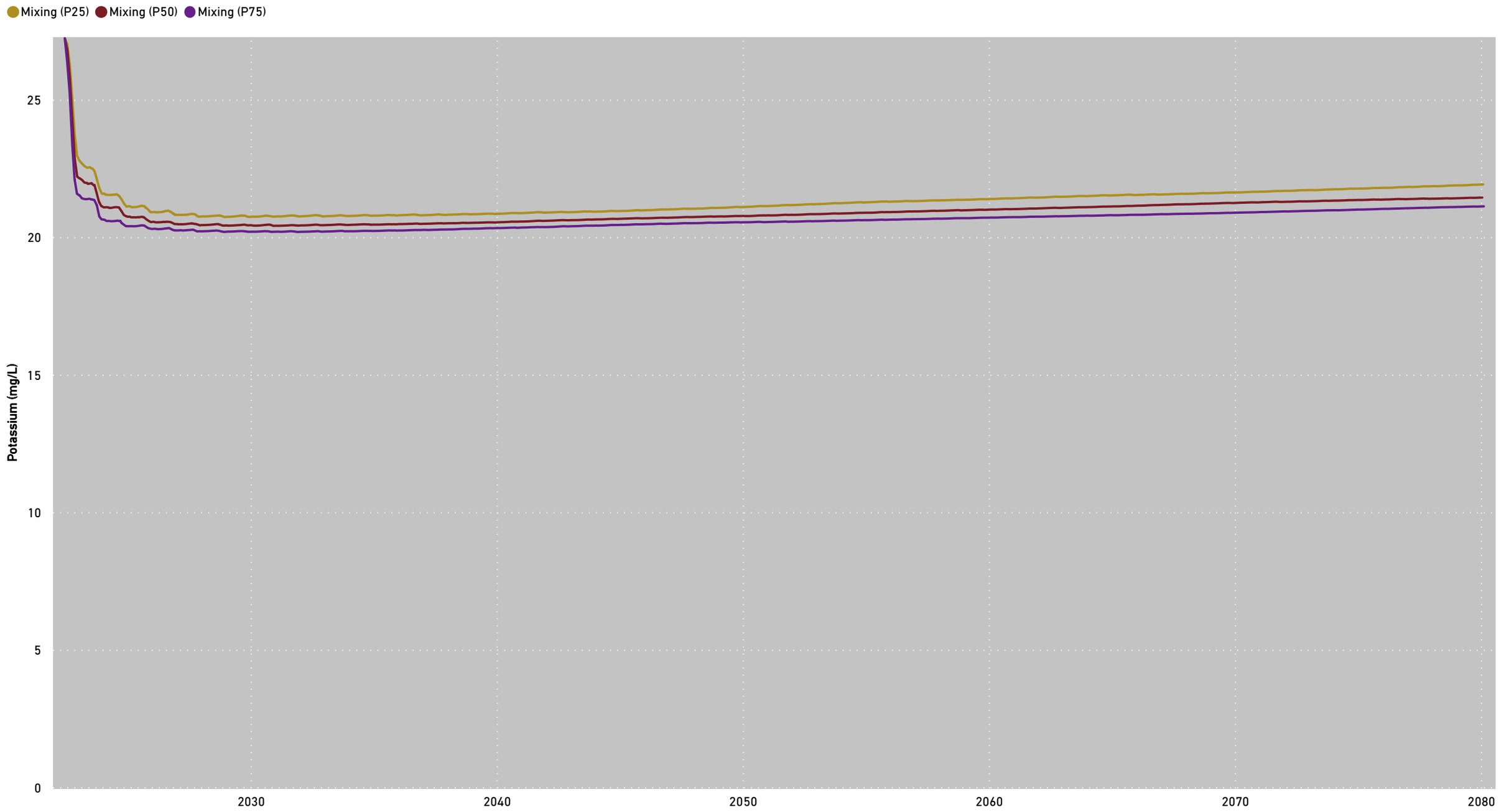

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - No loss of production: 5,000.00
Livestock WQG - No adverse effects: 4,000.00
Total Dissolved Solids (mg/L)
5K
4K
3K
2K
1K
2030
2040
2050
2060
2070
2080

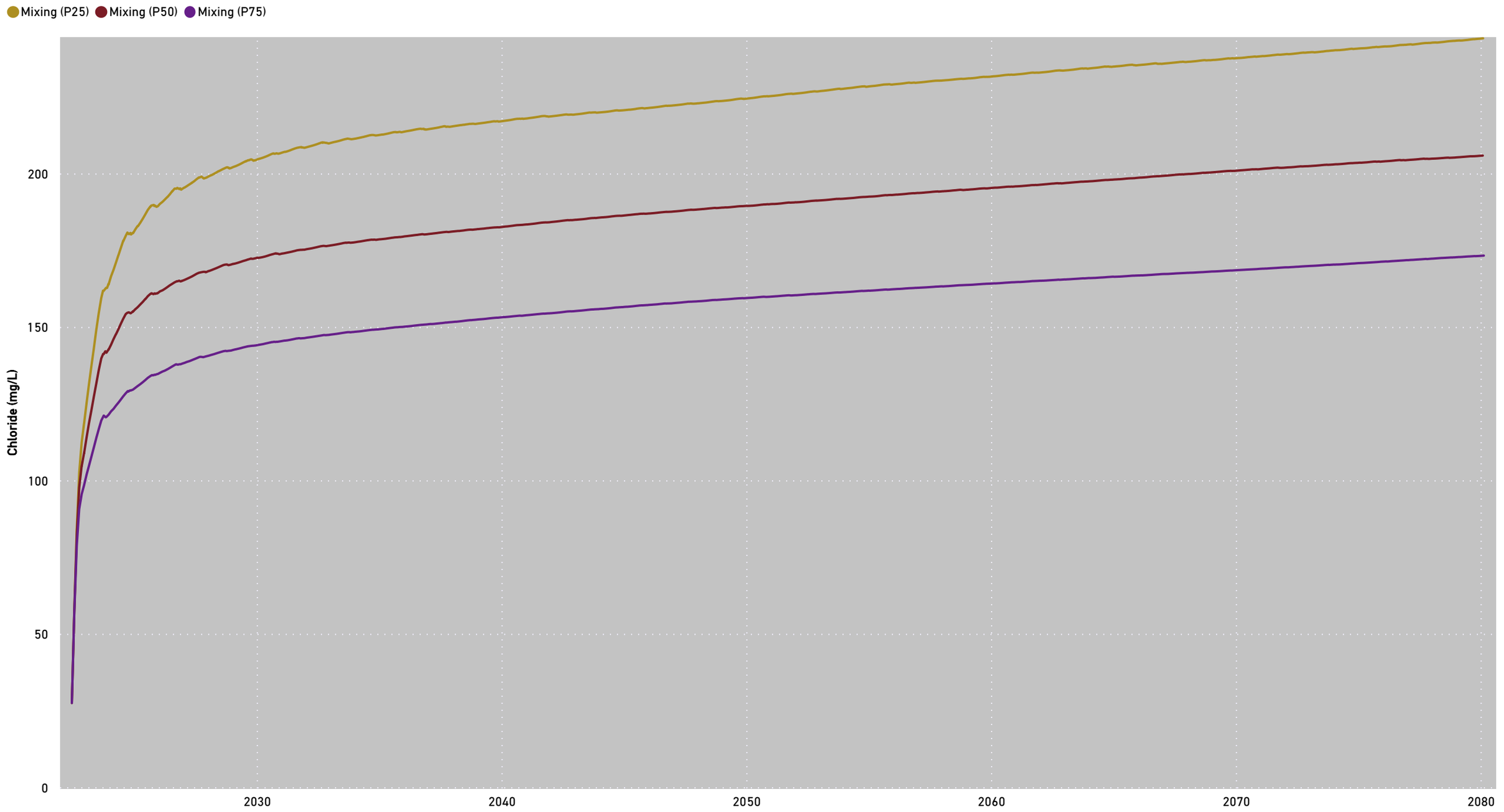

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 1,000.00
Calcium (mg/L)
1,000
800
600
400
200
0
2030
2040
2050
2060
2070
2080

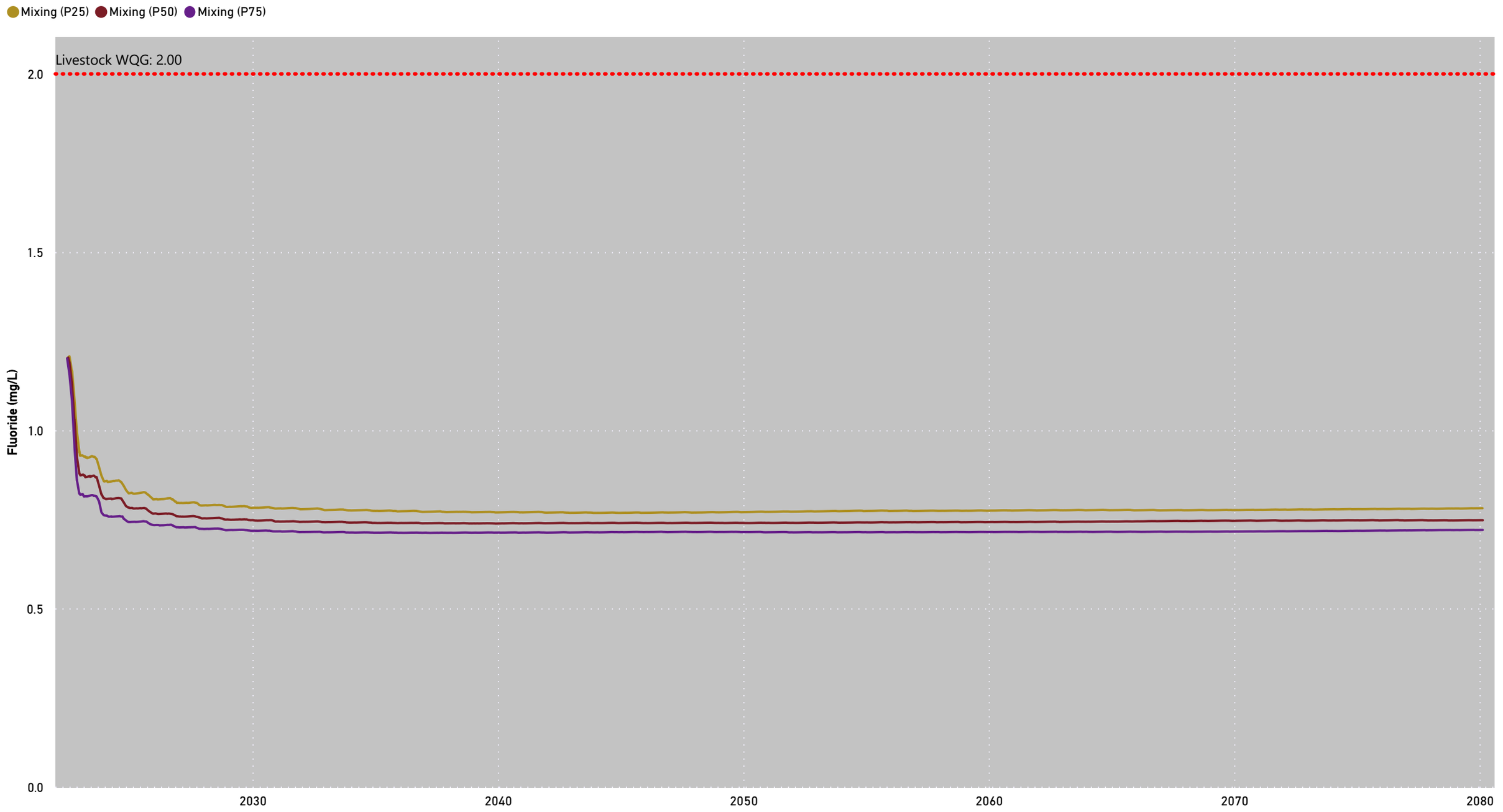

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - Higher Value: 2,000.00
Livestock WQG - Lower Value: 1,000.00
Sulfate (mg/L)
2,000
1,500
1,000
500
0
2030
2040
2050
2060
2070
2080

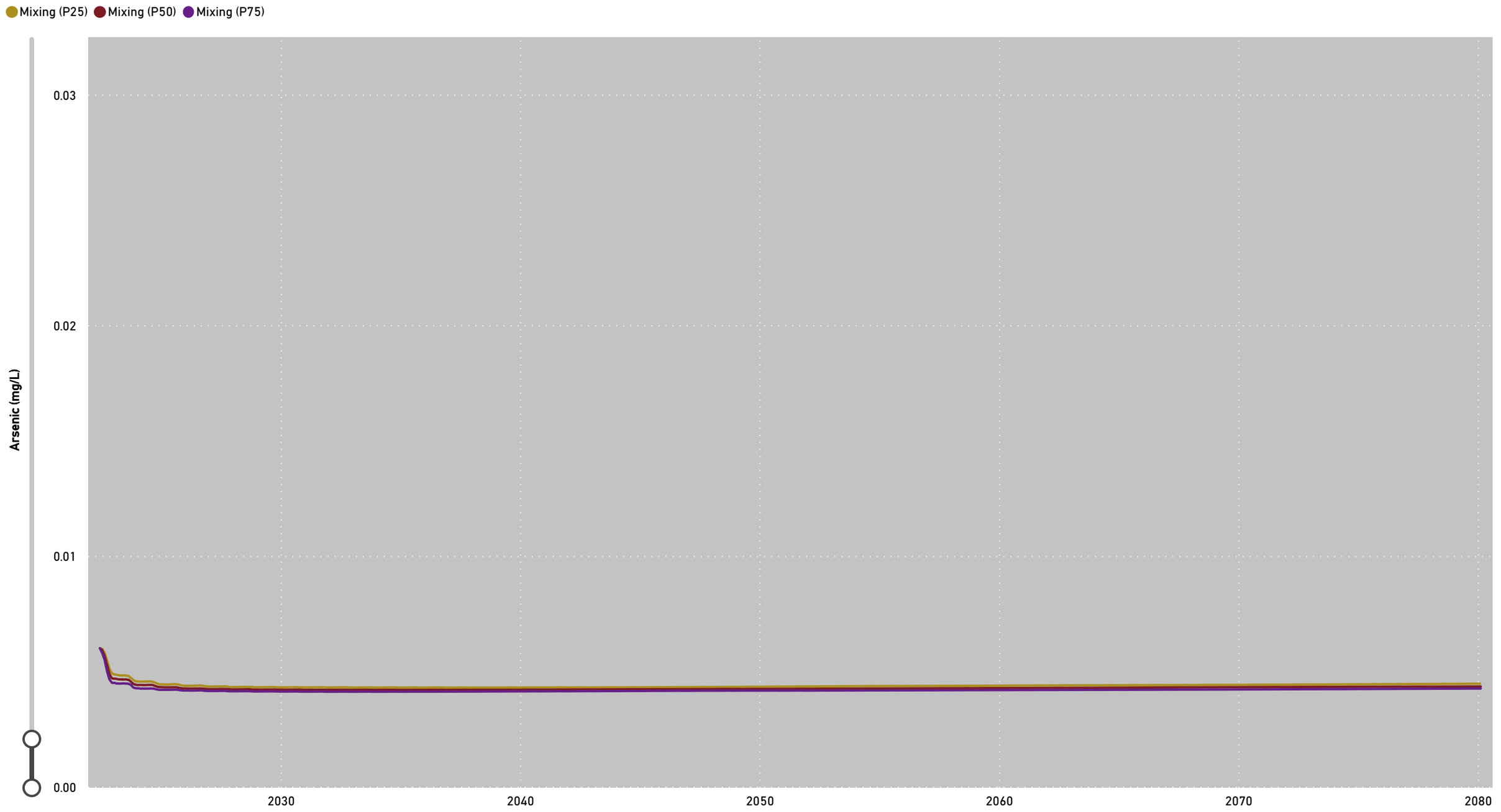

Mixing (P25)
Mixing (P50)
Mixing (P75)
Magnesium (mg/L)
60
50
40
30
20
10
0
2030
2040
2050
2060
2070
2080

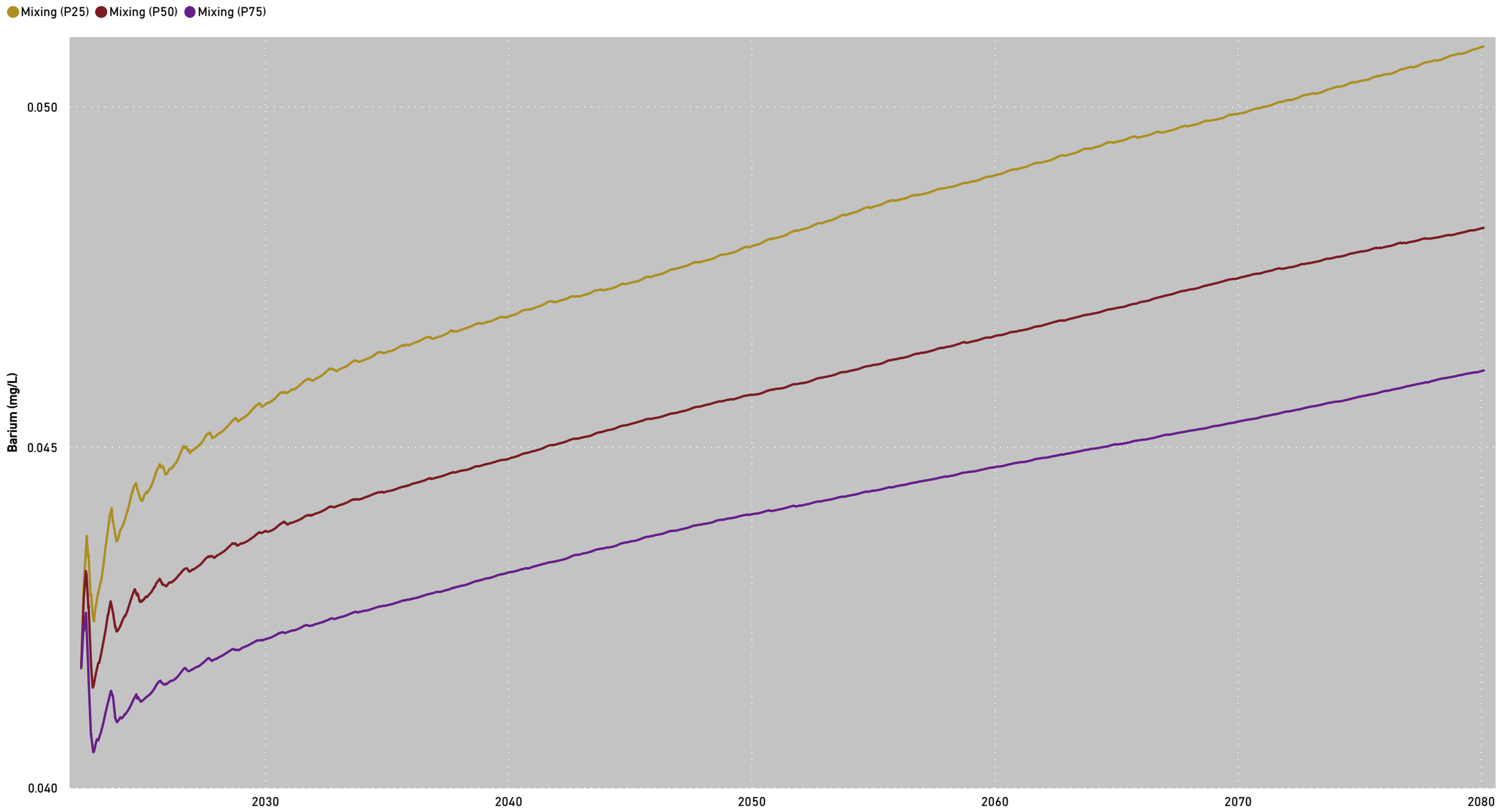

Mixing (P25)
Mixing (P50)
Mixing (P75)
Sodium (mg/L)
0
50
100
150
2030
2040
2050
2060
2070
2080

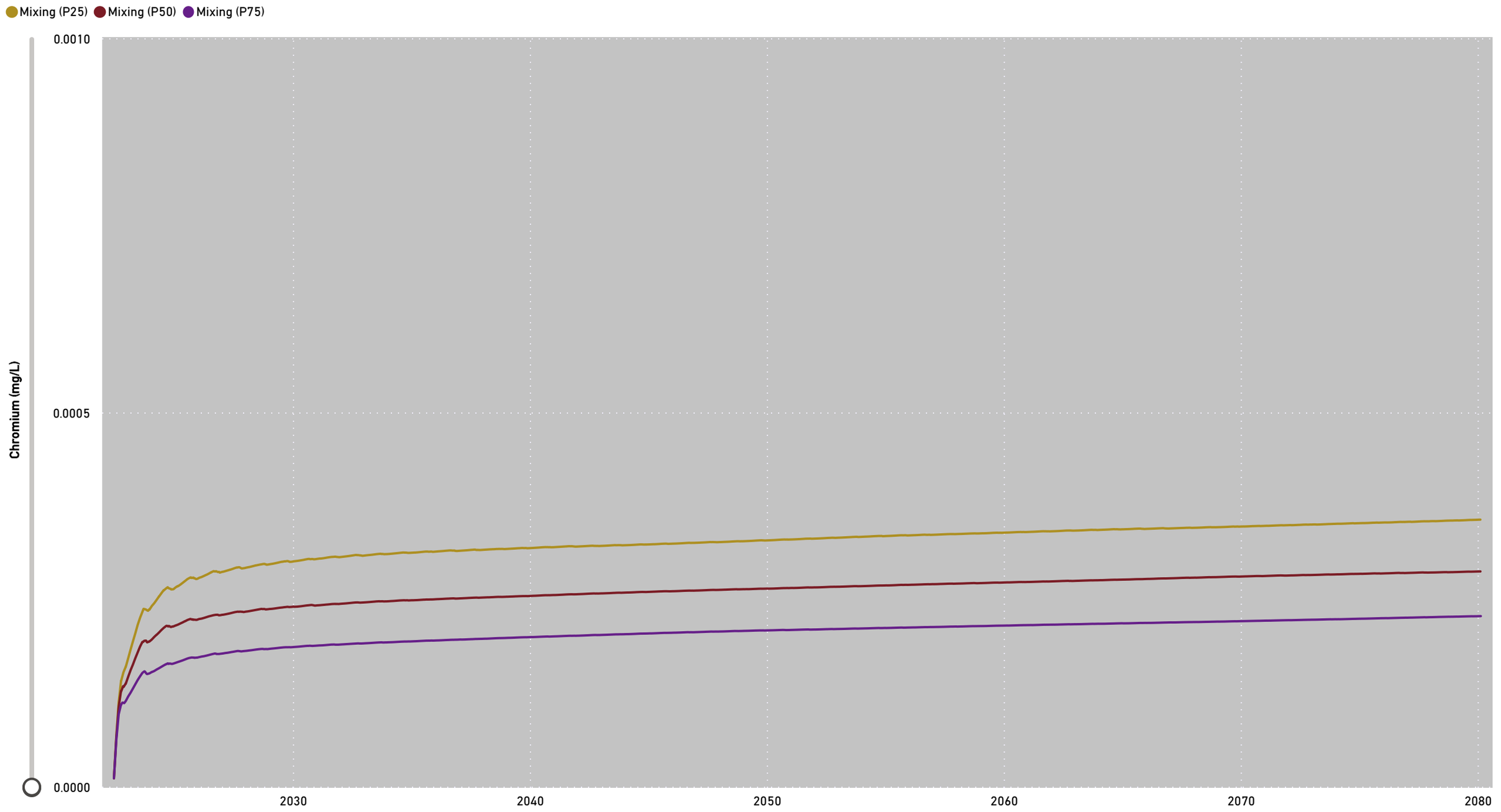

Mixing (P25)
Mixing (P50)
Mixing (P75)
Potassium (mg/L)
25
20
15
10
5
0
2030
2040
2050
2060
2070
2080

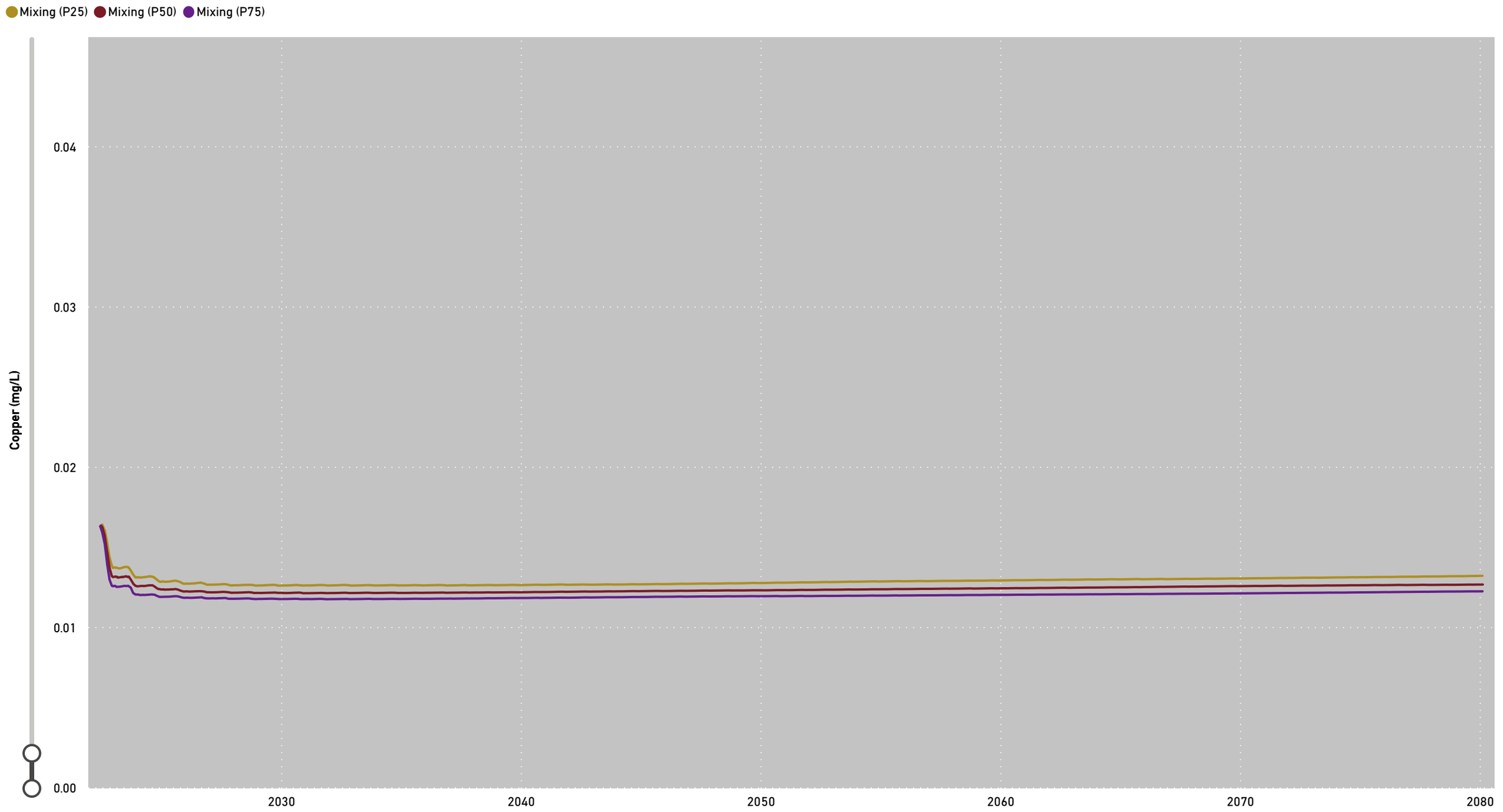

Mixing (P25)
Mixing (P50)
Mixing (P75)
Chloride (mg/L)
0
50
100
150
200
2030
2040
2050
2060
2070
2080

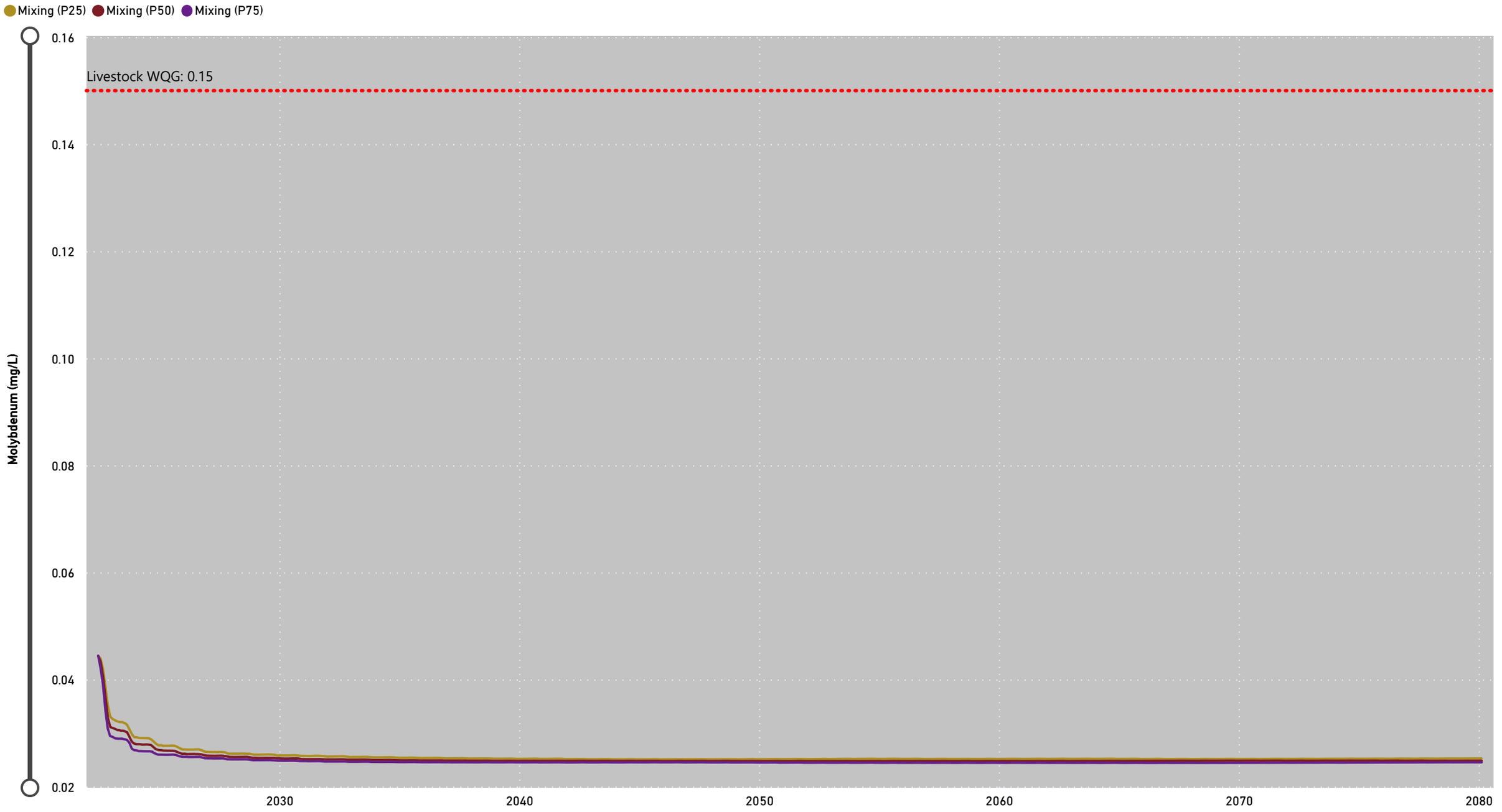

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 2.00
Fluoride (mg/L)
2.0
1.5
1.0
0.5
0.0
2030
2040
2050
2060
2070
2080

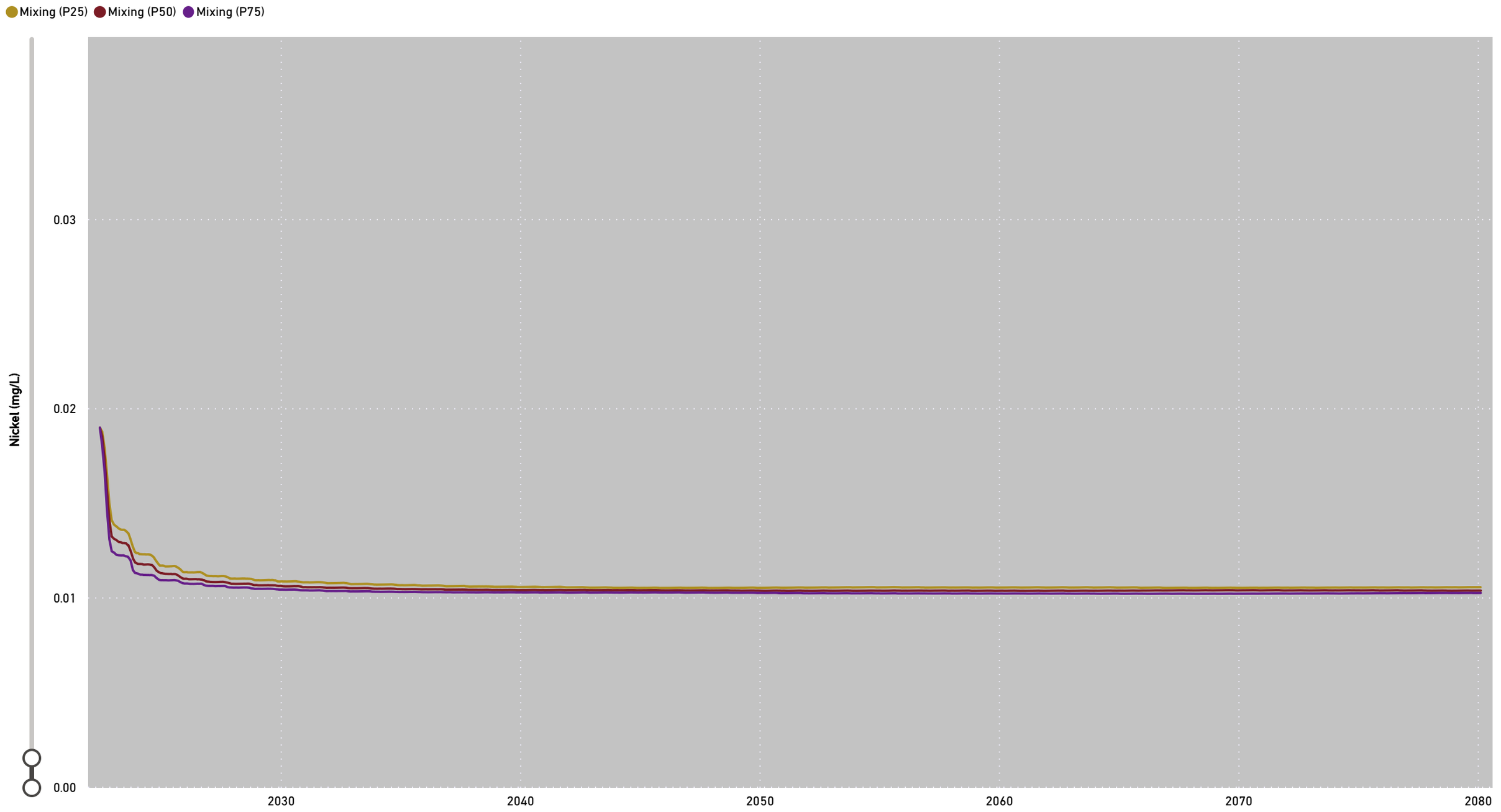

Mixing (P25)
Mixing (P50)
Mixing (P75)
Arsenic (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

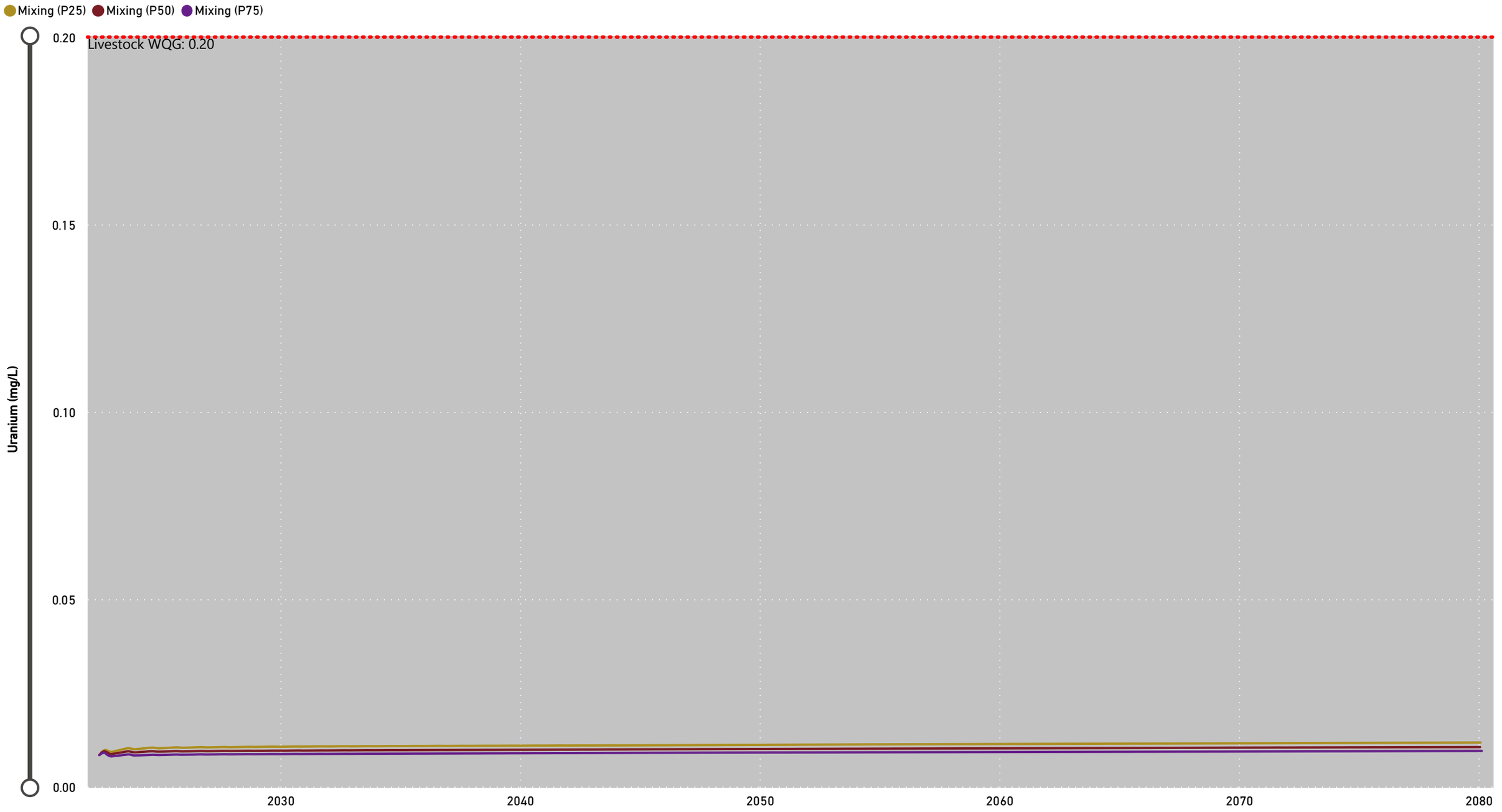

Mixing (P25)
Mixing (P50)
Mixing (P75)
Barium (mg/L)
0.050
0.045
0.040
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Chromium (mg/L)
0.0010
0.0005
0.0000
2030
2040
2050
2060
2070
2080

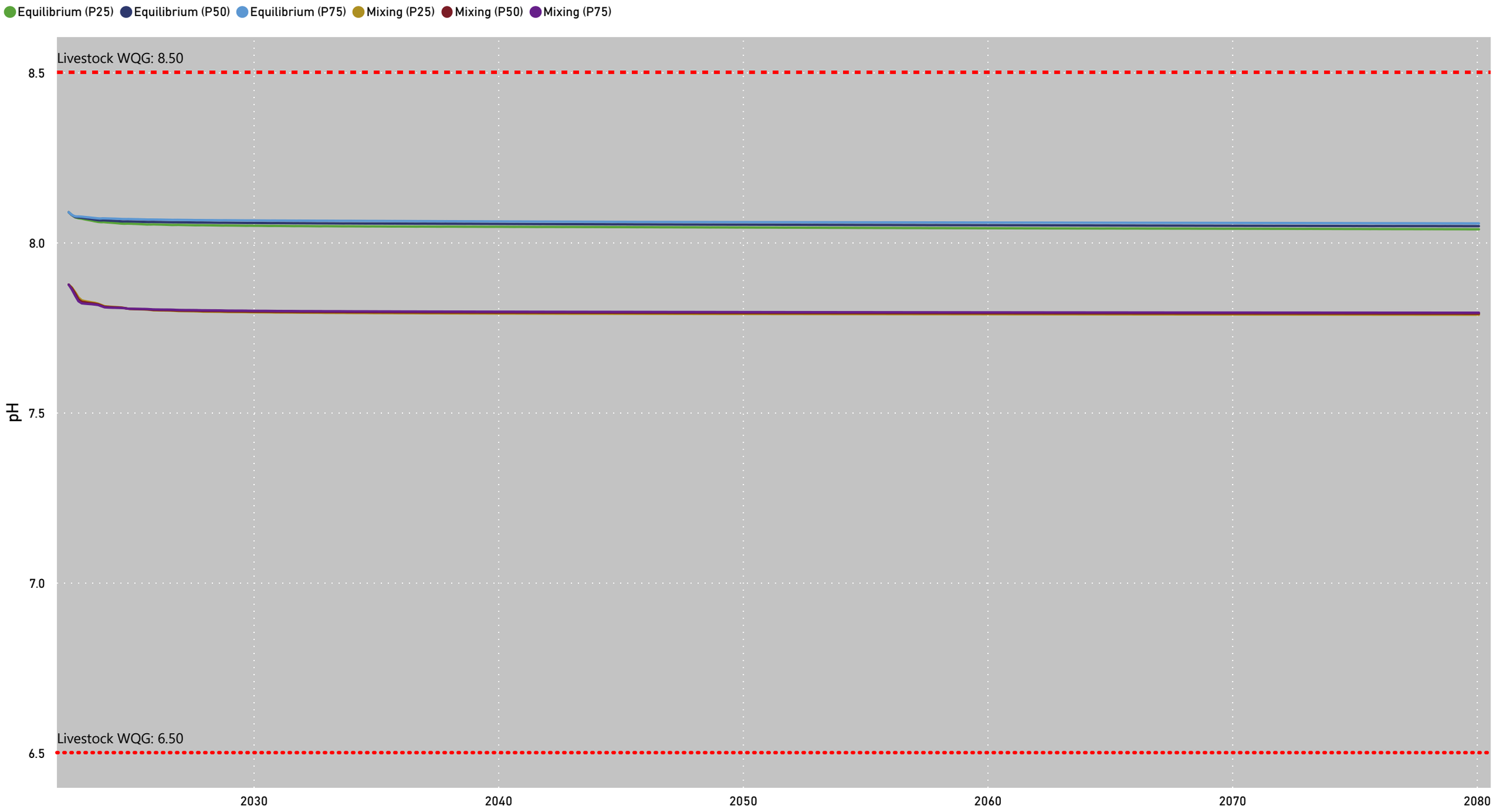

Mixing (P25)
Mixing (P50)
Mixing (P75)
Copper (mg/L)
0.04
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

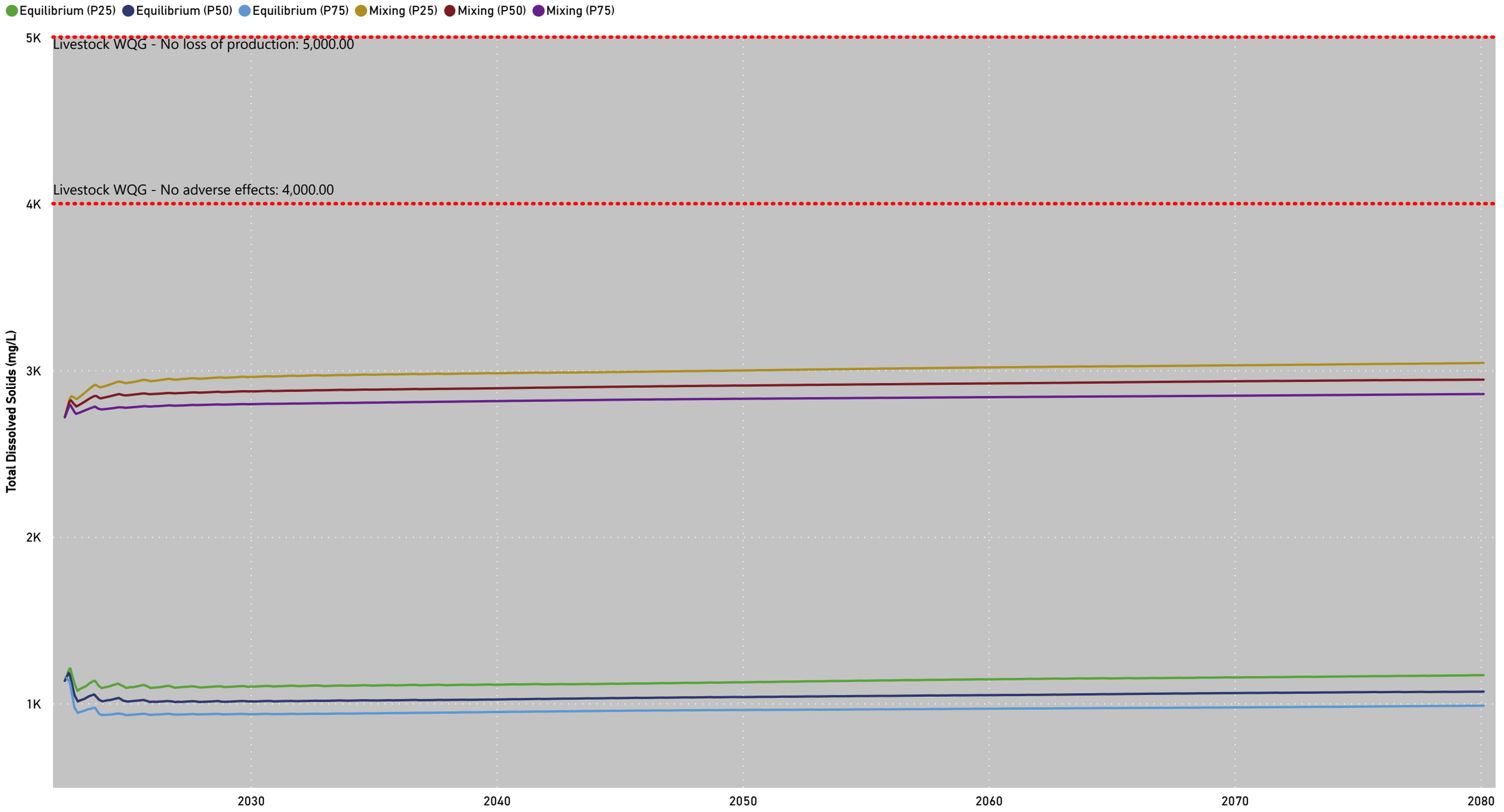

Mixing (P25)
Mixing (P50)
Mixing (P75)
Molybdenum (mg/L)
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
Livestock WQG: 0.15
2030
2040
2050
2060
2070
2080

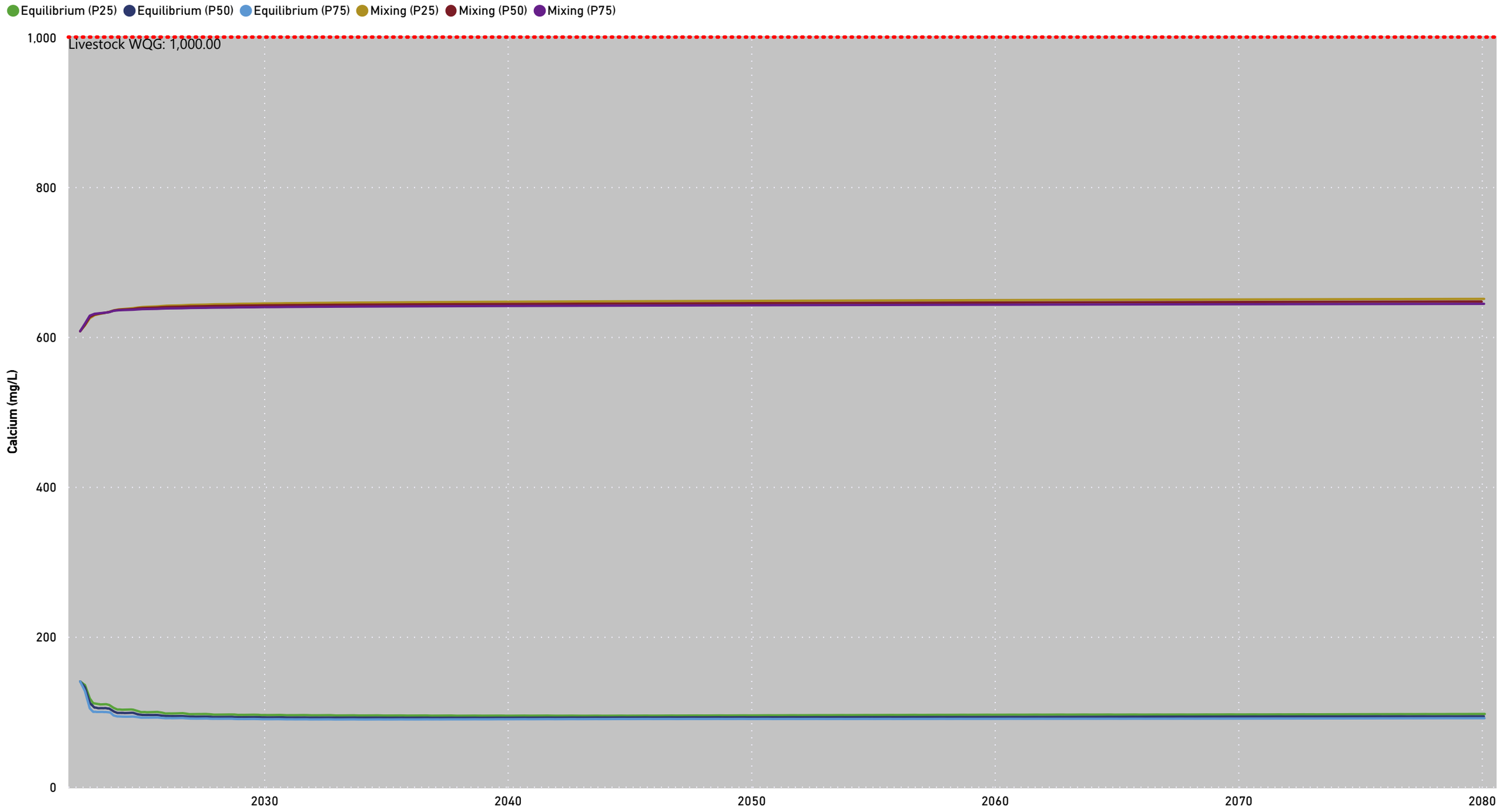

Mixing (P25)
Mixing (P50)
Mixing (P75)
Nickel (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

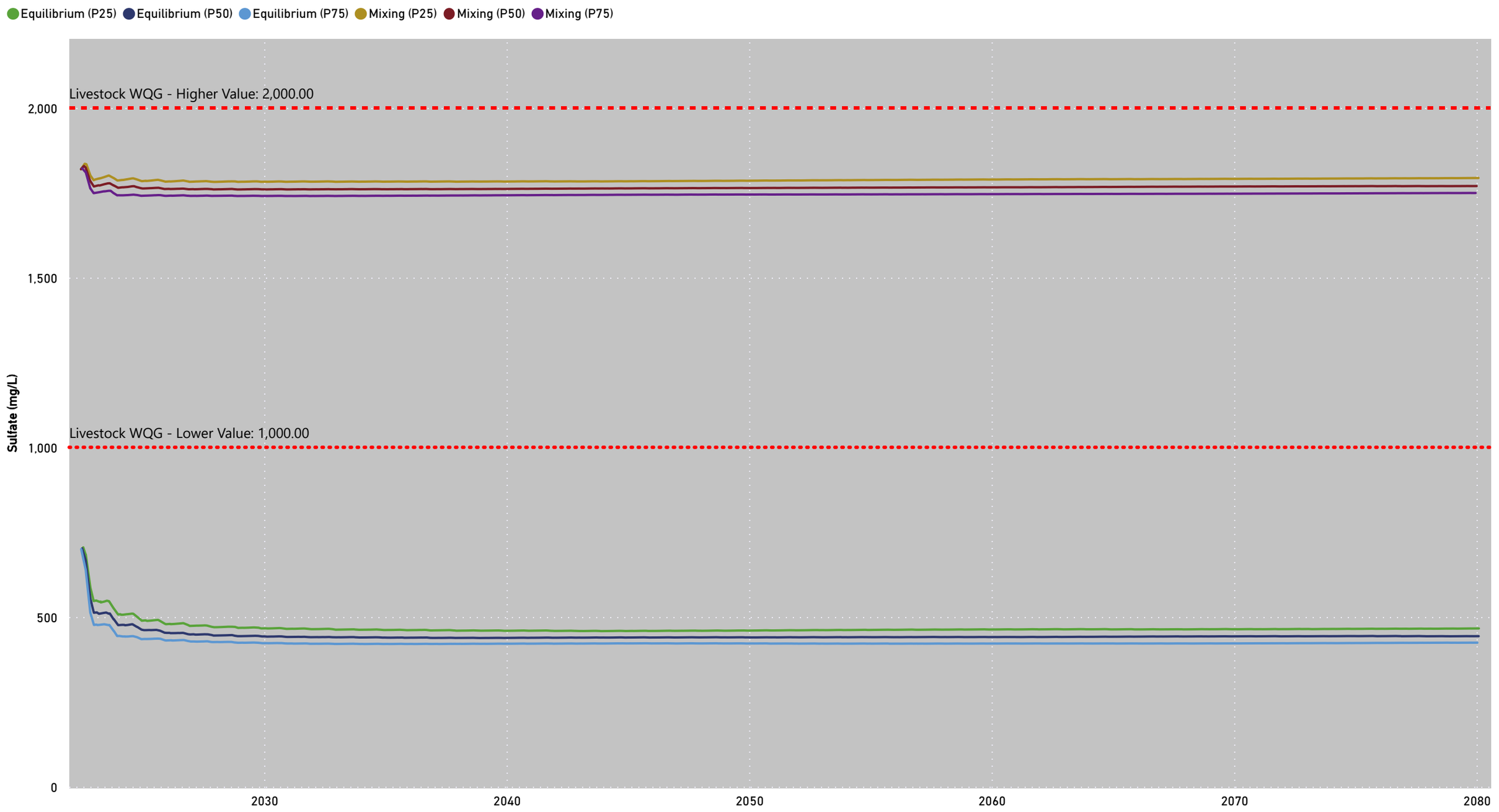

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 0.20
Uranium (mg/L)
0.20
0.15
0.10
0.05
0.00
2030
2040
2050
2060
2070
2080

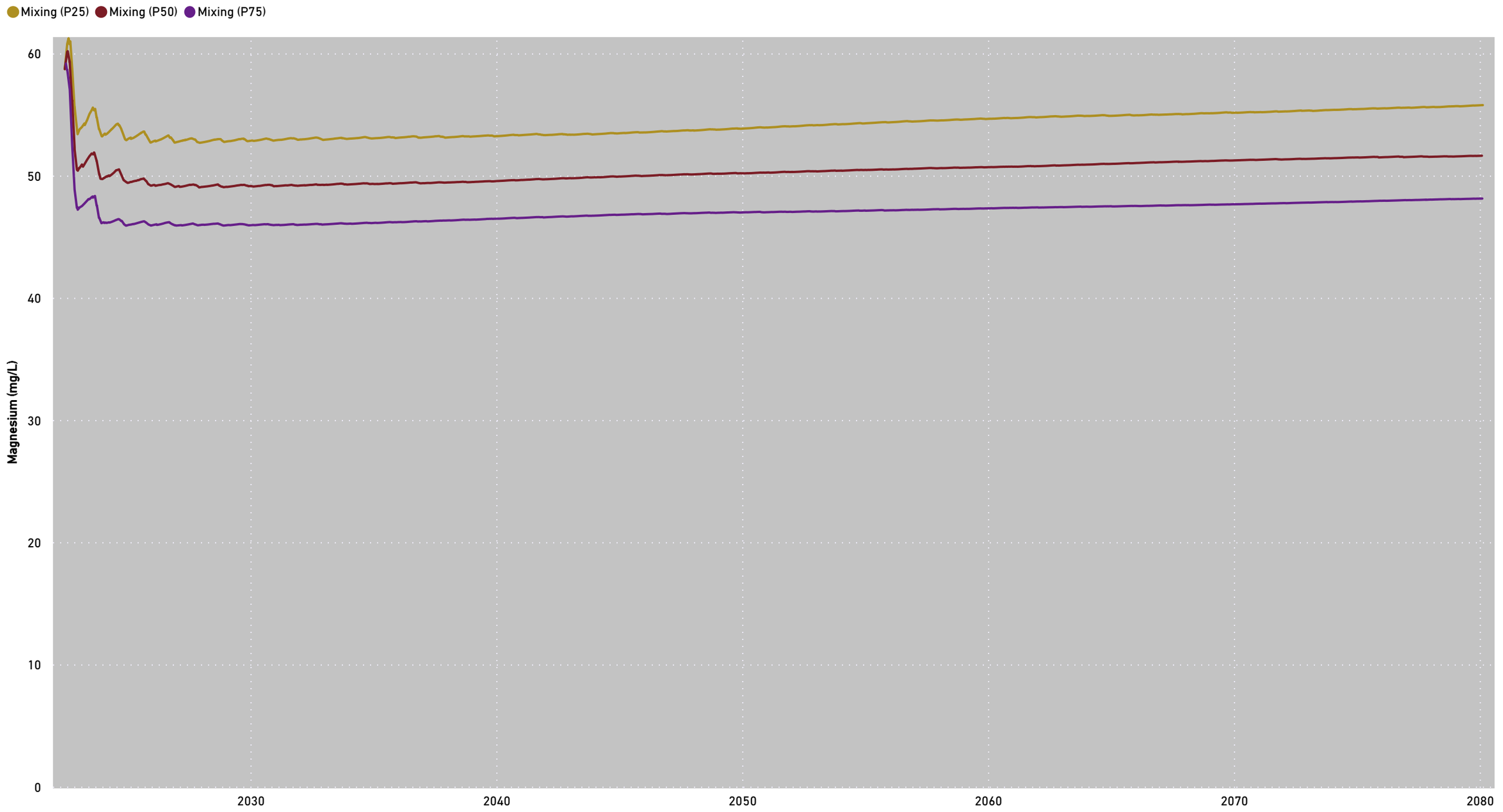
Appendix F.2 South Pit (Scenario 2) modelled long-term water quality

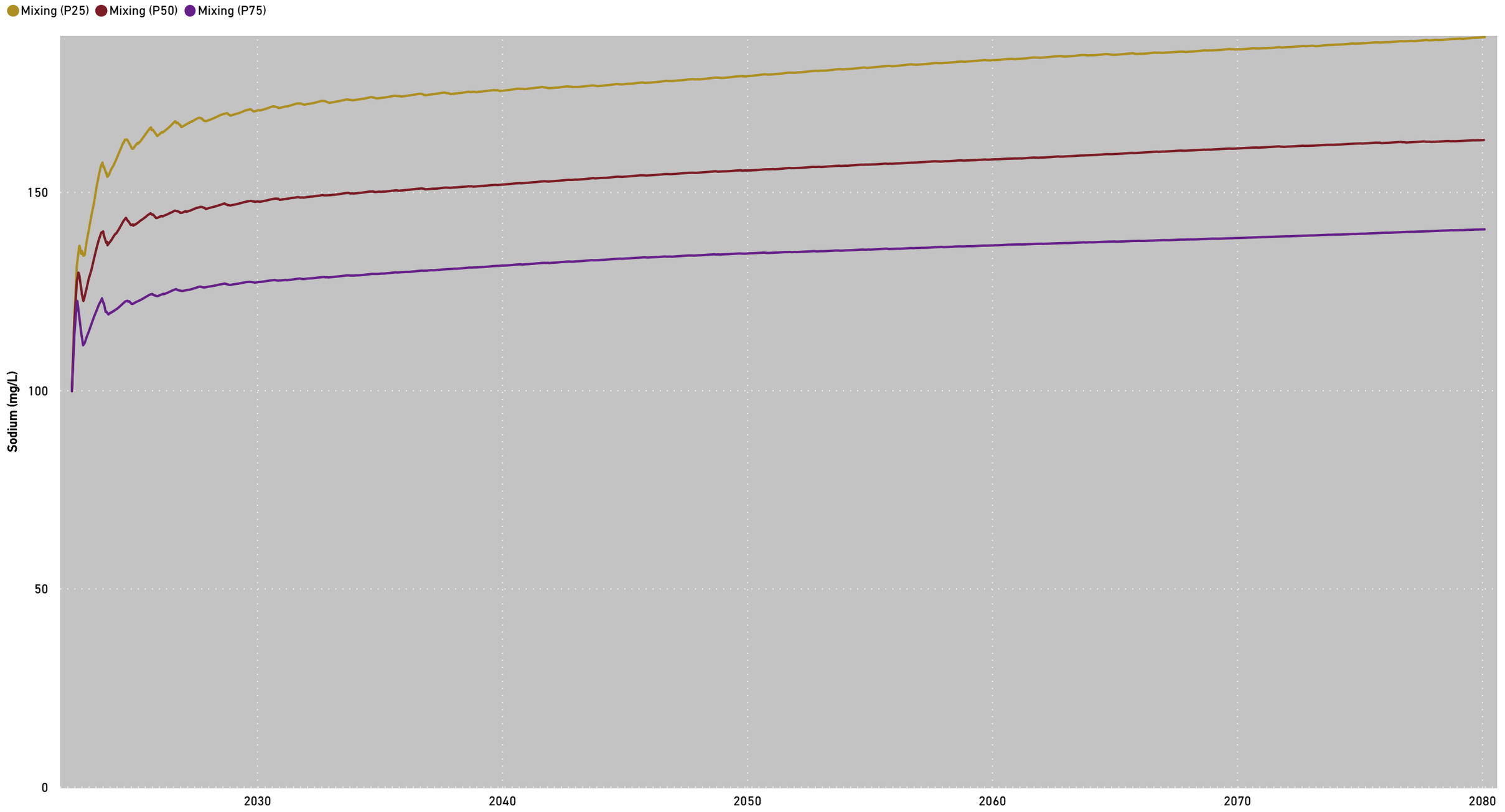

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 8.50
Livestock WQG: 6.50
pH
8.5
8.0
7.5
7.0
6.5
2030
2040
2050
2060
2070
2080

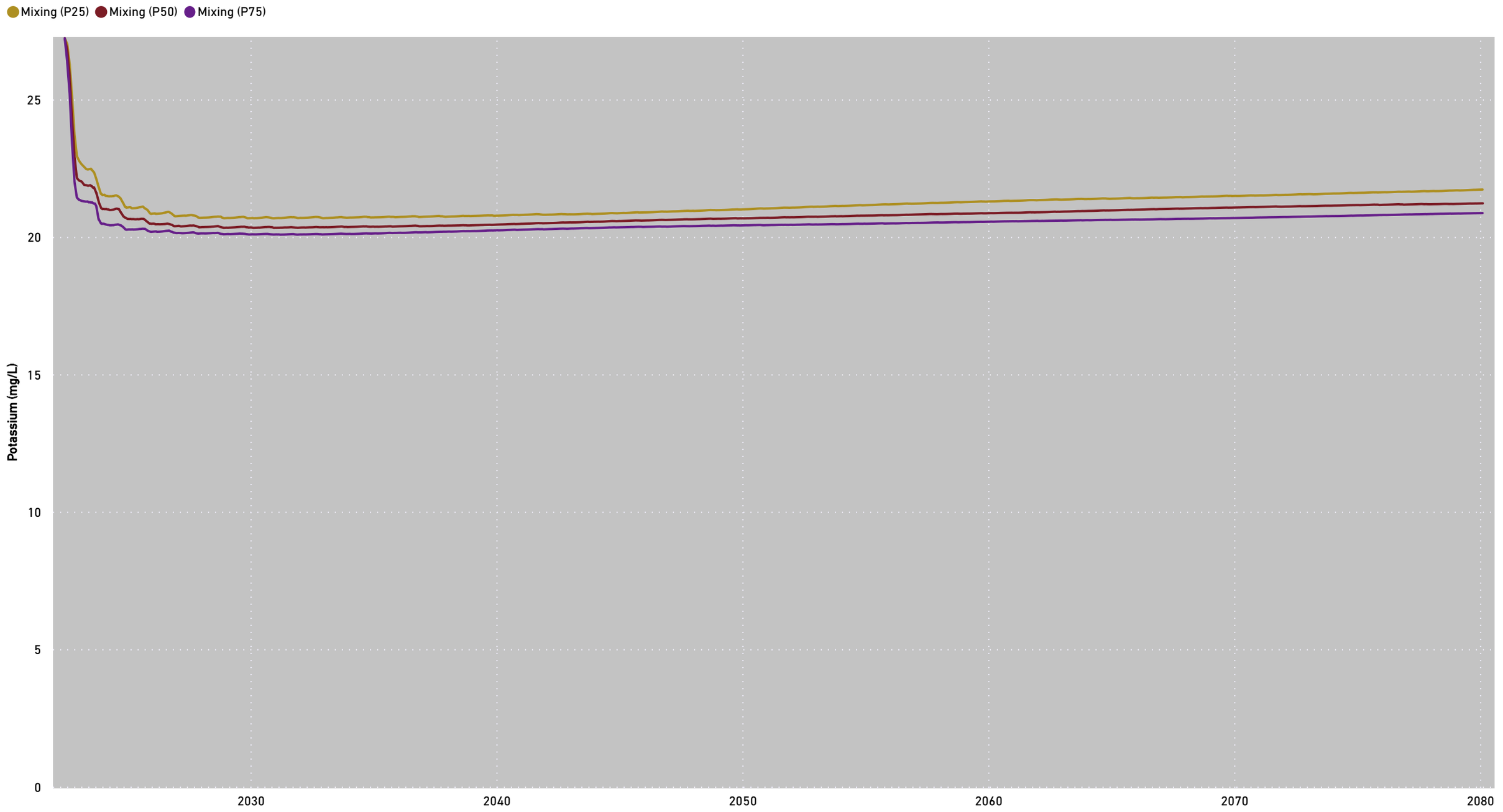

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - No loss of production: 5,000.00
Livestock WQG - No adverse effects: 4,000.00
Total Dissolved Solids (mg/L)
5K
4K
3K
2K
1K
2030
2040
2050
2060
2070
2080

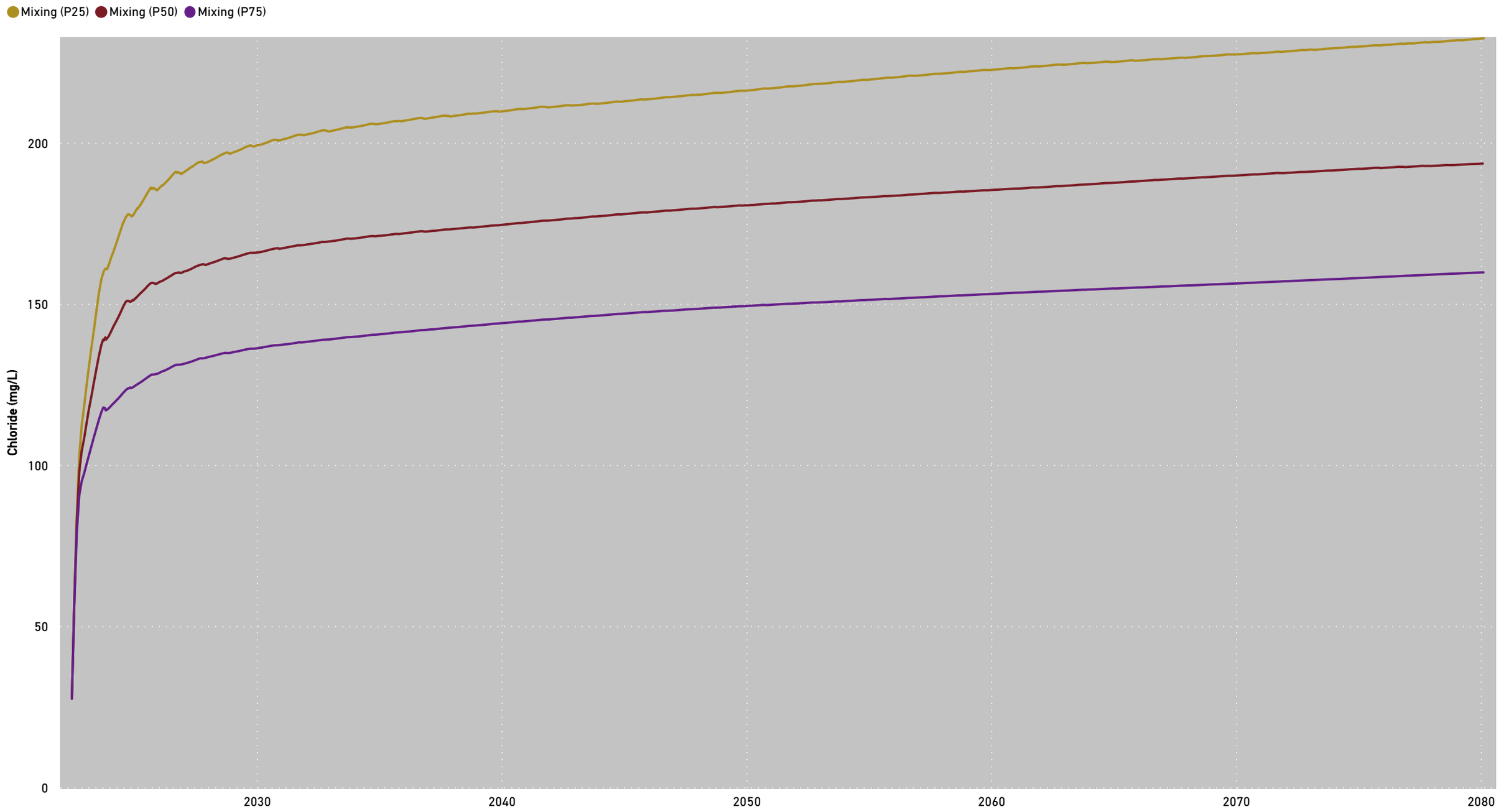

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 1,000.00
Calcium (mg/L)
1,000
800
600
400
200
0
2030
2040
2050
2060
2070
2080

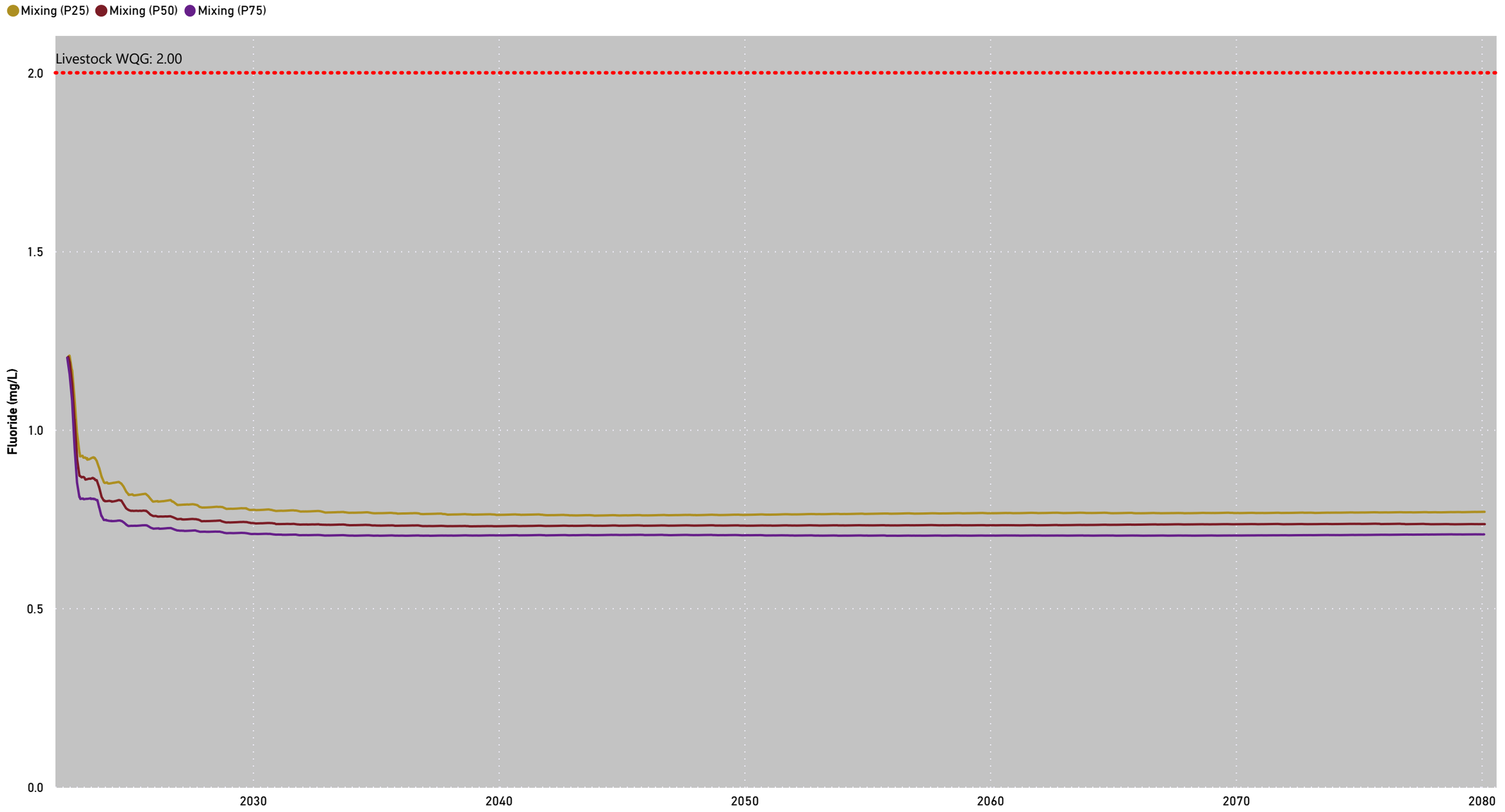

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - Higher Value: 2,000.00
Livestock WQG - Lower Value: 1,000.00
Sulfate (mg/L)
2,000
1,500
1,000
500
0
2030
2040
2050
2060
2070
2080

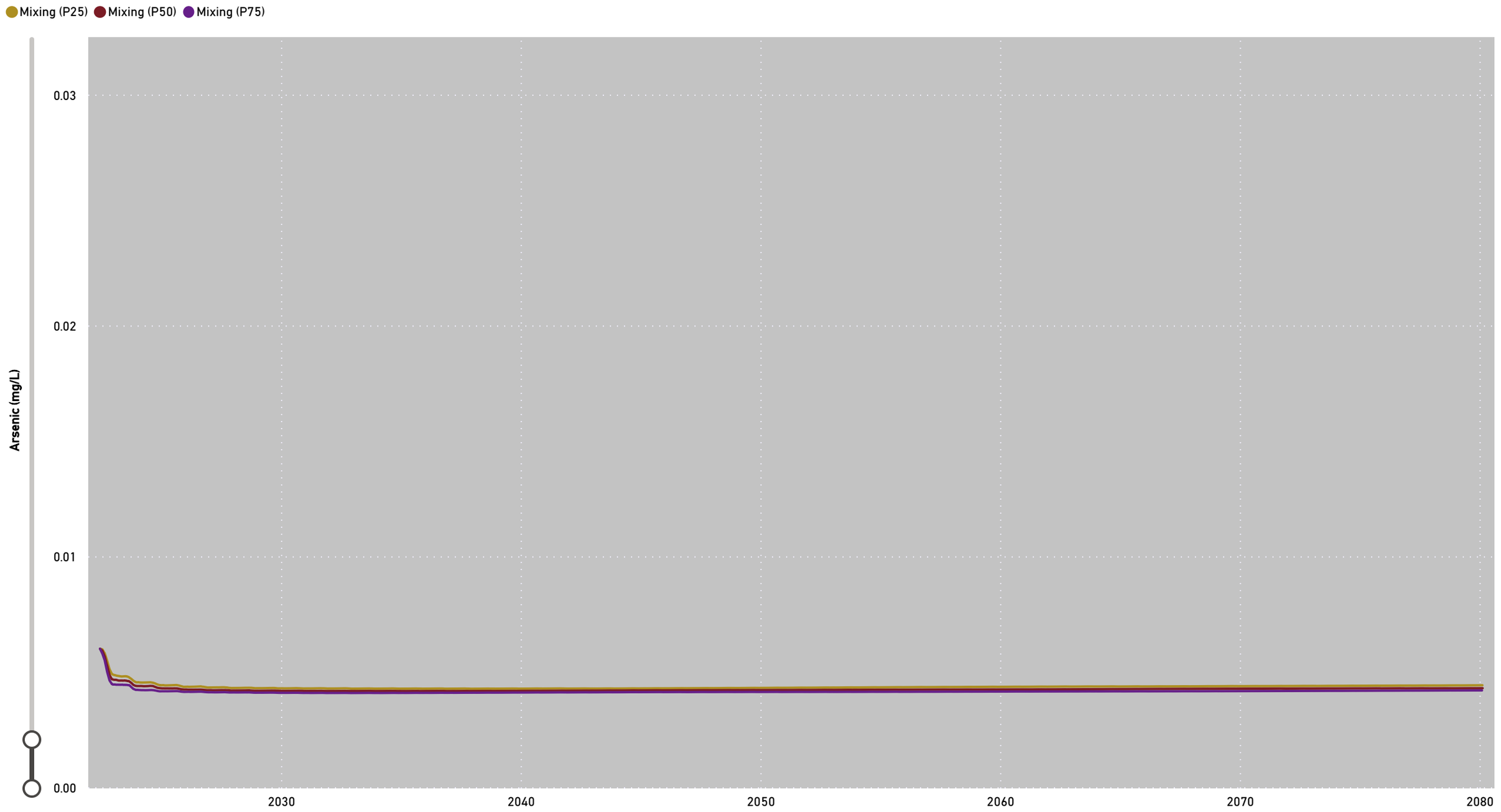

Mixing (P25)
Mixing (P50)
Mixing (P75)
Magnesium (mg/L)
60
50
40
30
20
10
0
2030
2040
2050
2060
2070
2080

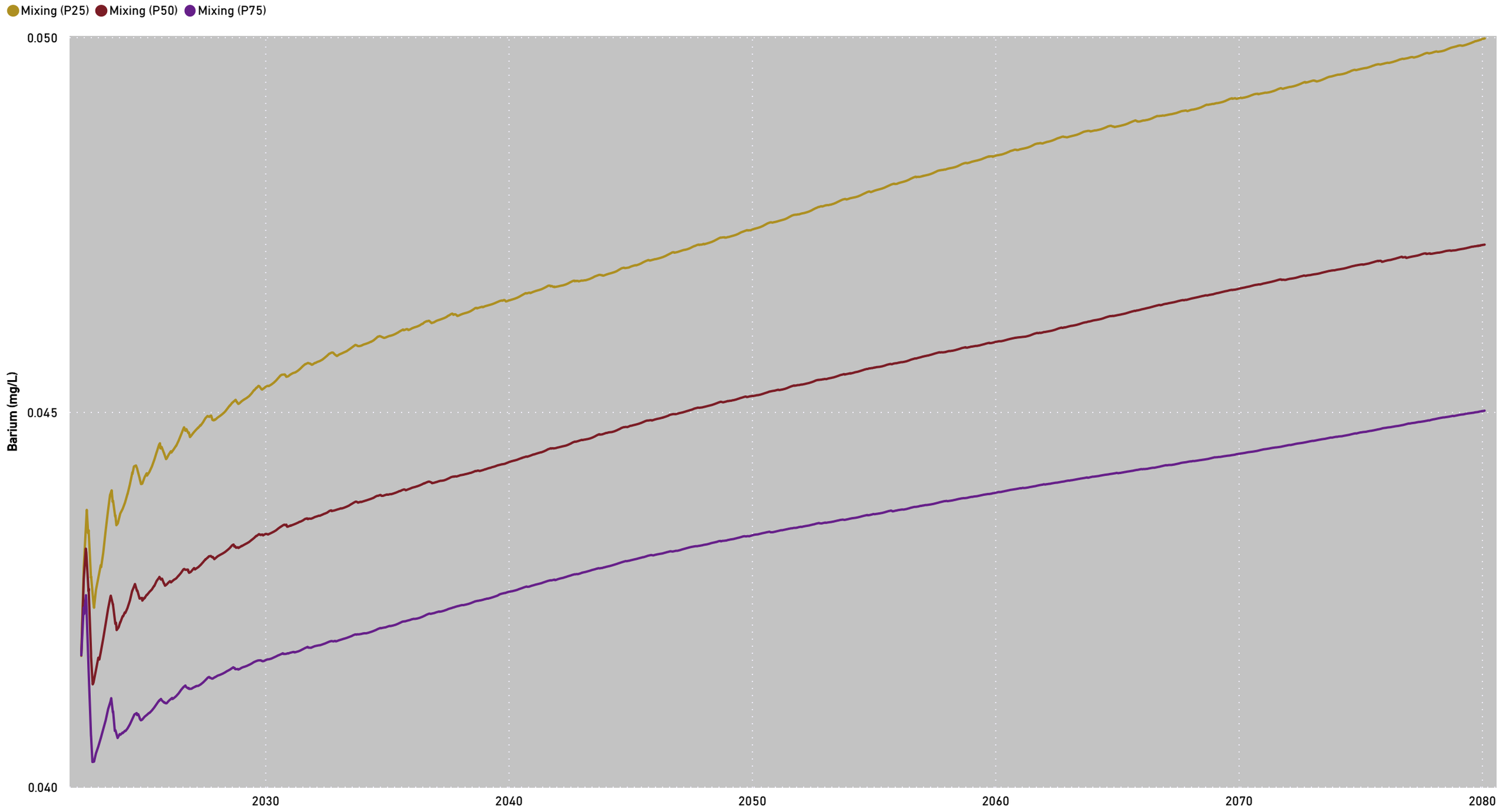

Mixing (P25)
Mixing (P50)
Mixing (P75)
Sodium (mg/L)
0
50
100
150
2030
2040
2050
2060
2070
2080

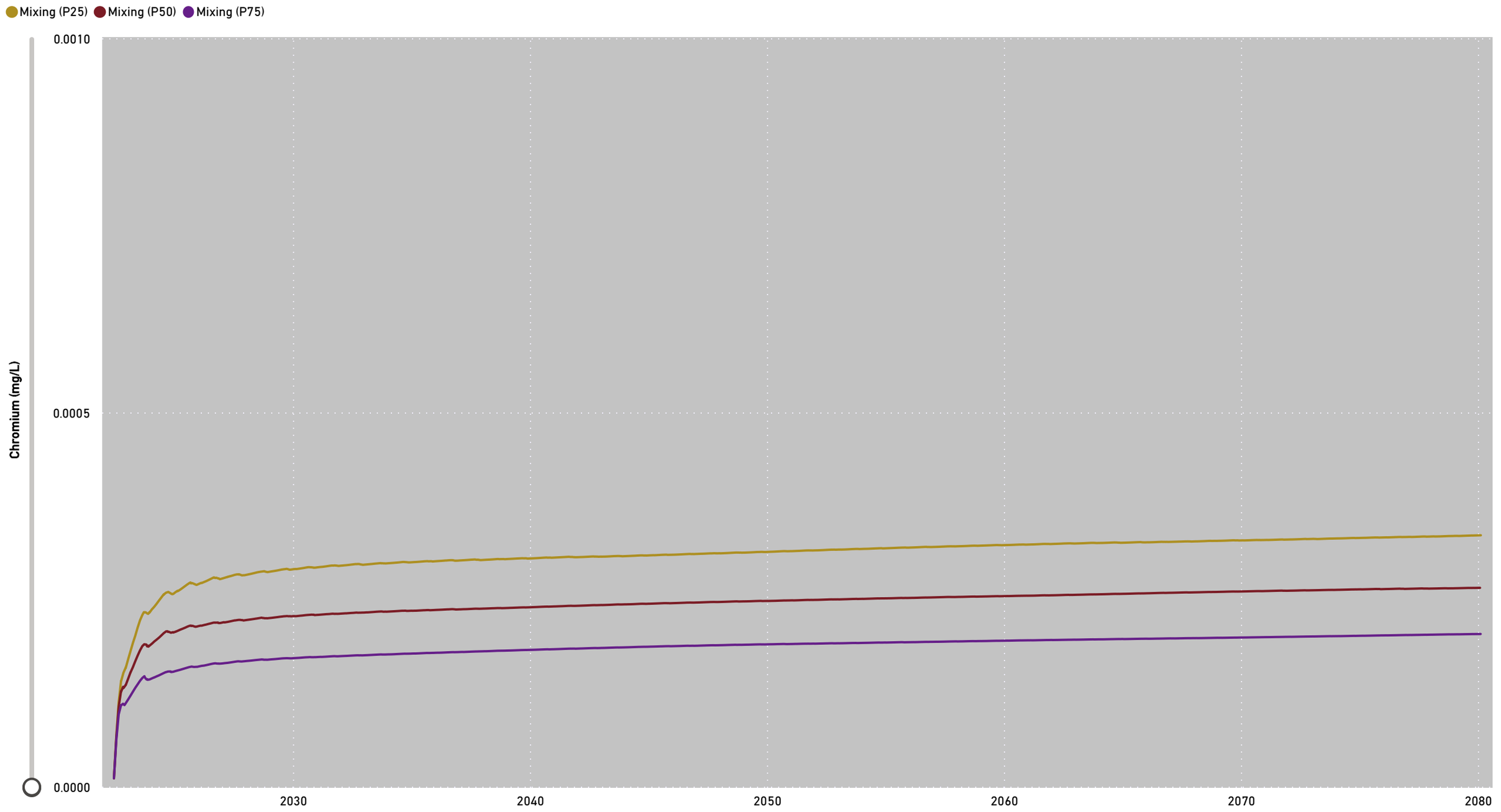

Mixing (P25)
Mixing (P50)
Mixing (P75)
Potassium (mg/L)
25
20
15
10
5
0
2030
2040
2050
2060
2070
2080

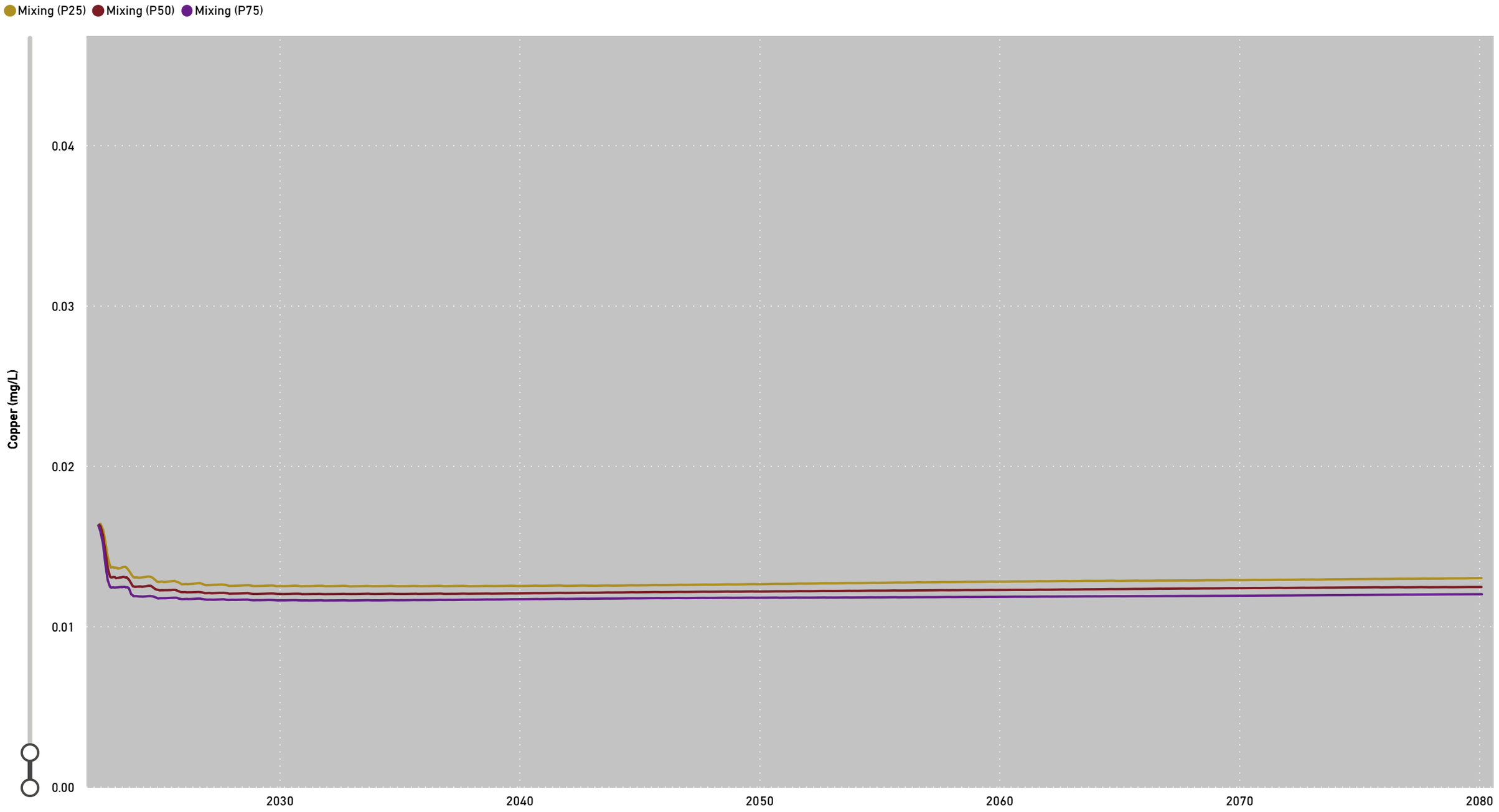

Mixing (P25)
Mixing (P50)
Mixing (P75)
Chloride (mg/L)
0
50
100
150
200
2030
2040
2050
2060
2070
2080

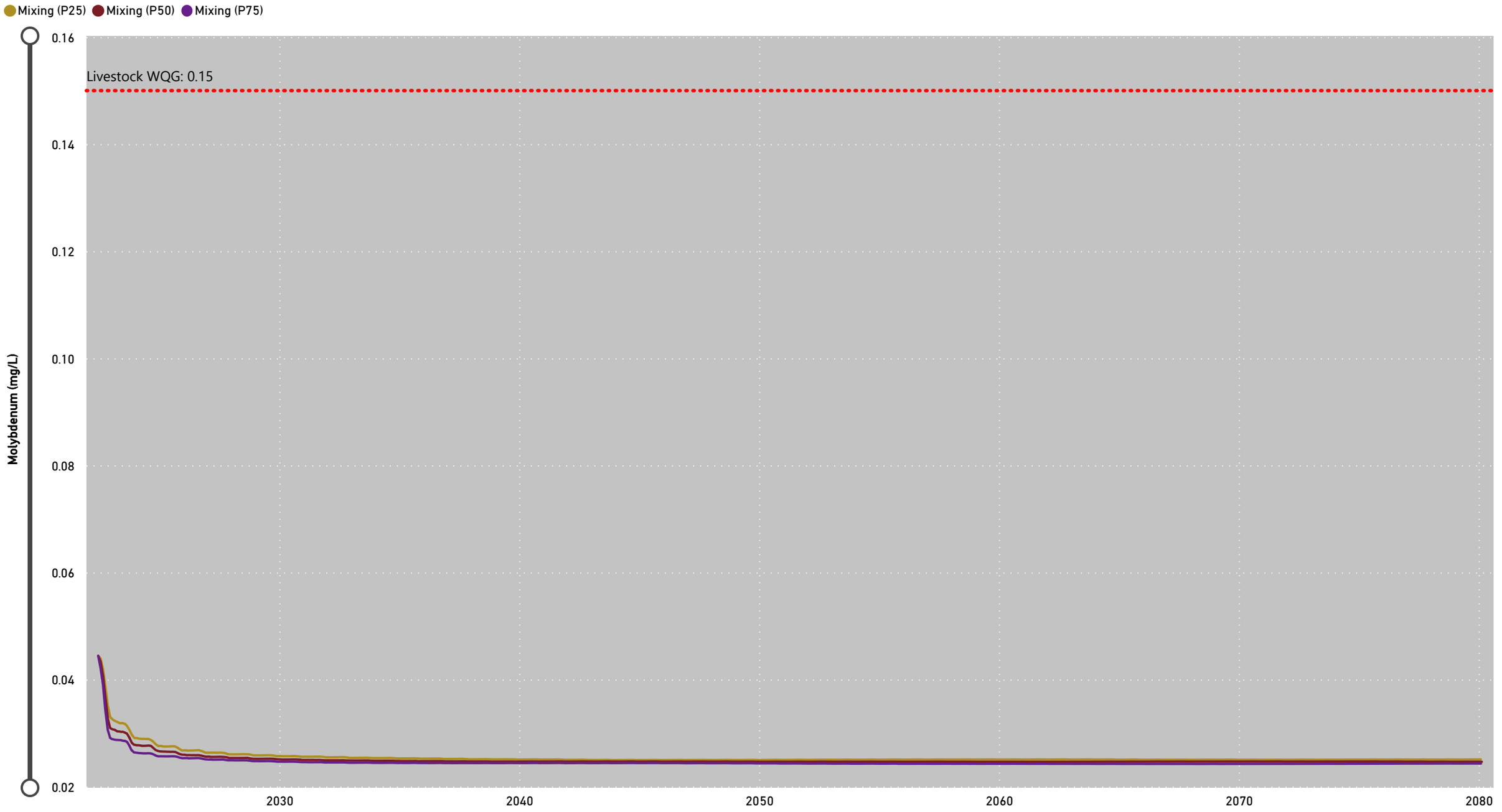

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 2.00
Fluoride (mg/L)
2.0
1.5
1.0
0.5
0.0
2030
2040
2050
2060
2070
2080

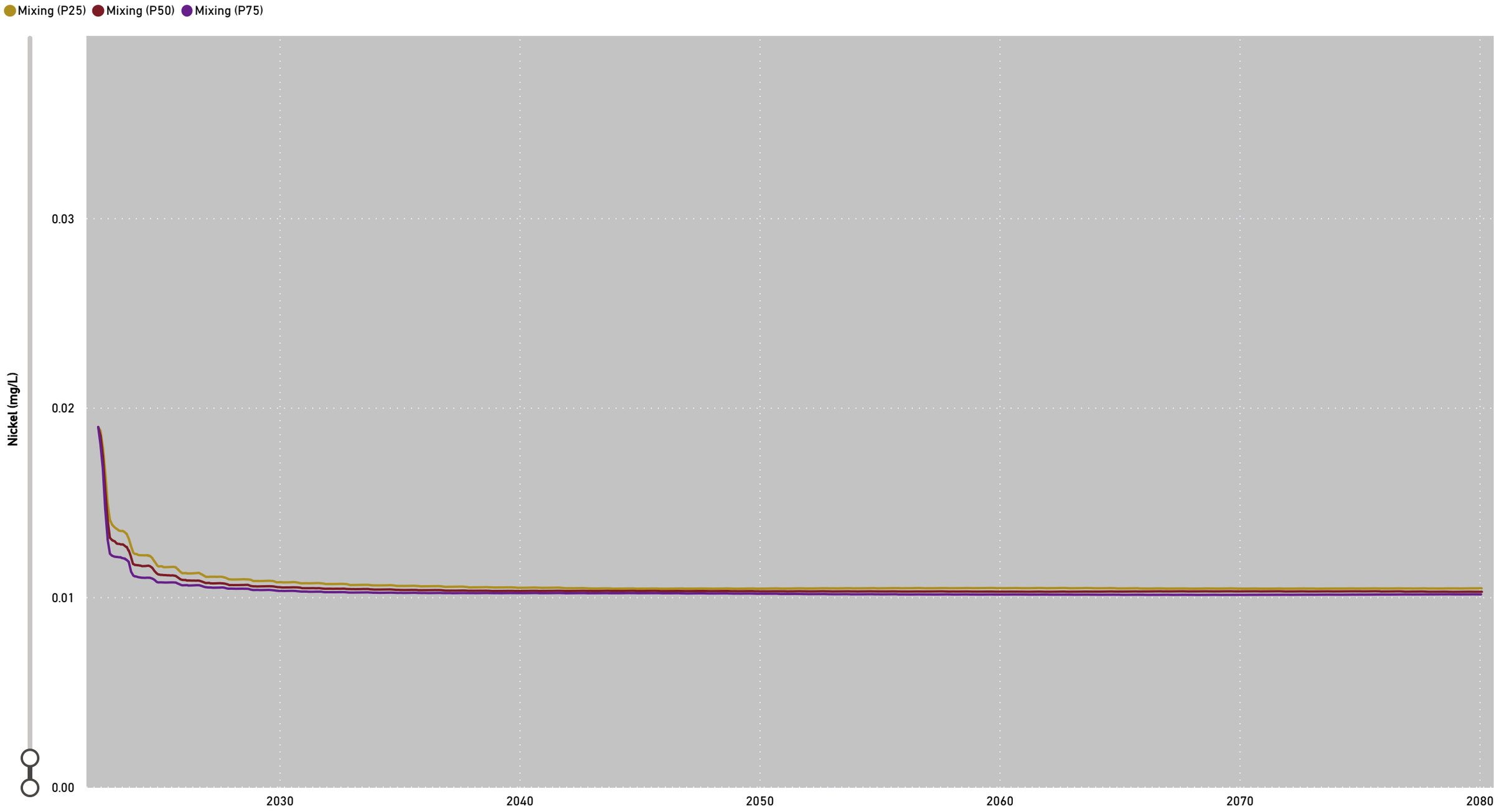

Mixing (P25)
Mixing (P50)
Mixing (P75)
Arsenic (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

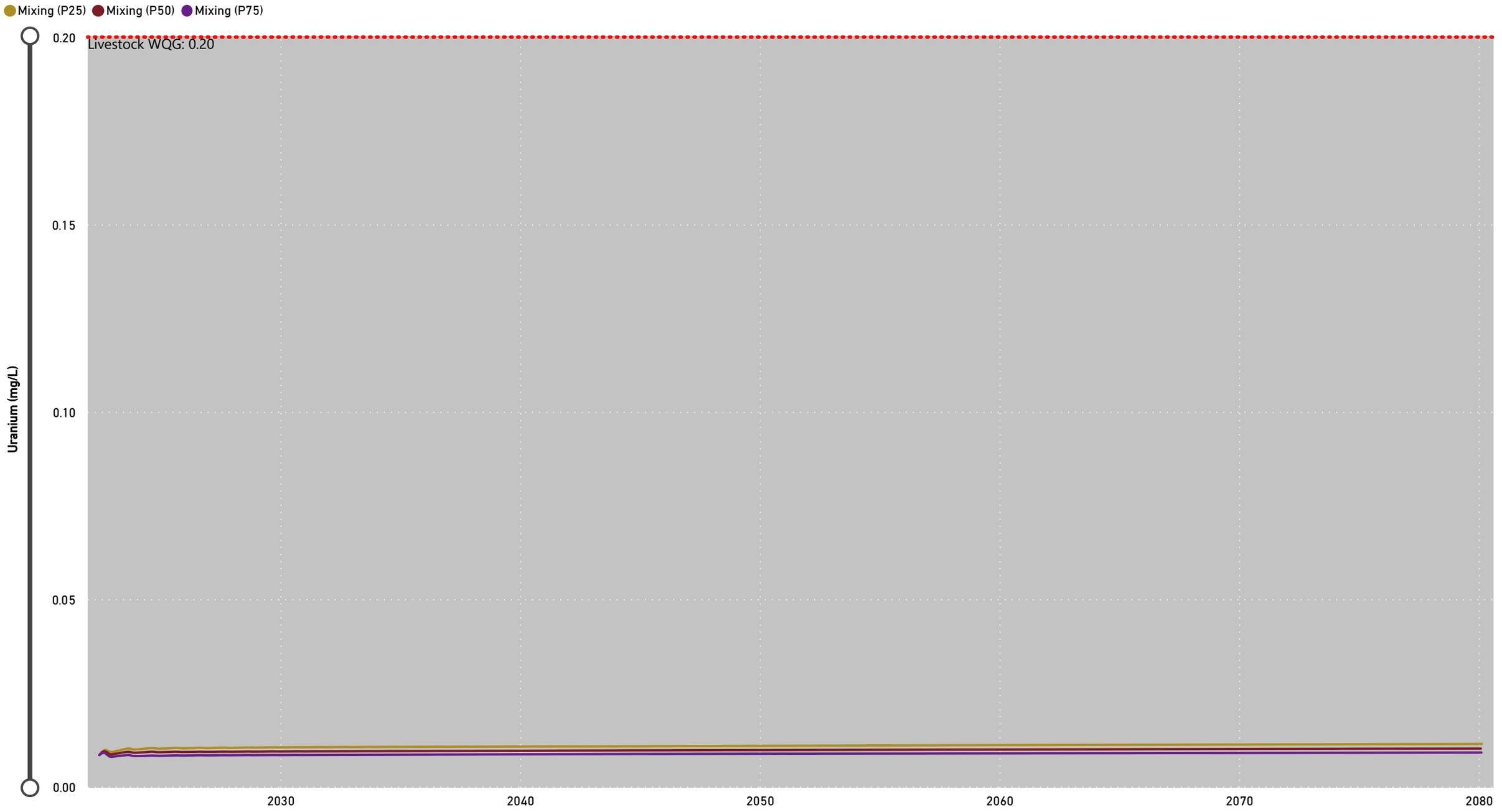

Mixing (P25)
Mixing (P50)
Mixing (P75)
Barium (mg/L)
0.050
0.045
0.040
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Chromium (mg/L)
0.0010
0.0005
0.0000
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Copper (mg/L)
0.04
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Molybdenum (mg/L)
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
Livestock WQG: 0.15
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Nickel (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 0.20
Uranium (mg/L)
0.20
0.15
0.10
0.05
0.00
2030
2040
2050
2060
2070
2080

Appendix G

Kinetic column leach test results

Appendix G.1 Kinetic column leach test results

APPENDIX A-1: Leachate assay results for the Barbara column leach tests: PAF1

Parameters		Sample #16993 - PAF1														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	612	496	489	477	553	555	551	542	543	546	545	549	555	559	535
pH	-	7.7	7.7	7.3	7.3	6.8	7.1	7.2	7.3	7.4	7.4	7.5	7.4	7.4	7.5	7.3
EC	µS/cm	231	496	621	625	381	395	391	429	445	441	436	376	371	366	444
Alkalinity	mg/l	29	15	19	16	18	11	14	14	16	13	15	16	17	22	16
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.07	0.11	0.04	0.04	0.01	0.01	0.04	0.03	0.02	0.02	0.02	0.03	0.04	0.02	0.03
As	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
B	mg/l	0.05	0.05	0.28	0.08	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.07
Ba	mg/l	0.03	0.02	0.04	0.04	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.024
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	44	54	67	40	89	85	76	80	80	77	60	70	67	68
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	6	5	2	1	1	1	1	1	1	1	1	1	1	2
Co	mg/l	0.001	0.013	0.018	0.020	0.007	0.02	0.01	0.01	0.007	0.008	0.008	0.006	0.007	0.007	0.011
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.01	0.13	0.06	0.05	0.03	0.07	0.05	0.04	0.038	0.030	0.033	0.031	0.033	0.028	0.048
F	mg/l	0.3	0.9	1.0	0.8	0.5	0.6	0.4	0.4	0.6	0.3	0.4	0.2	0.3	0.3	0.5
Fe	mg/l	0.05	0.21	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	14	16	14	11	18	15	14	14	15	13	12	12	13	14
Mg	mg/l	12	29	28	30	17	28	20	15	15	14	12	8	8	8	18
Mn	mg/l	0.06	0.14	0.08	0.07	0.03	0.05	0.05	0.04	0.04	0.044	0.04	0.036	0.04	0.04	0.05
Mo	mg/l	0.002	0.006	0.004	0.003	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.003	0.002	0.003	0.003
Na	mg/l	30	19	15	13	6	9	6	5	3	3	2	2	1	1	7
Ni	mg/l	0.005	0.017	0.024	0.027	0.009	0.020	0.012	0.006	0.005	0.004	0.005	0.004	0.004	0.004	0.011
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.06	0.04	0.04	0.02	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02
Si	mg/l	0.6	1.1	1.9	1.5	1.0	1.4	3.4	1.5	1.5	1.8	1.3	1.5	1.5	1.6	1.6
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	247	310	275	157	273	334	265	228	233	185	164	155	197	233
Sr	mg/l	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.10	0.09	0.09	0.08	0.08	0.08	0.10
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-2: Leachate assay results for the Barbara column leach tests: NAF1

Parameters		Sample #16995 - NAF1														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	614	503	496	491	549	551	548	546	549	551	555	557	560	561	540
pH	-	8.5	8.1	7.6	7.5	7.3	7.4	7.4	7.5	7.6	7.6	7.7	7.6	7.6	7.6	7.6
EC	µS/cm	119	126	135	139	105	121	126	142	152	140	139	128	125	131	131
Alkalinity	mg/l	40	26	27	23	19	26	22	19	24	22	23	21	22	25	23
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.1	0.3	0.3	0.3	0.1	0.2	0.2	0.23	0.17	0.19	0.15	0.15	0.16	0.14	0.2
As	mg/l	0.001	0.001	0.002	0.003	0.002	0.003	0.004	0.003	0.003	0.004	0.003	0.003	0.003	0.003	0.003
B	mg/l	0.05	0.05	0.3	0.08	0.05	0.18	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08
Ba	mg/l	0.032	0.003	0.006	0.005	0.003	0.003	0.003	0.005	0.003	0.003	0.003	0.002	0.003	0.002	0.003
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	5	8	10	10	12	10	16	12	14	12	12	14	11	11
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	2	5	1	1	1	1	1	1	1	1	1	1	1	1
Co	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.005	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F	mg/l	0.3	0.2	0.3	0.2	0.1	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Fe	mg/l	0.1	0.2	0.2	0.1	0.05	0.1	0.1	0.1	0.08	0.05	0.08	0.05	0.05	0.05	0.10
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	10	14	6	8	7	4	6	5	5	4	4	3	3	6
Mg	mg/l	12	2	2	1	1	1	1	1	1	1	1	1	1	1	1
Mn	mg/l	0.06	0.07	0.07	0.04	0.03	0.02	0.007	0.005	0.004	0.002	0.002	0.002	0.001	0.001	0.019
Mo	mg/l	0.002	0.015	0.009	0.008	0.008	0.005	0.005	0.007	0.007	0.004	0.003	0.004	0.004	0.004	0.006
Na	mg/l	30	9	5	4	4	6	2	4	2	2	1	1	1	1	3
Ni	mg/l	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1.000
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	0.6	0.9	1.5	0.9	0.7	1.1	3	1.1	0.9	1.1	0.7	1.0	1.0	1.0	1.2
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	19	30	17	24	21	33	36	16	18	12	9	11	10	20
Sr	mg/l	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.006	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.01	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-3: Leachate assay results for the Barbara column leach tests: NAF2

Parameters		Sample #16996 - NAF2														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	602	510	500	496	512	515	520	532	535	539	542	551	559	563	529
pH	-	8.2	8.0	7.5	7.5	7.3	7.4	7.5	7.5	7.6	7.5	7.6	7.5	7.5	7.6	7.5
EC	µS/cm	111	149	179	175	139	141	145	210	222	225	221	196	187	182	182
Alkalinity	mg/l	31	31	29	24	20	22	27	21	23	26	25	23	24	25	25
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.07	0.32	0.29	0.22	0.10	0.18	0.17	0.17	0.14	0.14	0.09	0.15	0.13	0.14	0.17
As	mg/l	0.001	0.006	0.015	0.021	0.018	0.030	0.030	0.033	0.035	0.036	0.029	0.034	0.029	0.029	0.027
B	mg/l	0.05	0.05	0.3	0.1	0.05	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08
Ba	mg/l	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	6	11	17	13	20	21	29	30	35	28	21	23	20	21
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	5	2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1
Co	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.01	0.003	0.005	0.005	0.001	0.004	0.003	0.005	0.004	0.002	0.005	0.003	0.002	0.005	0.004
F	mg/l	0.3	0.3	0.4	0.3	0.1	0.2	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.2
Fe	mg/l	0.1	0.2	0.2	0.1	0.05	0.1	0.1	0.1	0.07	0.06	0.08	0.07	0.07	0.07	0.10
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	16	14	14	10	13	10	9	10	11	9	8	7	7	11
Mg	mg/l	12	3	4	4	3	4	3	4	3	4	3	2	2	2	3
Mn	mg/l	0.06	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.003	0.002	0.002	0.002	0.001	0.001	0.008
Mo	mg/l	0.002	0.01	0.008	0.008	0.005	0.005	0.004	0.007	0.006	0.007	0.004	0.004	0.004	0.005	0.006
Na	mg/l	30	10	6	5	3	4	2	2	2	4	1	1	1	1	3
Ni	mg/l	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.003	0.003	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	0.6	0.9	1.6	1.1	0.9	1.2	3.4	1.4	1.3	1.6	1.2	1.7	1.4	1.4	1.5
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	30	52	52	36	50	65	74	59	64	43	26	30	29	47
Sr	mg/l	0.09	0.01	0.02	0.03	0.02	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.02	0.02	0.03
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-4: Leachate assay results for the Barbara column leach tests: NAF3 (previously PAF2)

Parameters		Sample #16994 - NAF3														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	609	510	499	Column terminated	-	-	-	-	-	-	-	-	-	-	505
pH	-	7.9	8.1	7.7		-	-	-	-	-	-	-	-	-	-	7.9
EC	µS/cm	109	101	96		-	-	-	-	-	-	-	-	-	-	99
Alkalinity	mg/l	28	28	34		-	-	-	-	-	-	-	-	-	-	31
Acidity	mg/l	-	-	-		-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Al	mg/l	0.07	0.4	1.0		-	-	-	-	-	-	-	-	-	-	0.7
As	mg/l	0.001	0.01	0.01		-	-	-	-	-	-	-	-	-	-	0.012
B	mg/l	0.05	0.05	0.3		-	-	-	-	-	-	-	-	-	-	0.16
Ba	mg/l	0.03	0.009	0.01		-	-	-	-	-	-	-	-	-	-	0.011
Be	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Ca	mg/l	43	1	1		-	-	-	-	-	-	-	-	-	-	1
Cd	mg/l	0.0001	0.0001	0.0001		-	-	-	-	-	-	-	-	-	-	0.0001
Cl	mg/l	28	5	3		-	-	-	-	-	-	-	-	-	-	4
Co	mg/l	0.001	0.003	0.003		-	-	-	-	-	-	-	-	-	-	0.003
Cr	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Cu	mg/l	0.005	0.1	0.2		-	-	-	-	-	-	-	-	-	-	0.14
F	mg/l	0.3	0.8	0.8		-	-	-	-	-	-	-	-	-	-	0.8
Fe	mg/l	0.05	0.5	1.1		-	-	-	-	-	-	-	-	-	-	0.8
Hg	mg/l	0.0001	0.0001	0.0001		-	-	-	-	-	-	-	-	-	-	0.0001
K	mg/l	17	1	3		-	-	-	-	-	-	-	-	-	-	2
Mg	mg/l	12	1	1		-	-	-	-	-	-	-	-	-	-	1
Mn	mg/l	0.06	0.02	0.02		-	-	-	-	-	-	-	-	-	-	0.02
Mo	mg/l	0.002	0.01	0.01		-	-	-	-	-	-	-	-	-	-	0.011
Na	mg/l	30	16	15		-	-	-	-	-	-	-	-	-	-	16
Ni	mg/l	0.005	0.001	0.002		-	-	-	-	-	-	-	-	-	-	0.002
P	mg/l	1	1	1		-	-	-	-	-	-	-	-	-	-	1
Pb	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Sb	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Se	mg/l	0.01	0.01	0.01		-	-	-	-	-	-	-	-	-	-	0.01
Si	mg/l	1	3	5		-	-	-	-	-	-	-	-	-	-	3.965
Sn	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
SO_4	mg/l	113	6	8		-	-	-	-	-	-	-	-	-	-	7
Sr	mg/l	0.09	0.002	0.003		-	-	-	-	-	-	-	-	-	-	0.003
Th	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Tl	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
U	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Zn	mg/l	0.005	0.005	0.005		-	-	-	-	-	-	-	-	-	-	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-5: Leachate assay results for the Barbara column leach tests: NAF4

Parameters		Sample #17920 - NAF4														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	593	552	561	552	556	554	558	552	556	561	560	563	561	566	558
pH	-	7.9	7.1	7.3	7.4	7.4	7.6	7.5	7.5	7.4	7.4	7.6	7.5	7.5	7.6	7.4
EC	µS/cm	531	649	616	611	776	795	784	769	711	689	655	550	530	530	667
Alkalinity	mg/l	32	20	24	19	21	23	28	25	24	26	30	30	29	28	25
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.07	0.02	0.04	0.01	0.02	0.02	0.02	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.02
As	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
B	mg/l	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Ba	mg/l	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.03	0.02	0.02	0.02	0.02
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	57	150	170	144	162	165	217	167	103	147	160	131	122	146
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	30	34	27	14	6	3	2	1	1	1	1	1	1	9
Co	mg/l	0.001	0.001	0.001	0.002	0.0	0.002	0.003	0.005	0.004	0.002	0.003	0.003	0.002	0.002	0.002
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.005	0.009	0.02	0.02	0.02	0.026	0.026	0.036	0.026	0.021	0.023	0.017	0.014	0.019	0.021
F	mg/l	0.3	0.3	0.6	0.6	0.6	0.8	0.5	0.1	0.4	0.3	0.4	0.4	0.4	0.3	0.4
Fe	mg/l	0.05	0.05	0.11	0.05	0.06	0.05	0.05	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.06
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	17	30	24	22	22	22	25	23	14	18	18	17	16	21
Mg	mg/l	12	22	38	40	35	37	36	42	28	14	22	22	19	18	29
Mn	mg/l	0.06	0.07	0.1	0.2	0.2	0.21	0.21	0.38	0.26	0.13	0.23	0.19	0.13	0.13	0.19
Mo	mg/l	0.002	0.004	0.003	0.004	0.003	0.003	0.002	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.002
Na	mg/l	30	32	37	32	21	15	9	7	4	2	2	1	1	1	13
Ni	mg/l	0.005	0.001	0.002	0.001	0.001	0.001	0.001	0.002	0.003	0.001	0.002	0.002	0.001	0.001	0.001
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	0.6	0.5	1.0	2.5	0.9	0.9	1.1	1.0	1.0	0.7	1.0	1	1	1	1.0
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	224	482	615	533	551	531	628	499	244	443	434	365	331	452
Sr	mg/l	0.09	0.11	0.19	0.21	0.15	0.16	0.14	0.17	0.14	0.07	0.11	0.10	0.08	0.08	0.13
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-6: Leachate assay results for the Barbara column leach tests: ROM1

Parameters		Sample #16997 - ROM1														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	603	499	503	499	495	500	510	521	525	528	536	540	550	553	520
pH	-	8.0	8.0	7.8	7.7	7.3	7.3	7.4	7.5	7.6	7.5	7.6	7.6	7.5	7.7	7.6
EC	µS/cm	136	131	185	183	158	162	169	141	156	155	149	138	129	128	153
Alkalinity	mg/l	34	30	25	22	20	24	25	23	25	24	26	24	25	24	24
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.1	0.7	2	0.5	0.4	0.7	1	0.6	0.9	0.9	1.0	0.7	0.8	0.71	0.86
As	mg/l	0.001	0.005	0.006	0.005	0.004	0.006	0.006	0.004	0.004	0.004	0.003	0.004	0.003	0.003	0.004
B	mg/l	0.05	0.05	0.3	0.2	0.09	0.3	0.1	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.10
Ba	mg/l	0.03	0.02	0.04	0.03	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.03
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	2	4	6	5	5	3	3	3	2	3	2	2	3	3
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	3	2	2	1	3	1	1	1	1	1	1	1	1	1
Co	mg/l	0.001	0.002	0.005	0.002	0.001	0.003	0.004	0.004	0.006	0.008	0.006	0.005	0.007	0.007	0.005
Cr	mg/l	0.001	0.001	0.003	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.002	0.002	0.004	0.001	0.002
Cu	mg/l	0.005	0.4	0.6	0.3	0.1	0.4	0.5	0.5	0.8	1.0	0.8	0.6	1.0	0.8	0.6
F	mg/l	0.3	2	2	1	1	1	0.7	0.5	0.8	0.5	0.1	0.3	0.3	0.3	0.8
Fe	mg/l	0.05	1	3	0.6	0.5	0.9	1.5	0.8	1.2	1.1	1.4	0.9	1.1	0.96	1.1
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	3	4	4	4	5	3	3	3	3	3	3	3	3	3
Mg	mg/l	12	2	4	6	5	5	3	2	3	2	3	2	3	3	3
Mn	mg/l	0.06	0.04	0.05	0.02	0.01	0.03	0.04	0.05	0.06	0.08	0.07	0.05	0.07	0.07	0.05
Mo	mg/l	0.002	0.02	0.01	0.01	0.009	0.006	0.004	0.003	0.004	0.002	0.001	0.001	0.001	0.001	0.005
Na	mg/l	30	18	24	24	18	16	13	10	10	8	7	6	6	6	13
Ni	mg/l	0.005	0.001	0.003	0.001	0.001	0.002	0.002	0.001	0.002	0.002	0.003	0.001	0.004	0.002	0.002
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	1	5	6	6	6	7	14	5	5	6	4	4	4	4	6
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	22	62	58	44	31	32	16	12	8	5	4	4	4	23
Sr	mg/l	0.09	0.008	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

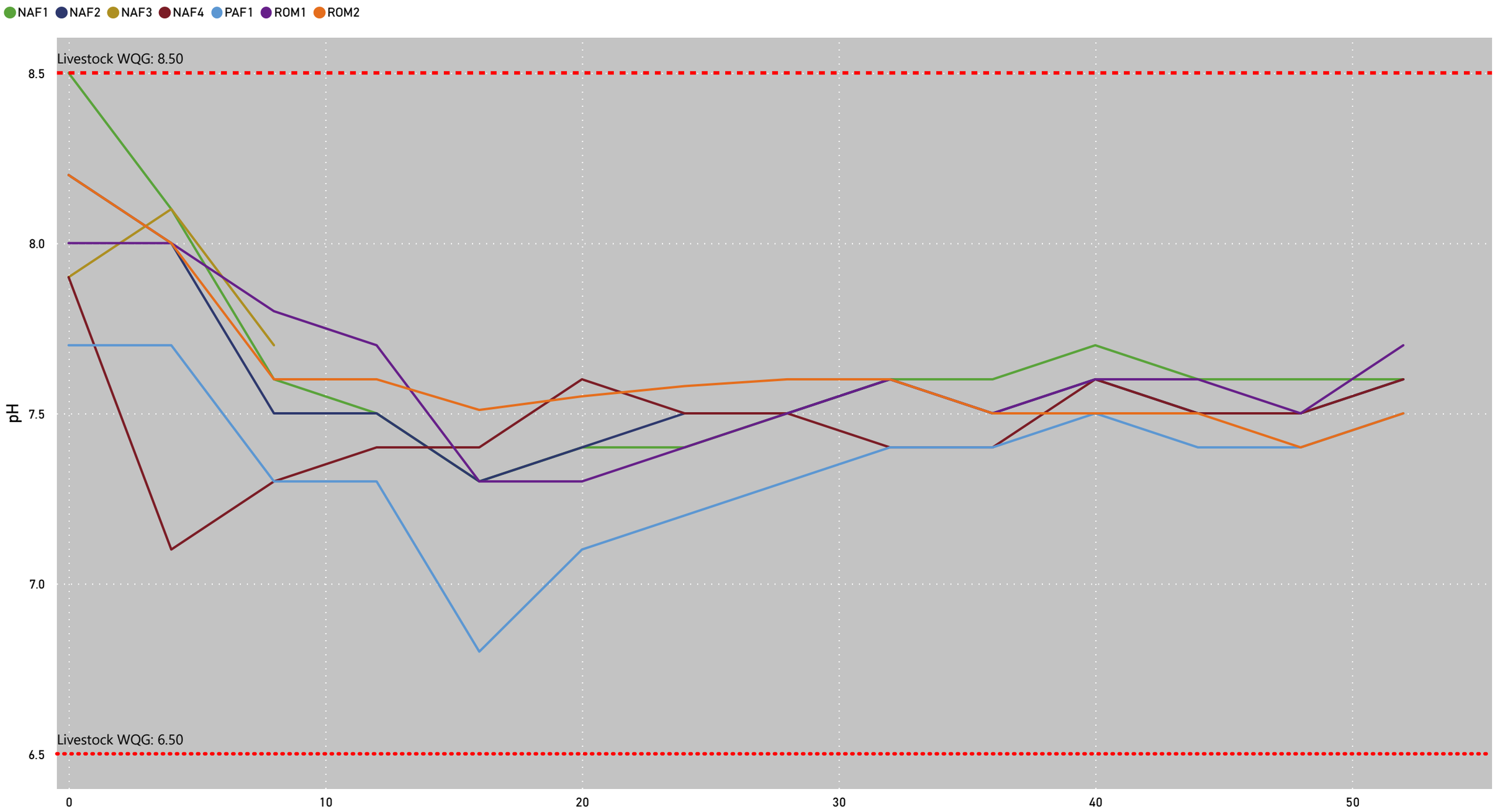
Underline indicates that the concentration is less than the limit of detection

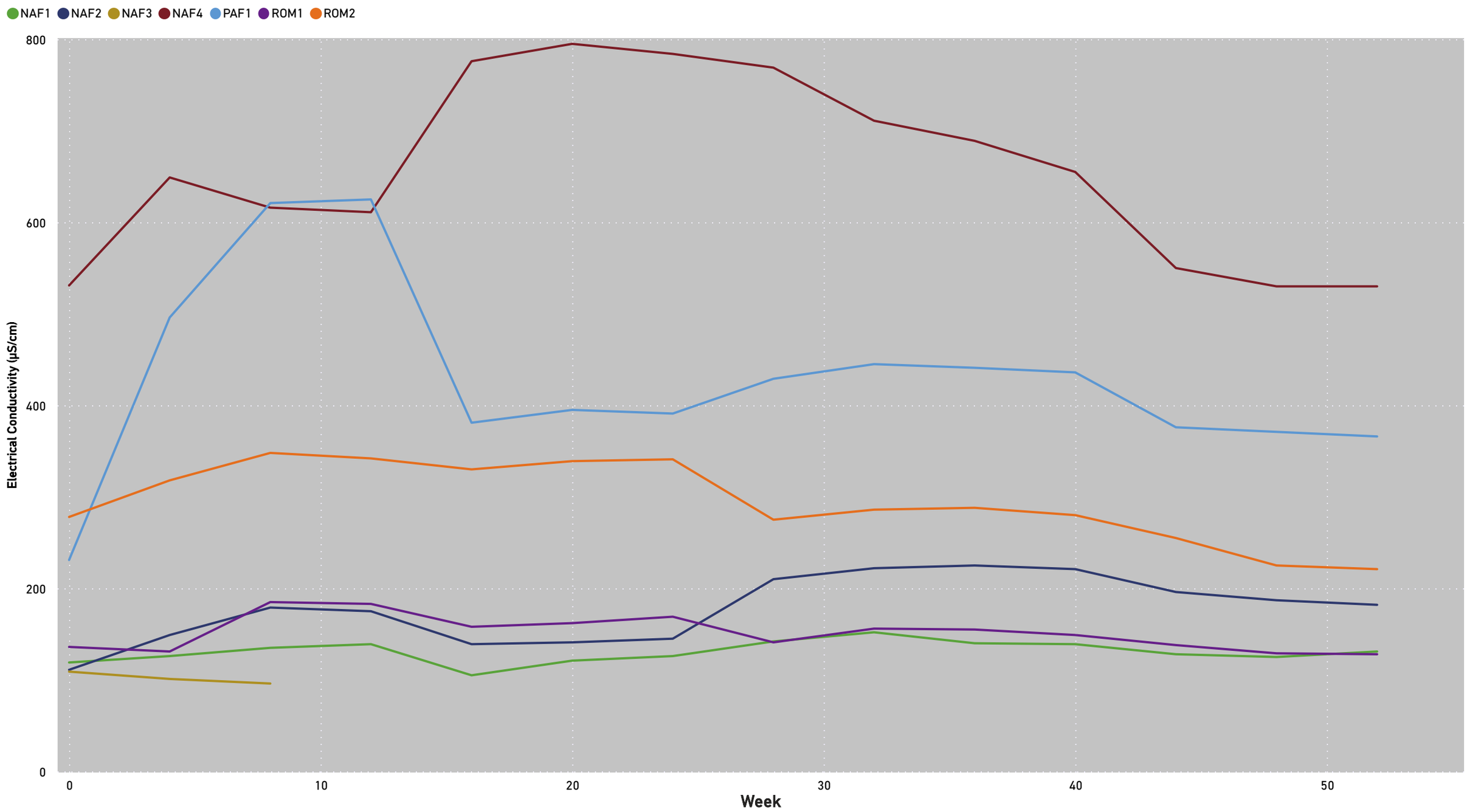
APPENDIX A-7: Leachate assay results for the Barbara column leach tests: ROM2

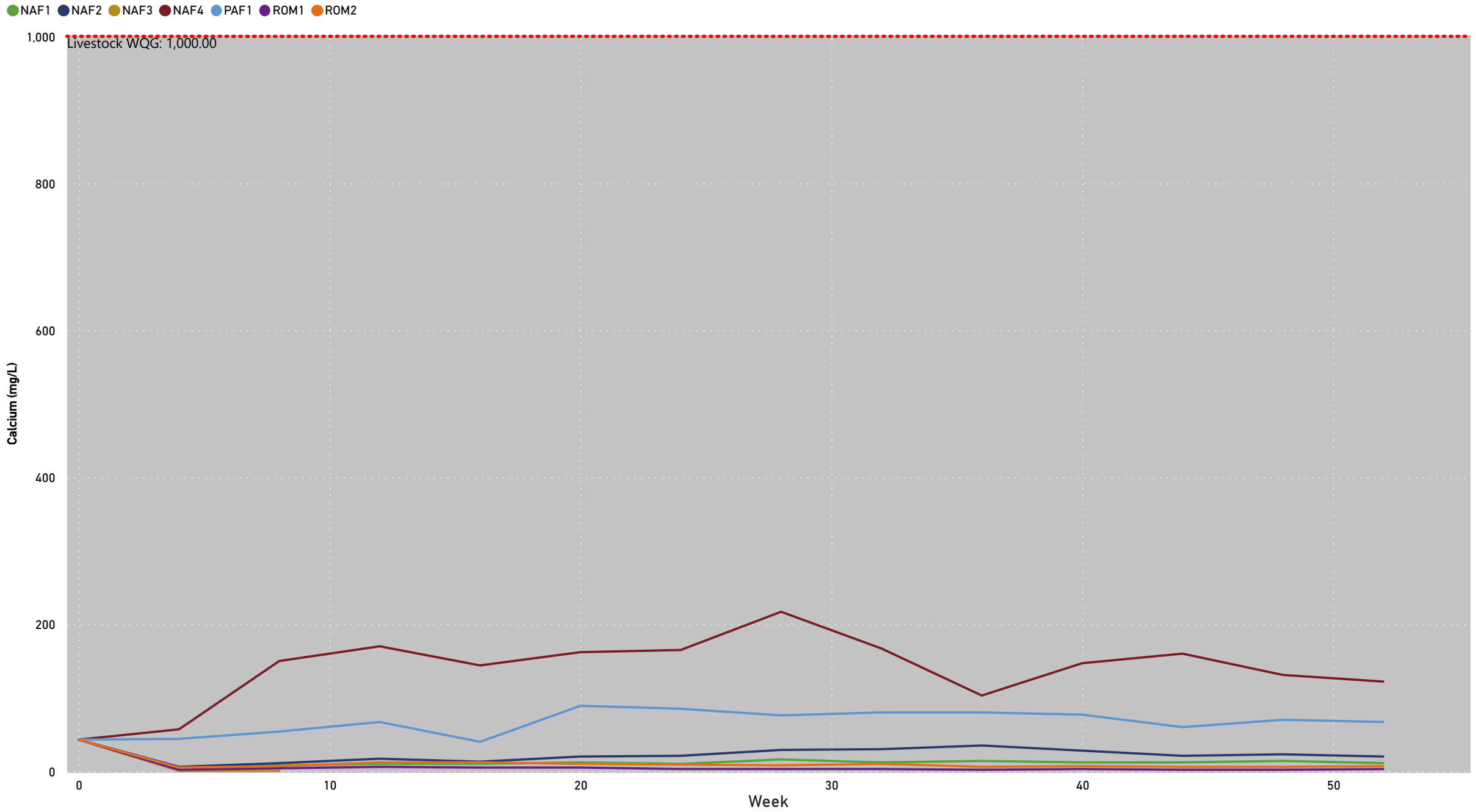
Parameters		Sample #16998 - ROM2														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	611	509	502	497	508	510	516	525	521	525	531	540	545	551	522
pH	-	8.2	8.0	7.6	7.6	7.51	7.55	7.58	7.6	7.6	7.5	7.5	7.5	7.4	7.5	7.6
EC	µS/cm	278	318	348	342	330	339	341	275	286	288	280	255	225	221	296
Alkalinity	mg/l	68	51	40	37	37	32	30	28	33	30	31	29	28	32	34
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.1	0.8	2.0	0.2	0.3	0.3	0.4	0.2	0.3	0.6	0.5	0.4	0.6	0.3	0.5
As	mg/l	0.001	0.006	0.006	0.003	0.003	0.003	0.004	0.003	0.003	0.004	0.003	0.003	0.002	0.002	0.003
B	mg/l	0.05	0.05	0.2	0.1	0.06	0.07	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.07
Ba	mg/l	0.03	0.03	0.04	0.03	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.03
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	5	7	12	12	10	9	8	10	6	7	6	6	7	8
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	3	3	1	1	1	1	1	1	1	1	1	1	1	1
Co	mg/l	0.001	0.004	0.004	0.001	0.001	0.001	0.001	0.001	0.002	0.005	0.004	0.003	0.006	0.003	0.003
Cr	mg/l	0.001	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.005	0.5	0.5	0.1	0.1	0.2	0.2	0.2	0.2	0.6	0.5	0.3	0.7	0.3	0.3
F	mg/l	0.3	3	2	2	1.4	1.3	1.0	0.8	1.2	0.7	0.1	0.4	0.4	0.4	1.1
Fe	mg/l	0.05	1	2	0.3	0.3	0.4	0.4	0.3	0.3	0.6	0.7	0.5	0.7	0.5	0.6
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	5	8	7	8	9	7	5	6	5	4	5	4	4	6
Mg	mg/l	12	5	8	10	12	10	8	7	8	5	6	5	5	5	7
Mn	mg/l	0.06	0.04	0.03	0.006	0.002	0.01	0.01	0.01	0.012	0.04	0.03	0.02	0.05	0.022	0.021
Mo	mg/l	0.002	0.01	0.01	0.008	0.007	0.005	0.003	0.003	0.004	0.002	0.001	0.001	0.001	0.001	0.005
Na	mg/l	30	47	45	41	34	27	24	19	20	13	12	10	8	8	24
Ni	mg/l	0.005	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	0.6	6	6	5	5	5	17	4	4	5	3	4	3	4	5.463
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	79	120	121	115	77	88	63	55	25	19	15	13	20	62
Sr	mg/l	0.09	0.02	0.04	0.05	0.04	0.03	0.04	0.03	0.04	0.02	0.03	0.03	0.02	0.03	0.031
Th	mg/l	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

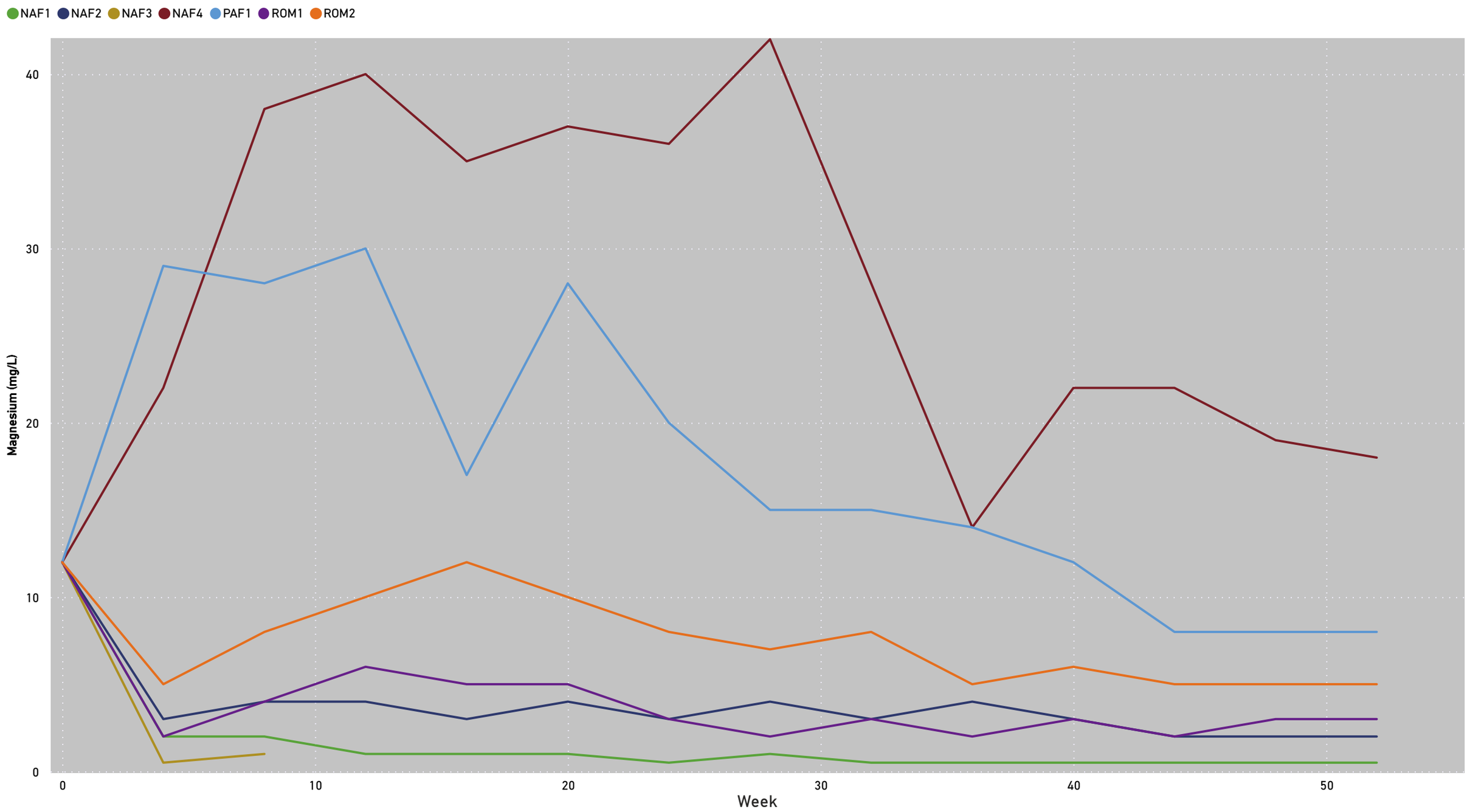
Underline indicates that the concentration is less than the limit of detection

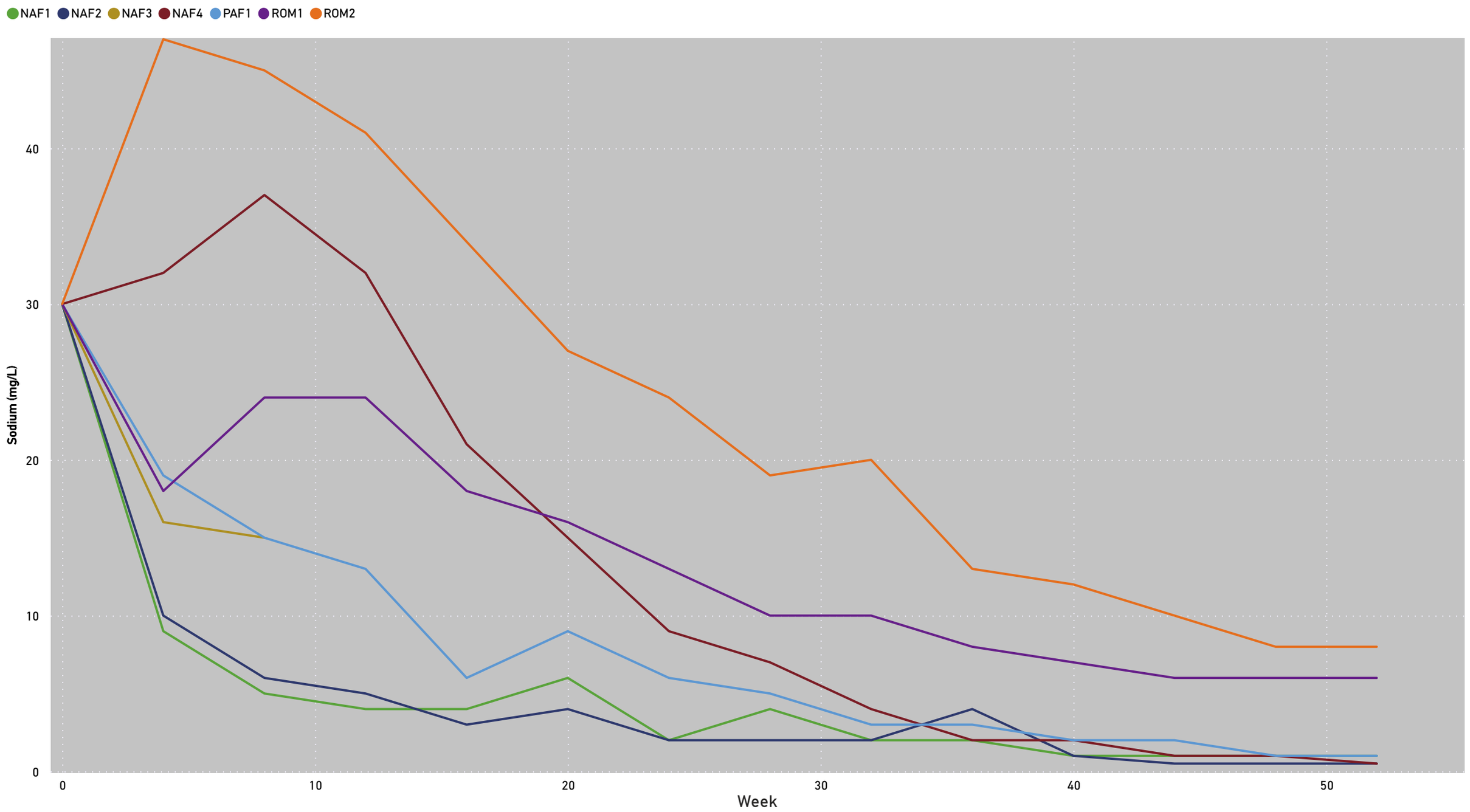
Appendix G.2 Kinetic column leach test results against livestock WQG

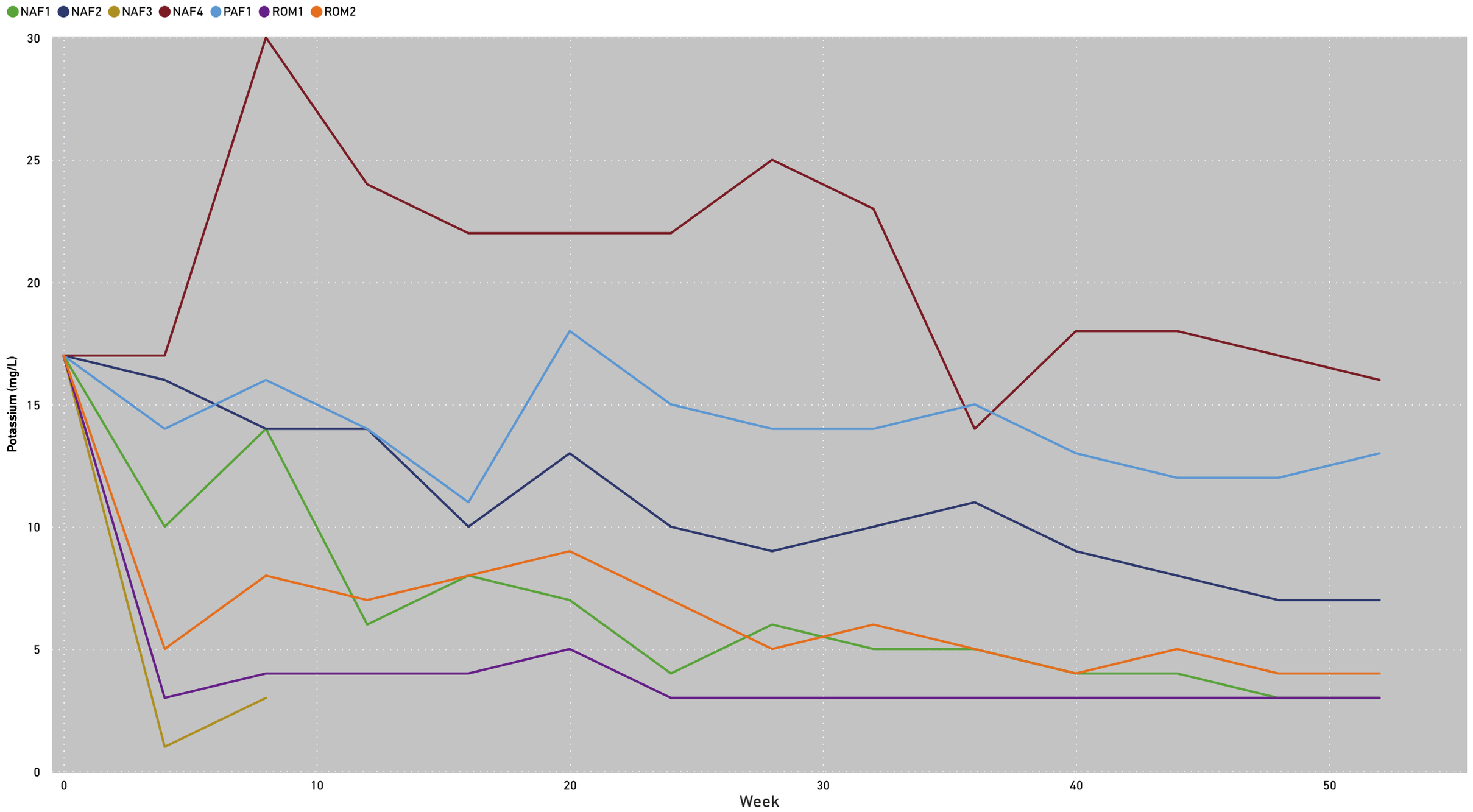

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG: 8.50
Livestock WQG: 6.50
pH
8.5
8.0
7.5
7.0
6.5
0
10
20
30
40
50

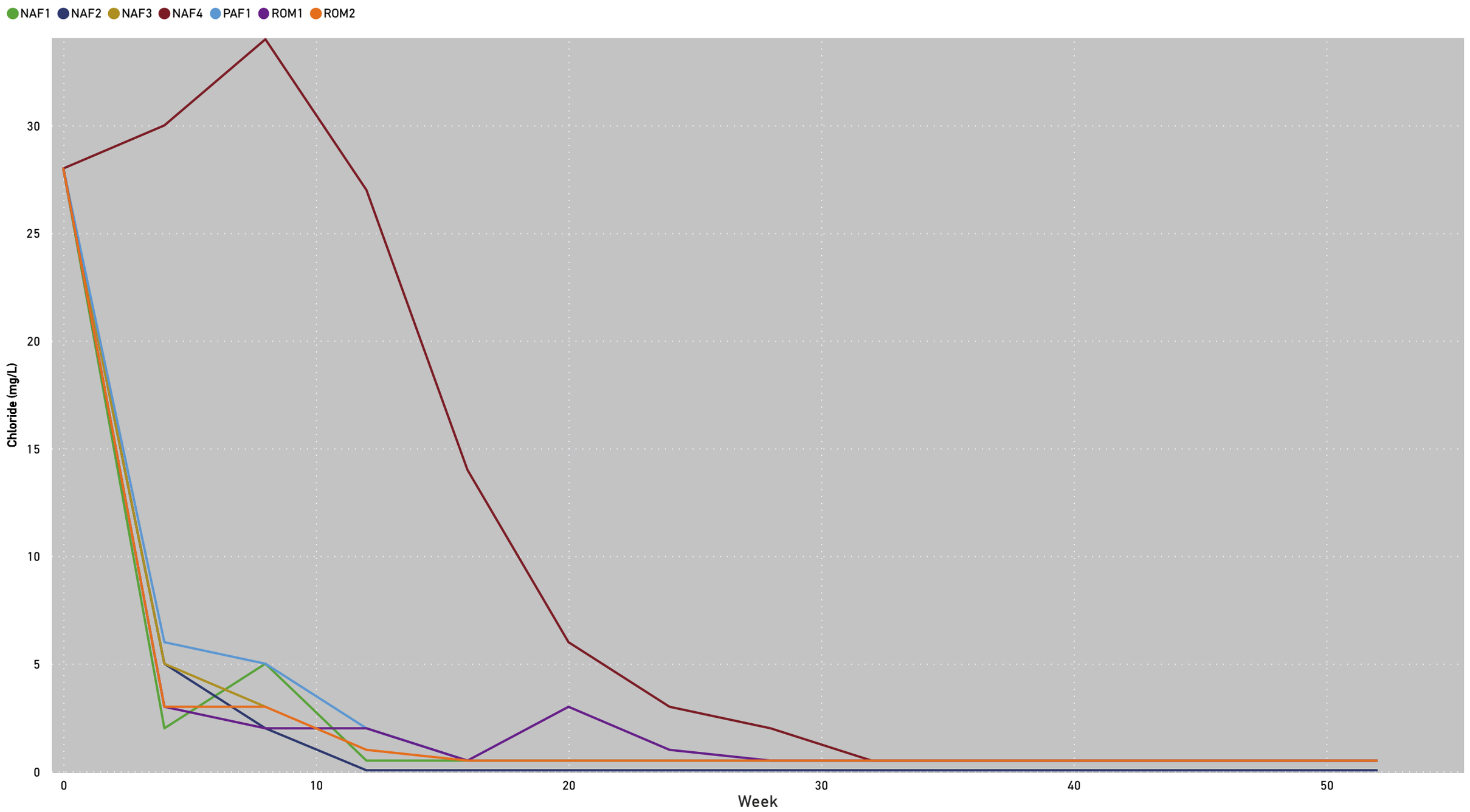

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
800
600
400
200
0
Electrical Conductivity (µS/cm)
0
10
20
30
40
50
Week

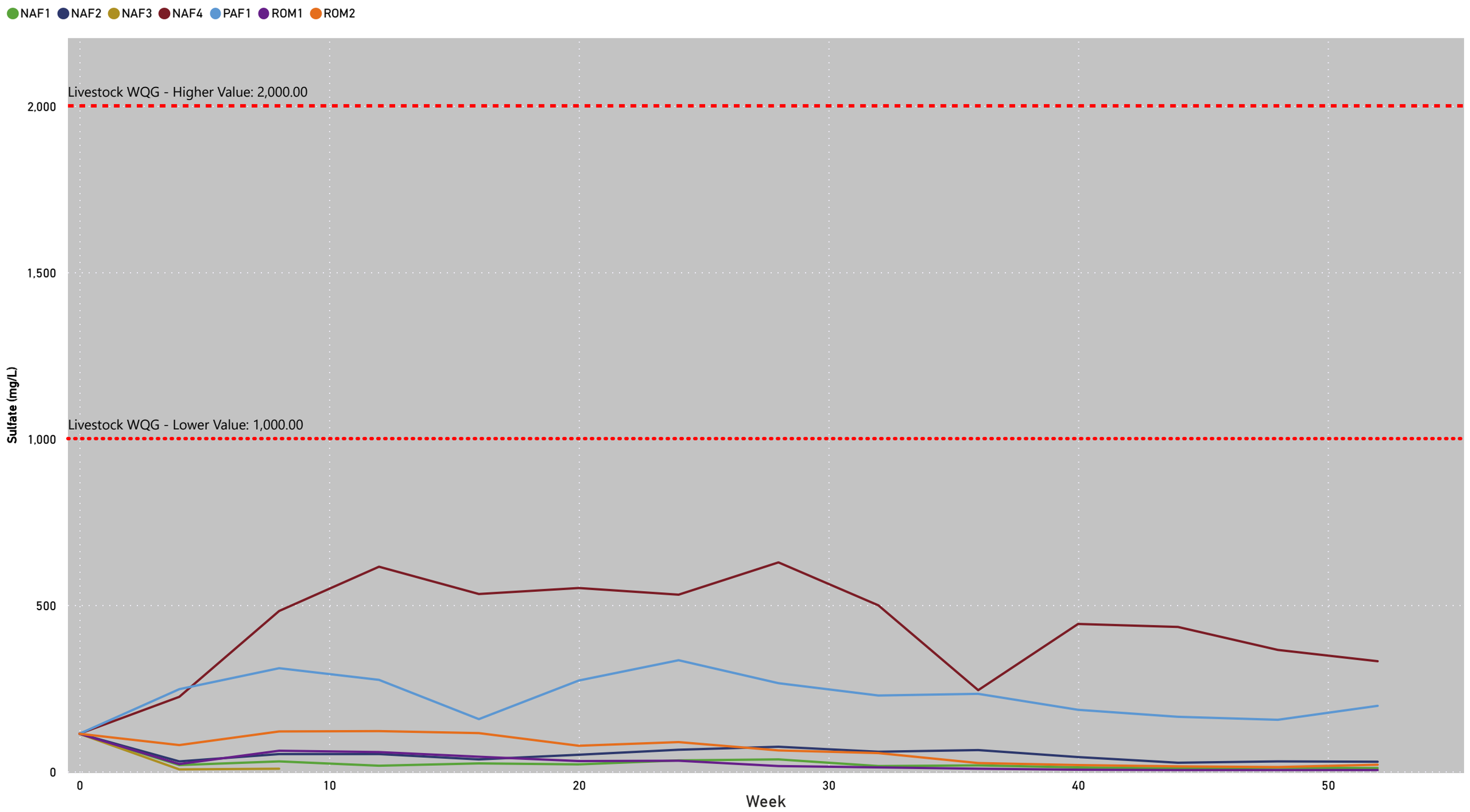

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG: 1,000.00
1,000
800
600
400
200
0
Calcium (mg/L)
0
10
20
30
40
50
Week

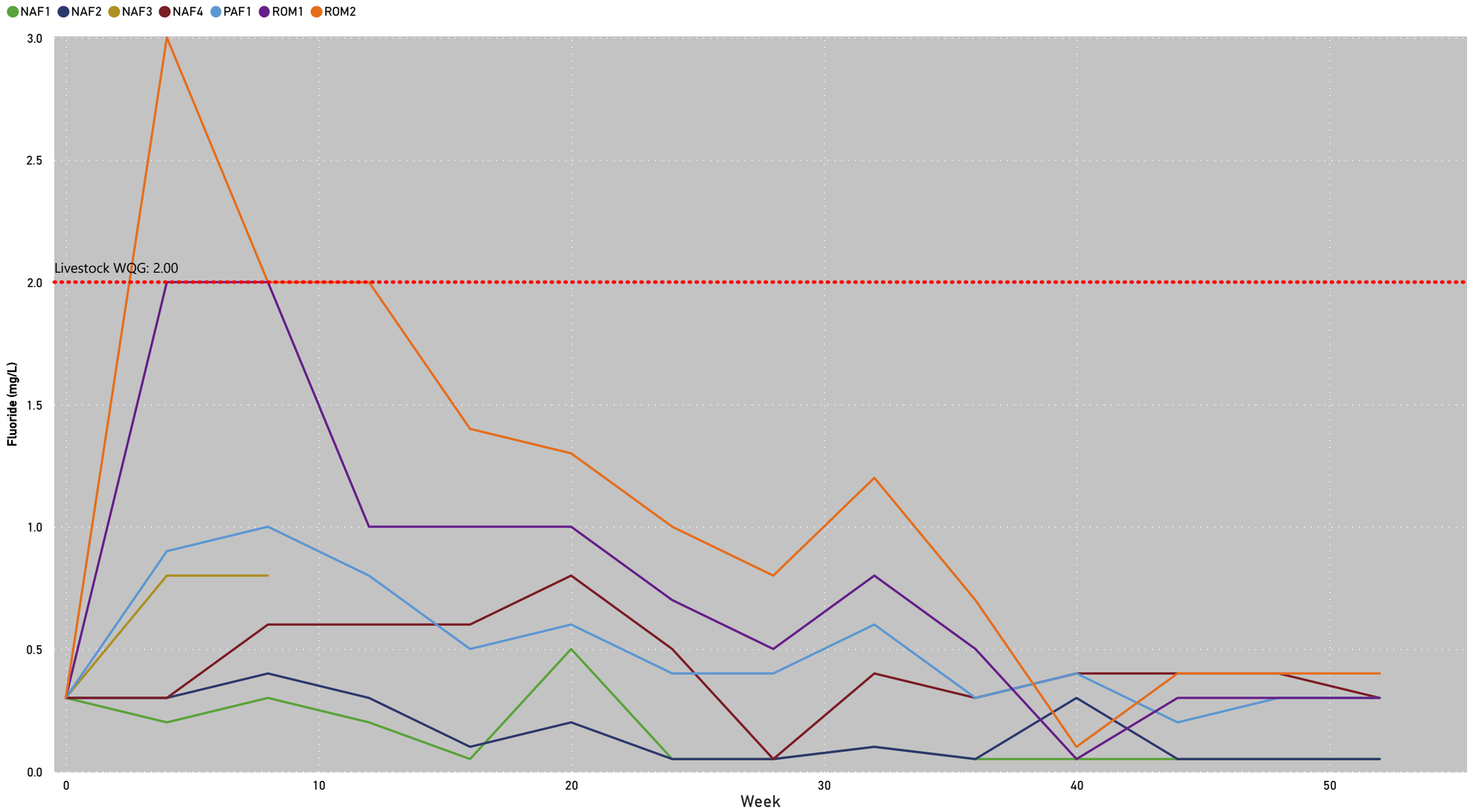

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Magnesium (mg/L)
0
10
20
30
40
0
10
20
30
40
50
Week

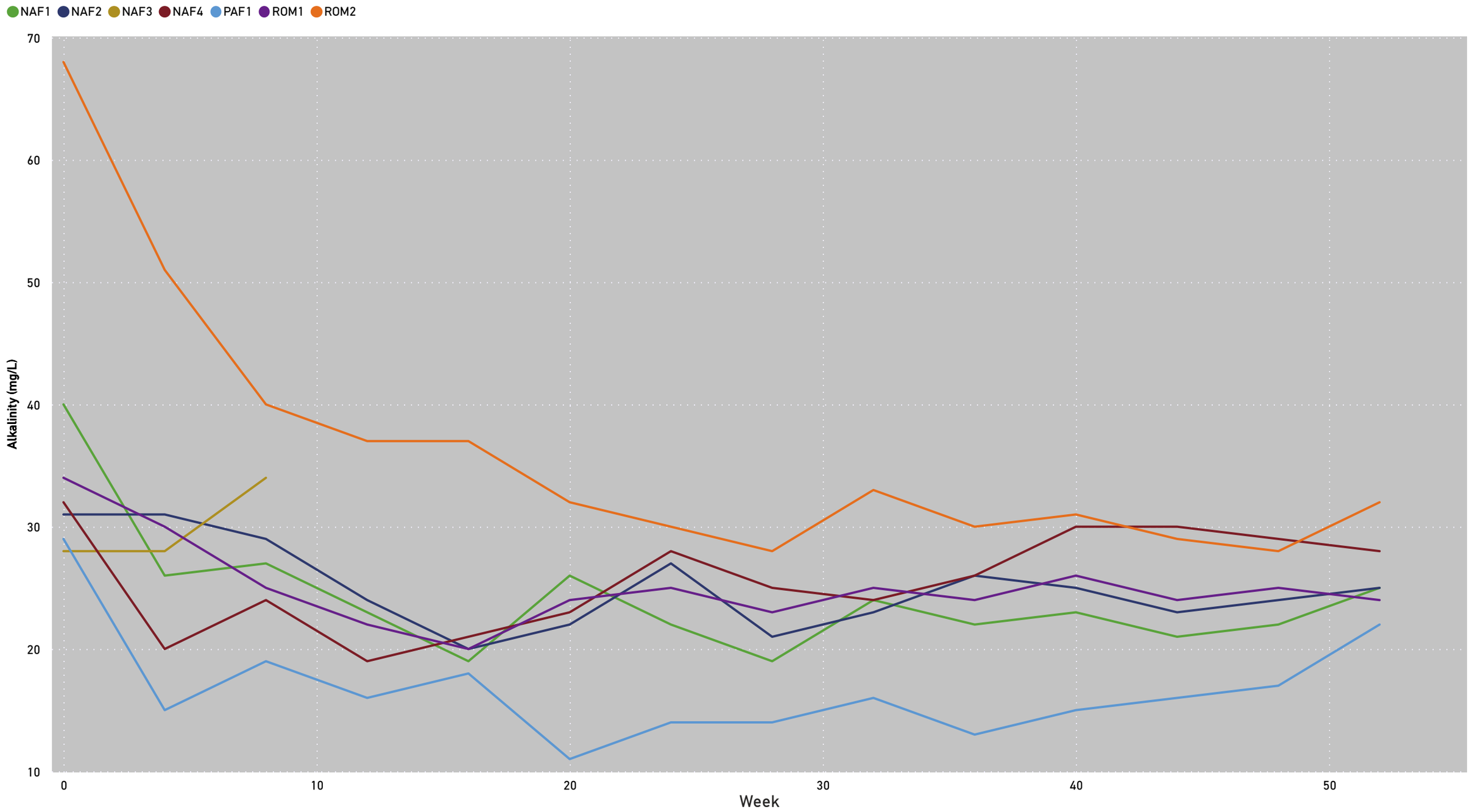

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Sodium (mg/L)
0
10
20
30
40
0
10
20
30
40
50
Week

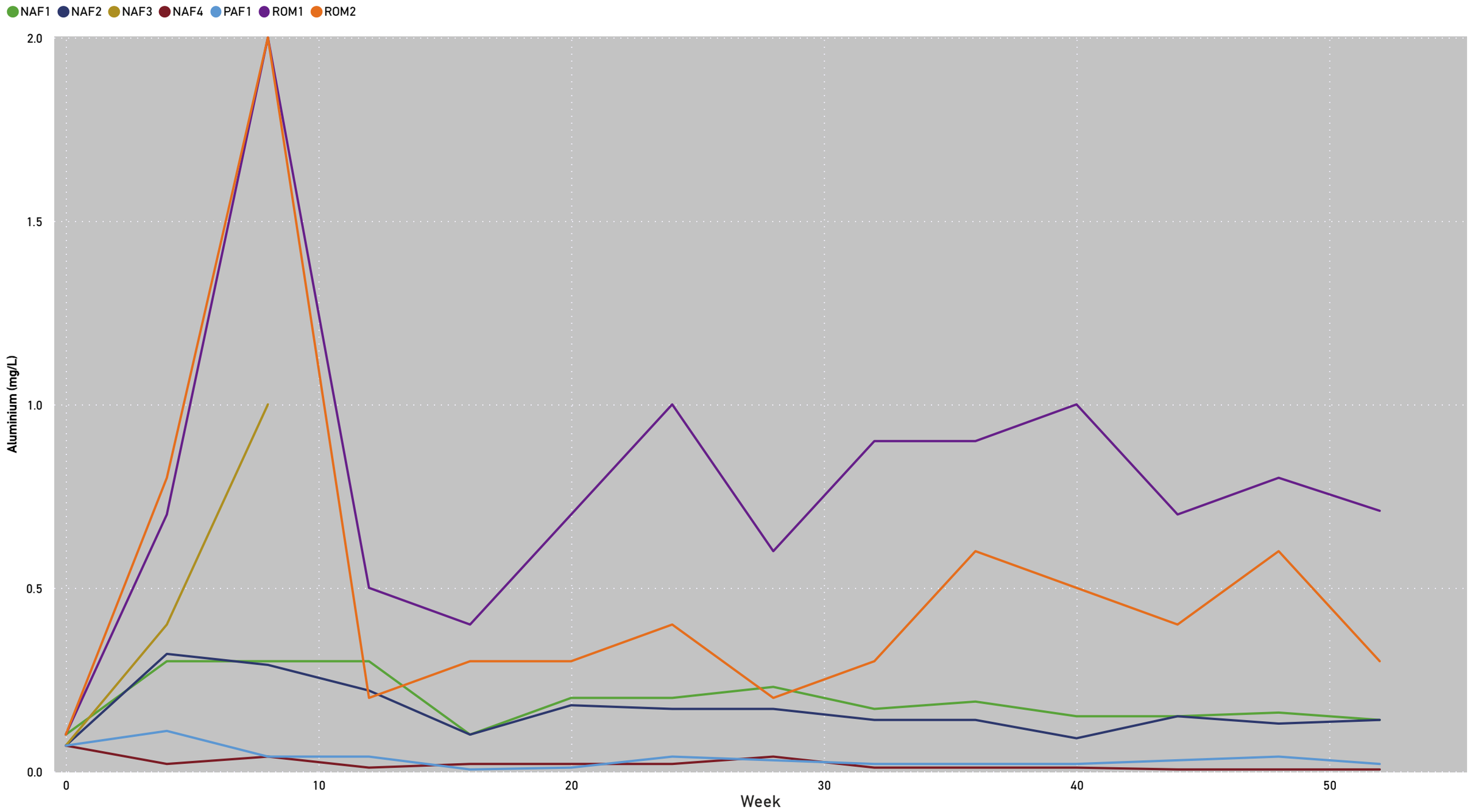

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Potassium (mg/L)
30
25
20
15
10
5
0
0
10
20
30
40
50
Week

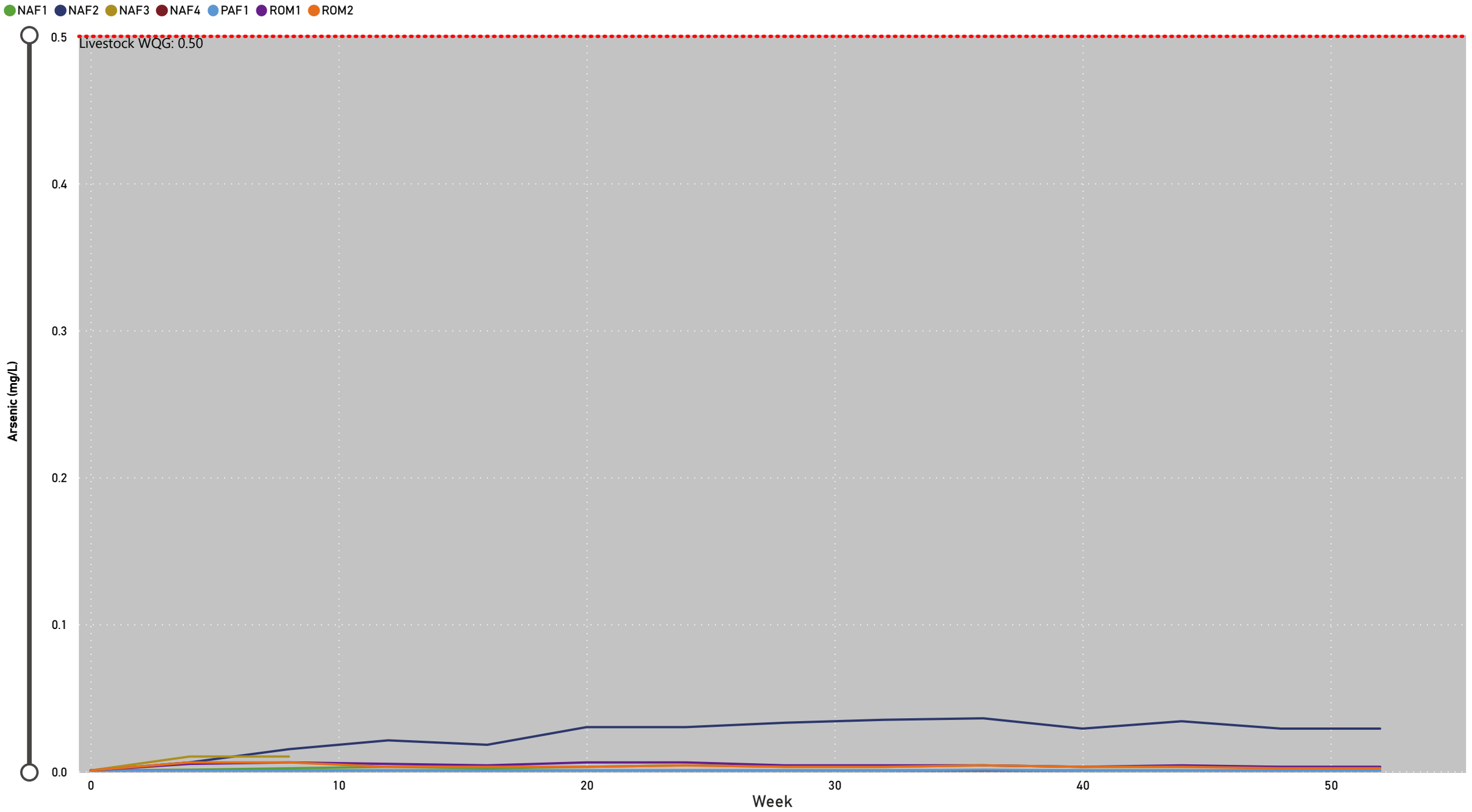

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Chloride (mg/L)
0
5
10
15
20
25
30
0
10
20
30
40
50
Week

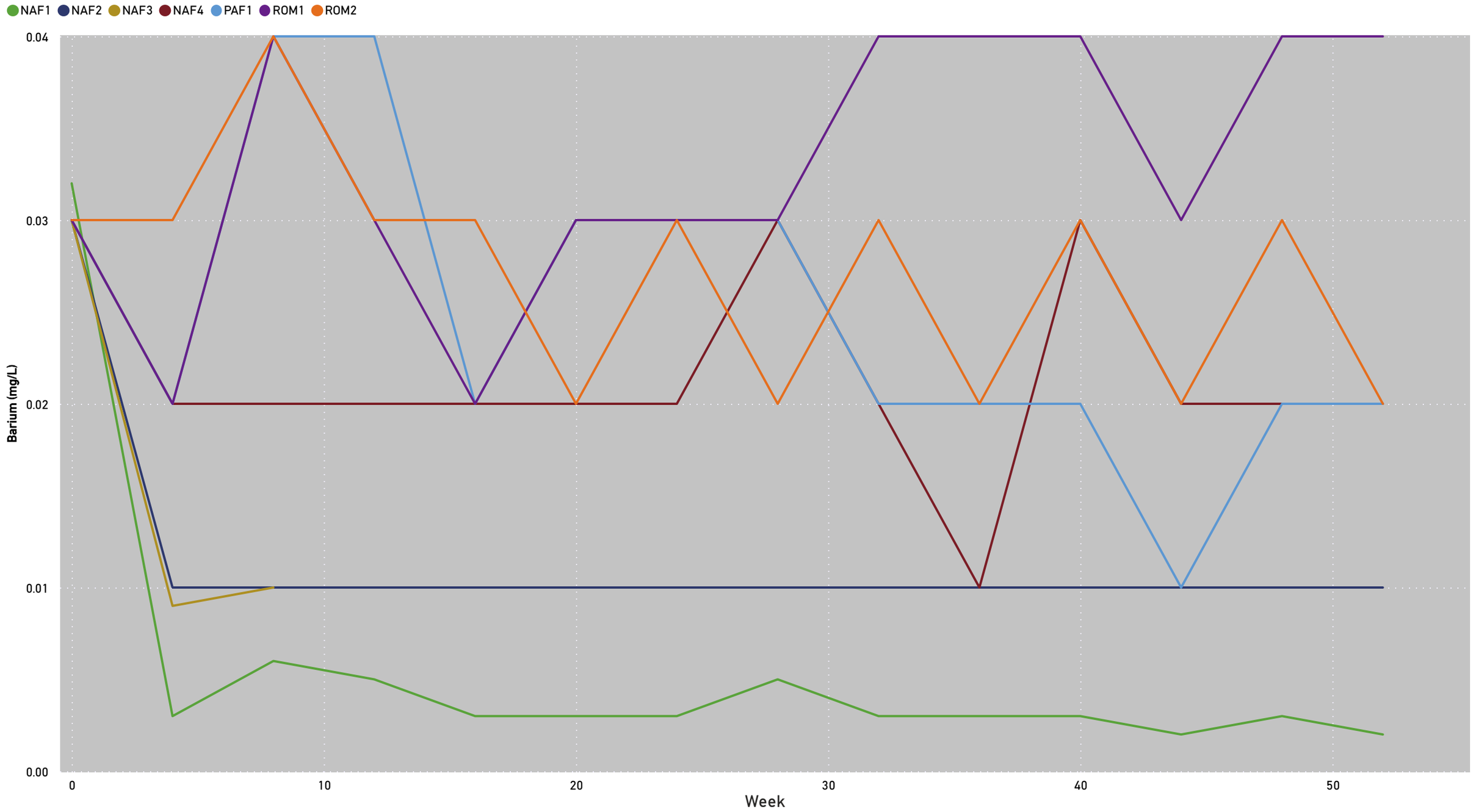

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG - Higher Value: 2,000.00
Livestock WQG - Lower Value: 1,000.00
Sulfate (mg/L)
2,000
1,500
1,000
500
0
0
10
20
30
40
50
Week

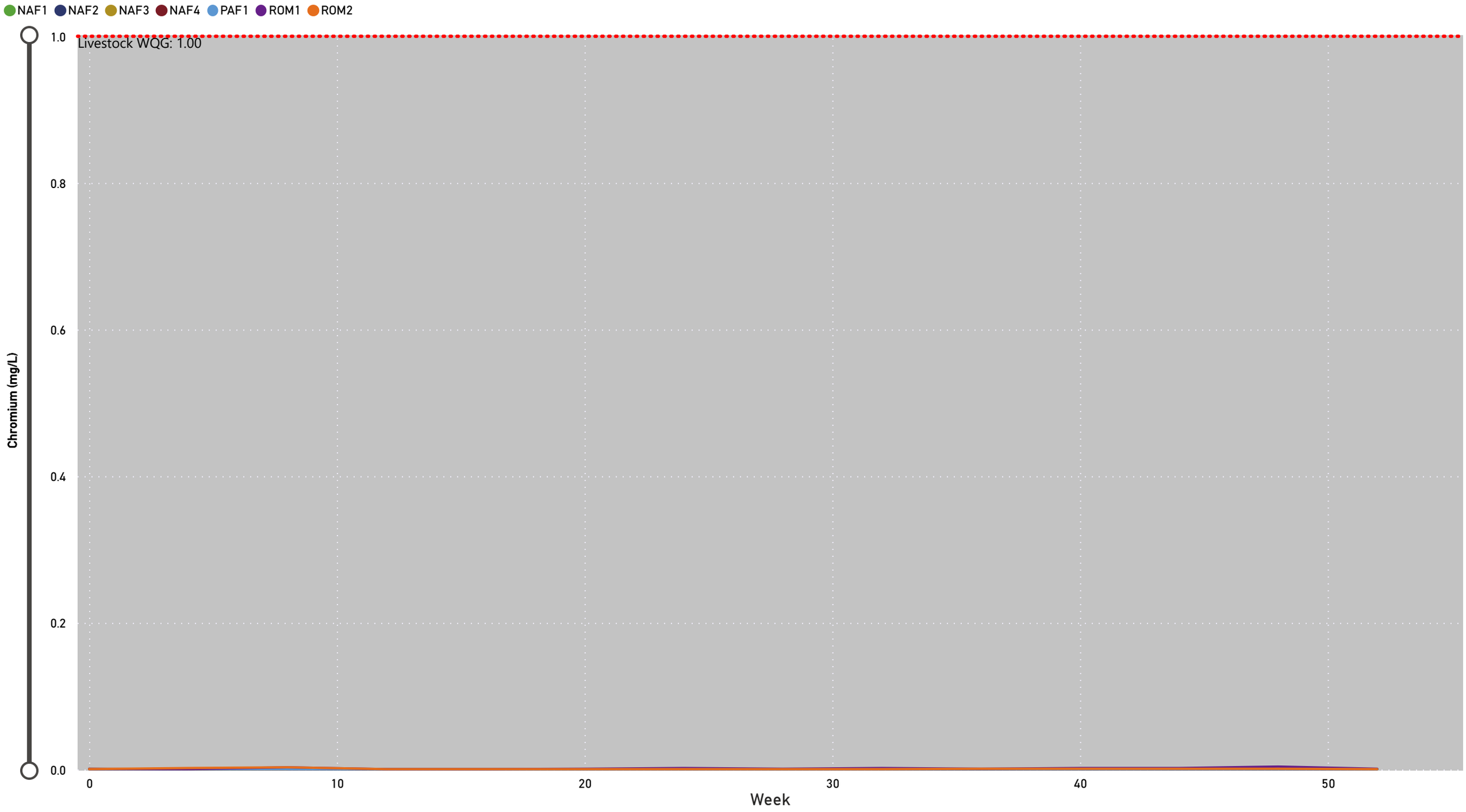

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG: 2.00
Fluoride (mg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
Week

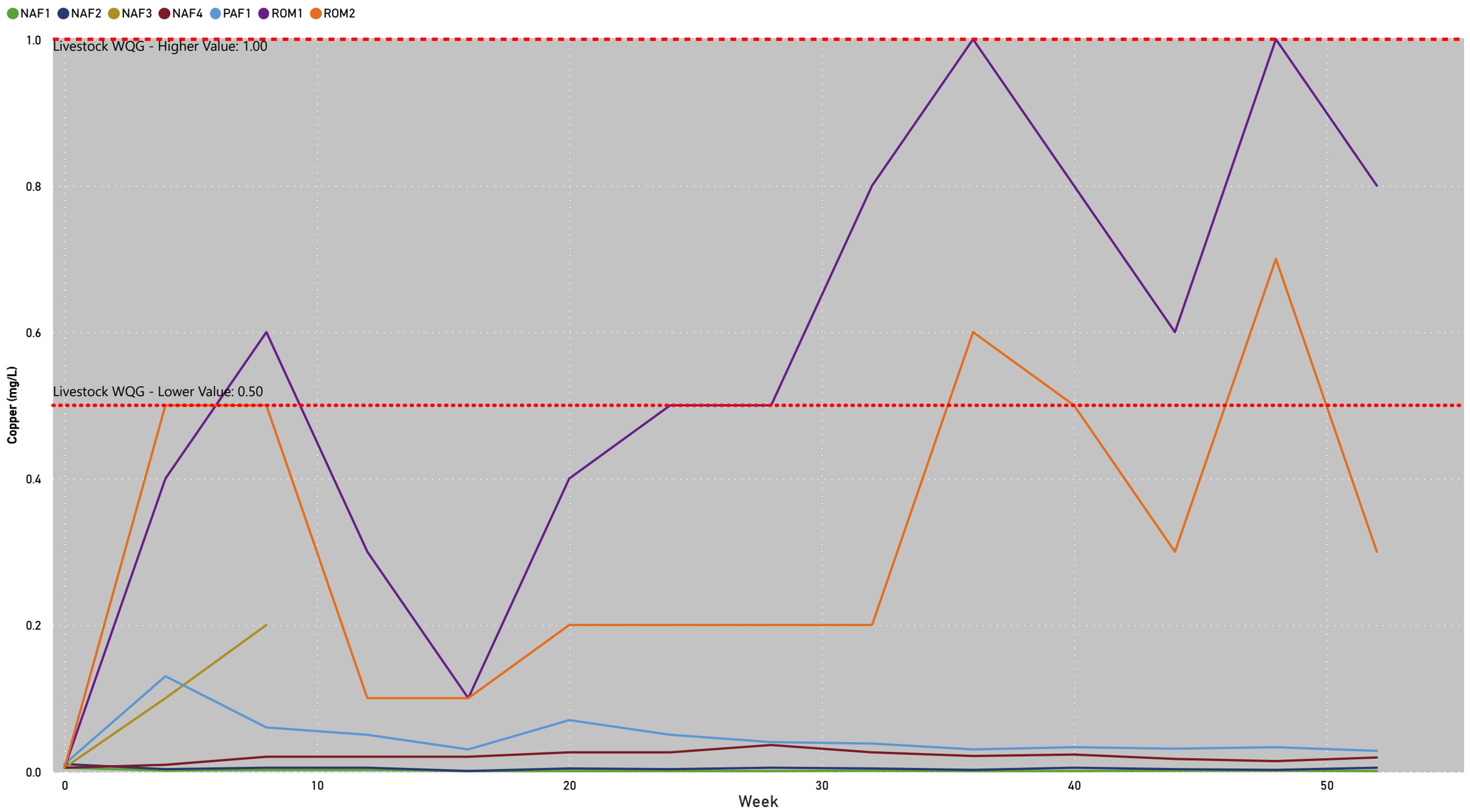

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Alkalinity (mg/L)
70
60
50
40
30
20
10
0
10
20
30
40
50
Week

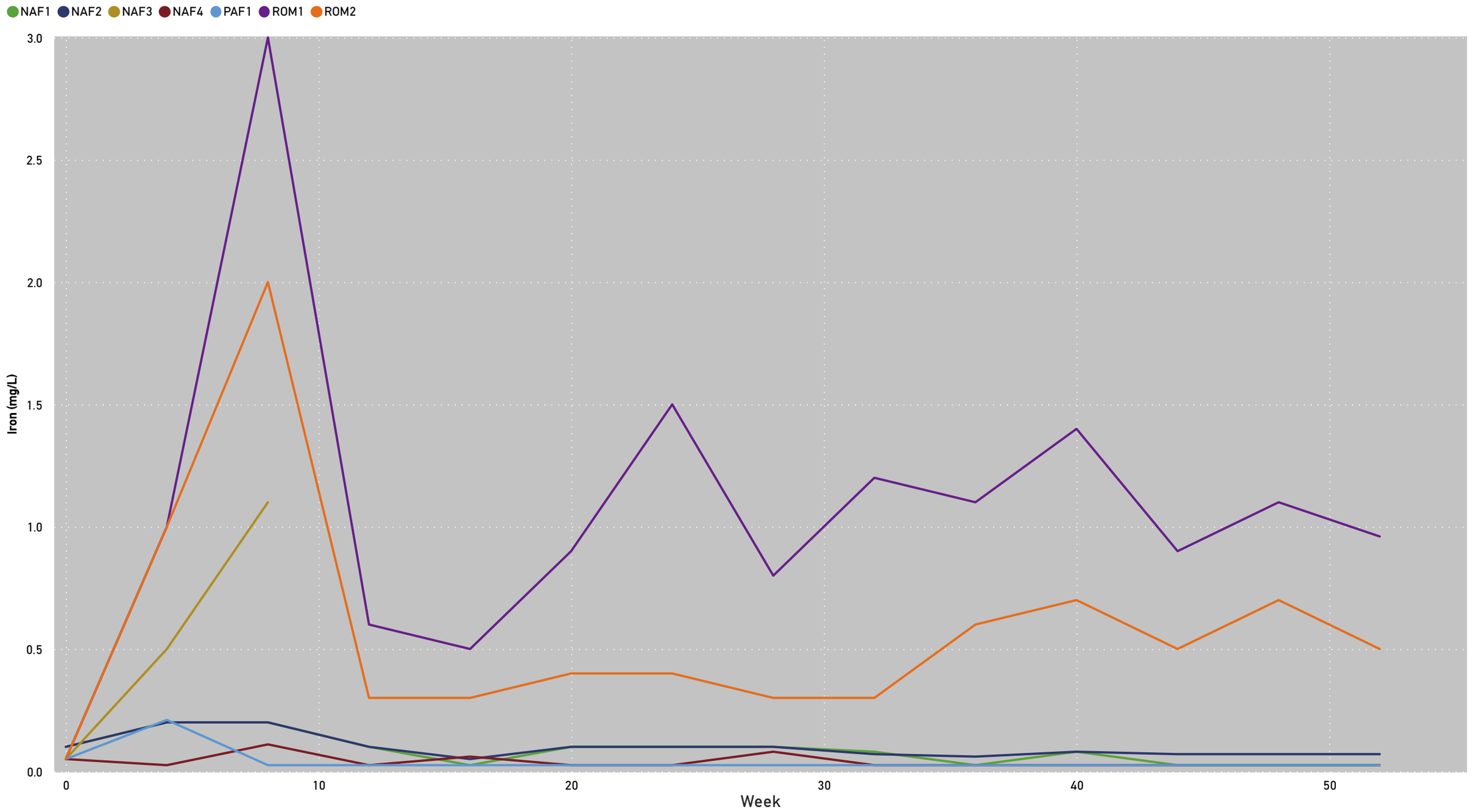

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Aluminium (mg/L)
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
Week

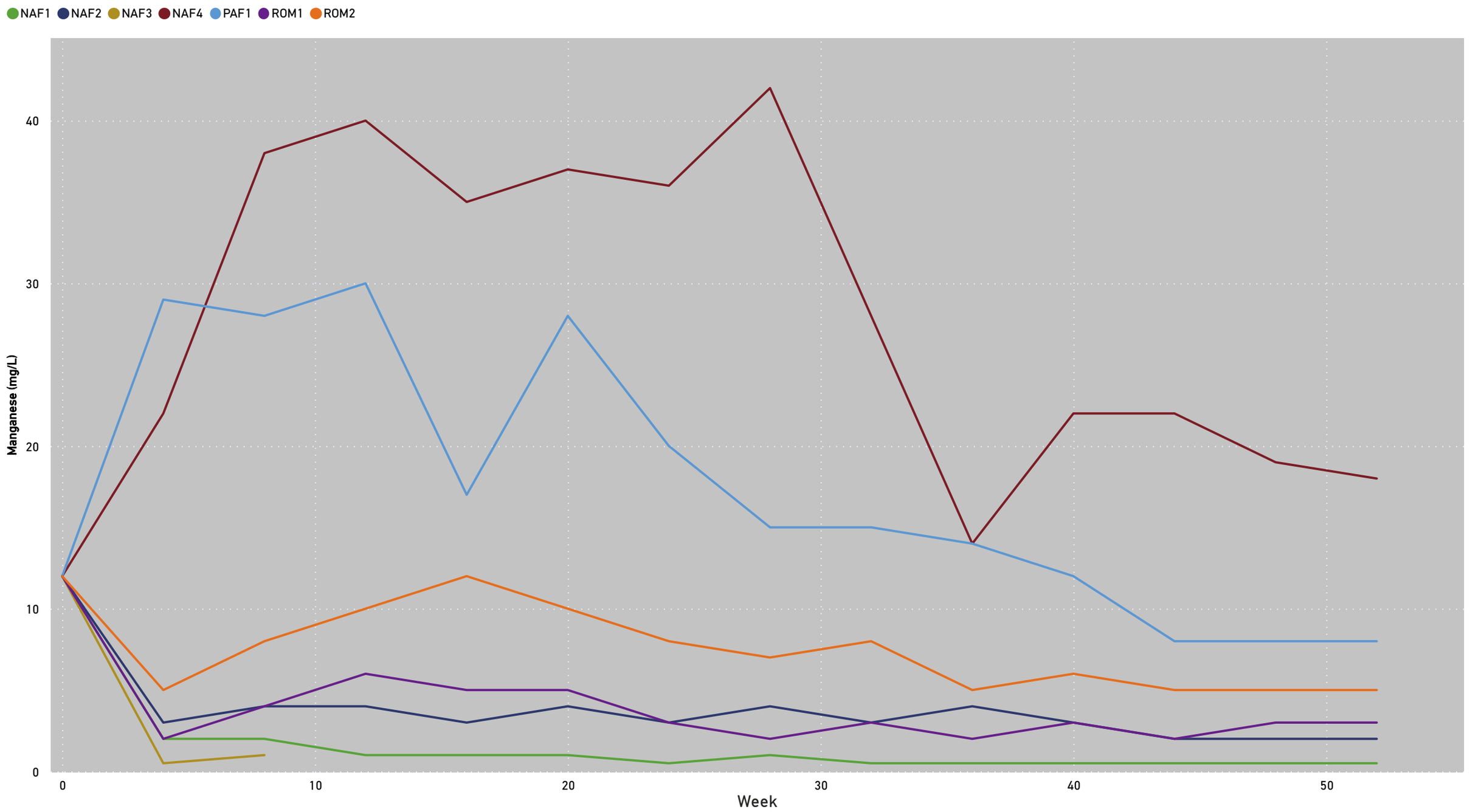

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG: 0.50
Arsenic (mg/L)
0.5
0.4
0.3
0.2
0.1
0.0
0
10
20
30
40
50
Week

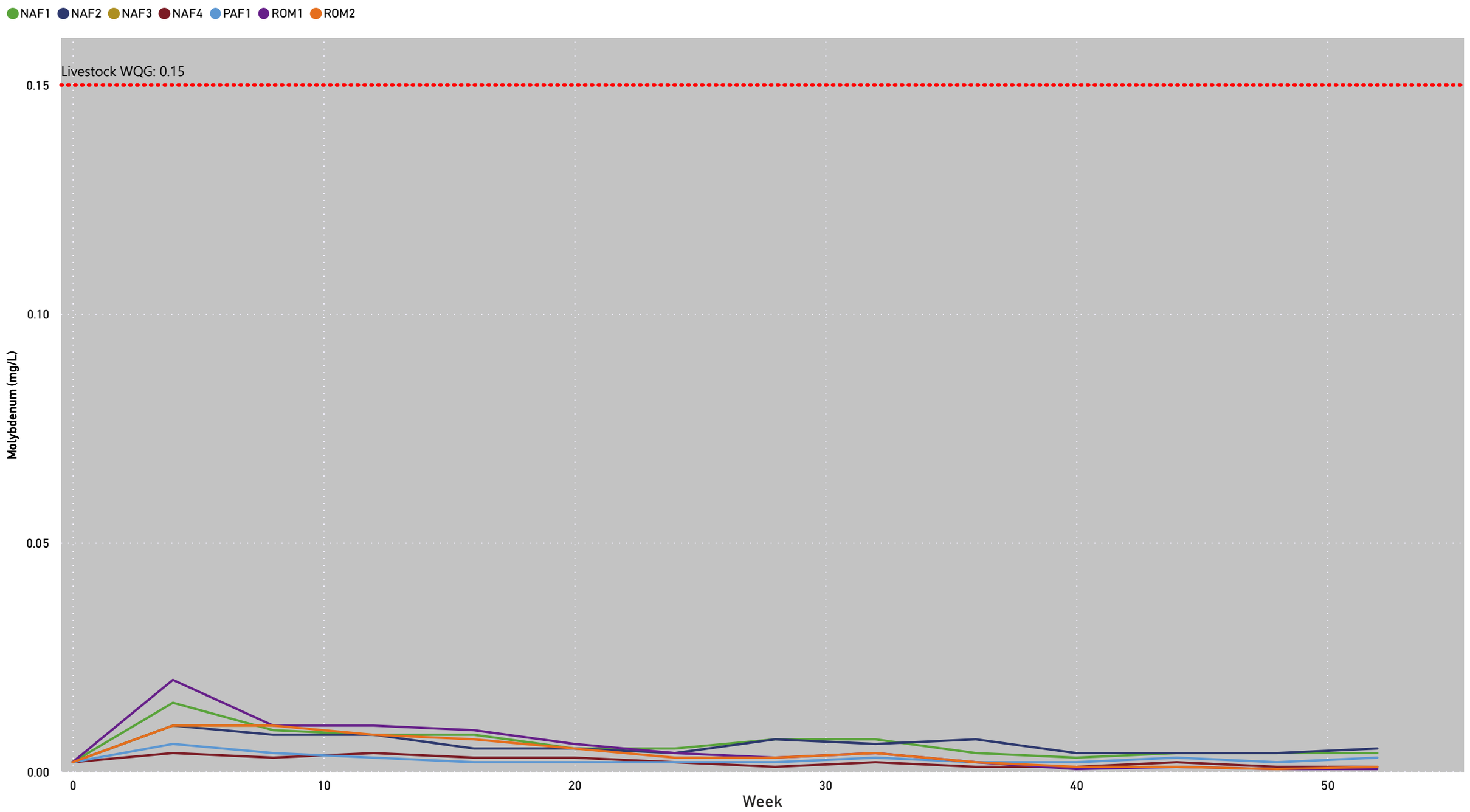

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
0.04
0.03
0.02
0.01
0.00
Barium (mg/L)
0
10
20
30
40
50
Week

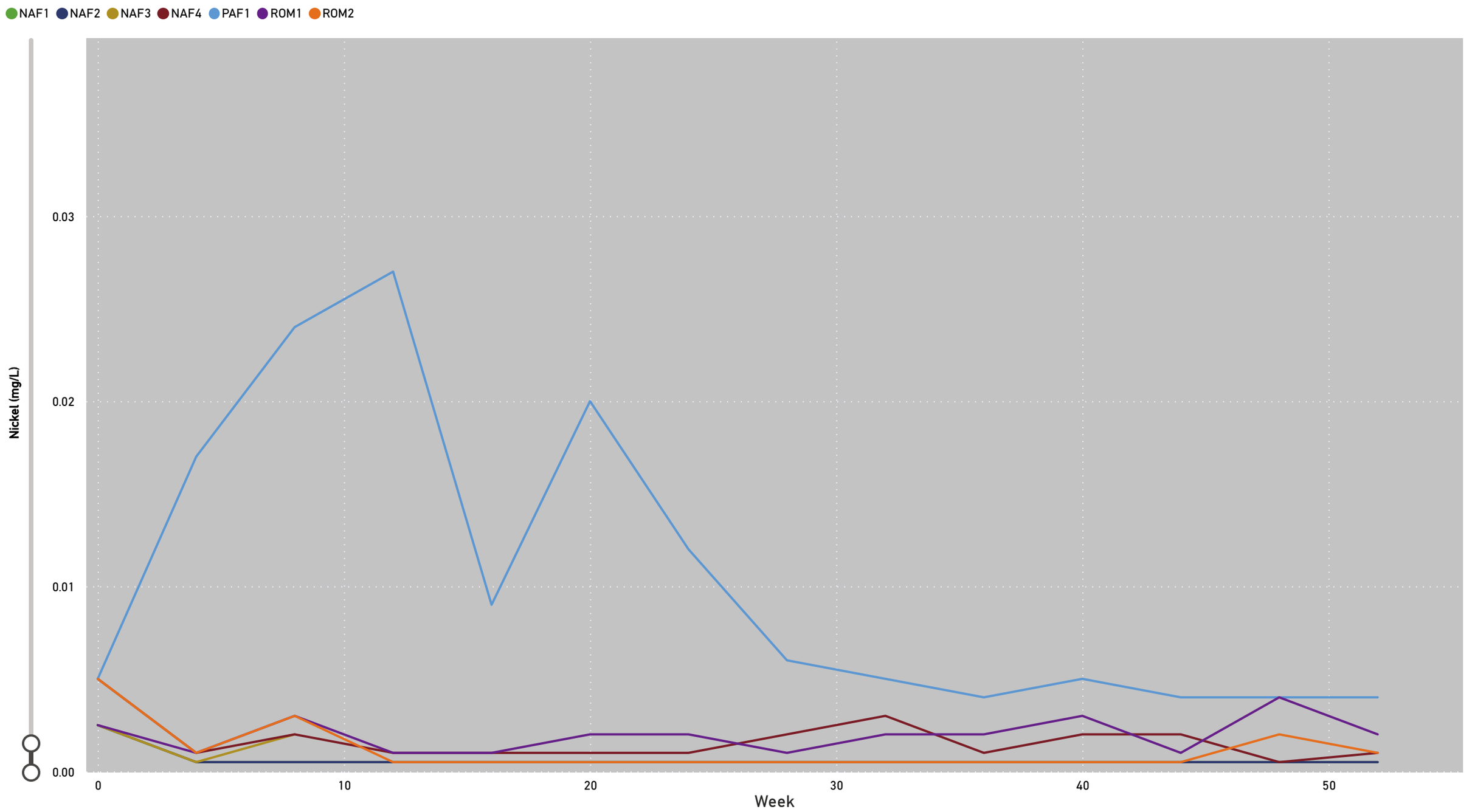

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG: 1.00
Chromium (mg/L)
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
Week

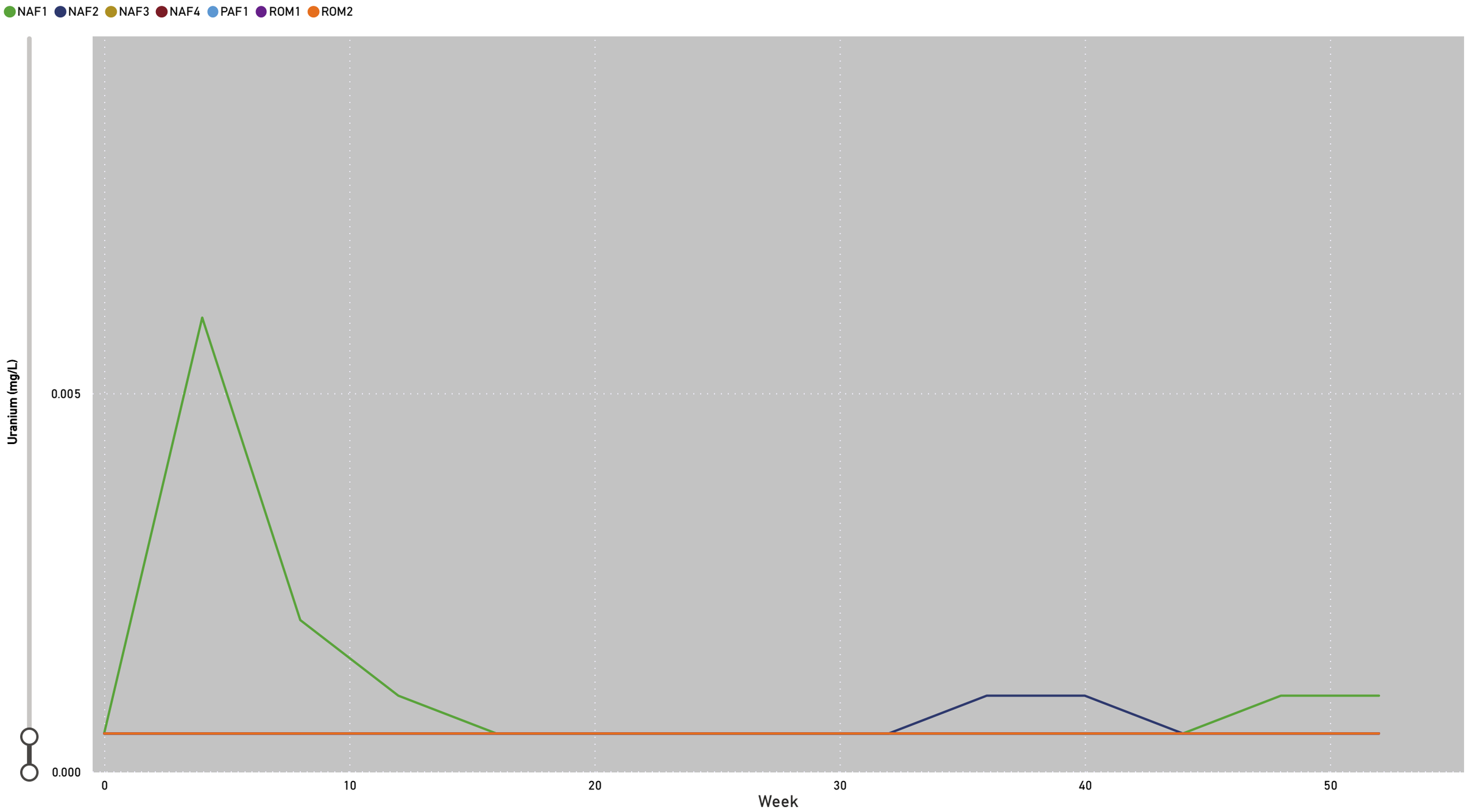

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG - Higher Value: 1.00
Livestock WQG - Lower Value: 0.50
Copper (mg/L)
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
Week

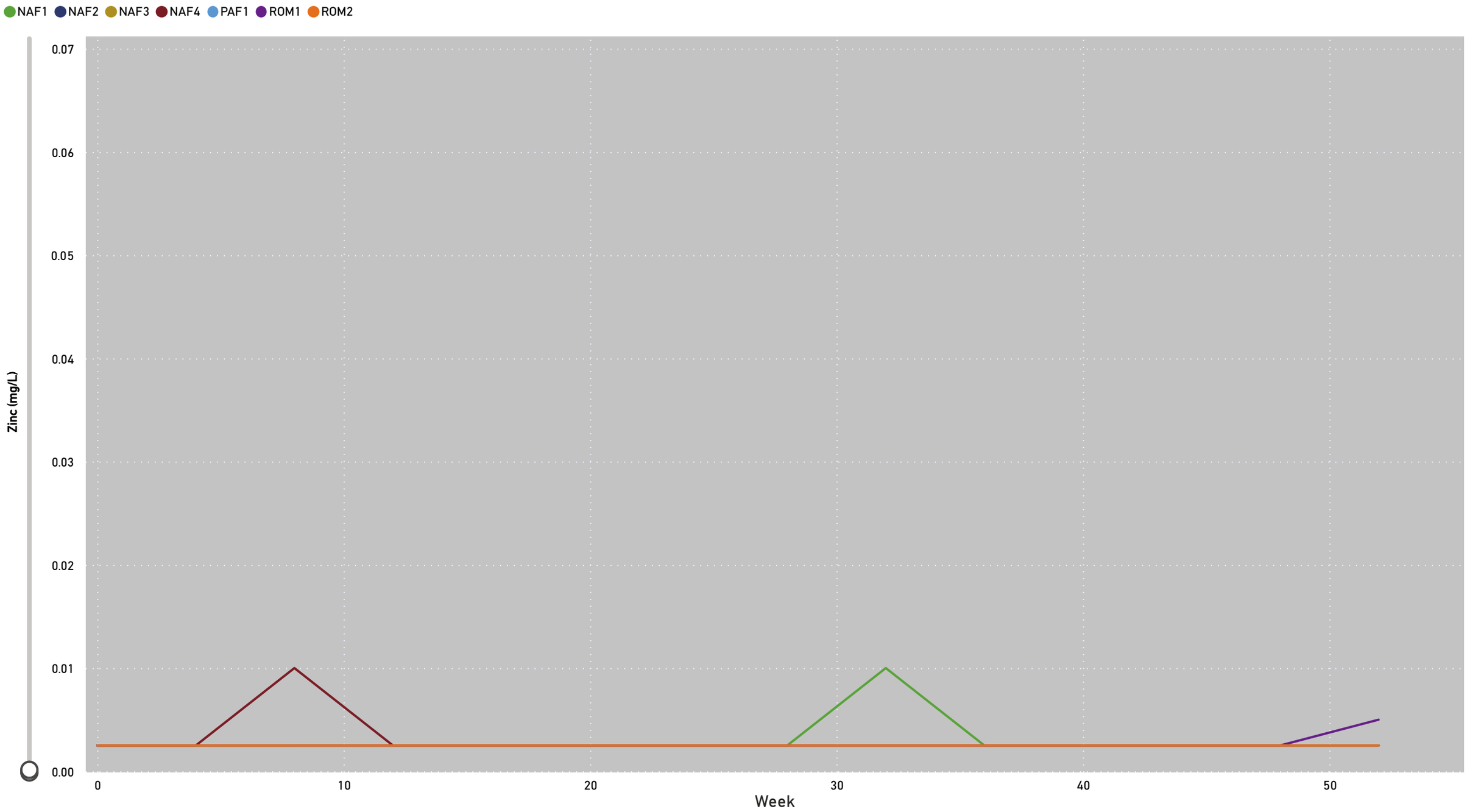

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Iron (mg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
Week


NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Manganese (mg/L)
0
10
20
30
40
0
10
20
30
40
50
Week


NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG: 0.15
0.15
0.10
0.05
0.00
Molybdenum (mg/L)
0
10
20
30
40
50
Week


NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Nickel (mg/L)
0.03
0.02
0.01
0.00
0
10
20
30
40
50
Week

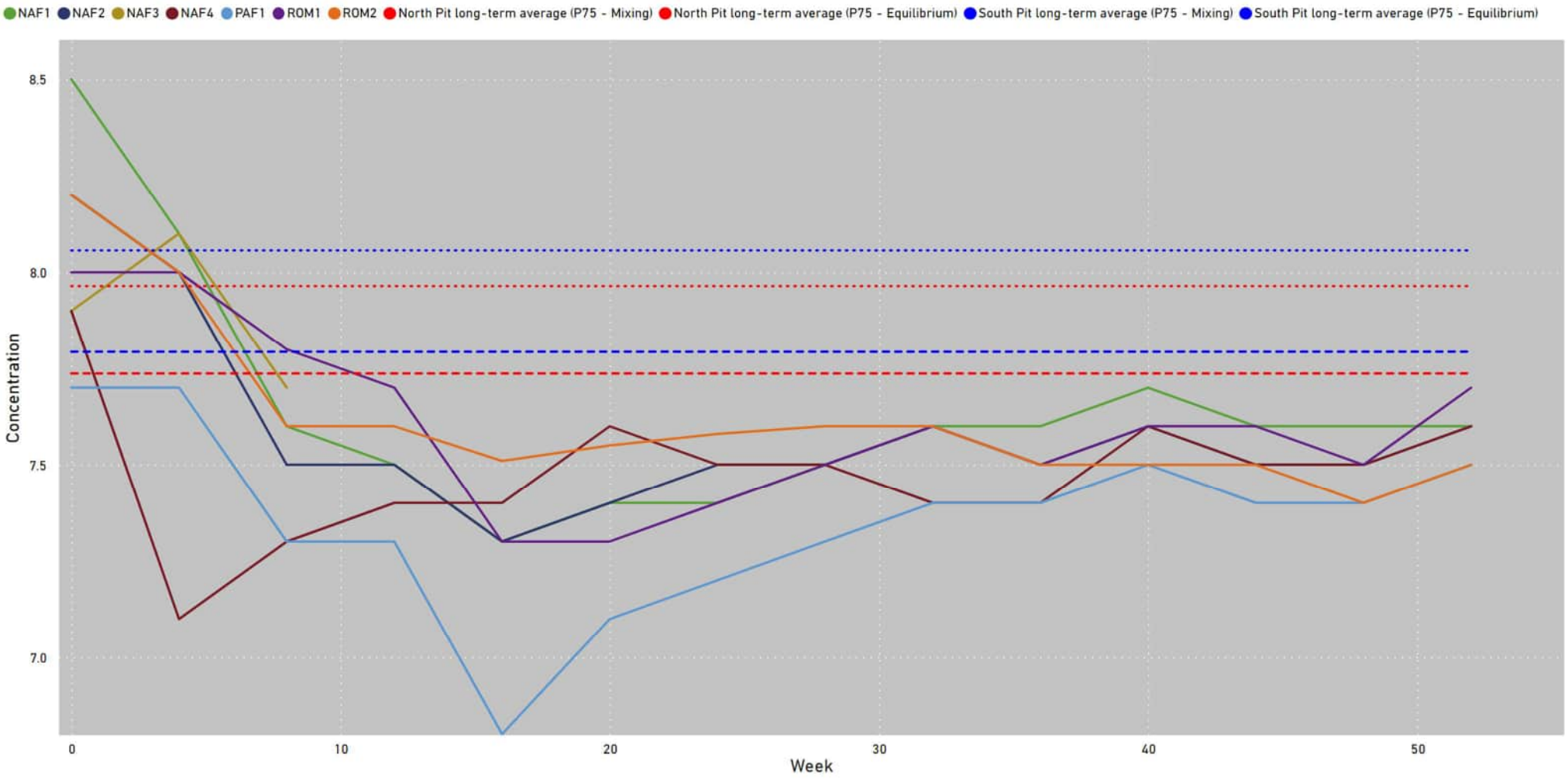

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Uranium (mg/L)
0.005
0.000
0
10
20
30
40
50
Week


NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Zinc (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
10
20
30
40
50
Week

Appendix G.3 Kinetic column leach test results against long-term pit water quality

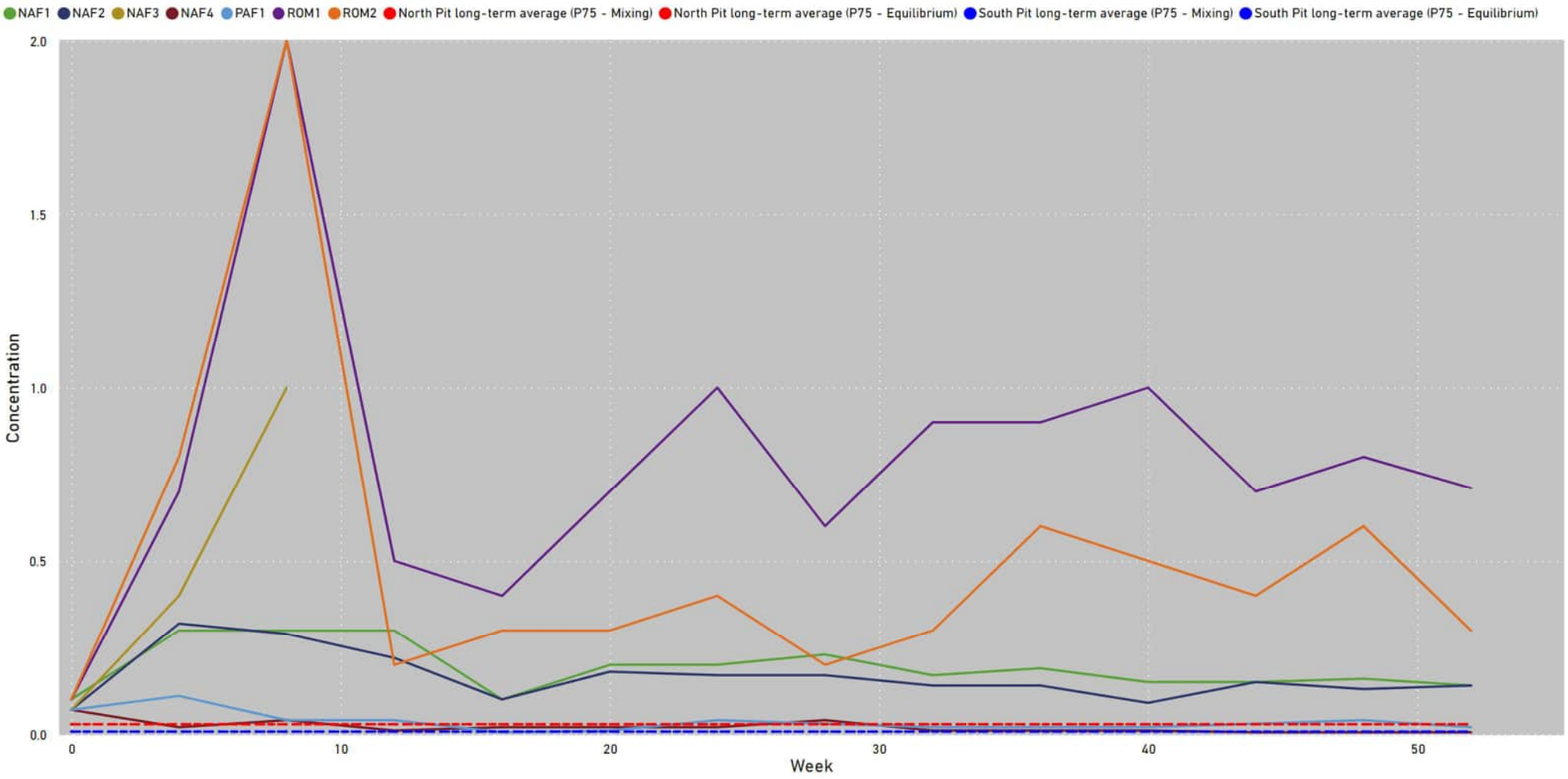
Parameter (Units)

pH (mg/L)



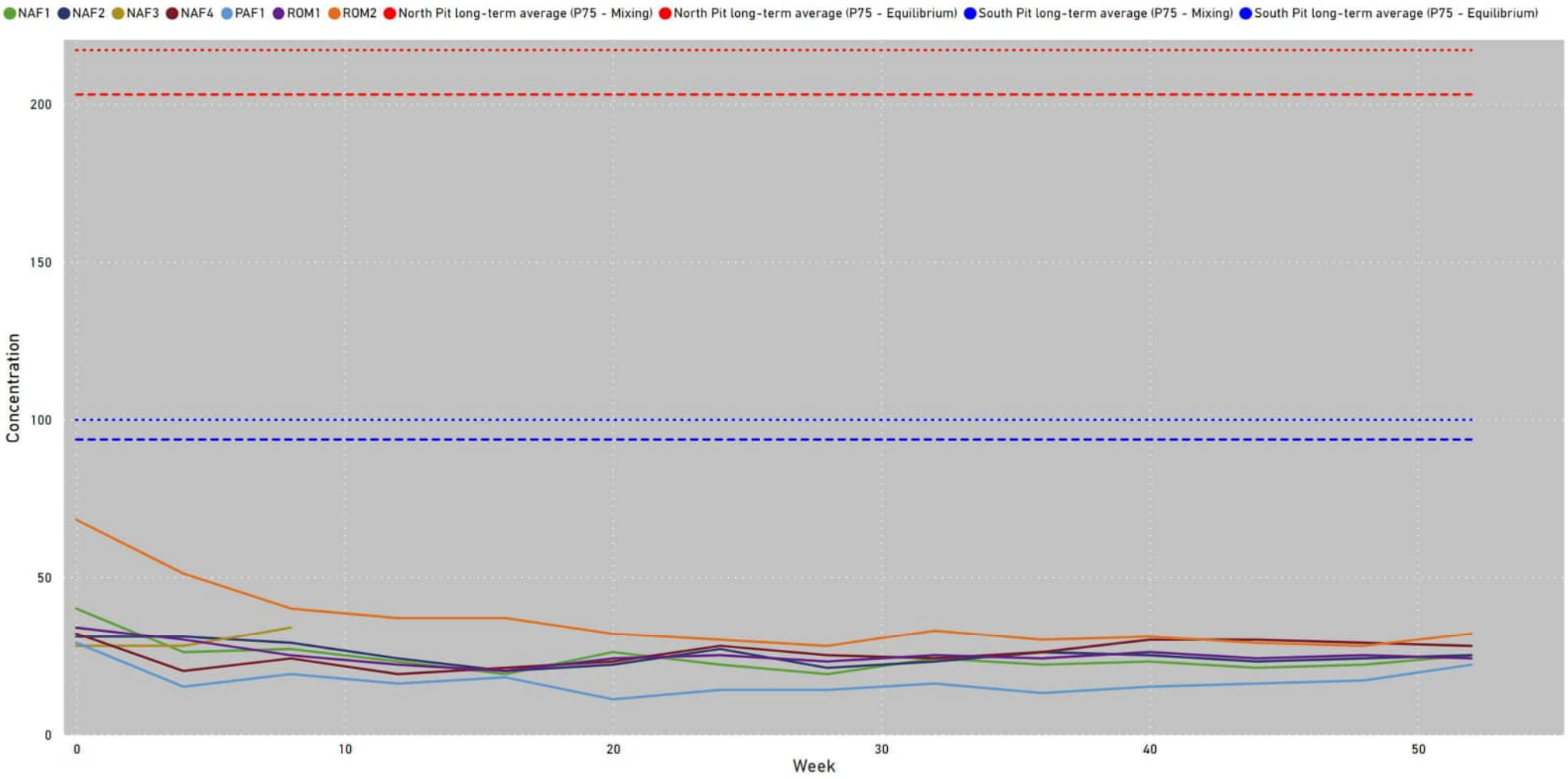
Parameter (Units)

Al (mg/L)



Parameter (Units)

Alkalinity (mg/L)



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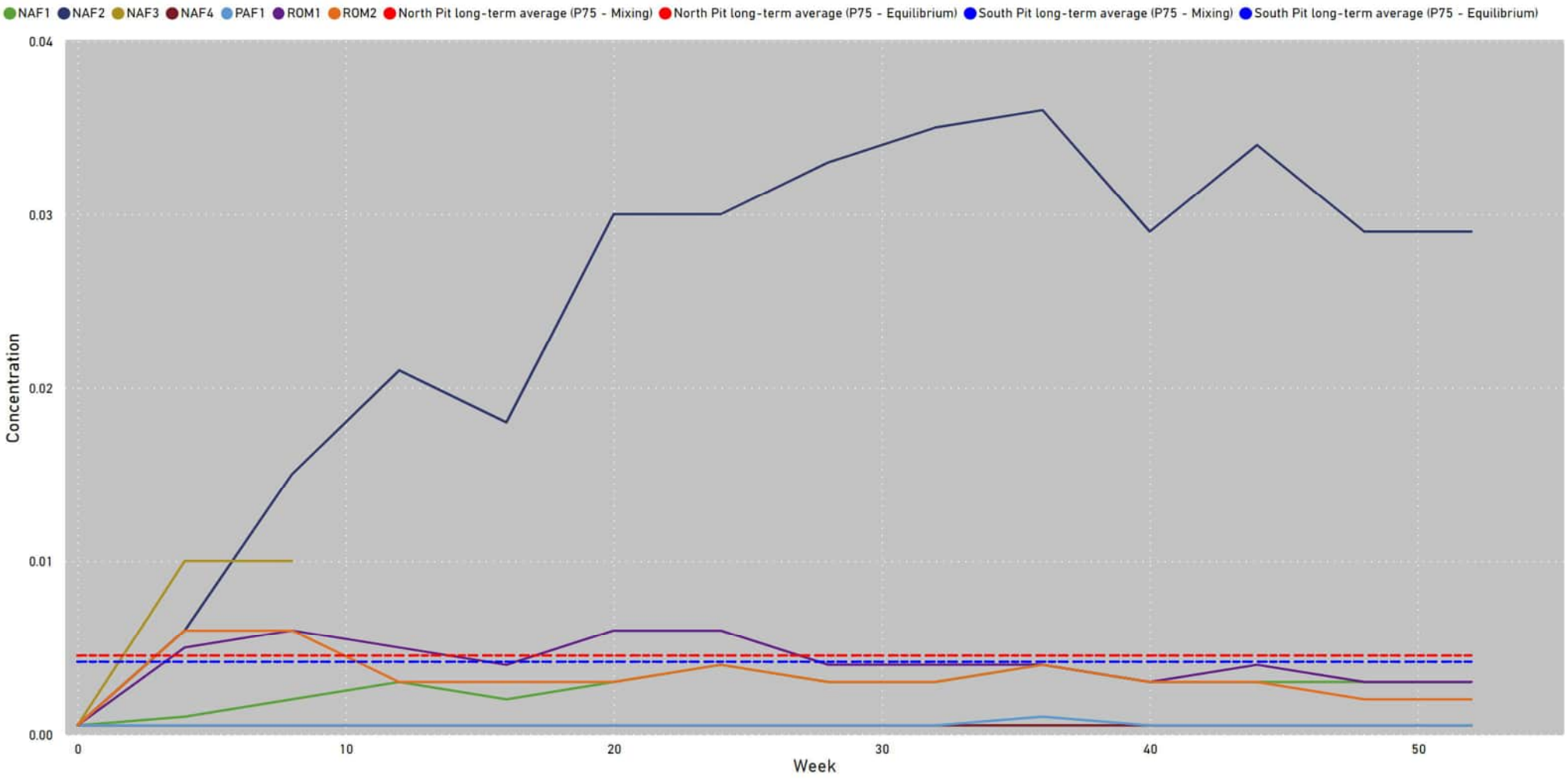

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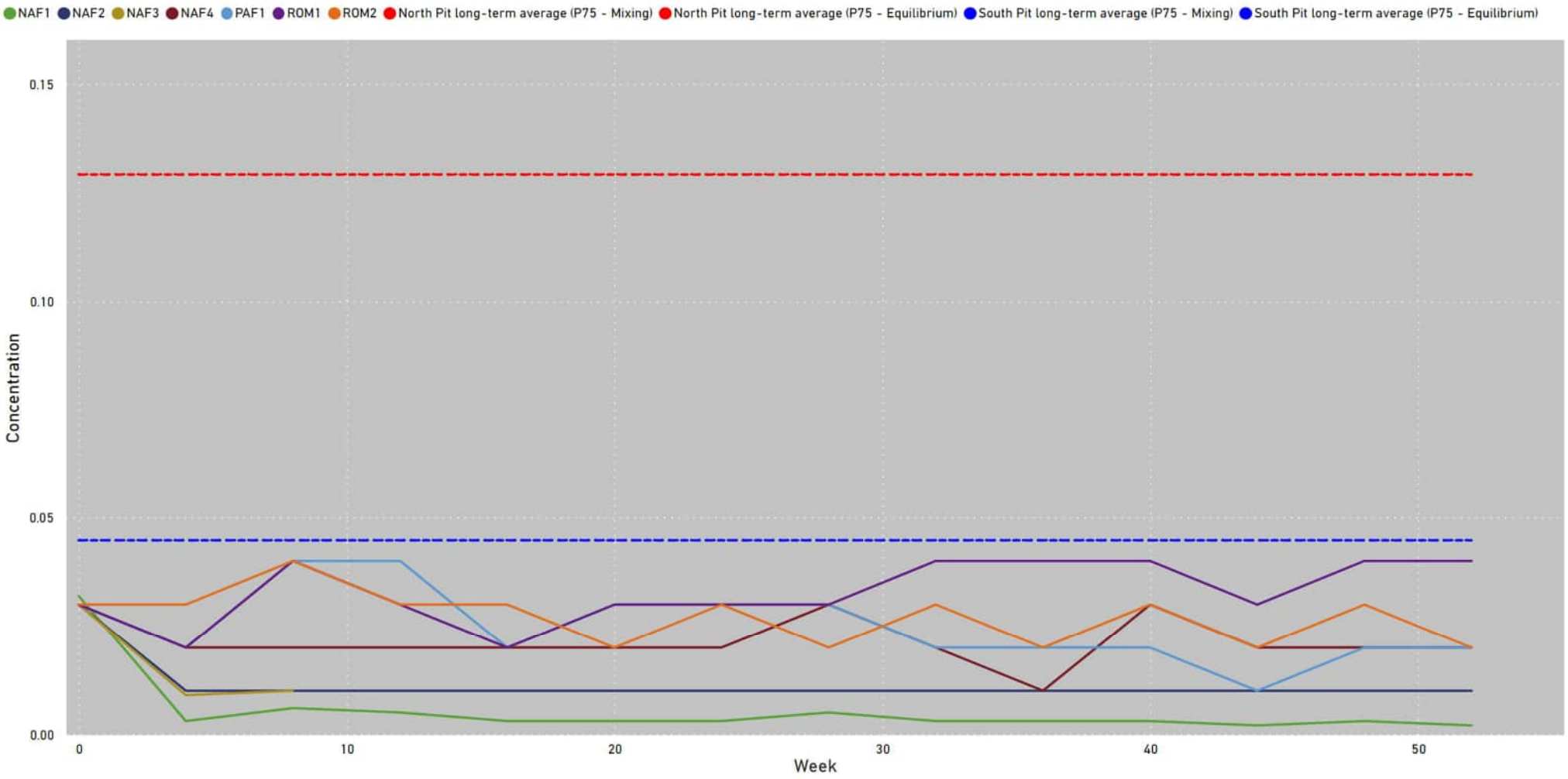

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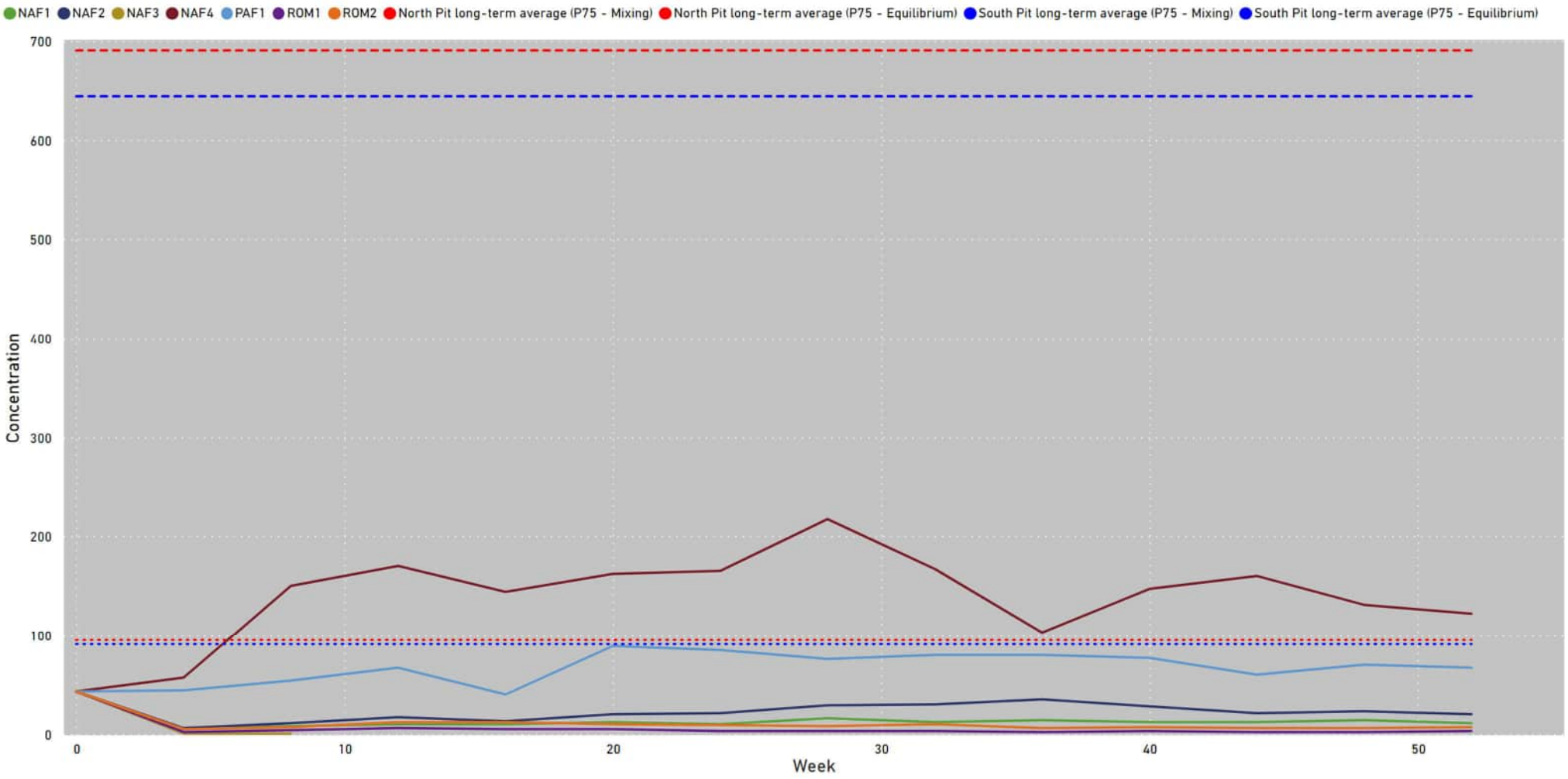

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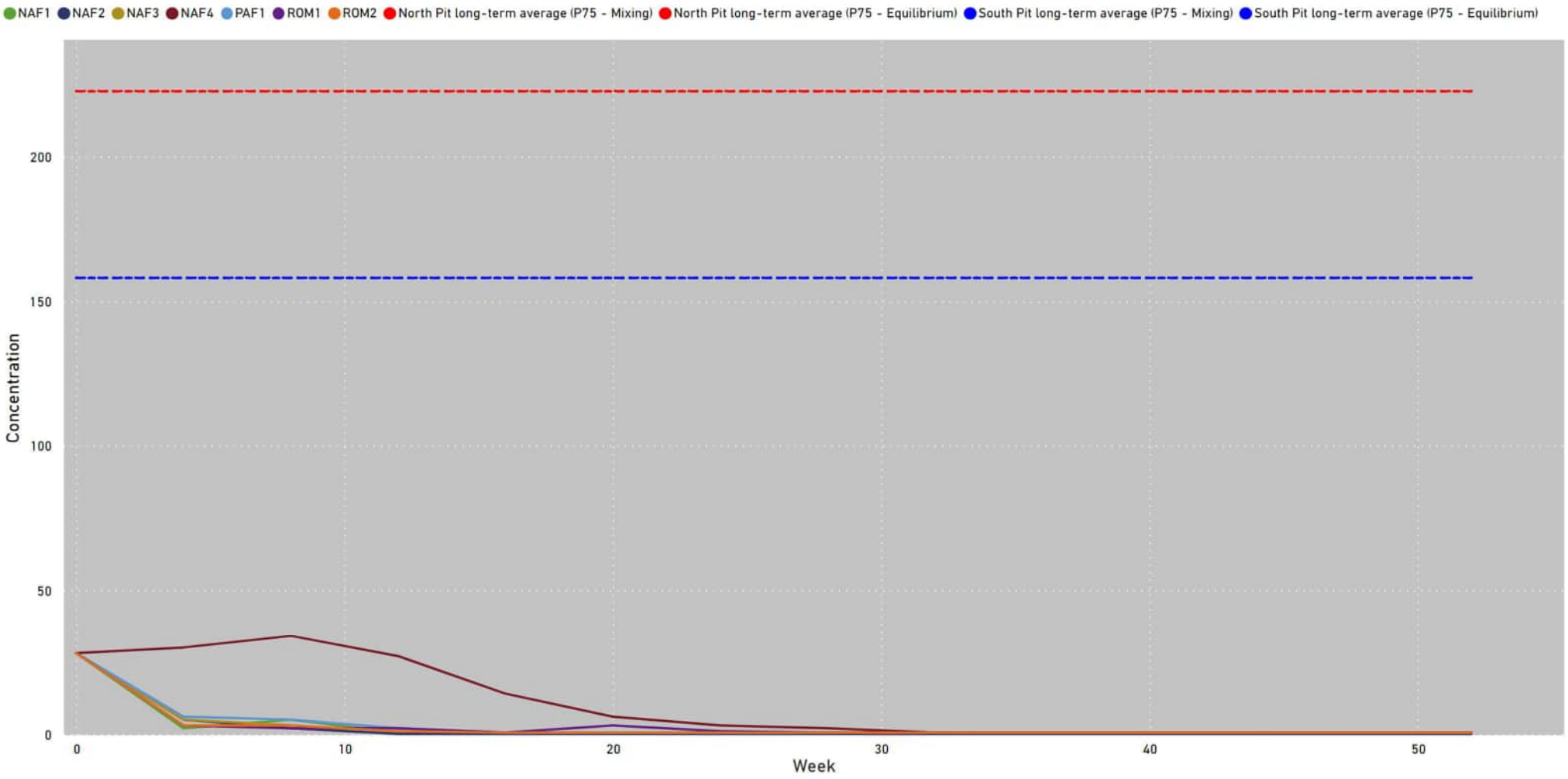

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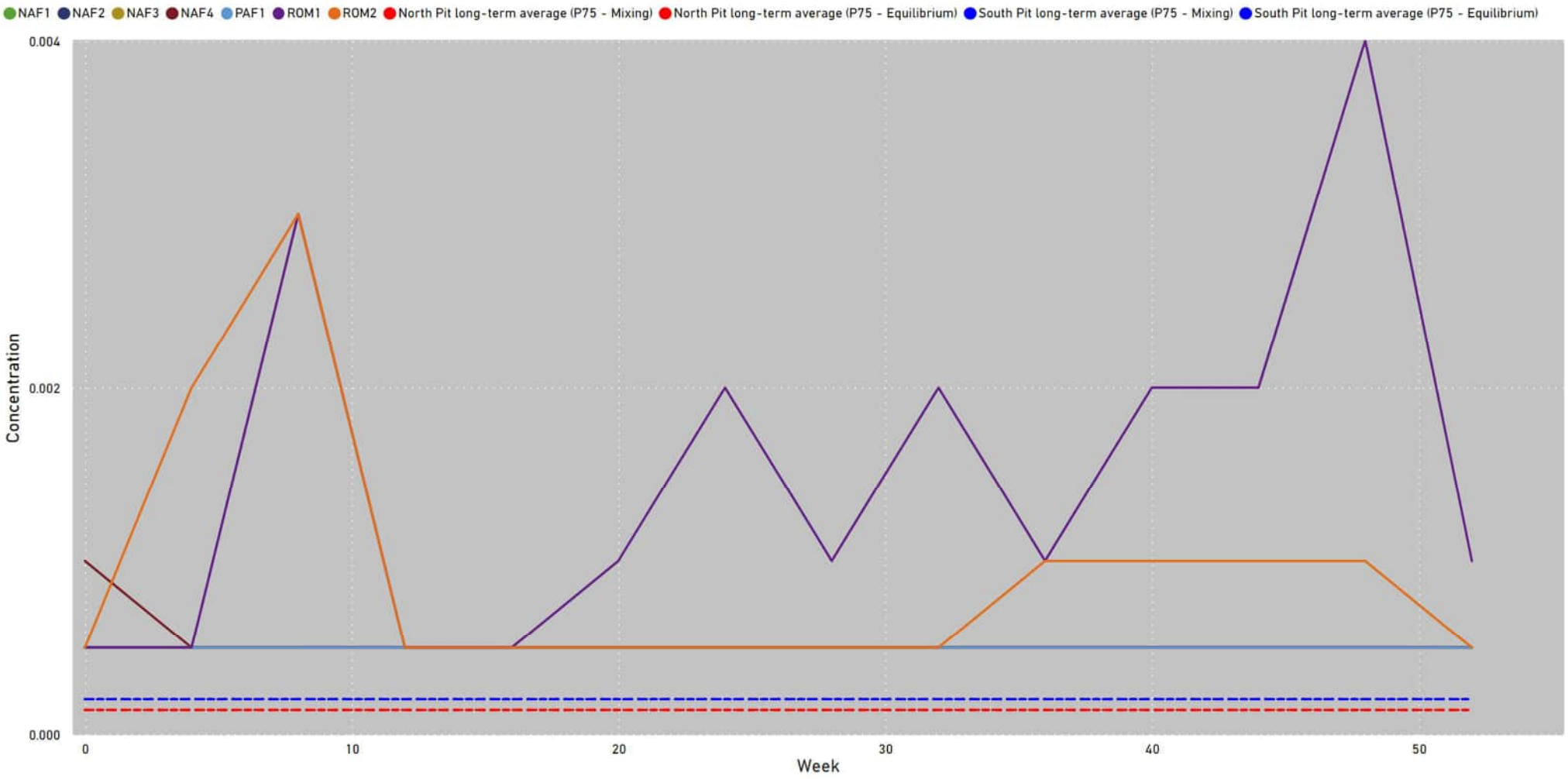

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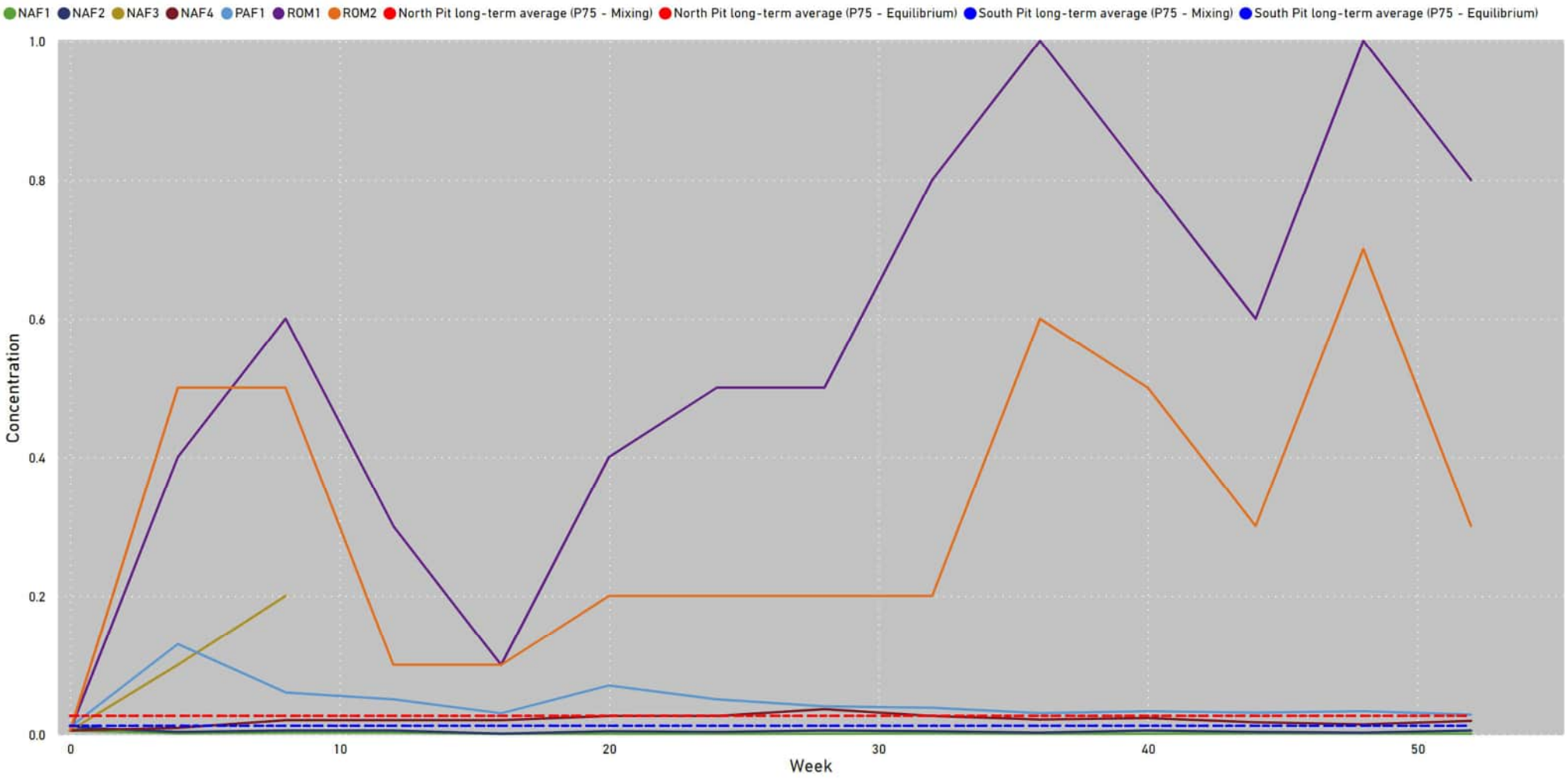

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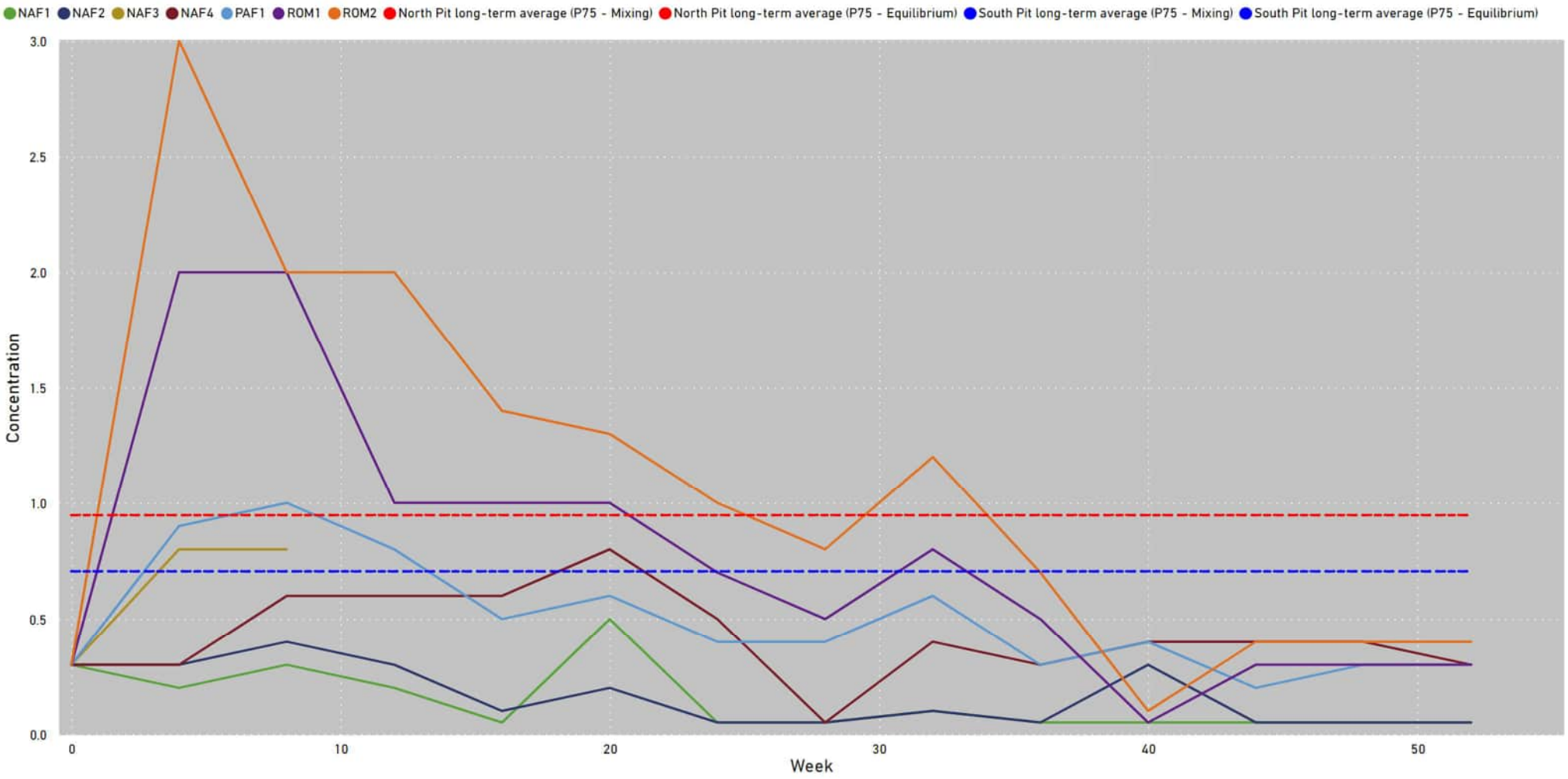

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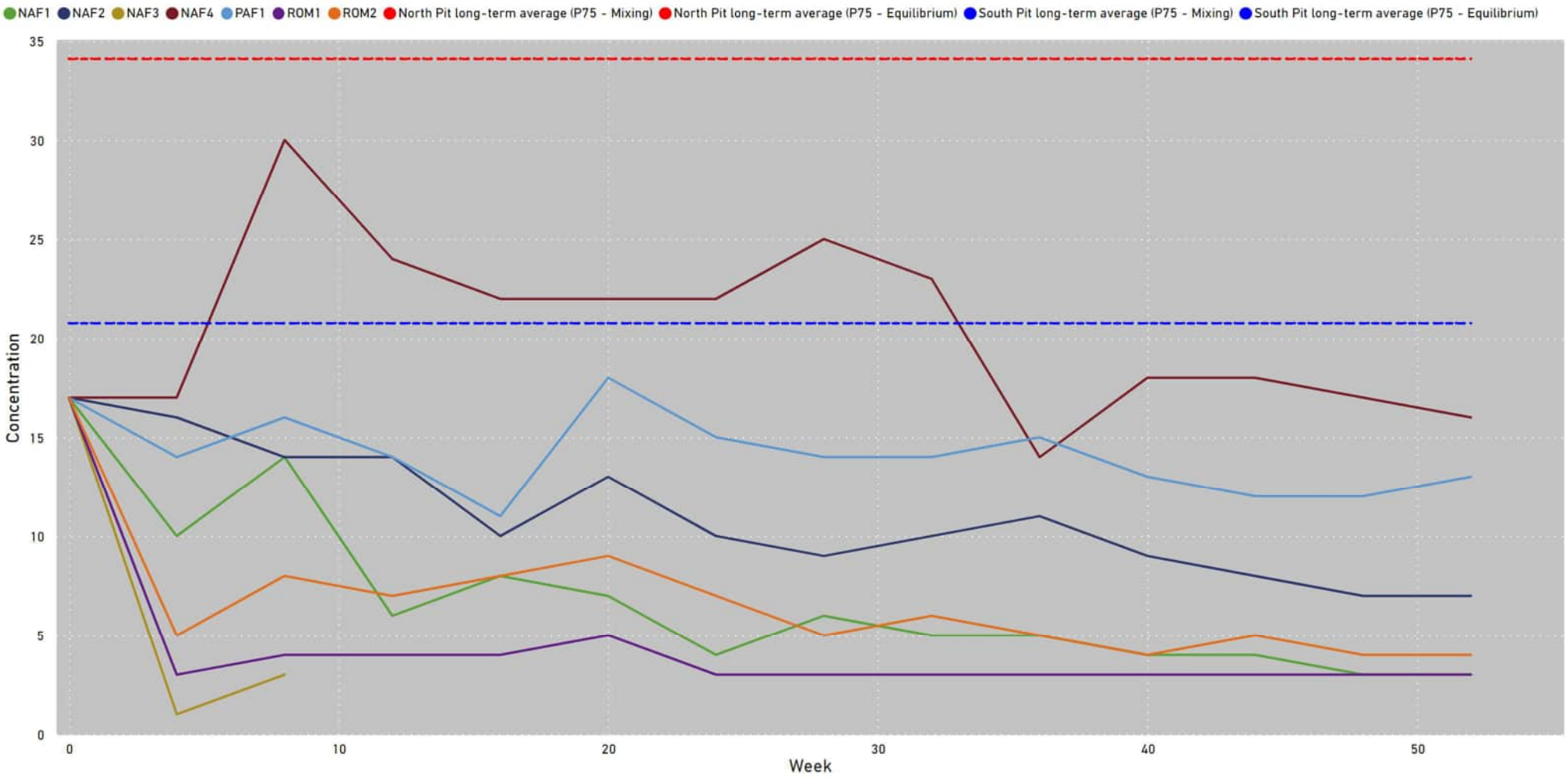

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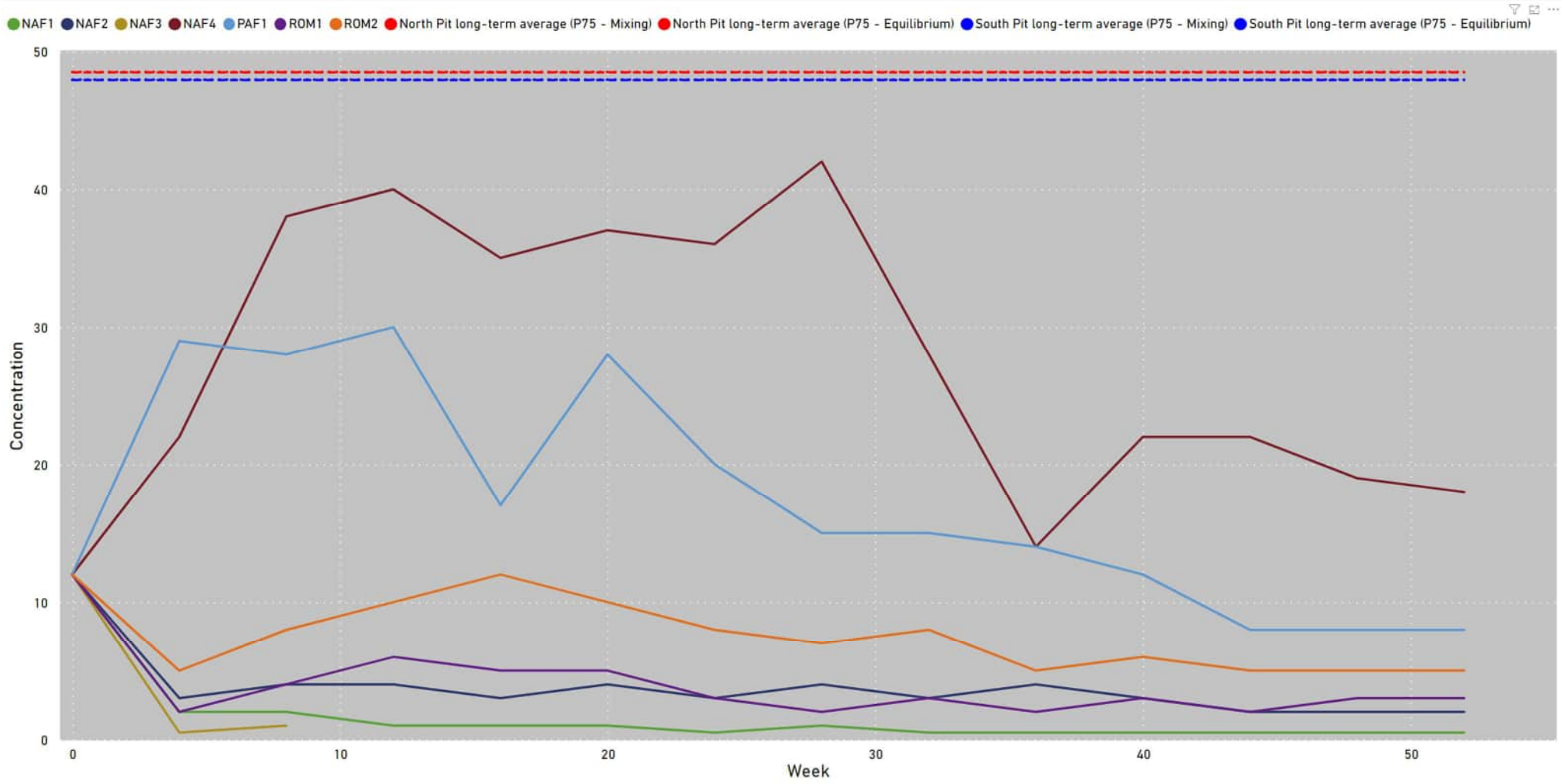

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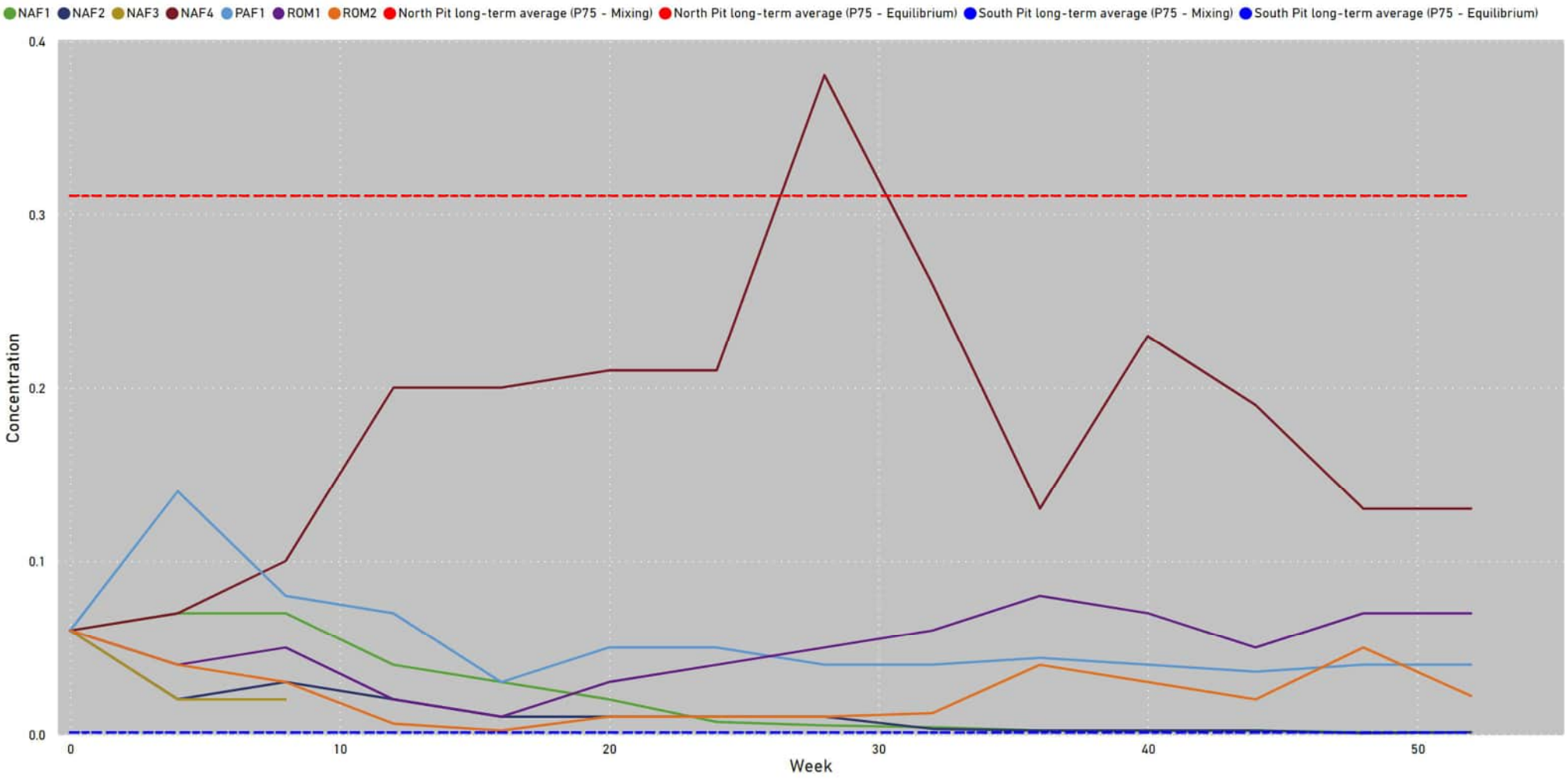

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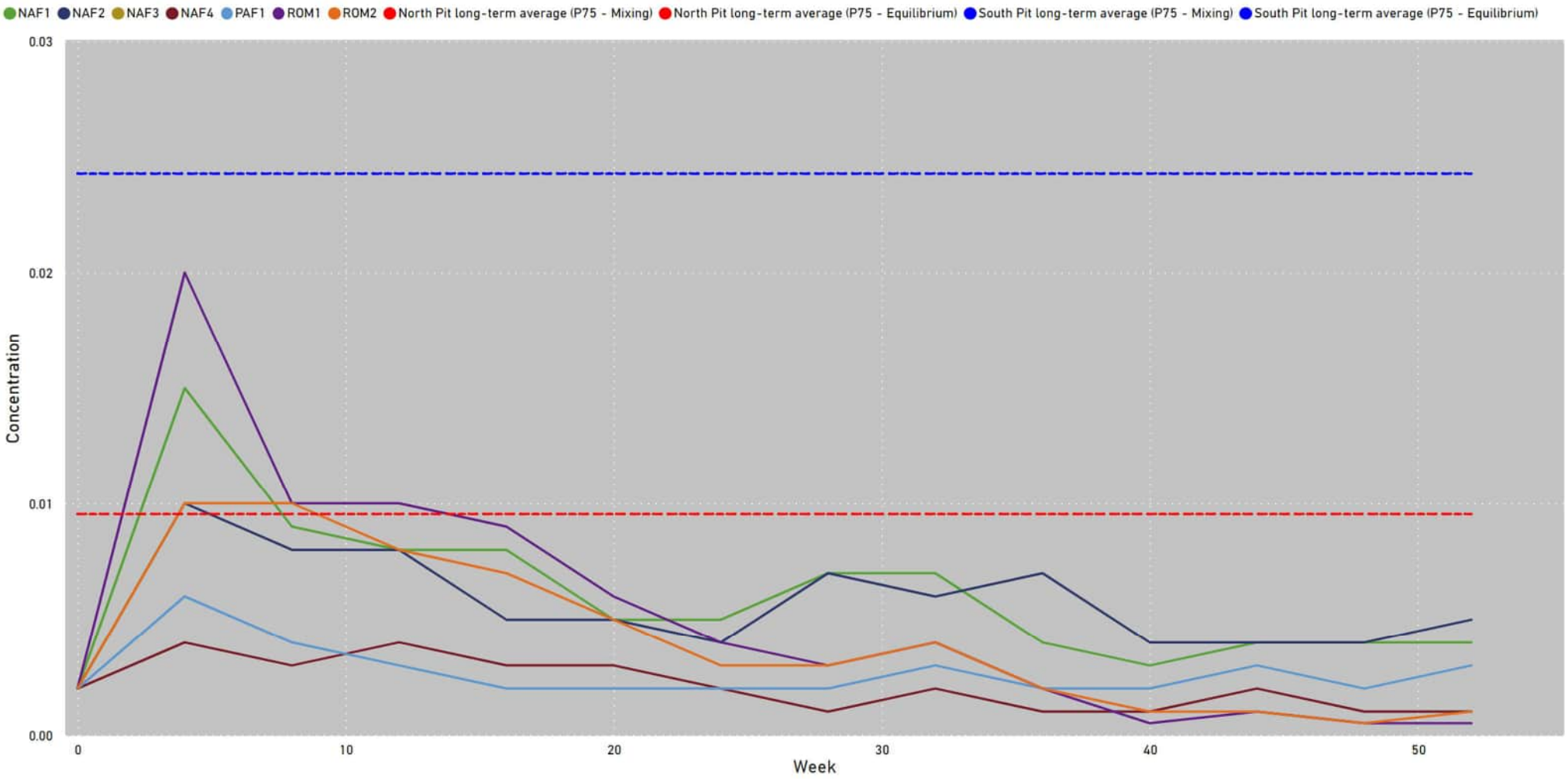

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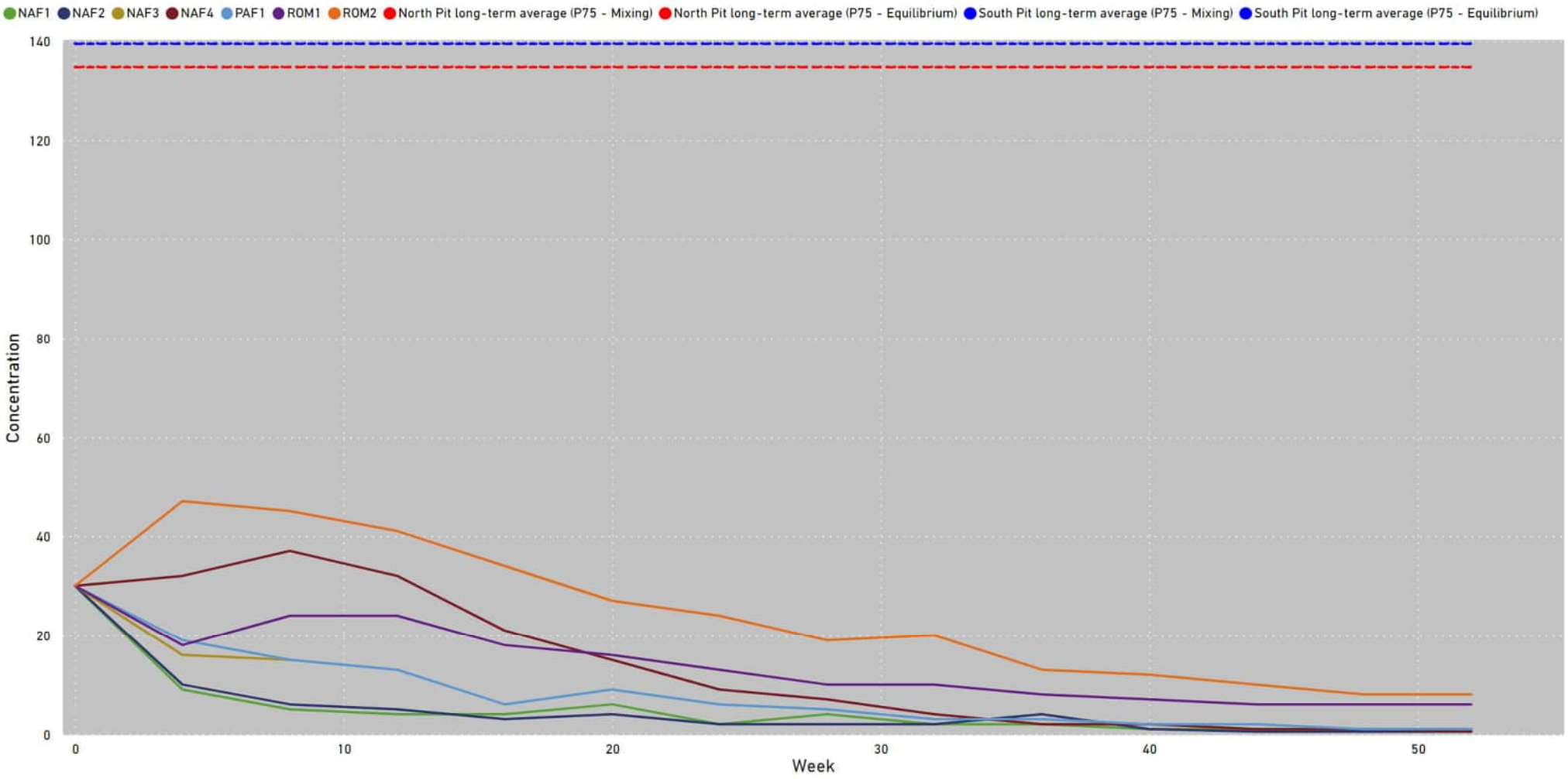

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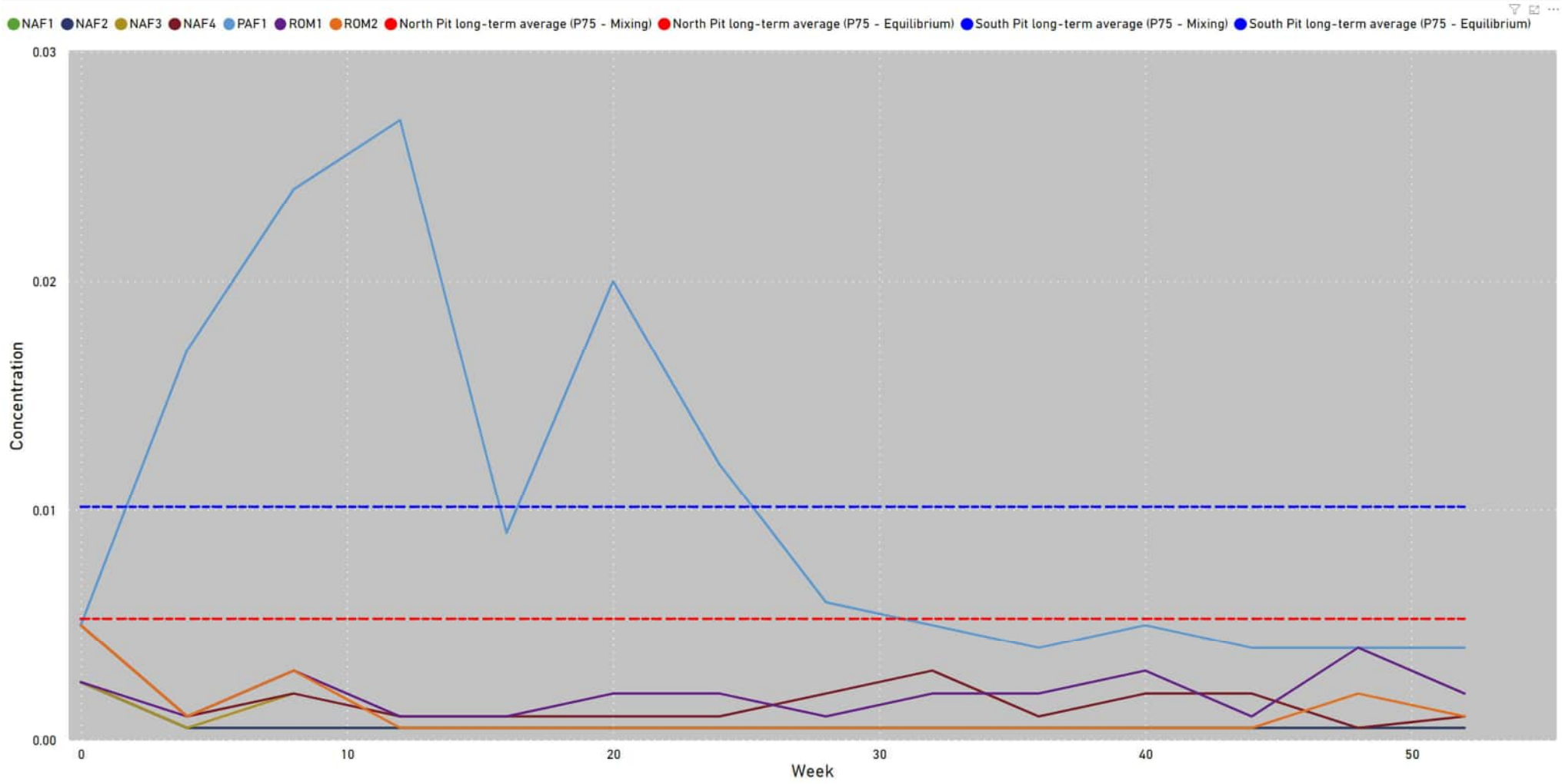

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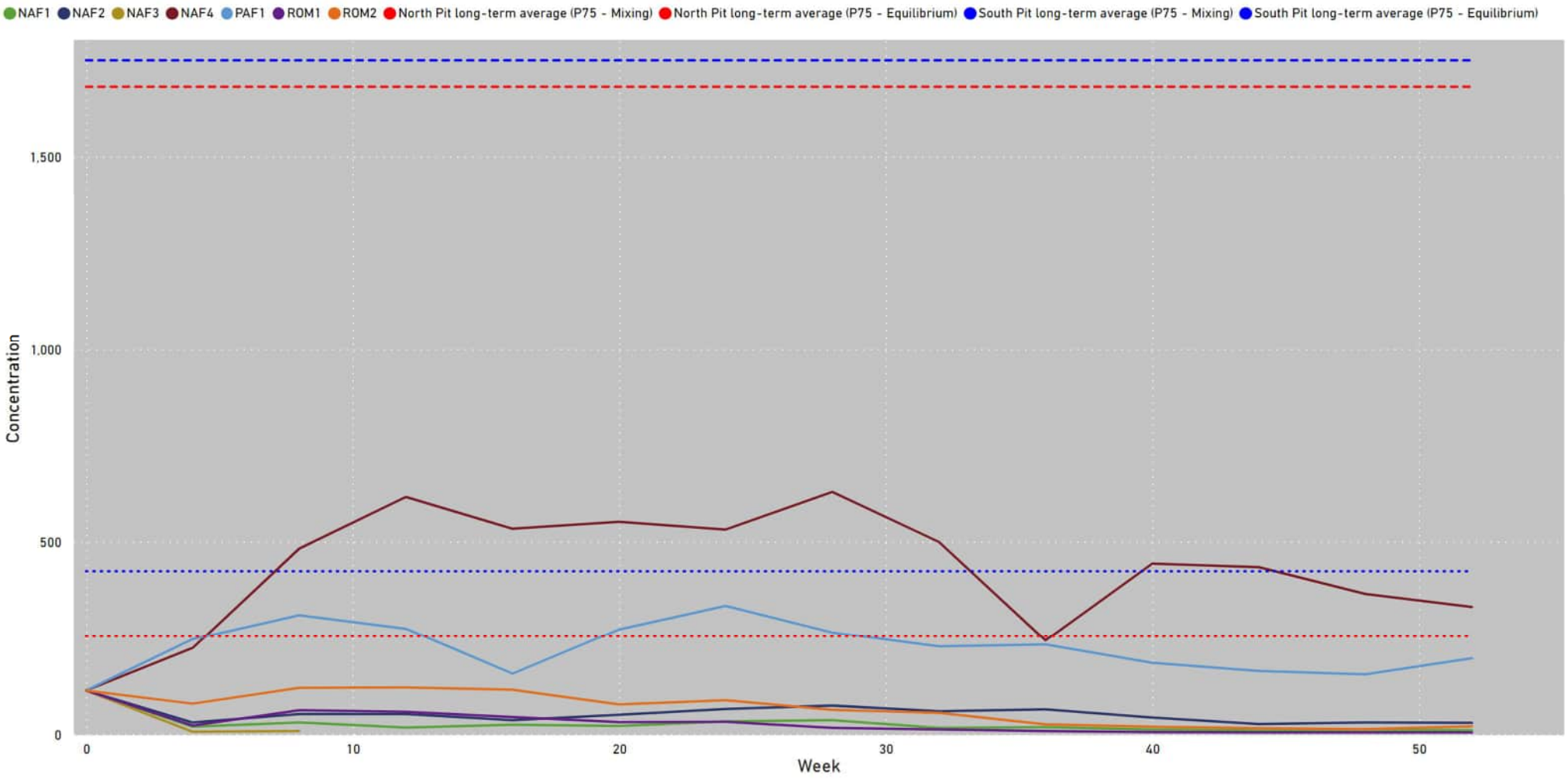

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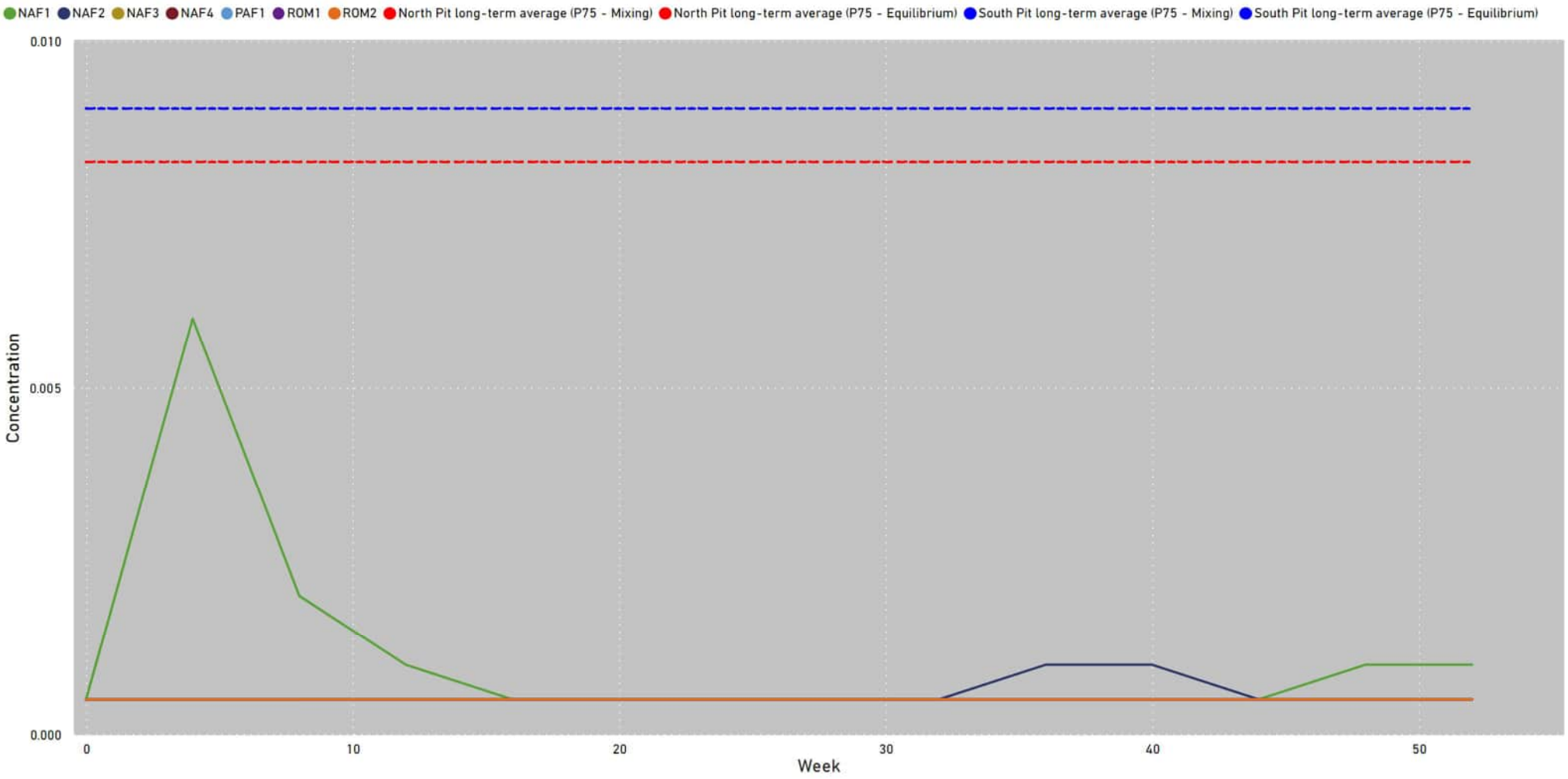

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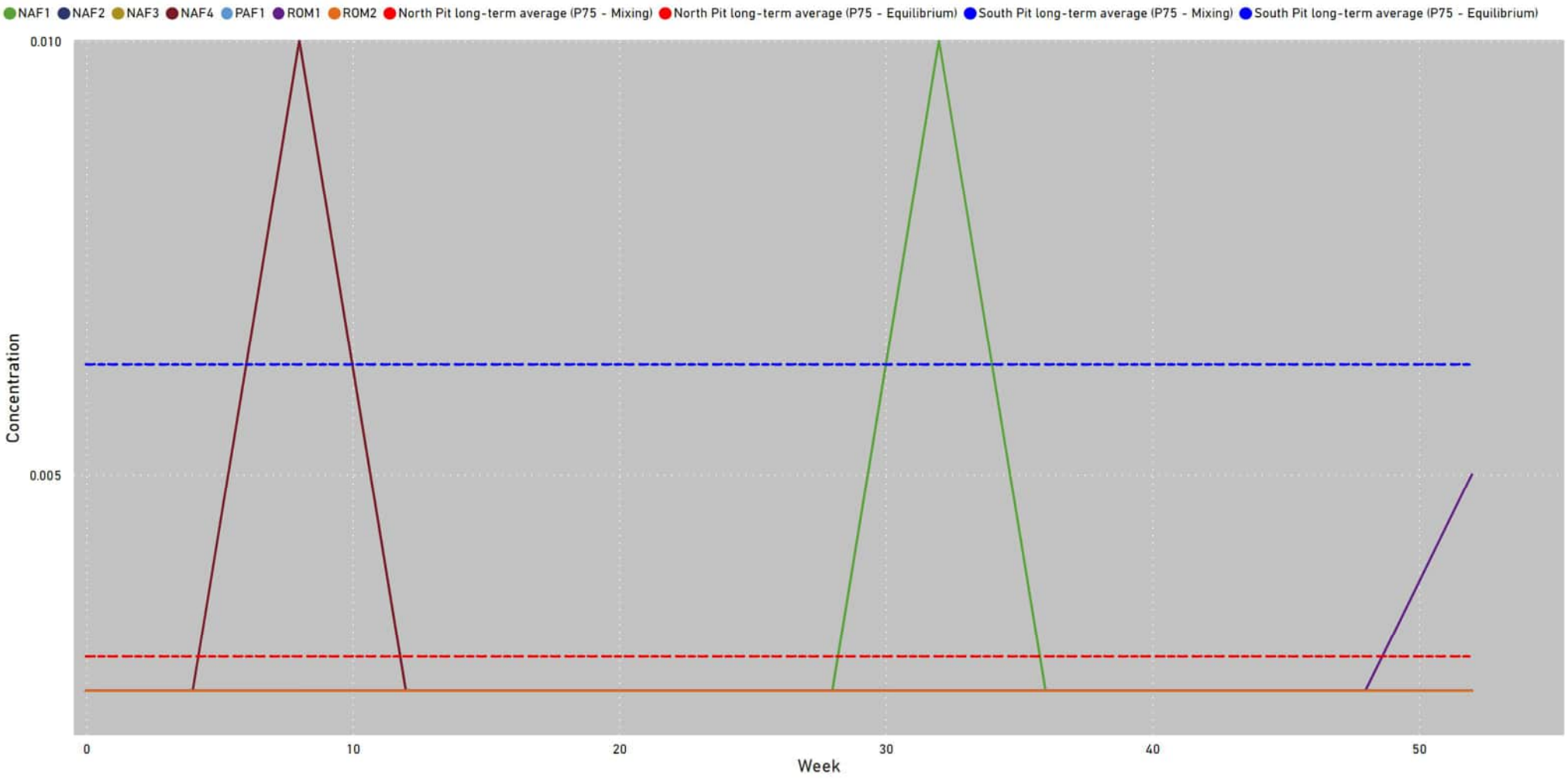

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Barbara Copper Project UG PRCP

Groundwater Technical Report

Prepared for Aeris Resources Limited | 20 March 2024

Barbara Copper Project UG PRCP

Groundwater Technical Report

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Date	20/03/2024

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Table of Contents

1 Introduction 1
1.1 Introduction 1
1.2 Relevant legislation and guidelines 1
1.3 Rehabilitation objectives 4
1.4 Post-mining land use 4
2 Environmental Authority EPML02840015 5
2.1 Authorised activities 5
2.2 EA groundwater-related conditions 5
2.3 EA groundwater monitoring program 7
3 BCP proposed underground mining 12
4 Environmental settings 17
4.1 Climate 17
4.2 Topography 23
4.3 Geomorphology and landforms 23
4.4 Vegetation 23
4.5 Surface water and hydrology 25
4.5.1 Drainage basins and catchments 25
4.5.2 Watercourses and water bodies 26
4.5.3 Surface water Environmental Values and Water Quality Objectives 26
4.5.4 Surface water quality characteristics 27
4.6 Soils 27
5 Geology 29
5.1 Local geology 29
5.2 Geochemistry 29
6 Hydrogeological settings 30
6.1 Water resource planning areas 30
6.2 Registered groundwater bores 30
6.3 Groundwater Dependent Ecosystems (GDE) 33
6.4 Groundwater beneficial use and environmental values 33
6.5 Stygofauna 34
6.6 Local aquifers 34
6.7 Aquifer hydraulic properties 35
6.8 Groundwater seeps/spring 40
7 Surface water monitoring results 43
7.1 Surface water monitoring network and events 43
7.2 2014 surface water monitoring (AARC, November 2014) 46

7.3 2022 REMP monitoring results 46
7.4 REMP and EA surface water quality results 47
7.4.1 Hydrogeochemistry 48
7.4.2 REMP and EA surface water quality results 49
7.5 Mine site surface water monitoring results 58
7.5.1 Hydrogeochemistry 58
7.5.2 Mine site surface water quality results 60
7.5.3 Assessment of water levels at BCP Spring locations and in the sump 66
8 Groundwater monitoring results 70
8.1 Groundwater monitoring network 70
8.2 Groundwater levels and flow 73
8.2.1 Groundwater levels in mineral exploration bores (2013) 73
8.2.2 Groundwater levels in monitoring bores (2014) 74
8.2.3 Groundwater levels in monitoring bores (2018-2024) 75
8.2.4 Assessment of water levels in seepage monitoring wells 84
8.3 Groundwater hydrogeochemistry and water types 92
8.4 Groundwater quality 98
8.4.1 Groundwater monitoring bores 98
8.4.2 Seepage monitoring bores 106
9 Hydrogeological conceptual site model 113
10 Final void hydrogeology 117
10.1 Introduction 117
10.2 Extent and level of drawdown around open pits and underground workings 117
10.3 Impacts on groundwater/surface water interaction 122
10.4 Groundwater inflows into open pits and underground works 122
10.4.1 Introduction 122
10.4.2 Marinelli and Niccoli method for inflow into mine pits 123
10.4.3 Steady-state groundwater inflow into open pits 124
10.4.4 Steady-state groundwater inflow into underground works 127
10.4.5 BCP stochastic water balance model results 128
10.5 North Pit, South Pit and WRD Sediment Dam final void water quality 132
10.5.1 Development of Water Quality Models 133
10.5.2 WRD Sediment Dam final void water quality 133
10.5.3 North Pit water quality 134
10.5.4 South Pit water quality 134
10.5.5 Summary 134
10.5.6 Conclusions 135
10.6 Underground workings final void water quality 135
10.6.1 Methodology 135
10.6.2 Summary of determinstic UG water balance model volumes 135
10.6.3 Representative initial water quality conditions 136

10.6.4 Modelled water quality in underground workings 140
10.6.5 Conclusions 140
10.7 Potential AMD impact on final void water quality 143
10.7.1 Summary of AMD investigations 143
10.7.2 Potential AMD impacts on final void water quality in open pits 147
10.7.3 Potential AMD impacts on underground final void water quality 151
10.8 Preliminary assessment of final void stratification 155
10.8.1 Introduction 155
10.8.2 Depth/area ratio assessment 156
10.8.3 One-dimension GLM model 156
11 BCP rehabilitation planning 162
11.1 Exposure pathway assessment 162
12 Conclusions 170
13 References 172
14 Limitations 174

Appendices

Appendix B Bore construction logs
Appendix C Registered bore reports
Appendix D Google Earth images of BCP Spring
Appendix E REMP and EA surface water monitoring data
Appendix F Mine site surface water monitoring data
Appendix G Groundwater monitoring data
Appendix H Seepage monitoring bore results
Appendix I Inflow calculations for open pits and underground works
Appendix J WQM results for open pits and WRD sediment dam
Appendix K WQM results for underground workings
Appendix L Summary of AMD Investigations

Figures

Figure 1 Location of the Barbara Copper Project
Figure 2 Location of BCP groundwater monitoring wells (regional scale)
Figure 3 Location of BCP groundwater monitoring wells (local scale)
Figure 4 Pre-mining 2014 topography

Figure 5 2021 topography
Figure 6 Mapped pre-clear regional ecosystems
Figure 7 Watercourses near the Project site
Figure 8 Surface water monitoring locations (regional scale)
Figure 9 Surface water monitoring locations (local scale)
Figure 10 Regional geology at BCP
Figure 11 Registered water bores within 5 km of BCP
Figure 12 Registered water bores within ML90241
Figure 13 BOM groundwater dependent ecosystems
Figure 14 Contour map of June 2014 groundwater levels
Figure 15 Contour map of June 2018 groundwater levels
Figure 16 Contour map of April 2022 groundwater levels
Figure 17 Contour map of April 2023 groundwater levels
Figure 18 Location of hydrogeological cross-section

Plates

Plate 1 BCP project layout 3
Plate 2 Proposed BCP underground mining schedule 13
Plate 3 Cumulative underground void volumes 14
Plate 4 Underground voids after mining 14
Plate 5 BCP UG mining – cumulative waste/backfill tonnage 15
Plate 6 BCP UG mining – PAF/NAF temporary storage requirements 16
Plate 7 Daily Rainfall (mm) from Mount Isa Aero weather station 029127 20
Plate 8 Average monthly rainfall (mm) and pan evaporation (mm) from SILO data 21
Plate 9 Cumulative Rainfall Distribution for BCP 22
Plate 10 Pre-mining vegetation communities at BCP 25
Plate 11 Distribution of soil management units within the Project area 28
Plate 12 Airlift Yield from Mineral Exploration Bores (RLA, 2014) 38
Plate 13 Drawdown and recovery water levels in BAWB07 39
Plate 14 Google Earth images for October 2015 and March 2020 41
Plate 15 Monthly rainfall (2002-2022) and Cumulative Rainfall Departure 42
Plate 16 Water elevation (mAHD) at BCP Spring (N), BCP Spring (S) and the sump 68
Plate 17 Water level changes (m) at BCP Spring (N), BCP Spring (S) and the sump 69
Plate 18 Depth to water (mbRL) in groundwater monitoring bores 78
Plate 19 Groundwater levels (mAHD) in groundwater monitoring bores 79
Plate 20 Depth to water (mbRL) in EA seepage monitoring bores 80
Plate 21 Groundwater levels (mAHD) in EA seepage monitoring bores 81
Plate 22 Depth to water (mbRL) in additional seepage monitoring bores 82
Plate 23 Groundwater levels (mAHD) in additional seepage monitoring bores 83
Plate 24 Data logger based groundwater levels (mAHD) versus manually obtained groundwater levels (mAHD) 88

Plate 25 Groundwater levels (mAHD) in seepage monitoring bores 1a, 2a, 3a, 5b, 6b, 8a and 9a versus rainfall 89
Plate 26 Groundwater level changes (m) in seepage bores 1a, 2a, 3a, 5b, 6b, 8a and 9a versus rainfall..... 90
Plate 27 Groundwater levels (mAHD) in selected seepage monitoring bores and BCP spring locations versus rainfall 91
Plate 28 Hydrogeological cross-section (A-A') with June 2018 groundwater levels..... 115
Plate 29 Hydrogeological cross-section (A-A') with April 2022 groundwater levels 116
Plate 30 North Pit radius of influence/drawdown 119
Plate 31 South Pit radius of influence/drawdown 120
Plate 32 Underground workings radius of influence/drawdown 121
Plate 33 Mine pit inflow conceptual model (Marinelli & Niccoli, 2000) 123
Plate 34 Calculated steady-state North Pit groundwater inflows..... 126
Plate 35 Calculated steady-state South Pit groundwater inflows..... 126
Plate 36 Calculated steady-state underground works groundwater inflows 128
Plate 37 Schematic BCP water balance model (ATC Williams, 2024) 129
Plate 38 South Pit accumulated groundwater inflows 130
Plate 39 Underground workings accumulated groundwater inflows 131
Plate 40 North Pit accumulated groundwater inflows 132
Plate 41 AMD plot for waste rock and ROM oxide and AMD classification (EGi, 2020) .. 145
Plate 42 North Pit waste rock cross-sections (AECOM 2014)..... 149
Plate 43 South Pit waste rock cross-sections (AECOM 2014)..... 149
Plate 44 Summary of EC values for all rock units within Barbara drill core samples (EGi, 2014) 150
Plate 45 North Pit GLM model results – temperature (°C) distribution 158
Plate 46 North Pit GLM model results – density distribution 158
Plate 47 North Pit GLM model results – salinity (g/L) distribution 159
Plate 48 South Pit GLM model results – temperature (°C) distribution 160
Plate 49 South Pit GLM model results – density distribution 161
Plate 50 North Pit GLM model results – salinity (g/L) distribution 161
Plate 51 BCP complete exposure pathway for groundwater 169

Tables

Table 1 Groundwater-related information required by the PRCP Guideline 1
Table 2 BCP environmentally relevant activity and location details (EA EPML02840015). 5
Table 3 EA Table E5 - Groundwater monitoring locations and frequency 8
Table 4 EA Table E6 - Groundwater quality objectives..... 9
Table 5 BCP seepage monitoring bores..... 10
Table 6 Underground void volumes after mining 12
Table 7 Monthly climate statistics for Mount Isa Airport station (BOM station 029127) 19
Table 8 Site preclear regional ecosystems..... 23

Table 9 Pre-mining vegetation communities at BCP 24
Table 10 Registered water bores within 10 km of the Project site 31
Table 11 Terrestrial GDEs within 5km of Project Site (BOM GDE Atlas) 33
Table 12 Mineral Exploration Bore Airlift Yield Test Results (RLA, 2014) 36
Table 13 Calculated hydraulic conductivity of aquifer sequences at BCP (RLA, 2014) 40
Table 14 Historical presence of BCP Spring on Google Earth images 41
Table 15 BCP surface water monitoring locations 44
Table 16 Water-type classification of REMP and EA surface water sampling locations 48
Table 17 Range of analysis results above the LOR at the REMP/EA surface water monitoring locations 51
Table 18 REMP and EA surface water exceedances of EA receiving water quality trigger levels 53
Table 19 REMP and EA surface water exceedances of EA receiving water WQOs 55
Table 20 REMP and EA surface water exceedances of ANZG aquatic ecosystem (slightly to moderately disturbed) protection DGVs 57
Table 21 Water-type classification of mine site surface water sampling locations 58
Table 22 Range of analysis results above the LOR at the mine site surface water monitoring locations 62
Table 23 Mine site surface water exceedances of ANZECC Livestock Water Quality Guidelines 64
Table 24 Mine site surface water exceedances of ANZG aquatic ecosystem (slightly to moderately disturbed) WQOs 65
Table 25 Datalogger periods at surface water monitoring locations 66
Table 26 BCP groundwater monitoring well details 71
Table 27 Exploration Drill Hole Groundwater Levels – October 2013 (RLA, 2014) 73
Table 28 Depth to Groundwater in BCP Groundwater Monitoring Bores (RLA, 2014) 74
Table 29 Datalogger periods at seepage monitoring bore locations 84
Table 30 Water-type classification of groundwater monitoring bores 92
Table 31 Water-type classification of seepage monitoring bores 94
Table 32 Range of analysis results above the LOR in the groundwater monitoring bores100
Table 33 Groundwater monitoring bore exceedances of EA Limit A 102
Table 34 Groundwater monitoring bore exceedances of EA Limit B 103
Table 35 Groundwater monitoring bore exceedances of ANZG Livestock Water Quality guidelines 104
Table 36 Groundwater monitoring bore exceedances of ANZG aquatic ecosystem (slightly to moderately disturbed) WQOs 105
Table 37 Range of analysis results above the LOR in the EA seepage monitoring bores108
Table 38 Range of analysis results above the LOR in the additional seepage monitoring bores 110
Table 39 Seepage monitoring bore exceedances of ANZG Livestock Water Quality guidelines 112
Table 40 Seepage monitoring bore exceedances of ANZG aquatic ecosystem (slightly to moderately disturbed) WQOs 112
Table 41 BCP hydrogeological conceptual model 113

Table 42 Groundwater inflow into mine pit equations and assumptions.....123
Table 43 Assumptions and variables for open pit groundwater inflow calculations 124
Table 44 Assumptions and variables for underground works groundwater inflow calculations 127
Table 45 Initial concentrations of relevant solutes/parameters for UG WQM.....137
Table 46 Modelled UG workings final void water quality concentrations (mg/L) 141
Table 47 BCP AMD classification (EGi, 2014).....143
Table 48 Acid rock drainage samples - acid generation lag time (EGi, 2014).....143
Table 49 Descriptions of Barbara waste rock and ROM oxide samples (EGi, 2020).....144
Table 50 Summary of leachate analysis from week 4 to 52 (EGi, 2020) 146
Table 51 Input water quality and water volumes for UG PAF disposal WQM.....152
Table 52 End-point UG water quality (mg/L) with PAF/NAF disposal.....154
Table 53 "*Relative Depth*" of open pits and sediment dam 156
Table 54 Potential sources of groundwater contamination and COPCs 163
Table 55 Potential pathways/release mechanisms.....165
Table 56 Potential sources of contamination and primary pathways/release mechanisms166
Table 57 Potential receptors or beneficial uses 167
Table 58 Potential exposure routes/pathways for potential receptors.....167

1 Introduction

1.1 Introduction

Aeris Resources Limited ('Aeris') engaged WMV Environmental Pty Ltd ('WMV Environmental') to prepare a "*Groundwater Technical Report*" in support of a submission of a Progressive Rehabilitation and Closure Plan (PRCP) for underground mining at Aeris' Barbara Copper Project (BCP).

BCP is located within Mining Lease (ML) ML90241 (Figure 1 in the Figures Section at the end of the main text) and is authorised under Environmental Authority (EA) EPML02840015 for resource activities relevant to mining metals (copper, lead, silver, zinc, gold and iron ore). The Project is an open-cut copper mine that has extracted approximately 772,000 tonnes of ore. The mine operated from June 2019 until March 2021 and was placed in care and maintenance in April 2021.

Aeris intends to expand the BCP operations to include underground mining. The existing and proposed mine features are presented in Plate 1.

1.2 Relevant legislation and guidelines

The Department of Environment and Science (DES) *Guideline: Progressive rehabilitation and closure plans (PRC plans) (ESR/2019/4964 Version 2.00: March 2021)* (DES, 2021) (referred to herein as the PRCP Guideline) provides the information to assist companies in complying with the amendments to the EP Act and the *Mineral and Energy Resources (Financial Provisioning) Act 2018 (Qld)* (MERFP Act).

Groundwater/hydrogeology-related information required/referenced in the PRCP Guideline is presented in Table 1.

Table 1 Groundwater-related information required by the PRCP Guideline

PRCP Guideline Section	Information required
Section 3.1 - Project planning	Information on groundwater levels and properties
Section 3.3 – Non-use management areas (NUMAs)	Not applicable. No NUMAs are proposed as part of the PRCP.
Section 3.6.1 – General rehabilitation practices: Hydrogeology	Assess the hydrogeology of the site and all connected strata and develop a conceptual model of the mine site's groundwater systems. This information must be integrated into the design of rehabilitation strategies and choice of PMLU or NUMA. The hydrogeological assessment should include the following steps: • determining the groundwater occurrence including the existence of, and depth to, aquifers and aquitards • locating groundwater recharge and discharge locations locally and regionally • groundwater quality within each of the aquifers and from surface expressions (i.e. seeps and springs) • current and potential future uses of groundwater including existing groundwater extraction bores • groundwater flow direction and velocity, including field tests to determine hydraulic conductivity • the development of potentiometric mapping and hydro stratigraphic cross sections

PRCP Guideline Section	Information required
	• groundwater modelling to determine contaminant transport and potential changes to groundwater level from dewatering or waste storage. The prediction of water quality impacts from mining activities is necessary to determine appropriate measures for the containment and management of contaminants and the potential impacts on environmental values should they be released.
Section 3.6.1 – General rehabilitation practices: Water management	The management of surface and groundwater is a key consideration in achieving long-term rehabilitation success. The rehabilitation planning part must include a description of the following: • a description of the contaminants that pose a risk to environmental values of the receiving environment • source, pathway and fate of contaminants that have the potential to impact environmental values • infiltration and seepage intervention and collection controls • surface water diversions and long-term management requirements • dewatering requirements • on-going water management and reduction requirements (i.e. treatment).
Section 3.6.3 - Voids	For mine sites with voids, the rehabilitation planning part must include a void closure plan that includes, but is not limited to, the following: • void hydrology, addressing the long-term water balance and water level in the voids, stratification connections to groundwater resources and potential for overflow • groundwater modelling to determine whether the void is acting as a sink or a source for groundwater • a water balance study including an assessment of void surface and groundwater interaction.

Section 3.6.4 – Underground mining	For underground mining operations, the rehabilitation planning part must include:
	• an assessment of groundwater interactions and potential lowering of groundwater levels that includes:
	  o consideration of the potential exposure of previously saturated geological formations to air - leading to AMD generation
	  o consideration of measures to avoid or minimise groundwater discharges to the surface through appropriate mine access planning, including post mining sealing off of tunnels, shafts, adits, boreholes, and other openings
	• the development of a hydrogeological conceptual model.

Appendix 2 PRCP schedule example RM8/ RM9 – Achievement of post-mining land use to stable condition	Milestone criteria relating to groundwater levels and groundwater quality.
Appendix 2 PRCP schedule example	Certification of groundwater monitoring in accordance with monitoring and maintenance program confirms cap is functioning as designed and there is no migration of contaminants.

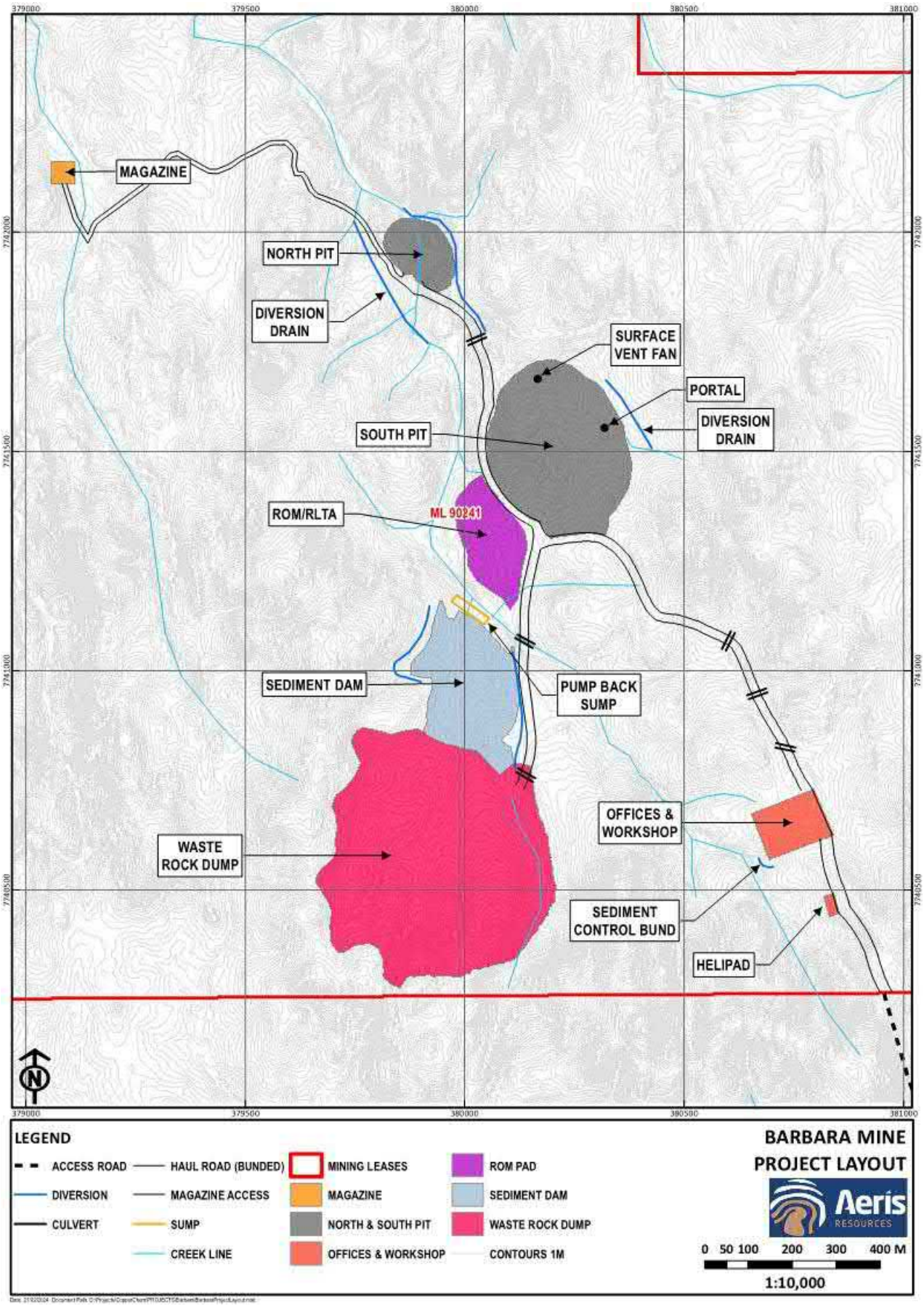


Plate 1 BCP project layout

1.3 Rehabilitation objectives

The overarching objective of mine rehabilitation and closure is to achieve a safe, stable and non-polluting site that can sustain the agreed post mining land uses (PMLU). Specific Rehabilitation objectives are provided in the main text of the PRC Plan for the Project. Objectives have been designed to reflect EA conditions and the Land Use Management Document (Round Oak, 2020a).

1.4 Post-mining land use

Current land uses on which the Project site is situated include low-intensity cattle grazing and mineral exploration activities. Historically, mining activities and cattle grazing have been the predominant land use, with evidence of this noted throughout the site, with fences, cattle grids, and disused mine shafts.

The following PMLUs are proposed for the site:

- North Pit and South Pit (including underground workings) – Water storage
- Sediment Dam – Water storage
- Waste Rock Dump – Native ecosystems
- Ancillary infrastructure, ROM pad, roads and exploration – Low-intensity grazing
- Diversion drains (North Pit creek diversion and levee) – Water management infrastructure

Specific infrastructure items will remain at closure for the landholder as specified in the consultation register. Infrastructure to remain at closure is summarised in Section 4.3.2 of the main PRCP document.

The proposed PMLUs for the Project are consistent with the outcomes identified in the consultation plan. The PMLUs support regional landscapes and production values for agriculture which is aligned with objective 2 from the Northwest Regional Plan.

2 Environmental Authority EPML02840015

2.1 Authorised activities

BCP is located within Mining Lease (ML) ML90241 and is authorised under Environmental Authority (EA) EPML02840015, effective from 30 September 2022, (Appendix A) for resource activities relevant to mining metals (Table 2).

Table 2 BCP environmentally relevant activity and location details (EA EPML02840015)

Activity	Location
Ancillary 08 - Chemical Storage 3 - Storing more than 500 cubic metres of chemicals of class C1 or C2 combustible liquids under AS 1940 or dangerous goods class 3 under subsection (1)(c)	ML90241: MOUNT ISA CITY
Ancillary 15 - Fuel burning Using fuel burning equipment that is capable of burning at least 500kg of fuel in an hour	ML90241: MOUNT ISA CITY
Ancillary 33 - Crushing, milling, grinding or screening Crushing, grinding, milling or screening more than 5000t of material in a year	ML90241: MOUNT ISA CITY
Ancillary 63 - Sewage Treatment 1(a-i) - Operating sewage treatment works, other than no-release works, with a total daily peak design capacity of 21 to 100EP - if treated effluent is discharged from the works to an infiltration trench or through an irrigation scheme	ML90241: MOUNT ISA CITY
Schedule 3 17 - Mining copper ore	ML90241: MOUNT ISA CITY
Schedule 3 16 - Mining gold ore	ML90241: MOUNT ISA CITY
Schedule 3 14 - Mining iron ore	ML90241: MOUNT ISA CITY
Schedule 3 19 - Mining metal ore, other than a metal ore mentioned in items 11, 12, 14, 15, 16,17 or 18	ML90241: MOUNT ISA CITY
Schedule 3 18 - Mining lead, silver or zinc separately or in any combination	ML90241: MOUNT ISA CITY

2.2 EA groundwater-related conditions

Conditions relating to groundwater are defined in Schedule E of the EA, as attached in Appendix A and provided below.

Groundwater

E8 The holder of this environmental authority must not release contaminants to groundwater.

E9 The extraction of groundwater must not cause environmental harm to any groundwater dependent ecosystems.

E10 Groundwater quality and levels must be monitored:

a) at the locations specified in Table E5 (Groundwater monitoring bore locations); and

b) at the frequencies specified in Table E5 (Groundwater monitoring bore locations); and

c) for the quality characteristics identified in Table E6 (Groundwater Quality Objectives).

E11 Groundwater measured from any compliance bore specified in Table E5 must not exceed the corresponding Limit A specified in Table E6 on any five consecutive sampling occasions.

E12 Groundwater measured from any compliance bore specified in Table E5 must not exceed the corresponding Limit B specified in Table E6 on any three consecutive sampling occasions.

E13 If groundwater measured from any compliance bore specified in Table E5 exceeds the corresponding Limit B specified in Table E6 on any one sampling occasion the environmental authority holder must resample the groundwater within the compliance bore for all exceeding parameters within ten business days of receipt of results.

Bore construction and maintenance and decommissioning

E14 The construction, maintenance and decommissioning of groundwater monitoring bores must be undertaken in a manner that:

a) prevents contaminants entering the groundwater; and

b) ensures the integrity of the bores to obtain representative groundwater samples from the target aquifer; and

c) maintains the hydrogeological environment within the aquifer.

E15 A bore drill log must be kept for each reference, compliance and observation groundwater monitoring bore which includes:

a) bore identification reference and geographic coordinate location;

b) specific construction information including but not limited to depth of bore, depth and length of casing, depth and length of screening and bore sealing details;

c) standing groundwater level and water quality parameters including physical parameters and results of laboratory analysis for the possible trigger parameters;

d) lithological data and stratigraphic interpretation by an appropriately qualified person to identify important features associated with groundwater monitoring; and

e) target aquifer formation of the bore.

Groundwater Management Program

E16 A Groundwater Management Program must be developed, documented and implemented by appropriately qualified persons.

E17 The Groundwater Management Program required by Condition E16 must:

a) identify potential sources of contamination to groundwater from the activity; and

b) ensure that all potential groundwater impacts due to the activity are identified, monitored and mitigated; and

c) document sampling and monitoring methodology; and

d) ensure that adequate groundwater monitoring and data analysis is undertaken to achieve the following objectives:

i. detect any impacts to groundwater levels due to the activity;

ii. detect any impacts to groundwater quality due to the activity;

iii. determine compliance with condition E11 and E12; and

iv. determine trends in groundwater quality; and

e) include an appropriate quality assurance and quality control program; and

f) include a conceptual groundwater model; and

g) include a review process to identify improvements to the program that includes addresses any comments provided by the administering authority.

E18 The Groundwater Management Program must be reviewed on an annual basis by an appropriately qualified person to determine if it continues to meet the requirements stated in condition E17.

E19 Monitoring and sampling must be carried out in accordance with written procedures and must address the requirements of the latest version of the following documents unless otherwise approved by the administering authority:

a) for waters and aquatic environments, the Queensland Government's Monitoring and Sampling Manual – Environmental Protection (Water) Policy;
b) for groundwater, Groundwater Sampling and Analysis - A Field Guide (2009:27 GeoCat#6890.1) and Australian Standard AS/NZS 5667.11:1998 Water Quality - Sampling - Guidance on sampling of groundwaters;
c) for subterranean aquatic fauna, the Guideline for the Environmental Assessment of Subterranean Aquatic Fauna.

2.3 EA groundwater monitoring program

Table 3 shows the details of the EA monitoring bores, with locations shown in Figure 2 and Figure 3. Table 4 shows the EA groundwater quality objectives. Appendix B provides the available bore construction logs.

Table 3 EA Table E5 - Groundwater monitoring locations and frequency

Monitoring Point	Location (GDA94 – Zone 54)		Surface RL (m)[1]	Total Depth (mbgl)[2]	Screened interval (mbgl)	Monitoring Frequency	
	Easting	Northing				Standing water level	Groundwater quality
Compliance bores							
BAWB05	380948	7740252	377.32	102	35-102	Monthly	Three monthly
Bore E	380022	7738827	334.23	85	28-83		
BAWB01	380432	7742097	352.68	104	20-101	Monthly	Three monthly
BAWB02	379480	7742395	310.59	104	96-102		
BAWB03	379834	7741692	329.50	104	50-102		
BAWB04	380043	7742054	329.14	100	94-100		
BAWB07	379849	7741936	328.74	127	18-146		
BAWBR1	380292	7740939	334.49	14	5-6		
BAWBR2	379912	7741279	322.98	14	2-3		
BAWBR3	379991	7741485	326.02	14	3-4		
Seepage monitoring bores							
Seepage Bore 1a	380084	7741046	336.819	6	1-5	Monthly	Three monthly
Seepage Bore 1b	380084	7741048	336.487	16	5-15		
Seepage Bore 2a	380025	7741117	331.218	6	1-5		
Seepage Bore 2b	380023	7741116	331.342	16	5-15		
Seepage Bore 3a	379985	7741133	332.189	6	1-5		
Seepage Bore 3b	379986	7741135	331.962	16	5-15		
Seepage Bore 4a	380711	7740798	355.061	6	1-5		
Seepage Bore 4b	380711	7740800	355.111	16	5-15		

Notes:

1. RL must be measured to the nearest 5cm from the top of the bore casing.
2. Metres below ground level

Table 4 EA Table E6 - Groundwater quality objectives

Contaminant[1]	Units	Limit type	Bore(s)	Limit A[3]	Limit B[4]
pH	pH	Range	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	7.0-8.5
Electrical conductivity (EC)	µS/cm	Maximum	BAWB01, BAWB02, BAWB07	1260	1365
			BAWB03, BAWB04, BAWB05, BAWBR1, BAWBR2, BAWBR3, Bore E	950	1010
Sulfate	mg/L	Maximum	BAWB01, BAWB03, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	65	73
			BAWB02	190	200
			BAWB04	16	21
Fluoride	mg/L	Maximum	BAWB02, BAWB03, BAWB04, BAWB05, BAWBR1, BAWBR2, BAWBR3	0.8	0.9
			BAWB01, BAWB07, Bore E	1.6	1.7
Arsenic	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.013[2]
Barium	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	0.140	0.170
			BAWB04	0.400	0.420
			BAWB05	0.2	0.3
Bismuth	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.0007[5]
Cobalt	mg/L	Maximum	BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.0014[5]
			BAWB01	-	0.0028
Chromium	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.001[2]
Copper	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	0.003	0.008
Molybdenum	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.034[2]
Nickel	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.011[2]

Contaminant[1]	Units	Limit type	Bore(s)	Limit A[3]	Limit B[4]
Selenium	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.011[2]
Uranium	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	0.006	0.007
Major cations			BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	For interpretation only	
Major anions			BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	For interpretation only	
Total Hardness			BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	For interpretation only	

Notes:

1. All metals and metalloids must be measured as 'dissolved' (from analysis of a field filtered sample)
2. Contaminant limit based on ANZECC (2000), Table 3.4.1, 95% aquatic species protection level for slightly to moderately disturbed ecosystem.
3. Derived from site-specific values, based off dissolved concentration of metals (80th percentiles).
4. Derived from site-specific values, based off dissolved concentration of metals (95th percentiles).
5. Based off ANZECC (2000) low reliability metals and metalloids, Section 8.3.7.1

Aeris installed additional seepage monitoring bores adjacent to the WRD Dam end-2022 as part of the BCP Spring/Seepage assessment. Seepage monitoring bores have been installed as paired bores at some locations, i.e. adjacent shallow (6 metres deep) and deep (16 metres deep) bores. Table 5 presents the details of all seepage monitoring bores, with locations shown in Figure 3.

Table 5 BCP seepage monitoring bores

Monitoring Point		Location (GDA94 – Zone 54)		Surface RL (m)	Total Depth (mbgl)	Screened interval (mbgl)	Date Installed
		Easting	Northing				
EA seepage monitoring bores							
1	Seepage Bore 1a	380084	7741046	336.819	6	1 - 5	Jun 2019
	Seepage Bore 1b	380084	7741048	336.487	16	5 - 15	Jun 2019
2	Seepage Bore 2a	380025	7741117	331.218	6	1 - 5	Jun 2019
	Seepage Bore 2b	380023	7741116	331.342	16	5 - 15	Jun 2019
3	Seepage Bore 3a	379985	7741133	332.189	6	1 - 5	Jun 2019
	Seepage Bore 3b	379986	7741135	331.962	16	5 - 15	Jun 2019
4	Seepage Bore 4a	380711	7740798	355.061	6	1 - 5	Jun 2019
	Seepage Bore 4b	380711	7740800	355.111	16	5 - 15	Jun 2019

Monitoring Point		Location (GDA94 – Zone 54)		Surface RL (m)	Total Depth (mbgl)	Screened interval (mbgl)	Date Installed
		Easting	Northing				
Additional seepage monitoring bores							
6	Seepage Bore 5a	379978	7740810	338.46	10	6 – 10	Dec-2022
	Seepage Bore 5b	379979	7740810	341.95	15	11 – 15	Dec-2022
7	Seepage Bore 6a	379913	7740838	337.96	10	6 – 10	Dec-2022
	Seepage Bore 6b	379912	7740840	339.66	15	11 - 15	Dec-2022
7	Seepage Bore 7a	379929	7741239	328.95	6	3.5 – 6	Dec-2022
8	Seepage Bore 8a	380021	7741146	329.45	6	3.5 – 6	Dec-2022
9	Seepage Bore 9a	380058	7741122	331.45	6	3.5 – 6	Dec-2022

3 BCP proposed underground mining

Underground mining schedule and volumes

Plate 2 presents the proposed underground mining schedule over 4 years of mining. Plate 3 shows the cumulative void volumes generated during the underground mining.

Mining sequence is planned to be bottom up with rockfill utilised as the backfill medium. After a stope panel is completed, it is filled with waste rock and becomes the floor for the subsequent stopes above it. This mining method is commonly known as the Modified Avoca method and is utilised at other Aeris mines, including Mt Colin.

The backfill method planned for Barbara UG is development waste rock placed into completed stope voids. The waste will be temporarily moved to surface during development mining operations and will be returned UG once stoping commences. The waste balance shows that all waste generated during the Barbara underground operations will be able to be utilised as backfill. NAF material generated from the UG mining may be able to be utilised as cover material for the existing waste rock dump (WRD).

An excess of water currently exists at Barbara with both pits containing a significant amount of water. Water will be drawn from the South Pit and utilised for UG mining. Water will also be required for dust suppression on surface roads and UG. Mt Colin mine currently uses approximately 5ML of water each month but can use up to 8-10 ML per month when evaporating and using water for dust suppression. Water usage rates at Barbara are expected to be similar to Mt Colin.

The portal will be located on the initial section of the ramp located along the Eastern wall. The portal requires separation of the exhaust fan to prevent recirculation of air into the mine. The surface vent fan will be located within the footprint of the existing South pit.

Table 6 and Plate 4 show the void remaining in the mine after completion of underground mining activities. The table assumes all workings will be fully submerged after completion of mining.

Table 6 Underground void volumes after mining

Void	Volume	Overbreak	Void Ratio	Total Void	Units
Development	102000	5%	100%	107100	m³ (Cubic Metres)
Open Stopes	84000	15%	100%	96600	m³ (Cubic Metres)
Backfilled Stopes	225000	15%	30%	77625	m³ (Cubic Metres)
Total				281325	m³ (Cubic Metres)
				281.3	ML (Megalitres)

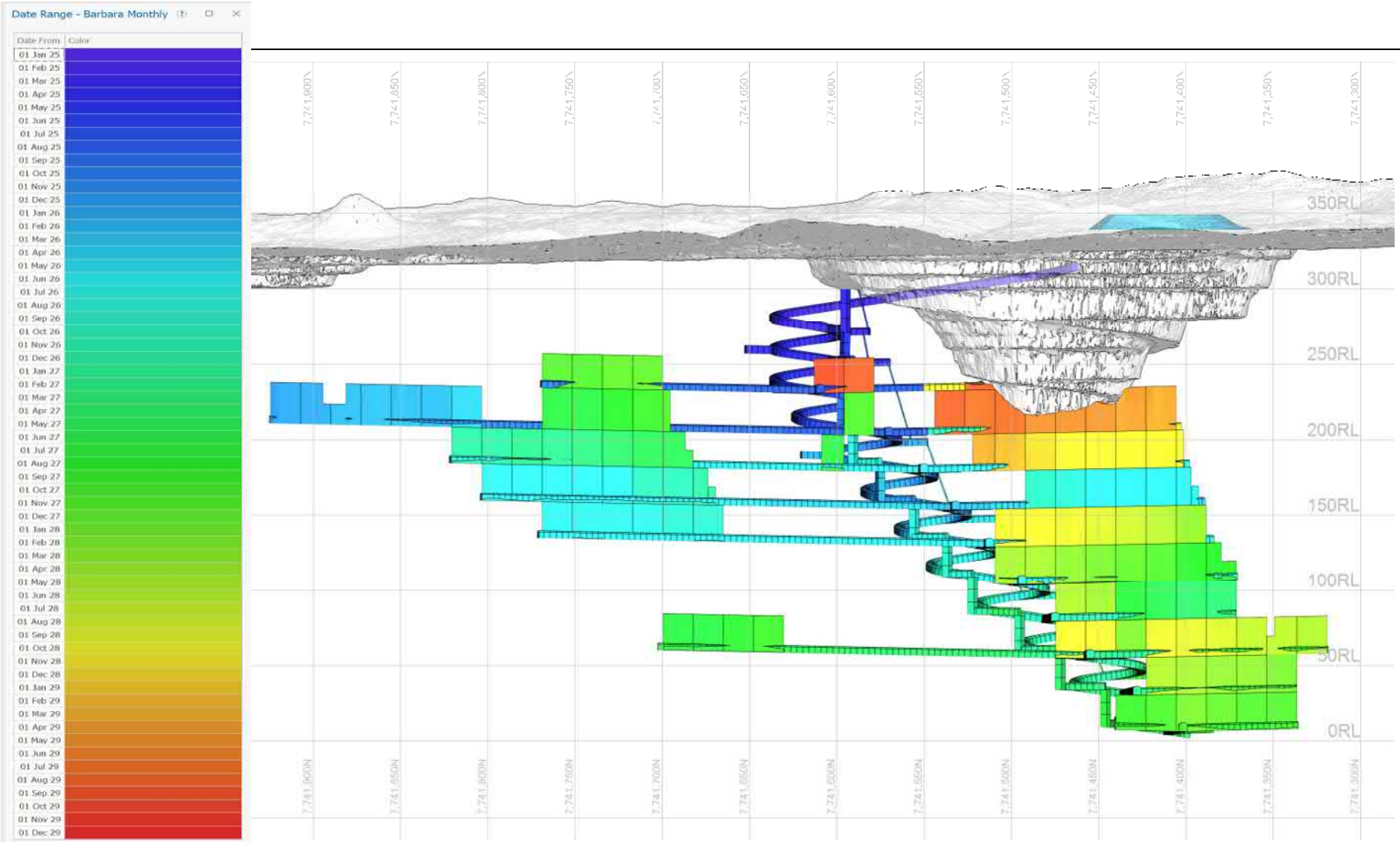


Plate 2 Proposed BCP underground mining schedule

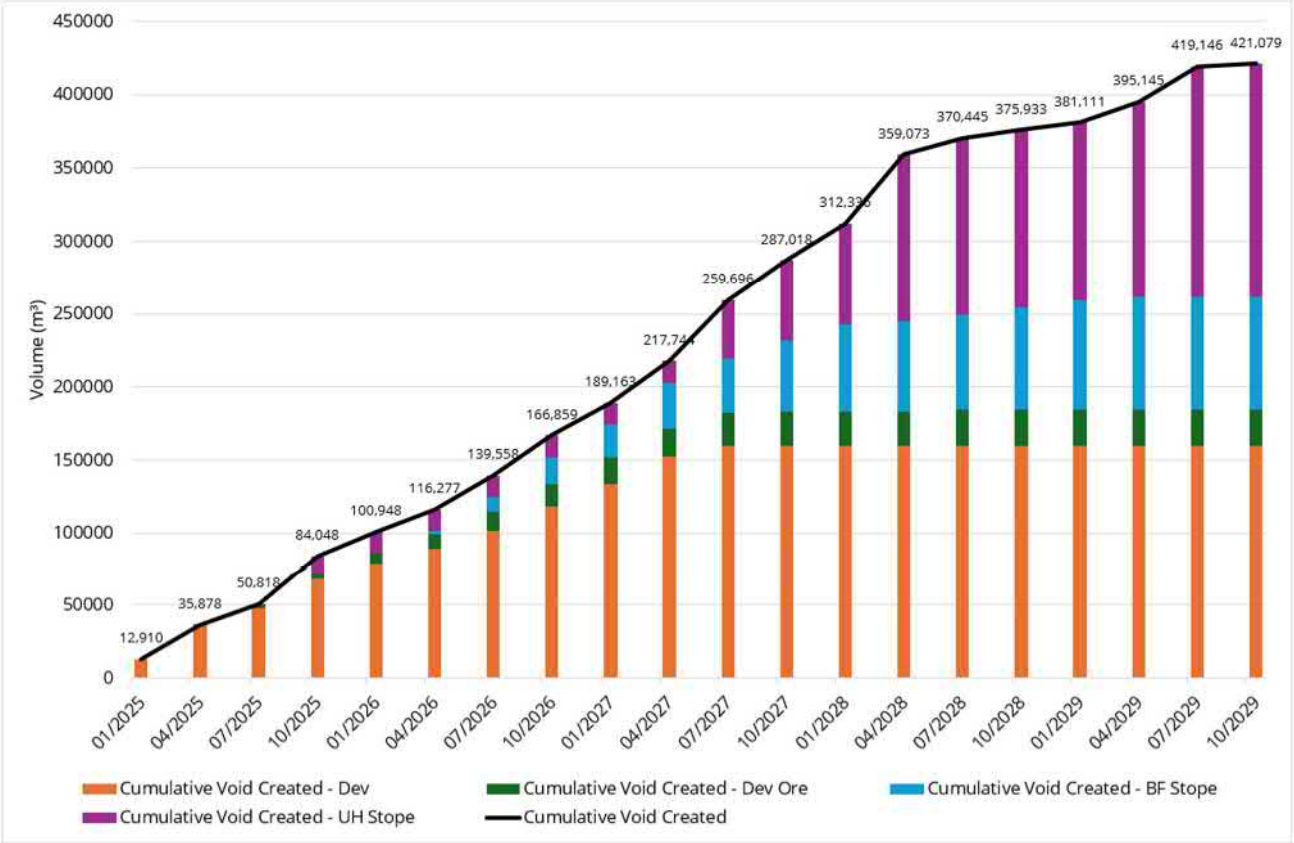


Plate 3 Cumulative underground void volumes

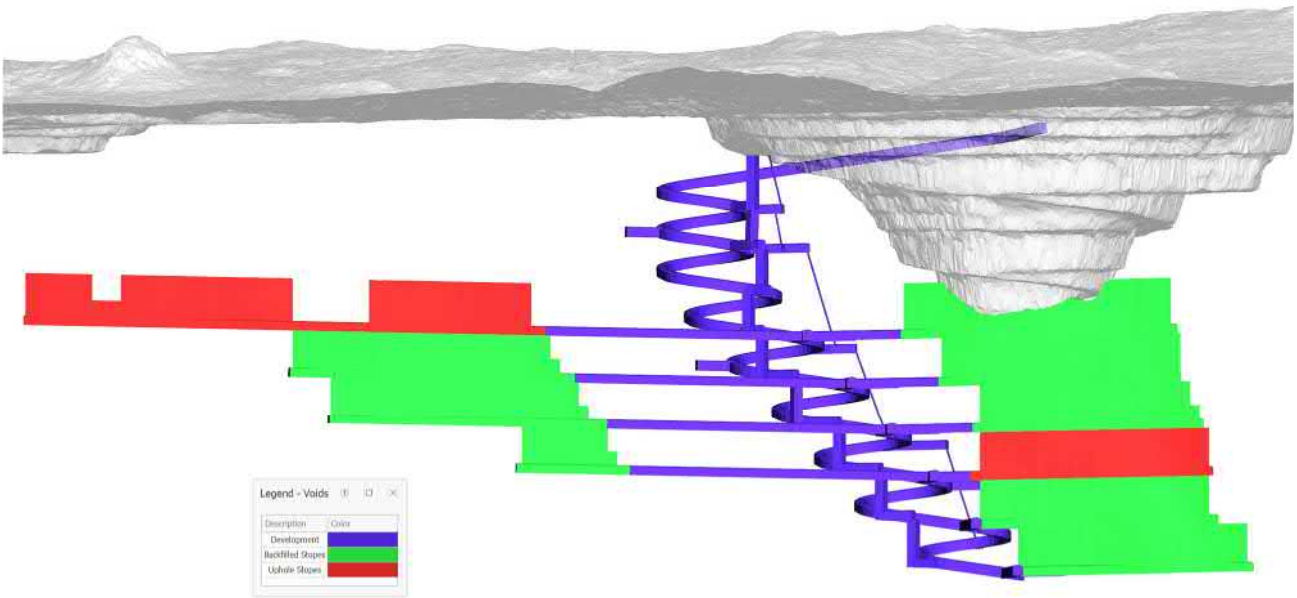


Plate 4 Underground voids after mining

Water management

The water management strategy will involve drawing down and using the South Pit water over the life of the mine with the intent to empty it to allow mining below the South Pit. The South pit requires full

dewatering to allow completion of UG mining. Methods used to reduce water levels in storage areas include:

- usage as dust suppression on roads within the mining lease
- set up of evaporation spray lines in existing water storage areas.

The North Pit can remain as water storage for the entire life of mine as the planned workings don't interact with the bottom of the pit.

Waste management

The backfill method planned for Barbara UG is development waste rock placed into completed stope voids. The waste will be temporarily moved to surface during development mining operations and will be returned UG once stoping commences.

The waste balance (Plate 5 and Plate 6) shows that all waste generated during the Barbara underground operations can be utilised as backfill. NAF material generated from the UG mining may be able to be utilised as cover material for the existing waste rock dump (WRD).

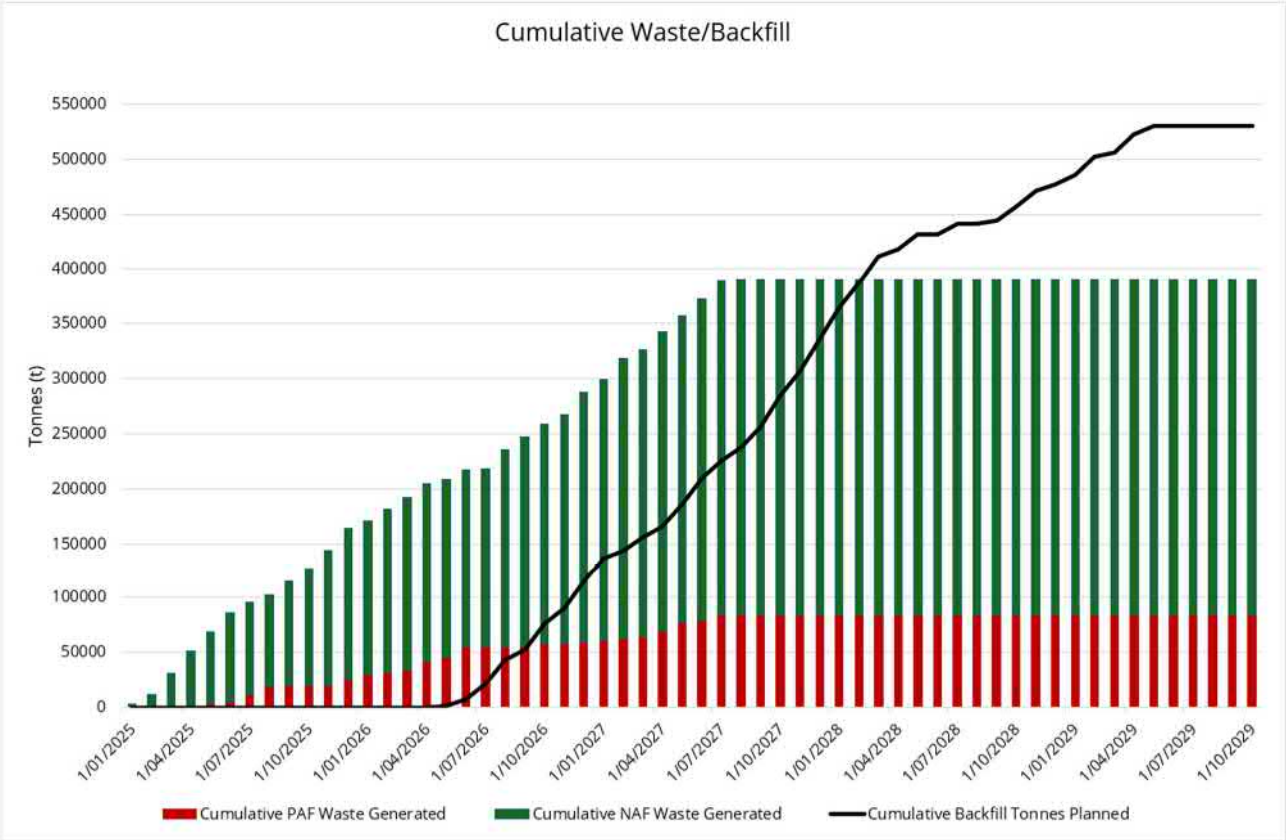


Plate 5 BCP UG mining – cumulative waste/backfill tonnage

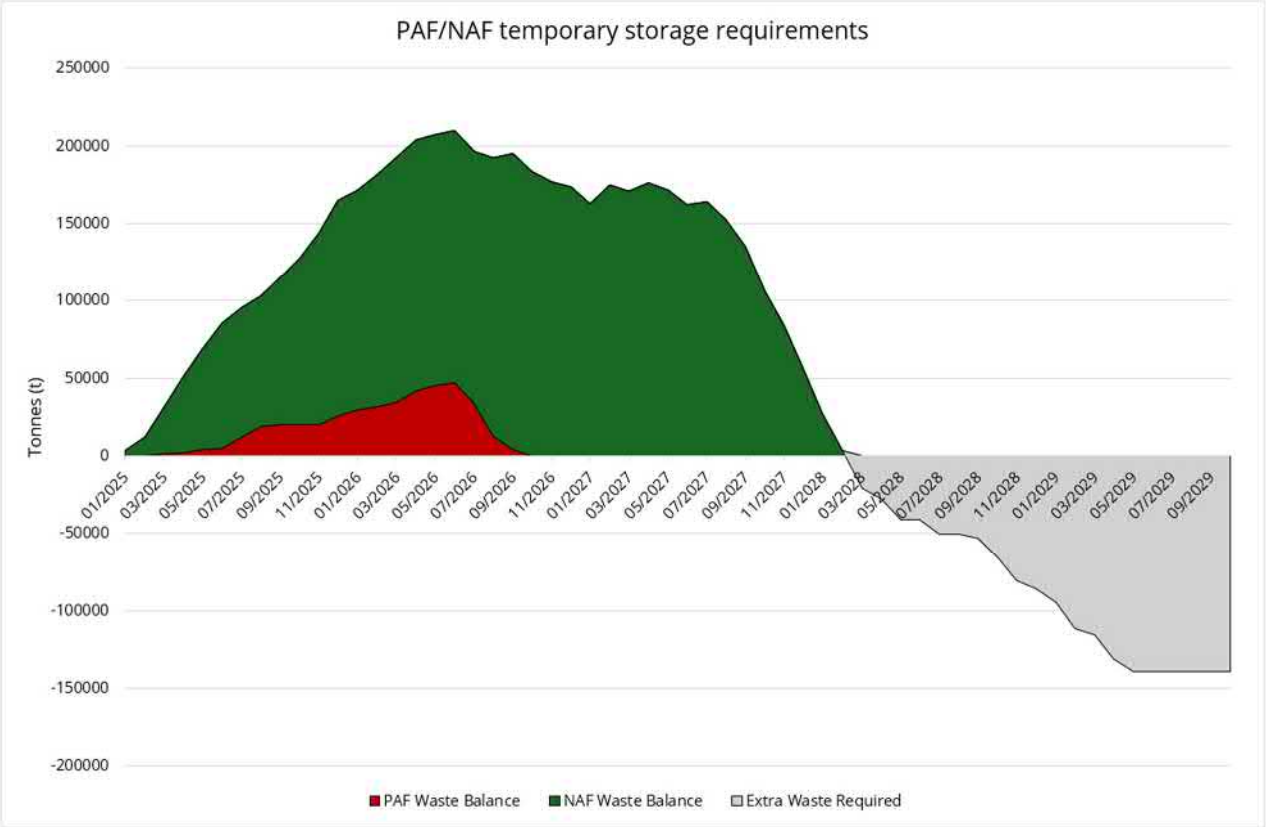


Plate 6 BCP UG mining – PAF/NAF temporary storage requirements

4 Environmental settings

4.1 Climate

Climate data for the Project site were assessed from Bureau of Meteorology (BOM) records. The nearest BOM meteorological station to the Project site is Mount Isa Airport (Station 029127). This station has data on rainfall and evaporation, key factors in assessing groundwater recharge.

Table 7 presents the station's monthly climate statistics from 1966 to 2023, with daily rainfall shown in Plate 7. The climate in Mt Isa is semi-arid to arid (Köppen Australian climate classification subtype BSh – semi-arid climate in low altitudes).

The climate of Mount Isa is governed by three main criteria: Tropical location (latitude), elevation and distance from the coast. With the Gulf of Carpentaria approximately 340km to the north and the Coral Sea 740km to the east-northeast, the climate of Mount Isa is suitably described as 'Tropical Continental' (http://www.bom.gov.au/qld/mt_isa/climate.shtml)

Three main seasons are experienced in Mount Isa:

- mild temperatures with low humidity from May to August.
- hot temperatures with low humidity from September to December.
- hot temperatures with high humidity from January to April.

Summer storms and floods dominate precipitation in the semi-arid to arid climate of Mount Isa. Evaporation is greatest in summer, with average evaporation exceeding 250 mm/month from September to April. Even in the average wettest summer months of January and February, evaporation exceeds average monthly rainfall approximately threefold. The evaporation rate is primarily temperature-related, with the highest mean monthly evaporation occurring in November and the lowest mean in June.

Climate data for BCP has been obtained from the SILO database (https://www.longpaddock.qld.gov.au/silo/point-data/) (Queensland Government, 2022). Average monthly rainfall and evaporation SILO data at BCP is presented in Plate 8.

The climate data shows the following:

- The average annual temperature is 32.1°C at Mt Isa and 33.4°C at Cloncurry. The warmest month, on average, is December, and the coolest month is June/July.
- The average annual rainfall is 459 mm at Mt Isa and 495 mm at Cloncurry.
- The highest rainfall occurs mostly in the wet summer from October/November to March.
- Monthly evaporation rates exceed rainfall every month of the year, even during the wet season. Evaporation is greatest in summer, with average evaporation exceeding 250 mm/month from September to January.

The Cumulative Rainfall Departure (CRD) from normal rainfall (Plate 9) is a concept sometimes utilised to evaluate the temporal correlation of rainfall with surface water or groundwater levels. A general analysis approach is that:

- a positive slope (upward) indicates a wetter than average period resulting in potential recharge that increases groundwater storage
- a negative slope (downward) indicates a drier-than-average period resulting in potentially limited recharge events that reduce groundwater storage. Water levels generally decline, resulting in a reduction of available drawdown and recovery rates in the boreholes.

The CRD graph in Plate 9 shows prolonged periods of below long-term average rainfall and/or negative slopes between 1920 and 1996, with an upward trend from 1996 to 2013. From 2013 onwards, the CRD trend has mainly been downwards.

Table 7 Monthly climate statistics for Mount Isa Airport station (BOM station 029127)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Mean maximum temperature (°C)	36.6	35.5	34.5	32.1	28	25	24.9	27.5	31.5	34.9	36.6	37.4	32
Mean minimum temperature (°C)	23.9	23.3	21.8	18.5	13.9	10	8.7	10.2	14.2	18.6	21.5	23.1	17.3
Rainfall													
Mean rainfall (mm) for years 1966 to 2023	115.2	101.9	63.5	13.5	11.6	6.9	6.1	3.4	8.8	19.2	38.8	72	460.7
Highest rainfall (mm) for years 1966 to 2023	535.2	278.2	276.6	167.8	176.4	111.8	67.4	41.8	117	91.4	205.6	275.2	1092.4
Lowest rainfall (mm) for years 1966 to 2023	0.2	2.2	0	0	0	0	0	0	0	0	0	0	93.4
Decile 5 (median) monthly rainfall (mm) for years 1966 to 2023	75.5	85.6	39.5	1.4	1.2	0.1	0	0.4	0.3	10.4	27.3	59.2	421.2
Mean number of days of rain >= 1 mm for years 1966 to 2023	7.9	7	4.2	1.4	1.1	0.7	0.6	0.5	1	2.4	4	5.8	36.6
Mean number of days of rain >= 10 mm for years 1966 to 2023	3.2	2.9	1.7	0.4	0.4	0.3	0.2	0.1	0.2	0.6	1.3	2	13.3
Mean number of days of rain >= 25 mm for years 1966 to 2023	1.4	1.3	0.9	0.2	0.1	0.1	0.1	0	0.1	0.1	0.3	0.9	5.5
Other daily elements													
Mean daily sunshine (hours) for years 1975 to 2016	8.7	8.8	9	9.6	9.4	9.5	9.8	10.4	10.3	10	9.7	9.3	9.5
Mean number of clear days for years 1966 to 2010	6	5	10.5	13.3	16	19.8	22.3	23.1	20.1	17.9	12.1	9.3	175.4
Mean number of cloudy days for years 1966 to 2010	11.4	10.4	8	4.7	5.2	3.2	2.8	2	2.2	3.4	5.4	8.2	66.9
Evaporation													
Mean daily evaporation (mm) for years 1975 to 2016	9.6	8.9	8.9	8.3	6.4	5.3	5.5	6.9	8.9	10.5	11	10.5	8.4
9 am conditions													
Mean 9am temperature (°C) for years 1966 to 2012	28.9	27.9	27	24.5	19.8	15.9	15.2	17.8	22.6	26.8	29	29.7	23.8
Mean 9am relative humidity (%) for years 1966 to 2012	52	58	49	42	46	50	45	37	31	29	33	41	43
Mean 9am wind speed (km/h) for years 1966 to 2012	11.8	11	12	13.3	11.4	10.2	10.1	12.1	15.1	16.2	15.2	13.4	12.6
3 pm conditions													
Mean 3pm temperature (°C) for years 1966 to 2010	34.6	33.8	33.1	30.9	27	24.1	23.8	26.2	30	33.3	34.8	35.4	30.6
Mean 3pm relative humidity (%) for years 1966 to 2010	35	38	32	27	29	28	25	20	18	18	22	27	27
Mean 3pm wind speed (km/h) for years 1966 to 2010	14.3	13.9	14.3	14	12.8	13.1	13	13.8	13.4	13.8	13.8	13.6	13.6

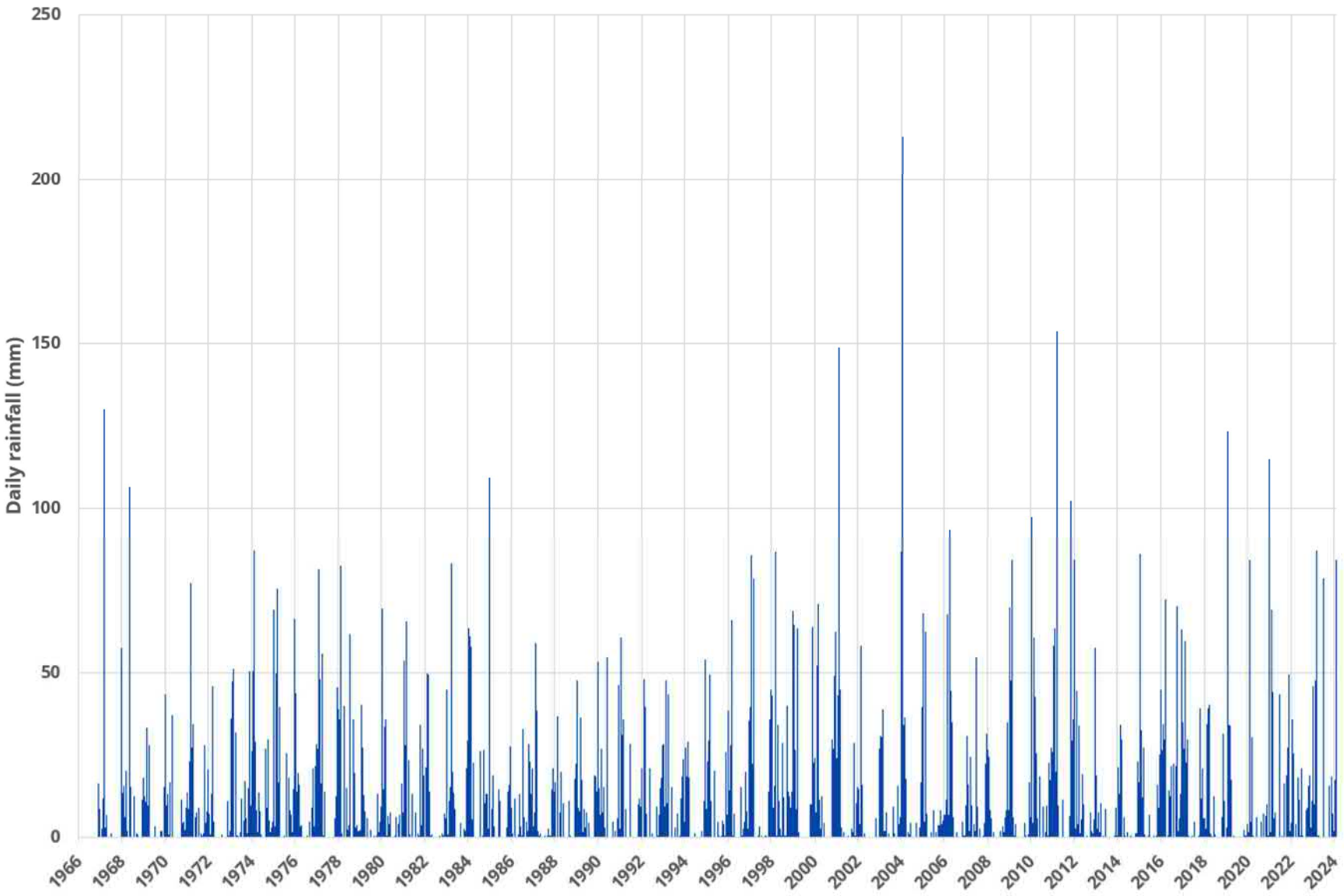


Plate 7 Daily Rainfall (mm) from Mount Isa Aero weather station 029127

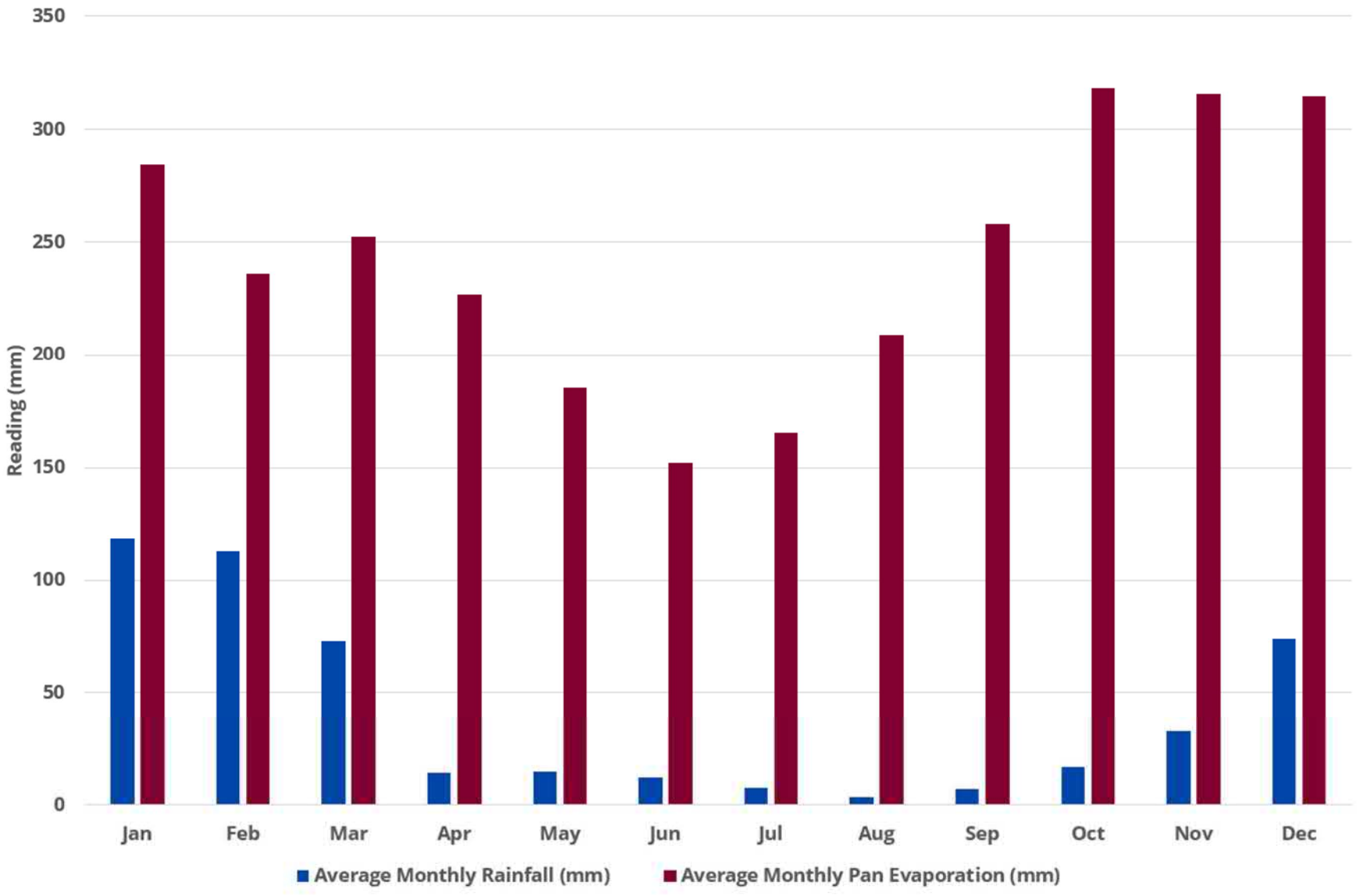


Plate 8 Average monthly rainfall (mm) and pan evaporation (mm) from SILO data

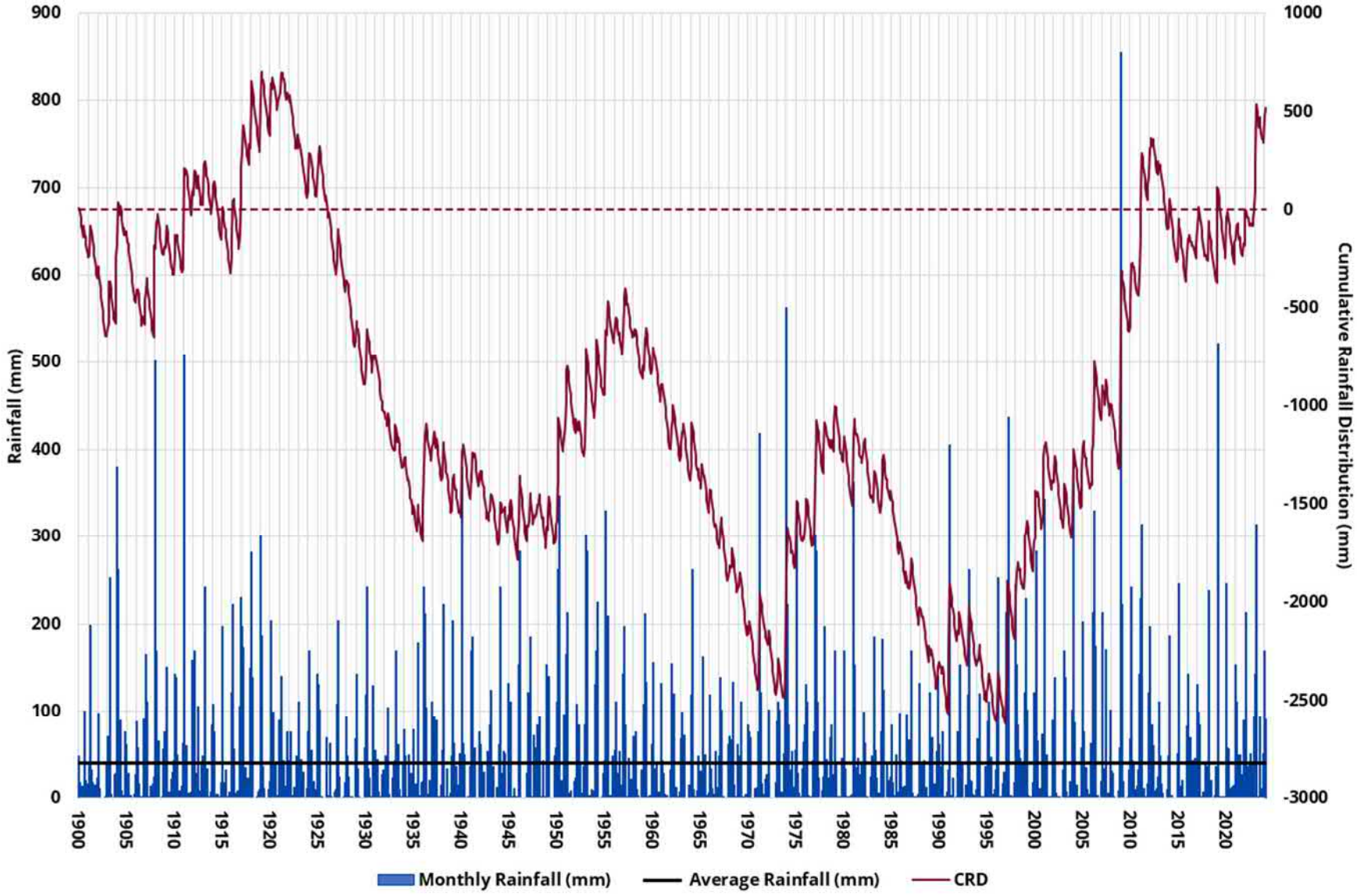


Plate 9 Cumulative Rainfall Distribution for BCP

4.2 Topography

Figure 4 shows the pre-mining 2014 topography, whilst Figure 5 shows the 2021 topography based on a LiDAR survey undertaken by ROM. Since 2021, no site operations that would significantly alter the topography have been undertaken at BCP.

The elevation at and near BCP ranges from 330 m Australian Datum Height (AHD) on the west side of the mine area to approximately 390 m (AHD) on the south side of the project area (GeoResGlobe 2022).

4.3 Geomorphology and landforms

The Project site is largely situated on rocky undulating hills and outcropping, rocky ridgelines in the Mount Isa Inlier of the northwest Highlands Bioregion (AARC, 2014b; AARC, 2014c).

Syndicated Metals Ltd (2014) describes the geomorphology and drainage characteristics at BCP as follows:

> *"There are three main landform types in the Barbara area. These are: erosional hills, ridges and plateaus, colluvial footslopes and alluvial channels. The area is dominated by exposed and subcropping Proterozoic rocks forming the hills and plateaus which dominate the landscape. Small areas of proximal colluvium are found as footslopes flanking the sides of ridges and at the base of scarps. Minimal alluvial sediments are found in immature drainage systems."*

4.4 Vegetation

Regional ecosystems

Table 8 and Figure 6 present the pre-clear regional ecosystems within BCP mapped under the *Vegetation Management Act 1999*.

Table 8 Site preclear regional ecosystems

RE	VM Act 1999 Status	Biodiversity status	RE description
12.3.10a	Endangered – Dominant vegetation	E	Eucalyptus populnea woodland on alluvial plains
12.9-10.6/ 12.9-10.2	Endangered – Dominant vegetation	E/NC	Acacia harpophylla open forest on sedimentary rocks/ Corymbia citriodora subsp. variegata +/- Eucalyptus crebra open forest on sedimentary rocks

RE: regional ecosystem

There are no identified remnant regional ecosystems at BCP.

2014 flora survey (AARC)

AARC conducted flora surveys before mining to assess vegetation communities and ecological values. Survey timing was selected per the '*Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland*' (Neldner *et al*., 2017). Seven vegetation communities were identified across the Project site, all classified as remnant vegetation. No flora species of conservation significance were found in the Investigation Area (AARC, 2014c).

A summary of the vegetation communities is provided in Table 9 and Plate 10. The following vegetation has been known to have a moderately to high dependency on groundwater:

- Eucalyptus camaldulensis
- Eucalyptus leucophloia and Eucalyptus leucophylla
- Eucalyptus persistens
- Eucalyptus normantonensis

Table 9 Pre-mining vegetation communities at BCP

Community	Description	Regional Ecosystem
1	Low Open Woodland of Snappy Gum (Eucalyptus leucophloia) on metamorphic hills	1.11.2d - Low open woodland of Eucalyptus leucophloia often with E. leucophylla, Corymbia spp., Terminalia aridicola and/or Brachychiton collinus on rock outcrops with a very sparse shrub layer of Acacia spp. and a sparse to very sparse ground layer of Triodia pungens. Occurs on steep rocky slopes and crests on metamorphosed igneous rocks.
2	Low Open Woodland of Cloncurry Box (Eucalyptus leucophylla) and Bloodwood (Corymbia terminalis) on Metamorphic hills	1.11.3 - Low open woodland of Corymbia terminalis usually with Eucalyptus leucophylla or E. leucophloia with Acacia spp. dominated shrub layer and ground layer of Triodia spp. and/or tussock grasses. Includes areas of Acacia spp. shrubland and Triodia spp. grassland. Occurs on metabasalts and dolerites; skeletal soils, some shallow loams.
3	Low Open Woodland of Cloncurry Box (E. leucophylla) on Alluvial Flats	1.3.6x1b - Floodplain (other than floodplain wetlands). Eucalyptus leucophylla woodland with a mid-dense ground layer dominated by tussock grasses. Occurs on narrow terraces.
4	River Red Gum (Eucalyptus camaldulensis) and Northern Swamp Box (Lophostemon grandiflorus) Riparian Woodland	1.3.7b - Riverine wetland or fringing riverine wetland. Fringing woodland of Eucalyptus camaldulensis, usually with Lophostemon grandiflorus and Melaleuca bracteata and/or M. dissitiflora. Occurs on recent levees and channel deposits of medium and smaller tributaries which are dry for most of the year; alluvial soils.
5	Low Open Woodland of Arid Peach (Terminalia aridicola) on Rocky Outcrops	1.11.2x4: Low open woodland of Terminalia aridicola, often with Brachychiton collinus, Alphitonia spp. and Corymbia aspera with mid-dense shrub layer of Acacia spp. and ground layer of mixed tussock grasses and Triodia spp. Occurs on rock outcrops on hills and ranges on strongly folded siliceous sedimentary and metamorphic pre-Cambrian rocks.
6	Capricornia (Corymbia Capricornia) Ridges	1.11.2x1b: Low open woodland of Eucalyptus herbertiana and/or Corymbia capricornia, mixed shrub layer and ground layer of Triodia pungens and tussock grasses. Occurs on hills on Surprise Creek Formation.
7	Low Open Woodland of Cloncurry Box (E. leucophylla) and Bloodwood (C. terminalis) on granites	1.12.1x1: Low open woodland of Eucalyptus leucophylla often with Corymbia terminalis or C. aparrerinja, shrub layer of Acacia chisholmii with hummock grass ground layer of Triodia spp. Includes areas of treeless Triodia spp. grasslands and Acacia spp. shrublands. Occurs on ranges and stony hills and rises on igneous rocks; skeletal soils and some shallow red earths.

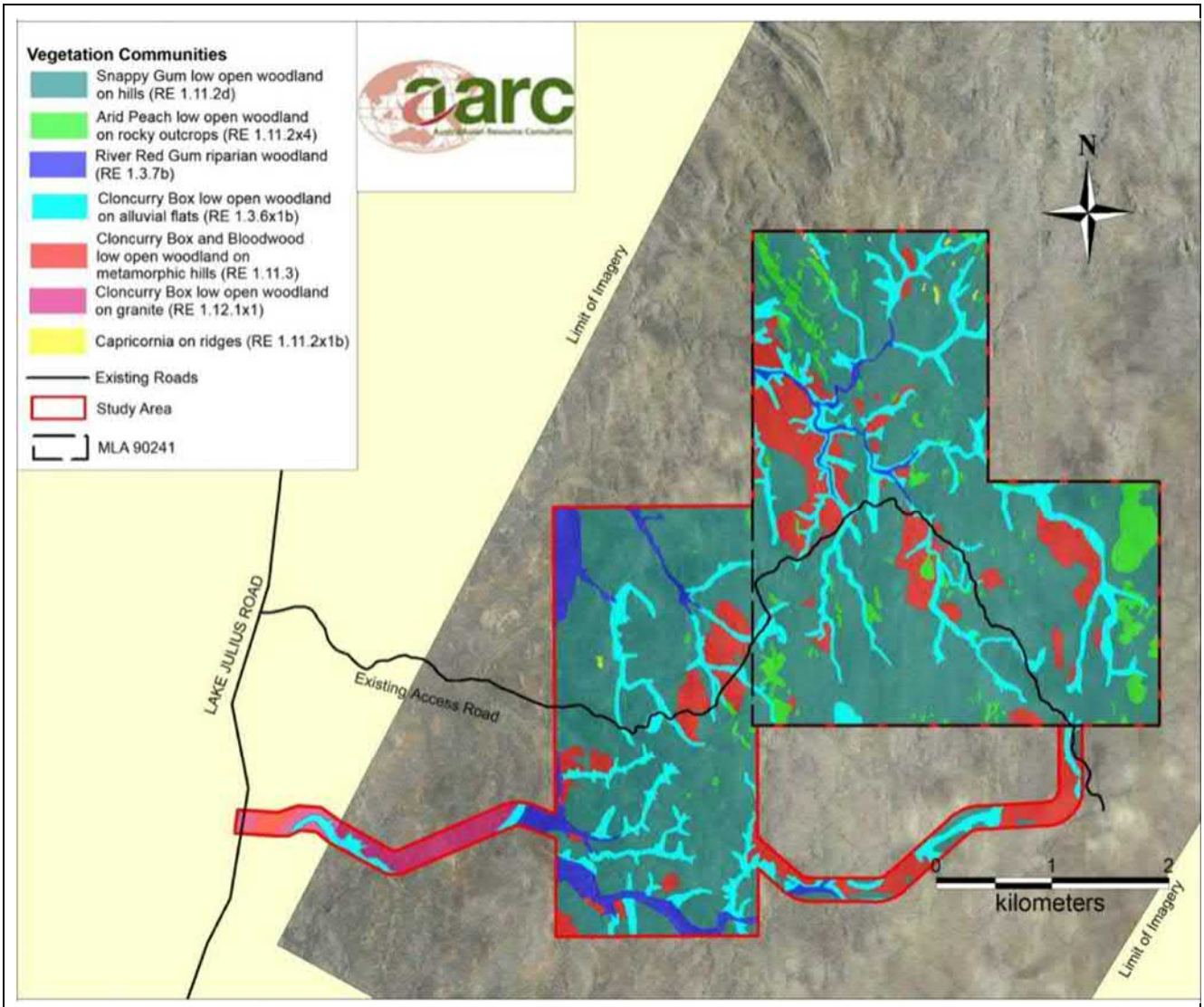


Plate 10 Pre-mining vegetation communities at BCP

4.5 Surface water and hydrology

4.5.1 Drainage basins and catchments

BCP lies within the Leichardt drainage basin, which spans an area of approximately 32,878 km^2, originating from the south of Mount Isa and draining via the Leichardt River into the Gulf of Carpentaria (AARC, 2014c).

Relevant drainage basin details are as follows:

- Drainage Division: Gulf (Division IX)
- Drainage Basin: Leichardt (Basin number 913)
- Drainage Sub-Basin: Leichardt River (sub number 9130)

Under the *Water Act 2000*, water plans are developed to sustainably manage and allocate water resources in Queensland. A water plan may apply to rivers, lakes and springs; overland flow and/or underground water.

BCP is within the *Water Plan (Gulf) 2007* water plan (State of Queensland, 2018). Relevant details are as follows:

- Water Plan Catchment: Leichardt River Catchment
- Water Plan Sub-Catchments: Upper Leichardt River sub-catchment + Lower Leichardt River sub-catchment

4.5.2 Watercourses and water bodies

Watercourses

There are no major watercourses in and near BCP. The BCP area is traversed by numerous drainage lines and ephemeral watercourses that only flow after heavy rainfall and drain into the Leichhardt River (Figure 7).

Drainages tend to drain to the northwest, down from the steeper hills in the south and through the central BCP area. Deposition of alluvium within drainage systems is minimal, and no paleochannels are present in the area.

One larger, third-order watercourse flows through the south-western and north-western areas of the BCP area. Except for one stream order 3 watercourse, all other watercourses near BCP are classified as stream orders 1 and 2. The third order watercourse passes from the east, through the south-west portion of BCP, flows west, off-site and returns through the western boundary in the north before heading off-site and draining north-west into the Leichhardt River.

All other drainage lines and tributaries at BCP drain into the third-order watercourse. The Leichhardt River eventually drains into the Gulf of Carpentaria.

Water bodies

There are no wetlands, dams, rockpools, lakes or reservoirs mapped within a 5km radius of mining lease ML90241.

Springs and groundwater seeps

In July 2021, a body of water was identified within an unnamed drainage feature at the BCP. The waterbody was approximately 450m to the north and downgradient of the waste rock dump (WRD), 100m to the north of the WRD Sediment Dam, and about 40m to the west of the run-of-mine (ROM) pad. Given the highly ephemeral nature of the watercourses within the vicinity of the project, the water body was determined to be a spring (the 'BCP Spring') at the time.

The presence of standing water downgradient of the WRD Sediment Dam was also noted at the spring location during the 2021 pre-wet season inspection conducted by the then Department of Environment and Science (DES, now DESI) on 16 August 2021. The spring was not recorded as a matter of concern during the inspection outcome letter dated 1 September 2021. DES informally requested the inclusion of the waterbody in subsequent receiving environment monitoring surveys.

Section 6.8 provides more information and discussion on the occurrence of springs/seeps within the creeks and drainage lines at and near BCP.

4.5.3 Surface water Environmental Values and Water Quality Objectives

The purpose of the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EPP Water and Wetland Biodiversity) is to achieve the object of the *Environmental Protection Act 1994* (EP Act) in relation to waters and wetlands. That is, protecting Queensland's water environment while allowing for development that is ecologically sustainable.

Environmental values (EVs) and water quality objectives (WQOs) are being progressively determined for Queensland waters. EVs define the uses of the water by aquatic ecosystems and for human uses

(e.g. drinking water, irrigation, aquaculture, recreation). WQOs define objectives for the physical, chemical and biological characteristics of the water (e.g. nitrogen content, dissolved oxygen, turbidity, toxicants, fish).

The management intent for waters is stated in section 15 of the EPP Water and Wetland Biodiversity. For waters of high ecological value, the water quality is to be maintained. For slightly disturbed waters, the water quality is to be improved where needed, to achieve the WQOs. For moderately disturbed waters, water quality is to be maintained, or improved where needed, to meet the WQOs. In highly disturbed waters, water quality is to be improved so that it achieves the WQOs.

As EVs and WQOs are established for Queensland waters in accordance with the EPP Water and Wetland Biodiversity, after approval they are included in Schedule 1. For waters not included in Schedule 1, the EVs and WQOs are respectively determined in accordance with section 6 and section 11 of the EPP Water and Wetland Biodiversity.

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) include a management framework adopted in the EPP Water and Wetland Biodiversity.

To date, no EVs or WQOs have been determined for the Leichardt River catchment.

4.5.4 Surface water quality characteristics

Section 7 provides a detailed discussions on the surface water monitoring results that are relevant for this groundwater technical report.

4.6 Soils

A Soil and Land Suitability Assessment (SLSA) was conducted by AustralAsian Resource Consultants Pty Ltd (AARC, 2014) to classify soil types, assess the suitability of topsoil material and identify potential management limitations associated with soil characteristics at the Project site.

Three broad Soil Management Units (SMU) were confirmed within the study area, dominated by moderately undulating lands with much rock outcrop and quartz gravels dominated by shallow gravel-strewn loams. Rock outcrops dominate up to 20 % of the study area, with slopes over 25% typically constituting areas of exposed rock. The SMUs are (Plate 11):

- SMU 1 - River Red Gum Sands restricted to higher-order drainage lines and ephemeral watercourses;
- SMU 2 - Cloncurry Box Drainage Terraces occurring along terraces adjacent open drainage depressions; and
- SMU 3 - Snappy Gum Slopes on steep low hills.

SMU 1 soils have a high gravel and cobble content, with abundant rounded coarse fragments and a loose surface. Finer soil material has often been removed via alluvial action, with occasional evidence of distinct depositional horizons associated with stream flow and regular and prolonged inundation. These areas are sparsely covered with surface vegetation but associated with larger river red gum and riverine species.

Soils of SMU 2 typically have lower fine gravel content but have larger (20-60+ mm) sub-rounded to rounded fragments present throughout the profile. This soil also constitutes a Tenosol classification. Within SMU 2 there is evidence of very minor areas of gully erosion associated with the ephemeral watercourses which transect SMU 2; however, soil chemistry is not strongly indicative of a predisposition to erosivity or dispersion.

SMU 3 consist of slopes of clayey sands to sandy clay loams with moderate to high gravel content (coarse fragment size: 6-20mm and 20-60mm; shape: angular) on steep low hills. These areas are

often dominated on the steeper slopes by extensive areas of rock outcrop. Slopes within the SMU vary from 0 – 20+ % with an average of 6%.

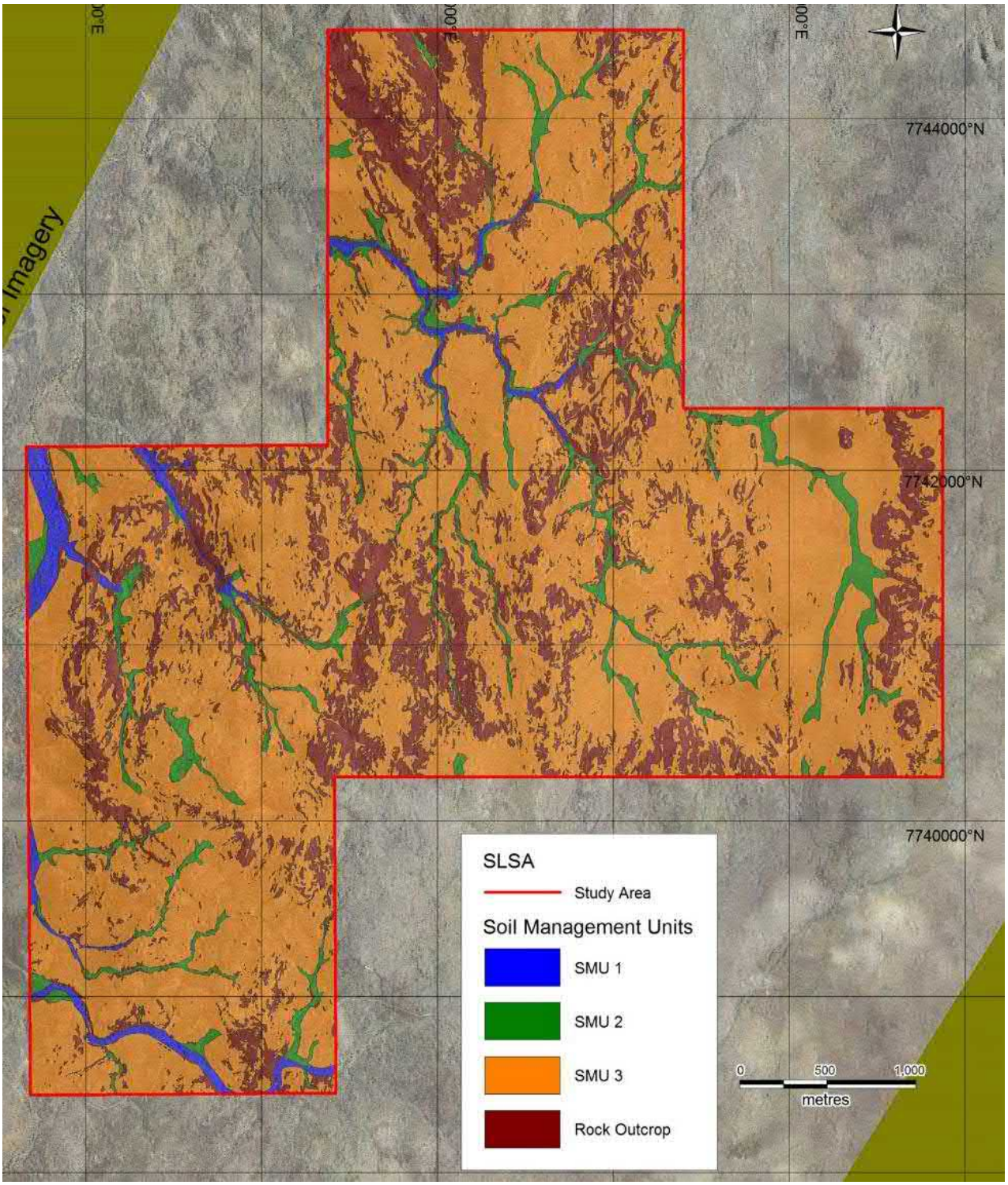


Plate 11 Distribution of soil management units within the Project area

5 Geology

5.1 Local geology

The BCP orebody at the Project site is hosted within the Leichardt Metamorphics within the Kalkadoon-Leichhardt belt of the Mt Isa Inlier. The regional geology is presented in Figure 10, which shows a segment of the *Cloncurry, Queensland 1:250,000 Geological Series map* (Department of Mines, Queensland and Bureau of Mineral Resources, Geology and Geophysics, 1983). The area is structurally complex, with structural repetition of stratigraphic units and wrench faulting common.

Syndicated Metals Ltd (August 2014) describes the local geology of the Barbara Copper Project site as follows:

> *"Bedrock geology in the area comprises Proterozoic rocks of the Mount Isa Inlier. Rock types at Barbara include felsic volcanics (forming the hills), dolerite/amphibolite (in the drainages/valleys) and basalt (forming plateaus). The felsic volcanics are the dominant rock type in the project area. The felsic and mafic volcanics dip at 60 degrees towards the northeast and the dolerites are sub-vertical within the project area. These three rock types are resistant to weathering and extensive outcrop occurs throughout the area."*

The orebody is located within what is informally termed as the Barbara Shear Zone, which is a shear-hosted deposit within the acid volcanics. The NW striking lode dips at approximately 60° to the southwest and varies from 2m to 30m true thickness.

5.2 Geochemistry

The Barbara deposit lies within the Mount Isa Inlier. The copper-gold-silver-cobalt mineralisation is structurally controlled by the Barbara Shear Zone and occurs as a series of sulfide lodes hosted within a package of felsic volcanic rocks intruded by dolerite dykes.

Sulfide mineralisation comprises semi-massive pyrrhotite/pyrite with chalcopyrite and chalcopyrite stringer veins. Two phases of mineralisation occur with a low-grade copper-cobalt phase overprinted with a later coarse-grained, chalcopyrite-gold-silver phase, forming both hangingwall and footwall zones of higher-grade mineralisation.

The copper sulphide in the area can occur close to the surface with a maximum thickness of 45 m and consists of massive sulphide through to stringer veins within an alteration zone of biotite, tourmaline and quartz. The weathering profile averages around 15 m deep.

An assessment of geochemical characteristics of waste rock and ore material at Barbara was conducted by the Environmental Geochemistry International Pty Ltd (EGI). A total of 121 drill core samples from 14 locations were analysed. Most samples representing waste had low sulphur contents and were non-acid forming (NAF) but there were some waste samples from close to mineralised zones that had elevated sulphur contents and were potentially acid-forming (PAF). Ore samples had high sulphide contents and approximately half of the ore samples tested were PAF.

The Australian Standard Leaching Procedure testing on waste rock samples showed that all of the freshly mined waste rock is expected to be alkaline, with pH values ranging between 8.6 -9.0.

On average, sulphate concentrations for PAF waste were slightly higher than for NAF waste. Other differences were relatively minor. Most extracts had trace concentrations of aluminium (median 0.19 mg/L). Still, the concentrations of copper and other environmentally important elements were low, and in most cases, the concentrations were close to, or below, the analytical detection limits. The Australian Standard Leaching Procedure testing on ore material recorded that all samples were slightly alkaline and that the concentrations of environmentally important elements were low, with the possible exception of manganese which for the ore samples exhibited a median concentration of 0.16 mg/L compared to 0.001 mg/L for the waste samples (EGI, 2014).

6 Hydrogeological settings

6.1 Water resource planning areas

The Project site is located within the *Water Plan (Gulf) 2007* (State of Queensland, 2018). The water plan applies to "underground water" that is not water to which the *Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017* (State of Queensland, 2017) applies.

The Project site is not within any groundwater management area defined within either water plan.

6.2 Registered groundwater bores

A search for registered water bores within a 5km radius of the project site was undertaken in June 2022 through the Queensland Globe. Thirty (30) registered bores were identified, with locations shown in Figure 11 and Figure 12 and relevant details in Table 10. Bore cards are attached in Appendix C. Most registered bores were mine monitoring bores, with only four bores designated as having a "water supply" role. Three "water supply" bores located within the ML are bores drilled and installed by the mining company owning the mining lease. None of these bores are currently operational for water supply purposes nor are intended to be in the future.

Table 10 Registered water bores within 10 km of the Project site

Registered Number	Date Drilled	Original Name	Status	Latitude	Longitude	Roles	Comments
Inside ML90241							
146948	26-Jan-14	BAWB03	Existing	-20.4103073	139.848289	Mine monitoring	MT BARBARA
146949	30-Jan-14	BAWB04	Existing	-20.4160841	139.850251	Mine monitoring	MT BARBARA
146950	31-Jan-14	BAWB01	Existing	-20.424750	139.853915	Mine monitoring	MT BARBARA
146951	1-Feb-14	BAWB05	Existing	-20.4324213	139.858801	Mine monitoring	MT BARBARA
146952	2-Feb-14	BAWB02	Existing	-20.4129705	139.844879	Mine monitoring	MT BARBARA
146953	4-Feb-14	BARC071	Existing	-20.4171471	139.848477	Water supply	
146954	5-Feb-14	BARC065	Existing	-20.4191827	139.850315	Water supply	
163352	4-Oct-14	BOWBR1	Existing	-20.4261718	139.85256	Mine monitoring	SYNDICATED METALS LTD
163353	25-Sep-14	-	Abandoned and Destroyed	-20.4156453	139.842863	Mine monitoring	SYNDICATED METALS LTD
163359	4-Oct-14	BAWBR 3	Abandoned and Destroyed	-20.42122	139.849712	Mine monitoring	SYNDICATED METALS PTY LTD
163360	4-Oct-14	BAWBR 2	Abandoned and Destroyed	-20.4230761	139.848941	Mine monitoring	SYDICATED METALS PTY LTD
163369	29-Sep-14	WB ""B""	Abandoned and Destroyed	-20.4272295	139.855607	Mine monitoring	SYNDICATED METALS PTY LTD
184264	15-Jul-19	SB3A	Existing	-20.4244177	139.849621	Mine monitoring	BARBARA COPPER PROJECT
184265	15-Jul-19	SB3B	Existing	-20.4244177	139.849621	Mine monitoring	BARBARA COPPER PROJECT
184266	16-Jul-19	SB2A	Existing	-20.4245647	139.849984	Mine monitoring	BARBARA COPPER PROJECT
184267	16-Jul-19	SB2B	Existing	-20.4245647	139.849984	Mine monitoring	BARBARA COPPER PROJECT
184268	16-Jul-19	SB1A	Existing	-20.425183	139.850583	Mine monitoring	BARBARA COPPER PROJECT
184269	16-Jul-19	SB1B	Existing	-20.425183	139.850583	Mine monitoring	BARBARA COPPER PROJECT
184270	26-Jul-19	SB4A	Existing	-20.4279796	139.856802	Mine monitoring	BARBARA COPPER PROJECT
184271	26-Jul-19	SB4B	Existing	-20.4279796	139.856802	Mine monitoring	BARBARA COPPER PROJECT
184272	28-Jul-19	-	Existing	-20.4160442	139.848344	Water supply	
Outside ML90241							
37655	18-Oct-71	GOANNA HOLE	Abandoned and Destroyed	-20.4068254	139.813691	-	
163354	26-Sep-14	WBE	Existing	-20.4451634	139.849869	Mine monitoring	SYNDICATED METALS LTD
163355	27-Sep-14	WBF	Abandoned and Destroyed	-20.4469011	139.850326	Mine monitoring	SYDICATED METALS LTD

Registered Number	Date Drilled	Original Name	Status	Latitude	Longitude	Roles	Comments
163356	28-Sep-14	WBO	Abandoned and Destroyed	-20.4433479	139.859554	Mine monitoring	SYNDICATED METALS LTD
163358	3-Oct-14	-	Abandoned and Destroyed	-20.4285718	139.811664	Mine monitoring	SYNDICATED METALS PTY LTD
163368	28-Sep-14	WB ""C""	Abandoned and Destroyed	-20.4433574	139.859395	Mine monitoring	SYNDICATED METALS LTD
163370	1-Oct-14	WB ""G""	Existing	-20.3908895	139.8197	Mine monitoring	SYNDICATED METALS PTY LTD
163371	2-Oct-14	STOCK YARDS	Abandoned and Destroyed	-20.3815216	139.806405	Mine monitoring	SYNDICATED METALS PTY LTD
184209	11-Apr-14	-	Existing	-20.3627075	139.80284	Water supply	

6.3 Groundwater Dependent Ecosystems (GDE)

Information relating to groundwater-dependent ecosystems (GDEs) within and surrounding the Project site was obtained from the following sources:

- The Queensland Globe (State of Queensland, 2022) (https://qldglobe.information.qld.gov.au/).
- BOM Groundwater Dependent Ecosystem Atlas (GDE Atlas) (Commonwealth of Australia, 2022) (http://www.bom.gov.au/water/groundwater/gde/map.shtml).

The search results indicate the following:

- No GDEs were identified through the Queensland Globe within a 5km radius of the project site.
- No aquatic or subterranean GDEs were identified through the BOM GDE Atlas within a 5km radius of the Project site.
- Terrestrial GDEs identified through the BOM GDE Atlas within the 5km radius (Figure 13) are presented in Table 11. Only the low-potential terrestrial GDEs are present within ML90241.

Table 11 Terrestrial GDEs within 5km of Project Site (BOM GDE Atlas)

GDE Potential	Vegetation Type
High potential GDE - from national assessment	Eucalyptus spp. dominated open-forest and woodlands drainage lines and alluvial plains.
Moderate potential GDE - from national assessment	Eucalyptus spp. (E. leucophloia, E. leucophylla, E. persistens, E. normantonensis) low open-woodlands often with Triodia spp. dominated ground layer.
Low potential GDE - from national assessment	Eucalyptus spp. (E. leucophloia, E. leucophylla, E. persistens, E. normantonensis) low open-woodlands often with Triodia spp. dominated ground layer.

6.4 Groundwater beneficial use and environmental values

A search of groundwater bores on Queensland Globe (Section 6.2) indicates there are 30 registered bores within 10 km of the Project site, as follows:

- Twenty-five (25) of these bores are mine monitoring bores, several of which have been abandoned and destroyed.
- Five (5) bores are privately owned. However, one has been abandoned and destroyed, and two have been drilled for the Barbara Copper Project. Only two bores (RN184209 and RN184272) are genuinely private and exist.

Concerning potential beneficial use of the groundwater:

- No homesteads within the immediate vicinity of the Project area would rely on groundwater for drinking water or domestic use. However, the two private, existing bores could potentially be used for farm water supply (e.g. livestock watering or irrigation).
- The Project site is not situated near any township, and the surrounding landscape is not likely to be utilised by the public for recreational purposes.
- No aquaculture practices or industrial activities are occurring in the surrounding landscape.
- Terrestrial GDEs have been identified within 5km of the Project site.

Based on the above, groundwater environmental values applicable to the Project under the EPP Water and Wetland Biodiversity (DES, 2019) would include the following:

- Aquatic ecosystems – slightly to moderately disturbed waters – the biological integrity of high ecological value waters with slightly modified physical or chemical indicators but effectively unmodified biological indicators.
- Stock watering – suitability of water supply for the production of healthy livestock.
- Cultural and spiritual values – custodial, spiritual, cultural and traditional heritage, hunting, gathering and ritual responsibilities.

6.5 Stygofauna

Stygofauna are small aquatic invertebrates that spend their entire lives below the surface in groundwater. A pilot survey for stygofauna was conducted at the BCP and consisted of two field sampling events, sampling 10 bores in January and 9 bores in April 2014 (AARC, 2014b). Survey design and sampling were conducted in accordance with the Western Australian (WA) Environmental Protection Authority's *Environmental Assessment Guideline No. 12: Consideration of Subterranean Fauna in Environmental Impact Assessment in WA* (WA EPA 2013) and *Draft Guidance Statement 54a Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia* (WA EPA 2007).

Sampling was conducted to ascertain the presence (or absence) of stygofauna and the significance of stygofaunal communities within the zone of impact (groundwater dewatering).

The stygofauna identified during the pilot study included:

- two individuals of the Diptera taxa (stygoxenes)
- three insect species (Collembola, Coleoptera and Thysanura), although these are classified as troglobites, not stygofauna
- twelve Tubificida individuals
- two Parabathynellidae individuals.

Results indicate that the BCP site yielded a comparatively low abundance and diversity of taxa compared with other Stygofauna sampling sites across Australia. Although not represented in the area beyond the BCP site, these taxa are expected to be identified in groundwater associated with similar geological attributes likely.

6.6 Local aquifers

During the drilling of monitoring bores BAWB01 to BAWB05 and BARC07 in early 2014, the following observations were made (RLA, 2014):

- Shearing in Barbara Shear Zone is almost vertical and pervasive to several hundred metres.
- The most productive aquifer intervals are either in the orebody itself or where a combination of shearing and quartz veining occurs.
- Quartz veining is suspected to be generally massive (Michael Martin, Syndicated Metals, pers. comm.).
- Shearing is not constrained to any particular lithology because it is a shear zone.
- There is no predictable depth pattern for the occurrence of aquifer intervals. This is typical of sheared fractured rock terrain.
- Airlift yields are highly variable. This is typical of fractured rock aquifers.
- BAWB01 and BARC071 were the most productive in terms of airlift yield.
- Drilling and construction logs show no groundwater at all at depths of less than 19m below the ground surface.

- Three of the groundwater monitoring bores encountered no free groundwater at all during drilling. Two of these bores (BAWB02 and BAWB04) subsequently slowly 'made' water.

Based on the historical investigations undertaken for Syndicated Metals Ltd, the occurrence of aquifer/groundwater bearing systems can be described as follows:

- The primary aquifer occurs within the Leichardt Metamorphics, generally at the base of the weathered zone.
- Syndicated Metals (2014) has extensively investigated the regolith and has concluded that there is almost no potential for the development of regolith aquifers. There is little regolith at the Project site and no regolith aquifers are identifiable.
- Syndicated Metals (2014) reports that deposition of alluvium within drainage systems is minimal, and there are no paleochannels in the area. There is little or no potential for the development of alluvial aquifers at the Project site.

6.7 Aquifer hydraulic properties

Airlift yield testing in ore body

Five of the RC mineral exploration drill holes in the ore body were selected for airlift yield (ALY) testing (RLA, 2014). Details of the results of the airlift yield testing program are shown in Table 12, and graphs of the airlift yields against time are shown in Plate 12.

The airlift yield testing program illustrated that groundwater yield from the orebody inevitably declined as airlifting continued over two hours. The airlift yield testing program results suggest groundwater depletion of the orebody under continuous extraction (either by pumping or groundwater inflow to open pits).

Table 12 Mineral Exploration Bore Airlift Yield Test Results (RLA, 2014)

	BARC057		BARC042		BARC039		BARC065		BARC025	
Hole Depth (m)	144		162		70		126		62	
Water Level (mbgl)	20		11		9		27		2	
Time (mins)	Height above V-Notch (mm)	Flow rate (L/s)	Height above V-Notch (mm)	Flow rate (L/s)	Height above V-Notch (mm)	Flow rate (L/s)	Height above V-Notch (mm)	Flow rate (L/s)	Height above V-Notch (mm)	Flow rate (L/s)
5	66	1.6	27	0.2	40	0.5	65	1.5	30	0.2
10	65	1.5	24	0.1	39	0.4	60	1.2	26	0.2
15	65	1.5	23	0.1	39	0.4	59.5	1.2	26	0.2
20	63	1.4	22	0.1	38	0.4	59	1.2	25	0.1
25	62.5	1.4	22	0.1	38	0.4	59	1.2	24	0.1
30	62	1.3	22	0.1	37	0.4	58	1.1	23.5	0.1
35	61	1.3			37	0.4	57.5	1.1	23	0.1
40	61	1.3			35	0.3	57	1.1	23	0.1
45	60	1.2			35	0.3	56	1.0	22.5	0.1
50	60	1.2			35	0.3	55	1.0	22.5	0.1
55	59.5	1.2			34.5	0.3	54	1.0	22	0.1
60	59	1.2			34	0.3	53	0.9	22	0.1
65	58	1.1			34	0.3	53	0.9		
70	58	1.1			34	0.3	52.5	0.9		
75	56.5	1.1			34	0.3	52	0.9		
80	56	1.0			33.5	0.3	52	0.9		
85	56	1.0			33.5	0.3	51.5	0.8		
90	56	1.0			33	0.3	51	0.8		
95	55	1.0			32.5	0.3	50.5	0.8		
100	55	1.0			32.5	0.3	50	0.8		
105	54.5	1.0			32.5	0.3	49.5	0.8		
110	54	1.0			33	0.3	49	0.7		
115	54	1.0			33	0.3	48.5	0.7		
120	54	1.0			33	0.3	48.5	0.7		

	BARC057		BARC042		BARC039		BARC065		BARC025	
Hole Depth (m)	144		162		70		126		62	
Water Level (mbgl)	20		11		9		27		2	
125	54	1.0								
130	54	1.0								

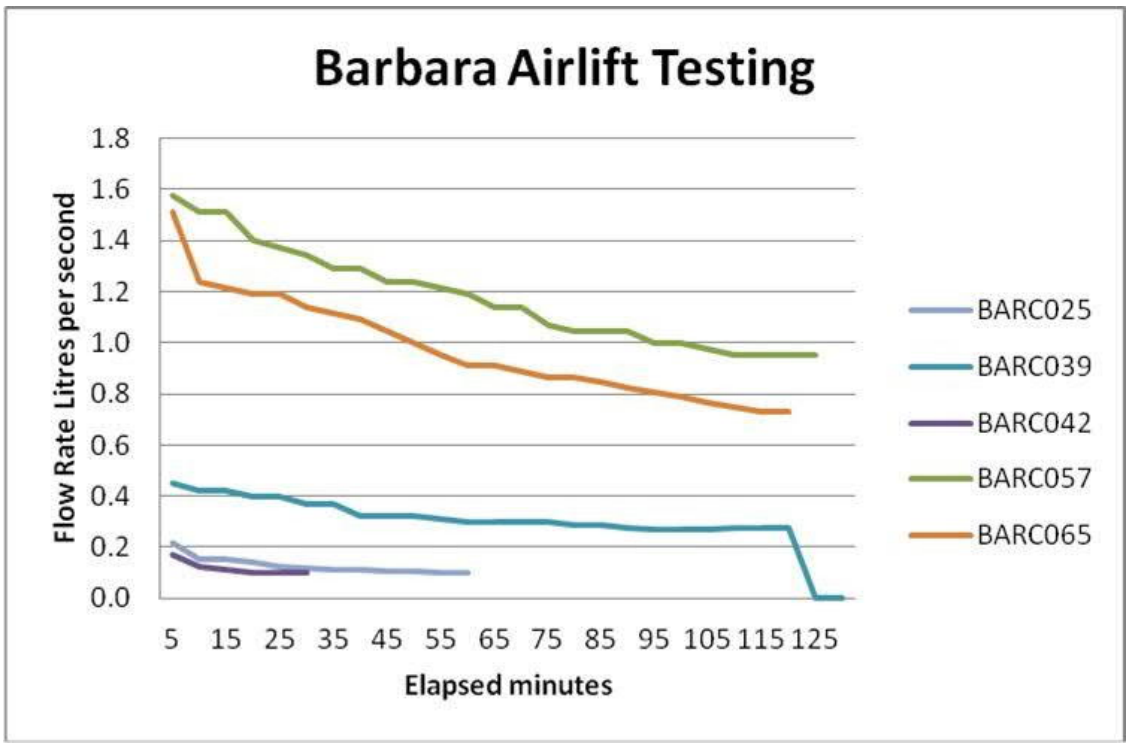


Plate 12 Airlift Yield from Mineral Exploration Bores (RLA, 2014)

Pumping Test

A pumping test was conducted on a temporary production bore installed for drilling water supply. This bore was subsequently designated BAWB07 and incorporated into the BCP's groundwater monitoring network.

Before the pumping test, the standing water level in BAWB07 was 28.79m below the top of the casing. BAWB07 was pumped at a discharge rate of 1.62 L/s. Plate 13 shows the drawdown and recovery water levels plotted against the logarithm of time for this pumping test.

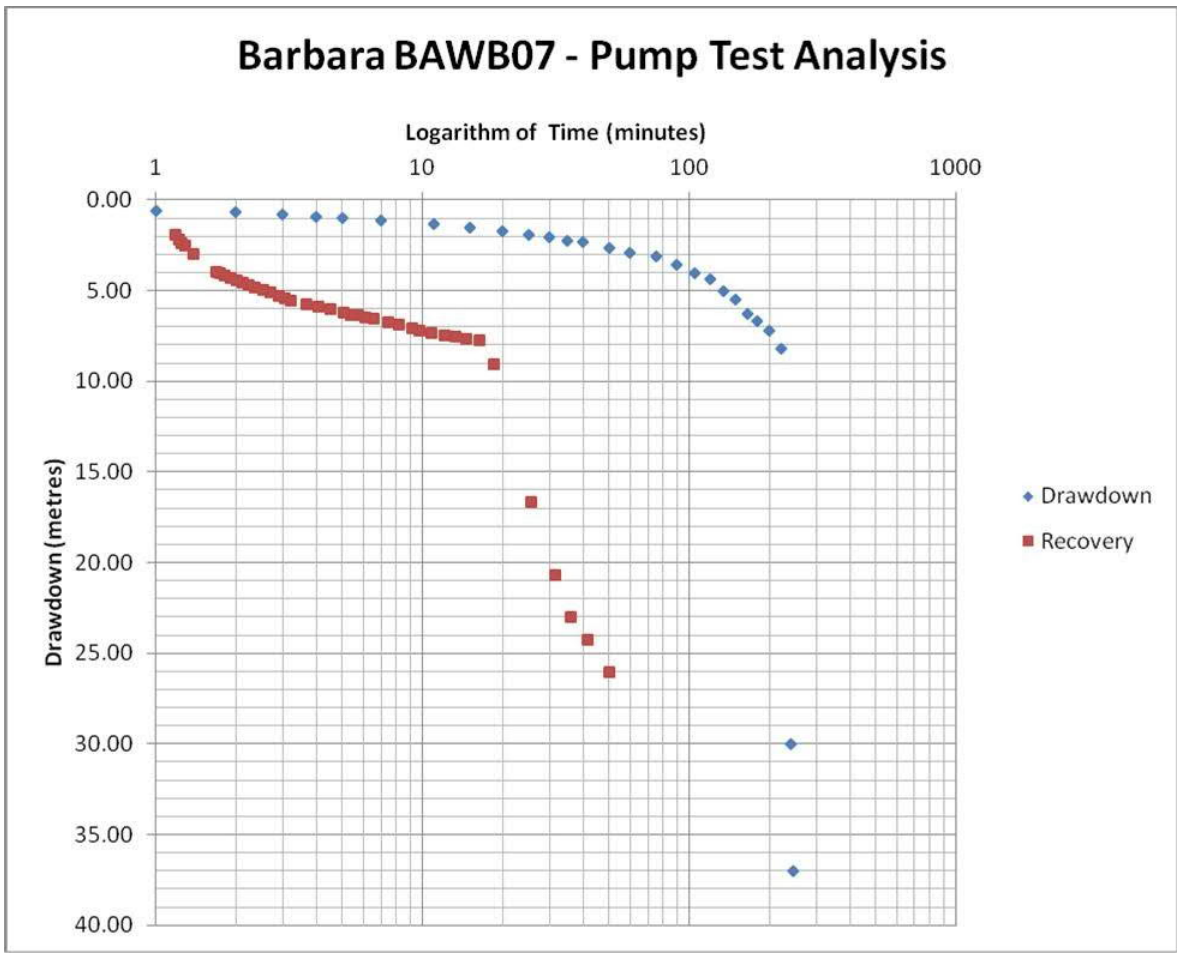


Plate 13 Drawdown and recovery water levels in BAWB07

The drawdown and recovery curves indicate that:

- A hydraulic discharge barrier was reached after a pumping time of 75 minutes. This hydraulic discharge barrier is at a depth of 31.92m in the bore.
- A second hydraulic discharge barrier was reached after a pumping time of 221 minutes when the drawdown became so great that the bore pump would have broken suction at 250 minutes. Pumping was discontinued at 245 minutes. This hydraulic discharge barrier is at a depth of 36.99m in the bore.
- Recovery from a drawdown of 37m to a drawdown of 7.75m was relatively rapid (about 10 minutes).
- Recovery from a residual drawdown of 7.75m to the original standing water level in the bore took almost 22 hours.

The results of the pumping test indicate that:

- the prime aquifer interval in BAWB07 resides in the depth interval from 28 to 37m
- once the groundwater from this aquifer interval was exhausted by pumping, there was little or no groundwater contribution from the strata at a depth of greater than 37m
- the groundwater that resided within the orebody would have been depleted once open-pit mine development commenced
- natural recharge will be slow.

Falling head permeability tests

RLA (2014) references falling head permeability tests undertaken on bores BAWB01, BAWB02, BAWB04 and BAWB05. Table 13 shows the calculated hydraulic conductivity (a term used synonymously with permeability) of the aquifer sequences in the Barbara Copper Project bores that could be tested (RLA, 2014).

Table 13 Calculated hydraulic conductivity of aquifer sequences at BCP (RLA, 2014)

Bore	k m/s	k m/d	k m/d	Qualitative description
BAWB01	9.26E-03	8.00E+02	800.00	Locally high
BAWB02	2.23E-10	1.93E-05	0.00002	Extremely low
BAWB04	2.29E-08	1.98E-03	0.00198	Very low
BAWB05	7.94E-09	6.86E-04	0.00069	Very low

6.8 Groundwater seeps/spring

In July 2021, a body of water was identified within an unnamed drainage feature at the BCP. The waterbody was approximately 450m to the north and downgradient of the waste rock dump (WRD), 100m to the north of the WRD Sediment Dam, and about 40m to the west of the run-of-mine (ROM) pad. Given the highly ephemeral nature of the watercourses within the vicinity of the project, the water body was determined to be a spring (the 'BCP Spring') at the time.

The presence of standing water downgradient of the WRD Sediment Dam was also noted at the spring location during the 2021 pre-wet season inspection conducted by the then Department of Environment and Science (DES, now DESI) on 16 August 2021. The spring was not recorded as a matter of concern during the inspection outcome letter dated 1 September 2021. DES informally requested the inclusion of the waterbody in subsequent receiving environment monitoring surveys.

Round Oak Minerals Limited ('Round Oak'), the EA holder who owned the BCP in 2021 and now is a subsidiary of Aeris Resources, initiated ongoing investigations into the BCP Spring, including sampling the spring, the WRD Sediment Dam, the Sump between the dam and the spring and the existing seepage monitoring bores.

Sample collection was undertaken to investigate:

- the quality of the water compared to that of other sampling locations in the vicinity
- the source of the BCP Spring waterbody
- the pathway(s) by which the water is transported and expressed
- any potential impacts on downstream water quality and the receiving environment,

Sampling of the BCP Spring commenced on 22 August 2021 during the 2021 dry season REMP survey. It continued in subsequent sampling events to determine the water quality characteristics of the BCP Spring and to enable comparison with groundwater and surface waters in the project vicinity. The results of the investigations were presented in Round Oak's report "*Barbara Copper Project. Initial Investigation, Spring Water Quality*", dated May 2022.

Anecdotal information and visual observations indicate that the BCP Spring waterbody exhibits a novel, non-historical habitat. However, a review of Google Earth images indicates that surface water has been present at the location of the BCP Spring before any mine development. Appendix D presents Google Earth images for different dates and an orthomosaic aerial obtained in 2021. Plate 14 shows Google Earth images for October 2015 (with surface water present at the BCP Spring) and March 2020 (with no surface water present).

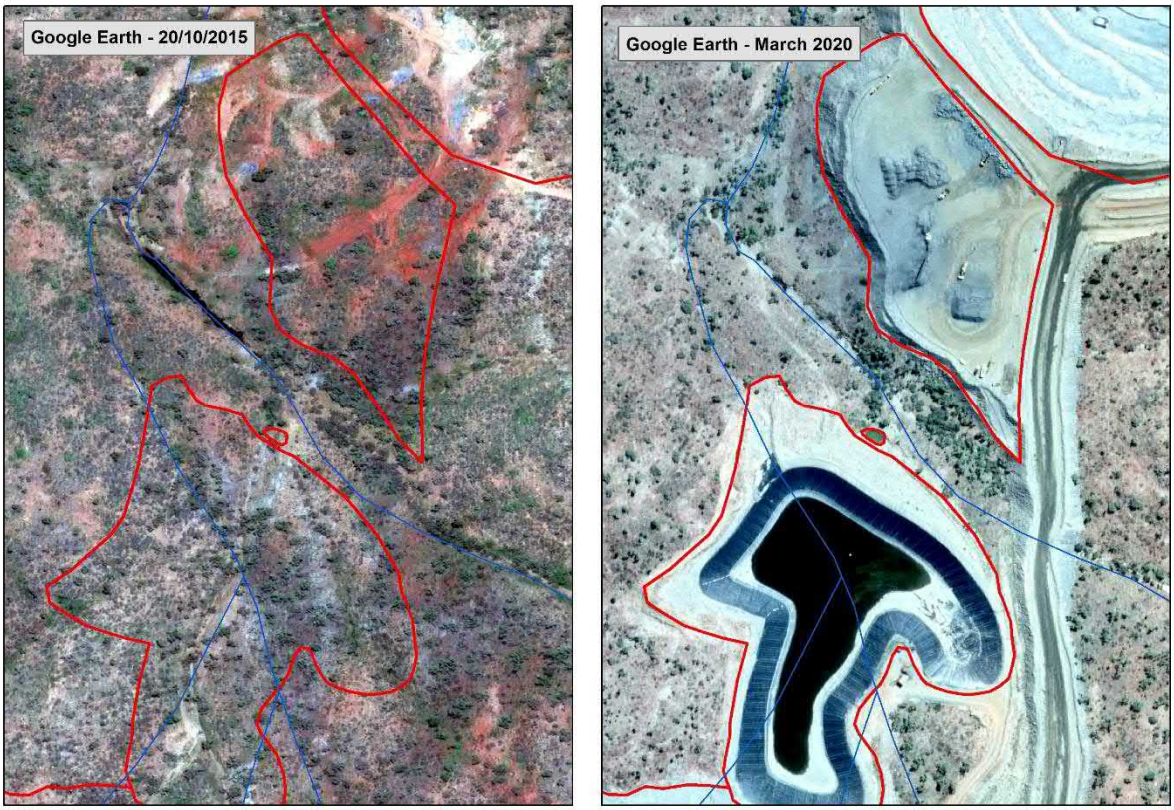


Plate 14 Google Earth images for October 2015 and March 2020

The presence of surface water in the unnamed creek at locations north of the WRD Sediment Dam on the aerials in Appendix D is presented in Table 14.

Table 14 Historical presence of BCP Spring on Google Earth images

Source	Date	Water visible?
Google Earth	31/01/2003	Yes
Google Earth	04/07/2005	No
Google Earth	09/08/2005	No
Google Earth	22/09/2006	No
Google Earth	06/12/2011	Yes
Google Earth	04/01/2013	Yes
Google Earth	03/10/2013	No
Google Earth	20/10/2015	No
Google Earth	07/03/2020	Yes
Google Earth	15/05/2020	No
Orthomosaic	01/05/2021	Yes
Google Earth	01/04/2023	Yes

Plate 15 shows the monthly rainfall measured at the Mt Isa Aero weather station from 2002 to 2022, together with the Cumulative Rainfall Departure curve and markers for the historical imagery.

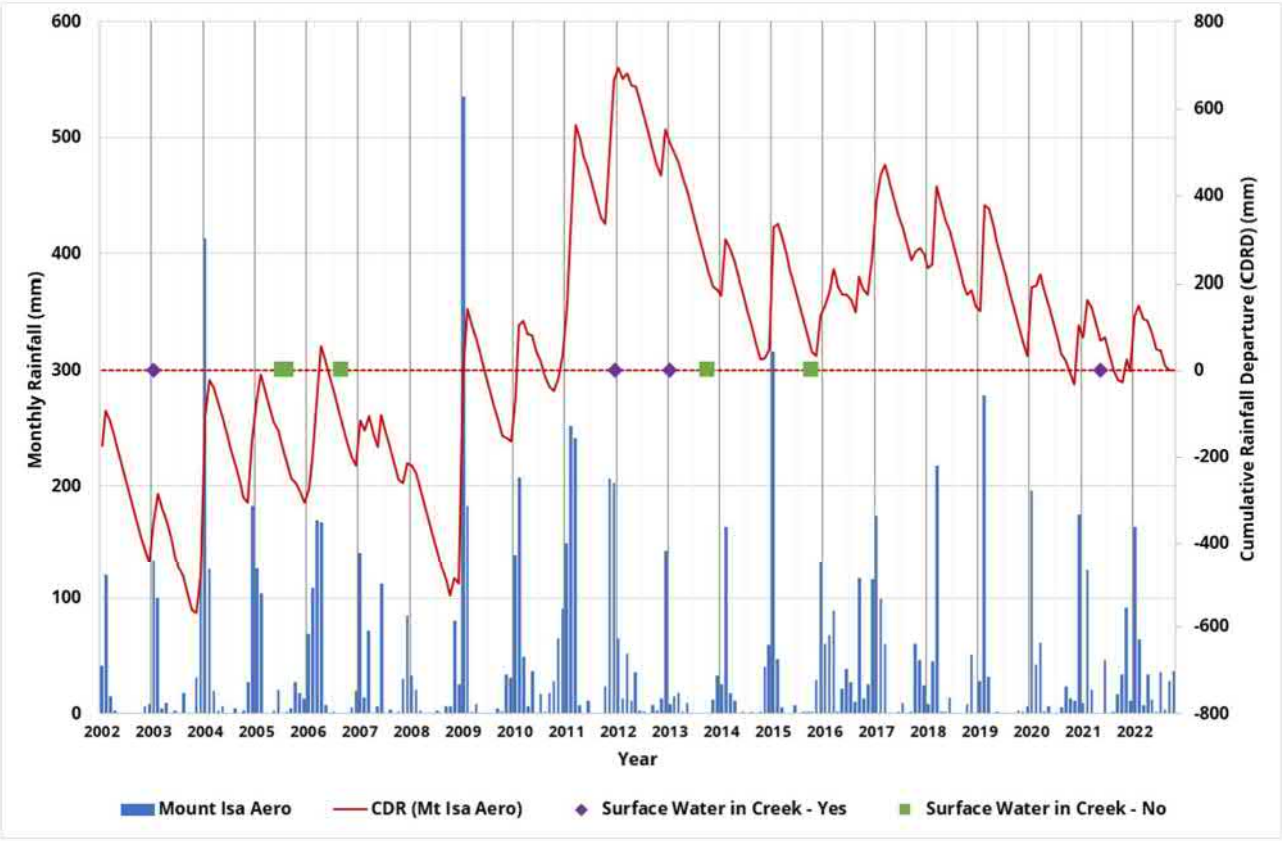


Plate 15 Monthly rainfall (2002-2022) and Cumulative Rainfall Departure

The Cumulative Rainfall Departure (CRD) from normal rainfall is a concept sometimes utilised to evaluate the temporal correlation of rainfall with surface water or groundwater levels. A general analysis approach is that:

- a positive slope (upward) indicates a wetter than average period resulting in potential recharge that increases groundwater storage
- a negative slope (downward) indicates a drier-than-average period, resulting in a potentially limited recharge event that reduces groundwater storage. Water levels generally decline, resulting in reduced available drawdown and recovery rates in the boreholes.

The overlay of the aerial imagery from Table 14 on the monthly rainfall and CRD graph in Plate 15 indicates that the presence of water within the unnamed creek at the BCP Spring generally correlates with wet weather periods and/or a positive slope in the CRD curve.

Round Oak/Aeris developed an action plan to assess the occurrence and water quality of the BCP spring. The results of this assessment are summarised in Section 7.5.

7 Surface water monitoring results

7.1 Surface water monitoring network and events

Surface water sampling and monitoring have been undertaken at BCP since 2014 as part of the following investigations or sampling events:

- In 2014, as part of the submission by Syndicated Metals Ltd and CopperChem Ltd of a site-specific application for an Environmental Authority for the Mining Lease Application (MLA) 90241. Results are provided in the report "*Barbara Copper Project. Assessment of Environmental Impacts (Site Specific EA Application) (Document reference: AEI; Version 1 dated 10/12/2014*" (Syndicated Metal & CopperChem, 2014). Sampling and monitoring were undertaken at up to 12 aquatic survey locations (AQ1 to AQ12).
- Between 2018 and 2024, as part of the receiving environment monitoring program (REMP) implemented by ROM at the Project to monitor surface water quality during wet and dry seasons over time. REMP monitoring was undertaken at up to 11 locations (B1 to B9, B1US, BCP Spring).
- Sampling at receiving water reference sites (BASW09, BASW05) and compliance monitoring sites (BASW01, BASW04, BASW08, BASW11) in accordance with the conditions of EA EPPML02840015.
- Surface water sampling by ROM as part of the BCP Spring investigations at several locations within the mine site.

Figure 8 and Table 15 show the surface water sampling locations.

Table 15 BCP surface water monitoring locations

Location ID	Type/Purpose	Location Description	Easting (GDA94 Z54)	Northing (GDA94 Z54)
Receiving environment				
B1	REMP surface water	Previously furthest upstream site prior to current infrastructure development and establishment of B1US. Adjacent to historical disturbance.	380436	7740728
B1.1US	REMP surface water	Located on a small drainage line upstream of site B1 and a confluence with the drainage feature where B1US is situated. Adjacent to historical disturbance.	380519	7740563
B1US	REMP surface water	Furthest upstream site on the main watercourse. Upstream of historical activities.	380677	7740482
B2	REMP surface water	Approximately 1.8km downstream from B1 on the main watercourse. Downstream of historical disturbance.	379678	7742242
B3	REMP surface water	Eastern tributary of the main watercourse. Upstream of historical disturbance.	379897	7742670
B4	REMP surface water	On the main watercourse, below the confluence of the eastern tributary. Approximately 370m downstream of B2. Downstream of historical disturbance.	379398	7742448
B5	REMP surface water	Southern tributary of the main watercourse. Upstream of historical disturbance.	379136	7741925
B6	REMP surface water	Eastern tributary of the main watercourse. Upstream of historical disturbance.	379089	7743128
B7	REMP surface water	On the main watercourse, below the confluence of all tributaries. Approximately 1.3km downstream of B4. Downstream of historical disturbance.	378660	7743261
B8	REMP surface water	Previously furthest downstream site prior to establishment of B9. Approximately 1.6km downstream of B7. Downstream of historical disturbance.	377326	7743786
B9	REMP surface water	Furthest downstream site on the main watercourse, positioned approximately 500m east of Lake Julius Road and 3.1km downstream of B8. Downstream of historical disturbance.	374831	7744106
EA EPML02840015				
BASW09	EA receiving waters reference site	Drainage feature outside and northeast of disturbance footprint catchment	377540	7738673
BASW05	EA receiving waters reference site	Drainage feature southwest and outside of disturbance footprint catchment	380736	7742273

Location ID	Type/Purpose	Location Description	Easting (GDA94 Z54)	Northing (GDA94 Z54)
BASW01	EA receiving waters compliance site	Watercourse at Mining Lease west boundary	378513	7743286
BASW04	EA receiving waters compliance site	Watercourse downstream of North Pit	379491	7742440
BASW08	EA receiving waters compliance site	Drainage feature at the top of the catchment (Mining Lease entry)	380776	7740396
BASW11	EA receiving waters compliance site	Drainage feature upstream of the junction with watercourse	379884	7742685
Mine site monitoring				
BCP North Pit	Open Pit	Barbara North Pit	379907	7741954
BCP South Pit	Open Pit	Barbara South Pit	380222	7741506
BCP Spring	Spring	Additional site added per DES request. Located ~730m downstream of B1. Site is adjacent to the current mining infrastructure and disturbance.	379947	7741249
BCP Spring (N)	Spring	-	379954	7741241
BCP Spring (S)	Spring	-	380085	7741125
Pooled water S of sediment dam	Pooled water S of sediment dam	-		
Sediment Dam	Sediment Dam	-	380005	7741050
Seepage	Seepage	-		
Sump	Sump	-	380014	7741134

As EVs and WQOs have not yet been determined under the EPP Water and Wetland Biodiversity, the surface water quality data has been assessed against one or more of the following guidelines (depending on the time and purpose of the sampling):

- Australian and New Zealand Environmental Conservation Council (ANZECC & ARMCANZ, 2000) tropical Australia upland streams guideline values were used for pH, turbidity, and dissolved oxygen (DO)
- QWQG (EHP, 2009) regional guideline values for the Gulf Rivers – upland streams – Gulf salinity zone for electrical conductivity (EC)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) default guideline values (DGV's) for heavy metals (recognised as toxicants in ANZG) for the protection of slightly to moderately disturbed systems (95% protection for aquatic organisms) for total and dissolved metals.
- The receiving water trigger levels and water quality objectives, as shown in EA EPML02840015.

7.2 2014 surface water monitoring (AARC, November 2014)

Physicochemical water quality was moderately poor. pH values were slightly alkaline and above the ANZECC aquatic ecosystems guideline range at several sites (AQ1 in the wet season, AQ4, AQ7, AQ8, AQ11). Conductivity levels were high in the dry season, with all sites exceeding the ANZECC guideline. Site AQ4 recorded conductivity levels above the ANZECC guideline in the wet season. Dissolved oxygen levels were low and below the ANZECC guideline range at most sites (AQ1 in the dry season, AQ2, AQ4, AQ6, AQ7, AQ11, AQ12). The high pH and conductivity values and the low DO levels recorded are typical of stagnant, ephemeral waterbodies.

Nutrient levels (i.e. total nitrogen and total phosphorus) exceeded the ANZECC guidelines at all sites in both surveys. These high results are likely attributable to natural factors, as no artificial nutrient sources (such as fertilisers and sewage) are present in the Investigation Area. Nitrogen sources include decaying organic matter and animal waste. Phosphorus is found in rocks and soil and is released into water through weathering and erosion. Animal and plant wastes are also a source of phosphorus. Nutrient levels tend to be high in ephemeral waterbodies, due to concentration from evaporation.

Metals levels in water were generally below the ANZECC guideline limits, with a few exceptions. In the wet season, total and dissolved silver (at AQ4, AQ6 and AQ7), total and dissolved copper (at all sites), total zinc (AQ8), total and dissolved aluminium (at AQ4, AQ7 and AQ8) and dissolved aluminium at AQ1 were above ANZECC aquatic ecosystems guidelines. Metal results were similar in the dry season, with total and dissolved copper (at AQ1, AQ8 and AQ11), total copper (AQ12), total and dissolved manganese (AQ12), total aluminium (AQ11 and AQ12) and total zinc (AQ11 and AQ12) exceeding the ANZECC guidelines. Copper, zinc and aluminium are naturally abundant elements, and their elevated levels are likely to be the result of mineralisation in the Project region. High silver levels are also likely to be attributable to local geology. High manganese levels were detected only at site AQ12. Manganese is an abundant metal in soil, and it is possible that trampling of the soft, sandy bed at AQ12 by cattle increased manganese levels at this site. No breaches of the Livestock Drinking Water guidelines were detected.

7.3 2022 REMP monitoring results

REMP surface water monitoring results are provided in the annual REMP reports submitted to DESI by Aeris Resources. The results of the 2022 REMP monitoring can be summarised as follows (SLR Consulting, 2022):

- In terms of surface water and stream sediment quality, REMP sites were generally in a good condition (with few parameters exceeding the GVs) over both the 2022 wet and dry season surveys; however, copper concentrations in both surface water and stream sediment samples were elevated above the published guideline values at some of the upstream and downstream sites.
- Comparisons of temporal downstream surface water data suggest that total and dissolved copper concentrations have fluctuated since the commencement of the REMP. A large increase in total copper concentrations was observed in water samples from site B8 during the 2022 dry season survey. Due to the ephemeral nature of watercourses within the BCP receiving environment, upstream and downstream surface water data has been infrequently collected. The confounding factors of historical mining activities, a naturally mineralised local landscape and current mining infrastructure make interpretation of downstream data in regard to mining related influences difficult. It is unknown if the Barbara project has contributed to the metal concentrations recorded at downstream sites.
- Stream sediment results from upstream site B1US should be interpreted with caution as the site is dominated by topsoil (rather than stream sediments) and may not be representative or comparable to other REMP sites. Whole and fine sediment fraction copper and nickel concentrations at upstream and downstream sites during the 2022 wet and dry season surveys are generally elevated above the ANZG guideline values. Fine fraction copper concentrations at downstream sites B2 and B4 were elevated above the ANZG GV-High during the 2022 survey(s) and higher compared to reference sites (excluding B1US). Exceedances of fine and/or whole fraction nickel concentrations were recorded at both upstream and downstream sites. Overall, elevated metal concentrations are likely caused by natural mineralisation in the local area; however, downstream site B2 may be influenced by confounding factors of historical mining, natural mineralisation and current mining activities. It is unknown to what degree each factor attributes to the high concentrations recorded at B2 and further investigation may be warranted.
- Macroinvertebrate indices at REMP sites have varied over time and generally improved at both upstream and downstream sites, with microhabitat quality and macroinvertebrate diversity likely being the biggest drivers for this variation. The high concentrations of total copper in surface water samples, and copper and nickel in the fine sediment fraction at REMP sites (which are more bioavailable than whole fraction sediment concentrations or total metal concentrations in water) do not appear to be having a detrimental effect on macroinvertebrate communities at these sites. It is recommended that macroinvertebrate sampling continue to be conducted, with the intention of establishing a robust dataset to enable more informed spatiotemporal comparisons of the BCP receiving environment.

In addition to the REMP monitoring, Aeris Resources also undertakes surface water sampling at the EA receiving waters reference and compliance monitoring sites in accordance with the requirements of EA EPML02840015.

7.4 REMP and EA surface water quality results

Appendix E provides relevant data, charts and plots, with:

- Appendix E.1: data tables
- Appendix E.2: time series of selected parameters
- Appendix E.3: box & whisker plots
- Appendix E.4: hydrogeochemistry plots

7.4.1 Hydrogeochemistry

Surface water samples were analysed for major ions and alkalinity to allow for hydrogeochemical analysis. Piper, Durov, Chadha and Gibbs diagrams for the REMP and EA surface water sample locations are presented in Appendix E.

Based on the ionic composition of the water samples and interpretation of the diagrams, the surface water at these sites can be classified as per Table 16.

Table 16 Water-type classification of REMP and EA surface water sampling locations

Location	Piper diagram water type	Durov diagram classification
B3	• Mixed Ca-Na-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed.
B4	• Mixed Ca-Na-HCO3	• 6: SO4 and Na are dominant. Water type is not frequently encountered and indicates probable mixing or uncommon dissolution influences.
B6	• Mixed Ca-Na-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed.
B7	• Mixed Ca-Na-HCO3	• 3: HCO3 and Na are dominant, indicates ion exchange water.
B8	• Ca-Mg-HCO3 • Mixed Ca-Na-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed. • 3: HCO3 and Na are dominant, indicates ion exchange water.
B9	• Ca-Mg-HCO3 • Mixed Ca-Na-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed.
BASW01	• Ca-Mg-HCO3 • Mixed Ca-Na-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed. • 3: HCO3 and Na are dominant, indicates ion exchange water. • 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing.
BASW04	• Ca-Mg-HCO3 • Mixed Ca-Na-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed.
BASW05	• Ca-Mg-HCO3 • Mixed Ca-Na-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed.

Location	Piper diagram water type	Durov diagram classification
		• 1: HCO3 and Ca dominant; frequently indicates recharging waters in limestone, sandstone and many other aquifers.
BASW09	• Ca-Mg-HCO3 • Mixed Ca-Na-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed. • 3: HCO3 and Na are dominant, indicates ion exchange water.
BASW11	• Ca-Mg-HCO3 • Mixed Ca-Na-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed. • 3: HCO3 and Na are dominant, indicates ion exchange water.

The ionic composition of the surface water samples obtained from the REMP and EA surface water monitoring locations indicates the following:

- Water type is predominantly mixed calcium-sodium-bicarbonate and/or calcium-magnesium-bicarbonate.
- Ion exchange processes predominantly define ionic composition.
- Ionic composition is influenced mainly by rainfall events and interaction between surface water and underlying, mineralised geology, as demonstrated by the Gibbs diagrams in Appendix E. Water types are generally consistent at all sampled locations, with no apparent difference between background (BASW09 and BASW05) and downstream (e.g. BASW04, B7) locations.
- There is no evidence that external factors (e.g. water runoff from the mine site) have affected the ionic composition at the sampled locations.

7.4.2 REMP and EA surface water quality results

Table 17 presents the range of analysis results above the LOR for selected analytes/parameters at the sampling locations. A summary of exceedances of the EA receiving water trigger levels and WQOs and the ANZG 2018 DGVs for protecting aquatic (slightly to moderately disturbed) ecosystems is presented in Table 18, Table 19 and Table 20, respectively.

The data and information indicate the following:

- Exceedances of the EQ receiving water trigger levels and WQOs and the ANZG aquatic ecosystem (slightly to moderately disturbed) protection DGVs have occurred before, during and after the open-cut mining. Generally, where an exceedance for a given analyte was identified post-mining, exceedances for the same analyte existed pre-mining or during mining.
- The time series graphs indicate that there is generally no increasing trend in analyte concentration with time, from before to during to post-mining. There may be some seasonal variations related to seasonal rainfall/storm events.
- The box & whisker plots show the natural variability of analyte concentrations at a given monitoring location.

The data and information provide no evidence that the mining operations have adversely impacted the water quality at these monitoring locations.

Table 17 Range of analysis results above the LOR at the REMP/EA surface water monitoring locations

Parameter	B3	B4	B6	B7	B8	B9	BASW01	BASW04	BASW05	BASW08	BASW09	BASW11
Alkalinity												
Bicarbonate Alkalinity as CaCO3 (mg/L)	74 - 200	460 - 460	130 - 220	130 - 560	100 - 740	160 - 300	24 - 242	40 - 499	23 - 295		17 - 824	27 - 407
Total Alkalinity as CaCO3 (mg/L)	74 - 200	460 - 460	130 - 220	150 - 560	100 - 740	160 - 300	24 - 242	40 - 531	23 - 295		17 - 824	27 - 407
Field Measurements												
Dissolved Oxygen (field) (% sat)							0 - 53.4	4.8 - 179.6	0 - 72.6	48.4 - 48.4	0 - 163	0 - 122.3
Electrical Conductivity (field) (µS/cm)							60 - 1293	126 - 1293	79 - 1027	1305 - 1305	49 - 1723	54 - 994
ORP (field) (mV)							22.2 - 185.8	1.8 - 168.4	-133.6 - 231.7	-21.1 - -21.1	-45.8 - 170	-16.2 - 216.1
pH (field)							5.87 - 8.61	6.78 - 8.89	5.34 - 8.63	9.09 - 9.09	6.6 - 9.52	5.95 - 9.09
Salinity (field) (PSU)							0.03 - 0.65	0.06 - 0.65	0.04 - 0.51	0.65 - 0.65	0.02 - 0.87	0.02 - 0.49
TDS (field) (ppm)							30 - 647	63 - 647	40 - 514	653 - 653	0.07 - 861	27 - 497
Temperature (field) (°C)							15 - 34.13	22.09 - 35.99	15.31 - 28.99	20.94 - 20.94	20.77 - 34.84	16.2 - 34.22
Turbidity (field) (FNU)							12.8 - 54.8	4 - 170	0 - 272	97 - 97	7.3 - 147	9.5 - 170
Hardness												
Total Hardness (mg CaCO3/L)	26 - 110	270 - 270	55 - 110	62 - 240	57 - 310	82 - 190	16 - 126	30 - 312	18 - 165		9 - 402	18 - 226
Major Ions												
Calcium (mg/L)	6 - 19	40 - 40	12 - 26	15 - 38	15 - 73	19 - 36	3 - 19	7 - 66	4 - 37		2 - 44	4 - 36
Chloride (mg/L)	7 - 34	110 - 110	10 - 28	12 - 97	7 - 60	7 - 76	2 - 30	4 - 86	2 - 27		1 - 111	3 - 70
Fluoride (mg/L)	0.1 - 0.3	0.5 - 0.5	0.1 - 0.1	0.2 - 0.4	0.1 - 0.4	0.1 - 0.1	0.1 - 0.3	0.1 - 1.6	0.1 - 0.2		0.1 - 0.5	0.1 - 0.6
Magnesium (mg/L)	2.7 - 14	42 - 42	5.7 - 13	6.1 - 34	4.9 - 30	8.5 - 25	2 - 19	3 - 49	2 - 21		1 - 76	2 - 33
Potassium (mg/L)	3.6 - 12	9 - 9	4.1 - 5.5	5.6 - 9.9	7 - 160	8.7 - 13	2 - 21	4 - 20	2 - 60		3 - 70	2 - 32
Sodium (mg/L)	15 - 66	270 - 270	22 - 56	32 - 230	17 - 140	19 - 98	4 - 93	4 - 212	2 - 57		1 - 234	3 - 145
Sulfate (as SO4)	1.9 - 12	230 - 230	1.2 - 3.8	8.9 - 66	2.6 - 37	2 - 34	4 - 44	1 - 55	1 - 6		2 - 30	1 - 27
Metals (dissolved)												
Aluminium - dissolved (mg/L)	0.007 - 0.03		0.011 - 0.02	0.013 - 0.013	0.006 - 0.29							
Arsenic - dissolved (mg/L)			0.002 - 0.002	0.002 - 0.002	0.004 - 0.004		0.001 - 0.001	0.001 - 0.004	0.001 - 0.003		0.001 - 0.003	0.001 - 0.003
Barium - dissolved (mg/L)	0.015 - 0.047	0.08 - 0.08	0.026 - 0.047	0.031 - 0.072	0.032 - 0.29	0.035 - 0.07	0.009 - 0.07	0.019 - 0.419	0.015 - 0.176		0.005 - 0.18	0.01 - 0.127
Chromium - dissolved (mg/L)							0.002 - 0.002				0.001 - 0.001	
Cobalt - dissolved (mg/L)					0.005 - 0.005		0.001 - 0.003	0.001 - 0.005	0.001 - 0.004		0.001 - 0.002	0.002 - 0.003
Copper - dissolved (mg/L)	0.001 - 0.004	0.005 - 0.005	0.002 - 0.002	0.002 - 0.012	0.001 - 0.004	0.002 - 0.003	0.002 - 0.039	0.004 - 0.208	0.001 - 0.018		0.001 - 0.005	0.001 - 0.018
Molybdenum - dissolved (mg/L)	0.0007 - 0.0007	0.002 - 0.002	0.0006 - 0.0006	0.001 - 0.003	0.0009 - 0.002	0.0007 - 0.0007	0.001 - 0.002	0.001 - 0.003	0.002 - 0.002		0.001 - 0.003	0.001 - 0.003
Nickel - dissolved (mg/L)					0.003 - 0.003		0.002 - 0.008	0.001 - 0.007	0.001 - 0.002		0.001 - 0.001	0.001 - 0.004
Selenium - dissolved (mg/L)												
Uranium - dissolved (mg/L)	0.001 - 0.001	0.005 - 0.005	0.0005 - 0.0005	0.0009 - 0.012	0.0018 - 0.0029	0.0018 - 0.0018	0.001 - 0.001	0.002 - 0.004	0.001 - 0.001		0.002 - 0.005	0.001 - 0.002
Zinc - dissolved (mg/L)												
Metals (total)												
Aluminium - total (mg/L)	0.067 - 0.55	0.066 - 0.066	0.02 - 0.028	0.03 - 0.75	0.035 - 4.9	0.07 - 0.26						
Arsenic - total (mg/L)			0.002 - 0.002	0.002 - 0.002	0.006 - 0.006		0.001 - 0.002	0.001 - 0.005	0.001 - 0.004		0.001 - 0.004	0.001 - 0.003
Barium - total (mg/L)	0.02 - 0.068	0.085 - 0.085	0.026 - 0.052	0.033 - 0.075	0.036 - 0.38	0.039 - 0.075	0.017 - 0.074	0.02 - 0.376	0.026 - 0.215		0.012 - 0.316	0.013 - 0.16
Chromium - total (mg/L)					0.0036 - 0.0036		0.001 - 0.003	0.002 - 0.002	0.004 - 0.016		0.002 - 0.002	
Cobalt - total (mg/L)	0.001 - 0.001	0.001 - 0.001	0.002 - 0.002	0.001 - 0.001	0.011 - 0.011		0.001 - 0.003	0.001 - 0.006	0.003 - 0.007		0.001 - 0.005	0.001 - 0.003
Copper - total (mg/L)	0.002 - 0.006	0.006 - 0.006	0.001 - 0.002	0.003 - 0.014	0.002 - 0.033	0.004 - 0.004	0.002 - 0.046	0.003 - 0.311	0.002 - 0.039		0.001 - 0.009	0.002 - 0.024
Molybdenum - total (mg/L)		0.002 - 0.002	0.0006 - 0.0006	0.001 - 0.003	0 - 0.001	0.0007 - 0.0007	0.001 - 0.002	0.001 - 0.004	0.001 - 0.002		0.002 - 0.004	0.001 - 0.002
Nickel - total (mg/L)	0.001 - 0.001			0.001 - 0.001	0.007 - 0.007		0.002 - 0.004	0.001 - 0.004	0.001 - 0.009		0.001 - 0.003	0.001 - 0.002
Selenium - total (mg/L)												
Uranium - total (mg/L)	0.0011 - 0.0011	0.0051 - 0.0051	0.0005 - 0.0005	0.001 - 0.012	0.002 - 0.0029	0.0019 - 0.0019	0.001 - 0.001	0.002 - 0.004	0.001 - 0.001		0.002 - 0.006	0.001 - 0.002
Nutrients												

Parameter	B3	B4	B6	B7	B8	B9	BASW01	BASW04	BASW05	BASW08	BASW09	BASW11
Nitrite + Nitrate as N (mg/L)												
Total Kjeldahl Nitrogen as N (mg/L)								0.9 - 0.9				
Total Nitrogen as N (mg/L)								0.9 - 0.9				
Total Phosphorus as P (mg/L)								0.07 - 0.07				
Physico-Chemical Parameters												
Electrical Conductivity (µS/cm)	130 - 500	1600 - 1600	230 - 460	280 - 1400	200 - 930	260 - 840	57 - 573	120 - 1260	58 - 666		39 - 1710	57 - 963
pH (lab)	7.3 - 8.4		7.8 - 8	8 - 8.4	7.4 - 7.8	7.8 - 7.8	6.48 - 8.43	7.17 - 8.58	6.47 - 8.21		6.8 - 8.97	6.68 - 8.69
Turbidity (NTU)	6.6 - 6.6		3 - 3	4 - 4	5.7 - 5.7	12 - 12	1.7 - 137	2.9 - 130	4.2 - 205		1.1 - 129	1.6 - 58.3

Table 18 REMP and EA surface water exceedances of EA receiving water quality trigger levels

Parameter/Period	B3	B4	B6	B7	B8	B9	BASW01	BASW04	BASW05	BASW08	BASW09	BASW11
Aluminium - dissolved (mg/L)												
3. Post-open cut mining					✓							
Aluminium - total (mg/L)												
2. Open cut mining	✓				✓	✓						
3. Post-open cut mining	✓	✓		✓	✓	✓						
Chromium - dissolved (mg/L)												
3. Post-open cut mining							✓					
Chromium - total (mg/L)												
1. Pre-open cut mining								✓				
2. Open cut mining									✓		✓	
3. Post-open cut mining					✓		✓	✓	✓			
Cobalt - dissolved (mg/L)												
1. Pre-open cut mining								✓	✓			
2. Open cut mining							✓	✓	✓			✓
Copper - dissolved (mg/L)												
1. Pre-open cut mining							✓	✓	✓		✓	✓
2. Open cut mining	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓
3. Post-open cut mining	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓
Copper - total (mg/L)												
1. Pre-open cut mining							✓	✓	✓		✓	✓
2. Open cut mining	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓
3. Post-open cut mining	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓
Electrical Conductivity (µS/cm)												
1. Pre-open cut mining							✓	✓	✓		✓	✓
2. Open cut mining											✓	✓
Electrical Conductivity (field) (µS/cm)												
1. Pre-open cut mining							✓	✓	✓		✓	✓
2. Open cut mining							✓	✓	✓	✓	✓	✓
Fluoride (mg/L)												

Parameter/Period	B3	B4	B6	B7	B8	B9	BASW01	BASW04	BASW05	BASW08	BASW09	BASW11
1. Pre-open cut mining								✓				
pH (field)												
1. Pre-open cut mining							✓	✓	✓		✓	✓
2. Open cut mining							✓	✓	✓	✓	✓	✓
3. Post-open cut mining							✓	✓	✓		✓	✓
pH (lab)												
1. Pre-open cut mining							✓	✓	✓		✓	✓
2. Open cut mining							✓	✓			✓	✓
3. Post-open cut mining							✓	✓	✓		✓	✓
Uranium - dissolved (mg/L)												
3. Post-open cut mining				✓								
Uranium - total (mg/L)												
3. Post-open cut mining				✓								

✓ Exceedance observed

Table 19 REMP and EA surface water exceedances of EA receiving water WQOs

Parameter	B3	B4	B6	B7	B8	B9	BASW01	BASW04	BASW05	BASW08	BASW09	BASW11
Aluminium - dissolved (mg/L)												
3. Post-open cut mining					✓							
Aluminium - total (mg/L)												
2. Open cut mining	✓				✓	✓						
3. Post-open cut mining	✓	✓		✓	✓	✓						
Chromium - dissolved (mg/L)												
3. Post-open cut mining							✓					
Chromium - total (mg/L)												
1. Pre-open cut mining								✓				
2. Open cut mining									✓		✓	
3. Post-open cut mining					✓		✓	✓	✓			
Cobalt - dissolved (mg/L)												
1. Pre-open cut mining								✓	✓			
2. Open cut mining							✓	✓	✓			✓
Copper - dissolved (mg/L)												
1. Pre-open cut mining							✓	✓	✓		✓	✓
2. Open cut mining	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓
3. Post-open cut mining	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓
Copper - total (mg/L)												
1. Pre-open cut mining							✓	✓	✓		✓	✓
2. Open cut mining	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓
3. Post-open cut mining	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓
Electrical Conductivity (µS/cm)												
1. Pre-open cut mining							✓	✓	✓		✓	✓
2. Open cut mining											✓	✓
Electrical Conductivity (field) (µS/cm)												
1. Pre-open cut mining							✓	✓	✓		✓	✓
2. Open cut mining							✓	✓	✓	✓	✓	✓
Fluoride (mg/L)												

Parameter	B3	B4	B6	B7	B8	B9	BASW01	BASW04	BASW05	BASW08	BASW09	BASW11
1. Pre-open cut mining								✓				
pH (field)												
1. Pre-open cut mining							✓	✓	✓		✓	✓
2. Open cut mining							✓	✓	✓	✓	✓	✓
3. Post-open cut mining							✓	✓	✓		✓	✓
pH (lab)												
1. Pre-open cut mining							✓	✓	✓		✓	✓
2. Open cut mining							✓	✓			✓	✓
3. Post-open cut mining							✓	✓	✓		✓	✓
Uranium - dissolved (mg/L)												
3. Post-open cut mining				✓								
Uranium - total (mg/L)												
3. Post-open cut mining				✓								

✓ Exceedance observed

Table 20 REMP and EA surface water exceedances of ANZG aquatic ecosystem (slightly to moderately disturbed) protection DGVs

Parameter	B3	B4	B6	B7	B8	B9	BASW01	BASW04	BASW05	BASW08	BASW09	BASW11
Aluminium - dissolved (mg/L)												
3. Post-open cut mining					✓							
Aluminium - total (mg/L)												
2. Open cut mining	✓				✓	✓						
3. Post-open cut mining	✓	✓		✓	✓	✓						
Chromium - dissolved (mg/L)												
3. Post-open cut mining							✓					
Chromium - total (mg/L)												
1. Pre-open cut mining								✓				
2. Open cut mining									✓		✓	
3. Post-open cut mining					✓		✓	✓	✓			
Copper - dissolved (mg/L)												
1. Pre-open cut mining							✓	✓	✓		✓	✓
2. Open cut mining	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓
3. Post-open cut mining	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓
Copper - total (mg/L)												
1. Pre-open cut mining							✓	✓	✓		✓	✓
2. Open cut mining	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓
3. Post-open cut mining	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓

✓ Exceedance observed

7.5 Mine site surface water monitoring results

Aeris has undertaken regular surface water monitoring and sampling at several locations within ML90241 as part of routine monitoring and investigations related to the occurrence of the BCP Spring(s). The locations included the following:

- BCP North Pit: Barbara North open pit
- BCP South Pit: Barbara South open pit
- BCP Spring: An additional site within the drainage line south of the sediment dam was where the BCP Spring was first noticed. The site was added to the REMP program as per DES request.
- BCP Spring (N): Sampling site in the immediate vicinity of the BCP Spring site.
- BCP Spring (S): Additional sampling site further south along the drainage line.
- Sediment Dam: sampling site within the Sediment Dam
- Sump: sampling site within the sump excavated south of the Sediment Dam
- Pooled water south of the sediment dam

Details of these locations are provided in Table 15, with locations shown in Figure 8. The investigations included the following:

- Sampling of surface water at the above locations.
- Installation of automated data loggers to record water levels/depths at BCP Spring (N), BCP Spring (S) and SUMP

Appendix F provides relevant data, charts and plots, with:

- Appendix F.1: data tables
- Appendix F.2: time series of selected parameters
- Appendix F.3: box & whisker plots
- Appendix F.4: hydrogeochemistry plots

7.5.1 Hydrogeochemistry

Surface water samples were analysed for major ions and alkalinity to allow for hydrogeochemical analysis. Piper, Durov, Gibbs and Chadha diagrams for the mine site surface water sample locations are presented in Appendix F.4.

Based on the ionic composition of the water samples and interpretation of the diagrams, the surface water at these sites can be classified as per Table 21.

Table 21 Water-type classification of mine site surface water sampling locations

Location	Piper diagram water type	Durov diagram classification
BCP North Pit	• Mixed Ca-Mg-Cl	• 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing.
BCP South Pit	• Ca-Mg-Cl-SO4	• 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing.
BCP Spring	• Mixed Ca-Na-HCO3	• 6: SO4 and Na are dominant. Water type is not frequently encountered and

Location	Piper diagram water type	Durov diagram classification
	• Na-K-Cl-SO4	indicates probable mixing or uncommon dissolution influences.
BCP Spring (N)	• Mixed Ca-Na-HCO3 • Na-K-Cl-SO4	• 6: SO4 and Na are dominant. Water type is not frequently encountered and indicates probable mixing or uncommon dissolution influences.
BCP Spring (S)	• Mixed Ca-Na-HCO3 • Na-K-Cl-SO4	• 6: SO4 and Na are dominant. Water type is not frequently encountered and indicates probable mixing or uncommon dissolution influences. • 3: HCO3 and Na are dominant, indicates ion exchange water.
Pooled water S of sediment dam	• Ca-Mg-Cl-SO4	• 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing.
Sediment Dam	• Mixed Ca-Mg-Cl • Ca-Mg-Cl-SO4	• 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing.
Seepage	• Mixed Ca-Na-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed.
Sump	• Na-K-Cl-SO4 • Mixed Ca-Na-HCO3	• 6: SO4 and Na are dominant. Water type is not frequently encountered and indicates probable mixing or uncommon dissolution influences.

The ionic composition of the surface water samples obtained from the REMP and EA surface water monitoring locations indicates the following:

- The water type at the mine site surface water monitoring locations is different and more variable than at the REMP and EA surface water monitoring locations.
- Water types can be summarised as follows:
  - BCP North and South Pits: mixed Ca-Mg-Cl and Ca-Mg-Cl-SO4 water types, with no dominant anion or cation, indicating water exhibiting dissolution or mixing. The water types reflect the local geology and interaction between water in the open pits, evaporation and groundwater inflow. The south pit is deeper than the north pit, and the water type in the south pit is probably influenced by localised mineralisation at depth.
  - BCP Spring locations and Sump: water types at each location vary between mixed Ca-Na-HCO3 and Na-K-Cl-SO4. These water types indicate probable mixing or uncommon dissolution influences (e.g. from underlying mineralisation).
  - Sediment dam and pooled water south of the dam: water types at this location vary between mixed Ca-Mg-Cl and Ca-Mg-Cl-SO4. No dominant anion or cation is present, indicating water exhibiting dissolution or mixing.

- Ionic composition is influenced mainly by rainfall events and interaction between surface water and underlying, mineralised geology, as demonstrated by the Gibbs diagrams in Appendix E. Water types are generally consistent at all sampled locations, with no apparent difference between background (BASW09 and BASW05) and downstream (e.g. BASW04, B7) locations.

7.5.2 Mine site surface water quality results

Table 22 presents the range of analysis results above the LOR for selected analytes/parameters at the mine site sampling locations. A summary of exceedances of the ANZECC livestock water quality guidelines and ANZG 2018 DGVs for protecting aquatic (slightly to moderately disturbed) ecosystems is presented in Table 23 and Table 24, respectively.

The data and information indicate the following:

- Exceedances of the ANZECC livestock water quality guidelines and the ANZG aquatic (slightly to moderately disturbed) ecosystem protection DGVs have occurred mainly for salinity, selected metals (aluminium, arsenic, chromium, copper, molybdenum and selenium), fluoride and sulfate.
- Surface water is generally alkaline, with field pH values between 7.8 and 10.1.
- Salinity levels are lowest in the BCP North and South Pit (reflecting rainfall recharge and groundwater inflow). Elevated salinity levels are observed in the sump and at BCP Spring (N), BCP Spring (S) and BCP Spring locations.
- With respect to major ions:
  - Calcium levels in the sediment dam are higher than in other locations and appear to increase with time. Catchment runoff captured in the sediment dam is known to be alkaline due to localised soil composition.
  - Magnesium levels are lowest in the BCP North and South Pits and highest at the BCP Spring locations. Except for the pits, magnesium levels appear to increase with time.
  - Sodium levels are highest at the Sump, BCP Spring (N) and BCP Spring locations and lowest in the BCP North and South Pits. Except for the pits, sodium levels vary with time, most likely in response to rainfall events.
  - Chloride levels are highest at the Sump, BCP Spring and BCP Spring (N) locations and lowest in the BCP North and South Pits. Except for the pits, chloride levels vary with time, most likely in response to rainfall events.
  - Sulfate levels are lowest in the BCP North and South Pits and high, but within the same range, at the other locations. Except for the pits, sulfate concentrations have appeared to vary and have increased since 2020.
  - Bicarbonate alkalinity is lowest in the Sediment Dam and the BCP North and South Pits and highest at the BCP Spring locations. Except for the sediment dam and the pits, bicarbonate alkalinity appears to vary with time, most likely in response to rainfall events.
- With respect to metals:
  - Metal concentrations are generally low, except for barium, copper, molybdenum, nickel, selenium and uranium at some locations.
  - There is generally no increasing trend in metal concentrations. There may be some seasonal variations related to seasonal rainfall/storm events.
- The box & whisker plots show the natural variability of analyte concentrations at a given monitoring location.

The data and information show that a range of variable factors influences the water quality at the mine site surface water locations, as follows:

- Water quality at the BCP Spring locations and the Sump differs from the water quality in the sediment dam and the open pits. The water quality indicates probable mixing or uncommon dissolution influences (e.g. from underlying mineralisation).
- Water quality in the open pits appears to be affected by rainfall and groundwater inflow.
- Water quality in the sediment dam appears to be affected mainly by surface water runoff from the surrounding catchment, which is known to have alkaline soils.

Water quality at the mine site locations also differs from the REMP and EA surface water quality, indicating that more localised factors affect the mine site surface water quality.

Table 22 Range of analysis results above the LOR at the mine site surface water monitoring locations

Parameter	BCP North Pit	BCP South Pit	BCP Spring	BCP Spring (N)	BCP Spring (S)	Culvert Outflow	Pooled water S of sediment dam	Sediment Dam	Seepage	Sump	U/S of Culvert
Alkalinity											
Bicarbonate Alkalinity as CaCO3 (mg/L)	98 - 382	78 - 93	321 - 1700	243 - 1470	227 - 938	166 - 166	73 - 152	38 - 129	744 - 744	83 - 1300	202 - 202
Carbonate Alkalinity as CaCO3 (mg/L)			66 - 1400	93 - 490	24 - 438			10 - 28		25 - 331	
Total Alkalinity as CaCO3 (mg/L)	98 - 382	78 - 93	470 - 2950	243 - 1960	227 - 1230	166 - 166	73 - 152	50 - 129	744 - 744	83 - 1420	202 - 202
Field Measurements											
Dissolved Oxygen (field) (% sat)	0 - 196	0 - 162.8	1.2 - 311.6	23.8 - 315.9	1.2 - 127.6		94.2 - 94.2	0 - 211.4		0.4 - 186.6	145.8 - 145.8
Electrical Conductivity (field) (µS/cm)	738 - 1386	977 - 1591	2278 - 9392	968 - 5416	674 - 3324		4632 - 4632	65 - 2752		340 - 6686	530 - 530
ORP (field) (mV)	-34.1 - 237.2	-40.3 - 207.4	-31.3 - 131.5	-58.8 - 142.5	-58.6 - 2.3		-54.2 - -54.2	-22.1 - 252.9		-57.4 - 133	9.3 - 9.3
pH (field)	7.89 - 8.86	8.14 - 9.12	8.78 - 10.06	8.55 - 8.94	8.3 - 8.64		8.23 - 8.23	7.76 - 9.38		8.12 - 9.84	9.12 - 9.12
Salinity (field) (PSU)	0.3 - 0.68	0.47 - 0.8	1.15 - 5.24	0.48 - 2.71	0.33 - 1.68		2.3 - 2.3	0.03 - 1.43		0.16 - 3.64	0.25 - 0.25
TDS (field) (ppm)	369 - 693	489 - 796	1139 - 4695	484 - 2708	338 - 1662		2315 - 2315	32 - 1375		171 - 3343	265 - 265
Temperature (field) (°C)	19.82 - 32.84	22.41 - 33.96	27.42 - 32.05	22.65 - 29.33	22.62 - 28.88		21.88 - 21.88	19.72 - 33.8		24.15 - 32.25	33.35 - 33.35
Turbidity (field) (FNU)	3 - 3							2.1 - 2.1			
Hardness											
Total Hardness (mg CaCO3/L)	157 - 249		390 - 570	138 - 885	110 - 916	77 - 77	2100 - 3550	215 - 1720	450 - 450	37 - 546	74 - 74
Major Ions											
Bromide (mg/L)	0.12 - 0.12		0.88 - 2.36					0.11 - 0.21		0.086 - 1.56	
Calcium (mg/L)	38 - 128	103 - 153	12 - 39	15 - 45	15 - 93	11 - 11	430 - 754	42 - 358	50 - 58	10 - 75	10 - 10
Chloride (mg/L)	16 - 153	14 - 22	170 - 912	52 - 554	26 - 278	20 - 20	136 - 326	15 - 186	49 - 49	17 - 721	20 - 20
Fluoride (mg/L)	1 - 1.9	0.8 - 1.1	0.6 - 2.5	0.6 - 1.9	0.5 - 2.1	0.5 - 0.5	0.4 - 0.6	0.6 - 2.6	1.9 - 1.9	0.2 - 1.2	0.5 - 0.5
Iodide (mg/L)			0.62 - 0.62							0.68 - 0.68	
Magnesium (mg/L)	15 - 43	53 - 60	24 - 140	21 - 204	16 - 179	12 - 12	229 - 406	19 - 248	78 - 79	3 - 96	12 - 12
Potassium (mg/L)	9 - 33	15 - 25	7 - 42	4 - 21	4 - 8	4 - 4	21 - 34	13 - 84	6 - 7	2 - 12	4 - 4
Sodium (mg/L)	54 - 156	72 - 101	375 - 2260	174 - 1660	106 - 744	85 - 90	482 - 958	42 - 690	195 - 213	41 - 1410	90 - 94
Sulfate (as SO4)	142 - 583	481 - 713	227 - 1040	112 - 1640	55 - 767	33 - 33	1540 - 3220	168 - 2140	79 - 79	32 - 970	25 - 25
Metals (dissolved)											
Aluminium - dissolved (mg/L)			0.011 - 0.013								
Arsenic - dissolved (mg/L)	0.001 - 0.003	0.006 - 0.012	0 - 0.035	0.002 - 0.017	0.001 - 0.004	0.002 - 0.002	0.001 - 0.002	0.002 - 0.006	0.003 - 0.003	0.001 - 0.012	0.002 - 0.002
Barium - dissolved (mg/L)	0.041 - 0.093	0.037 - 0.052	0.059 - 0.118	0.046 - 0.109	0.033 - 0.176	0.034 - 0.034	0.069 - 0.12	0.06 - 0.139	0.124 - 0.124	0.021 - 0.15	0.03 - 0.03
Boron - dissolved (mg/L)			0.09 - 0.09					0.06 - 0.07		0.13 - 0.13	
Chromium - dissolved (mg/L)			0.002 - 0.002							0.002 - 0.002	
Cobalt - dissolved (mg/L)	0.001 - 0.004	0.001 - 0.012	0.001 - 0.014	0.001 - 0.001	0.001 - 0.002		0.005 - 0.007	0.001 - 0.003	0.001 - 0.001	0.001 - 0.003	
Copper - dissolved (mg/L)	0.005 - 0.054	0.011 - 0.069	0.011 - 0.196	0.014 - 0.067	0.003 - 0.012	0.012 - 0.012	0.012 - 0.03	0.004 - 0.027	0.001 - 0.001	0.008 - 0.04	0.012 - 0.012
Iron - dissolved (mg/L)			0.09 - 0.09								
Molybdenum - dissolved (mg/L)	0.006 - 0.02	0.024 - 0.043	0.005 - 0.016	0.004 - 0.012	0.002 - 0.006	0.004 - 0.004	0.009 - 0.018	0.019 - 0.146	0.014 - 0.014	0.001 - 0.008	0.003 - 0.003
Nickel - dissolved (mg/L)	0.001 - 0.018	0.007 - 0.024	0.001 - 0.006	0.001 - 0.002	0.002 - 0.002		0.001 - 0.001	0.001 - 0.027		0.001 - 0.002	
Selenium - dissolved (mg/L)	0.01 - 0.03	0.01 - 0.01	0.002 - 0.029				0.16 - 0.28	0.01 - 0.13		0.01 - 0.04	
Uranium - dissolved (mg/L)	0.002 - 0.014	0.006 - 0.008	0.015 - 0.057	0.005 - 0.033	0.002 - 0.014	0.003 - 0.003	0.003 - 0.036	0.002 - 0.021	0.011 - 0.011	0.002 - 0.076	0.003 - 0.003
Vanadium - dissolved (mg/L)			0.03 - 0.03								
Metals (total)											
Aluminium - total (mg/L)			0.11 - 0.99								
Arsenic - total (mg/L)	0.001 - 0.003	0.007 - 0.012	0.004 - 0.066	0.002 - 0.018	0.001 - 0.004	0.002 - 0.002	0.001 - 0.003	0.002 - 0.005	0.003 - 0.003	0.002 - 0.013	0.002 - 0.002
Barium - total (mg/L)	0.035 - 0.088	0.037 - 0.053	0.059 - 0.165	0.046 - 0.118	0.041 - 0.188	0.035 - 0.035	0.073 - 0.128	0.057 - 0.142	0.133 - 0.133	0.024 - 0.163	0.032 - 0.032
Boron - total (mg/L)			0.1 - 0.1					0.07 - 0.07		0.14 - 0.14	
Chromium - total (mg/L)			0.0009 - 0.005	0.001 - 0.001			0.001 - 0.002		0.001 - 0.001	0.001 - 0.004	

Parameter	BCP North Pit	BCP South Pit	BCP Spring	BCP Spring (N)	BCP Spring (S)	Culvert Outflow	Pooled water S of sediment dam	Sediment Dam	Seepage	Sump	U/S of Culvert
Cobalt - total (mg/L)	0.001 - 0.004	0.001 - 0.015	0.001 - 0.016	0.001 - 0.002	0.001 - 0.003	0.001 - 0.001	0.005 - 0.007	0.001 - 0.003	0.002 - 0.002	0.001 - 0.004	0.001 - 0.001
Copper - total (mg/L)	0.008 - 0.065	0.012 - 0.072	0.017 - 0.392	0.023 - 0.098	0.006 - 0.021	0.021 - 0.021	0.013 - 0.03	0.008 - 0.036	0.007 - 0.007	0.011 - 0.051	0.021 - 0.021
Iron - total (mg/L)			1.06 - 1.06							0.3 - 0.3	
Molybdenum - total (mg/L)	0.007 - 0.022	0.026 - 0.051	0 - 0.025	0.004 - 0.013	0.003 - 0.007	0.004 - 0.004	0.01 - 0.017	0.022 - 0.156	0.018 - 0.018	0.001 - 0.009	0.004 - 0.004
Nickel - total (mg/L)	0.002 - 0.017	0.007 - 0.025	0.001 - 0.012	0.001 - 0.004	0.001 - 0.004		0.001 - 0.002	0.001 - 0.006	0.002 - 0.002	0.001 - 0.003	
Selenium - total (mg/L)	0.02 - 0.03	0.01 - 0.01	0.002 - 0.054				0.16 - 0.28	0.01 - 0.14		0.01 - 0.04	
Uranium - total (mg/L)	0.003 - 0.016	0.007 - 0.008	0.016 - 0.091	0.005 - 0.044	0.003 - 0.018	0.003 - 0.003	0.004 - 0.038	0.004 - 0.023	0.012 - 0.012	0.002 - 0.083	0.003 - 0.003
Vanadium - total (mg/L)			0.04 - 0.04							0.01 - 0.01	
Nutrients											
Nitrate as N (mg/L)	0.09 - 0.09		0.14 - 0.14					17.3 - 34.6		0.32 - 0.32	
Nitrite + Nitrate as N (mg/L)	0.09 - 0.09		0.15 - 0.15					17.6 - 35.3		0.32 - 0.32	
Nitrite as N (mg/L)			0.01 - 0.01					0.29 - 0.65			
Physico-Chemical Parameters											
Electrical Conductivity (µS/cm)	556 - 1360	1250 - 1520	1890 - 8850	956 - 7080	619 - 3420	491 - 491	5690 - 9460	739 - 5280	1500 - 1500	279 - 6290	471 - 471
pH (lab)	7.85 - 8.26	7.92 - 8.17	8.61 - 9.3	8.27 - 9.19	7.85 - 8.54	8.09 - 8.09	7.89 - 8.04	7.51 - 8.73	7.73 - 7.73	8 - 9.14	8.28 - 8.28
Turbidity (NTU)	0.2 - 3.4	0.2 - 1	1.8 - 155	1.6 - 33.1	1.3 - 19.1	19.7 - 19.7	0.8 - 3.6	0.5 - 2.1	10.9 - 10.9	2.6 - 38.7	19.7 - 19.7

Table 23 Mine site surface water exceedances of ANZECC Livestock Water Quality Guidelines

Parameter	BCP North Pit	BCP South Pit	BCP Spring	BCP Spring (N)	BCP Spring (S)	Pooled water S of sediment dam	Sediment Dam	Seepage	Sump
Electrical Conductivity (µS/cm)									
3. Post-open cut mining			✓	✓		✓			✓
Electrical Conductivity (field) (µS/cm)									
3. Post-open cut mining			✓						✓
Fluoride (mg/L)									
2. Open cut mining							✓		
3. Post-open cut mining			✓		✓				
Molybdenum - total (mg/L)									
2. Open cut mining							✓		
Selenium - dissolved (mg/L)									
2. Open cut mining	✓								
3. Post-open cut mining			✓			✓	✓		✓
Selenium - total (mg/L)									
2. Open cut mining	✓								
3. Post-open cut mining			✓			✓	✓		✓
Sulfate (as SO4) (mg/L)									
3. Post-open cut mining			✓	✓		✓	✓		

✓ Exceedance observed

Table 24 Mine site surface water exceedances of ANZG aquatic ecosystem (slightly to moderately disturbed) WQOs

Parameter	BCP North Pit	BCP South Pit	BCP Spring	BCP Spring (N)	BCP Spring (S)	Pooled water S of sediment dam	Sediment Dam	Seepage	Sump
Aluminium - total (mg/L)									
3. Post-open cut mining			✓						
Arsenic - dissolved (mg/L)									
3. Post-open cut mining			✓	✓					
Arsenic - total (mg/L)									
3. Post-open cut mining			✓	✓					
Chromium - dissolved (mg/L)									
3. Post-open cut mining			✓						✓
Chromium - total (mg/L)									
3. Post-open cut mining			✓			✓			✓
Copper - dissolved (mg/L)									
2. Open cut mining	4						✓		
3. Post-open cut mining	✓	✓	✓	✓	✓	✓	✓		✓2
Copper - total (mg/L)									
2. Open cut mining	✓						✓	✓	
3. Post-open cut mining	✓	✓	✓	✓	✓	✓	✓		✓
Selenium - dissolved (mg/L)									
2. Open cut mining	✓						✓		
3. Post-open cut mining		✓	✓			✓	✓		✓
Selenium - total (mg/L)									
2. Open cut mining	✓						✓		
3. Post-open cut mining		✓	✓			✓	✓		✓

7.5.3 Assessment of water levels at BCP Spring locations and in the sump

To assess the water levels and response to rainfall events, Aeris installed automated data loggers at three locations, i.e. BCP Spring (N), BCP Spring (S) and SUMP. Data was downloaded on a regular basis and collected data was compensated for barometric pressure changes. Table 25 shows the timeframes/periods the dataloggers were operational.

Table 25 Datalogger periods at surface water monitoring locations

Location/Data File		Recording Period	
BCP Spring (N)		14/12/2022 06:00	29/09/2023 14:00
#S(N)1	BCP Spring (N)_2023-01-06_13-20	14/12/2022 06:00	6/01/2023 13:00
#S(N)2	BCP Spring (N)_2023-05-14_10-00	6/01/2023 18:00	5/02/2023 11:00
#S(N)3	BCP Spring (N)_2023-05-14_1 (2)	5/02/2023 14:00	14/05/2023 09:00
#S(N)4	BCP Spring (N)_2023-06-23_11-01	14/05/2023 12:00	23/06/2023 10:00
#S(N)5	BCP Spring (N)_2023-07-22_11-22	23/06/2023 13:00	22/07/2023 11:00
#S(N)6	BCP Spring (N)_2023-09-03_11-39	22/07/2023 13:00	3/09/2023 11:00
#S(N)7	BCP Spring (N)_2023-09-29_15-12	3/09/2023 13:00	29/09/2023 14:00
BCP Spring (S)		14/12/2022 06:00	29/09/2023 14:00
#S(S)1	BCP Spring (S)_Append_2023-01-0	14/12/2022 06:00	6/01/2023 13:00
#S(S)2	BCP Spring (S)_2023-05-14_10-22	6/01/2023 18:00	5/02/2023 11:00
#S(S)3	BCP Spring (S)_2023-05-14_1 (2)	5/02/2023 14:00	14/05/2023 09:00
#S(S)4	BCP Spring (S)_2023-06-23_11-15	14/05/2023 12:00	23/06/2023 10:00
#S(S)5	BCP Spring (S)_2023-07-22_11-27	23/06/2023 13:00	22/07/2023 11:00
#S(S)6	BCP Spring (S)_Append_2023-09-0	22/07/2023 13:00	3/09/2023 11:00
#S(S)7	BCP Spring (S)_2023-09-29_14-51	3/09/2023 13:00	29/09/2023 14:00
SUMP		14/12/2022 06:00	29/09/2023 14:00
#SP1	SUMP_2023-01-06_13-32-38-158-Ba	14/12/2022 06:00	6/01/2023 13:00
#SP2	SUMP_2023-05-14_10-12-58-223-Ba	6/01/2023 18:00	5/02/2023 11:00
#SP3	SUMP_2023-05-14_10-12-58-22 (2)	5/02/2023 14:00	14/05/2023 09:00
#SP4	SUMP_2023-06-23_11-13-07-584-Ba	14/05/2023 12:00	23/06/2023 10:00
#SP5	SUMP_2023-07-22_11-16-45-000-Ba	23/06/2023 13:00	22/07/2023 11:00
#SP6	SUMP_2023-09-03_11-44-33-405-Ba	22/07/2023 13:00	3/09/2023 11:00
#SP17	SUMP_2023-09-29_15-04-02-346-Ba	3/09/2023 13:00	29/09/2023 14:00

Data logger recordings were processed to calculate equivalent absolute surface water elevations (in mAHD) and plotted against rainfall. In addition, increases/decreases in water levels relative to the first reading were calculated and plotted against rainfall to assess the response of water levels to rainfall events.

Time series are provided as follows:

- Plate 16: Water elevations (mAHD) at BCP Spring (N), BCP Spring (S) and the sumps

- Plate 17: Water level changes at BCP Spring (N), BCP Spring (S) and the sumps

The datalogger recordings indicate the following:

- Water levels at the BCP Spring (N) and BCP Spring (S) locations rise almost immediately in response to significant rainfall events. For example, water levels rose approximately 65cm at the BCP spring sites in response to the rainfall events in early March 2023. It is considered that the nearly immediate rise is mainly due to “first flush” flow in the creek and not as much to localised runoff from the mine site and direct rainfall accumulation. Following the rainfall event, water levels decline (almost exponentially) due to reduced creek flow. Once the flow in the creek has reduced to a trickle or stopped, water levels at the BCP Spring (N) and BCP Spring (S) locations reach an “equilibrium” between baseflow within the creek, shallow groundwater interaction and evaporation.
- Water levels in the Sump also respond to rainfall events. However, the water from the sump is pumped back into the sediment dam regularly to prevent overflow. This pump-back operation masks the long-term impact of rainfall and evaporation on sump water levels.

The corresponding changes in shallow groundwater levels and potential correlation with surface water level changes are discussed in Section 8.2.4.

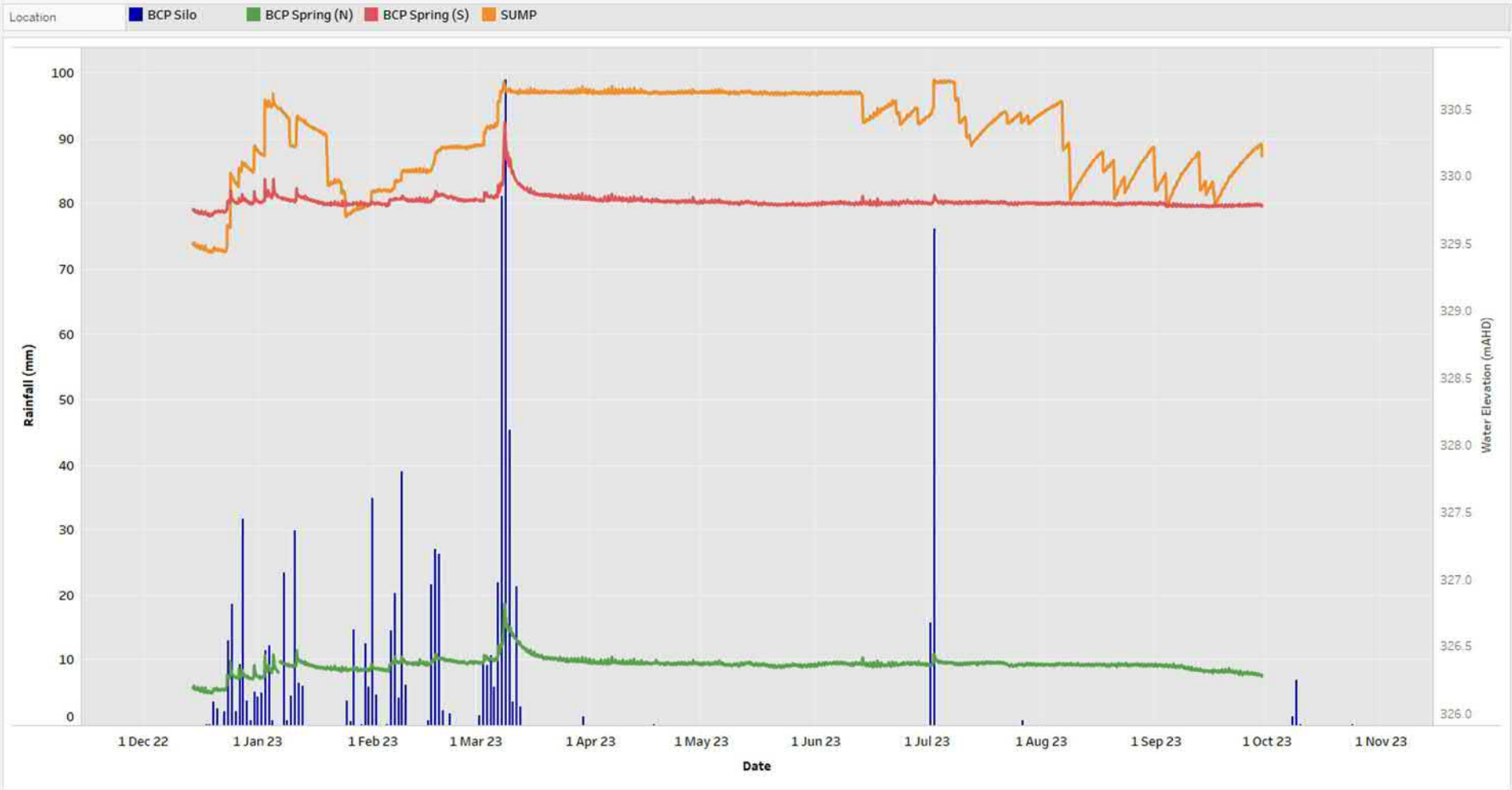


Plate 16 Water elevation (mAHD) at BCP Spring (N), BCP Spring (S) and the sump

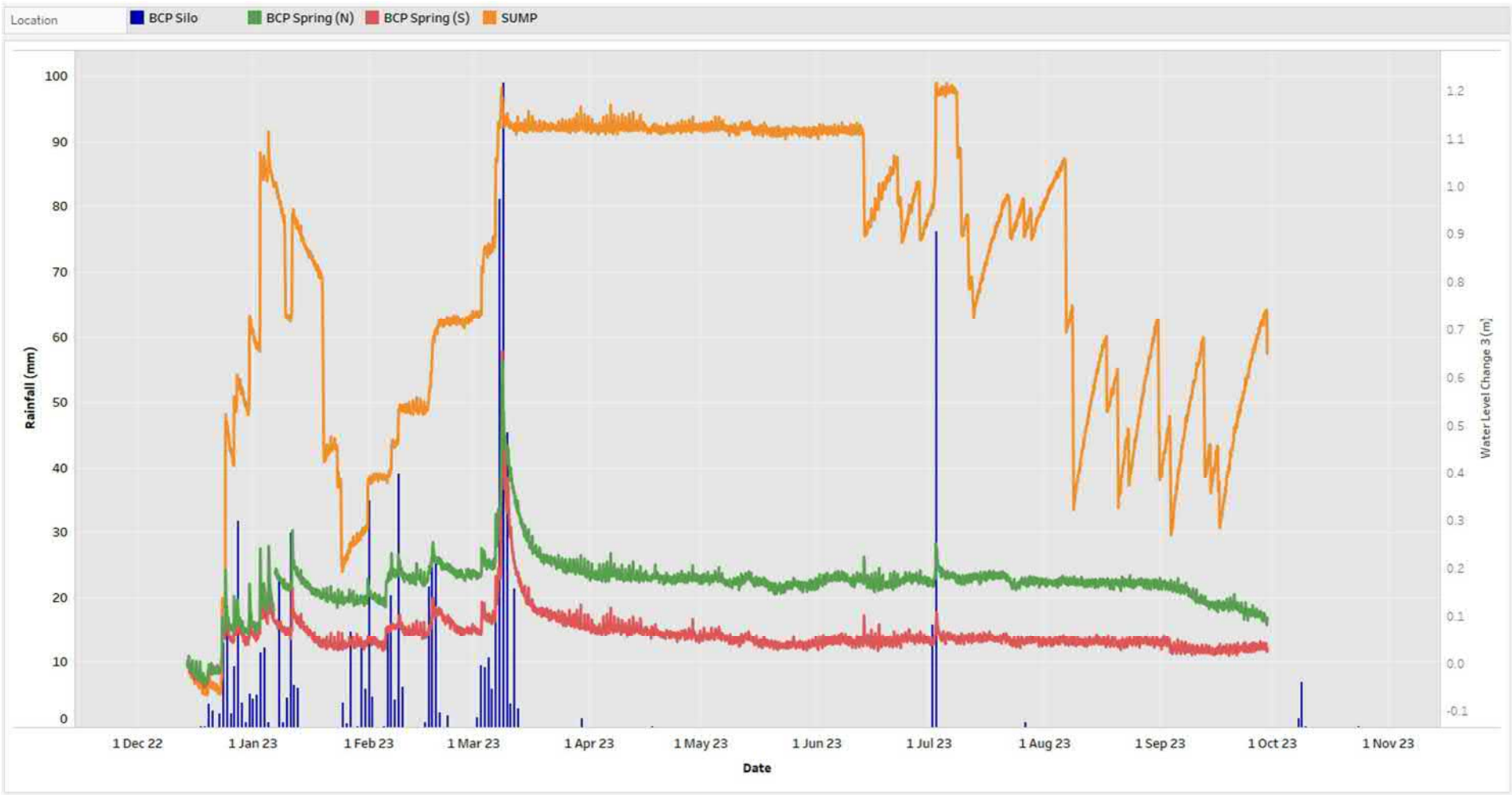


Plate 17 Water level changes (m) at BCP Spring (N), BCP Spring (S) and the sump

8 Groundwater monitoring results

8.1 Groundwater monitoring network

Groundwater monitoring and sampling have been undertaken at BCP since 2014 as part of different environmental monitoring and investigation programs. Details of the groundwater monitoring bores are provided in Table 26, with locations shown in Figure 2 and Figure 3. Available drilling logs are presented in Appendix B.

Table 26 BCP groundwater monitoring well details

Well ID	Easting	Northing	Total Depth (mbgl)	Surface RL (mAHD)	Aquifer interval (mbgl)	Screened Interval (mbgl)	Screened Formation	Purpose/comments
EA groundwater compliance bores								
Bore E	380026	7738835	85	334.23	-	28-83	Basalt/ dolerite	-
BAWB01	380432	7741097	104	352.68	22-23/34-35/43-44	20-101	Rhyolite	Groundwater level and groundwater quality along strike of the ore body to the south east
BAWB02	379480	7742395	104	310.59	No aquifer encountered	96-102	Rhyolite	Groundwater level and groundwater quality along strike of the ore body to the north west, in the Green Zone ore body.
BAWB03	379834	7741692	104	329.50	No aquifer encountered	50-102	Rhyolite	Groundwater level and groundwater quality normal to strike of the ore body to the south west
BAWB04	380043	7742054	100	329.14	No aquifer encountered	94-100	Rhyolite	Groundwater level and groundwater quality normal to strike of the ore body to the north east
BAWB05	380948	7740252	102	377.32	39-40/49-51	35-102	Rhyolite	Background bore for groundwater level and groundwater quality assessment remote from any influence of the mining operation
BAWB07	379849	7741936	127	328.74	No drilling or construction log available. Groundwater level and groundwater quality within the ore body			
BAWBR01	380292	7740939	14	334.49	-	5-6	Dolerite	-
BAWBR02	379912	7741279	14	322.98	-	2-3	Dolerite	-
BAWBR03	379991	7741485	14	326.02	-	3-4	Dolerite	-
EA seepage monitoring bores								
Seepage Bore 1a	380084	7741046	6	336.819		1-5	Rhyolite	Assess seepage from sediment dam

Well ID	Easting	Northing	Total Depth (mbgl)	Surface RL (mAHD)	Aquifer interval (mbgl)	Screened Interval (mbgl)	Screened Formation	Purpose/comments
Seepage Bore 1b	380084	7741048	16	336.487		5-15	Rhyolite	Assessment of seepage from sediment dam
Seepage Bore 2a	380025	7741117	6	331.218		1-5	Rhyolite	Assessment of seepage from sediment dam
Seepage Bore 2b	380023	7741116	16	331.342		5-15	Rhyolite	Assessment of seepage from sediment dam
Seepage Bore 3a	379985	7741133	6	332.189		1-5	Rhyolite	Assessment of seepage from sediment dam
Seepage Bore 3b	379986	7741135	16	331.962		5-15	Rhyolite	Assessment of seepage from sediment dam
Seepage Bore 4a	380711	7740798	6	355.061		1-5	Rhyolite	Assessment of seepage from sediment dam
Additional seepage monitoring bores								
Seepage Bore 5a	379978	7740810	10	338.46		6 – 10		Assessment of potential impact from WRD on shallow and deeper groundwater
Seepage Bore 5b	379979	7740810	15	341.95		11 – 15		
Seepage Bore 6a	379913	7740838	10	337.96		6 – 10		Assessment of potential impact from WRD on shallow and deeper groundwater
Seepage Bore 6b	379912	7740840	15	339.66		11 - 15		
Seepage Bore 7a	379929	7741239	6	328.95		3.5 – 6		Assessment of relationship between shallow groundwater and BCP Spring (N)
Seepage Bore 8a	380021	7741146	6	329.45		3.5 – 6		Assessment of relationship between shallow groundwater and sump
Seepage Bore 9a	380058	7741122	6	331.45		3.5 – 6		Assessment of relationship between shallow groundwater and BCP Spring (S)
Other monitoring bores								
BARC071	379656	7742085	146		19-22/108-109	18-146	Rhyolite	Groundwater level and groundwater quality within the ore body

8.2 Groundwater levels and flow

8.2.1 Groundwater levels in mineral exploration bores (2013)

Between 2008 and 2012, mineral exploration drilling programs were undertaken at and near the Project site. This included the drilling of nine (9) percussion holes, twenty-two (22) diamond drill holes (DDH), and seventy-five (75) reverse circulation (RC) drill holes for the Barbara Copper Project.

Several of the DDH and RC holes remained open for a time, which permitted the measurement of groundwater levels across the ore body. Syndicated Metals undertook a groundwater level measuring campaign in October 2013 in forty (40) exploration drill holes.

Table 27 shows the groundwater level data that were obtained from this campaign. This data shows that the median depth to groundwater in the BCP ore body is about 12m below the ground surface (which equates to a groundwater level elevation of about 302m AHD).

Table 27 Exploration Drill Hole Groundwater Levels – October 2013 (RLA, 2014)

Hole ID	Easting (MGA94)	Northing (MGA94)	Depth to groundwater (mbRL)	Surface RL (mAHD)	Groundwater Level Elevation (mAHD)
BADD002	380146.3	7741437	8.65	327.026	318.376
BADD003	380148.9	7741504	14.43	320.731	306.301
BADD004	380007.3	7741402	7	322.47	315.47
BADD005	380034.1	7741365	9.41	323.2	313.79
BADD006	379967	7741326	8.2	321.1	312.9
BADD008	380144.8	7741390	13.49	324.058	310.568
BADD009	380145	7741434	12.7	323.021	310.321
BARC006	380178.6	7741609	20.29	323.359	303.069
BARC007	380145	7741580	37.93	305.661	267.731
BARC008	380144	7741635	33.56	307.498	273.938
BARC009	380143.4	7741669	30.71	307.936	277.226
BARC010	380147.3	7741437	9.87	325.806	315.936
BARC012	380253.1	7741463	18.64	320.301	301.661
BARC015	380150.5	7741532	22	316.931	294.931
BARC016	380010.3	7741401	7.34	322.31	314.97
BARC017	380036.4	7741365	9.7	322.91	313.21
BARC018	379952.9	7741871	20.36	307.02	286.66
BARC022	379968.8	7741325	8.32	320.82	312.5
BARC023	379896.2	7741919	6.75	309.71	302.96
BARC027	379926.6	7741868	16.41	308.304	291.894
BARC030	380019.8	7741789	12.84	308.835	295.995
BARC031	380059.4	7741764	23.6	309.877	286.277
BARC032	380192.2	7741487	12.5	323.542	311.042
BARC033	380194.6	7741421	7.42	327.381	319.961
BARC038	379856.4	7741890	12.41	307.081	294.671
BARC039	379928.3	7741938	9	309.702	300.702
BARC040	379907.3	7741962	6.79	308.588	301.798
BARC043	379856	7741888	11.67	307.881	296.211
BARC044	379902.1	7741846	6.12	309.65	303.53

Hole ID	Easting (MGA94)	Northing (MGA94)	Depth to groundwater (mbRL)	Surface RL (mAHD)	Groundwater Level Elevation (mAHD)
BARC046	379922.2	7741820	10.43	310.302	299.872
BARC047	379921.9	7741818	10.4	310.315	299.915
BARC049	380110.9	7741463	11.71	318.432	306.722
BARC050	380192.4	7741422	6.52	328.371	321.851
BARC059	379923.7	7741815	11.2	309.68	298.48
BARC061	379911.2	7741761	8.82	309.733	300.913
BARC062	380134.4	7741289	15.64	323.318	307.678

8.2.2 Groundwater levels in monitoring bores (2014)

Table 28 shows the depth to groundwater measured in the dedicated groundwater monitoring bores at the Barbara Copper Project in May and July 2014. Groundwater levels generally fell slightly between May and July 2014 (RLA, 2014).

The depths to groundwater in bores BAWB07 and BARC071 differ by about 5m. These bores are close to each other and are separated topographically by about 1m. Such differing depths to groundwater are not unusual in fractured rock aquifers and illustrate the disconnect between aquifers over such short horizontal distances.

Table 28 Depth to Groundwater in BCP Groundwater Monitoring Bores (RLA, 2014)

Groundwater monitoring bore	Date of Measurement	Standing water level (m below measurement point)
BAWB01	21/05/2014	16.24
BAWB01	29/07/2014	16.33
BAWB02	21/05/2014	8.26
BAWB02	29/07/2014	9.00
BAWB04	20/05/2014	14.38
BAWB04	29/07/2014	14.46
BAWB05	21/05/2014	25.96
BAWB05	29/07/2014	25.81
BAWB07	20/05/2014	16.38
BAWB07	29/07/2014	16.93
BARC071	21/05/2014	21.55
BARC071	29/07/2014	21.70

Contours of the Australian Height Datum (AHD) elevation of the 2014 groundwater level at each of the Barbara Copper Project groundwater monitoring bores are presented in Figure 14.

The contours and potentiometric surface profile show that, provided hydraulic continuity exists throughout the Leichhardt Metamorphics, groundwater flow will be from southwest to northeast within the Barbara Shear Zone. The local depression in the potentiometric surface is due to depression by pumping within the orebody.

The groundwater gradient within the Barbara Shear Zone is 0.02 or 2%, which is relatively steep. This steep gradient reflects the low hydraulic conductivity of the aquifers within the Leichhardt Metamorphics.

8.2.3 Groundwater levels in monitoring bores (2018-2024)

Groundwater monitoring bores

The time series of measured groundwater levels in the groundwater monitoring bores are presented in Plate 18 and Plate 19. Overall, the measurements indicate the following:

- In 2018, the depth to groundwater ranged between 5 and 25 mbRL. These levels are within the range observed in October 2013 within the RC exploration drill holes (Table 27).
- In early 2019, the water levels in the bores rose in response to the significant rainfall in February 2019 and were between 5 and 10 metres shallower than in 2018.
- Since early 2019, groundwater levels in the bores have declined, reflecting recovery after the rainfall event, the open-cut mining operations and the dewatering of the aquifers due to groundwater seepage/inflow into the open pits. The decline rate has slowed down since mining started in June 2019. Groundwater levels did rise in response to rainfall events.
- Since mining finished in March 2021, groundwater levels seem to be slowly recovering to pre-mining levels.
- In early 2023, groundwater levels rose in response to the significant rainfall events in January/February 2023.

Seepage monitoring bores

Plate 20 to Plate 23 present time series of measured groundwater levels in the seepage monitoring bores. Overall, the measurements indicate the following:

- Seepage monitoring bores 4a/4b:
  - The bores are located near the offices and workshop area along the access road to the mine site. The bores were installed as background monitoring bores.
  - Between October 2019 and November 2023, groundwater levels in shallow bore 4a varied between 349.3 mAHD and 350.3 mAHD. Groundwater levels in deeper bore 4b varied between 348.3 mAHD and 349.9 mAHD.
  - Groundwater level fluctuations in response to rainfall were minor but more pronounced in deeper bore 4b than in shallow bore 4a. The vertical gradient between shallow and deep bore is minor.
- Seepage monitoring bores 1a/1b:
  - These shallow (1a) and deep (1b) bores were installed northeast of the sediment dam, between the sediment dam and the creek.
  - Between October 2019 and November 2023, groundwater levels in shallow bore 1a varied between 331.1 mAHD and 333.3 mAHD. Groundwater levels in deeper bore 1b varied between 328.1 mAHD and 333.3 mAHD.
  - Groundwater levels in the shallow and deep bore have slowly increased since installed in 2019, mainly during the open-cut mining. After the end of the open-cut mining, groundwater levels slightly fluctuate in response to rainfall.
  - Overall, there is a minor vertical gradient (< 1m) from the shallow to the deeper bore. The vertical gradient does not imply the existence of different aquifers.
- Seepage monitoring bores 2a/2b and 3a/b:

- The shallow (2a/3a) and deep (2b/3b) bores were installed adjacent to the sump between the sediment dam and the creek.
- Between October 2019 and November 2023, groundwater levels variations were as follows:
  - Shallow bore 2a: from 324.8 mAHD to 330.2 mAHD
  - Shallow bore 3a: from 329.4 mAHD to 331.0 mAHD
  - Deeper bore 2b: from 328.5 mAHD to 331.6 mAHD.
  - Deeper bore 3b: from 329.5 mAHD to 332.7 mAHD.
- Groundwater levels in the shallow and deep bores have generally increased since installation in 2019. Groundwater levels are lower during the open-cut mining, most likely due to the mine dewatering operations. Groundwater levels rise/recover quickly once the open-cut mining ends.
- Until July 2021, groundwater levels in shallow bore 2a were below the levels in deep bore 2b, indicating a vertical gradient from the deep to the shallow bore. In July 2021, water levels in the shallow bore 2a dropped and then rose in December 2021 to reach levels close to those in deep bore 2b. The sudden drop and rise are most likely associated with the sump excavation between the sediment dam and the creek, with the sump recharging the shallow water-bearing sediment. The vertical upward gradient is still present, albeit at a lower gradient. Fluctuations due to rainfall events are masked by the influence of seepage from the sump into underlying formations.
- Groundwater levels in shallow bore 3a are similar to the levels in deep bore 3b during the open-cut mining, indicating the impact of mine dewatering. After the open-cut mining, groundwater levels rise/recover, with a higher recovery in the deep bore 3b than in shallow bore 3b. The vertical gradient between deep 3b and shallow bore 3a is greater than between bore 2b and 2a. The excavation and operation of the sump have not affected the groundwater levels in shallow bore 3a to the same extent as in shallow bore 2a. Fluctuations due to rainfall events are evident.

- Seepage monitoring bores 5a/b and 6a/b:
  - These shallow (5a and 6a) and deep (5b and 6b) bores were installed between the WRD and sediment dam to assess the impact of potential seepage through the base of the WRD on groundwater.
  - Between January 2023 and November 2023, groundwater levels variations were as follows:
    - Shallow bore 5a: from 336.1 mAHD to 335.1 mAHD
    - Shallow bore 6a: from 335.6 mAHD to 335.1 mAHD
    - Deeper bore 5b: from 339.6 mAHD to 338.6 mAHD.
    - Deeper bore 6b: from 335.5 mAHD to 335.4 mAHD.
  - Large-scale groundwater level variations (as opposed to minute variations observed using data loggers and discussed in Section 8.2.4) are minor, with limited long-term responses to rainfall events.
  - Groundwater levels in deep seepage monitoring bore 5b are higher than in the shallow bore 5a. During the drilling of bore 5b, groundwater inflow was observed at depth of ±12 mbgl. The bore is located within an old drainage line that runs in a northerly direction underneath the

WRD and the sediment dam to join the unnamed creek north of the sediment dam. Groundwater levels in this bore may be affected by subflow within this drainage line or by infiltration of water through the base of the WRD.

  - Groundwater levels in shallow bore 6a and deep bore 6b are similar, with no vertical gradient.

- Seepage bore 7a, 8a and 9a:
  - Shallow bore 7a was installed near the BCP Spring (N). Between January 2023 and November 2023, groundwater levels varied from 327.3 mAHD to 326.1 mAHD.
  - Shallow bore 8a was installed between the sump and the creek. Between January 2023 and November 2023, groundwater levels varied from 328.7 mAHD to 328.5 mAHD.
  - Shallow bore 9a was installed near the BCP Spring (S). Between January 2023 and November 2023, groundwater levels varied from 331.7 mAHD to 330.1 mAHD.
  - Large-scale groundwater level variations (as opposed to minute variations observed using data loggers and discussed in Section 8.2.4) are minor, with limited long-term responses to rainfall events.
  - Since May 2023, groundwater levels have generally remained stable in bores 8a and 9a. Groundwater levels in bore 7a appear to decline towards the nearby topographical level of the creek (at ±326 mAHD)

Groundwater flow direction

Contour maps of groundwater levels are presented as follows:

- Figure 15 presents a contour map of the June 2018 groundwater levels.
- Figure 16 presents a contour map of the April 2022 groundwater levels.
- Figure 17 presents a contour map of the April 2023 groundwater levels.

Groundwater flow generally follows topography and is in a northerly direction underneath the WRD and sediment dam and in a north-westerly direction along the creek.

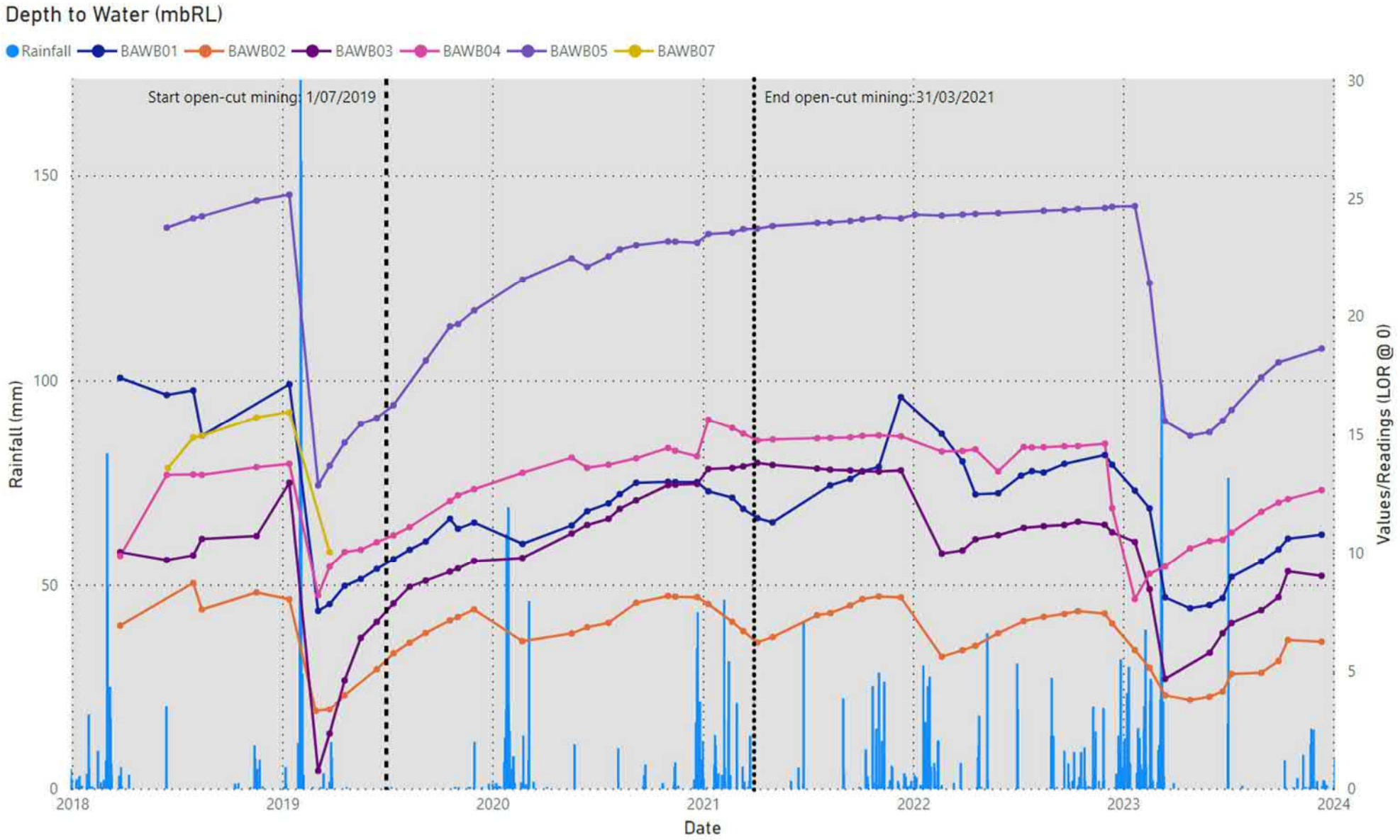


Plate 18 Depth to water (mbRL) in groundwater monitoring bores

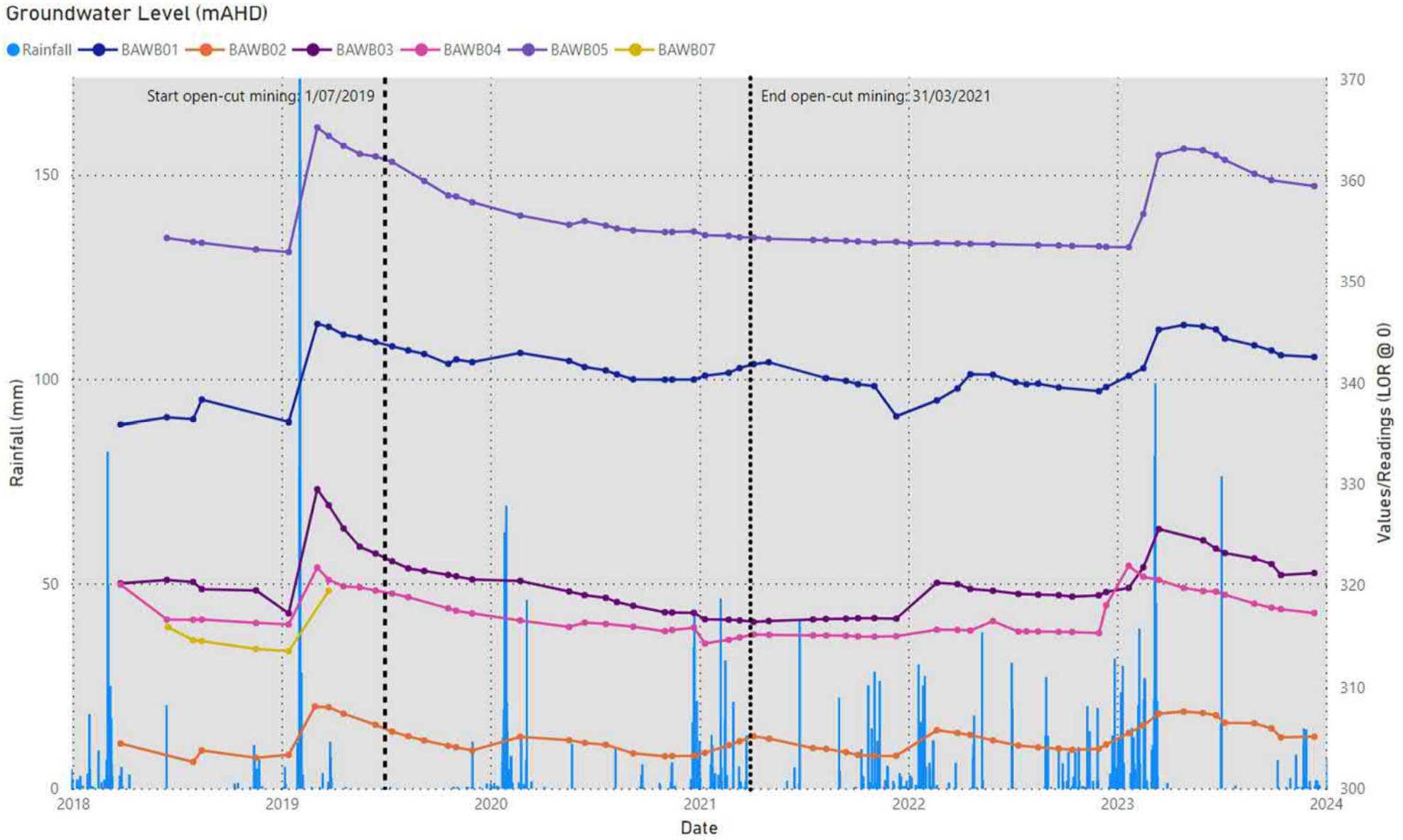


Plate 19 Groundwater levels (mAHD) in groundwater monitoring bores

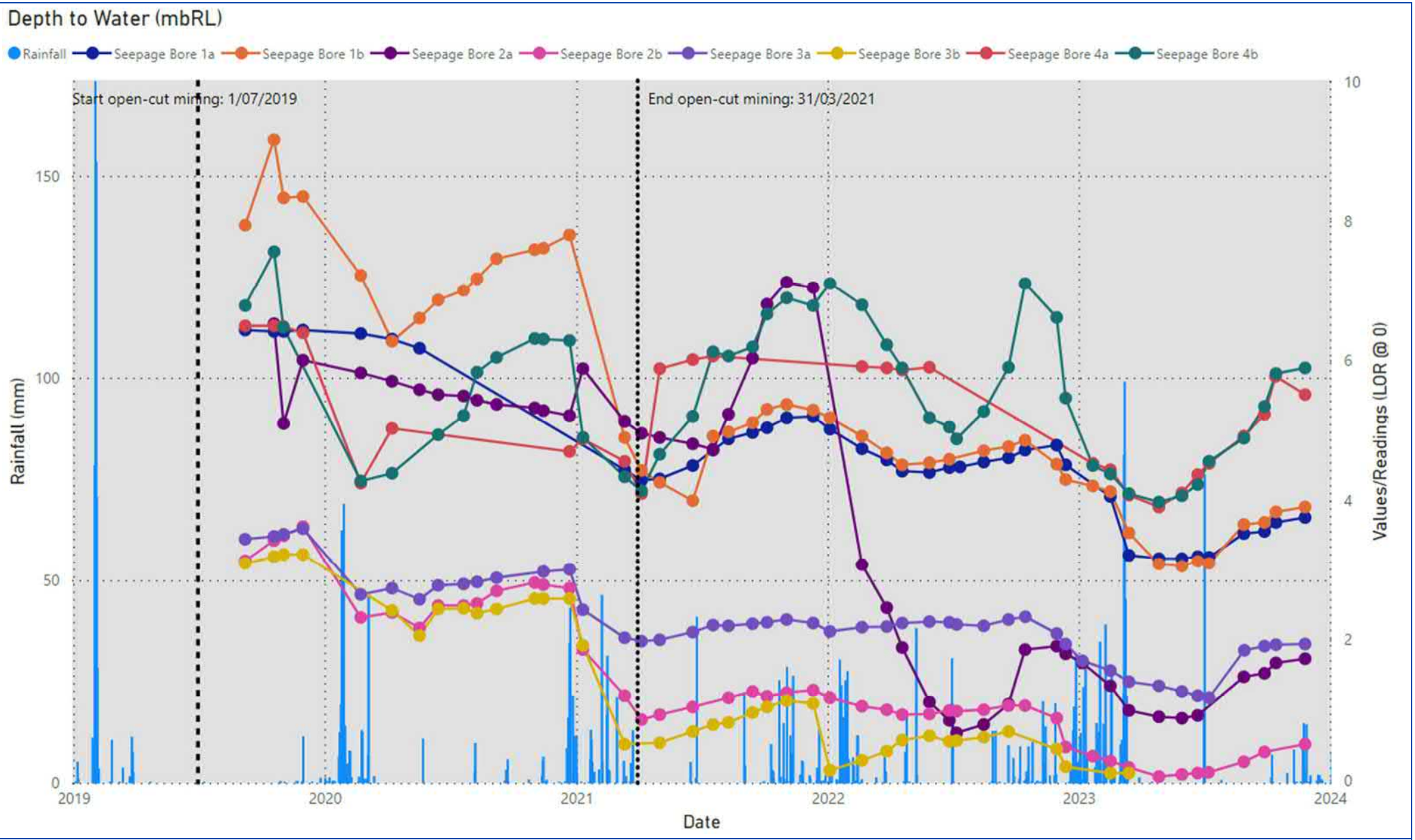


Plate 20 Depth to water (mbRL) in EA seepage monitoring bores

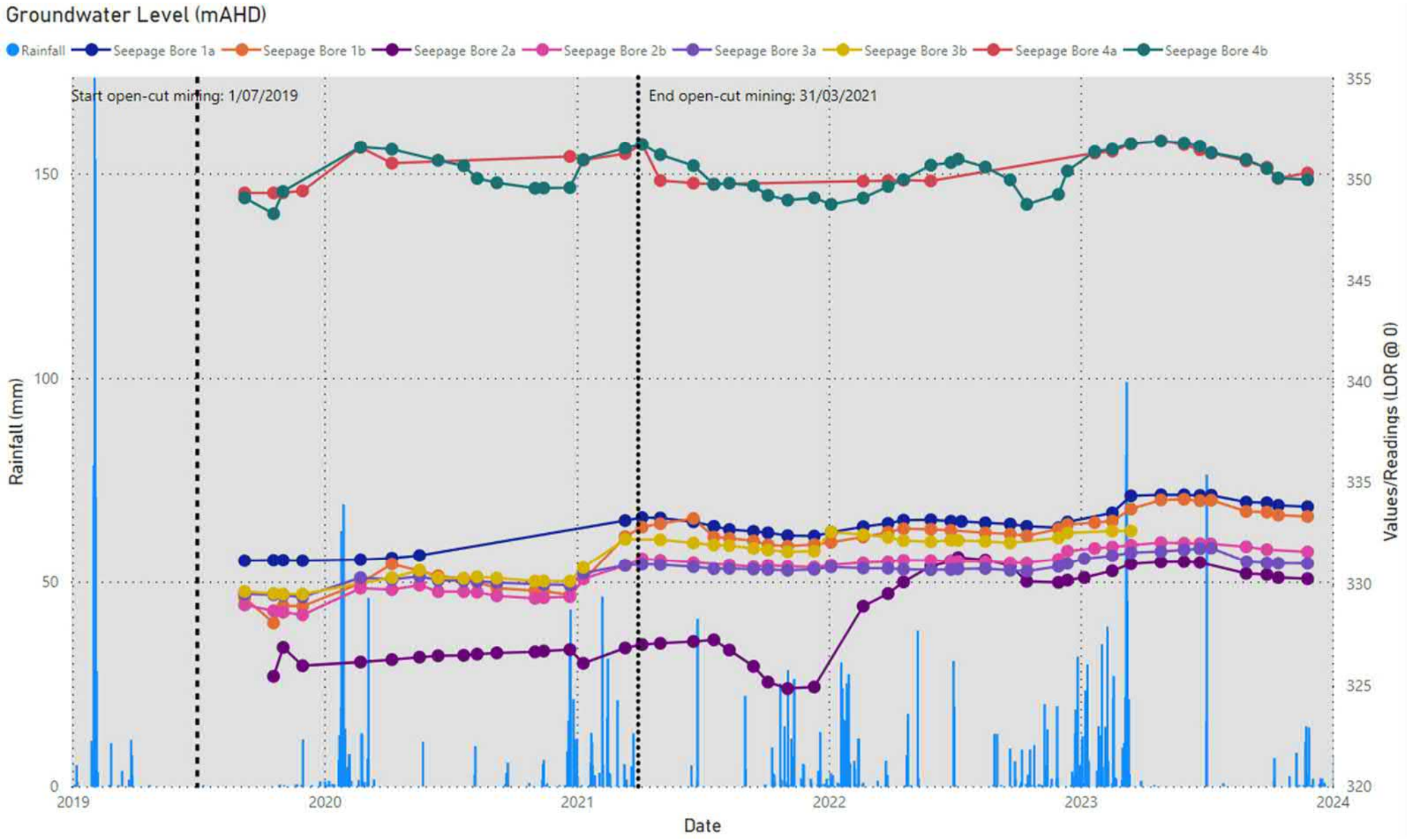


Plate 21 Groundwater levels (mAHD) in EA seepage monitoring bores

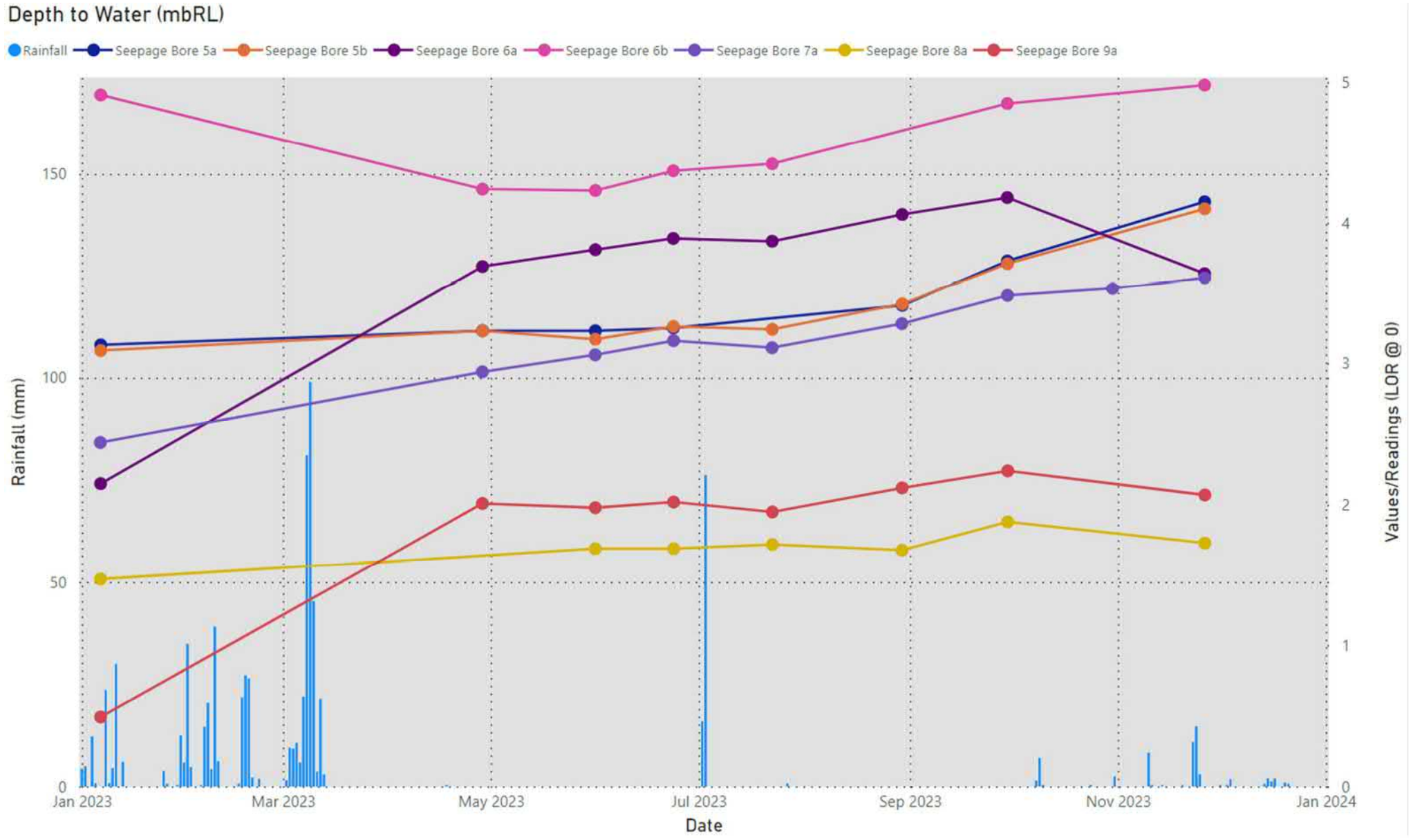


Plate 22 Depth to water (mbRL) in additional seepage monitoring bores

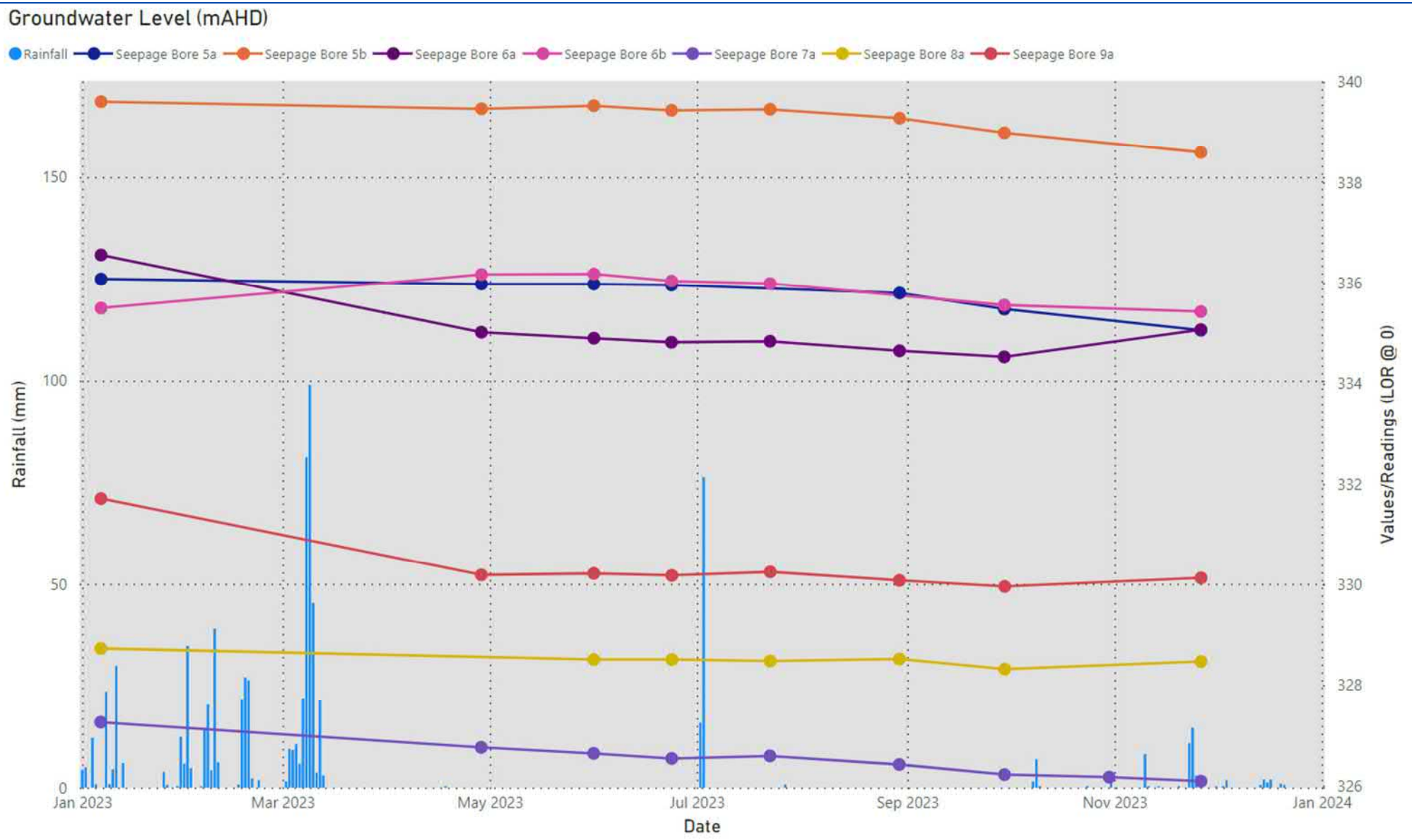


Plate 23 Groundwater levels (mAHD) in additional seepage monitoring bores

8.2.4 Assessment of water levels in seepage monitoring wells

To assess the water levels and response to rainfall events, Aeris installed automated data loggers in several seepage monitoring bores (Table 29). Data was downloaded regularly and compensated for barometric pressure changes. Table 29 shows the timeframes/periods the dataloggers were operational.

Table 29 Datalogger periods at seepage monitoring bore locations

Row Labels	Min. of Date and Time	Max. of Date and Time
Seep 1a	14/12/2022 06:00	29/09/2023 13:00
Seep 1a_2023-01-06_13-45-00-242	14/12/2022 06:00	6/01/2023 13:00
Seep 1a_Append_2023-02-05_11-18	6/01/2023 18:00	5/02/2023 11:00
Seep 1a_2023-05-14_10-25-16-833	5/02/2023 14:00	14/05/2023 09:00
Seep 1a_Append_2023-06-23_11-18	14/05/2023 12:00	23/06/2023 10:00
Seep 1a_2023-07-22_10-58-34-004	23/06/2023 13:00	22/07/2023 10:00
Seep 1a_2023-09-03_12-02-26-140	22/07/2023 13:00	3/09/2023 11:00
Seep 1a_2023-09-29_13-54-29-857	3/09/2023 13:00	29/09/2023 13:00
Seep 2a	14/12/2022 06:00	29/09/2023 14:00
Seep 2a_2023-01-06_13-28-27-350	14/12/2022 06:00	6/01/2023 13:00
Seep 2a_2023-02-05_11-12-33-098	6/01/2023 18:00	5/02/2023 11:00
Seep 2a_2023-05-14_10-10-36-649	5/02/2023 14:00	14/05/2023 09:00
Seep 2a_2023-06-23_11-07-31-909	14/05/2023 12:00	23/06/2023 10:00
Seep 2a_2023-07-22_11-02-21-664	23/06/2023 13:00	22/07/2023 11:00
Seep 2a_2023-09-03_11-48-39-821	22/07/2023 13:00	3/09/2023 11:00
Seep 2a_2023-09-29_14-02-16-472	3/09/2023 13:00	29/09/2023 14:00
Seep 3a	14/12/2022 06:00	29/09/2023 14:00
Seep 3a_2023-01-06_13-26-01-559	14/12/2022 06:00	6/01/2023 13:00
Seep 3a_2023-02-05_11-10-09-928	6/01/2023 18:00	5/02/2023 11:00
Seep 3a_2023-05-14_10-06-32-219	5/02/2023 14:00	14/05/2023 09:00
Seep 3a_2023-06-23_11-05-16-218	14/05/2023 12:00	23/06/2023 10:00
Seep 3a_2023-07-22_11-04-57-060	23/06/2023 13:00	22/07/2023 11:00
Seep 3a_2023-09-03_11-42-20-245	22/07/2023 13:00	3/09/2023 11:00
Seep 3a_2023-09-29_14-11-17-723	3/09/2023 13:00	29/09/2023 14:00
Seep 5b	14/12/2022 06:00	29/09/2023 13:00
Seep 5b_2023-01-06_13-43-11-781	14/12/2022 06:00	6/01/2023 13:00
Seep 5b_2023-02-05_11-22-56-347	6/01/2023 18:00	5/02/2023 11:00
Seep 5b_2023-05-14_10-27-44-437	5/02/2023 14:00	14/05/2023 09:00
Seep 5b_2023-06-23_11-22-49-485	14/05/2023 12:00	23/06/2023 10:00
Seep 5b_2023-07-22_11-07-26-000	23/06/2023 13:00	22/07/2023 11:00
Seep 5b_Append_2023-09-03_12-05	22/07/2023 13:00	3/09/2023 11:00
Seep 5b_2023-09-29_13-50-45-218	3/09/2023 13:00	29/09/2023 13:00
Seep 6b	14/12/2022 06:00	29/09/2023 13:00
Seep 6b_2023-01-06_13-40-50-964	14/12/2022 06:00	6/01/2023 13:00
Seep 6b_2023-02-05_11-21-22-507	6/01/2023 18:00	5/02/2023 11:00
Seep 6b_2023-05-14_10-30-36-146	5/02/2023 14:00	14/05/2023 09:00
Seep 6b_2023-06-23_11-20-44-358	14/05/2023 12:00	23/06/2023 10:00

Row Labels	Min. of Date and Time	Max. of Date and Time
Seep 6b_2023-07-22_11-10-17-524	23/06/2023 13:00	22/07/2023 11:00
Seep 6b_2023-09-03_12-10-41-784	22/07/2023 13:00	3/09/2023 11:00
Seep 6b_2023-09-29_13-41-30-879	3/09/2023 13:00	29/09/2023 13:00
Seep 8a	14/12/2022 06:00	29/09/2023 14:00
Seep 8a_2023-01-06_13-34-25-119	14/12/2022 06:00	6/01/2023 13:00
Seep 8a_2023-02-05_11-14-40-420	6/01/2023 18:00	5/02/2023 11:00
Seep 8a_2023-05-14_10-16-22-227	5/02/2023 14:00	14/05/2023 09:00
Seep 8a_2023-06-23_11-09-18-812	14/05/2023 12:00	23/06/2023 10:00
Seep 8a_2023-07-22_11-12-44-380	23/06/2023 13:00	22/07/2023 11:00
Seep 8a_2023-09-03_11-51-46-130	22/07/2023 13:00	3/09/2023 11:00
Seep 8a_2023-09-29_14-32-44-838	3/09/2023 13:00	29/09/2023 14:00
Seep 9a	14/12/2022 06:00	29/09/2023 14:00
Seep 9a_2023-01-06_13-36-18-670	14/12/2022 06:00	6/01/2023 13:00
Seep 9a_2023-02-05_11-16-14-723	6/01/2023 18:00	5/02/2023 11:00
Seep 9a_2023-05-14_10-18-54-663	5/02/2023 14:00	14/05/2023 09:00
Seep 9a_2023-06-23_11-11-16-577	14/05/2023 12:00	23/06/2023 10:00
Seep 9a_2023-07-22_11-14-50-664	23/06/2023 13:00	22/07/2023 11:00
Seep 9a_2023-09-03_11-54-49-258	22/07/2023 13:00	3/09/2023 11:00
Seep 9a_2023-09-29_14-41-00-590	3/09/2023 13:00	29/09/2023 14:00

Data logger recordings were processed to calculate equivalent absolute groundwater levels in the seepage bores. As part of the quality control, the groundwater levels calculated using the data loggers were compared against manually obtained groundwater levels to ensure that the data logger data was reliable. Plate 24 shows the calculated versus manually obtained groundwater levels, presenting an acceptable correlation between data logger and manual recordings. Therefore, the data logger recordings accurately represent the minute and short-term responses of groundwater levels to rainfall events.

Time series are provided as follows:

- Plate 25: Groundwater levels (mAHD) in seepage monitoring bores 1a, 2a, 3a, 5b, 6b, 8a and 9a versus rainfall
- Plate 26: Groundwater level changes (m) in seepage monitoring bores 1a, 2a, 3a, 5b, 6b, 8a and 9a versus rainfall

The datalogger recordings indicate the following:

- Seepage monitoring bores 1a, 2a and 3a
  - These shallow seepage monitoring bores were installed between the sediment dam and the creek, with bores 2a and 3a installed near the sump.
  - Groundwater levels in these bores rise almost immediately in response to significant rainfall events. The rise and recovery of groundwater levels is as follows:
    - The magnitude of the rise in groundwater levels following significant rainfall events is the largest in seepage monitoring bore 1a. This bore is furthest from and outside the radius of influence of the sump. Recovery of groundwater levels in bore 1a is less gradual and steeper than in bores 2a and 3a.

    - The magnitude of groundwater level rise following significant rainfall events in bore 3a is not as large as in bore 1a. Bore 3a is located near the sump; however, the influence of the sump on water levels at this location is minor. Recovery of groundwater levels in bore 3a is more gradual and less steep than in bore 1a.
    - Groundwater levels in bore 2a rise in response to rainfall, but to a lesser extent than in bores 1a and 3a. The water levels in bore 2a are most likely influenced by the water levels in the sump.

- Seepage monitoring bores 5b and 6b
  - These deep bores were installed between the WRD and sediment dam to assess the impact of potential seepage through the base of the WRD on groundwater. Bore 5b was installed at/within a drainage line that runs northwards from underneath the WRD and sediment dam and then joins the main creek downstream of the BCP Spring (N) location.
  - Groundwater levels in both bores generally respond in a similar manner (i.e. similar magnitude) to rainfall events. However, the recovery/decrease in water levels varies, with the recovery in bore 5a being steeper and quicker than in bore 6b. This is most likely due to the fact that bore 5b was installed at/near the drainage line, allowing for groundwater flow/migration along this drainage line. Infiltration of water from the WRD through its base into the underlying drainage line and/or groundwater may also affect the groundwater levels in seepage monitoring bore 5b.
- Seepage monitoring bores 8a and 9a
  - Shallow bore 8a was installed between the sump and the creek, whilst shallow bore 9a was installed near the BCP Spring (S).
  - Groundwater level rises to rainfall are larger in bore 9a than in bore 8a. Recovery of water levels is generally steeper in bore 9a than in bore 8a. Groundwater level changes at both bores appear correlated with water level changes at the BCP Spring (S) and (N) sites. However, water levels in bores 8a may also be influenced by the nearby sump.

Comparison of groundwater levels in seepage monitoring bores near the creek and water levels within the creek (Plate 27) indicates the following:

- Groundwater levels in shallow seepage monitoring bores 1a, 2a and 3a are generally above the water level at the BCP Spring (S) and BCP Spring (N) sites. These bores are located immediately downgradient of the WRD sediment dam. Groundwater levels fluctuate in response to rainfall events. The dissimilarity in fluctuations (in terms of amplitude and pattern) between groundwater levels in these bores and water levels at the spring indicates that there is limited groundwater throughflow and connectivity from immediately north of the sediment dam to the creek.
- Seepage monitoring bore 9a is located nearest to the BCP Spring (S) site. Groundwater levels in this bore are gently declining towards the water level at the BCP Spring (S) site, indicating a hydraulic connectivity between the shallow groundwater and the water body at this location. However, it is considered that the hydraulic gradient towards the water body is the result of a temporary rise in groundwater levels after the March 2023 and July 2023 rainfall events. The rainfall-event generated gradient will dissipate and disappear with time so that the shallow groundwater no longer recharges the water body, until the next significant rainfall event. The ephemeral occurrence of the water bodies along the creek supports this hypothesis.

- Seepage monitoring bore 8a is located near the creek, with groundwaters below the water level at BCP Spring (S). This indicates limited groundwater throughflow and connectivity from this location to the creek.

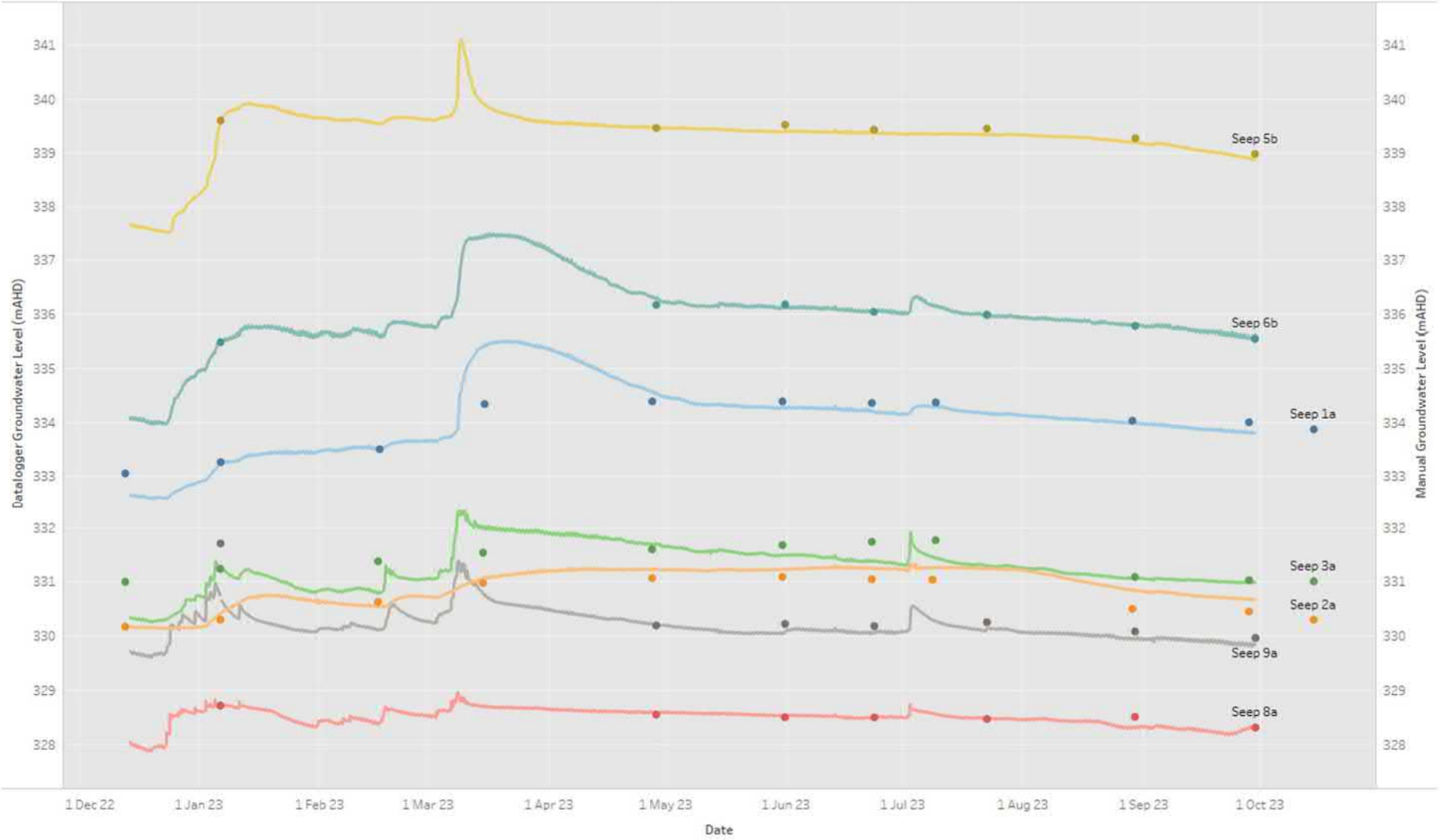


Plate 24 Data logger based groundwater levels (mAHD) versus manually obtained groundwater levels (mAHD)

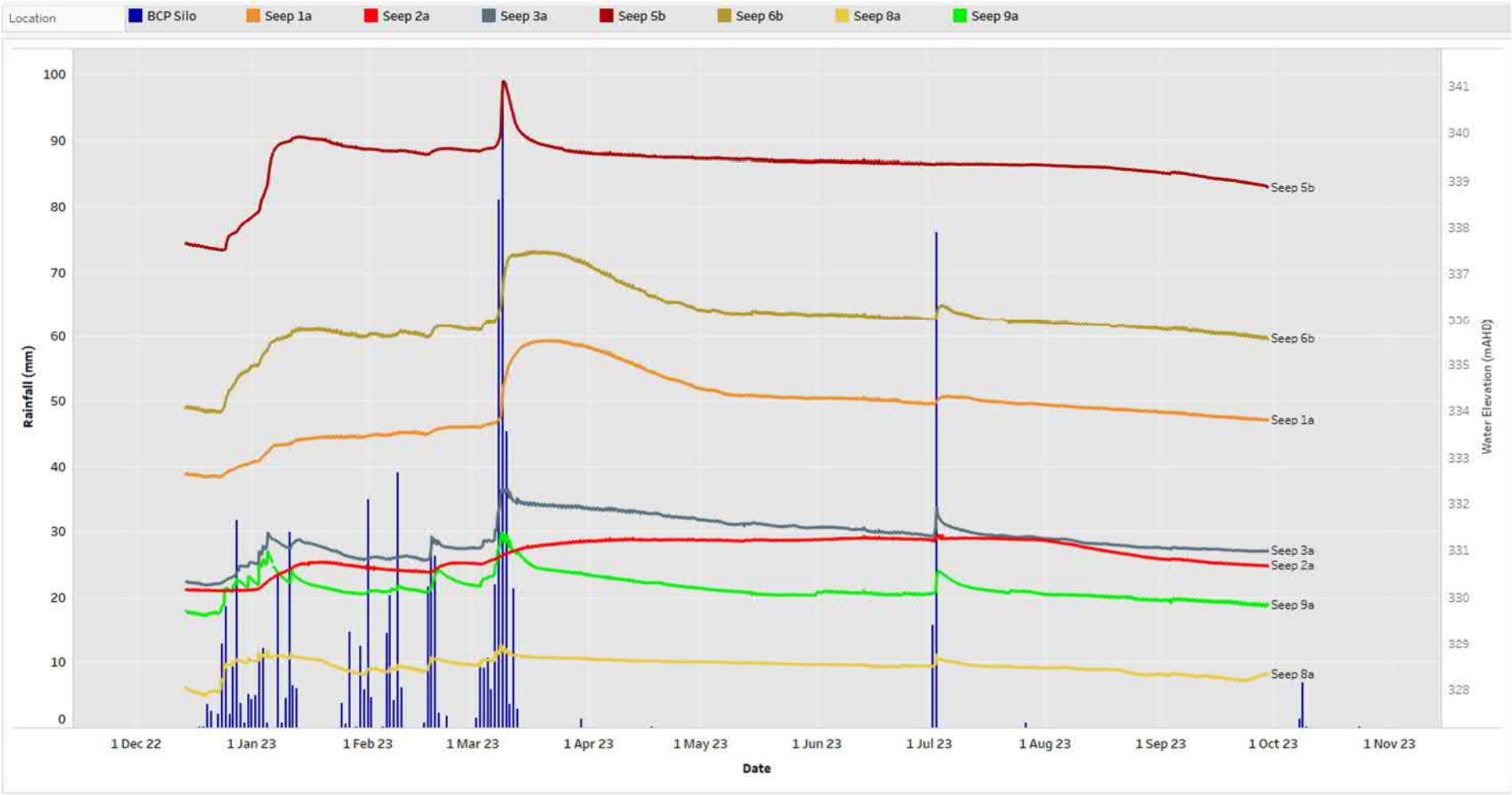


Plate 25 Groundwater levels (mAHD) in seepage monitoring bores 1a, 2a, 3a, 5b, 6b, 8a and 9a versus rainfall

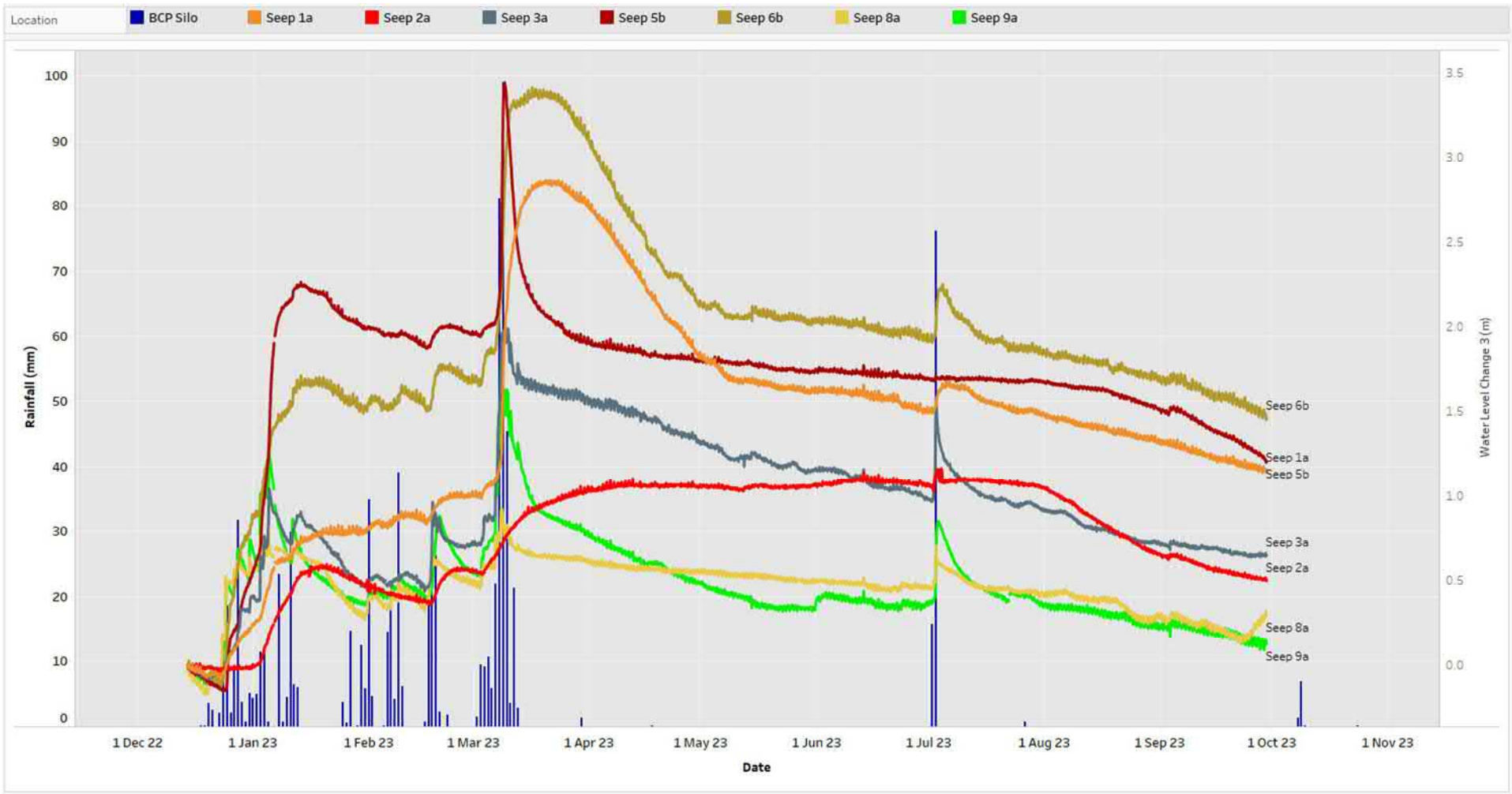


Plate 26 Groundwater level changes (m) in seepage bores 1a, 2a, 3a, 5b, 6b, 8a and 9a versus rainfall

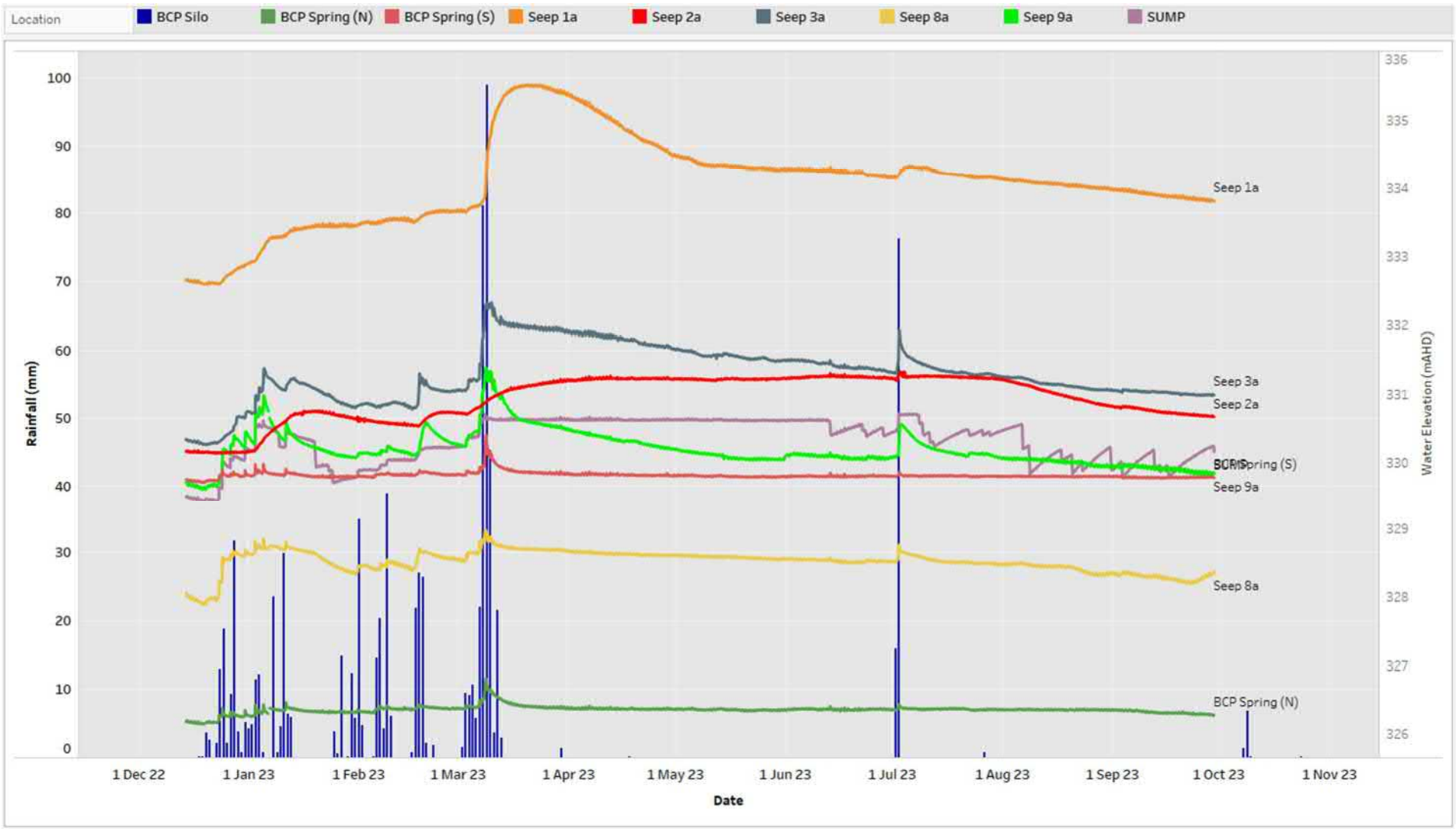


Plate 27 Groundwater levels (mAHD) in selected seepage monitoring bores and BCP spring locations versus rainfall

8.3 Groundwater hydrogeochemistry and water types

Groundwater samples were analysed for major ions and alkalinity to allow for hydrogeochemical analysis. Piper, Durov and Chadha diagrams of the groundwater samples from the groundwater monitoring and the seepage monitoring bores are presented in Appendix G.4 and Appendix H.4, respectively.

Groundwater monitoring bores

Based on the ionic composition of the water samples, the groundwater in the monitoring wells at BCP can be classified as per Table 30.

Table 30 Water-type classification of groundwater monitoring bores

Location	Screened lithology	Piper diagram water type	Durov diagram classification
BARC071	Rhyolite	• Mixed Ca-Na-HCO3	• 3: HCO3 and Na are dominant, indicates ion exchange water.
BAWB01	Rhyolite	• Ca-Mg-HCO3 • Mixed Ca-Na-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed. • 3: HCO3 and Na are dominant, indicates ion exchange water.
BAWB02	Rhyolite	• Mixed Ca-Na-HCO3	• 3: HCO3 and Na are dominant, indicates ion exchange water. • 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed.
BAWB03	Rhyolite	• Mixed Ca-Na-HCO3 • Ca-Mg-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed.
BAWB04	Rhyolite	• Ca-Mg-HCO3 • Na-K-HC03	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed.
BAWB05	Rhyolite	• Ca-Mg-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed.
BAWB07	Ore body?	• Mixed Ca-Na-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed.

Location	Screened lithology	Piper diagram water type	Durov diagram classification
			• 3: HCO3 and Na are dominant, indicates ion exchange water.
BAWBR01	Dolerite	• Na-K-Cl-SO4	• 6: SO4 and Na are dominant. Water type is not frequently encountered and indicates probable mixing or uncommon dissolution influences.
BAWBR02	Dolerite	• Mixed Ca-Na-HCO3 • Na-K-Cl-SO4	• 6: SO4 and Na are dominant. Water type is not frequently encountered and indicates probable mixing or uncommon dissolution influences. • 3: HCO3 and Na are dominant, indicates ion exchange water.
BAWBR03	Dolerite	• Na-K-Cl-SO4	• 6: SO4 and Na are dominant. Water type is not frequently encountered and indicates probable mixing or uncommon dissolution influences. • 3: HCO3 and Na are dominant, indicates ion exchange water. • 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing.
Bore E	Basalt/dolerite	• Ca-Mg-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed.

The ionic composition of the water samples obtained from groundwater monitoring bores indicates the following:

- The water type of bores screened in rhyolite or orebody (BARC071 and BAWB01 to BAWB07) is different than at other bores (BAWBR01 to BAWBR03 and Bore E).
- Water types can be summarised as follows:
  - Rhyolite/ore body bores (BARC071 and BAWB01 to BAWB07): water type is mixed Ca-Na-HCO3 and/or Ca-Mg-HCO3. Groundwater quality is predominantly associated with ion exchange reactions.
  - Dolerite/basalt bores (BAWBR01 to BAWBR03, Bore E): water type is mixed Ca-Na-HCO3, Na-K-Cl-SO4 and/or Ca-Mg-HCO3. Groundwater quality is predominantly associated with mixing/dissolution and ion exchange reactions.
- Water types appear to be influenced mainly by screened lithology, as evidenced by the Gibbs diagrams. Open-cut mining operations do not appear to have changed or adversely affected the water type over time.

- There is no indication of high sulphate content in the groundwater at these locations, even in the groundwater from bore BAWB02 (located in the Green Zone orebody) or from bores BAWB07 and BARC071 (located in the BCP orebody).

Seepage monitoring bores

Based on the ionic composition of the water samples, the groundwater in the seepage monitoring wells at BCP can be classified as per Table 31.

Table 31 Water-type classification of seepage monitoring bores

Location	Screened formation	Piper diagram water type	Durov diagram classification
Seepage Bore 1a	Rhyolite	• Mixed Ca-Mg-Cl	• 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing.
Seepage Bore 1b	Rhyolite	• Variable (evolution?) • Mixed Ca-Na-HCO3 • Na-K-Cl-SO4 • Mixed Ca-Mg-Cl	• 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing (2021-2023). • 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed (2019-2020).
Seepage Bore 2a	Rhyolite	• Na-K-Cl-SO4	• 6: SO4 and Na are dominant. Water type is not frequently encountered and indicates probable mixing or uncommon dissolution influences (2020-2021). • 9: Cl and Na dominant. Frequently indicates end-point waters through dissolution (2022-2023).
Seepage Bore 2b	Rhyolite	• Mixed Ca-Na-HCO3 • Ca-Mg-HCO3	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed (2019-2023). • 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing (2023).
Seepage Bore 3a	Rhyolite	• Mixed Ca-Na-HCO3 • Ca-Mg-HCO3 • Na-K-Cl-SO4 • Mixed Ca-Mg-Cl	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed (2020-2021).

Location	Screened formation	Piper diagram water type	Durov diagram classification
			• 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing (2019, 2022-2023).
Seepage Bore 3b	Rhyolite	• Ca-Mg-HCO3 • Mixed Ca-Mg-Cl	• 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed (2020-2021). • 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing (2019, 2022-2023).
Seepage Bore 4a	Rhyolite	• Na-K-HCO3 • Mixed Ca-Na-HCO3	• 3: HCO3 and Na are dominant, indicates ion exchange water (2020-2023). • 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed (2022).
Seepage Bore 4b	Rhyolite	• Mixed Ca-Na-HCO3 • Ca-Mg-HCO3	• 3: HCO3 and Na are dominant, indicates ion exchange water (2019-2023). • 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed (2022-2023).
Seepage Bore 5a	Rhyolite	• Mixed Ca-Mg-Cl • Ca-Mg-Cl-SO4	• 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing (2023).
Seepage Bore 5b	Rhyolite	• Na-K-Cl-SO4	• 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing (2023).
Seepage Bore 6a	Rhyolite	• Mixed Ca-Mg-Cl • Ca-Mg-Cl-SO4	• 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing (2023).
Seepage Bore 6b	Rhyolite	• Mixed Ca-Na-HCO3	• 3: HCO3 and Na are dominant, indicates ion exchange water (2023). • 2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an

Location	Screened formation	Piper diagram water type	Durov diagram classification
			important ion exchange is presumed (2023).
Seepage Bore 7a	Rhyolite	• Mixed Ca-Na-HCO3	• 3: HCO3 and Na are dominant, indicates ion exchange water (2023).
Seepage Bore 8a	Rhyolite	• Na-K-Cl-SO4 • Mixed Ca-Na-HCO3	• 6: SO4 and Na are dominant. Water type is not frequently encountered and indicates probable mixing or uncommon dissolution influences (2023).
Seepage Bore 9a	Rhyolite	• Na-K-Cl-SO4 • Mixed Ca-Na-HCO3	• 6: SO4 and Na are dominant. Water type is not frequently encountered and indicates probable mixing or uncommon dissolution influences (2023). • 5: No dominant anion or cation, indicates water exhibiting dissolution or mixing (2023).

The ionic composition/water types in the seepage monitoring bores are more varied than in the groundwater monitoring bores and appear to be influenced by multiple factors, including screened lithology, depth of the bore and proximity to mine features and the creek.

The ionic composition indicates the following:

- Seepage monitoring bores 4a/4b:
  - The bores are located near the offices and workshop area along the access road to the mine site. The bores were installed as background monitoring bores.
  - Water types include Na-K-HCO3, mixed Ca-Na-HCO3 and Ca-Mg-HCO3.
  - Water types are related to ion exchange with screened lithology.
- Seepage monitoring bores 1a/1b:
  - These shallow (1a) and deep (1b) bores were installed northeast of the sediment dam, between the sediment dam and the creek.
  - Water type in the shallow bore (1a) is mixed Ca-Mg-Cl and related to dissolution or mixing. Gibbs diagram indicated rock and evaporation dominance.
  - Water type in the deep bore (1b) varies between mixed Ca-Na-HCO3, Na-K-Cl-SO4 and mixed Ca-Mg-Cl. Water types are associated with dissolution/mixing and/or ion exchange with screened lithology. Gibbs diagram indicates rock and evaporation dominance.
- Seepage monitoring bores 2a/2b
  - The bores were installed adjacent to the sump between the sediment dam and the creek.
  - Water type in the shallow bore (2a) is Na-K-Cl-SO4 and is associated with mixing or uncommon dissolution influences. Gibbs diagram indicates mainly evaporation dominance.

  - Water type in the deep bore (2b) varies between mixed Ca-Na-HCO3, Na-K-Cl-SO4 and mixed Ca-Mg-Cl. Water types are associated mainly with ion exchange and some dissolution or mixing. Gibbs diagram indicates mainly rock dominance.
- Seepage monitoring bores 3a/3b
  - The bores were installed adjacent to the sump between the sediment dam and the creek.
  - Water type in the shallow bore (3a) is variable (mixed Ca-Na-HCO3, Ca-Mg-HCO3, Na-K-Cl-SO4 and mixed Ca-Mg-Cl) and mainly associated with ion exchange. Gibbs diagram indicates mainly rock dominance, with some evaporation.
  - Water type in the deep bore (3b) varies between Ca-Mg-HCO3 and mixed Ca-Mg-Cl. Water types are associated mainly with ion exchange and some dissolution or mixing. Gibbs diagram indicates mainly rock dominance.
- Seepage monitoring bores 5a and 5b
  - These bores were installed between the WRD and sediment dam to assess the impact of potential seepage through the base of the WRD on groundwater.
  - Water type in the shallow bore (5a) is mixed Ca-Mg-Cl and Ca-Mg-Cl-SO4 and associated with dissolution or mixing. Gibbs diagram indicates mainly rock dominance.
  - Water type in the deep bore (5b) is mixed Na-K-Cl-SO4 and associated with dissolution or mixing. Gibbs diagram indicates evaporation dominance.
- Seepage monitoring bores 5a and 5b
  - These bores were installed between the WRD and sediment dam to assess the impact of potential seepage through the base of the WRD on groundwater.
  - Water type in the shallow bore (6a) is mixed Ca-Mg-Cl and Ca-Mg-Cl-SO4 and associated with dissolution or mixing. Gibbs diagram indicates evaporation and rock dominance.
  - Water type in the deep bore (6b) is mixed Ca-Na-HCO3 and associated with ion exchange. Gibbs diagram indicates evaporation dominance.
- Seepage bore 7a
  - Shallow bore 7a was installed near the BCP Spring (N).
  - Water type in this bore is mixed Ca-Na-HCO3, associated with ion exchange. Gibbs diagram indicates evaporation and rock dominance.
- Seepage bore 8a
  - Shallow bore 8a was installed between the sump and the creek.
  - Water type in this bore is Na-K-Cl-SO4 and mixed Ca-Na-HCO3 and indicates probably mixing or uncommon dissolution influences. Gibbs diagram indicates evaporation and rock dominance.
- Seepage bore 8a
  - Shallow bore 9a was installed near the BCP Spring (S).
  - Water type in this bore is Na-K-Cl-SO4 and mixed Ca-Na-HCO3 and indicates probably mixing or uncommon dissolution influences. Gibbs diagram indicates evaporation dominance.

8.4 Groundwater quality

8.4.1 Groundwater monitoring bores

Table 32 presents the range of analysis results above the LOR for selected analytes/parameters in the groundwater monitoring bores. Time series and box & whisker plots are provided in Appendix G.

Table 33 to Table 36 show the occurrence of exceedances against the EA Limit A and Limit B values, the ANZECC livestock water quality guidelines and the ANZG 2018 DGVs for protecting aquatic (slightly to moderately disturbed) ecosystems.

The data and information indicate the following:

- The box & whisker plots show the natural variability of analyte concentrations within a given bore or between bores screened within a given formation.
- Field water quality parameters:
  - pH values range from slightly acidic (±6.5) to slightly alkaline (±8.75), with pH generally increasing since the end of open-cut mining. The increase in pH is considered associated with ion exchange between the groundwater and the screened formations. Highest pH values are observed in bores BAWBR01, BAWBR02 and BAWBR03 that are screened in dolerite/basalt.
  - Based on field EC readings), groundwater quality is mainly fresh in bores BAWB01 to BAWB07 and slightly brackish in bores BAWBR01, BAWBR02 and BAWBR03. There is no discernible trend in EC values.
- Major ions
  - Concentrations of anions, cations and bicarbonate alkalinity are generally low in bores BAWB01 to BAWB07, screened in rhyolite, with no discernible trend over time.
  - Concentrations of anions, cations and bicarbonate alkalinity are generally higher in bores BAWBR01 to BAWBR03, screened in dolerite and/or basalt, with no discernible trend over time. The highest sulfate concentration is observed in bore BAWBR01.
  - Major ion concentrations reflect the natural groundwater-aquifer interactions at the monitoring locations. There is no evidence to date that the historical open-cut mining has affected major ion levels at the bores.
- Metals
  - Dissolved metal concentrations vary between bores and are influenced by the screened formation and natural groundwater-rock formation interactions.
  - Elevated metal concentrations (relative to the other bores) have been observed as follows:
    - BAWB07: arsenic
    - BAWB04: barium and manganese
    - BAWB05: molybdenum
    - BAWB02: boron
    - BAWBR01: cobalt, molybdenum and uranium
  - The absence of commonality or a pattern between the bores indicates that the elevated concentrations are associated with localised lithology/mineralisation and not due to historical mining operations.

- Exceedances of the EA Limit A and Limit B values have occurred before, during and after the open-cut mining. Generally, where an exceedance for a given analyte was identified post-mining, exceedances for the same analyte existed pre-mining or during mining.

Table 32 Range of analysis results above the LOR in the groundwater monitoring bores

Parameter	BARC071	BAWB01	BAWB02	BAWB03	BAWB04	BAWB05	BAWB07	BAWBR01	BAWBR02	BAWBR03	Bore E
Alkalinity											
Bicarbonate Alkalinity as CaCO3 (mg/L)	404 - 406	163 - 695	124 - 510	108 - 546	166 - 601	66 - 501	419 - 554	2120 - 2220	290 - 2200	255 - 662	261 - 515
Carbonate Alkalinity as CaCO3 (mg/L)			13 - 18		4 - 4	13 - 26					28 - 28
Total Alkalinity as CaCO3 (mg/L)	404 - 406	163 - 695	137 - 510	108 - 546	170 - 601	66 - 501	419 - 554	2120 - 2220	290 - 2200	255 - 662	261 - 515
Field Measurements											
Dissolved Oxygen (field) (% sat)		0 - 131.5	0 - 450.6	0 - 296.3	0 - 422.6	0 - 116.1	2.4 - 25.2	6 - 198.3	0 - 208.5	0 - 72	0 - 171.1
Electrical Conductivity (field) (µS/cm)	842 - 976	14.63 - 1529	13.9 - 1416	665 - 1221	82 - 1269	11.17 - 1142	998 - 1264	28.4 - 665	557 - 7385	665 - 1621	844 - 1226
ORP (field) (mV)		-104.5 - 184.8	-200.4 - 302.4	-154.9 - 208.9	-156.8 - 187.9	-190.1 - 158.4	-77.3 - 43.9	-118.7 - 26.7	-300.9 - 104.9	-156.8 - 43.6	-71.1 - 219.2
pH (field)	6.69 - 8.05	5.91 - 7.98	6.39 - 8.6	6.12 - 8.11	6.17 - 8.12	6.99 - 8.68	6.62 - 8.01	7.67 - 8.38	7.05 - 8.99	7.4 - 8.86	6.09 - 8.51
Salinity (field) (PSU)		0.06 - 0.76	0.36 - 0.7	0.32 - 0.6	0.19 - 0.63	0.3 - 0.56	0.5 - 0.58	0.32 - 17.79	0.26 - 4.07	0.32 - 0.81	0.41 - 0.6
TDS (field) (ppm)		563 - 765	378 - 713	352 - 610	200 - 635	312 - 571	541 - 590	14.19 - 332	279 - 3692	332 - 810	431 - 613
Temperature (field) (°C)		27 - 35.42	24.52 - 33.61	27.11 - 33.53	23.25 - 35.33	21.99 - 33.47	24.79 - 31.68	30.6 - 33.48	23.81 - 31.97	28.84 - 32.28	27.47 - 33.55
Hardness											
Total Hardness (mg CaCO3/L)		112 - 440	77 - 320	63 - 295	69 - 288	43 - 327	236 - 307	1140 - 1140	80 - 1300	114 - 517	194 - 405
Major Ions											
Calcium (mg/L)	39 - 41	22 - 55	16 - 75	15 - 77	11 - 79	9 - 58	44 - 62	125 - 142	17 - 184	26 - 118	30 - 63
Chloride (mg/L)	32 - 36	7 - 65	11 - 82	7 - 23	7 - 67	5 - 28	36 - 49	5420 - 5490	58 - 950	16 - 220	22 - 77
Fluoride (mg/L)		0.3 - 1.8	0.3 - 0.9	0.3 - 2.4	0.2 - 0.6	0.2 - 0.8	0.8 - 1.7	2 - 2.4	0.3 - 1	0.2 - 1	0.5 - 1.6
Magnesium (mg/L)	15 - 15	9 - 80	6 - 41	5 - 26	10 - 31	5 - 53	26 - 37	173 - 199	9 - 277	12 - 54	24 - 76
Potassium (mg/L)	9 - 10	4 - 9.6	1 - 16	4 - 14	2 - 11	4 - 25	5 - 10	35 - 37	2 - 20	5 - 12	6 - 14
Sodium (mg/L)	150 - 153	32 - 242	26 - 229	29 - 150	37 - 168	16 - 118	117 - 173	7790 - 8580	170 - 1570	72 - 627	70 - 137
Sulfate (as SO4)	48 - 52	17 - 104	44 - 220	14 - 56	1 - 39	13 - 84	39 - 75	7220 - 7360	80 - 1290	47 - 737	28 - 74
Metals (dissolved)											
Aluminium - dissolved (mg/L)		0.012 - 0.012	0.017 - 0.017	0.03 - 0.03	0.012 - 0.012	0.02 - 0.034					
Arsenic - dissolved (mg/L)	0.009 - 0.01	0.001 - 0.003	0.001 - 0.001	0.001 - 0.001	0.001 - 0.004	0.001 - 0.002	0.002 - 0.018	0.006 - 0.006	0.001 - 0.01	0.002 - 0.003	0.001 - 0.003
Barium - dissolved (mg/L)	0.053 - 0.06	0.03 - 0.216	0.083 - 0.179	0.057 - 0.169	0.06 - 0.493	0.071 - 0.374	0.054 - 0.152	0.091 - 0.096	0.003 - 0.162	0.031 - 0.068	0.06 - 0.474
Bismuth - dissolved (mg/L)									0.00006 - 0.00006		
Boron - dissolved (mg/L)	0.19 - 0.24	0.034 - 0.26	0.27 - 0.35	0.15 - 0.15	0.06 - 0.13	0.04 - 0.08	0.05 - 0.08			0.12 - 0.12	
Cadmium - dissolved (mg/L)			0.0001 - 0.0001		0.0002 - 0.0002	0.0005 - 0.0005					
Chromium - dissolved (mg/L)		0.001 - 0.002	0.001 - 0.004		0.001 - 0.002	0.002 - 0.002	0.001 - 0.002		0.001 - 0.007	0.001 - 0.006	
Cobalt - dissolved (mg/L)		0.001 - 0.005	0.001 - 0.002	0.001 - 0.002	0.001 - 0.004		0.001 - 0.001	0.013 - 0.015	0.002 - 0.005	0.001 - 0.001	0.001 - 0.002
Copper - dissolved (mg/L)	0.002 - 0.004	0.001 - 0.018	0.001 - 0.01	0.001 - 0.012	0.001 - 0.02	0.001 - 0.024	0.001 - 0.015	0.007 - 0.007	0.005 - 0.247	0.002 - 0.008	0.001 - 0.008
Lead - dissolved (mg/L)		0.001 - 0.001	0.003 - 0.003		0.003 - 0.003		0.001 - 0.006				
Manganese - dissolved (mg/L)	0.131 - 0.137	0.098 - 1.5	0.288 - 1.4		0.684 - 4.06	0.3 - 1.4	0.058 - 0.086			0.007 - 0.007	
Molybdenum - dissolved (mg/L)		0.002 - 0.009	0.001 - 0.007	0.001 - 0.005	0.002 - 0.005	0.005 - 0.031	0.003 - 0.005	0.209 - 0.212	0.002 - 0.018	0.003 - 0.011	0.001 - 0.008
Nickel - dissolved (mg/L)		0.001 - 0.003	0.001 - 0.016	0.001 - 0.004	0.001 - 0.004	0.001 - 0.005	0.001 - 0.004		0.002 - 0.025		0.001 - 0.007
Selenium - dissolved (mg/L)					0.003 - 0.003						
Silicon - dissolved (mg/L)		28 - 28	13 - 13	15 - 15	18 - 18	13 - 13					
Uranium - dissolved (mg/L)		0.001 - 0.007	0.002 - 0.008	0.002 - 0.008	0.001 - 0.003	0.001 - 0.006	0.004 - 0.005	0.461 - 0.496	0.003 - 0.143	0.002 - 0.096	0.001 - 0.007
Vanadium - dissolved (mg/L)		0.008 - 0.01		0.003 - 0.003		0.002 - 0.002				0.003 - 0.003	
Zinc - dissolved (mg/L)	0.012 - 0.014	0.007 - 0.02	0.005 - 0.026	0.06 - 0.06	0.007 - 0.024	0.007 - 0.015	0.005 - 0.008			0.046 - 0.046	
Metals (total)											
Aluminium - total (mg/L)		0.021 - 0.03	0.024 - 0.09	0.09 - 0.09	0.02 - 0.039	0.044 - 0.19					
Arsenic - total (mg/L)	0.011 - 0.011	0.001 - 0.003	0.001 - 0.002	0.001 - 0.001	0.001 - 0.004	0.001 - 0.005	0.002 - 0.019	0.006 - 0.007	0.001 - 0.011	0.002 - 0.003	0.001 - 0.004
Barium - total (mg/L)	0.06 - 0.064	0.027 - 0.253	0.083 - 0.197	0.058 - 0.183	0.068 - 0.529	0.088 - 0.399	0.066 - 0.105	0.076 - 0.096	0.067 - 0.182	0.031 - 0.068	0.06 - 0.258
Bismuth - total (mg/L)									0.00009 - 0.0002		

Parameter	BARC071	BAWB01	BAWB02	BAWB03	BAWB04	BAWB05	BAWB07	BAWBR01	BAWBR02	BAWBR03	Bore E
Boron - total (mg/L)	0.2 - 0.24	0.03 - 0.18	0.26 - 0.35	0.15 - 0.15	0.06 - 0.13	0.04 - 0.07	0.05 - 0.09			0.12 - 0.12	
Cadmium - total (mg/L)		0.0001 - 0.0002	0.0005 - 0.0005		0.0003 - 0.0003	0.0003 - 0.0004	0.0001 - 0.0001			0.0002 - 0.0002	
Chromium - total (mg/L)		0.001 - 0.001	0.002 - 0.011	0.001 - 0.001	0.002 - 0.006	0.001 - 0.004	0.001 - 0.001		0.001 - 0.013	0.002 - 0.006	0.001 - 0.012
Cobalt - total (mg/L)	0.002 - 0.002	0.001 - 0.007	0.001 - 0.014	0.001 - 0.002	0.002 - 0.004	0.001 - 0.002		0.013 - 0.014	0.001 - 0.009	0.002 - 0.002	0.001 - 0.002
Copper - total (mg/L)	0.006 - 0.013	0.001 - 0.034	0.001 - 0.051	0.001 - 0.012	0.001 - 0.369	0.001 - 0.019	0.002 - 0.029	0.009 - 0.009	0.009 - 0.89	0.004 - 0.022	0.001 - 0.005
Iron - total (mg/L)		0.14 - 0.14	0.17 - 0.17	0.071 - 0.071	1.4 - 1.4	0.71 - 0.71					
Lead - total (mg/L)	0.002 - 0.003	0.001 - 0.003	0.001 - 0.008		0.001 - 0.003	0.001 - 0.006	0.001 - 0.019				
Manganese - total (mg/L)	0.138 - 0.159	0.12 - 1.49	0.294 - 1.4	0.007 - 0.007	0.696 - 4.35	0.346 - 1.4	0.074 - 0.116			0.006 - 0.006	
Molybdenum - total (mg/L)		0.001 - 0.006	0.001 - 0.005	0.001 - 0.004	0.002 - 0.005	0.007 - 0.033	0.003 - 0.005	0.195 - 0.216	0.001 - 0.017	0.004 - 0.011	0.002 - 0.008
Nickel - total (mg/L)	0.001 - 0.001	0.001 - 0.003	0.001 - 0.014	0.001 - 0.004	0.001 - 0.004	0.001 - 0.014	0.001 - 0.002		0.001 - 0.033	0.001 - 0.002	0.001 - 0.009
Selenium - total (mg/L)					0.003 - 0.003						
Silicon - total (mg/L)		29 - 29	13 - 13	15 - 15	18 - 18	14 - 14					
Uranium - total (mg/L)		0.002 - 0.007	0.003 - 0.006	0.003 - 0.007	0.001 - 0.003	0.002 - 0.006	0.003 - 0.005	0.448 - 0.459	0.004 - 0.156	0.003 - 0.1	0.002 - 0.008
Vanadium - total (mg/L)		0.01 - 0.011		0.003 - 0.003		0.001 - 0.002				0.003 - 0.003	
Zinc - total (mg/L)	0.017 - 0.022	0.006 - 0.024	0.006 - 0.035	0.074 - 0.074	0.007 - 0.038	0.006 - 0.02	0.011 - 0.028			0.061 - 0.061	
Nutrients											
Nitrite + Nitrate as N (mg/L)		0.03 - 0.18	0.02 - 0.08	0.89 - 2.56	0.28 - 0.28	0.02 - 0.04	0.39 - 0.39				0.12 - 0.12
Total Kjeldahl Nitrogen as N (mg/L)		0.1 - 0.1	3.2 - 3.7	0.1 - 0.4	0.2 - 0.3	0.3 - 0.4	0.1 - 0.1				
Total Nitrogen as N (mg/L)		0.1 - 0.3	3.2 - 3.7	1 - 3	0.2 - 0.5	0.3 - 0.4	0.5 - 0.5				0.1 - 0.1
Total Phosphorus as P (mg/L)		0.02 - 0.06	0.26 - 0.26	0.02 - 0.03	0.03 - 0.08	0.03 - 0.06	0.04 - 0.04				0.01 - 0.01
Physico-Chemical Parameters											
Electrical Conductivity (µS/cm)		389 - 1560	331 - 1340	246 - 1130	233 - 950	164 - 996	951 - 1130	28600 - 31300	883 - 7280	1250 - 3190	653 - 1280
pH (lab)		6.98 - 8.06	7.56 - 8.66	7.24 - 8.2	7.25 - 8.33	7.1 - 8.4	7.31 - 7.71	8.07 - 8.09	7.46 - 8.24	7.71 - 8.2	7.01 - 8.39
Total Dissolved Solids (mg/L)		750 - 750	820 - 820	470 - 470	560 - 560	600 - 600					
Turbidity (NTU)		0.1 - 32.9	0.2 - 47.8	0.3 - 41.4	0.4 - 50.7	0.3 - 18.5	0.3 - 16.2	9.6 - 16.6	1.9 - 20	0.6 - 16.1	0.2 - 61.4

Table 33 Groundwater monitoring bore exceedances of EA Limit A

Row Labels	BARC071	BAWB01	BAWB02	BAWB03	BAWB04	BAWB05	BAWB07	BAWBR01	BAWBR02	BAWBR03	Bore E
Barium - dissolved (mg/L)											
1. Pre-open cut mining		✓			✓	✓					
2. Open cut mining		✓			✓	✓					
3. Post-open cut mining		✓			✓	✓					
Copper - dissolved (mg/L)											
1. Pre-open cut mining		✓									
2. Open cut mining		✓									
3. Post-open cut mining											
Electrical Conductivity (µS/cm)											
1. Pre-open cut mining		✓		✓							
2. Open cut mining		✓		✓							
3. Post-open cut mining				9							
Electrical Conductivity (field) (µS/cm)											
1. Pre-open cut mining		✓		✓							
2. Open cut mining		✓		✓							
3. Post-open cut mining				✓							
Fluoride (mg/L)											
1. Pre-open cut mining		✓									
2. Open cut mining		✓									
3. Post-open cut mining		✓	1								

✓: indicates occurrence of exceedances

Table 34 Groundwater monitoring bore exceedances of EA Limit B

Row Labels	BARC071	BAWB01	BAWB02	BAWB03	BAWB04	BAWB05	BAWB07	BAWBR01	BAWBR02	BAWBR03	Bore E
Barium - dissolved (mg/L)											
1. Pre-open cut mining		✓			✓	✓					
2. Open cut mining		✓			✓						
3. Post-open cut mining					✓	✓					
Chromium - dissolved (mg/L)											
1. Pre-open cut mining		✓									
2. Open cut mining											
3. Post-open cut mining											
Cobalt - dissolved (mg/L)											
1. Pre-open cut mining		✓	✓								
2. Open cut mining		✓									
Copper - dissolved (mg/L)											
1. Pre-open cut mining											
2. Open cut mining		✓									
3. Post-open cut mining											
Electrical Conductivity (µS/cm)											
1. Pre-open cut mining		✓		✓							
2. Open cut mining		✓		✓							
3. Post-open cut mining				✓							
Electrical Conductivity (field) (µS/cm)											
1. Pre-open cut mining		✓		✓							
2. Open cut mining		✓		✓							
3. Post-open cut mining				✓							
Fluoride (mg/L)											
1. Pre-open cut mining											
2. Open cut mining											
3. Post-open cut mining		✓									
pH (field)											
1. Pre-open cut mining		✓									
2. Open cut mining		✓									
3. Post-open cut mining		✓									
pH (lab)											
2. Open cut mining		✓									
Sulfate (as SO4) (mg/L)											
1. Pre-open cut mining		✓	✓								
2. Open cut mining		✓									
3. Post-open cut mining					✓						

✓: indicates occurrence of exceedances

Table 35 Groundwater monitoring bore exceedances of ANZG Livestock Water Quality guidelines

Row Labels	BARC071	BAWB01	BAWB02	BAWB03	BAWB04	BAWB05	BAWB07	BAWBR01	BAWBR02	BAWBR03	Bore E
Electrical Conductivity (µS/cm)											
1. Pre-open cut mining											
2. Open cut mining											
3. Post-open cut mining								✓	✓		
Electrical Conductivity (field) (µS/cm)											
1. Pre-open cut mining											
2. Open cut mining											
3. Post-open cut mining									✓		
Fluoride (mg/L)											
1. Pre-open cut mining											
2. Open cut mining											
3. Post-open cut mining				✓				✓			
Molybdenum - dissolved (mg/L)											
1. Pre-open cut mining											
2. Open cut mining											
3. Post-open cut mining								✓			
Molybdenum - total (mg/L)											
1. Pre-open cut mining											
2. Open cut mining											
3. Post-open cut mining								✓			
Selenium - dissolved (mg/L)											
3. Post-open cut mining								✓			
Selenium - total (mg/L)											
3. Post-open cut mining								✓			
Sulfate (as SO4) (mg/L)											
1. Pre-open cut mining											
2. Open cut mining											
3. Post-open cut mining								✓	✓		
Uranium - dissolved (mg/L)											
1. Pre-open cut mining											
3. Post-open cut mining								✓			
Uranium - total (mg/L)											
3. Post-open cut mining								✓			

✓: indicates occurrence of exceedance

Table 36 Groundwater monitoring bore exceedances of ANZG aquatic ecosystem (slightly to moderately disturbed) WQOs

Row Labels	BARC071	BAWB01	BAWB02	BAWB03	BAWB04	BAWB05	BAWB07	BAWBR01	BAWBR02	BAWBR03	Bore E
Aluminium - total (mg/L)											
1. Pre-open cut mining			✓	✓		✓					
Arsenic - dissolved (mg/L)											
1. Pre-open cut mining							✓				
Arsenic - total (mg/L)											
1. Pre-open cut mining							✓				
3. Post-open cut mining											
Cadmium - dissolved (mg/L)											
1. Pre-open cut mining						✓					
Cadmium - total (mg/L)											
1. Pre-open cut mining			✓		✓	✓					
Chromium - dissolved (mg/L)											
1. Pre-open cut mining		✓			✓	✓	✓			✓	
2. Open cut mining			✓								
3. Post-open cut mining								✓	✓	✓	
Chromium - total (mg/L)											
1. Pre-open cut mining			✓		✓	✓				✓	✓
2. Open cut mining			✓								✓
3. Post-open cut mining					✓			✓	✓	✓	✓
Copper - dissolved (mg/L)											
1. Pre-open cut mining	✓	✓	✓	✓	✓	✓	✓			✓	✓
2. Open cut mining		✓		✓	✓	✓			✓		✓
3. Post-open cut mining		✓	✓	✓	✓	✓		✓	✓	✓	✓
Copper - total (mg/L)											
1. Pre-open cut mining	✓	✓	✓	✓	✓	✓	✓			✓	✓
2. Open cut mining		✓	✓	✓	✓	✓			✓		✓
3. Post-open cut mining		✓	✓	✓	✓	✓		✓	✓	✓	✓
Lead - dissolved (mg/L)											
1. Pre-open cut mining							✓				
Lead - total (mg/L)											
1. Pre-open cut mining			✓			✓	✓				
Manganese - dissolved (mg/L)											
1. Pre-open cut mining					✓						
2. Open cut mining					✓						
Manganese - total (mg/L)											
1. Pre-open cut mining					✓						
2. Open cut mining					✓						
Selenium - dissolved (mg/L)											
3. Post-open cut mining								✓			
Selenium - total (mg/L)											
3. Post-open cut mining								✓			
Zinc - dissolved (mg/L)											
1. Pre-open cut mining	✓	✓	✓	✓	✓	✓				✓	
Zinc - total (mg/L)											
1. Pre-open cut mining	✓	✓	✓	✓	✓	✓	✓			✓	

8.4.2 Seepage monitoring bores

Table 37 and Table 38 present the range of analysis results above the LOR for selected analytes/parameters in the seepage monitoring bores. Time series and box & whisker plots are provided in Appendix H.

It is noted that monitoring and sampling of the EA seepage monitoring bore commenced during the open-cut mining. Therefore, there is no pre-mining information and data for these bores. The additional seepage monitoring bores were installed at the end of 2022; therefore, only post-open-cut mining results are available for these bores.

Table 39 to Table 40 show the occurrence of exceedances against the ANZECC livestock water quality guidelines and the ANZG 2018 DGVs for protecting aquatic (slightly to moderately disturbed) ecosystems. It is noted that groundwater quality objectives for the seepage monitoring bores have not been defined in EPML02840015.

The data and information indicate the following:

- The box & whisker plots show the variability of analyte concentrations within a given bore or between bore locations.
- Physico-chemical parameters:
  - Field pH values range from slightly acidic to alkaline, with pH generally increasing since the bores were installed. However, laboratory pH values range from near neutral to slightly alkaline, without an increasing trend. Note that the very alkaline pH in bore 6b is not considered representative of groundwater conditions at that location. Most likely, the pH is affected by cement or bentonite grout from the construction of the monitoring bore.
  - Based on field and laboratory EC, groundwater quality is brackish to saline, increasing with time. Salinity increased suddenly in bore 2a in November 2021. The reason for this increase is not obvious. Elevated salinity (relative to other bores) is observed at bores 2a, 5a and 6a. Bores 5a and 5b are located between the WRD and sediment dam.
- Major ions
  - Highest concentrations (relative to other bores) have been observed as follows:
    - Calcium: bores 1a, 5a, 6a and 6b
    - Magnesium: bores 5a and 6a
    - Potassium: bore 6b
    - Sodium: bore 2a
    - Chloride: bore 2a
    - Fluoride: bores 2a and 7a
    - Sulfate: bores 2a, 5a, 5b and 6a
    - Bicarbonate alkalinity: bores 4a, 4b 7a, 8a and 9a
  - Sodium, chloride, fluoride and sulfate concentrations in bore 2a increased suddenly in November 2021. Groundwater levels at bore 2a also increased suddenly in November 202, which may be related to the excavation of the sump. However, concentrations of these ions in the sump are less than in bore 2a and do not follow the same trend. The increase in ion concentrations may be related to leaching of chemicals from the natural lithology due to rising groundwater levels.
  - An increasing trend in calcium and magnesium concentrations can be discerned in most bores, except in bores 7a, 8a and 9a. An increasing trend in sodium, chloride and sulfate concentrations can be discerned in most bores, except in bores 6a, 6b, 7a, 8a and 9a.

- Dissolved metals
  - Highest metal concentrations (relative to other bores) have been observed as follows:
    - Bore 1b: As
    - Bore 7a: As
    - Bore 2a: As, Mo, Cu, U
    - Bore 2b: Ba, Se
    - Bore 3a: Ba
    - Bore 3b: Ba
    - Bore 4a: As, Ba
    - Bore 4b: As
    - Bore 5a: Co, Cu, Se
    - Bore 5b: Co, Cu, Mo, Se
    - Bore 6a: Co, Ni, Se
    - Bore 6b: Ba, Cr, Cu, Mo, Ni, Se
  - With respect to shallow bore 2a located north of the sediment dam and near the sump, arsenic, barium, copper and molybdenum concentrations are in the same range as for the sediment dam. However, uranium concentrations in bore 2b are higher. The elevated metal concentrations may be related to leaching of chemicals from the natural lithology due to rising groundwater levels.
  - The occurrence of high metal concentrations in bores 5a/5b and 6a/b, located between the WRD and sediment dam, may indicate some seepage from the WRD into the underlying groundwater.

Table 37 Range of analysis results above the LOR in the EA seepage monitoring bores

Row Labels	Seepage Bore 1a	Seepage Bore 1b	Seepage Bore 2a	Seepage Bore 2b	Seepage Bore 3a	Seepage Bore 3b	Seepage Bore 4a	Seepage Bore 4b
Alkalinity								
Bicarbonate Alkalinity as CaCO3 (mg/L)	446 - 578	135 - 697	286 - 690	160 - 694	38 - 1060	99 - 543	346 - 1200	645 - 1020
Carbonate Alkalinity as CaCO3 (mg/L)		8 - 8		8 - 8	13 - 13	8 - 8	412 - 412	35 - 35
Hydroxide Alkalinity as CaCO3 (mg/L)								
Total Alkalinity as CaCO3 (mg/L)	446 - 578	143 - 697	286 - 690	168 - 694	50 - 1060	107 - 543	758 - 1200	680 - 1020
Field Measurements								
Appearance or Colour	0	0	0	0	0	0	0	0
Depth of Bore (mbgl)	6 - 6	16 - 16	6 - 6.7	16 - 16	6 - 6	16 - 16	6 - 6	16 - 16
Depth to Water (mbRL)	3.17 - 6.43	3.09 - 9.17	0.67 - 7.12	0.05 - 3.63	1.34 - 3.6	0.05 - 3.23	3.91 - 6.49	3.98 - 7.56
Depth to Water (mbGL)	6.17 - 6.38	6.27 - 7.22	5.43 - 5.82	2.17 - 2.49	2.58 - 2.83	2.06 - 2.45	4.25 - 5.03	4.28 - 5.21
Depth to Water Comments	0		0				0	0
Dissolved Oxygen (field) (% sat)	0 - 136.1	0 - 193.4	2 - 110.6	0 - 252.5	0 - 343.1	0 - 468	0 - 68.3	0 - 133.1
Dry?	0		0				0	0
Electrical Conductivity (field) (µS/cm)	1241 - 2730	1232 - 3789	10.58 - 9912	1206 - 2554	1093 - 2746	974 - 1804	1508 - 2436	1514 - 2286
Groundwater Level (mAHD)	306.61 - 373.54	306.41 - 373.38	306.2 - 377.3	308.59 - 377.11	308.53 - 375.89	308.74 - 377.48	305.32 - 351.301	305.05 - 372.82
GWL Depth Reference Elevation	311.33 - 378.09	311.33 - 378.09	311.33 - 378.09	311.33 - 378.09	311.33 - 378.09	311.33 - 378.09	311.33 - 378.09	311.33 - 378.09
Odour	0	0	0	0	0	0	0	0
ORP (field) (mV)	-63.4 - 100.8	-64.3 - 231	-78.5 - 199.5	-43.4 - 216.7	-63.3 - 223.9	-59.9 - 231.4	-81.1 - -20.9	-66.8 - 193.9
pH (field)	7.1 - 7.9	6.1 - 8.03	7.75 - 8.92	6.02 - 8.1	6.33 - 7.75	5.95 - 7.66	7.16 - 8.1	6.18 - 8.03
Salinity (field) (PSU)	0.61 - 1.39	0.6 - 1.98	1.17 - 5.95	0.59 - 1.15	0.53 - 102	0.47 - 0.91	0.75 - 1.24	0.75 - 1.16
TDS (field) (ppm)	620 - 1365	616 - 1894	1148 - 5293	603 - 1127	547 - 1373	486 - 902	754 - 1217	757 - 1143
Temperature (field) (°C)	26.91 - 32.68	25.11 - 35.7	26.52 - 31.86	27.83 - 36.26	25.84 - 35.19	24.67 - 35.4	29.36 - 33.08	26.92 - 34
Turbidity (field) (FNU)		0.7 - 18.5	19.8 - 19.8	1.1 - 33.7	0 - 9.9	0 - 2.2		1.4 - 7.7
Hardness								
Total Hardness (mg CaCO3/L)	616 - 1180	90 - 1340	329 - 578	81 - 702	40 - 787	86 - 817	340 - 526	315 - 632
Ion Balance								
Ionic Balance (%)	0.11 - 5.53	0.68 - 10.9	0.28 - 6.68	0.24 - 10.7	0.22 - 12.3	1.1 - 10.2	0.06 - 6.13	1.05 - 9.67
Total Anions (meq/L)	14.4 - 34.2	3.81 - 44.6	26 - 109	3.99 - 23.4	1.36 - 33.6	2.57 - 22.2	19.2 - 28.1	16.2 - 23.4
Total Cations (meq/L)	14.4 - 34.2	3.2 - 46.7	25.5 - 119	3.21 - 26	1.27 - 36.6	3.07 - 27.2	19.4 - 28.4	17.4 - 24.4
Major Ions								
Calcium (mg/L)	207 - 415	18 - 280	86 - 150	16 - 160	11 - 170	18 - 182	4 - 70	31 - 85
Chloride (mg/L)	65 - 301	11 - 410	276 - 2170	12 - 154	6 - 294	8 - 162	62 - 161	44 - 122
Fluoride (mg/L)	0.2 - 0.9	1 - 2	1 - 5.8	1 - 1.6	0.5 - 1.6	0.9 - 1.3	1.4 - 2.1	1.9 - 4
Magnesium (mg/L)	24 - 89	11 - 166	23 - 64	10 - 79	3 - 92	10 - 88	74 - 122	56 - 108
Potassium (mg/L)	1 - 4	4 - 8	9 - 16	1 - 8	3 - 10	4 - 7	6 - 10	5 - 7
Sodium (mg/L)	46 - 353	32 - 453	414 - 2500	36 - 272	11 - 498	31 - 246	220 - 440	212 - 312
Sulfate (as SO4)	116 - 747	31 - 1130	515 - 1630	14 - 361	9 - 376	10 - 441	69 - 99	42 - 110
Metals (dissolved)								
Arsenic - dissolved (mg/L)		0.001 - 0.004	0.001 - 0.004	0.001 - 0.002	0.001 - 0.002	0.001 - 0.001	0.002 - 0.008	0.002 - 0.005
Barium - dissolved (mg/L)	0.084 - 0.329	0.06 - 0.274	0.06 - 0.121	0.106 - 0.239	0.123 - 0.25	0.089 - 0.274	0.085 - 0.202	0.068 - 0.131
Bismuth - dissolved (mg/L)								
Chromium - dissolved (mg/L)					0.002 - 0.002		0.001 - 0.001	
Cobalt - dissolved (mg/L)	0.001 - 0.009	0.001 - 0.006	0.001 - 0.002	0.001 - 0.001	0.001 - 0.005	0.001 - 0.002	0.001 - 0.002	0.001 - 0.003
Copper - dissolved (mg/L)	0.001 - 0.003	0.001 - 0.003	0.002 - 0.01	0.001 - 0.004	0.001 - 0.007	0.002 - 0.002	0.001 - 0.001	0.001 - 0.003
Molybdenum - dissolved (mg/L)	0.001 - 0.003	0.003 - 0.007	0.014 - 0.05	0.003 - 0.006	0.002 - 0.014	0.001 - 0.005	0.011 - 0.019	0.009 - 0.017
Nickel - dissolved (mg/L)	0.001 - 0.002	0.003 - 0.003	0.001 - 0.004	0.001 - 0.002	0.001 - 0.013		0.002 - 0.007	

Row Labels	Seepage Bore 1a	Seepage Bore 1b	Seepage Bore 2a	Seepage Bore 2b	Seepage Bore 3a	Seepage Bore 3b	Seepage Bore 4a	Seepage Bore 4b
Selenium - dissolved (mg/L)	0.02 - 0.02	0.02 - 0.03	0.05 - 0.06			0.02 - 0.02		
Uranium - dissolved (mg/L)	0.012 - 0.016	0.005 - 0.026	0.014 - 0.328	0.005 - 0.021	0.003 - 0.244	0.003 - 0.018	0.009 - 0.016	0.006 - 0.017
Metals (total)								
Arsenic - total (mg/L)	0.001 - 0.001	0.002 - 0.004	0.001 - 0.005	0.001 - 0.002	0.001 - 0.002	0.001 - 0.001	0.003 - 0.008	0.002 - 0.005
Barium - total (mg/L)	0.086 - 0.362	0.063 - 0.27	0.063 - 0.131	0.111 - 0.266	0.13 - 0.258	0.101 - 0.288	0.109 - 0.22	0.07 - 0.138
Bismuth - total (mg/L)				0.00014 - 0.00014				
Chromium - total (mg/L)			0.002 - 0.002	0.001 - 0.003	0.003 - 0.003	0.001 - 0.001	0.001 - 0.001	
Cobalt - total (mg/L)	0.001 - 0.01	0.001 - 0.007	0.001 - 0.005	0.001 - 0.005	0.001 - 0.006	0.001 - 0.003	0.001 - 0.005	0.001 - 0.004
Copper - total (mg/L)	0.001 - 0.01	0.001 - 0.01	0.003 - 0.02	0.002 - 0.07	0.001 - 0.013	0.001 - 0.027	0.001 - 0.01	0.001 - 0.008
Molybdenum - total (mg/L)	0.001 - 0.003	0.003 - 0.008	0.018 - 0.054	0.003 - 0.007	0.003 - 0.016	0.002 - 0.005	0.013 - 0.021	0.012 - 0.021
Nickel - total (mg/L)	0.001 - 0.003	0.001 - 0.002	0.001 - 0.01	0.001 - 0.004	0.001 - 0.004	0.001 - 0.001	0.001 - 0.002	0.001 - 0.001
Selenium - total (mg/L)	0.02 - 0.02	0.02 - 0.03	0.05 - 0.06			0.02 - 0.02		
Uranium - total (mg/L)	0.012 - 0.019	0.005 - 0.026	0.014 - 0.325	0.006 - 0.024	0.005 - 0.247	0.005 - 0.02	0.01 - 0.019	0.007 - 0.017
Physico-Chemical Parameters								
Electrical Conductivity (µS/cm)	1320 - 2880	267 - 3910	2340 - 11200	248 - 2210	109 - 2940	192 - 2200	1690 - 2550	1440 - 2080
pH (lab)	7.27 - 7.9	7.16 - 8.42	7.99 - 8.25	7.28 - 8.45	7.14 - 8.82	7.13 - 8.47	7.81 - 8.34	7.41 - 8.36
Turbidity (NTU)	0.4 - 8.9	0.2 - 48.4	0.4 - 9.4	0.2 - 74.8	0.2 - 36.2	0.1 - 51.2	0.4 - 6.9	0.4 - 8.6

Table 38 Range of analysis results above the LOR in the additional seepage monitoring bores

Row Labels	Seepage Bore 5a	Seepage Bore 5b	Seepage Bore 6a	Seepage Bore 6b	Seepage Bore 7a	Seepage Bore 8a	Seepage Bore 9a
Alkalinity							
Bicarbonate Alkalinity as CaCO3 (mg/L)	176 - 301	124 - 158	78 - 172		670 - 951	570 - 937	550 - 846
Carbonate Alkalinity as CaCO3 (mg/L)				175 - 659			
Hydroxide Alkalinity as CaCO3 (mg/L)				371 - 819			
Total Alkalinity as CaCO3 (mg/L)	176 - 301	124 - 158	78 - 172	601 - 1480	670 - 951	570 - 937	550 - 846
Field Measurements							
Appearance or Colour	0	0	0	0	0	0	0
Depth to Water (mbRL)	3.13 - 3.23	3.09 - 3.23	2.15 - 3.69	4.24 - 4.91	2.44 - 2.94	1.47 - 1.64	0.49 - 2.01
Dissolved Oxygen (field) (% sat)	28.7 - 47.1	56.9 - 56.9	68.5 - 92.6	26.2 - 30.8	118.2 - 265.1	77.2 - 246.7	58.8 - 155.6
Electrical Conductivity (field) (µS/cm)	1595 - 1777	2242 - 2242	1208 - 2581	4872 - 7459	1979 - 2512	1905 - 4305	2525 - 2599
Groundwater Level (mAHD)	323.53 - 323.63	323.67 - 352.581	331.54 - 333.08	319.01 - 322.52	324.32 - 352.871	325.12 - 354.341	323.43 - 324.75
GWL Depth Reference Elevation	326.76 - 326.76	326.76 - 355.811	335.23 - 335.23	323.92 - 326.76	326.76 - 355.811	326.76 - 355.811	323.92 - 326.76
Odour	0	0	0	0	0	0	0
ORP (field) (mV)	-54.4 - -44.3	-59.1 - -59.1	-56.1 - 14.9	-162.8 - 138.7	-58.5 - -5.5	-49.6 - -9	-54.7 - 1.4
pH (field)	9.08 - 9.23	9.06 - 9.06	7.52 - 8.26	12.64 - 12.8	8.21 - 8.32	8.18 - 8.56	8.03 - 8.14
Salinity (field) (PSU)	0.8 - 0.89	1.14 - 1.14	0.6 - 1.33	2.6 - 4.09	1 - 1.28	0.96 - 2.27	1.29 - 1.33
TDS (field) (ppm)	797 - 889	1122 - 1122	604 - 1291	2435 - 3730	990 - 1256	952 - 2151	1263 - 1300
Temperature (field) (°C)	28.08 - 29.5	28.67 - 28.67	27.2 - 27.54	26.54 - 28.07	30.01 - 30.61	28.8 - 29.73	29.71 - 30.6
Hardness							
Total Hardness (mg CaCO3/L)	448 - 2060	405 - 632	448 - 2500	372 - 692	227 - 380	118 - 529	577 - 765
Ion Balance							
Ionic Balance (%)	3.8 - 20.4	4.66 - 13	3.53 - 24	2.25 - 15.8	0.72 - 3.83	0.15 - 3.96	0.85 - 7.81
Total Anions (meq/L)	12.9 - 43	17.3 - 23.6	10.1 - 46.2	21.8 - 48.2	21 - 28.6	20 - 50.1	27.5 - 30.2
Total Cations (meq/L)	17.1 - 62.9	20.6 - 27.7	13 - 69.1	26.7 - 50.4	22.7 - 30.6	20.5 - 49.7	29.4 - 32.6
Major Ions							
Calcium (mg/L)	110 - 483	91 - 161	102 - 481	149 - 316	35 - 66	21 - 94	74 - 106
Chloride (mg/L)	23 - 171	52 - 82	13 - 118	76 - 116	97 - 155	127 - 453	129 - 185
Fluoride (mg/L)	0.5 - 1	1.2 - 1.5	0.2 - 0.3	1.4 - 2.2	3.3 - 5.2	0.8 - 1.4	1.7 - 2.4
Magnesium (mg/L)	41 - 211	39 - 71	35 - 316	13 - 13	34 - 59	16 - 100	88 - 125
Potassium (mg/L)	7 - 19	2 - 4	4 - 16	48 - 120	2 - 5	2 - 11	2 - 2
Sodium (mg/L)	183 - 494	287 - 353	83 - 442	382 - 794	390 - 526	394 - 916	368 - 447
Sulfate (as SO4)	418 - 1660	626 - 879	392 - 1910	327 - 738	235 - 286	243 - 895	382 - 650
Metals (dissolved)							
Arsenic - dissolved (mg/L)	0.001 - 0.001	0.001 - 0.002		0.001 - 0.003	0.003 - 0.007	0.001 - 0.002	0.002 - 0.003
Barium - dissolved (mg/L)	0.083 - 0.125	0.098 - 0.15	0.046 - 0.102	0.178 - 0.301	0.075 - 0.093	0.042 - 0.178	0.146 - 0.192
Bismuth - dissolved (mg/L)							
Chromium - dissolved (mg/L)		0.005 - 0.005		0.012 - 0.05	0.002 - 0.002	0.003 - 0.003	
Cobalt - dissolved (mg/L)	0.001 - 0.004	0.002 - 0.004	0.001 - 0.006	0.002 - 0.002	0.001 - 0.002	0.001 - 0.002	0.002 - 0.003
Copper - dissolved (mg/L)	0.002 - 0.029	0.003 - 0.013	0.002 - 0.005	0.027 - 0.04	0.001 - 0.004	0.001 - 0.004	0.001 - 0.002
Molybdenum - dissolved (mg/L)	0.007 - 0.02	0.066 - 0.1	0.001 - 0.004	0.234 - 0.612	0.015 - 0.027	0.003 - 0.008	0.003 - 0.006
Nickel - dissolved (mg/L)	0.001 - 0.003	0.004 - 0.006	0.001 - 0.015	0.012 - 0.015	0.001 - 0.003	0.001 - 0.001	0.001 - 0.001
Selenium - dissolved (mg/L)	0.02 - 0.14	0.01 - 0.03	0.02 - 0.3	0.02 - 0.04			0.01 - 0.02
Uranium - dissolved (mg/L)	0.009 - 0.032	0.002 - 0.004	0.001 - 0.006		0.018 - 0.03	0.008 - 0.038	0.006 - 0.016
Metals (total)							
Arsenic - total (mg/L)	0.001 - 0.001	0.002 - 0.002		0.002 - 0.004	0.003 - 0.01	0.001 - 0.004	0.002 - 0.003
Barium - total (mg/L)	0.08 - 0.126	0.094 - 0.148	0.048 - 0.107	0.178 - 0.308	0.087 - 0.107	0.049 - 0.268	0.148 - 0.196

Row Labels	Seepage Bore 5a	Seepage Bore 5b	Seepage Bore 6a	Seepage Bore 6b	Seepage Bore 7a	Seepage Bore 8a	Seepage Bore 9a
Bismuth - total (mg/L)							
Chromium - total (mg/L)	0.003 - 0.005	0.006 - 0.006		0.012 - 0.132	0.002 - 0.002	0.023 - 0.023	0.002 - 0.002
Cobalt - total (mg/L)	0.001 - 0.006	0.002 - 0.004	0.001 - 0.006	0.002 - 0.005	0.001 - 0.004	0.001 - 0.016	0.003 - 0.004
Copper - total (mg/L)	0.003 - 0.02	0.006 - 0.014	0.002 - 0.009	0.031 - 0.073	0.002 - 0.019	0.001 - 0.014	0.003 - 0.016
Molybdenum - total (mg/L)	0.009 - 0.021	0.074 - 0.105	0.001 - 0.005	0.234 - 0.66	0.016 - 0.026	0.003 - 0.01	0.004 - 0.007
Nickel - total (mg/L)	0.001 - 0.004	0.004 - 0.005	0.002 - 0.142	0.014 - 0.016	0.002 - 0.004	0.001 - 0.01	0.001 - 0.002
Selenium - total (mg/L)	0.02 - 0.15	0.01 - 0.04	0.03 - 0.29	0.02 - 0.04			0.01 - 0.02
Uranium - total (mg/L)	0.009 - 0.032	0.003 - 0.005	0.001 - 0.006	0.002 - 0.002	0.017 - 0.034	0.01 - 0.046	0.006 - 0.022
Physico-Chemical Parameters							
Electrical Conductivity (µS/cm)	1570 - 5510	1770 - 2600	1170 - 5430	3660 - 7640	1960 - 2660	2040 - 4430	2520 - 2840
pH (lab)	7.5 - 8.09	7.55 - 8.05	6.65 - 7.68	11.7 - 12.1	7.59 - 8.23	7.31 - 8.2	7.49 - 8.09
Turbidity (NTU)	0.3 - 25.8	0.5 - 4.2	0.5 - 7.3	3.1 - 42.6	4.7 - 61.2	1 - 477	1.5 - 24.5

Table 39 Seepage monitoring bore exceedances of ANZG Livestock Water Quality guidelines

Row Labels	Seepage Bore 1a	Seepage Bore 1b	Seepage Bore 2a	Seepage Bore 2b	Seepage Bore 3a	Seepage Bore 3b	Seepage Bore 4a	Seepage Bore 4b	Seepage Bore 5a	Seepage Bore 5b	Seepage Bore 6a	Seepage Bore 6b	Seepage Bore 7a	Seepage Bore 8a	Seepage Bore 9a
Chromium - dissolved (mg/L)															
2. Open cut mining					✓										
3. Post-open cut mining										✓		✓	✓	✓	
Chromium - total (mg/L)															
2. Open cut mining			✓	✓											
3. Post-open cut mining			✓		✓				✓	✓		✓	✓	✓	✓
Copper - dissolved (mg/L)															
2. Open cut mining		✓	✓	✓	✓	✓		✓							
3. Post-open cut mining	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓
Copper - total (mg/L)															
2. Open cut mining		✓	✓	✓	✓	✓	✓	✓							
3. Post-open cut mining	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Selenium - dissolved (mg/L)															
3. Post-open cut mining	✓	✓	✓			✓			✓	✓	✓	✓			✓
Selenium - total (mg/L)															
3. Post-open cut mining	✓	✓	✓			✓			✓	✓	✓	✓			✓

✓: indicates occurrence of exceedance

Table 40 Seepage monitoring bore exceedances of ANZG aquatic ecosystem (slightly to moderately disturbed) WQOs

Row Labels	Seepage Bore 1a	Seepage Bore 1b	Seepage Bore 2a	Seepage Bore 2b	Seepage Bore 3a	Seepage Bore 3b	Seepage Bore 4a	Seepage Bore 4b	Seepage Bore 5a	Seepage Bore 5b	Seepage Bore 6a	Seepage Bore 6b	Seepage Bore 7a	Seepage Bore 8a	Seepage Bore 9a
Chromium - dissolved (mg/L)															
2. Open cut mining					✓										
3. Post-open cut mining										✓		✓	✓	✓	
Chromium - total (mg/L)															
2. Open cut mining			✓	✓											
3. Post-open cut mining			✓		✓				✓	✓		✓	✓	✓	✓
Copper - dissolved (mg/L)															
2. Open cut mining		✓	✓	✓	✓	✓		✓							
3. Post-open cut mining	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓
Copper - total (mg/L)															
2. Open cut mining		✓	✓	✓	✓	✓	✓	✓							
3. Post-open cut mining	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Selenium - dissolved (mg/L)															
3. Post-open cut mining	✓	✓	✓			✓			✓	✓	✓	✓			✓
Selenium - total (mg/L)															
3. Post-open cut mining	✓	✓	✓			✓			✓	✓	✓	✓			✓

✓: indicates occurrence of exceedance

9 Hydrogeological conceptual site model

Based on the available data and information, the BCP hydrogeological conceptual model is presented in Table 41. Hydrogeological cross-sections through the Project area, showing the underlying geology/lithology and groundwater levels in June 2018 and April 2022, are presented in Plate 28 and Plate 29, respectively. The location of the cross-section is presented in Figure 18.

Table 41 BCP hydrogeological conceptual model

Aspect	Description
Groundwater occurrence/aquifers	• The primary aquifer occurs within the Leichardt Metamorphics, generally at the base of the weathered zone. • There is little regolith at the Project site, and no regolith aquifers are identifiable. • Deposition of alluvium within drainage systems is minimal, and no paleochannels are present in the area. There is little or no potential for the development of alluvial aquifers at the Project site
Hydraulic properties	• Results of falling head permeability tests indicate that hydraulic conductivities are generally very low.
Recharge/ discharge mechanisms	• Direct rainfall recharge through overlying soil and sediments is minor. • The main recharge mechanism to the Leichhardt Metamorphics aquifer at Barbara Copper Project is episodic recharge via lineaments aligned with watercourses.
Depth to groundwater	• Depth to groundwater, as measured in open mineral exploration bores in October 2013, ranged from 7 to 37 mbgl. • In 2018, depth to water in monitoring bores ranged between 5 and 25 mbgl. • Since 2019, groundwater levels have declined, reflecting the open-cut mining operations and dewatering of the aquifers due to groundwater seepage/inflow into the open pits. The decline rate slowed down since mining started in June 2019. • Since mining finished in March 2021, groundwater levels seem to be slowly recovering to pre-mining levels.
Groundwater flow	Prior to the commencement of mining, the contours and potentiometric surface profile show that, provided hydraulic continuity exists throughout the Leichhardt Metamorphics. Groundwater flow will be from south-west to north-east within the Barbara Shear Zone.
Groundwater – Surface water interaction	Pre-mining depth to groundwater at the Barbara Copper Project ws more than 8m below ground level. The drainage features at the Barbara Copper Project are immature and only incised to a shallow depth. None of the drainage incisions reach 8m depth. Therefore, groundwater-surface water interaction on a semi local/regional scale is minimal. Ephemeral water bodies (groundwater seeps/springs) are known to occur at and in the vicinity of the mine site. These water bodies are the results of significant rainfall events, with rainfall and flow in the creeks accumulating in lower-lying creek sections. Some minor temporary interaction with shallow groundwater is expected. However, this interaction dissipates as shallow groundwater levels drop.
Water quality	• Groundwater can generally be classified as a sodium-bicarbonate type with minor variations.

Aspect	Description
	• Bedrock groundwater is generally fresh and near neutral to slightly alkaline. • There is no indication of high sulphate content in the groundwater. • Top 5 naturally occurring metals (in order of highest to lowest concentration) include manganese, iron, barium, copper and boron. • The data and information indicate no evidence that the mining operations have adversely impacted the natural bedrock groundwater quality.
Groundwater beneficial use	• Two (2) private registered water bores are located within 10km radius of the mining lease. • There are no homesteads within the immediate vicinity of the Project area that would rely on groundwater for drinking water or domestic use. However, the two private, existing bores could potentially be used for farm water supply (e.g. livestock watering or irrigation). • The Project site is not situated near any township, and the surrounding landscape is not likely to be utilised by the public for recreational purposes. • No aquaculture practices or industrial activities are occurring in the surrounding landscape. • Terrestrial GDEs have been identified within 5 km of the Project site. • Groundwater environmental values would include the protection of aquatic ecosystems, livestock watering and cultural/spiritual values.
Groundwater dependent ecosystems	• No aquatic or subterranean GDEs were identified through the BOM GDE Atlas within a 5 km radius of the Project site. • Terrestrial GDEs identified within 5km radius comprise mainly eucalyptus within open forest and woodlands drainage lines and alluvial plains. Most of this vegetation has been classified as low potential to moderate potential GDEs.
Stygofauna	• Survey in 2014 indicated that the Project site yielded a comparatively low abundance and diversity of taxa compared with other Stygofauna sampling sites across Australia.

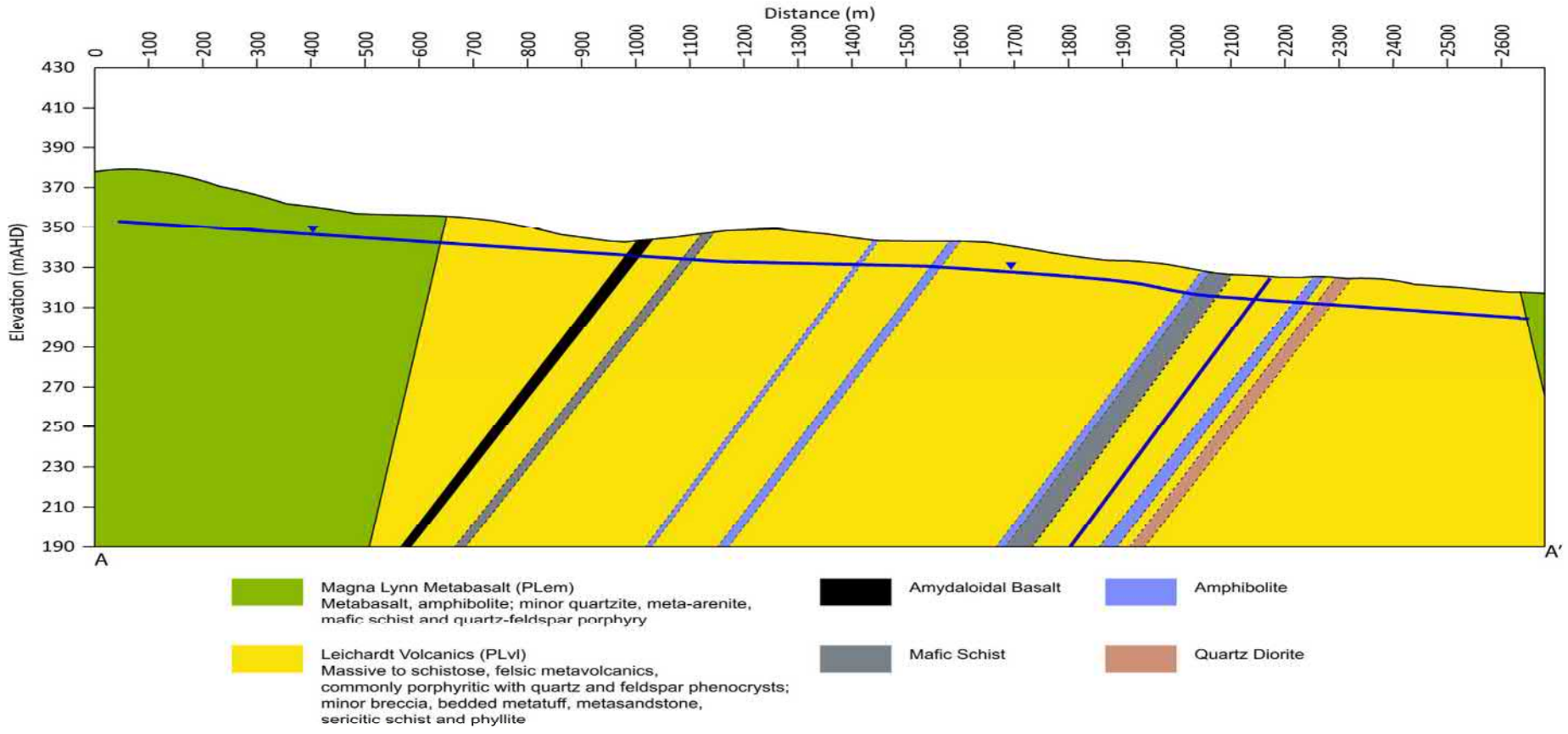


Plate 28 Hydrogeological cross-section (A-A') with June 2018 groundwater levels

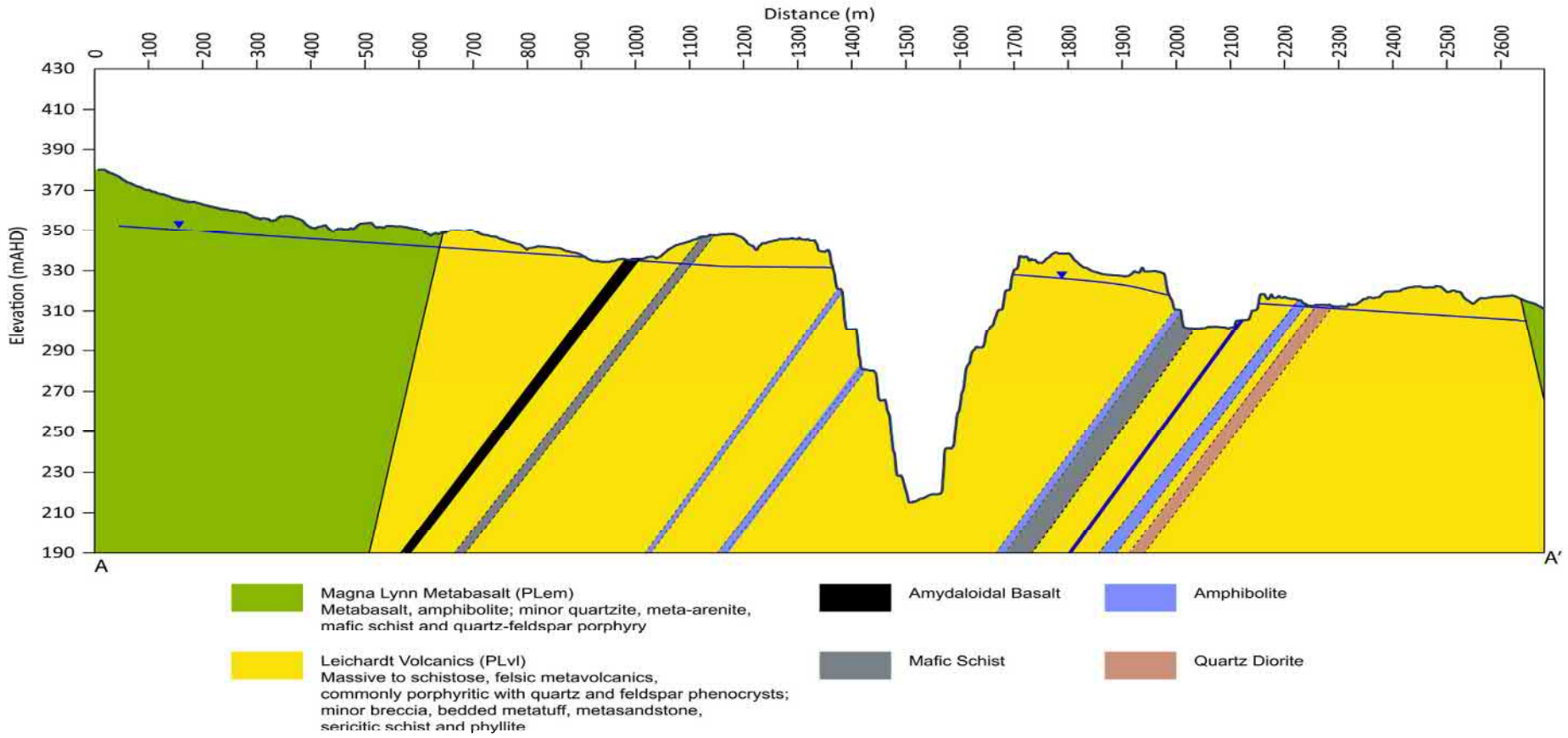


Plate 29 Hydrogeological cross-section (A-A') with April 2022 groundwater levels

10 Final void hydrogeology

10.1 Introduction

The North Pit, South Pit, underground workings and WRD Sediment Dam are intended to remain as PMLUs of water storage for livestock watering purposes.

The assessment of the final void hydrogeology is based on:

- final void water balance modelling (ATC William, 2023ba, ATC Williams, 2024)
- water quality modelling of the open pits and WRD Sediment Dam undertaken by ATC Williams (ATC William, 2023b) with further interpretation of the data by WMV Environmental (2023)
- underground workings final void water quality presented in this report.

A summary of the results/outcomes of these assessments, as detailed in the relevant technical reports, is provided below. The below sections must be read in conjunction with these detailed technical reports.

The final void hydrogeological assessment includes the following:

1. Assessment of extent and level drawdown from the open pits and proposed underground mining and potential impacts on surface water bodies.
2. Assessment of the level of groundwater inflow into the open pits and underground workings.
3. Assessment of final void water quality and impacts on environmental values.
4. Assessment of final underground workings water quality and impacts on environmental values.
5. Open pits stratification assessment

Given the relative impermeability (i.e. low hydraulic conductivity) of the aquifers and the short duration of the underground mining (i.e. four years), analytical models have been adopted for the groundwater impact assessment. The analytical models are based on scientific equations and calculations, as detailed in the below sections. The analytical models represent the open pits and underground workings as large-diameter wells with a radius and depth representative of the final void volume and depth during the different stages of mining/dewatering.

Numerical, 2D or 3D modelling is not considered warranted at this stage, as the groundwater impact assessment did not identify non-manageable adverse impacts on the receiving environment.

10.2 Extent and level of drawdown around open pits and underground workings

A “radius of influence” is defined as the maximum distance at which drawdown can be detected with the usual measure devices in the field (Dragoni, 1999). Empirical, analytical formulas can be used to calculate the radius of influence around a void that can be represented by a large diameter pumping well.

The radius of influence, R, can be estimated using Sichardt’s equation (Powers, 1992) as follows:

$$R = 3000\,(H - h)\sqrt{K_{sat}} + r_0$$

with: R = radius of influence [m]

H = groundwater level at extent of drawdown (i.e. regional groundwater level) [mAHD]

h = water level in the void [mAHD]

s = (H – h) = drawdown in the void

K_{sat} = saturated hydraulic conductivity [m/s]

r_o = equivalent well radius, calculated taking into consideration the void geometry as

$$r_0 = \sqrt{\frac{a \times b}{\pi}}$$ with a= average height of the void; b = average width of the void

Detailed calculations of the radius of influence for the North Pit, South Pit and underground workings are presented in Appendix I.

Plate 30, Plate 31 and Plate 32 show the calculated radii of influence during mining from the North Pit, South Pit and underground workings, respectively.

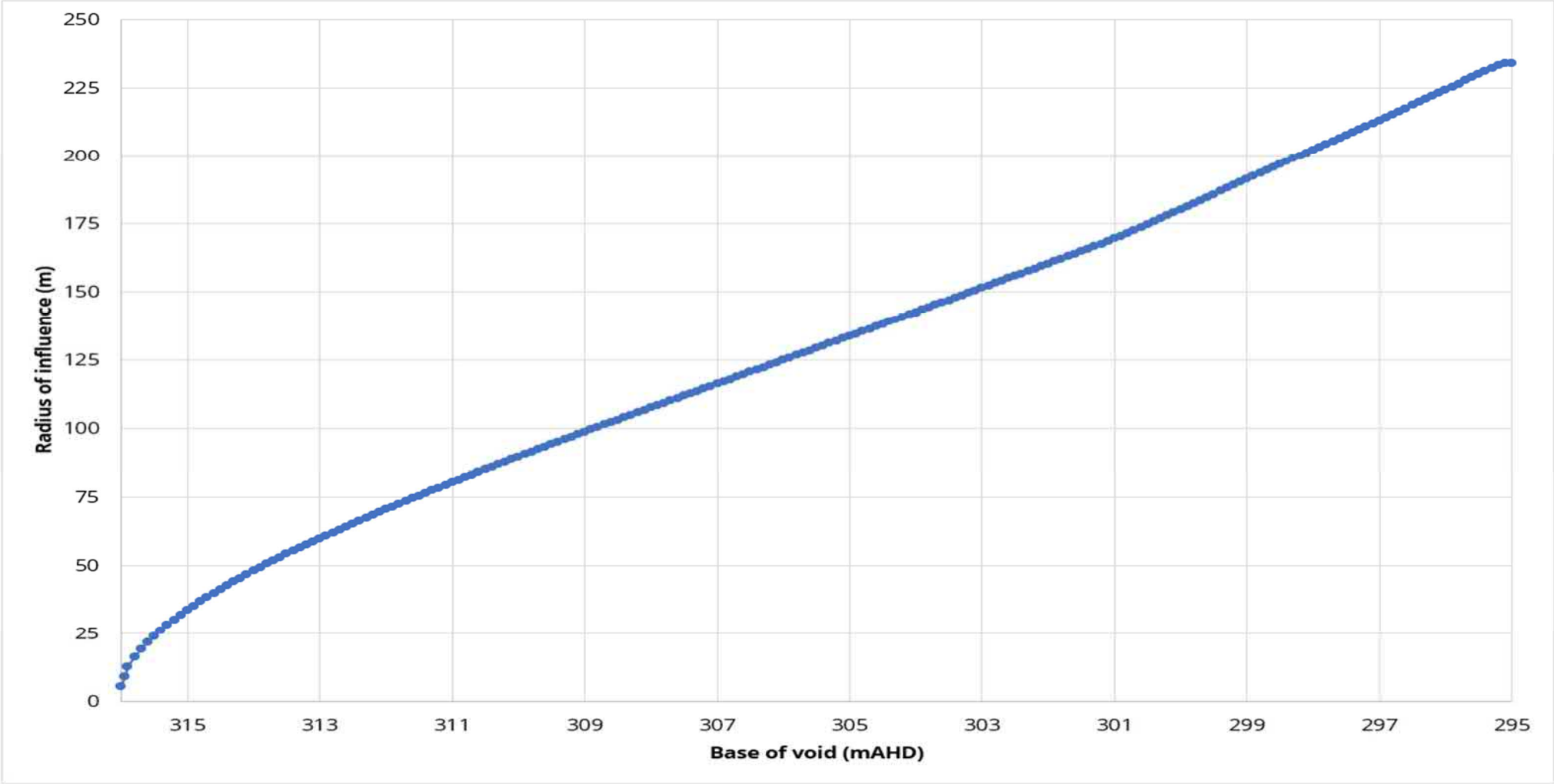


Plate 30 North Pit radius of influence/drawdown

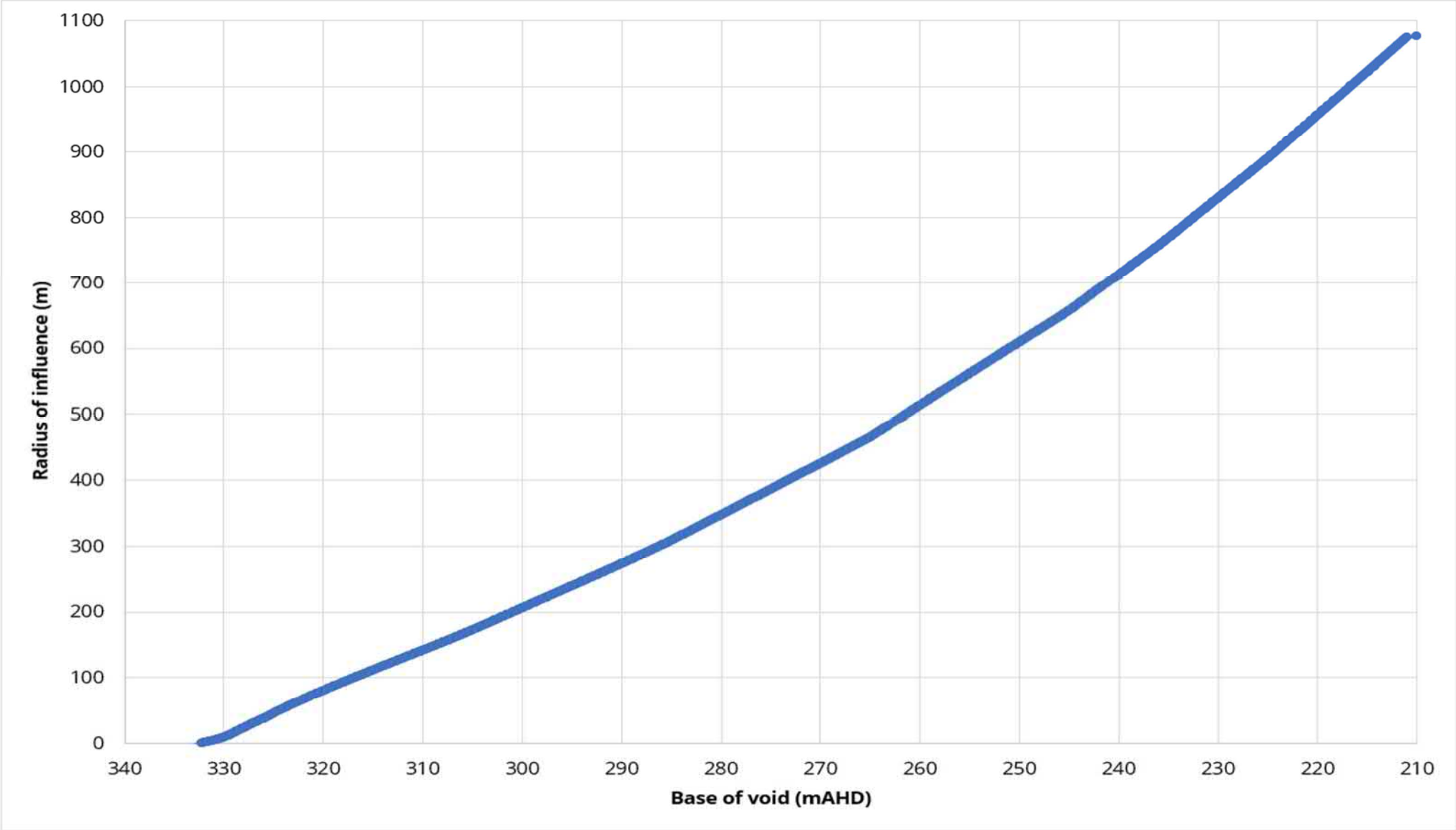


Plate 31 South Pit radius of influence/drawdown

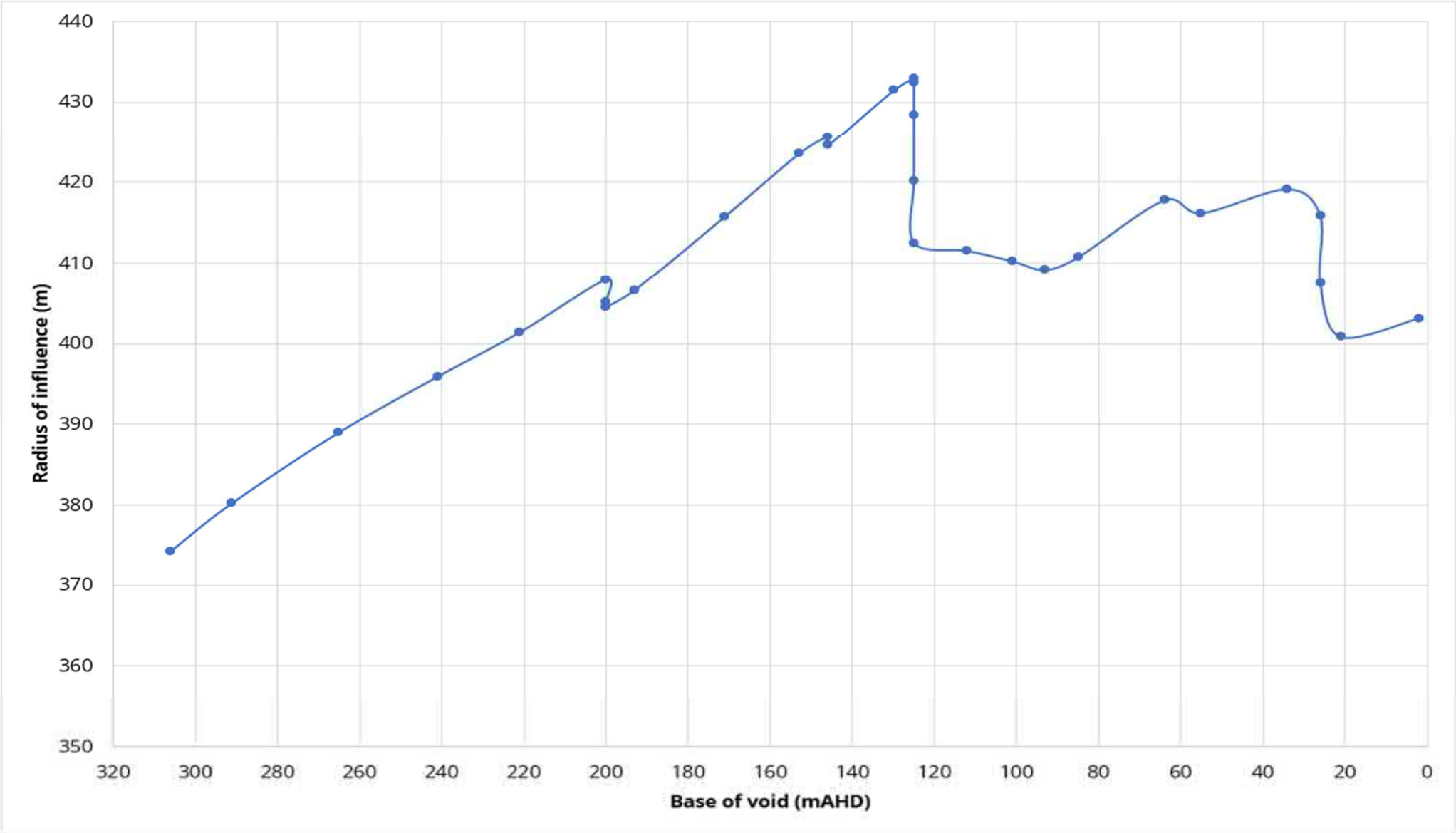


Plate 32 Underground workings radius of influence/drawdown

It is noted that the calculated radii are considered conservative and an overestimate of the actual radius of influence as:

- The empirical equations apply to “steady-state” (i.e. indefinite time) conditions only, without consideration of the temporal influence of storativity within the aquifers.
- The equations do not consider the decrease in saturated hydraulic conductivity with depth or the potential presence of boundary conditions (e.g. faults, lithological barriers).

Overall, the potential radius of influence would be much less than the empirically calculated radius and remain within the ML boundaries. Gauging of existing groundwater monitoring bores (BAWB01 to BAWB07, BAWBR01 to BAWBR03) does not show a significant impact of the open-cut mining on groundwater levels.

Data searches have indicated that there are only three registered water bores within ML90241 with a designated “water supply” role, i.e. bores RN146953, RN146954 and RN184272. However, these bores were drilled and installed by the mining company owning the mining lease at the time of installation. None of these bores are currently operational for water supply purposes, nor are they intended to be in the future. No active water supply bores are located within the conservative radius of influence/drawdown of the open pits and underground workings.

10.3 Impacts on groundwater/surface water interaction

Based on the monitoring data, the groundwater/surface water interaction can be summarised as follows:

- On a semi-local to regional scale, groundwater levels are generally at a depth below ground level that would limit any groundwater/surface water interaction. This is evidenced by the ephemeral nature of the creeks at and near the mine site.
- On a local scale, two semi-permanent water bodies are present within the creek, named BCP Spring (S) and BCP Spring (N). The water bodies are most likely the results of significant rainfall events leading to significant flow within the creeks, with water stagnating in lower-lying parts of the creek. Monitoring of shallow groundwater levels and levels at the water bodies indicates that there is limited hydraulic connectivity between the shallow groundwater and the creek.

Although the current open pits act as a groundwater sink, these pits/voids do not adversely impact the surface water environment due to the limited (to almost non-existent) connectivity between the deeper groundwater and the creek.

In a similar vein, the proposed underground operations will not impact the groundwater/surface water interaction, as such interaction does not exist.

10.4 Groundwater inflows into open pits and underground works

10.4.1 Introduction

Interaction between groundwater and surface water bodies at and near BCP is considered minimal, with groundwater levels generally below the base of the creeks/drainages. Creeks and drainage lines are generally ephemeral, with temporary flow only occurring after significant rainfall/runoff events. Springs/seeps occur at and near BCP.

Given the limited groundwater/surface water interaction, a numerical, 3D groundwater model to assess groundwater inflows into the open pits and underground working is not considered warranted. An analytical solution to assess potential groundwater inflow into the open pits and

the underground mine during and upon cessation of mining and mine dewatering has been adopted. Analytical models, based on the equations developed by Marinelli and Niccoli (Marinelli & Niccoli, 2000) for inflow into a mine pit, were developed for the open pit and the underground works.

10.4.2 Marinelli and Niccoli method for inflow into mine pits

Plate 33 presents the conceptual model used by the analytical equations of Marinelli and Niccoli to calculate the groundwater inflow into a mine pit.

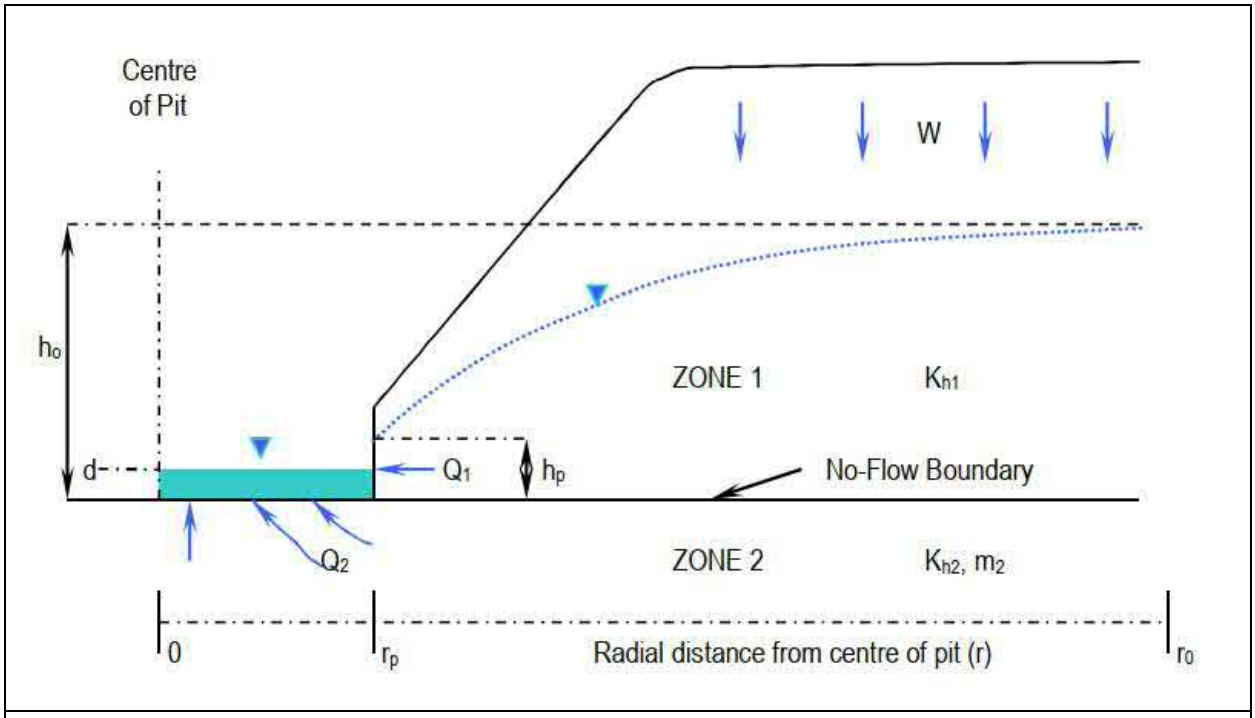


Plate 33 Mine pit inflow conceptual model (Marinelli & Niccoli, 2000)

With Marinelli and Niccoli's method, groundwater flow into a mine pit/underground works is divided into two zones, with Zone 1 representing lateral flow through the pit/underground workings walls and Zone 2 the inflows from the base of the pit/underground working. Table 42 presents the equations and assumptions used to calculate the groundwater inflows from each zone.

Table 42 Groundwater inflow into mine pit equations and assumptions

Zone 1	Zone 2
Inflow Equations	
$Q_1 = W \pi (r_0^2 - r_p^2)$	$Q_2 = 4 r_p \left(\frac{K_{h2}}{m_2}\right) (h_0 - d)$ $m_2 = \sqrt{\frac{K_{h2}}{m_2}}$
Q_1 = volumetric flow rate from Zone 1 W = recharge flux	Q_2 = volumetric flow rate from Zone 2 K_{h2} = horizontal hydraulic conductivity

Zone 1	Zone 2
r_0 = radius of influence r_p = effective pit radius	K_{v2} = vertical hydraulic conductivity m_2 = anisotropy parameter h_0 = pre-mining saturated thickness above base of Zone 1 d = depth of water in pit
Assumptions	
• Pit walls are approximated as a circular cylinder. • Groundwater flow is horizontal and the Dupuit-Forchheimer approximation can be used to account for changes in saturated thickness due to depression of the water table. • The static (pre-mining) water table is approximately horizontal. • Uniform distributed recharge occurs across the site as a result of surface infiltration from rainfall. • All recharge within the radius of influence (cone of depression), of the pit is assumed to be captured by the pit. • Groundwater flow toward the pit is axially symmetric. • The aquifer is infinite in extent (i.e. the cone of depression does not encounter any zero recharge boundaries).	• Hydraulic head is initially uniform (hydrostatic) throughout Zone 2. Initial head is equal to the elevation of the initial water table in Zone 1. • The disk sink has a constant hydraulic head equal to the elevation of the pit lake water surface. If the pit is completely dewatered, the disk sink head is equal to elevation of the pit bottom. • Flow to the disk sink is three-dimensional and axially symmetric. • Materials within Zone 2 are anisotropic, and the principal coordinate directions for hydraulic conductivity are horizontal and vertical.

10.4.3 Steady-state groundwater inflow into open pits

Groundwater inflow rates into the open pits were calculated using the open pit geometry (open area versus depth), proposed mining and backfilling schedule, calculations of equivalent effective radius and several assumptions for equation input values reflecting the BCP hydrogeological conceptual model.

Appendices I.1 and I.2 present the geometry and void volume details and detailed groundwater inflow calculations for the North and South Pit, respectively. Table 43 presents the parameters, values and assumptions made in the calculations.

Table 43 Assumptions and variables for open pit groundwater inflow calculations

Variable		Assumptions	North pit	South pit
Zone 1				
W	recharge flux	Assumed 2% of long-term annual rainfall in Mt Isa (461 mm/year)	0.000025 m/day	
r_0	radius of influence	Based on the distance from the centre of the open	100 m	200 m

Variable		Assumptions	North pit	South pit
		pit/underground workings to groundwater bore BAWBR03, representing the actual extent of the cone of depression due to mining.		
r_p	effective pit radius	Calculated for different pit levels, based on pit geometry and open pit area.	See Appendix I.	
Zone 2				
K_{h2}	horizontal hydraulic conductivity	Aquifer tests indicated hydraulic conductivity of 2.29 10^{-08} m/s or 0.00198 m/day. Based on the conceptual model, hydraulic conductivity decreases with depth.	0.00198 m/day	
K_{v2}	vertical hydraulic conductivity	The conceptual model indicates very limited vertical flow.	0.00020 m/day (10% of horizontal hydraulic conductivity)	
m_2	anisotropy parameter	Calculated	See Appendix I.	
h_0	pre-mining saturated thickness above base of Zone 1	Calculated as the difference between average groundwater level measured in 2018 (at 324 mAHD) and base of the open pits.	See Appendix I.	
d	depth of water in pit	Calculated as the difference between the elevation of the water level and the base of the open pits.	See Appendix I.	
Calculated groundwater inflow				
Q_1, Q_2	Groundwater inflow	Calculated	See Appendix I.	

Plate 34 and Plate 35 present the calculated steady-state groundwater inflows with depth into the open pits based on the water level in the pits. It is noted that the estimates of groundwater represent the groundwater that resided in the orebody prior to mining, with long-term natural recovery of groundwater levels expected to be slow. As such, the inflow estimates are conservative. The actual inflows will depend on the water balance model results, presented in ATC William's report "*Barbara Copper Project. WMP Update for Underground Workings – Water Balance Model. Ref 118131.16.R00, 31 February 2024*" (ATC Williams, 2024).

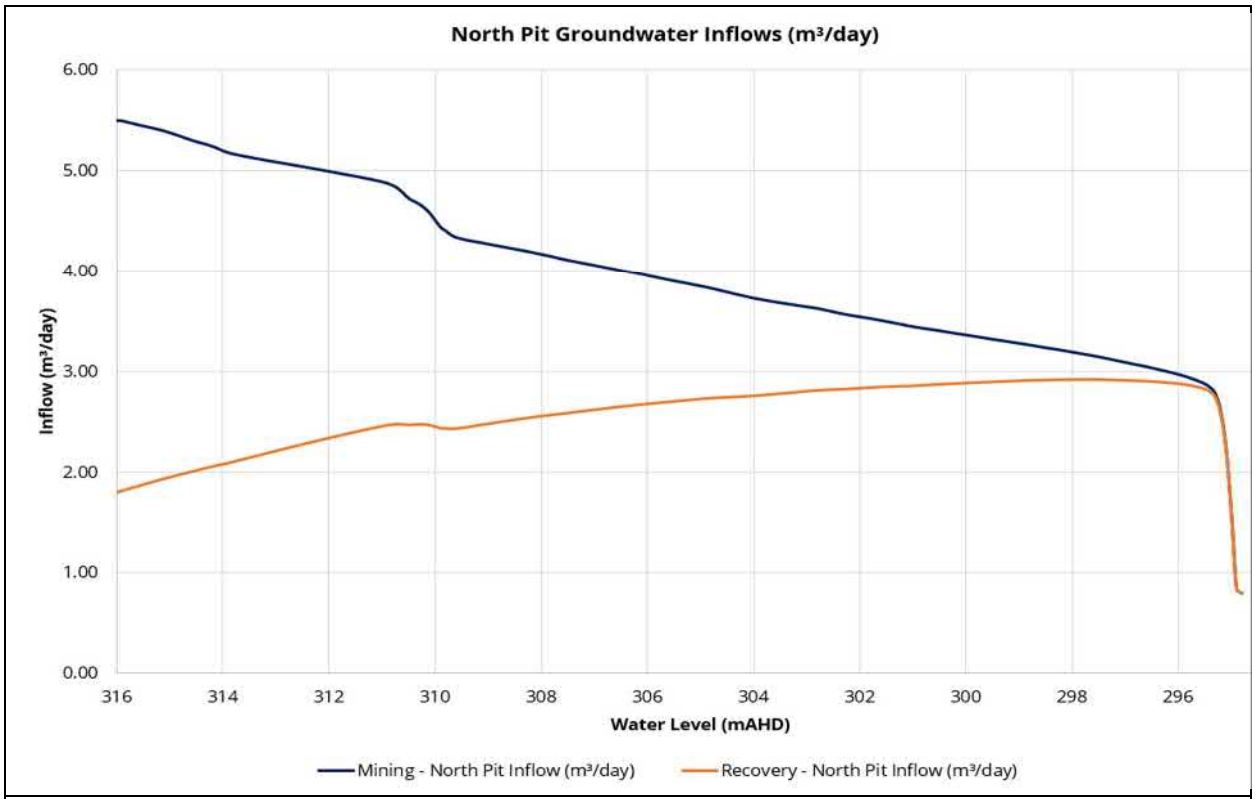


Plate 34 Calculated steady-state North Pit groundwater inflows

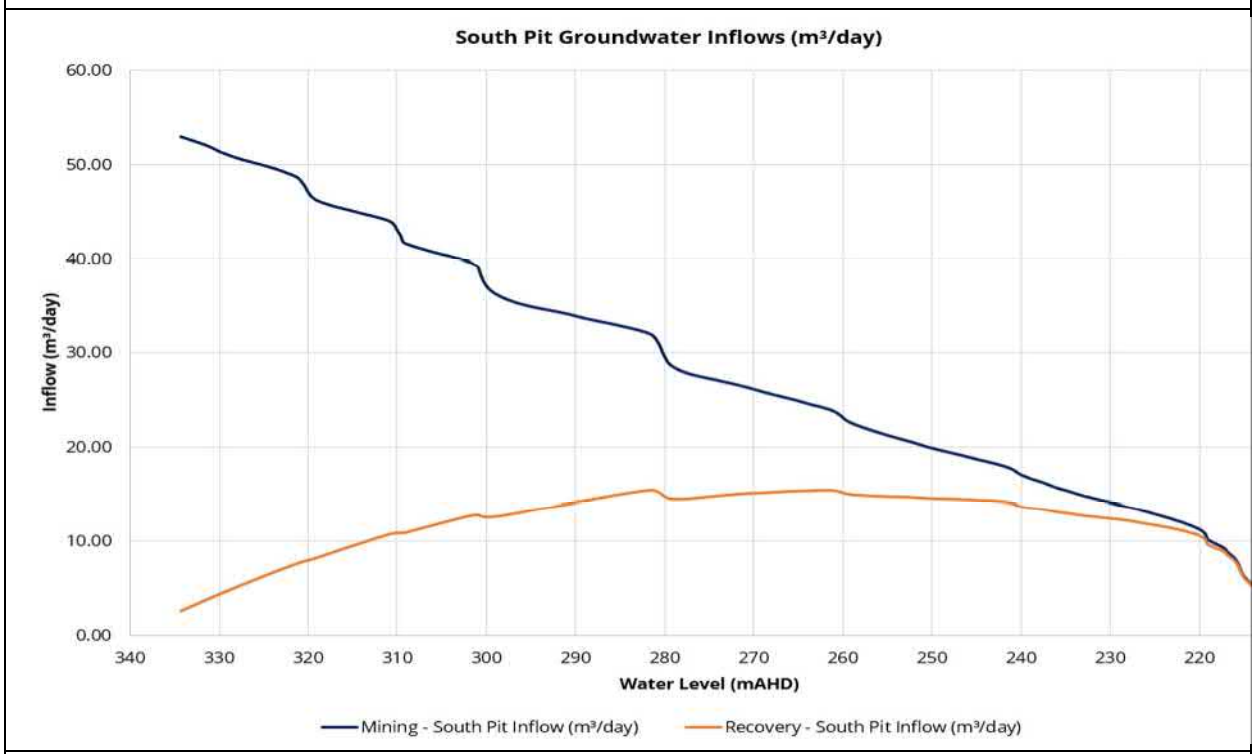


Plate 35 Calculated steady-state South Pit groundwater inflows

10.4.4 Steady-state groundwater inflow into underground works

Groundwater inflow rates into the underground works were calculated using the underground works geometry (open area versus depth), calculations of equivalent effective void radius and several assumptions for equation input values reflecting the hydrogeological conceptual model at MTC.

Table 44 presents the parameters, values and assumptions made in the calculations. Appendix I.3 presents the calculated steady-state groundwater inflows.

Table 44 Assumptions and variables for underground works groundwater inflow calculations

Variable		Assumptions	North pit	South pit	Underground workings
Zone 1					
W	recharge flux	Assumed 2% of long-term annual rainfall in Mt Isa (461 mm/year)	0.000025 m/day		
r_0	radius of influence	Based on the distance from the centre of the underground workings to groundwater bore BAWBR03, representing the actual extent of the cone of depression due to mining.	100 m		
r_p	effective pit radius	Calculated for different void levels, based on void geometry.	See Appendix I.		
Zone 2					
K_{h2}	horizontal hydraulic conductivity	Aquifer tests indicated hydraulic conductivity of 2.29 10^{-08} m/s or 0.00198 m/day. Based on the conceptual model, hydraulic conductivity decreases with depth.	0.00198 m/day		
K_{v2}	vertical hydraulic conductivity	The conceptual model indicates very limited vertical flow.	0.00020 m/day (10% of horizontal hydraulic conductivity)		
m_2	anisotropy parameter	Calculated	See Appendix I.		
h_0	pre-mining saturated thickness above base of Zone 1	Calculated as the difference between average groundwater level measured in 2018 (at 324 mAHD) and base of the UG void.	See Appendix I.		
d	depth of water in pit	Calculated as the difference between the elevation of the water level and the base of the UG void.	See Appendix I.		
Calculated groundwater inflow					

Variable		Assumptions	North pit	South pit	Underground workings
Q_1, Q_2	Groundwater inflow	Calculated	See Appendix I.		

It is noted that the estimates of groundwater represent the groundwater that resided in the orebody prior to mining, with long-term natural recovery of groundwater levels expected to be slow. As such, the inflow estimates are conservative.

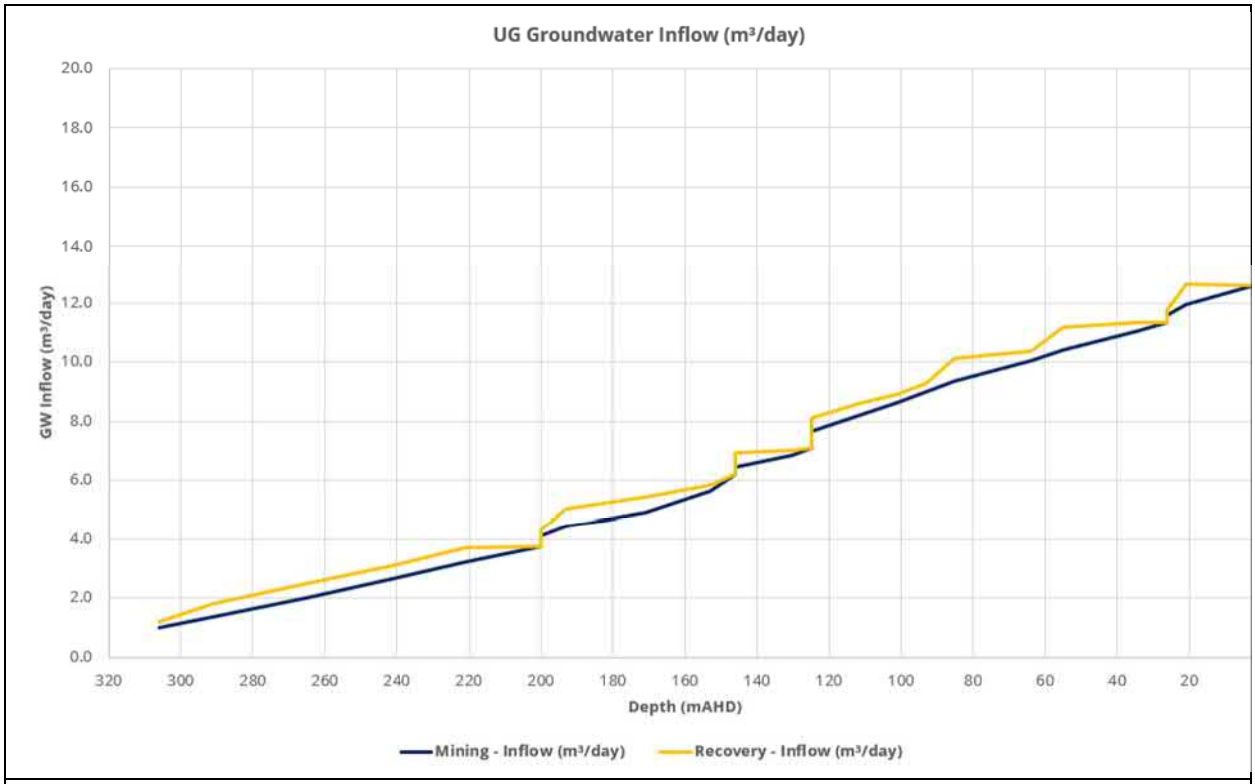


Plate 36 Calculated steady-state underground works groundwater inflows

10.4.5 BCP stochastic water balance model results

ATC Williams developed a water balance model (WBM) for BCP using Goldsim Pro (Goldsim v12.1). The WBM was used to assess the impact of surface water runoff (mine impacted and non-impacted), evaporation and groundwater in/outflows on/into the open pit and underground voids. The outcomes of the WBM are presented in ATC William's report "*Barbara Copper Project. WMP Update for Underground Workings – Water Balance Model. Ref 118131.16.R00, 31 February 2024*" (ATC Williams, 2024).

Plate 37 presents a schematic of the BCP mine water balance model. A detailed description of the model input data, the modelled processes, the scenarios, and the modelling results is provided in ATC Williams' report (ATC Williams, 2024) and included as an appendix to the main PRPC report.

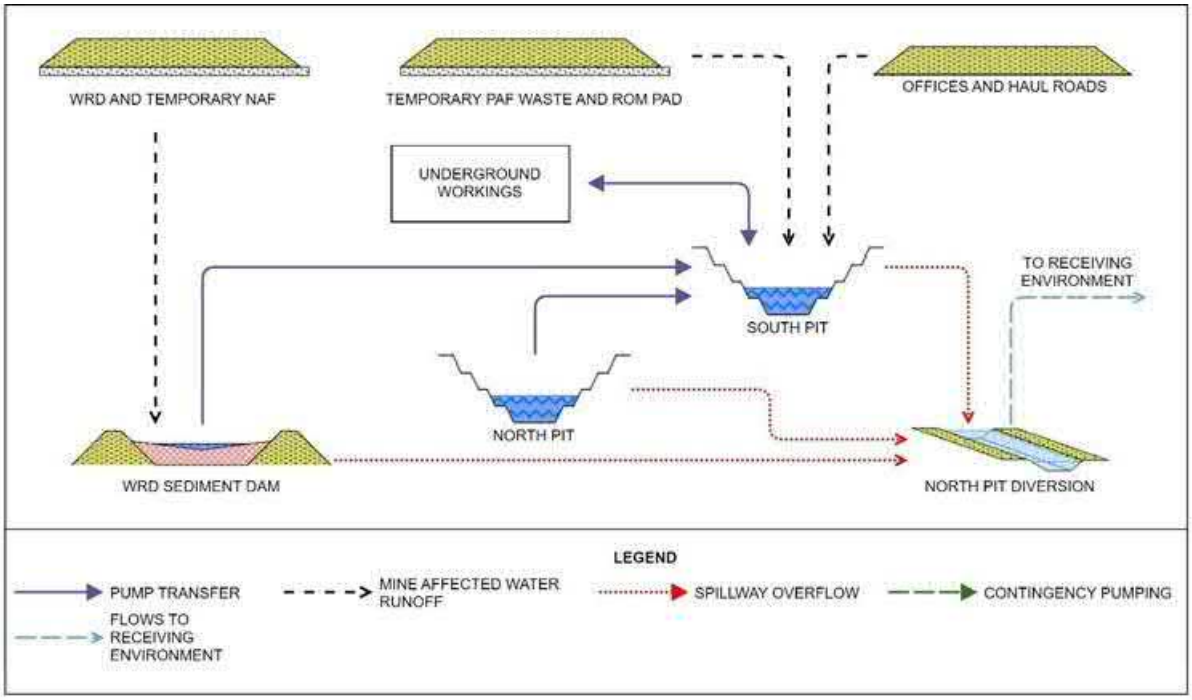


Plate 37 Schematic BCP water balance model (ATC Williams, 2024)

The results of the WBM can be summarised as follows.

South Pit

The WBM indicates the following:

- Under median climatic conditions, the South Pit will be rapidly dewatered by October 2025 to meet site water demands.
- Under median climatic conditions, the South Pit does not store any water until February 2041, as all rainfall and runoff enters the Underground Workings as the crown pillar has been removed.
- The maximum modelled water level in the South Pit is 290 m AHD, under the 99th percentile realisation. As the pit crest is 334 m AHD, this indicates the South Pit does not overtop or spill. The level of 290 m AHD is only reached in sequentially very wet years.
- The long-term median water level in the South Pit is approximately 260 m AHD, approximately 10 metres above the current recorded water level.
- There were no modelled groundwater outflows from the South Pit as the South Pit is a regional groundwater sink. The 0.55 ML/day of site water demands are met by the South Pit from January 2025 to October 2025. Beyond October 2025, the South Pit meets site water demands when water is available in the South Pit.

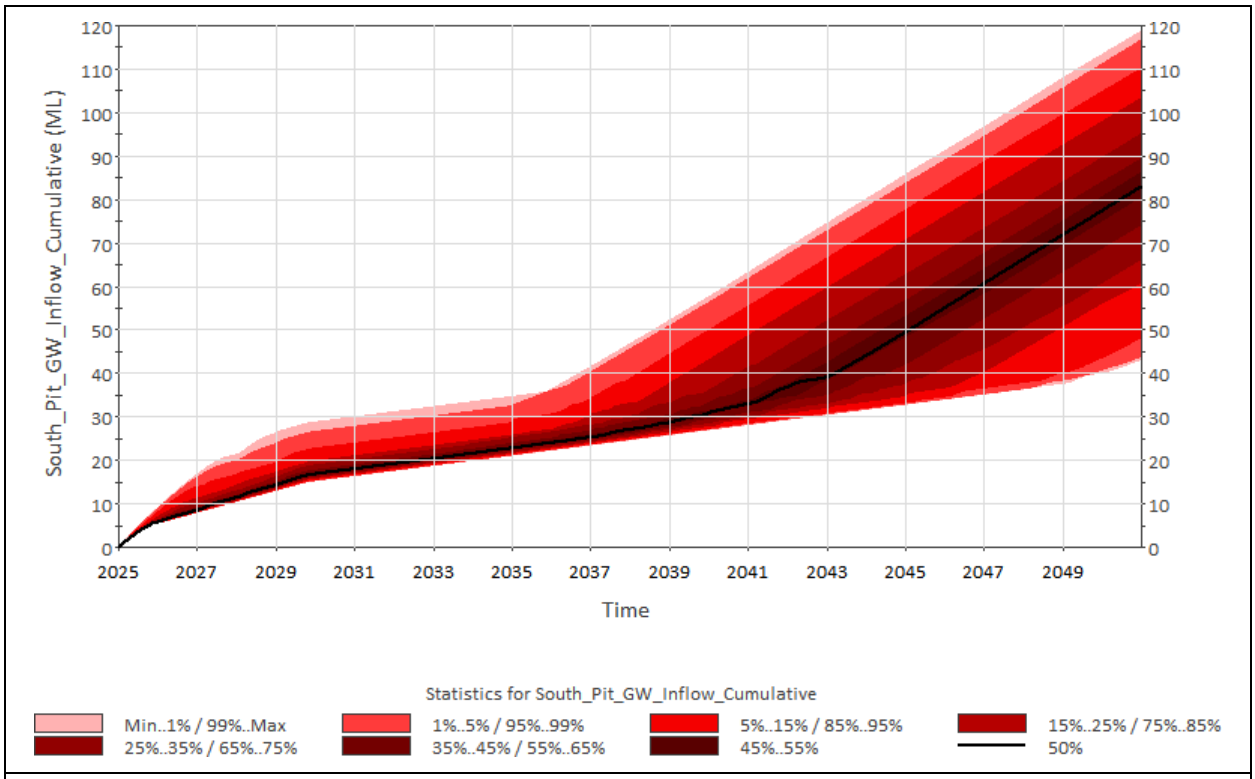


Plate 38 South Pit accumulated groundwater inflows

Underground Workings

The WBM indicates the following:

- Under operational conditions, the Underground Workings do not store any water between 2025 and 2029, as they are being actively dewatered.
- Under mean climatic conditions, the Underground Workings commence filling in 2030 and will be filled by 2041. This is primarily driven by water ingress from the South Pit, which is connected to the Underground Workings via the removal of the crown pillar.

Plate 39 depicts the variation in groundwater inflow over time. From this chart, the following insights can be derived:

- Given the complexity of the underground workings, characterised by changes in available volume over time, stage storage curves were not adopted in the WBM. Instead, the model incorporates projections of groundwater inflow over time. This explains the invariability of the groundwater estimations between different realizations shown on Plate 39.
- The mean accumulated groundwater inflow into the Underground Workings between 2025 and 2050 is approximately 20 ML, or 4.11 ML/year.
- The remainder of the water required to fill the Underground Workings is supplied by inflows from the South Pit.

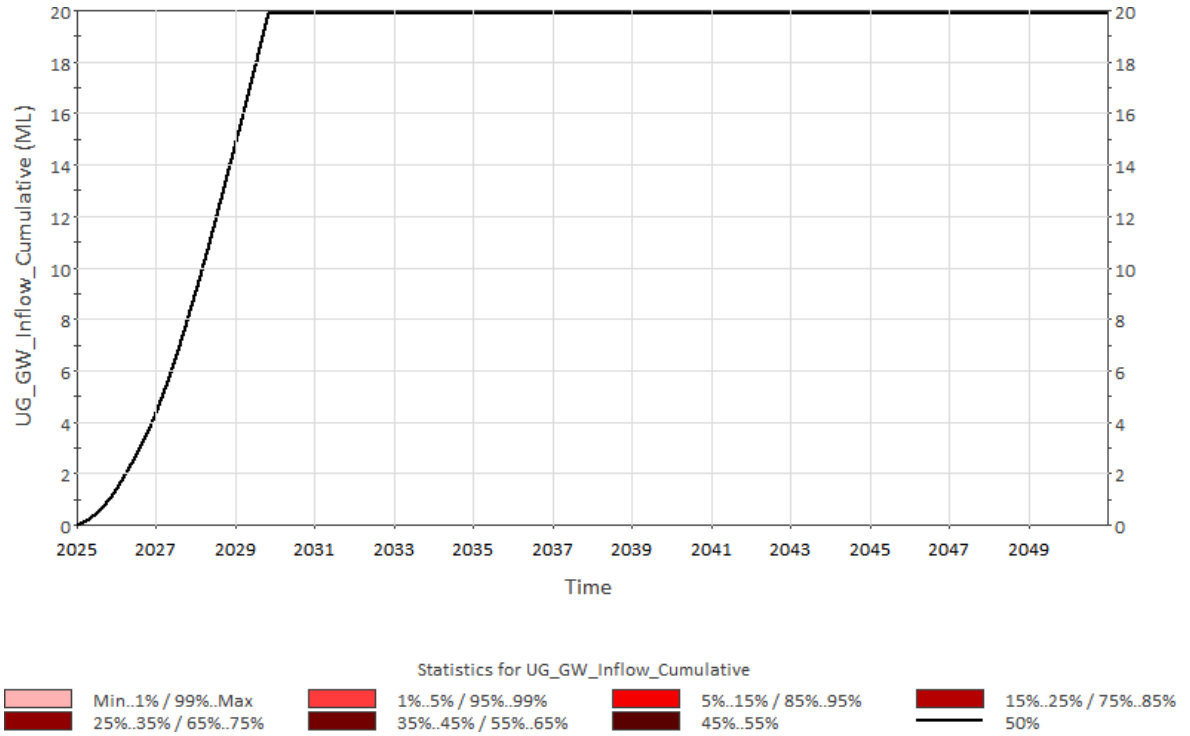


Plate 39 Underground workings accumulated groundwater inflows

North Pit

The WBM indicates the following:

- Under median climatic conditions, the North Pit will be rapidly dewatered by March 2026 to meet site water demands.
- Under median climatic conditions, between March 2026 and October 2029 (excluding the January-March period each year), the North Pit is dry, indicating the site may be in a net water deficit.
- The maximum modelled water level in the North Pit is 307 m AHD. As the pit crest is 316 m AHD, this indicates the North Pit does not overtop or spill. The level of 307 m AHD is only reached in sequentially very wet years.
- The long-term median water level in the North Pit varies between 298 m AHD and 299 m AHD, which is approximately 10 metres below the current recorded water level.

Plate 40 depicts the variation in groundwater inflow over time.

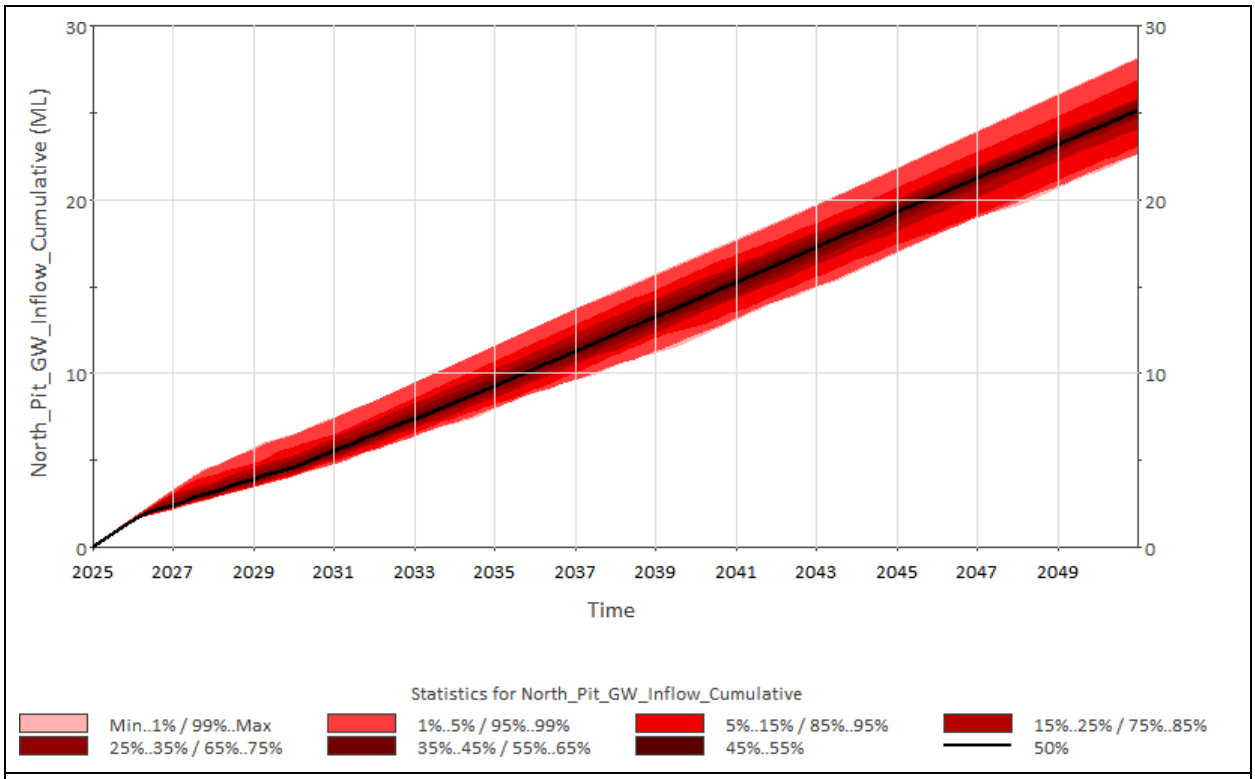


Plate 40 North Pit accumulated groundwater inflows

WRD Sediment Dam

The WBM indicates the following:

- Under median climatic conditions, the WRD Sediment Dam will be dewatered by October 2026.
- Under median climatic conditions, between October 2026 and October 2029 (excluding January-March each year), there are periods where the WRD Sediment Dam is dry, indicating the site may be in a net water deficit.
- The maximum modelled water level in the WRD Sediment Dam is 336.8 m AHD. The spillway level is at 336.8m AHD. There are 2 realisations where the WRD Sediment Dam spills. This only occurs in sequentially very wet years.
- The long-term median water level in the WRD Sediment Dam varies between 330 m AHD to 331.2 m AHD, approximately 2.5 metres below the current recorded water level.
- Due to the presence of the HDPE liner on the WRD Sediment Dam, no groundwater inflows or outflows were modelled.

10.5 North Pit, South Pit and WRD Sediment Dam final void water quality

Appendix J provides a detailed description of the water quality models (WQMs) for the final void water quality in the North Pit, South Pit and WRD Sediment Dam. Relevant aspects and results are summarised as follows.

10.5.1 Development of Water Quality Models

In 2023 and as part of the preparation of the PRCP for the BCP Project, ATC Williams developed water quality models (WQMs) for the North Pit, South Pit and WRD Sediment Dam by linking the output of the Goldsim WBM with a PHREEQC (USGS, ver. 3.6.2.15100) geochemical model. It is noted that these WQMs models did not include the proposed underground workings. However, the results of these WQMs are still considered relevant and representative to assess final void water quality in the open pits and WRD Sediment Dam. An assessment of the underground workings final void water quality is presented in Section 10.6 and Section 10.7.3.

Given the complexity of linking the Goldsim probabilistic output to PHREEQC, three different water balance scenarios were evaluated, corresponding with the following Goldsim™ WBM stochastic results:

- The median climatic conditions corresponding with an occurrence probability of 50% (i.e. 50th percentile or P50).
- Interquartile climatic conditions, corresponding with 25th percentile ant 75th percentile climatic conditions.

Higher probabilities were not considered since increased rainfall, groundwater discharge into the pit void, and lower evaporation rates would result in improved water quality and represent a lower risk to the downstream environment or closure condition.

With respect to the geochemical process, two main scenarios were considered to evaluate the mixing of the different water types:

- A first scenario/model that only included the mixing of different water types (in terms of volumes and water quality) followed by evaporative processes in the voids/sediment dam. This model is denoted as the "mixing" model.
- A second scenario/model included speciation equilibrium modelling, i.e. the precipitation/dissolution of minerals from/into solution when the different water types are mixed. In the first instance, only the mineral phase considered was gypsum, whereby gypsum precipitation could occur if calcium and sulphate concentrations in the mixed water were sufficiently elevated. This model is denoted as the "equilibrium" model.

Assumptions made in the water quality model include the following (ATC Williams, March 2023):

- In general, surface water inflow into the pit void was equilibrated with standard atmosphere conditions (CO_2(g) -3.2, O_2(g) 0.67)) and groundwater with carbonate (CO_2(g) -1.5) to maintain the pH values of site water quality solutions used in this assessment.
- To reduce the number of parameters in the model and allow for the focus on bulk water chemistry, the models assume that no stratification occurs within the pit void.
- Concerning the equilibrium model, an equilibrium reaction with gypsum was the only parameter considered relevant for the loss of solids from solution in the pit voids and sediment dam.

10.5.2 WRD Sediment Dam final void water quality

Detailed description and time series of the modelled long-term water quality in the WRD Sediment Dam are provided in Appendix J. Final void water quality can be summarised as follows:

- The solute concentrations at all times and for both models (i.e. mixing and equilibrium models) remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.
- The main processes that impact solute levels in the sediment dam are dilution due to rainfall runoff into the pit and concentration due to evaporation from the open pit. Due to the presence of the HDPE liner, groundwater inflow or outflow does not occur. The short-term or seasonal variations in solute concentrations can be correlated with the net balance between rainfall and evaporation.
- Under the 75th percentile climatic conditions, the WRD sediment Dam runs dry between early-2040 and end-2045. This affects the water quality in the WRD Sediment Dam.

10.5.3 North Pit water quality

Detailed time series of the modelled long-term water quality in the North Pit are provided in Appendix J. Final void water quality can be summarised as follows:

- The solute concentrations at all times and for both models (i.e. mixing and equilibrium models) remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.
- The main physical processes that impact solute levels in the open pit are dilution due to rainfall runoff, groundwater inflow into the pit, and concentration due to evaporation from the open pit. Groundwater inflow only plays a minor role, with long-term groundwater inflows comprising only ±10% of total inflows into the open pit. Short-term variations in solute concentrations are related to the net flow balance between inflows and evaporation. Whilst groundwater inflow is only a minor component of pit inflows, it does buffer the effect of evaporation on solute concentrations.

10.5.4 South Pit water quality

Detailed time series of the modelled long-term water quality in the South Pit are provided in Appendix J. Final void water quality can be summarised as follows:

- The solute concentrations at all times and for both models (i.e. mixing and equilibrium models) and scenarios remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.
- The main physical processes that impact solute levels in the open pit are dilution due to rainfall runoff, groundwater inflow into the pit, and concentration due to evaporation from the open pit. Groundwater inflow plays a moderate role, with long-term groundwater inflows (a combination of regional inflow and seepage from the North Pit) comprising ±20% of total inflows into the open pit. Short-term variations in solute concentrations are related to the net flow balance between inflows and evaporation. Groundwater inflow buffers the effect of evaporation on solute concentrations.

10.5.5 Summary

The water quality modelling indicates that the modelled solute concentrations at all times and for both models (i.e. mixing and equilibrium models) remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.

Long-term water quality in the pits and voids is determined by climatic conditions and geochemical reactions and tends to stabilise. The net flow balance between rainfall runoff plus groundwater inflow and evaporation determines short-term variations.

10.5.6 Conclusions

Based on the WQM results, the North Pit, South Pit and WRD Sediment Dam are considered suitable as PMLUs for livestock watering.

10.6 Underground workings final void water quality

10.6.1 Methodology

A WQM model was developed for the underground workings, based on the 2024 water balance model results for the underground working and considering the water quality results for the open pits, sediment dam, groundwater, surface water and rainfall.

The initial WQM model was a mixing model, assessing the underground workings water quality by mixing the water from the different WBM components that contribute to the water in the voids. The mixing model does not take into consideration the solubility limits of analytes and geochemical equilibrium mechanisms, such as the precipitation of minerals. As such, a mixing model is considered conservative and potentially overestimates final void water quality. A geochemical equilibrium model is only considered warranted if the mixing model results indicate potential impacts on environmental values.

Appendix K presents the results of the deterministic water balance models and detailed data and calculations for the underground workings final void water quality.

The following steps were undertaken in the final void quality assessment:

- Rainfall and evaporation time series/scenarios representing 5th, 25th, 50th, 75th and 100th percentile (a.k.a. the P05, P25, P50, P75 and P100 scenarios) were generated using the probabilistic WBM developed by ATC Williams (Appendix K.1).
- ATC Williams ran the WBM model in deterministic mode for each scenario to obtain detailed water balance volumes (i.e. inflows, storages and outflows) for the underground workings (Appendix K.2).
- A mixing model was developed for each scenario, using the water balance volumes and water quality characteristics of the different components to calculate the long-term water quality in the underground workings (Appendix K.3).

10.6.2 Summary of determinstic UG water balance model volumes

Section 10.4.5 provides a summary of ATC William's stochastic water balance model. For the purpose of the underground workings WQM, the WBM was re-run in determinstic mode for five difference climate scenarios. The determinsitic water balance model volumes (i.e. underground workings in- and outflows) are essential components of and directly relevant for the UG WQM.

Appendix K.1 presents time series of the deterministic water balance model volumes, which can be summarised as follows:

- Direct rainfall and evaporation volumes have not been included in the UG workings water balance, as these processes do not interact with the UG workings.

- Cumulative water volumes in the UG voids are determined by the UG's water management requirements, which include initial transfer of water from the North Pit, transfers from the WRD Sediment Dam and semi-regular transfers of water from the South Pit.
- Groundwater inflow in the underground voids occurs steadily over time.

10.6.3 Representative initial water quality conditions

A review of existing water quality data was undertaken to determine representative water quality input conditions (i.e. solute concentrations) for the different components of the WQM model. Table 45 presents the adopted input/initial concentrations for the solutes included in the mixing WQM.

Table 45 Initial concentrations of relevant solutes/parameters for UG WQM

WBM Component	Rainfall	North Pit			South Pit			Sediment Dam		Underground works
Process	Rain	Start in Pit	Runoff water	GW Inflow	Start in Pit	Runoff water	GW Inflow	Start in Dam	Runoff water	GW Inflow
Source of concentrations	Literature	BCP North Pit	EA receiving waters reference sites	BAWB03	BCP South Pit	EA receiving waters reference sites	BAWB03	WRD SSD	EA receiving waters reference sites	BAWB03
Physico-chemical										
Electrical Conductivity (µS/cm)	22	1324	1035.85	1,045	1591	1035.85	1,045	4507	1035.85	1,045
pH (-)	7.325	8.8	8.9255	8.112	8.958	8.9255	8.112	8.645	8.9255	8.112
Total Dissolved Solids	15	662	597	470	797	597	470	2428	597	470
Major ions (mg/L)										
Calcium	17.025	113	37	74.2	148.8	37	74.2	303.5	37	74.2
Magnesium	4.61	41.5	47.7	25	59.2	47.7	25	210	47.7	25
Sodium	4.84	133.5	168.85	146	100.8	168.85	146	543.2	168.85	146
Potassium	3.49	29.5	58.9	14	24.2	58.9	14	41.8	58.9	14
Chloride	5.8	97.5	74	20.4	21.2	74	20.4	146.1	74	20.4
Fluoride	0.22	1.75	0.5	0.9	1.08	0.5	0.9	1.59	0.5	0.9
Sulfate	51	515.5	24.6	53.4	638.2	24.6	53.4	1654	24.6	53.4
Alkalinity (mg/L $CaCO_3$)										

WBM Component	Rainfall	North Pit			South Pit			Sediment Dam		Underground works
Process	Rain	Start in Pit	Runoff water	GW Inflow	Start in Pit	Runoff water	GW Inflow	Start in Dam	Runoff water	GW Inflow
Source of concentrations	Literature	BCP North Pit	EA receiving waters reference sites	BAWB03	BCP South Pit	EA receiving waters reference sites	BAWB03	WRD SSD	EA receiving waters reference sites	BAWB03
Bicarbonate Alkalinity as CaCO3	35	256.5	389.1	483.2	92.6	389.1	483.2	101.9	389.1	483.2
Major alkalinity ions (mg/L)										
Bicarbonate	42.7	312.93	474.702	589.504	112.972	474.702	589.504	124.318	474.702	589.504
Total Metals (mg/L)										
Aluminium	0.0416	NA	NA	0.09	NA	NA	0.09	NA	NA	0.09
Arsenic	0.001	0.003	0.004	0.001	0.0118	0.004	0.001	0.0049	0.004	0.001
Barium	NA	0.0875	0.21445	0.148	0.0528	0.21445	0.148	0.129	0.21445	0.148
Beryllium	NA	<0.001	NA	<0.0001	NA	NA	<0.0001	<0.001	NA	<0.0001
Bismuth	NA	<0.0001	<0.001	<0.0001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.0001
Boron	<1	<0.05	NA	0.15	NA	NA	0.15	0.07	NA	0.15
Cadmium	0.0666	NA	NA	<0.0001	NA	NA	<0.0001	NA	NA	<0.0001
Chromium	<0.05	<0.001	0.0148	0.001	<0.001	0.0148	0.001	<0.01	0.0148	0.001
Cobalt	0.0007	0.00375	0.0059	0.0017	0.0147	0.0059	0.0017	0.0027	0.0059	0.0017
Copper	0.513	0.056	0.034	0.00765	0.0628	0.034	0.00765	0.0308	0.034	0.00765

WBM Component	Rainfall	North Pit			South Pit			Sediment Dam		Underground works
Process	Rain	Start in Pit	Runoff water	GW Inflow	Start in Pit	Runoff water	GW Inflow	Start in Dam	Runoff water	GW Inflow
Source of concentrations	Literature	BCP North Pit	EA receiving waters reference sites	BAWB03	BCP South Pit	EA receiving waters reference sites	BAWB03	WRD SSD	EA receiving waters reference sites	BAWB03
Iron	1.14	<0.05	NA	0.071	NA	NA	0.071	<0.05	NA	0.071
Lead	0.414	NA	NA	<0.001	NA	NA	<0.001	NA	NA	<0.001
Manganese	0.728	NA	NA	0.007	NA	NA	0.007	NA	NA	0.007
Mercury	NA	NA	NA	<0.0001	NA	NA	<0.0001	NA	NA	<0.0001
Molybdenum	<0.05	0.0215	0.00365	0.003	0.0482	0.00365	0.003	0.0684	0.00365	0.003
Nickel	<0.05	0.0145	0.0072	0.0038	0.0228	0.0072	0.0038	0.006	0.0072	0.0038
Selenium	<0.05	0.029	<0.001	<0.003	0.01	<0.001	<0.003	0.1265	<0.001	<0.003
Uranium	NA	0.011	0.0057	0.007	0.008	0.0057	0.007	0.0154	0.0057	0.007
Vanadium	NA	<0.01	NA	0.003	NA	NA	0.003	<0.01	NA	0.003
Zinc	1.23	NA	NA	0.074	NA	NA	0.074	NA	NA	0.074

NA: no analysis results

Literature source of rainfall water quality: Crosbie RS, Morrow D, Cresswell RG, Leaney FW, Lamontagne S and Lefournour M (2012) New insights into the chemical and isotopic composition of rainfall across Australia. CSIRO Water for a Healthy Country Flagship, Australia.

10.6.4 Modelled water quality in underground workings

Appendix K.3 presents the time series of modelled water quality in the underground workings final void for selected solutes over a period of 25 years (including 4 years of mining and 21 years post-mining). The time series of the modelled results indicate the following:

- Initial water quality is determined by the water quality of the water transferred into the UG voids (i.e. initial transfer of water from the North Pit, transfers from the WRD Sediment Dam and semi-regular transfers of water from the South Pit).
- Mid- to long-term water quality is governed by the mixing of the transferred water with groundwater inflow.

Table 46 presents a statistical summary of the WQM results, compared against the ANZECC Livestock Water Quality Guidelines and the PRCP schedule PRCP EPML02840015 – Water quality limits for North and South Pits and WRD Sediment Dam. The results indicate that the short- and long-term water quality within the UG workings remains below these guideline values.

10.6.5 Conclusions

The results of the mixing modelling indicate that groundwater quality in the UG voids remains below the relevant water quality guidelines values (livestock watering and PRCP criteria for voids) and that the underground workings are suitable for a livestock watering PLMU.

Table 46 Modelled UG workings final void water quality concentrations (mg/L)

	Guideline values	P05		P25		P50		P75		P100	
Analyte		Average	Max.	Average	Max.	Average	Max.	Average	Max.	Average	Max.
Aluminium	5 (1)	0.0602	0.0902	0.0546	0.0902	0.0591	0.0854	0.0506	0.0902	0.0576	0.0902
Arsenic	0.5 (1)(2)	0.0022	0.0030	0.0024	0.0027	0.0023	0.0026	0.0026	0.0029	0.0023	0.0026
Barium	-	0.1703	0.1797	0.1724	0.1797	0.1710	0.1788	0.1742	0.1829	0.1692	0.1761
Bicarbonate	-	539.3	590.6	524.6	590.6	539.1	576.3	515.2	590.6	527.0	590.58
Boron	5 (1)	0.0984	0.1503	0.0910	0.1503	0.0957	0.1358	0.0842	0.1503	0.0958	0.1503
Cadmium	0.01 (1)(2)	0.0048	0.0279	0.0045	0.0163	0.0051	0.0443	0.0049	0.0197	0.0044	0.0178
Calcium	500 (2) 1000 (1)	73.8	107.0	77.7	112.3	70.7	88.3	77.3	109.5	77.6	118.2
Chloride	-	44.1	67.3	49.0	53.6	43.9	49.1	51.7	56.4	46.5	50.3
Chromium	1 (1)	0.0055	0.0076	0.0060	0.0078	0.0058	0.0074	0.0065	0.0083	0.0055	0.0071
Cobalt	1 (1)	0.0032	0.0038	0.0034	0.0039	0.0033	0.0037	0.0035	0.0040	0.0032	0.0036
Copper	1 (1)(2)	0.0542	0.2223	0.0534	0.1348	0.0567	0.3440	0.0581	0.1620	0.0518	0.1457
Fluoride	2 (1)(2)	0.8218	0.9640	0.8226	1.0469	0.8047	0.9513	0.8083	1.0303	0.8282	1.0860
Iron		0.1269	0.5117	0.1175	0.3276	0.1309	0.7826	0.1222	0.3753	0.1188	0.3501
Lead	0.1 (1)(2)	0.0297	0.1736	0.0278	0.1016	0.0315	0.2755	0.0308	0.1227	0.0274	0.1109
Magnesium	150 (2) 2000 (1)	41.1	74.8	46.2	57.9	39.7	43.6	48.0	55.8	44.5	60.2
Manganese	1 (2)	0.0567	0.3085	0.0530	0.1833	0.0598	0.4869	0.0578	0.2194	0.0525	0.1994

	Guideline values	P05		P25		P50		P75		P100	
Analyte		Average	Max.	Average	Max.	Average	Max.	Average	Max.	Average	Max.
Molybdenum		0.0061	0.0189	0.0076	0.0133	0.0055	0.0087	0.0080	0.0127	0.0073	0.0143
Nickel	1 (1)	0.0050	0.0055	0.0052	0.0056	0.0051	0.0054	0.0054	0.0058	0.0051	0.0054
Potassium	-	30.4	36.7	32.7	37.9	30.9	35.8	34.5	39.8	30.9	35.4
Selenium		0.0055	0.0316	0.0085	0.0195	0.0043	0.0118	0.0091	0.0185	0.0079	0.0213
Sodium	-	172.5	223.5	182.6	219.0	168.5	181.1	185.0	213.1	179.2	227.6
Sulfate	2,000 (1)	118.1	444.1	153.9	306.5	102.4	197.2	161.4	293.7	147.7	330.1
Total Dissolved Solids	5,000 (1)(2)	602.4	907.6	652.9	815.0	584.2	632.6	666.1	789.9	637.1	849.4
Uranium	0.2 (1)	0.0070	0.0078	0.0071	0.0086	0.0069	0.0076	0.0071	0.0084	0.0071	0.0089
Vanadium	ND (1)	0.0019	0.0030	0.0017	0.0030	0.0019	0.0027	0.0016	0.0030	0.0018	0.0030
Zinc	20 (1)(2)	0.1353	0.5509	0.1253	0.3515	0.1397	0.8435	0.1304	0.4035	0.1265	0.3761

(1) ANZECC 2000 Liverstock (beef cattle) drinking water quality guidelines

(2) PRCP schedule PRCP EPML02840015 – Tabe 5: Water quality limits for North and South Pits and WRD Sediment Dam

10.7 Potential AMD impact on final void water quality

10.7.1 Summary of AMD investigations

Appendix L presents the results of the historical AMD investigations.

Waste rock characterisation

A waste rock geochemical assessment has been completed (EGi, 2014), which defines the geochemistry of waste rock materials. The assessment involved the analysis of 121 drill core samples from 14 diamond drill holes, representing the range of waste rock lithologies that were intersected during open pit mining operations across the North and the South Pit footprint. Detailed description of the methodology and results is provided in EGi's report "*Barbara Copper Project – Assessment of Waste Rock Geochemistry*" (EGi, 2014), included as Appendix G of the BCP PRCP Report.

Based on the analyses undertaken, the samples were classified by EGi (2014) into the following classes:

- Non-acid forming (NAF), the sample is not expected to generate acid in excess of the available acid neutralising capacity (ANC)
- Potentially acid forming (PAF), the sample may form sulphuric acid when in prolonged contact with water and oxygen
- Uncertain (UC), the sample may or may not form acid.

Based on the acid-forming properties of the material, water that remains in contact for medium to long-term durations may exhibit AMD.

NAPP and NAG characterisation demonstrates most waste rock samples are NAF, while ore samples are distributed between NAF and PAF. An AMD classification plot displaying the concurrence of NAPP and NAG test results is provided in Table 47.

Table 47 BCP AMD classification (EGi, 2014)

Waste/Ore	Classification	Number of Analyte Results	Proportion
Waste Rock (Cu ≤ 0.5% Grade)	PAF	7	7%
	NAF	83	89%
	UC	4	4%
Ore (Cu > 0.5% Grade)	PAF	15	56%
	NAF	12	44%

Additional kinetic NAG analyses were conducted for five samples (three waste, two ore) of PAF rock, to provide an indication of the lag time before significant acid generation occurs. Accordingly, the five samples analysed were PAF samples. The outcomes are presented in Table 48.

Table 48 Acid rock drainage samples - acid generation lag time (EGi, 2014)

Sample	Final pH	Lag Time
Ore #8050	3.1	Weeks to months
Ore #8112	2.7	At least a year to several years

Sample	Final pH	Lag Time
Waste #8066	4.7	At least a year to several years
Waste #8092	3.0	Several years
Waste #8072	6.3	At least a year to several years

Overall, lag times for samples classified as PAF were significant, and likely to exceed a year. Of the two analysed PAF ore samples, one was highly reactive (Ore #8050), with generation of acid expected to occur within weeks of being exposed to atmospheric conditions (water and oxygen).

NAF waste rock materials exhibited limited ANC, consequently blending of NAF and PAF samples may not result in significant changes to acid generation characteristics of the blended material, compared to the PAF material alone.

Additionally, sulphur speciation was conducted on the five samples used in the kinetic NAG analyses to determine the forms of sulphur present in rock. This revealed very minimal sulphate-sulphur present in rock with most sulphur present as sulphide-sulphur.

Kinetic column leach tests of waste rock and ROM oxide

A column leach test program involving samples representing waste rock and ROM oxide from the Project commenced on 30 August 2019, with leaching extending over 12 months during which a total of 13 leachate collections were made.

The results and the findings of the program are provided in EGi's report "*Kinetic Column Leach Testing of Waste Rock and ROM Oxide. Final Report - September 2020. Round Oak Mineral. Barbara Copper Project. Ref S4405/J000325/R1382*" (EGi, 2020) , included as Appendix I of the BCP PRCP Report.

The six samples (each sample comprised approximately 10 kg of rock pieces) were collected from the South Pit from various geological units according to geochemical characteristics. One sample was considered PAF, three samples represented NAF waste rock and the remaining two samples represented ROM oxide, as listed in Table 49 (EGi, 2020).

Table 49 Descriptions of Barbara waste rock and ROM oxide samples (EGi, 2020)

Material Class	Location	Northing	Easting	Depth in Pit	Geological Description
PAF1	South Pit	380252	7741437	330 RL	Oxidised sample quartz sericite schist, minor secondary copper.
NAF1	South Pit	380184	7741440	330 RL	Biotite schist
NAF2	South Pit	380122	7741495	325 RL	Biotite schist
NAF3 (previously PAF2)	South Pit	380193	7741549	325 RL	Oxidised sample quartz sericite schist with secondary copper, malachite and azurite.
NAF4	South Pit	na	na	na	na
ROM Oxide1	South Pit	380298	7741497	325 RL	Sample collected at the southern end of the shear zone and outside the ore zone. Very oxidised samples with minor

Material Class	Location	Northing	Easting	Depth in Pit	Geological Description
					secondary copper, malachite and azurite.
ROM Oxide2	South Pit	380224	7741519	325 RL	Sample collected from the hanging wall of the shear zone. Mainly oxidised schist, with secondary copper, malachite and azurite.

Chemical characterisation of three of the NAF samples and the two ROM oxide samples indicate NAF characteristics. One NAF sample recorded significant sulphide concentration, although this sample also presented moderate to high ANC which resulted in a negative NAPP test and was subsequently confirmed to be NAF. The PAF sample recorded a positive NAPP result and acidified during the NAG test. The acid forming characteristics of samples are summarised in Plate 41.

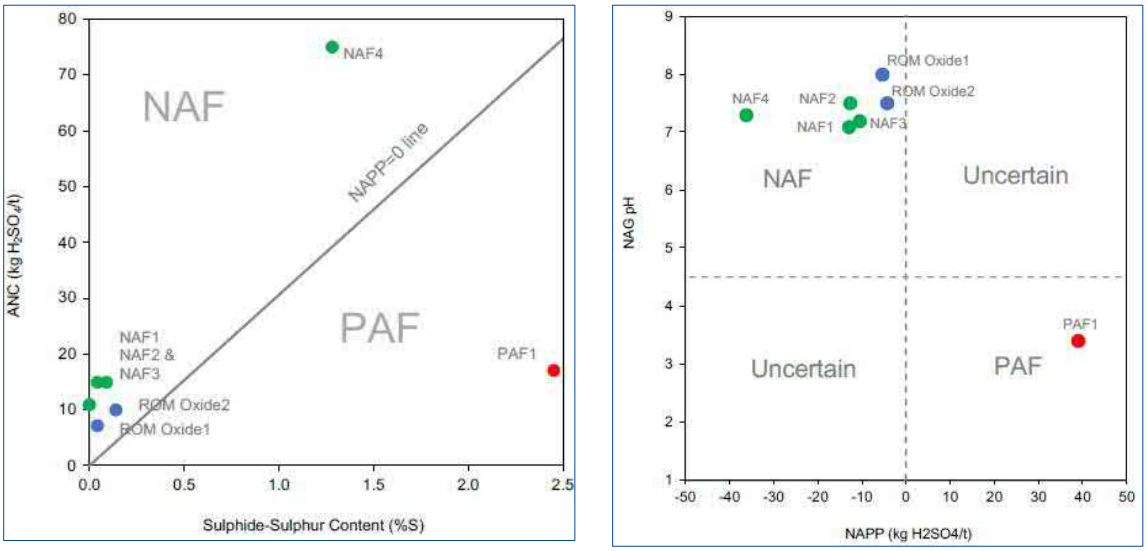


Plate 41 AMD plot for waste rock and ROM oxide and AMD classification (EGi, 2020)

The reactivity of sulphides in the PAF sample was assessed during a monitored NAG test (EGi, 2020). The monitored NAG test revealed an initial lag in acidification, attributed to the acid neutralising capacity of the rock material. After the lag period, pH began to decline while temperature increase as sulphidic material was oxidised. The results of the monitored NAG test indicate the sulphidic mineralisation is reactive, however, the lag period suggests acidification will only occur after many months or years under field conditions.

Two assessments for acid neutralising potential were conducted on samples, namely ANC and carbonate neutralising value (CNV). For all samples, CNVs were below ANC values. This suggests most acid neutralising capacity in rock is a result of carbonate mineralisation. This is particularly true for sample NAF4 which has the highest ANC. It is anticipated that for samples with very low ANCs, some acid neutralising may be derived from gangue minerals such as silicates.

The column leach test occurred for one year under conditions amenable to sulphide oxidation. The column was flushed every three weeks with the leachate collected for elemental analysis. The first-flush leachate collected from all samples was found to be alkaline, low in soluble salts, contained only trace concentrations of aluminium, iron and manganese. Dissolved metal concentrations were

generally below the limits of analytical detection. A summary of chemical characteristics for the leachate produced from each sample for weeks 4-52 is provided in Table 50. Detailed analysis results are provided in Appendix L.

Table 50 Summary of leachate analysis from week 4 to 52 (EGi, 2020)

Sample ID	Leachate Characteristics
PAF1	pH remained circum-neutral signifying the sample was in lag phase. Release of sulphate remained relatively low – ranging between 155 to 334 mg/L which indicates slow rate of sulphide oxidation. No leaching of iron or copper as a result of slow rates of pyrite and chalcopyrite oxidation. Despite significant enrichment of cobalt and selenium and minor enrichment of arsenic and nickel in the sample, arsenic concentration was below detection limits while only trace concentrations of cobalt, nickel and selenium were present in leachate. Only minor leaching of manganese and aluminium were recorded.
NAF 1 and NAF2	pH of leachate remained alkaline. Sulphate concentrations remain very low for the duration of the column leach (NAF1 average of 20 mg/L and NAF2 average of 47 mg/L. Results indicate sulphide oxidation is near non-existent. Calcium was recorded as a major cation in leachate with the average calcium concentration of 11 mg/L and 21 mg/L in NAF1 and NAF2 respectively. Concentration of copper, cobalt and chromium indicates no significant leaching of these metals. NAF2 presented minor leach of arsenic with concentrations in leachate increasing in the first six months before stabilising at 0.03 mg/L.
NAF4	pH of leachate remained slightly alkaline for the duration of the column test. Although leachate remained alkaline, there was a significant release of sulphate during the test with and average sulphate concentration of 452 mg/L at a release rate of 32 mg/kg/week. This corresponds to an IOR of $4.8x10^{-8}$ kg/O_2/m^3/sec. which is in the moderate range for sulphidic rock. Significant leaching of calcium was detected which reflects the carbonate minerals within sample reacting with the acidity generated by sulphide oxidation. Release of magnesium was also reported, suggesting carbonate mineralisation may have been partially dolomitic. Although the sample had a high copper content, the concentration of copper in leachate was minor at around 0.01 to 0.04 mg/L. It is thought that copper released during oxidation likely reprecipitated as copper oxyhydroxide. No significant leaching of iron, manganese, or any other element of environmental significance was detected.
Oxide ROM1 and ROM2	Both ROM oxide samples remains circum-neutral during the column leach test. Release of sulphate occurred during the first few months of the test, however this decreased thereafter. The copper concentration of leachate indicates some evidence of copper leaching, although results indicate a pH-dependent solubility control for copper release. As such, copper leaching is expected to remain constant as a result of circum-neutral pH.

Sample ID	Leachate Characteristics
	No significant leaching of cobalt or other metals of environmental significance was detected.

Solute concentrations within the AMD leachate

Representative AMD solute concentrations have been obtained through the kinetic column leach testing undertaken in 2020 (EGi, 2020).

Results of the testing are presented in Appendix L.1. Charts comparing the kinetic column leach test results against the adopted livestock drinking WQG are presented in Appendix L.2, whilst chart comparing the results against the long-term water quality in the open pits are included in Appendix L.3.

The results indicate the following:

- Long-term kinetic column leach results (at week 52 of the test program) are below the adopted livestock drinking WQG values.
- Long-term kinetic column leach results (at week 52 of the test program) are below the modelled long-term solute concentrations (average of modelled concentrations/levels after 50 years) in the open pits, except for aluminium, arsenic, calcium, chromium and copper in one or more column samples. However, the leach results of these solutes are below the livestock drinking WQG (where specified).
- As the AMD impact groundwater inflow constitutes only a minor component of the total inflow into the open pits, the mass load of the AMD solutes will be diluted by rainfall runoff and the pit water volume already in storage.

10.7.2 Potential AMD impacts on final void water quality in open pits

The presence of some potentially acid forming (PAF) rock within the open pit shells has potential implications for final void water quality. Some sulphide mineralisation will be exposed on the final pit floor and footwall benches as these final surfaces will be close to ore zones. Direct runoff from the open pit walls that comes in contact with PAF rock wall material or groundwater seepage through PAF pit wall material could affect the evolution of final void water quality over time.

The semi-quantitative assessment of the potential impacts of AMD on final void water quality presented further below was based on the results of geochemical investigations into the waste rock and oxide ore and the results of the water balance modelling. The potential for AMD to impact on the final void water quality depends on several factors, including:

- the area within the pit shells with exposed PAF material
- the proportion of this leachate water relative to total inflows in the open pits (i.e. the dilution effect)
- the solute concentrations within the leachate water from the exposed material
- the solute concentration and mass balance in the open pits.

Exposure to PAF material from pit walls

Exposure of some PAF rock around the pit shell has implications for pit water quality, especially late in mine life and closure. At closure, some sulphide mineralisation will be exposed on the final pit floor and footwall benches as these final surfaces will be close to ore zones.

Classification of waste rock and ore material undertaken by EGi in 2014 indicates that:

- the majority (89%) of the waste rock from the open pits will have a low sulfur content and will be non-acid forming (NAF). It follows that most exposed waste rock in the pit shells will be NAF.
- whilst most of the ore samples tested had high to very high sulphide content, only ±56% were classified as PAF.

A waste rock and ore block model was developed to provide the basis for initial mine planning, as presented in "*Waste Rock Management Plan*" developed by URS Australia in 2014. This management plan includes several cross-sections through the North Pit and South Pit, depicting the occurrence of PAF waste, NAF waste and ore within the proposed open pits.

These cross-sections (Plate 42 and Plate 43) demonstrate that only a minor part of the pit shell would contain exposed PAF waste or ore.

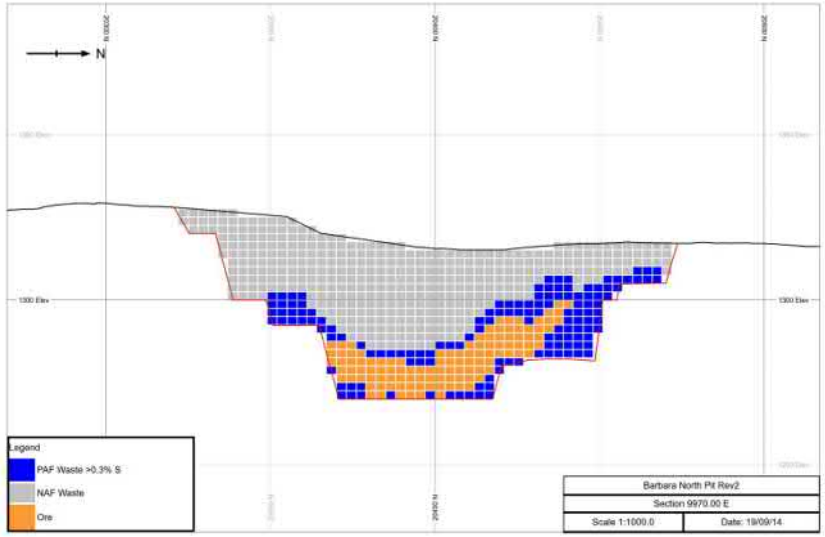
Proportion of AMD leachate relative to total inflows in the open pits

Exposed PAF rock may produce localised AMD from seepage of groundwater through the exposed PAF material. If PAF rock represents only a small fraction of total pit wall area then it is likely that any AMD produced would be diluted and neutralised to some extent by the much larger volume of alkaline runoff from NAF rock around the pit and by non-AMD impacted groundwater inflow.

Water balance modelling undertaken by ATC Williams (ATC Williams, 2023) indicate groundwater inflow into the open pits is minor compared to total inflow and existing pit volume. Cumulative groundwater inflow as percentage of total inflow are as follows:

- North Pit: ±10% of the total cumulative inflow
- South Pit: ±20% of total cumulative inflow

Assuming that only half of the groundwater inflow would pass through the PAF material in the pit shell, this potentially AMD impacted seepage water would only comprise ±5% and ±10% of total inflow, for North Pit and South Pit respectively. When considering the total inflow from rainfall runoff and the buffering effect of the water volume already present in the open pits, the volume of AMD impacted groundwater seeping into the open pits is sufficiently diluted to alleviate its potential adverse impacts on open pit water quality.



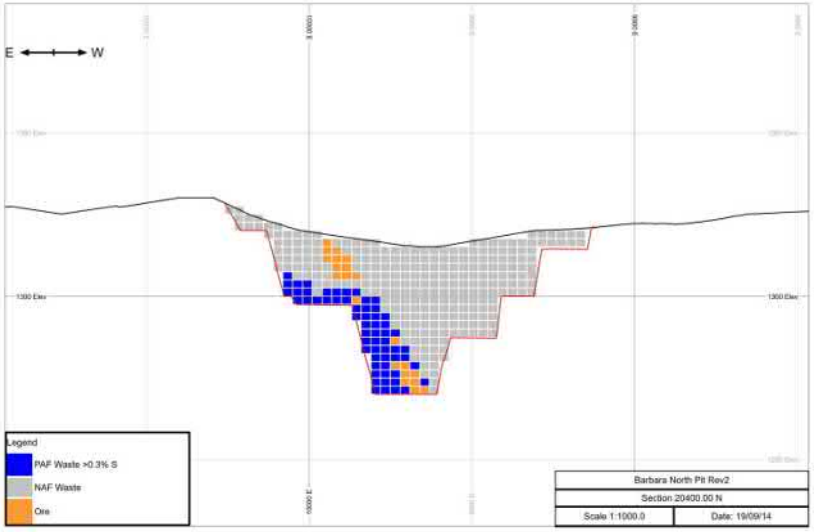
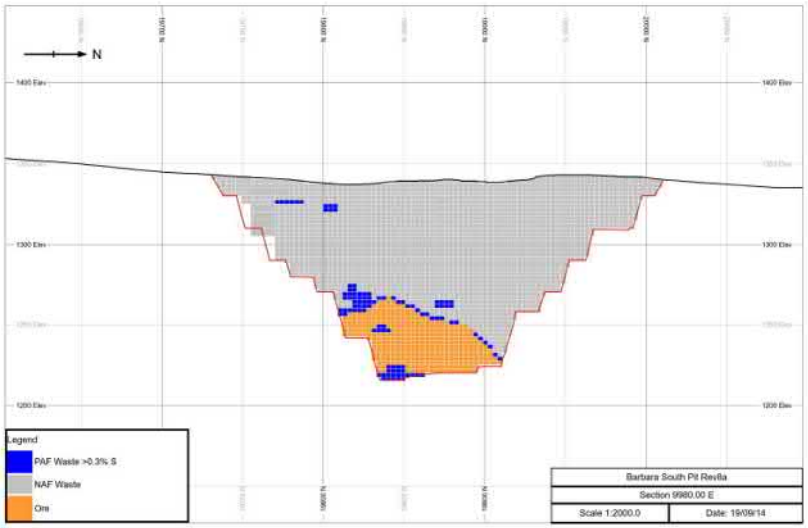


Plate 42 North Pit waste rock cross-sections (AECOM 2014)



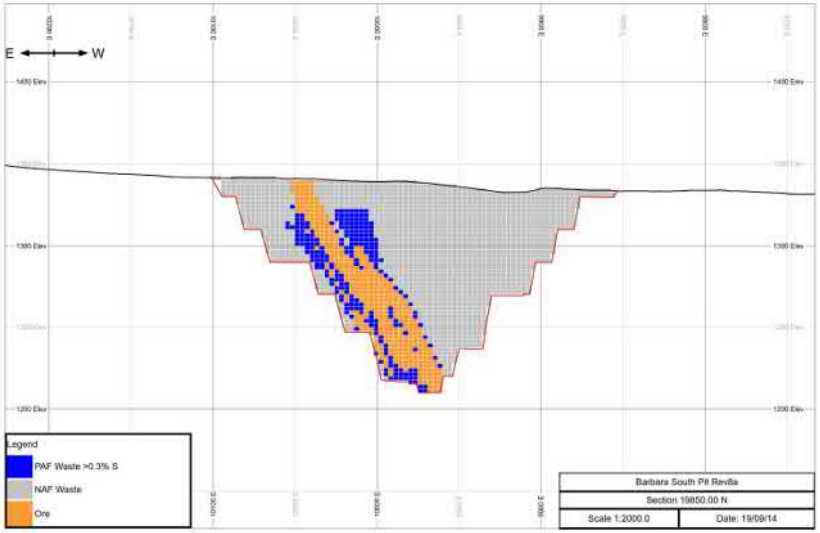


Plate 43 South Pit waste rock cross-sections (AECOM 2014)

Potential AMD impacts on open pit water quality

Saline drainage potential

Analyses of EC were performed to provide an indirect measure of the soluble salt content of mined rock and to assess the potential for saline drainage if material is exposed to atmospheric conditions (EGi, 2014). Plate 44 provides a summary of EC values per rock unit.

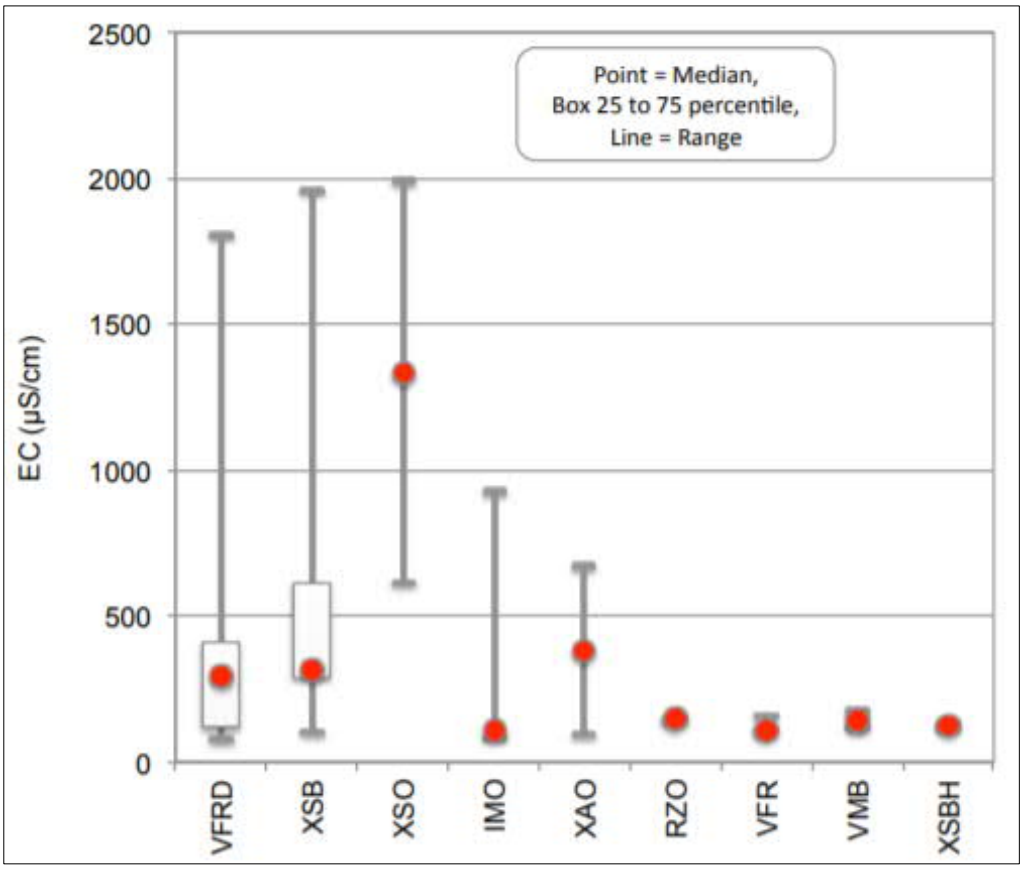


Plate 44 Summary of EC values for all rock units within Barbara drill core samples (EGi, 2014)

From the results presented in Plate 44, the following outcomes can be determined:

- 72% of the 87 VRFD (the dominant waste unit) analyses - generally comprising of the predominant waste rock unit (Porphyritic Rhyolite), resulted in an EC of less than 400 µS/cm, representative of 'non-saline water'.
- 21% of the 87 VRFD analyses resulted in an EC between 400 and 800 µS/cm, representative of 'slightly saline water'.
- 13 of the 121 drill core analyses conducted were classified indirectly as 'saline' (≥800 µS/cm). It is noted that 12 of the 13 analyses resulting in a 'saline' classification comprised high sulphur ore materials.

Based upon the EGi (2014) results, it is concluded that saline drainage was not considered a significant water quality issue, with respect to waste rock materials.

Metalliferous drainage potential

The elemental characterisation provides an indication of elements enriched in the solid rock material, however, may not be indicative of the potential for metal leaching to water. The leaching potential of ore and waste rock was, therefore, determined using an extraction with deionised water (kinetic column leach testing) (EGi, 2020).

The results indicate the following:

- Long-term kinetic column leach results (at week 52 of the test program) are below the adopted livestock drinking WQG values.
- Long-term kinetic column leach results (at week 52 of the test program) are below the modelled long-term solute concentrations (average of modelled concentrations/levels after 50 years) in the open pits, except for aluminium, arsenic, calcium, chromium and copper in one or more column samples. However, leach results of these solutes are below the livestock drinking WQG (where specified).

As the AMD impact groundwater inflow constitutes only a minor component of the total inflow into the open pits, the mass load of the AMD solutes will be diluted by rainfall runoff and the pit water volume already in storage.

Conclusions

The potential seepage of AMD groundwater into the open pits will not adversely impact the long-term water quality in the open pits and not affect the proposed PMLU as a water storage for livestock watering.

10.7.3 Potential AMD impacts on underground final void water quality

Introduction

As discussed in Section 3, the backfill method planned for Barbara UG is development waste rock placed into completed stope voids. Aeris waste balance indicates that ~390,747 tonnes (t) of waste rock are expected from UG mining, with ~306,456 t being non-acid-forming (NAF) and ~84,292 t being potentially acid-forming (PAF) material.

Waste rock will be characterised prior to disposal consistent with EA condition C3 to determine if it is PAF material. PAF material will be temporarily stockpiled within the ROM pad footprint before being returned underground as backfill. Additional waste rock (preferentially PAF) will be sourced from the existing WRD to backfill stope voids as there is a known waste rock deficit. NAF material may be used as a cover for the existing waste rock dump (WRD).

Methodology

The placement of PAF material within the UG voids has the potential to adversely affect the long-term water quality in the voids, which may, in turn, have an adverse impact on the environmental values of the receiving environment.

Geochemical modelling, using Phreeqc v3.0, was undertaken to assess the impact of the placement of PAF material on the UG void water quality. A mixing model was developed based on the following assumptions and input data:

- The mixing model considered the scenario whereby all PAF, NAF, and make-up material (e.g., PAF or ROM material) were placed in the UG voids, and these voids were filled with water.
- Water volumes in the final void were derived as follows:

- Volumes of water leaching from the PAF, NAF and make-up material have been derived from the Aeris' waste balance calculations (Section 3), assuming all waste material has been placed with a porosity of 30%.
- Volume of water in the underground voids has been derived from the UG workings WBM developed to assess final void water quality.

- Input water quality has been derived as follows:
  - Water quality from the PAF, NAF and make-up material has been calculated as the 95% percentile of the kinetic column leach test results.
  - Water quality of the UG final void water has been calculated as the 95% percentile of the UG mixing WQM model concentrations.
- Five different climate scenarios (P05, P25, P50, P75 and P100) were considered.

Table 51 shows the input water quality data and water volumes for the different scenarios.

Table 51 Input water quality and water volumes for UG PAF disposal WQM

	PAF Material	NAF Material	Make-up Material	P05	P25	P50	P75	P100
Water Quality (mg/L)								
Alkalinity (as HCO3)	22.0	28.0	22.0	571.9	553.4	567.3	540.5	558.0
pH	7.500	7.600	7.500	8.1120	8.1120	8.1120	8.1120	8.1120
Calcium	67.0	122.0	67.0	89.0	101.7	84.0	108.3	116.6
Magnesium	8.0	18.0	8.0	43.0	52.5	41.0	54.6	59.1
Sodium	1.0	1.0	1.0	184.3	206.2	176.2	209.6	224.5
Potassium	13.0	16.0	13.0	36.7	37.9	35.8	39.8	35.4
Chloride	<1.0	<0.1	<1.0	50.5	53.6	49.1	56.4	50.3
Fluoride	0.300	0.300	0.300	0.9477	0.9956	0.9179	1.0230	1.0796
Sulfate	197.0	331.0	197.0	165.8	246.5	141.4	286.6	319.6
Aluminium	0.020	0.140	0.020	0.0789	0.0776	0.0802	0.0784	0.0806
Arsenic	<0.001	0.029	<0.001	0.0026	0.0027	0.0026	0.0029	0.0026
Barium	0.020	0.020	0.020	0.1797	0.1797	0.1788	0.1829	0.1761
Boron	<0.050	<0.050	<0.050	0.1282	0.1302	0.1294	0.1305	0.1387
Cadmium	0.000	0.000	0.000	0.0070	0.0077	0.0075	0.0089	0.0063
Chromium	<0.001	<0.001	<0.001	0.0076	0.0078	0.0074	0.0083	0.0071
Cobalt	0.007	0.002	0.007	0.0038	0.0039	0.0037	0.0040	0.0036
Copper	0.028	0.019	0.028	0.0678	0.0722	0.0710	0.0817	0.0628
Iron	<0.050	0.070	<0.050	0.1777	0.1879	0.1857	0.2095	0.1666

	PAF Material	NAF Material	Make-up Material	P05	P25	P50	P75	P100
Lead	<0.001	<0.001	<0.001	0.0435	0.0477	0.0464	0.0552	0.0389
Manganese	0.040	0.130	0.040	0.0822	0.0895	0.0875	0.1027	0.0740
Molybdenum	0.003	0.005	0.003	0.0077	0.0110	0.0067	0.0124	0.0139
Nickel	0.004	0.001	0.004	0.0055	0.0056	0.0054	0.0058	0.0054
Selenium	<0.010	<0.010	<0.010	0.0086	0.0150	0.0068	0.0180	0.0205
Uranium	<0.001	0.001	<0.001	0.0077	0.0082	0.0074	0.0083	0.0088
Vanadium	-	-	-	0.0025	0.0024	0.0025	0.0024	0.0026
Zinc	<0.005	<0.005	<0.005	0.1896	0.2006	0.1983	0.2240	0.1776
Water Volume Calculations								
Water in voids (ML)	-	-	-	84.18	73.31	72.2	62.22	49.8
Waste Volume in UG Voids (tonnes)	84,2912	306456	139253	-	-	-	-	-
Porosity (%)	30%	30%	30%	-	-	-	-	-
Water Volume (tonnes)	25,287	91,937	41,776	-	-	-	-	-
Conversion from water ton to ML	0.001018	0.001018	0.001018	-	-	-	-	-
Water Volume (ML)	25.75	93.62	42.54	-	-	-	-	-
% volumes for mixing WQM								
Water Volume (ML)	25.75	93.62	42.54	84.18	73.31	72.2	62.22	49.8
P05 - % volume	0.105	0.380	0.173	0.34	-	-	-	-
P25 - % volume	0.109	0.398	0.181	-	0.312	-	-	-
P50 - % volume	0.1100	0.3999	0.1817	-	-	0.3084	-	-
P75 - % volume	0.1149	0.4177	0.1898	-	-	-	0.2776	-
P100 - % volume	0.1216	0.4422	0.2009	-	-	-	-	0.2352

Modelling results

Phreeqc v3.0 was used to model the mixing of the different water types and volumes with specific water quality characteristics for the five climate scenarios. Appendix K.4 presents the Phreeqc input and output files for each scenario.

Table 52 presents the modelled end-point water quality in the UG void. The modelled concentrations are below the ANZECC 2000 Livestock Drinking Water guidelines and below the BCP PRCP groundwater criteria.

Table 52 End-point UG water quality (mg/L) with PAF/NAF disposal

Analyte		Guideline Values	P05	P25	P50	P75	P100
Aluminium	Al	5 (1)	0.0858	0.0858	0.0866	0.0864	0.0873
Arsenic	As	0.5 (1)(2)	0.0119	0.0124	0.0124	0.0129	0.0134
Boron	B	5 (1)	0.0439	0.0407	0.0399	0.0363	0.0326
Barium	Ba	-	0.0747	0.0699	0.0690	0.0654	0.0567
Calcium	Ca	500 (2) 1000 (1)	95.5	99.8	94.3	101.6	103.0
Cadmium	Cd	-	0.0024	0.0024	0.0023	0.0025	0.0015
Chloride	Cl	-	17.3	16.7	15.1	15.7	11.8
Cobalt	Co	1 (1)	0.0040	0.0040	0.0040	0.0041	0.0040
Chromium	Cr	1 (1)	0.0026	0.0024	0.0023	0.0023	0.0017
Copper	Cu	1 (1)(2)	0.0382	0.0382	0.0377	0.0392	0.0322
Fluoride	F	2 (1)(2)	0.5219	0.5175	0.4907	0.5014	0.4837
Iron	Fe	-	0.0875	0.0866	0.0853	0.0876	0.0701
Potassium	K	-	22.3	21.9	21.2	21.7	19.68
Magnesium	Mg	150 (2) 2000 (1)	23.8	25.9	22.2	25.2	24.5
Manganese	Mn	1 (2)	0.0887	0.0913	0.0907	0.0951	0.0878
Molybdenum	Mo	-	0.0054	0.0063	0.0049	0.0065	0.0065
Sodium	Na	200(2)	63.7	65.1	55.0	59.1	53.6
Nickel	Ni	1 (1)	0.0034	0.0033	0.0032	0.0032	0.0030
Lead	Pb		0.0149	0.0149	0.0143	0.0154	0.0092
Sulfate	SO4	2,000 (1)	237.1	265.6	233.3	277.8	284.9
Selenium	Se		0.0029	0.0047	0.0021	0.0050	0.0048
Uranium	U	0.2 (1)	0.0030	0.0030	0.0027	0.0027	0.0025
Vanadium	V		0.0009	0.0007	0.0008	0.0007	0.0006
Zinc	Zn	20 (1)(2)	0.0649	0.0627	0.0611	0.0623	0.0418

(1) ANZECC 2000 Livestock (beef cattle) drinking water quality guidelines

(2) PRCP schedule PRCP EPML02840015 – Tabe 5: Water quality limits for North and South Pits and WRD Sediment Dam

Potential impacts of PAF/NAF disposal in UG voids on environmental values of receiving environment

The results of the geochemical modelling indicate that the disposal of PAF, NAF and make-up material in the UG voids does not adversely impact the environmental values and that the underground workings are suitable for a livestock watering PLMU.

10.8 Preliminary assessment of final void stratification

10.8.1 Introduction

All pit lakes are subject to physical and chemical processes that will determine the water quality of the pit lake, whether the pit lake can support aquatic life and terrestrial food webs, and the impact of the release of water to the receiving environment.

Some processes, such as wind forcing and convective mixing, are common to all pit lakes, while other factors (e.g., site-specific geochemistry, hydrology and mine pit morphology) will be specific to the mine pit and its mineralogical character.

Pit lakes undergo annual water temperature cycles due to heat exchange between water and the atmosphere. Heat exchange occurs through longwave radiation, shortwave radiation, conduction and evaporation, and temperature exchanges between the different vertical layers in the lake and the sediments. Temperature gradients in lakes can result in a water column with two or more stratified layers. Some shallow pit lakes may be perpetually mixed by wind and never stratify (Castendyk et al., 2015).

In Northern Australia, where the climate is characterised by a wet and dry season, lake stratification can occur. Stratification of a lake occurs during the summer 'wet' season, where warmer, fresher waters sit atop colder, more saline waters in a lake. With the onset of the winter 'dry' season, the fresher top layer increases in salinity due to evapoconcentration, and the water cools due to a decrease in temperature. This results in denser upper layer water mixing with water below (Boland and Padovan, 2002)

Stratification constrains the mixing of surface and deeper waters, can minimise replenishment of deep waters with oxygen, and can, therefore, control redox states, geochemical cycles, and acidification processes.

Based on thermal stratification, three different types of lakes can be defined:

- Holomictic lakes have a uniform density and temperature regardless of depth in a particular period of the year. The layers within a holomictic lake circulate or intermix at least once a year due to the breakdown of thermal stratification and wind power. Mixing is complete or partial.
- Meromictic lakes have layers of water that do not intermix. These lakes are permanently stratified with a deep-water body of high density, usually because of high salt content in the deepest layer. The waters of meromictic lakes are divided into three layers and the top layer being the mixolimnion while the bottom layer is known as the monimolimnion. The layer between the two is known as the chemocline.
- Amictic lakes have water whose surface is covered with ice throughout the year, which prevents the mixing of the waters beneath, therefore allowing such lakes to exhibit inverse cold water stratification where water temperature increases with the increase in depth. Due to the extremely cold temperatures that characterise amictic lakes, such lakes are only found in the polar regions, both in the Arctic and in Antarctica.

Pit lakes are especially prone to meromixis (i.e. perennial stratification) owing to their depth, wind sheltering provided by pit walls, and their likelihood of containing elevated solutes that can produce vertical differences in water density (Vandenberg and McCullough, 2017).

10.8.2 Depth/area ratio assessment

Early studies of stratification in natural and pit mine lakes have focused on simple lake depth/area ratios (e.g., Lyons et al., 1994; Doyle and Runnels, 1997) on the assumption that large area/depth ratios allow more wind mixing and, thus, are less prone to stratification and the development of anoxia (*Jewell, P.W. Stratification controls of pit mine lakes. Mining Engineering, February 2009).*

Mining pit lakes with a high depth-to-width ratio are less apt to undergo complete lake turnover (Doyle and Runnells, 1997). The aspect ratio of a given pit lake can be quantified by Z_r, otherwise known as the "*relative depth*" (Hutchinson 1957):

$$Z_r(\%) = 50\ x\ Z_m\ x\ \frac{\sqrt{\pi}}{\sqrt{A}}$$

where Z_m is the maximum depth, and A is the surface area of the lake.

Using the above equation, the "*relative depth*" for the open pits and sediment dam at BCP are as presented in Table 53.

Table 53 "*Relative Depth*" of open pits and sediment dam

Void	Maximum depth (Z_m [m])	Surface Area (A [m²])	Relative Depth (Z_r [%])
North Pit	16.746	11,639	1376%
South Pit	78.095	29,433	4043%
WRD Sediment Dam	6.795	9,828	367%

In a survey of mining pit lakes around the world, Doyle and Runnells (1997) suggested that most artificial lakes with Z_r > 25% are meromictic. Based on the "relative depth" calculations, there is the potential for the North Pit, South Pit and WRD sediment Dam to become meromictic, i.e. permanently stratified.

Doyle and Runnells (1997) did observe that there were a few lakes with Z_r > 25% that were holomictic and many lakes with Z_r < 25% that were meromictic. There are other factors that dictate whether a given pit lake is permanently stratified.

10.8.3 One-dimension GLM model

Introduction

A one-dimensional model was developed for the North Pit and south Pit to further assess the potential for stratification, using "*The General Lake Model*" (GLM). GLM has been developed by the Aquatic EcoDynamics Research Group team at the University of Western Australia (http://aed.see.uwa.edu.au) in collaboration with the Lake Ecosystem Restoration research group at the University of Waikato (http://www.lernz.com).

GLM is a 1D lake water balance and vertical stratification model that computes vertical profiles of temperature, salinity and density by accounting for the effect of inflows/outflows, mixing and surface heating and cooling, including the effect of ice cover on heating and mixing of the lake.

GLM incorporates a flexible Lagrangian layer structure similar to the approach of several 1-D lake model designs (Imberger and Patterson 1981; Hamilton and Schladow 1997). The Lagrangian

approach was originally introduced in the model DYRESM developed by the Centre for Water Research and allows for layers to change thickness by contracting and expanding in response to inflows, outflows, mixing and surface mass fluxes. When sufficient energy becomes available to overcome density gradients, two layers will merge thus accounting for the process of mixing.

GLM model setup

1D GLM models were developed for the North Pit and South Pit, to assess the potential for stratification to develop in these final voids.

The input data for GLM models were obtained from the following sources:

- Final void/lake geometry, including water depth/surface area relationship, maximum depths, surface length and width, initial void conditions. Relevant information was obtained from the pit geometry developed for the ATCW water balance models.
- Climatic data, including shortwave solar radiation, cloud cover, air temperature, relative humidity, wind speed and rainfall. Information was obtained from the SILO Data Drill Program for the Site Location (https://www.longpaddock.qld.gov.au/silo/gridded-data/).
- Water quality data, including temperature and salinity. Data was obtained from the existing surface water and groundwater monitoring programs.
- Inflow and outflow data, including flow rate, temperature and salinity.

A detailed description of the science and mathematics behind GLM, data input requirements, assumptions and output is provided in "*GLM - General Lake Model: Model overview and user information* "(Hipsey et al., 2014).

A stochastic approach to climate conditions was not adopted as part of this preliminary assessment. Such an approach would only be considered warranted if the results of the preliminary assessment indicate stratification in the voids to the extent that this could adversely affect final void water quality.

The GLM models were developed using daily climate data from 1/01/1973 to 19/03/2023 obtained from the SILO Data Drill Program for the BCP site. Adopting a daily timestep for this period is considered adequate to represent long-term climatic conditions, together with short-term variations, for the BCP site.

North Pit GLM model results

GLM model results include detailed water balance results and plots of temperature and density to visually assess the stratification in the open pit with depth and over time.

Modelled depth distributions of temperature, density and salinity over time are presented in Plate 45, Plate 46 and Plate 47, respectively.

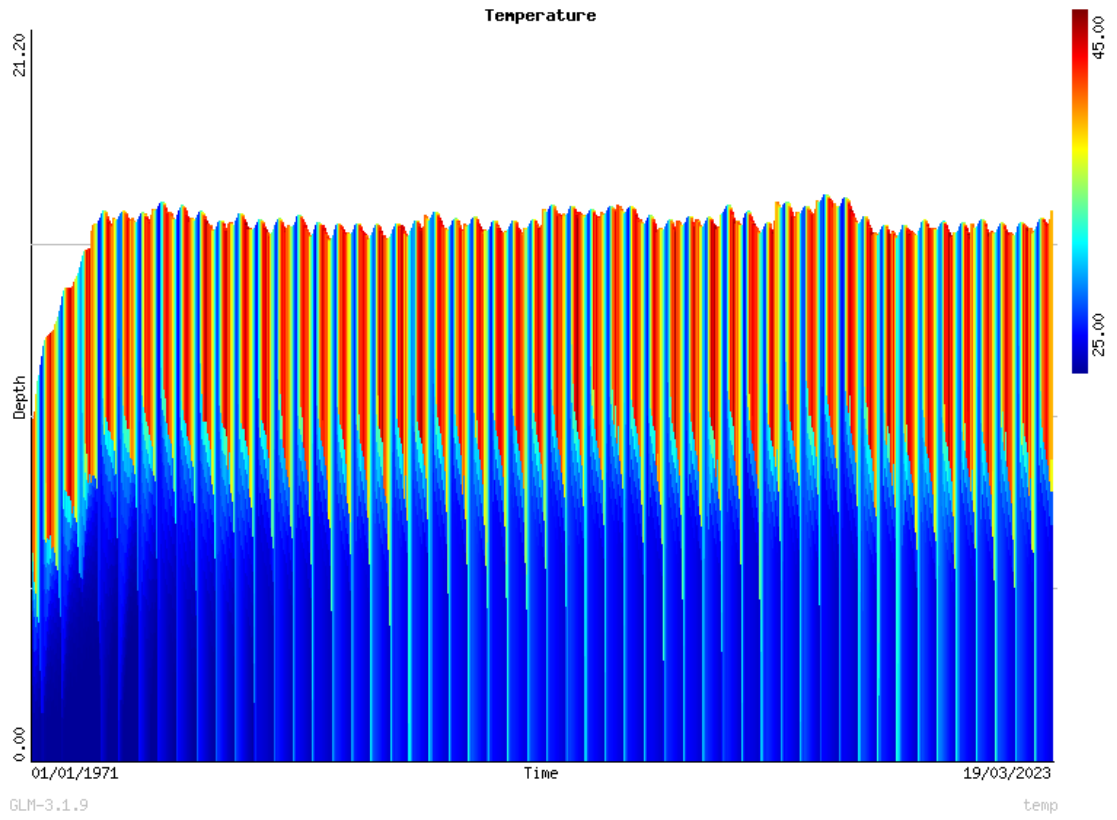


Plate 45 North Pit GLM model results – temperature (°C) distribution

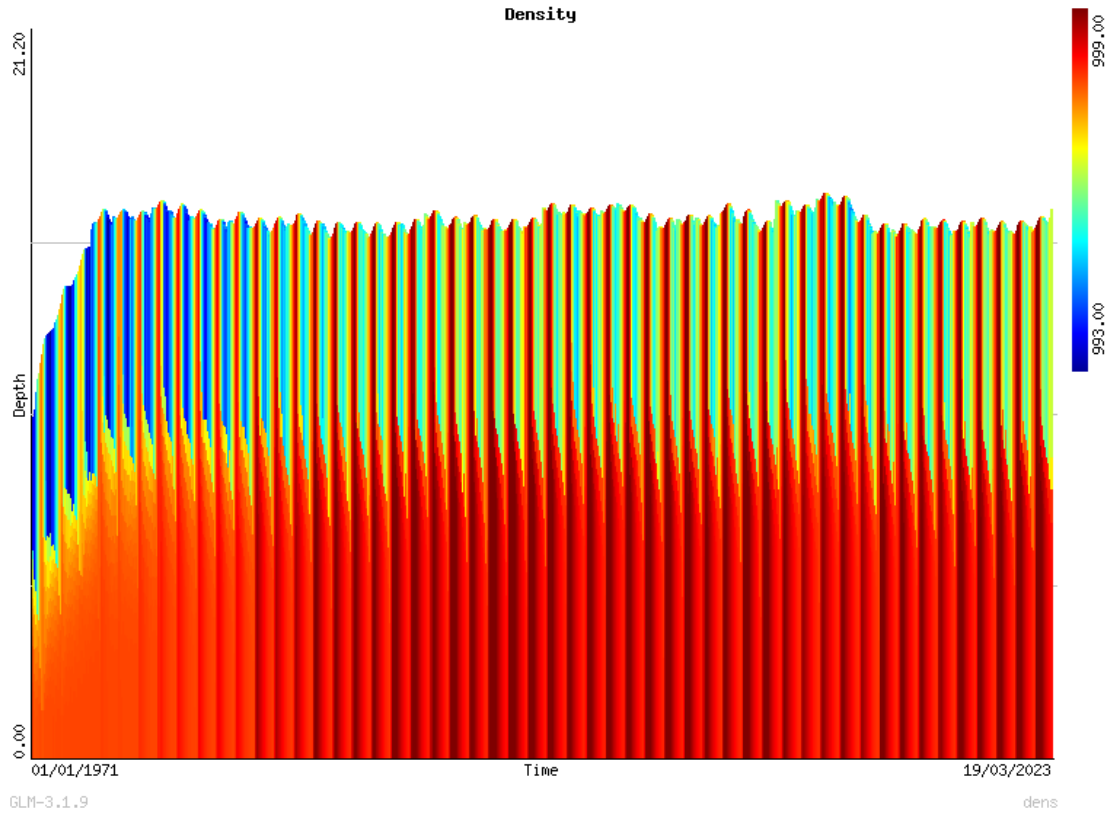


Plate 46 North Pit GLM model results – density distribution

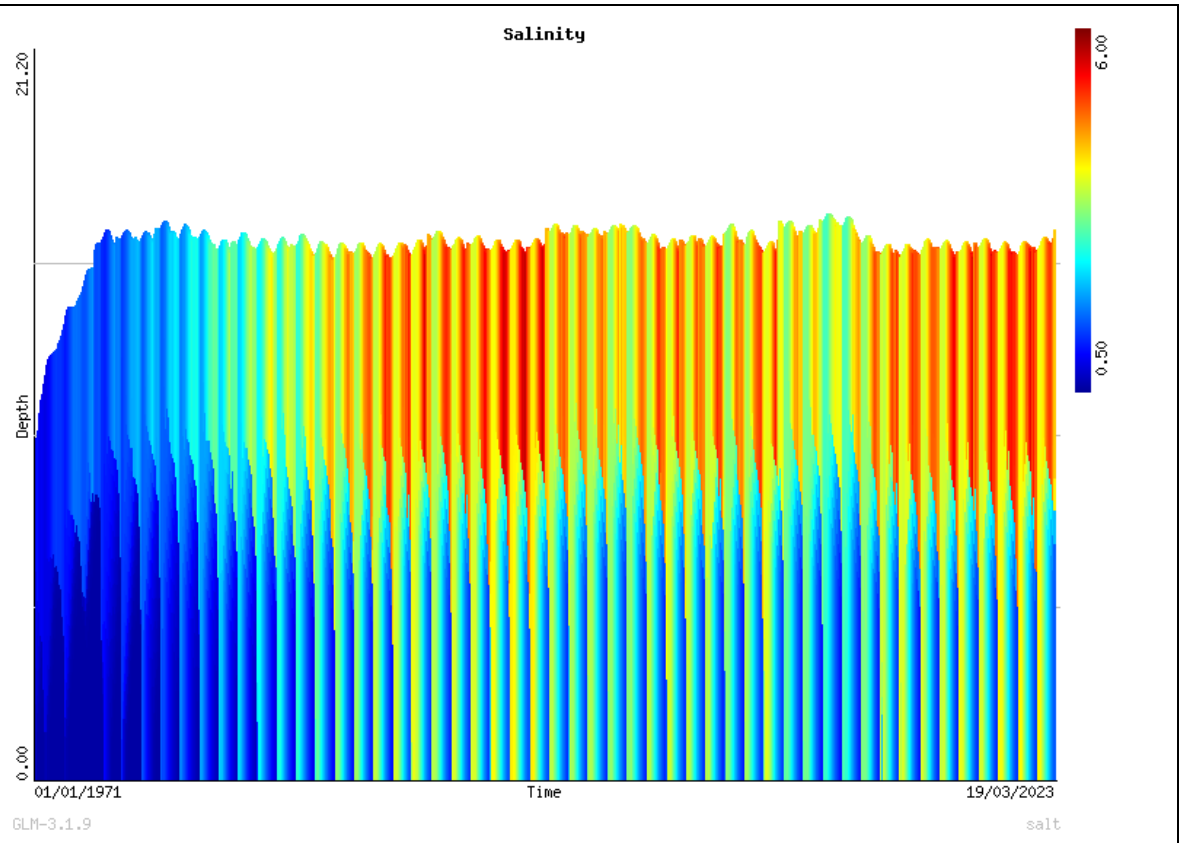


Plate 47 North Pit GLM model results – salinity (g/L) distribution

The preliminary GLM modelling results for the North Pit indicate the following:

- Thermal, density and salinity stratifications may develop over time on a seasonal basis within the North Pit.
- Three stratification zones may develop within the open pit during the dry, hot seasons. However, the stratifications dissipate during the wet season.
- As there is a uniform density and temperature distribution during at least one period of each year, the North Pit lake could be classified as a "holomictic" lake.

As the North Pit generally acts as a terminal groundwater sink, with minimal outflow/seepage towards the South Pit and as the stratification in the pit is seasonal, the PMLU of the pit as "water storage for livestock watering" is not adversely affected by the seasonal stratification.

South Pit GLM model results

GLM model results include detailed water balance results and plots of temperature and density to visually assess the stratification in the open pit with depth and over time.

Modelled depth distributions of temperature, density and salinity over time are presented in Plate 48, Plate 49 and Plate 50, respectively.

The preliminary GLM modelling results for the South Pit indicate the following:

- Thermal, density and salinity stratifications may develop over time on a seasonal basis within the South Pit.
- Three stratification zones may develop within the open pit during the dry, hot seasons. However, the stratifications dissipate during the wet seasons.

- As there is a uniform density and temperature distribution during at least one period of each year, the South Pit lake could be classified as a "holomictic" lake.

As the South Pit generally acts as a terminal groundwater sink and as the stratification in the pit is seasonal, the PMLU of the pit as "water storage for livestock watering" is not adversely affected by the seasonal stratification.

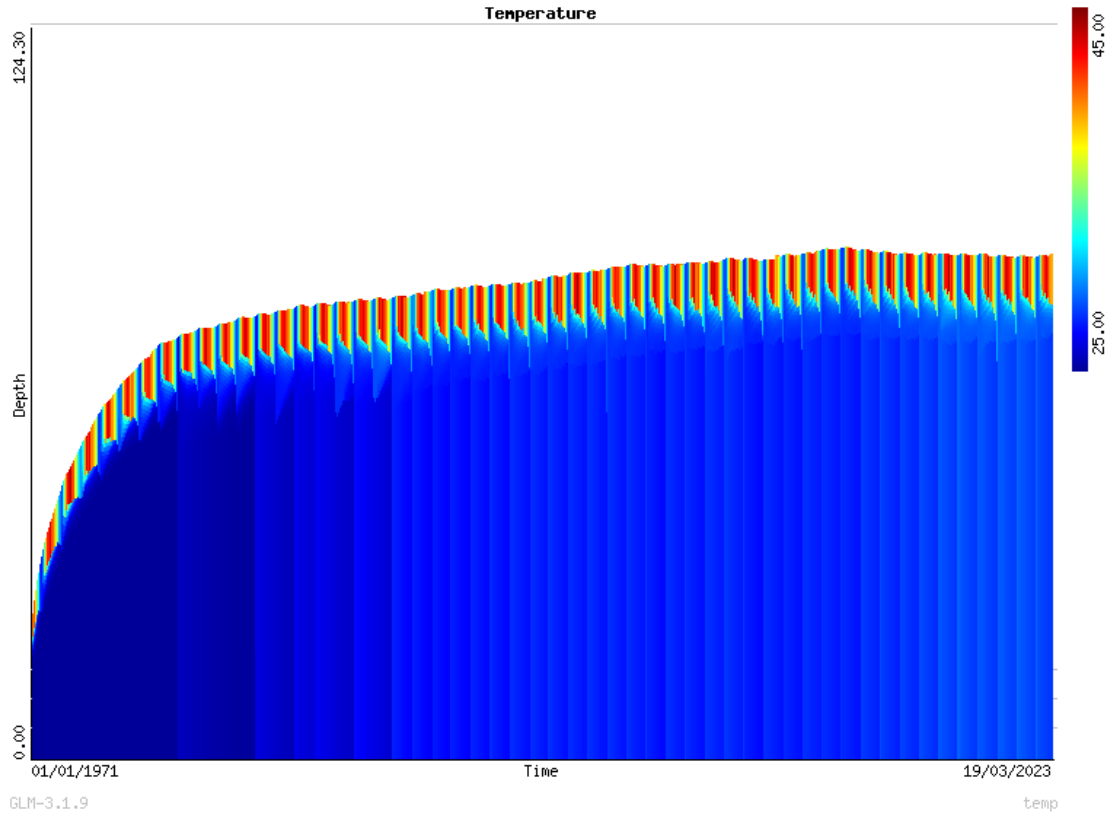


Plate 48 South Pit GLM model results – temperature (°C) distribution

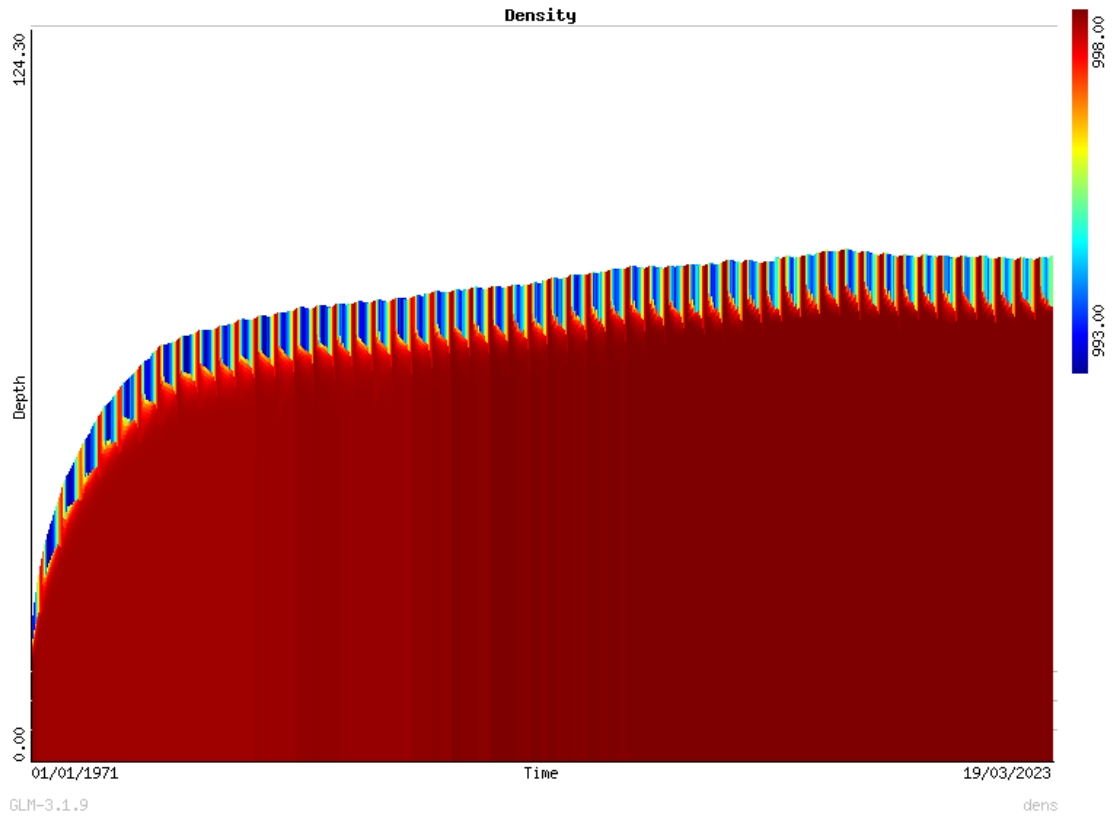


Plate 49 South Pit GLM model results – density distribution

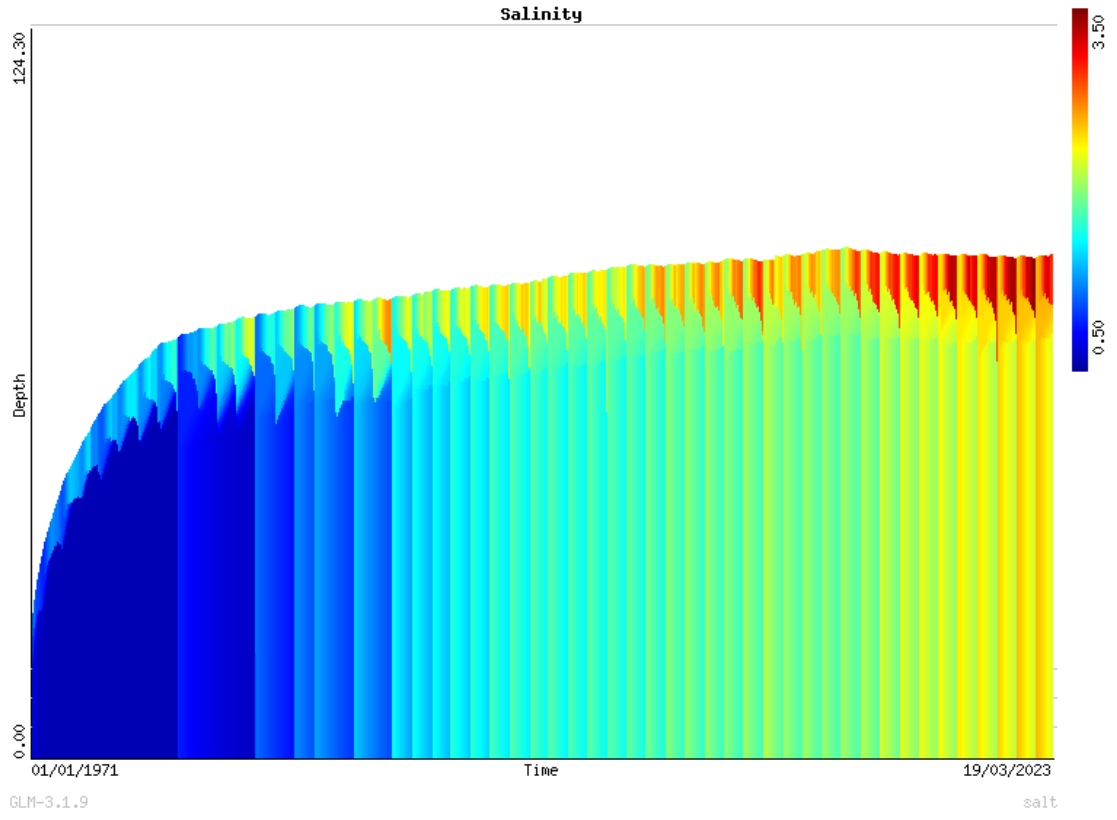


Plate 50 North Pit GLM model results – salinity (g/L) distribution

11 BCP rehabilitation planning

11.1 Exposure pathway assessment

An groundwater exposure pathway assessment has been undertaken as part of the water management rehabilitation planning. The exposure pathway assessment follows the concept of "source- pathway- receptor" (SPR) chain, whereby potential contaminants are generated within a source (e.g. waste rock dump) and transported through a pathway (seepage, groundwater) to a sensitive receptor (e.g. aquatic ecosystems). A risk to a potential receptor exists when there is a complete pathway from source to receptor.

An SPR conceptual site model (CSM) represents site-related information regarding contamination sources, receptors and exposure pathways between those sources and receptors. The CSM should identify complete and potential pathways between the known or potential source(s) and the receptor(s). Where the pathway between a source and a receptor is incomplete, the exposure to chemical substances via that pathway cannot occur but the potential for that pathway to be completed (for example, by abstraction of groundwater or a change in land use) should be considered in the assessment.

The essential elements of the CSM are:

- known and potential sources of contamination and contaminants of concern, including the mechanism(s) of contamination (e.g. 'top down' spill or subsurface release from corroded tank or pipe)
- potentially affected media (soil, sediment, groundwater, surface water, indoor and ambient air)
- human and ecological receptors that could be harmed at the exposure point
- potential and complete exposure pathways, i.e. means to transport substances from a source to a receptor.

A risk to a potential receptor exists when there is a complete pathway from source to receptor.

SPR CSM for BCP

With respect to the groundwater-related SPR CSM for BCP:

- Potential primary sources of contamination and associated chemicals of potential concern (COPCs) are presented in Table 54. Secondary sources of contamination result from release mechanisms from the primary sources and can include impacted soil, groundwater, surface water and/or sediments.
- Potential pathways (i.e. transport/migration) mechanisms of contamination are presented in Table 55.
- The potential pathways (release/transport mechanisms) associated with the potential primary sources of contamination are presented in Table 56.
- Potential receptors or beneficial uses that may be adversely impacted by contamination are presented in Table 57.
- Potential exposure pathways for human health and ecological receptors are presented in Table 58.

Table 54 Potential sources of groundwater contamination and COPCs

Source ID	Mine infrastructure	PMLU	Potential source(s)	Associated COPCs	Comments
S01	North Pit and South Pit voids	Water storage	• Water stored in open pits/voids. • AMD from PAF material in pit walls	• Acidity • Dissolved metals/ metalloids • Sulphides • Salinity (Total Dissolved Solids)	Current COPC concentrations in open pits are generally similar to background, pre-mining concentrations in groundwater.
S02	Underground workings	Water storage	• Water stored in voids. • AMD from PAF material in voids	• Acidity • Dissolved metals/ metalloids • Sulphides • Salinity (Total Dissolved Solids)	Modelled water quality data/results are below the livestock water drinking guidelines.
S03	WRD Sediment Dam	Water storage	• Water stored in dam	• Dissolved metals /metalloids. • Salinity (Total Dissolved Solids)	Current COPC concentrations in sediment dam are generally similar to background, pre-mining concentrations in groundwater.
S04	Waste Rock Dump (WRD)	Native ecosystems	• AMD from material in waste rock dump • Saline drainage	• Leachable metals/ metalloids • Salinity • Sulphides	Geochemical characterisation (leachate column testing) results of WRD material: • pH remained near neutral to slightly alkaline • Some evidence of copper leaching was observed. • Significant release of sulphate from some NAF material. • No significant leaching of other metals of environmental concern was detected. • Saline drainage potential is low and not considered a significant issue.

Source ID	Mine infrastructure	PMLU	Potential source(s)	Associated COPCs	Comments
S05	ROM Pad, ROM Pad Dam	Low intensity grazing	• AMD from material in ROM Pad • Saline drainage	• Leachable metals/metalloids • Salinity • Sulphides/sulphates	Geochemical characterisation (leachate column testing) results of wase rock, ore and ROM oxides: • pH remained near neutral to alkaline • Some evidence of copper leaching was observed. • No significant leaching of other metals of environmental concern was detected. • Saline drainage potential is low and not considered a significant issue.
S06	Light Infrastructure Area (administration buildings, fuel storage, power facility, workshop area, concrete mixing, road train loading, sewage treatment facility)	Low intensity grazing	• Chemical storage facilities • Fuel storage facilities	• Hydrocarbons (TPH/TRH/ BTEXN/PAHs/VOCs/SVOCs) • TDS and sediment.	• All infrastructure will be dismantled and removed. • All contamination will be remediated or removed from site, and a site contamination investigation completed.
S07	Explosive Magazine	Low intensity grazing	• Chemical storage facilities	• Hydrocarbons (TPH/TRH/ BTEXN/PAHs/VOCs/SVOCs) • Explosive, ammonia nitrate • TDS and sediment.	

Notes: TPH: Total Petroleum Hydrocarbons; TRH: Total Recoverable Hydrocarbons; BTEXN: benzene, toluene, ethylbenzene, xylenes and naphthalene; PAHs: Polycyclic Aromatic Hydrocarbons; VOCs: Volatile Organic Compounds; SVOCs: Semi-Volatile Organic Compounds.

Table 55 Potential pathways/release mechanisms

Spills and leaks		Runoff		Seepage/infiltration/leaching		Lateral transport/overflow	
P1	Spills and leaks of chemicals, fuels, oils, etc. directly onto the ground.	P2	Runoff of AMD impacted water from WRD and/or ROM pad into surrounding drainages and creeks	P4	Seepage/infiltration of AMD leachate from open pits, underground workings, WRD or ROM pad into groundwater and/or drainage lines.	P7	Lateral migration of contaminated groundwater.
		P3	Runoff from surface areas contaminated by spills and leaks into surrounding drainages and creeks.	P5	Seepage/infiltration of runoff/rainfall water over areas contaminated by spills, leaks or historical activities into underlying groundwater.		
				P6	Seepage/infiltration of water from sediment dam through base/walls into underlying groundwater and/or drainage lines.		

Table 56 Potential sources of contamination and primary pathways/release mechanisms

Potential source of contamination		Potential primary pathways/release mechanisms						
		P1	P2	P3	P4	P5	P6	P7
		Spills/leaks onto ground	Runoff from WRD/ROM Pad	Runoff from surface areas	Seepage of AMD leachate	Seepage of runoff/ rainfall	Seepage through base/ walls of sediment dam	Lateral migration of impacted groundwater
S01	North Pit and South Pit voids	-	-	-	Yes	-	-	Yes
S02	Underground working voids	-	-	-	Yes	-	-	Yes
S03	WRD Sediment Dam	-	-	-	-	-	Yes	Yes
S04	Waste Rock Dump (WRD)	-	Yes	-	Yes	-	-	Yes
S05	ROM Pad, ROM Pad Dam	Yes	Yes	-	Yes	-	-	Yes
S06	Light Infrastructure Area (administration buildings, fuel storage, power facility, workshop area, concrete mixing, road train loading, sewage treatment facility)	Yes	-	Yes	-	Yes	-	Yes
S07	Explosive Magazine	Yes	-	Yes	-	Yes	-	Yes

Table 57 Potential receptors or beneficial uses

Human Health		Receiving environment		Beneficial water use	
R1	Site workers/maintenance workers (e.g. during excavations/earth moving works)	R3	Aquatic ecosystems in drainage lines and/or creeks	R5	Beneficial use for livestock (primarily cattle) watering
R2	Pastoralists	R4	Terrestrial GDEs		

Table 58 Potential exposure routes/pathways for potential receptors

Receptor	E1: Ingestion Exposure	E2: Dermal Exposure	E3: Inhalation Exposure
Human Health	Incidental ingestion of contaminated groundwater	Dermal contact with contaminated groundwater	-
Ecological	Ingestion of contaminated water	Direct contact with impacted water	-
	Ingestion of bioaccumulated chemicals in animals or plants which have been exposed to contaminants in groundwater		
Beneficial Water Use	Ingestion of contaminated by livestock.	-	-

Exposure pathway assessment

A complete exposure pathway must exist for a receptor to be exposed to a chemical contaminant deriving from a site. An exposure pathway describes the course a chemical or physical agent takes from the source to the exposed individual and generally includes:

- a source and mechanism of chemical release
- a retention or transport medium (or media where chemicals are transferred between media)
- a point of potential human/ecological contact with the contaminated media
- an exposure route (e.g. ingestion, inhalation) at the point of exposure.

Where one or more of the above elements is missing, the exposure pathway is incomplete, and there is no risk to the receptor.

The BCP CSM and complete exposure pathway assessment are presented in Plate 51. Based on the groundwater CSM and the exposure pathway assessment, potential receptors that may be exposed to contaminated groundwater include the following:

- Aquatic ecosystems in or livestock accessing water courses that may be contaminated through seepage of contaminated groundwater. The likelihood is considered minimal as there is limited groundwater-surface water interaction at the Project site.
- Terrestrial GDEs that may be exposed to contaminated groundwater in drainage lines and creeks. The likelihood is considered minimal as there is limited groundwater-surface water interaction at the Project site.
- Livestock that may be exposed to contaminated groundwater. The likelihood is considered minimal as there are no homesteads in the immediate vicinity of the Project site and as groundwater flow velocity is low to very low.
- Pastoralists that may come in direct contact with groundwater. The likelihood is considered minimal.
- Livestock that may be drinking the water within the voids. The PMLU of the final voids and sediment dam is as water storage, with accessibility to the pastoralist/livestock.

Water quality modelling has indicated that the water quality in the final voids is below the livestock drinking water guidelines and that the final voids are suitable as a water storage PMLU.

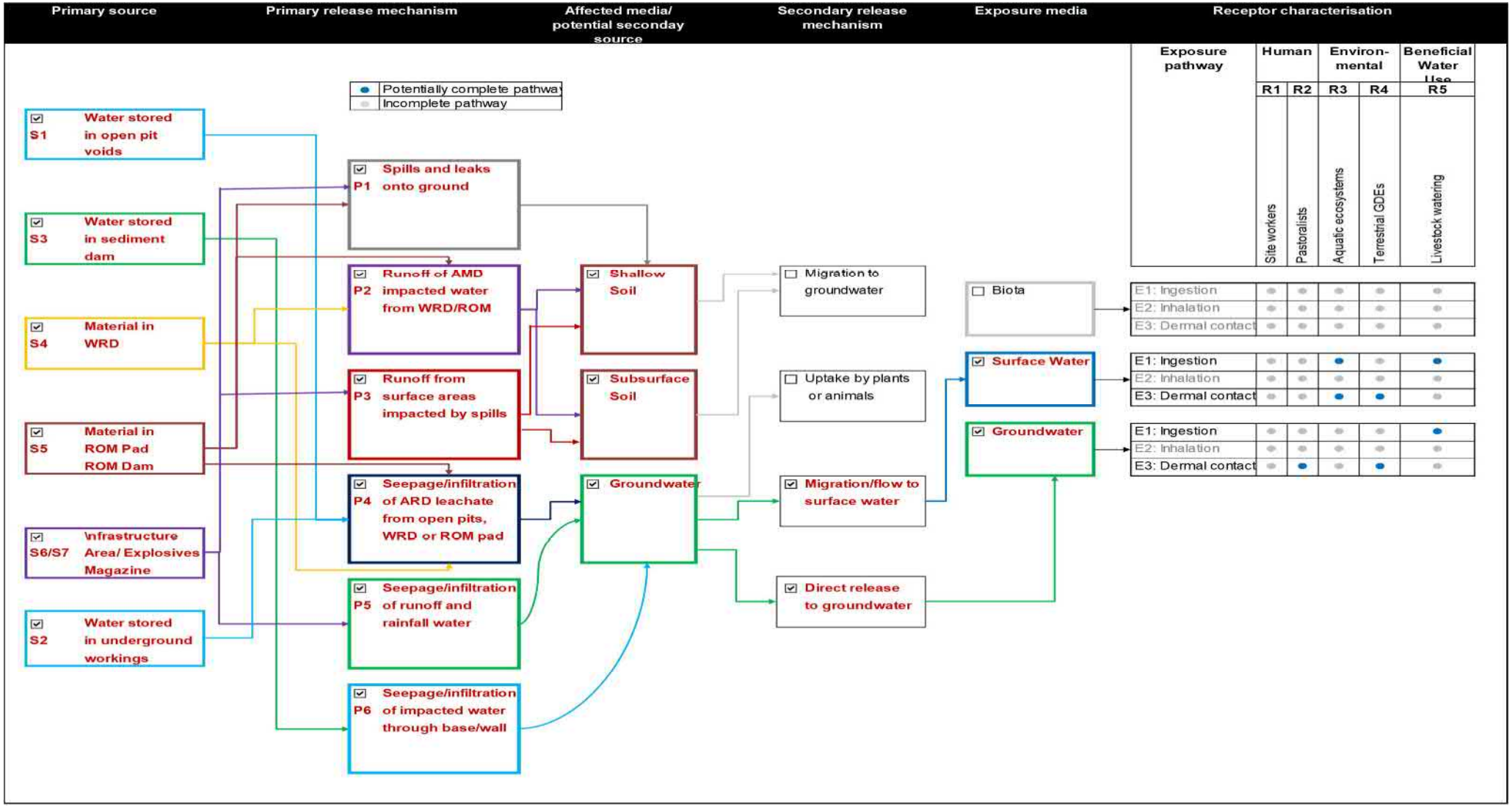


Plate 51 BCP complete exposure pathway for groundwater

12 Conclusions

Groundwater/surface water interaction

- On a semi-local to regional scale, groundwater levels are generally at a depth below ground level that would limit any groundwater/surface water interaction. This is evidenced by the ephemeral nature of the creeks at and near the mine site.
- On a local scale, two semi-permanent water bodies are present within the creek, named BCP Spring (S) and BCP Spring (N). The water bodies are most likely the results of significant rainfall events leading to significant flow within the creeks, with water stagnating in lower-lying parts of the creek. Monitoring of shallow groundwater levels and levels at the water bodies indicates that there is limited hydraulic connectivity between the shallow groundwater and the creek.
- Although the current open pits act as a groundwater sink, these pits/voids do not adversely impact the surface water environment due to the limited (to almost non-existent) connectivity between the deeper groundwater and the creek.
- In a similar vein, the proposed underground operations will not impact the groundwater/surface water interaction.
- There are no aquatic or subterranean GDEs within a 5km radius of the Project site. Only low-potential terrestrial GDEs are present within ML90241.

Final void water quality assessment

- The WQM indicates that the modelled solute concentrations in the North Pit, South Pit and WRD Sediment Dam remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.
- Regarding potential AMD impact on open pit water quality:
  - Long-term kinetic column leach results (at week 52 of the test program) are below the adopted livestock drinking WQG values.
  - Long-term kinetic column leach results (at week 52 of the test program) are below the modelled long-term solute concentrations (average of modelled concentrations/levels after 50 years) in the open pits, except for aluminium, arsenic, calcium, chromium and copper in one or more column samples. However, the leach results of these solutes are below the livestock drinking WQG (where specified).
  - As the AMD impact groundwater inflow constitutes only a minor component of the total inflow into the open pits, the mass load of the AMD solutes will be diluted by rainfall runoff and the pit water volume already in storage.
  - Therefore, it is considered that the seepage of AMD groundwater will not adversely impact the long-term water quality in the open pits.
- Regarding the potential impact on underground voids water quality:
  - Mixing water quality models indicate that the long-term water quality in the underground voids remains below the relevant water quality guidelines values (livestock watering and PRCP criteria for voids) and that the underground workings are suitable for a livestock watering PLMU.
  - Geochemical modelling using PHREEQC indicates that the placement of PAF and NAF material in the underground voids does not adversely impact the water quality, with long-term water quality remaining below the relevant water quality guidelines values (livestock watering and

PRCP criteria for voids) and that the underground workings are suitable for a livestock watering PLMU.

- Preliminary pit lake stratification modelling indicates that in the north Pit and South Pit:
  - Thermal, density and salinity stratifications may develop over time on a seasonal basis within the North Pit, with three stratification zones developing during the dry, hot seasons. However, the stratifications dissipate during the wet season.
  - As the pits generally act as a terminal groundwater sink, with minimal outflow/seepage and as the stratification in the pits is seasonal, the PMLU of the pit as "water storage for livestock watering" is not adversely affected by the seasonal stratification.
- Based on the investigation and modelling results, the North Pit, South Pit, WRD Sediment Dam and underground workings are considered suitable as PMLUs for livestock watering.

Water storage PMLU

Water quality modelling confirms that the open pits, underground voids and WRD sediment dam remain suitable as water storage PMLUs.

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14 Limitations

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That standard of care may change, and new methods and practices of exploration, testing, analysis and remediation may develop in the future, which might produce different results. WMV Environmental Pty Ltd's professional opinions contained in this document are subject to modification if additional information is obtained through further investigation, observations, or testing and analysis during any future assessment or remedial activities.

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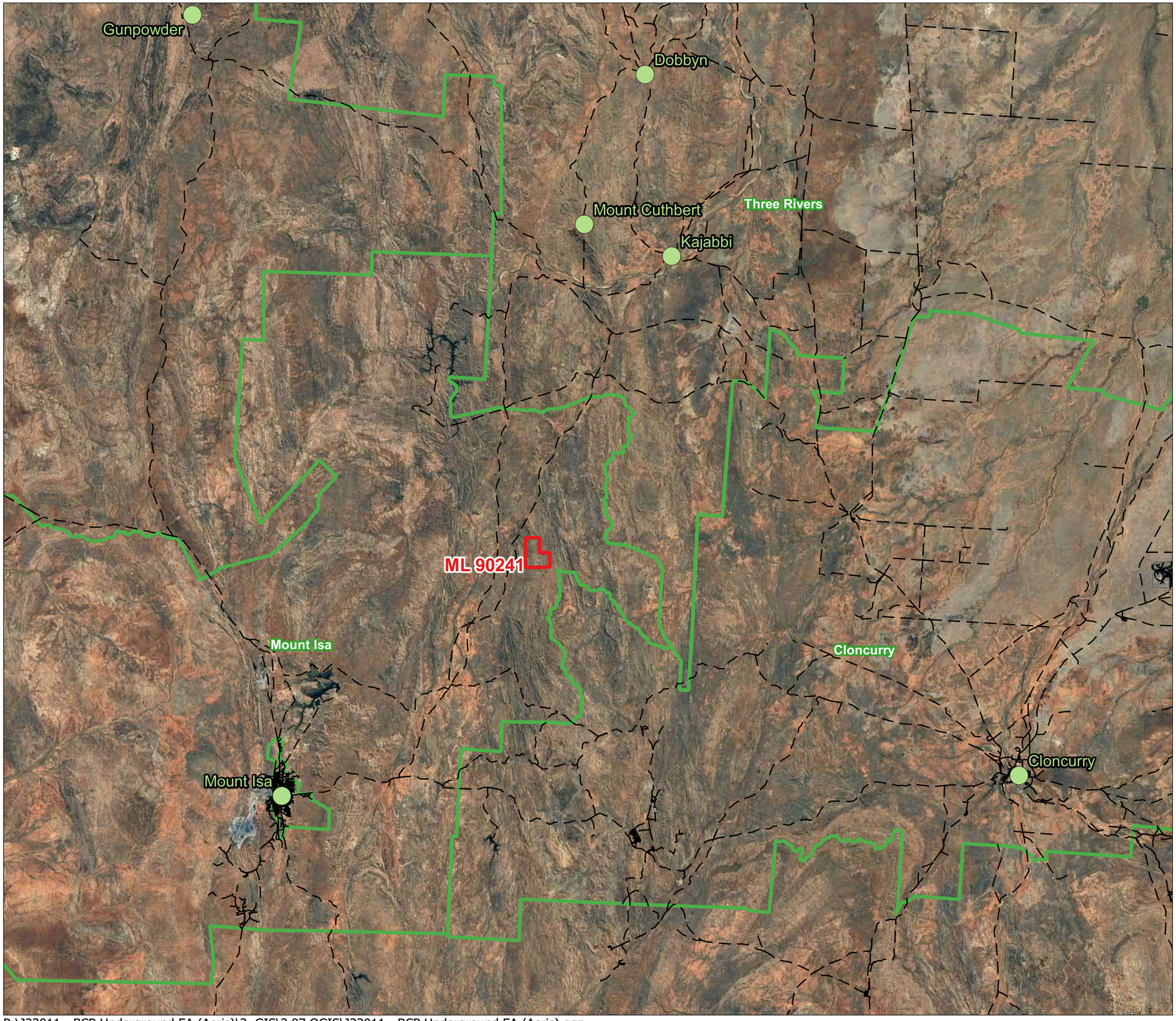
Figures

Figure 1 Location of the Barbara Copper Project
Figure 2 Location of BCP groundwater monitoring wells (regional scale)
Figure 3 Location of BCP groundwater monitoring wells (local scale)
Figure 4 Pre-mining 2014 topography
Figure 5 2021 topography
Figure 6 Mapped pre-clear regional ecosystems
Figure 7 Watercourses near the Project site
Figure 8 Surface water monitoring locations (regional scale)
Figure 9 Surface water monitoring locations (local scale)
Figure 10 Regional geology at BCP
Figure 11 Registered water bores within 5 km of BCP
Figure 12 Registered water bores within ML90241
Figure 13 BOM groundwater dependent ecosystems
Figure 14 Contour map of June 2014 groundwater levels
Figure 15 Contour map of June 2018 groundwater levels
Figure 16 Contour map of April 2022 groundwater levels
Figure 17 Contour map of April 2023 groundwater levels
Figure 18 Location of hydrogeological cross-section



Barbara Copper Project

Groundwater Technical Report for Underground EA Amendment

Figure 1 - Location of the Barbara Copper Project

0 10 20 km

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- Locality
- Road/track
- Populated place

Client: Aeris Resources Limited
Project No: J23011
Date created: 20/02/2024

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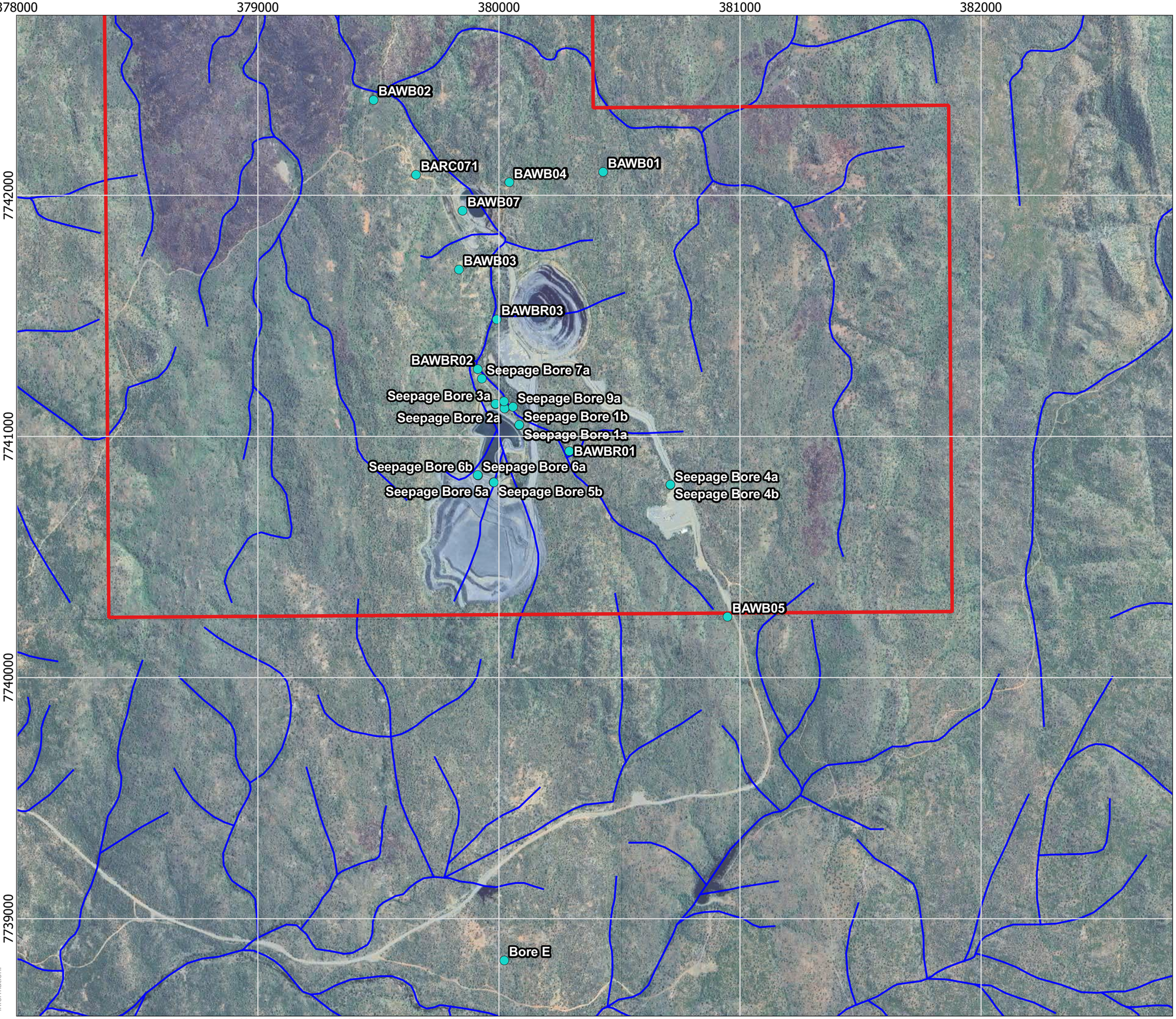

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Figure 2 - Location (regional) of BCP groundwater monitoring bores

0 200 400 600 800 m

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- Watercourse line

Monitoring Locations

- Monitoring bore

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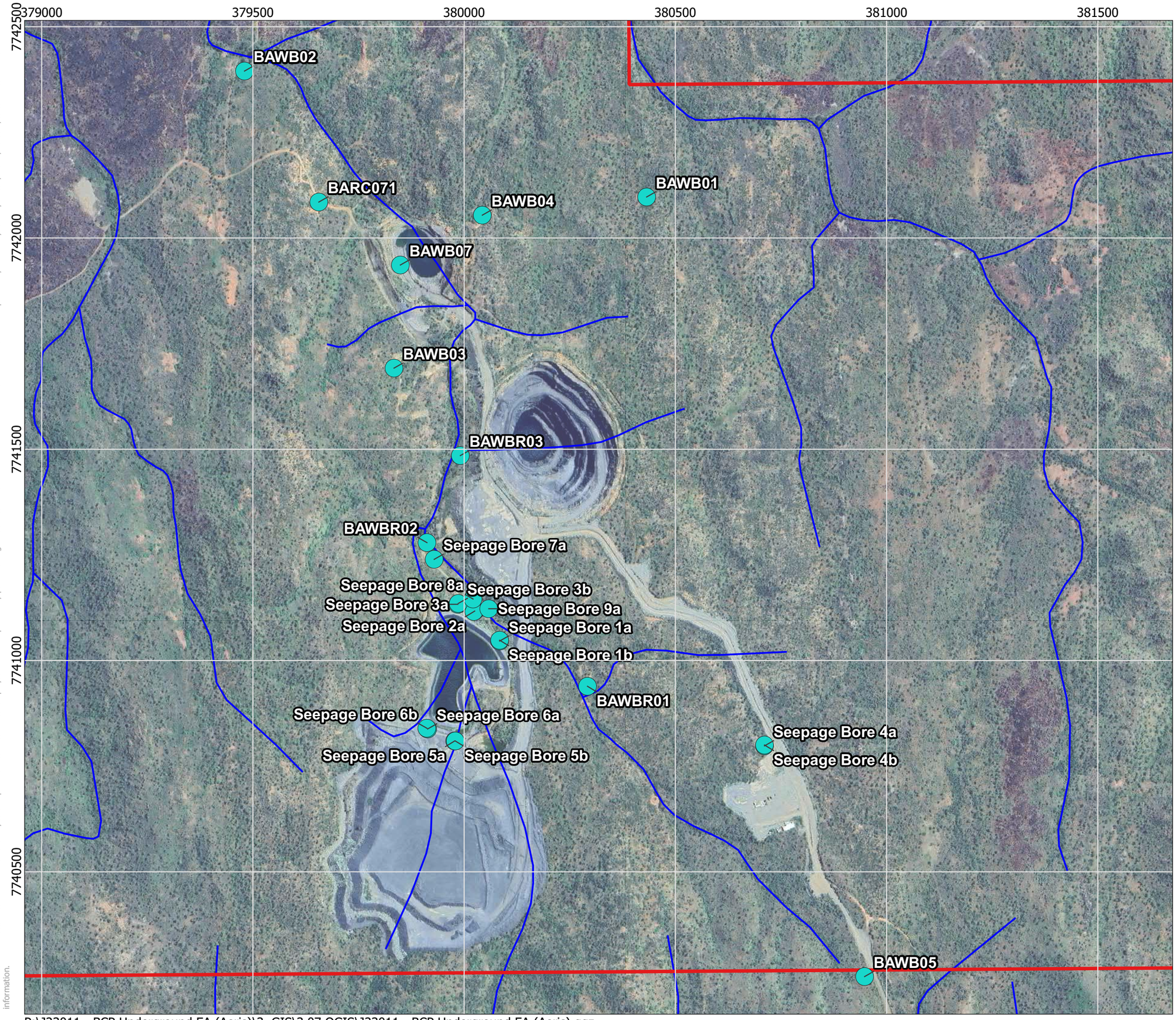

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Figure 3 - Location (local) of BCP groundwater monitoring bores

0 100 200 300 400 m

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

ML90241

Watercourse line

Monitoring Locations

Monitoring well

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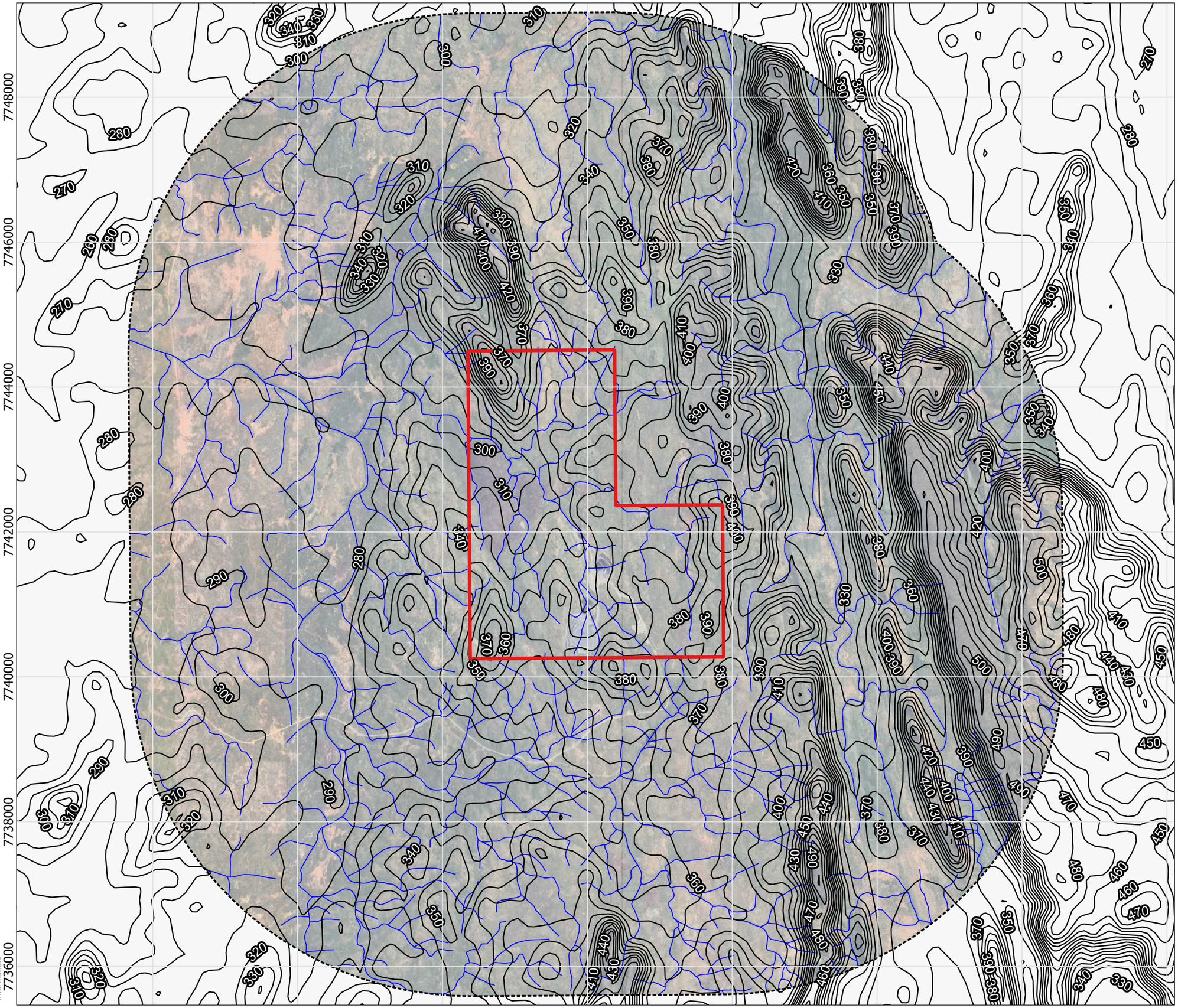

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Groundwater Technical Report for Underground EA Amendment

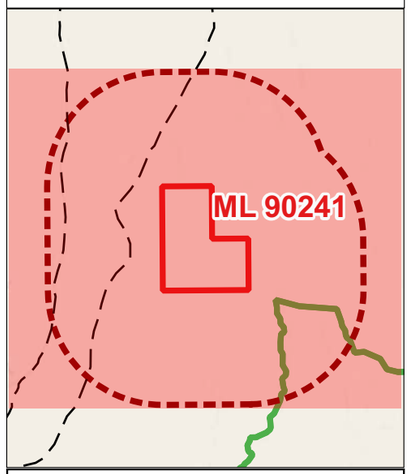
Figure 4 - Pre-mining 2014 topography

0 1 2 km

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- 2014 topography (mAHD)
- Watercourse
- 5000m Buffer



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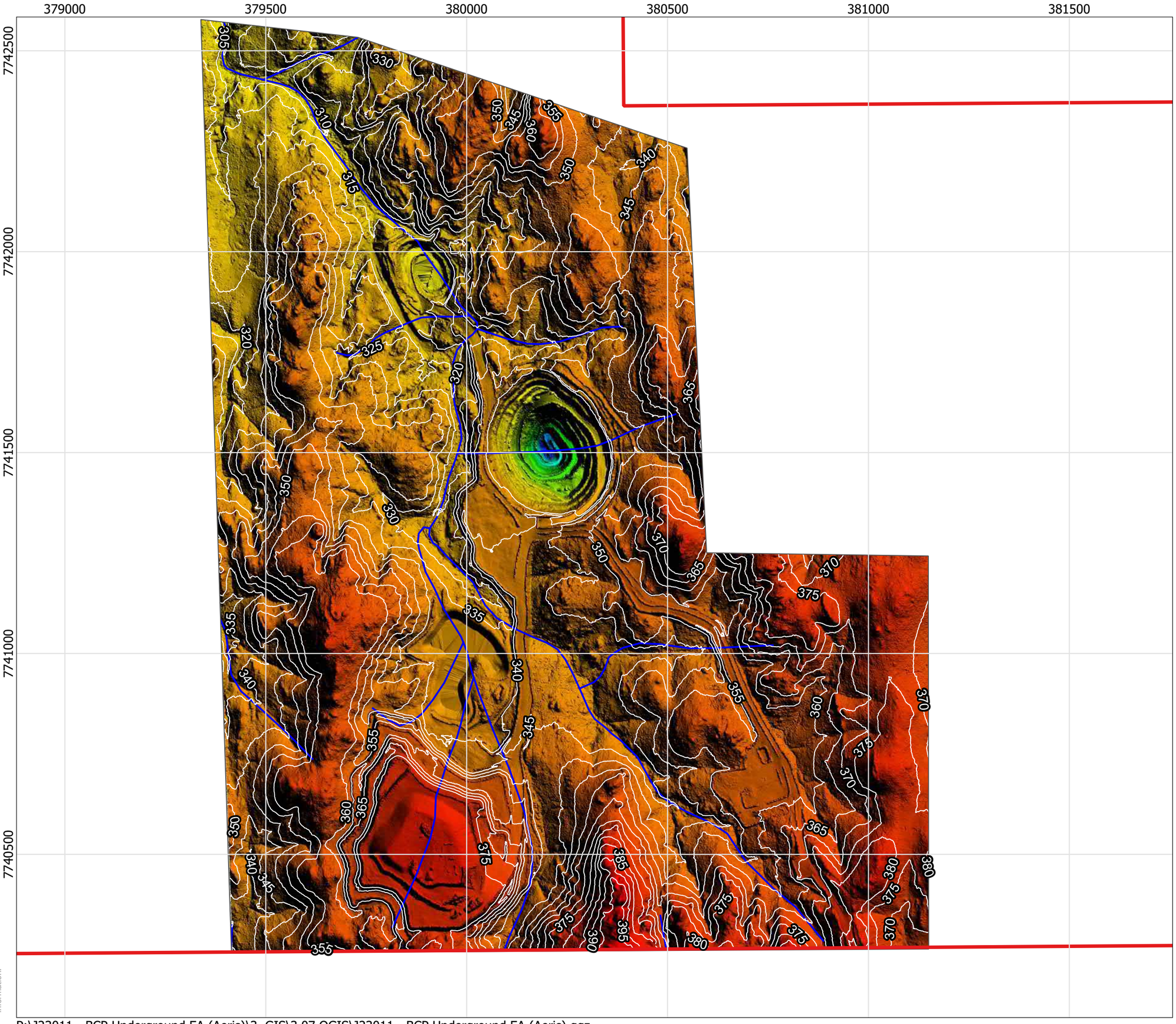

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Figure 5 - 2021 topography

0 100 200 300 400 m

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- 2021 topography (mAHD)
- Watercourse

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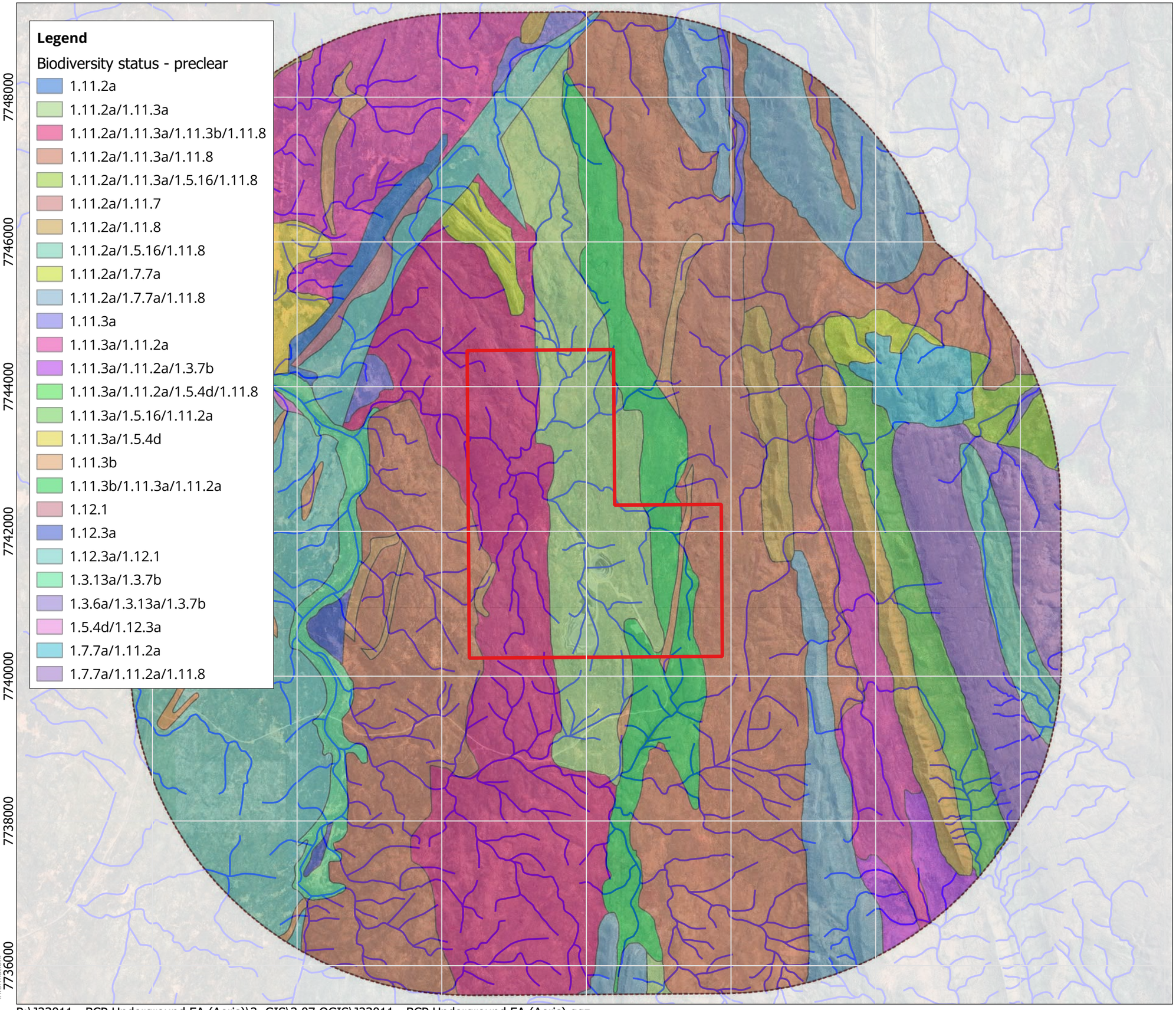

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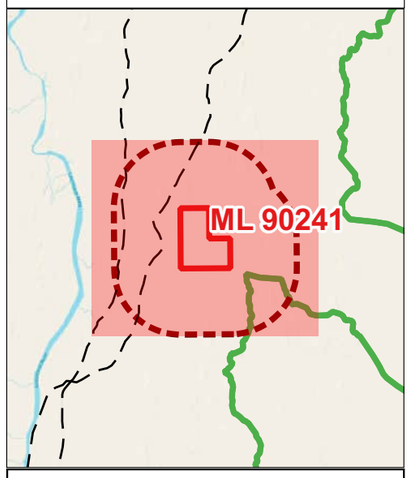
Figure 06 - Mapped pre-clear regional ecosystems

0 1 2 km

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- 5000m Buffer
- Watercourse line



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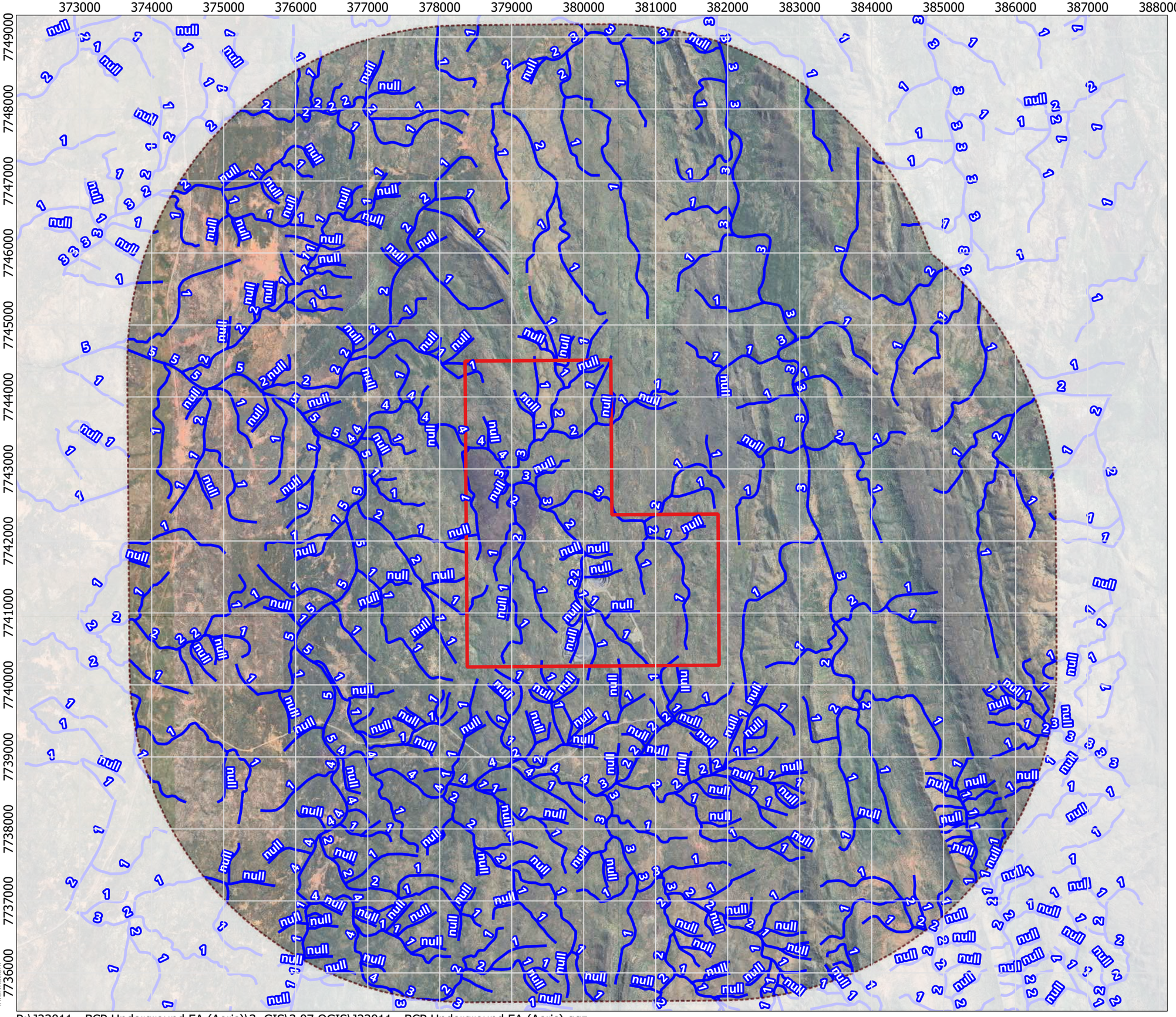

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Groundwater Technical Report for Underground EA Amendment

Figure 07 - Watercourses near the Project site

0 500 1,000 1,500 2,000 2,500 m

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- 5000m Buffer
- Watercourse (+ stream order)

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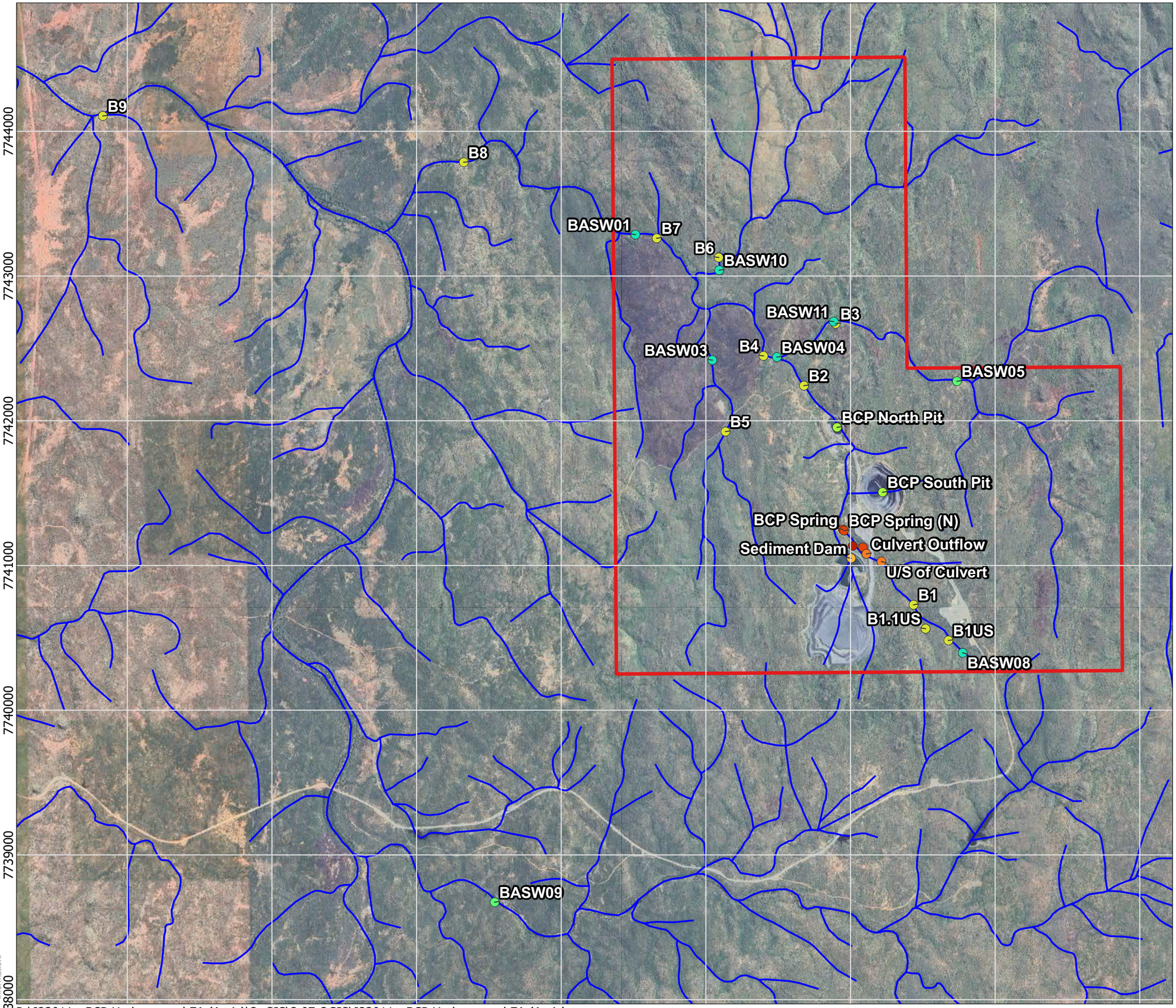

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Groundwater Technical Report for Underground EA Amendment

Figure 8 - Surface water sampling locations (regional)

0 500 1,000 m

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- Watercourse line

Monitoring Locations

- EA receiving water compliance site
- EA receiving water reference site
- Open pit
- REMP Surface Water
- Sediment dam
- Site runoff
- Spring
- Sump

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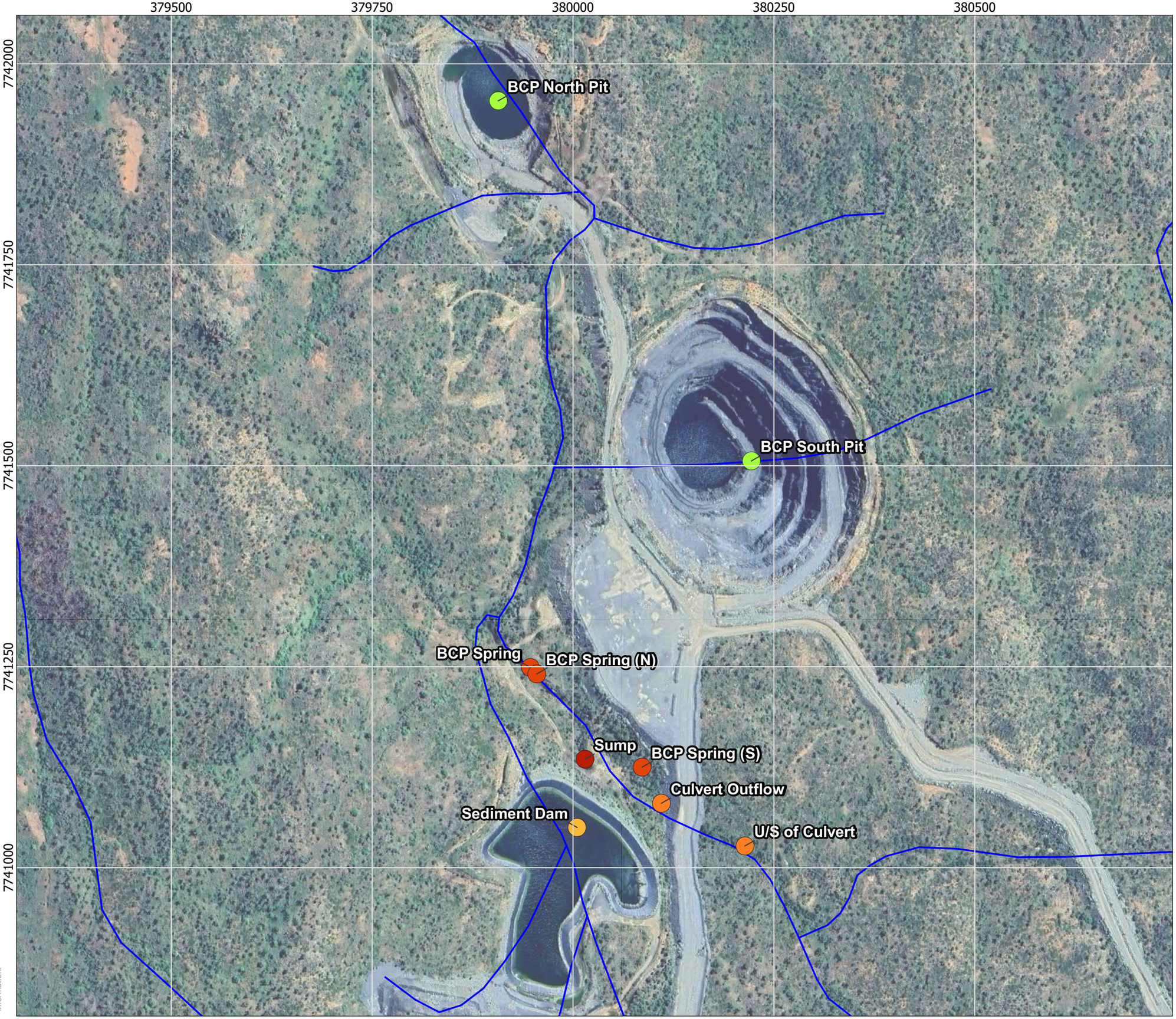

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Figure 9 - Surface water sampling locations (local)

0 100 200 m

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- Watercourse line

Monitoring Locations

- Open pit
- Sediment dam
- Site runoff
- Spring
- Sump

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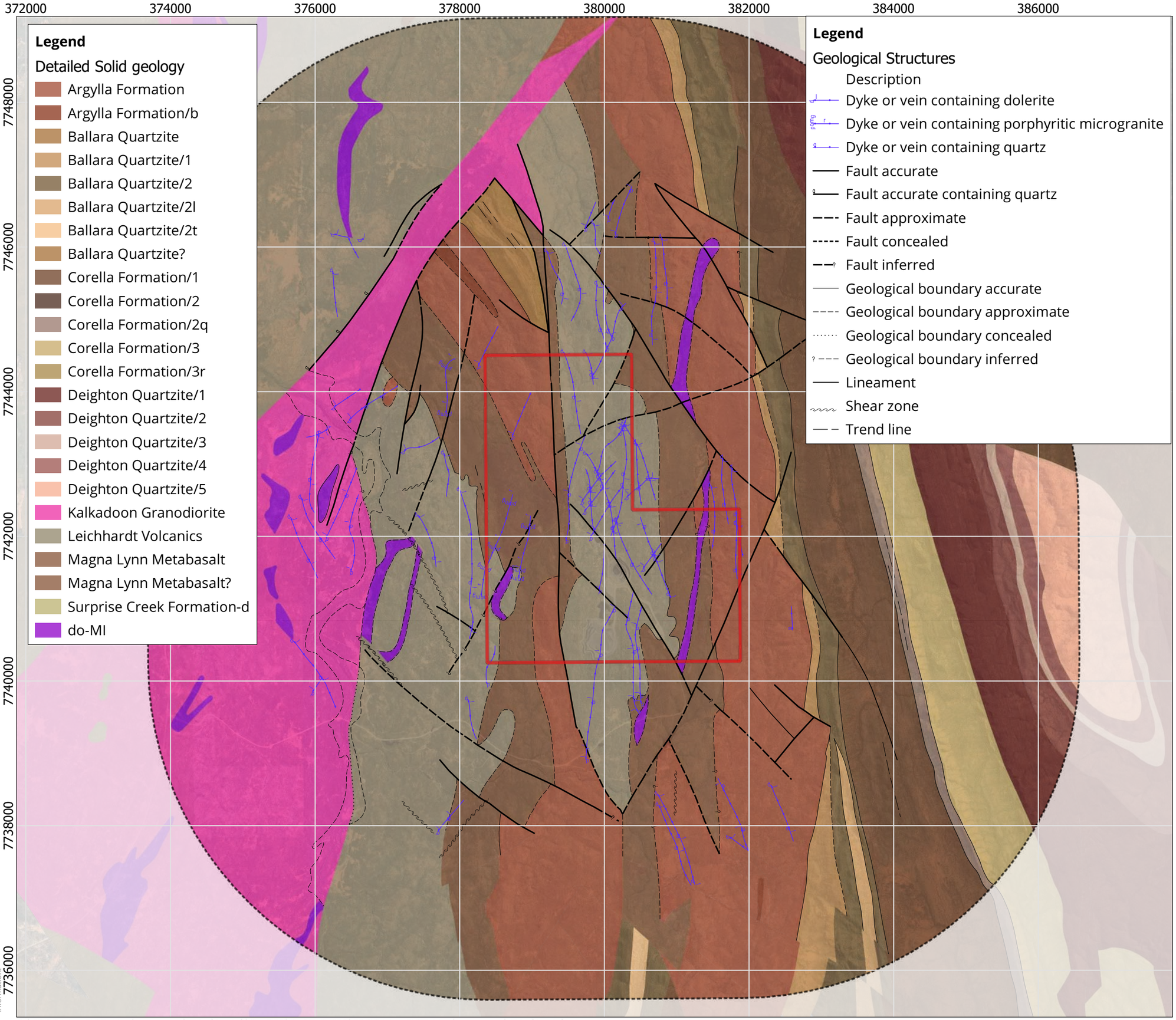

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Figure 10 - Regional geology at BCP

0 0.5 1 1.5 2 km

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- 5000m Buffer

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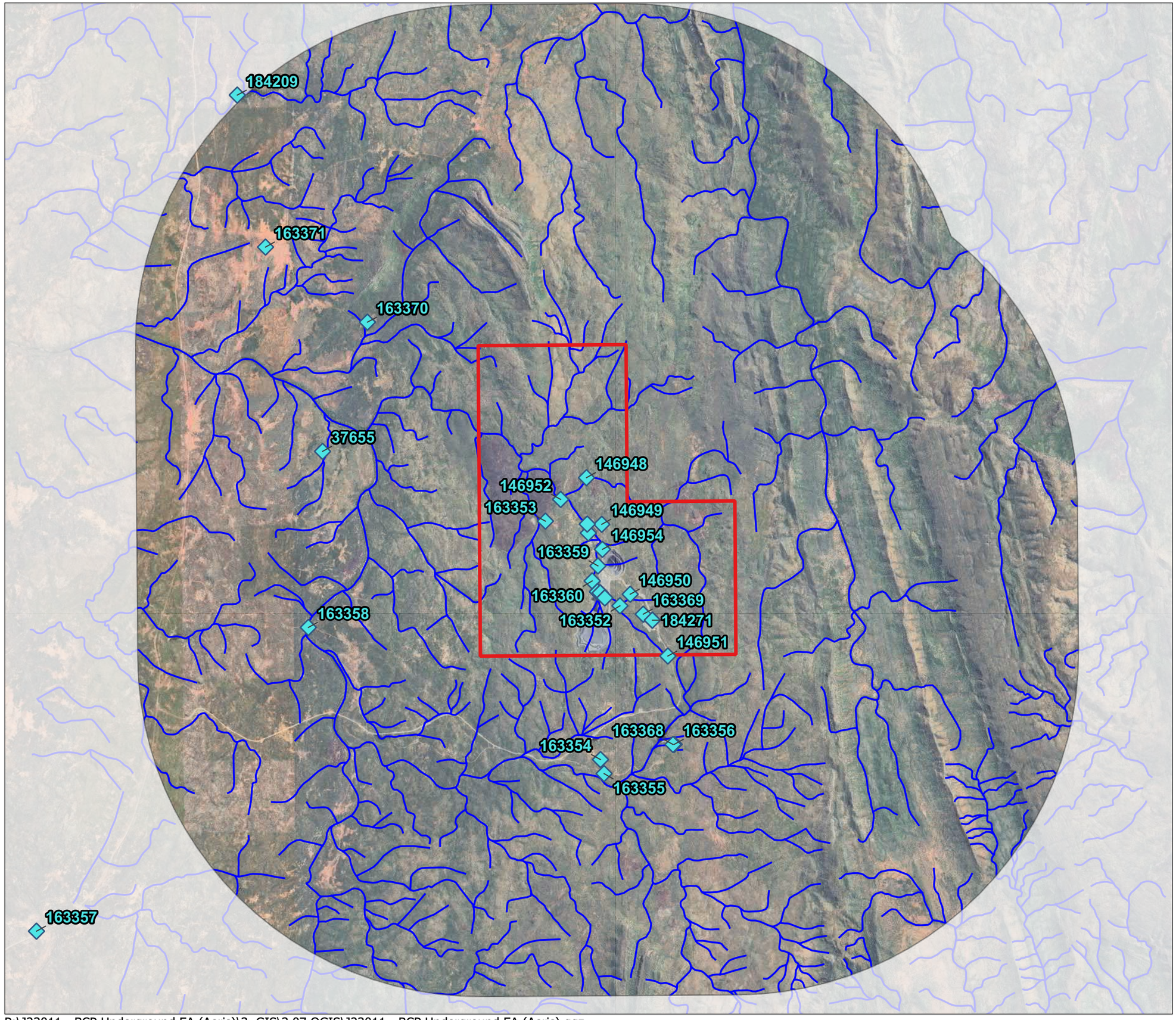

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Figure 11 - Registered bores within 5km radius of BCP

0 0.5 1 1.5 2 km

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- 5000m Buffer
- Watercourse line
- Registered water bores

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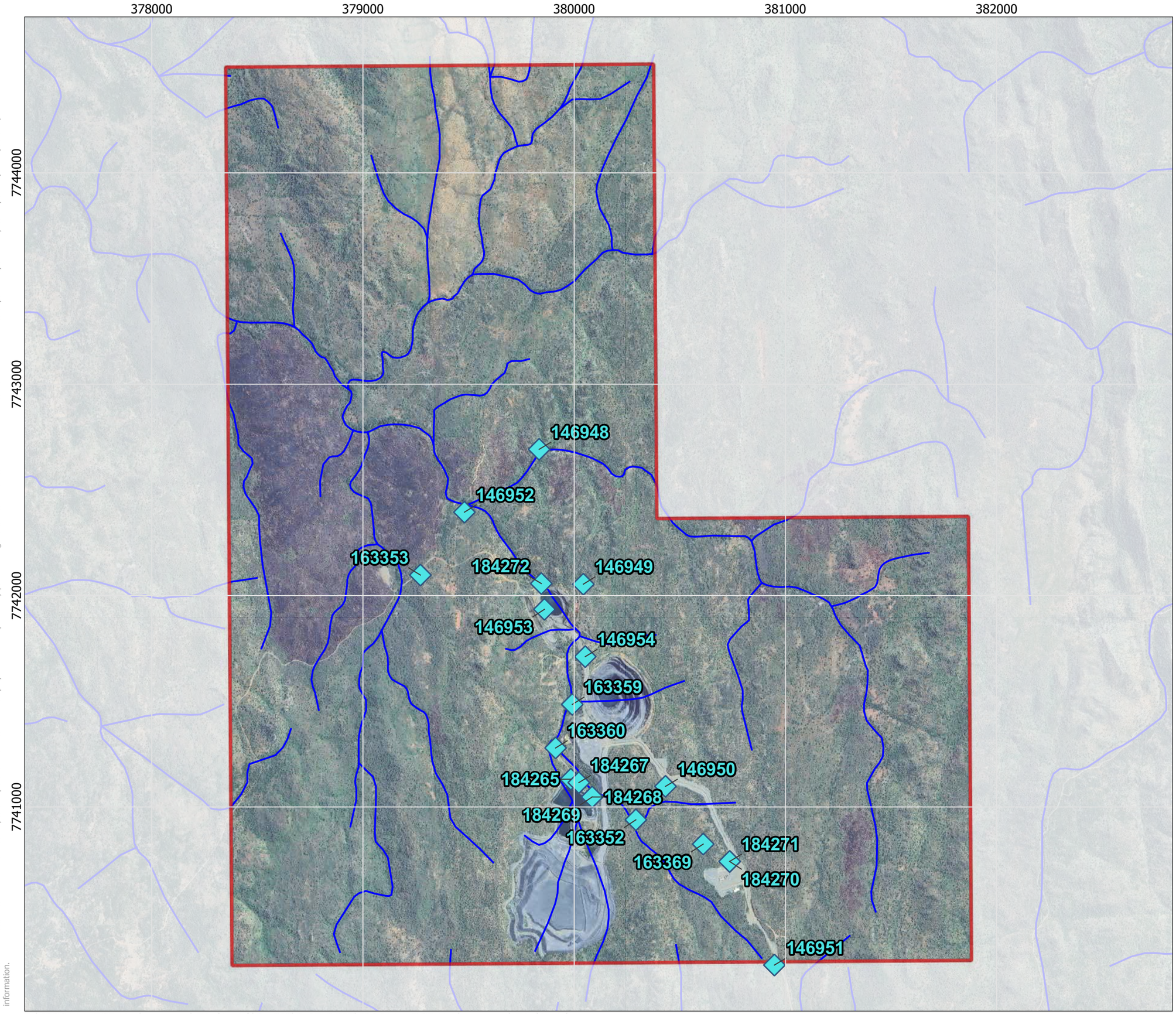

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Figure 12 - Registered bores within ML90241

0 250 500 750 m

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- Watercourse line
- Registered water bores

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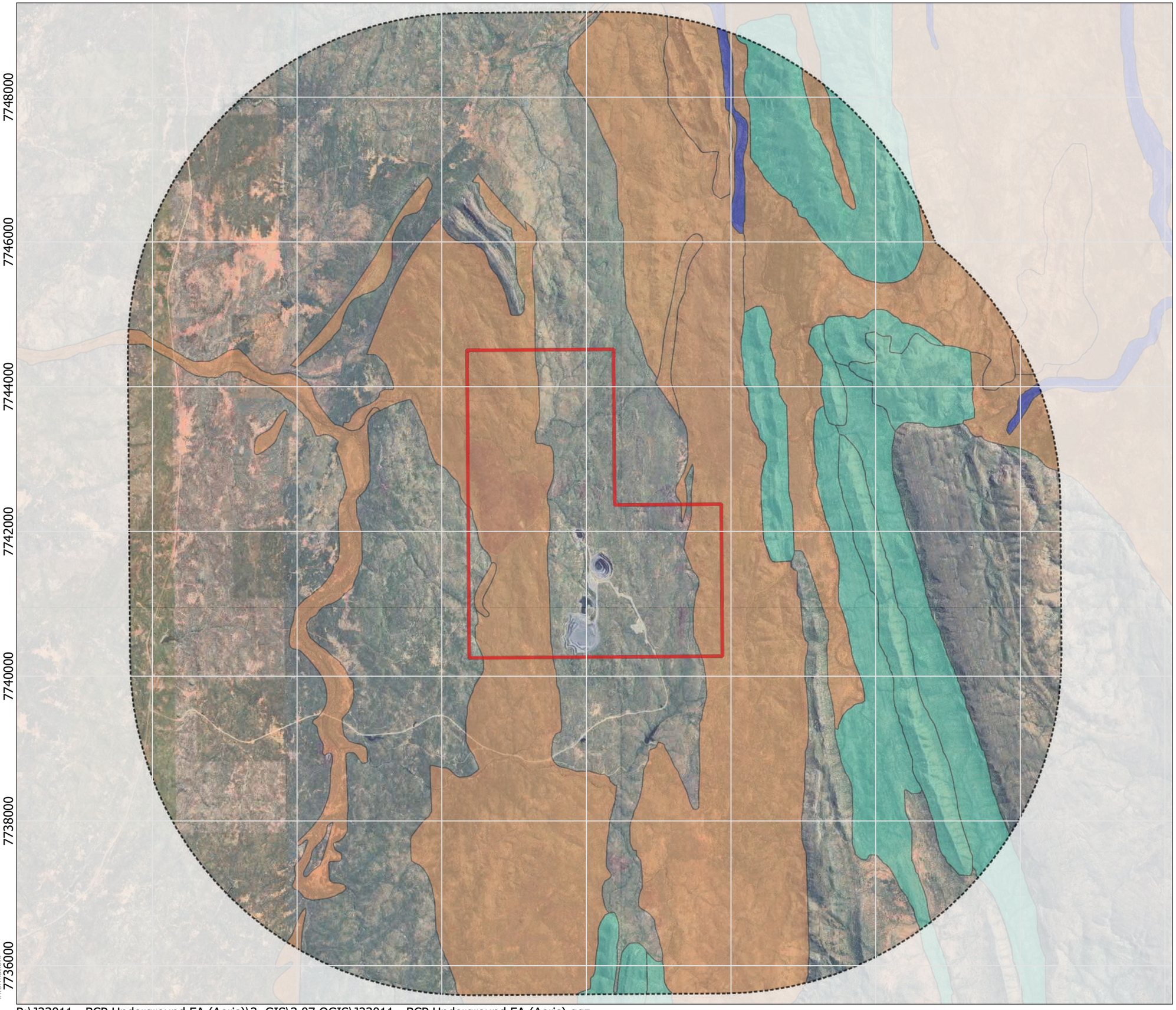

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Figure 13 - BOM Groundwater Dependent Ecosystems

0 1 2 km

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- 5000m Buffer

BOM Terrestrial GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE

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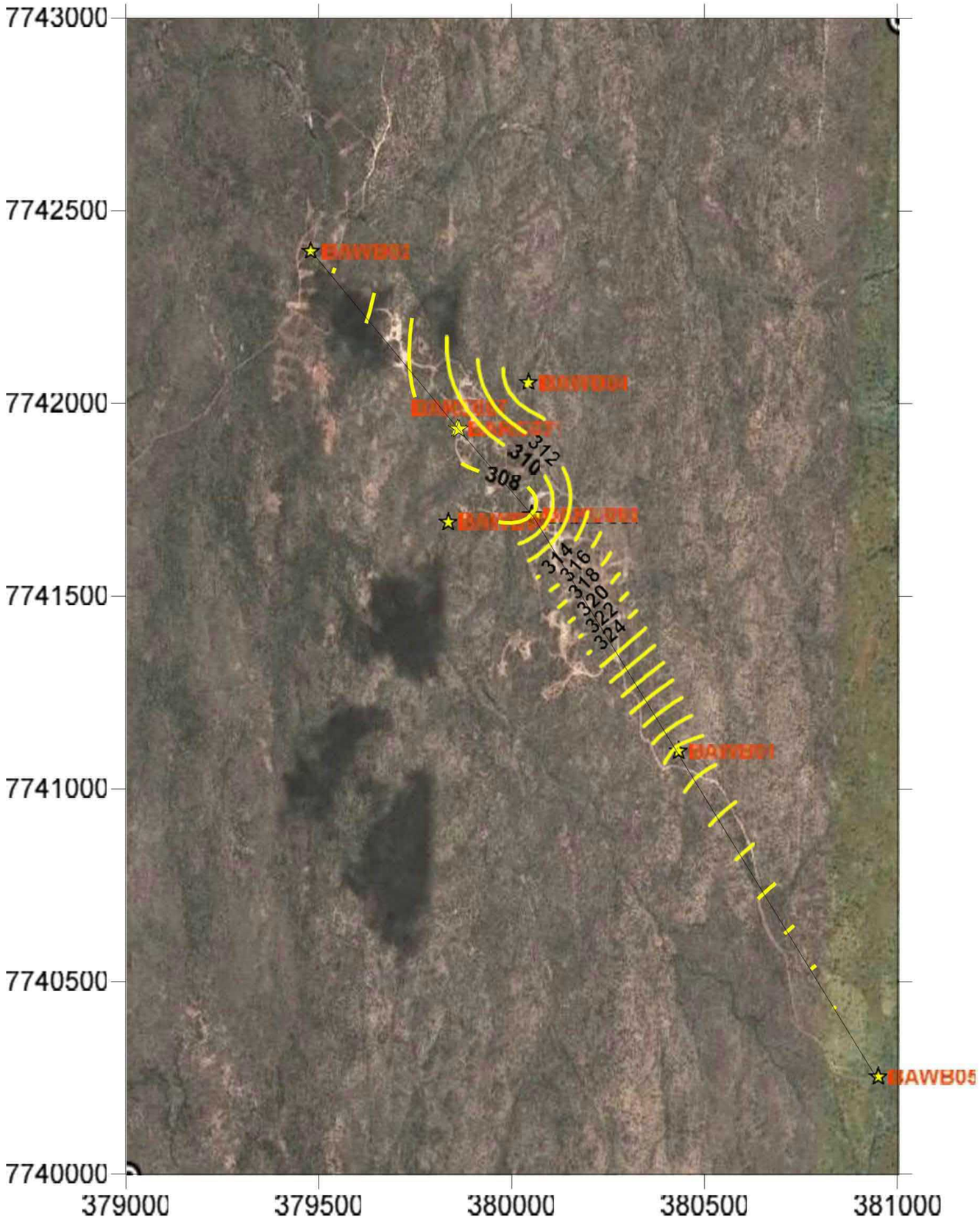

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Figure 14 - Contour map of June 2014 groundwater levels

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

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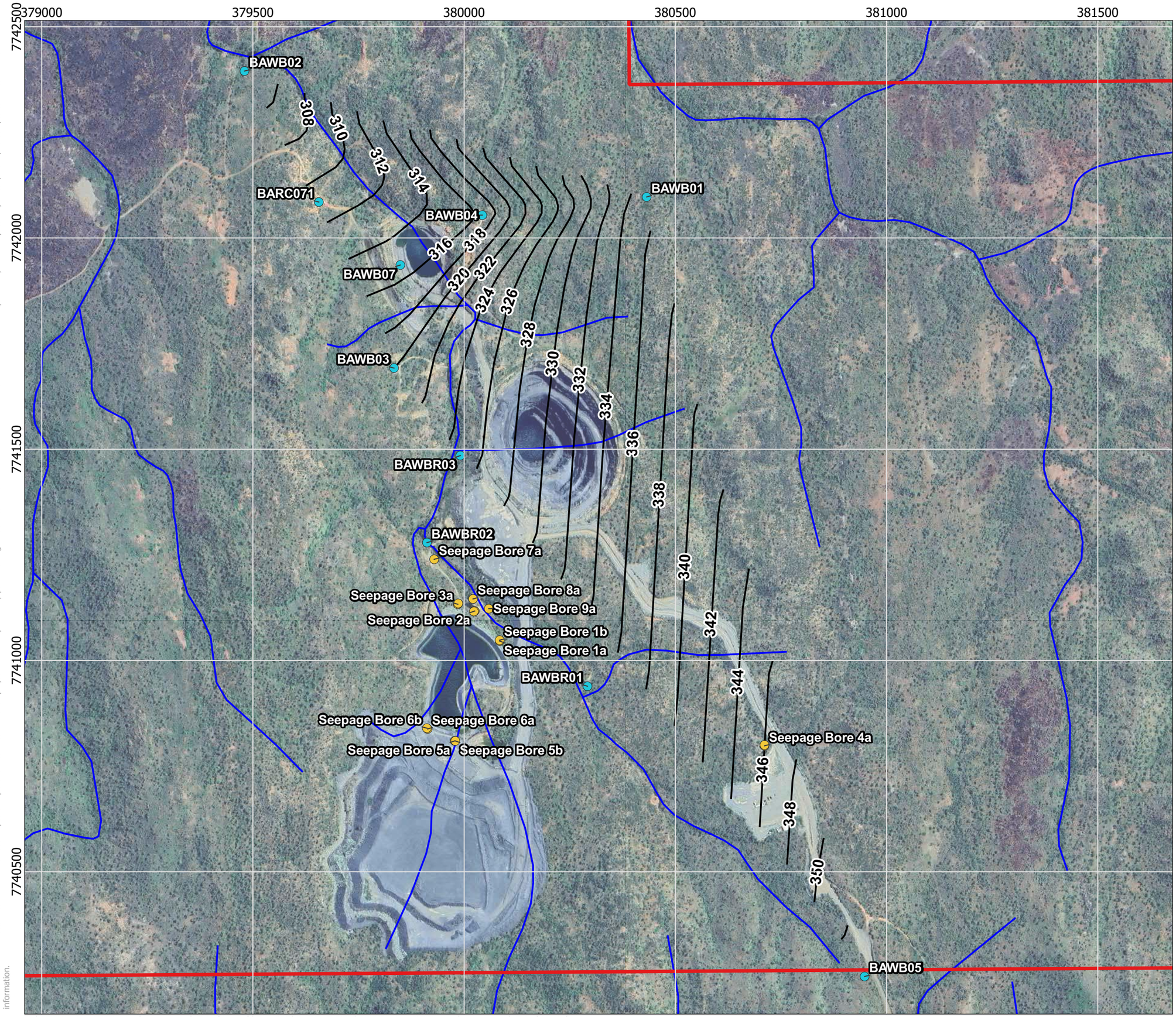

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Figure 15 - Contour map of June 2018 groundwater levels

0 100 200 300 400 m

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- Watercourse line
- Groundwater level (mAHD)

Monitoring Locations

- Groundwater bore
- Seepage monitoring bore

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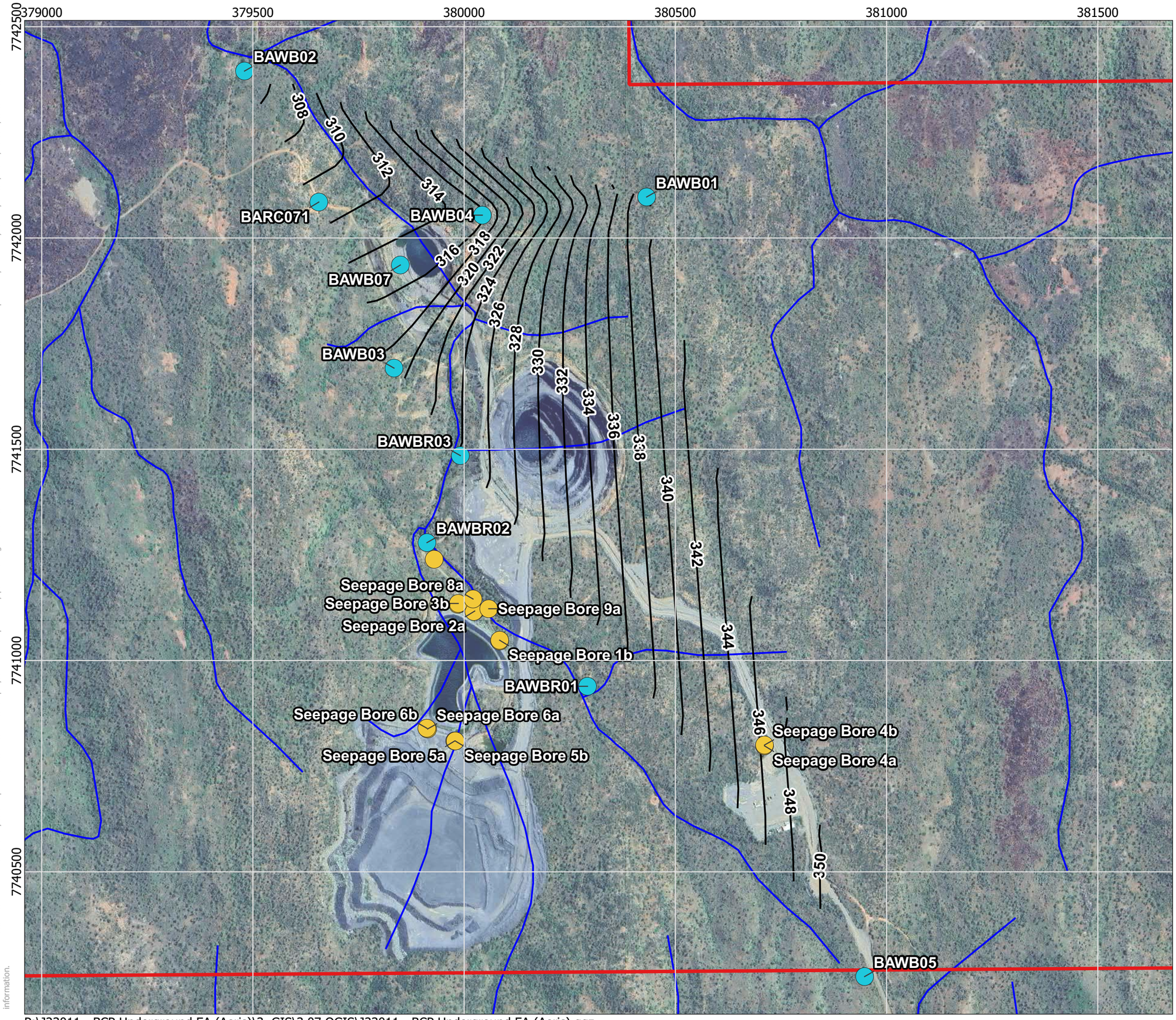

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Groundwater Technical Report for Underground EA Amendment

Figure 16 - Contour map of April 2022 groundwater levels

0 100 200 300 400 m

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- Watercourse line
- Groundwater level (mAHD)

Monitoring Locations

- Groundwater bore
- Seepage monitoring bore

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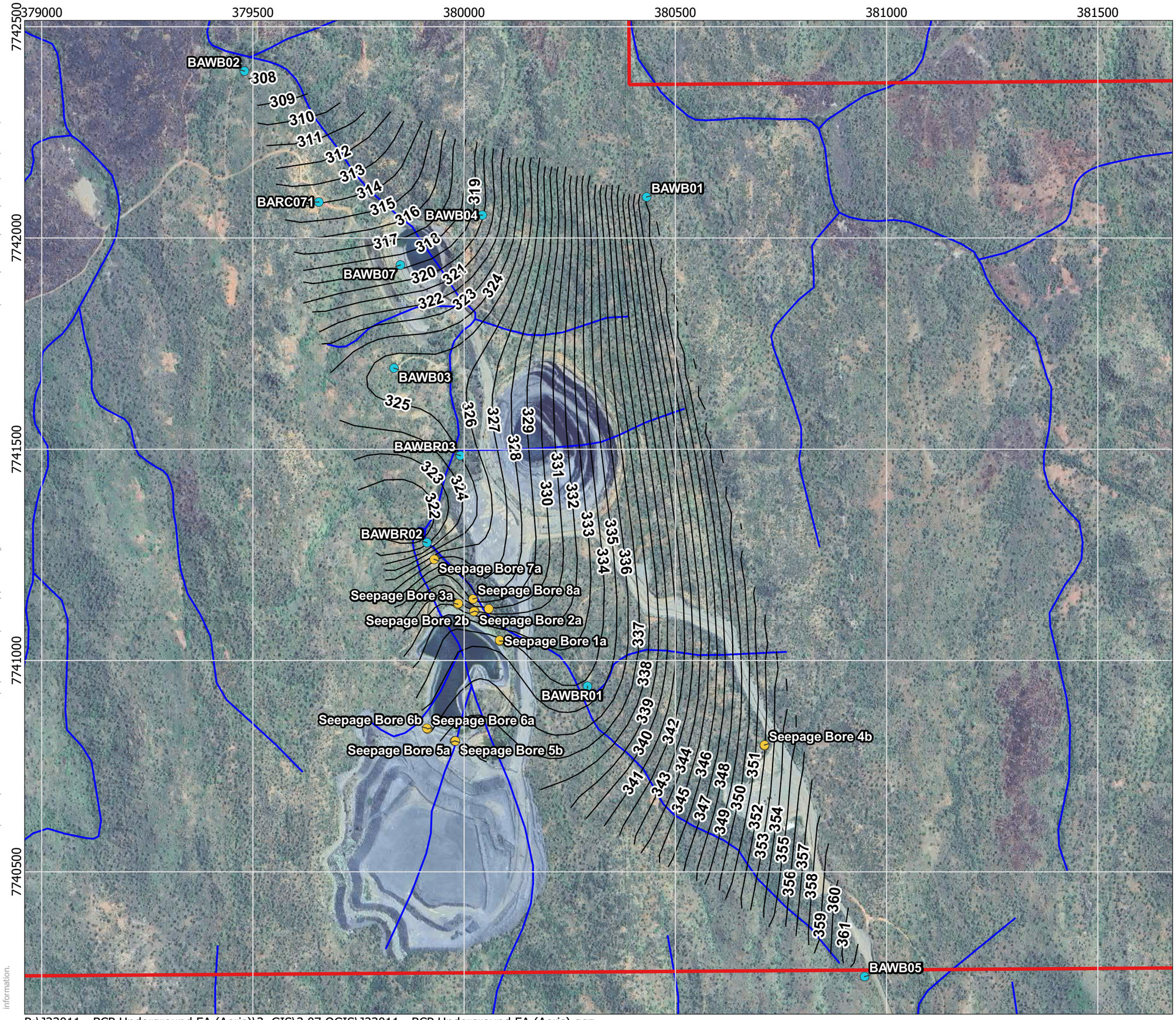

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Groundwater Technical Report for Underground EA Amendment

Figure 17 - Contour map of April 2023 groundwater levels

0 100 200 300 400 m

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

- ML90241
- Watercourse line
- Groundwater level (mAHD)

Monitoring Locations

- Groundwater bore
- Seepage monitoring bore

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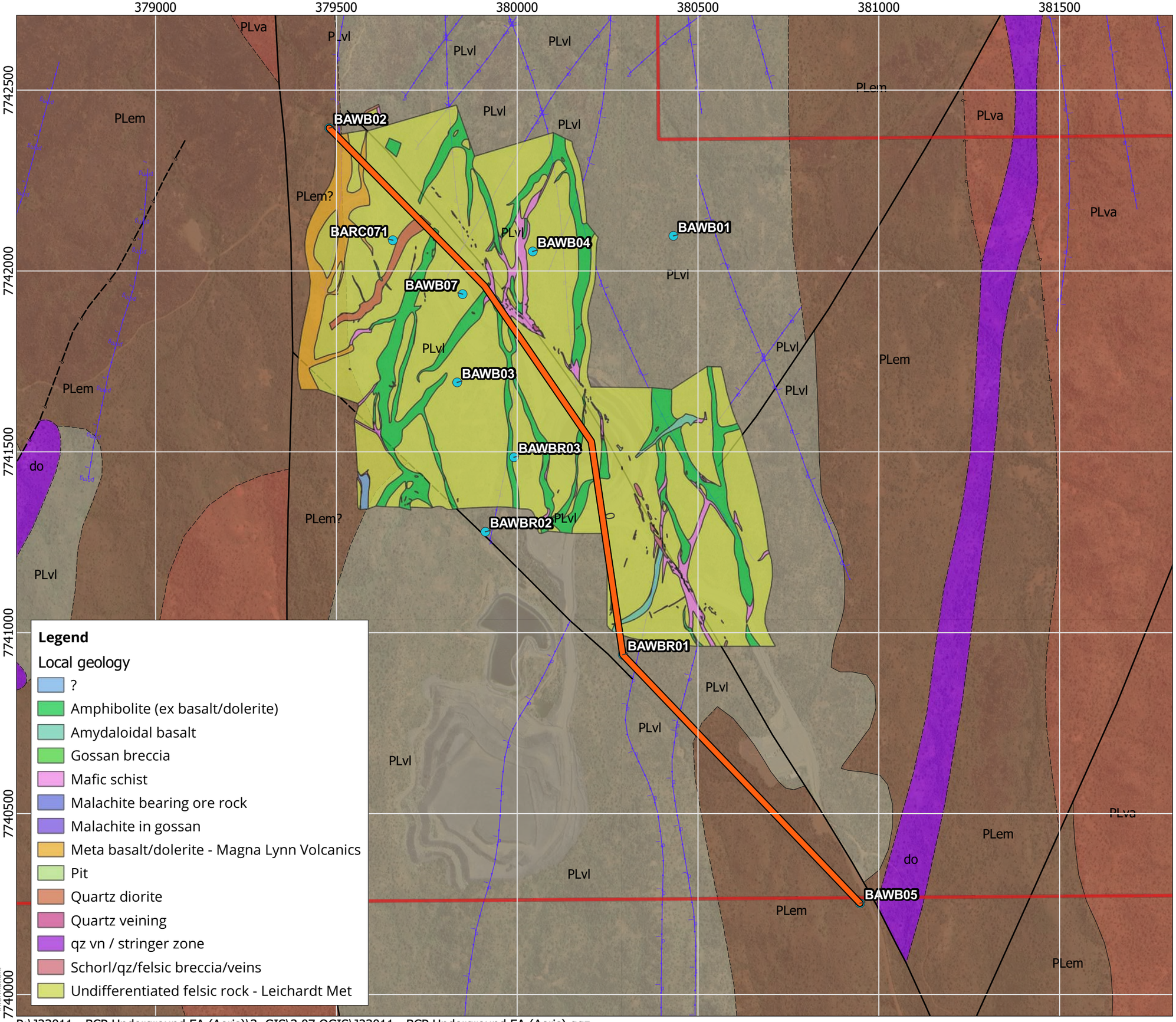

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Figure 18 - Location of hydrogeological cross-section

0 250 500 m

EPSG:28354
Datum:GDA94 / MGA zone 54

Legend

ML90241

Cross section

Monitoring bores

Groundwater bore

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Appendix A EA EPML02840015

Permit

Environmental Protection Act 1994

Environmental authority EPML02840015

This environmental authority is issued by the administering authority under Chapter 5 of the Environmental Protection Act 1994.

Environmental authority number: EPML02840015

Environmental authority takes effect on 3 February 2020

Environmental authority holder(s)

Name(s)	Registered address
ROUND OAK MINERALS PTY LIMITED	Level 32 10 Eagle Street BRISBANE CITY QLD 4000 Australia

Environmentally relevant activity and location details

Environmentally relevant activity/activities	Location(s)
Schedule 3 17: Mining copper ore Schedule 3 18: Mining lead, silver or zinc seperately or in any combination Ancillary 08 - Chemical Storage 3: Storing more than 500 cubic metres of chemicals of class C1 or C2 combustible liquids under AS 1940 or dangerous goods class 3 under subsection (1)(c) Ancillary 15 - Fuel burning Using fuel burning equipment that is capable of burning at least 500kg of fuel in an hour	ML90241

Schedule 3 16: Mining gold ore Schedule 3 19: Mining metal ore, other than a metal ore mentioned in itms 11, 12, 14, 15, 16,17 or 18 Schedule 3 14: Mining iron ore Ancillary 63 - Sewage Treatment 1: Operating sewage treatment works, other than no-release works, with a total daily peak design capacity of (a-i) 21 to 100EP if treated effluent is discharged from the works to an infiltration trench or through an irrigation scheme Ancillary 33 - Crushing, milling, grinding or screening Crushing, grinding, milling or screening more than 5000t of material in a year	

Additional information for applicants

Environmentally relevant activities

The description of any environmentally relevant activity (ERA) for which an environmental authority (EA) is issued is a restatement of the ERA as defined by legislation at the time the EA is issued. Where there is any inconsistency between that description of an ERA and the conditions stated by an EA as to the scale, intensity or manner of carrying out an ERA, the conditions prevail to the extent of the inconsistency.

An EA authorises the carrying out of an ERA and does not authorise any environmental harm unless a condition stated by the EA specifically authorises environmental harm.

A person carrying out an ERA must also be a registered suitable operator under the *Environmental Protection Act 1994* (EP Act).

Contaminated land

It is a requirement of the EP Act that an owner or occupier of contaminated land give written notice to the administering authority if they become aware of the following:

- the happening of an event involving a hazardous contaminant on the contaminated land (notice must be given within 24 hours); or
- a change in the condition of the contaminated land (notice must be given within 24 hours); or
- a notifiable activity (as defined in Schedule 3) having been carried out, or is being carried out, on the contaminated land (notice must be given within 20 business days);
- that is causing, or is reasonably likely to cause, serious or material environmental harm.

For further information, including the form for giving written notice, refer to the Queensland Government website www.qld.gov.au, using the search term 'duty to notify'.

Take effect

Please note that, in accordance with section 200 of the EP Act, an EA has effect:

a) if the authority is for a prescribed ERA and it states that it takes effect on the day nominated by the holder of the authority in a written notice given to the administering authority-on the nominated day; or

b) if the authority states a day or an event for it to take effect-on the stated day or when the stated event happens; or

c) otherwise-on the day the authority is issued.

However, if the EA is authorising an activity that requires an additional authorisation (a relevant tenure for a resource activity, a development permit under the *Sustainable Planning Act 2009* or an SDA Approval under the *State Development and Public Works Organisation Act 1971*), this EA will not take effect until the additional authorisation has taken effect.

If this EA takes effect when the additional authorisation takes effect, you must provide the administering authority written notice within 5 business days of receiving notification of the related additional authorisation taking effect.

If you have incorrectly claimed that an additional authorisation is not required, carrying out the ERA without the additional authorisation is not legal and could result in your prosecution for providing false or misleading information or operating without a valid environmental authority.

Kate Rutherford
Department of Environment and Science
Delegate of the administering authority
Environmental Protection Act 1994

Date issued: 03 February 2020

Enquiries:
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Obligations under the *Environmental Protection Act 1994*

In addition to the requirements found in the conditions of this environmental authority, the holder must also meet their obligations under the EP Act, and the regulations made under the EP Act. For example, the holder must comply with the following provisions of the Act:

- general environmental duty (section 319)
- duty to notify environmental harm (section 320-320G)
- offence of causing serious or material environmental harm (sections 437-439)
- offence of causing environmental nuisance (section 440)
- offence of depositing prescribed water contaminants in waters and related matters (section 440ZG)
- offence to place contaminant where environmental harm or nuisance may be caused (section 443)

Schedule A – General

A1 This environmental authority authorises environmental harm referred to in the conditions. Where there is no condition or this environmental authority is silent on a matter, the lack of a condition or silence does not authorise environmental harm.

A2 Contaminants with the potential to cause environmental harm must not be released directly or indirectly to the receiving environment, except as permitted under the conditions of this environmental authority.

A3 The environmental authority holder must ensure that the activity is carried out in accordance with *Table A1* and *Schedule J – Map 1 Location of authorised disturbance*.

Table A1 - Authorised disturbance ('Table A1')

Name of disturbance area	Maximum area of disturbance (ha)	Mining Lease	Purpose
Run-of-mine (ROM) pad	3.5	ML90241	Temporary storage, crushing and handling of ore.
Road train loading area	1	ML90241	Loading of ore for transport off-site.
North Pit	1.5	ML90241	Mining of ore and site water management. Note: The North pit is a regulated dam with minimum hydraulic performance criteria detailed in *Table H1* of this environmental authority.
South pit	6	ML90241	Mining of ore and site water management. Note: The North pit is a regulated dam with minimum hydraulic performance criteria detailed in *Table H1* of this environmental authority.
Waste rock dump (WRD)	23	ML90241	Storage and disposal of waste rock.
ROM pad dam	0.6	ML90241	Water management for stormwater runoff from the ROM pad area.
WRD dam	4	ML90241	Water management for stormwater runoff from the WRD area.
Diversion drain	0.5	ML90241	Water management to prevent stormwater runoff entering mine workings.
Topsoil stockpiles	2.5	ML90241	Storage of topsoil for site rehabilitation works.
Access Road, Haul Roads and tracks	20.5	ML90241	Site access.
Light Infrastructure Area: including Administration buildings, Fuel storage, Power facility and Workshop area.	2.5	ML90241	Site administration, Fuel storage and power generation, Maintenance and storage.
Sewage treatment facility	0.5	ML90241	Treatment of sewage.
Explosives magazine	0.5	ML90241	Storage of explosives.

A4 The holder of this environmental authority must:

a) Install all measures, plant and equipment necessary to ensure compliance with the conditions of this environmental authority;

b) Maintain such measures, plant and equipment in a proper and efficient condition;

c) Operate such measures, plant and equipment in a proper and efficient manner; and

d) Ensure all instruments and devices used for the measurement or monitoring of any parameter under any condition of this environmental authority are properly calibrated.

Monitoring

A5 Except where specified in another condition of this environmental authority, all monitoring data, records and reports required by this environmental authority or related to environmental management of the activities must be:

a) Carried out by an appropriately qualified person;

b) Kept for a period of not less than five years; and

c) Provided to the administering authority in the specified format within 10 business days of a request.

A6 The following information must be recorded in relation to all monitoring required under a condition of this environmental authority:

a) The date and time when the sample was taken;

b) The location where the sample was taken; and

c) Any other pertinent details of relevance to interpreting the sampling results (*i.e.* stream flow, wind conditions or any unusual observations such as odour or colouration).

Financial assurance

A7 Financial assurance must be lodged with the administering authority in the amount, the form and within the time required by the administering authority.

Risk management

A8 The holder of this environmental authority must develop and implement a risk management system for mining activities which mirrors the content requirement of the Standard for Risk Management (ISO31000:2009), or the latest edition of an Australian standard for risk management, to the extent relevant to environmental management, by 5 October 2016.

Notification of emergencies, incidents and exceptions

A9 The holder of this environmental authority must notify the administering authority by written notification within 24 hours, after becoming aware of any emergency or incident which results in the release of contaminants not in accordance, or reasonably expected to be not in accordance with, the conditions of this environmental authority.

A10 Within 10 business days following the initial notification of an emergency or incident, or receipt of monitoring results, whichever is the latter, further written advice must be provided to the administering authority, including the following:

a) Results and interpretation of any samples taken and analysed;

b) Outcomes of actions taken at the time to prevent or minimise unlawful environmental harm; and

c) Proposed actions to prevent a recurrence of the emergency or incident.

Complaints

A11 The holder of this environmental authority must record all environmental complaints received about the mining activities including:

a) Name, address and contact number for of the complainant;

b) Time and date of complaint;

c) Reasons for the complaint;

d) Investigations undertaken;

e) Conclusions formed;

f) Actions taken to resolve the complaint;

g) Any abatement measures implemented; and

h) Person responsible for resolving the complaint.

A12 The holder of this environmental authority must, when requested by the administering authority, undertake relevant specified monitoring within a reasonable timeframe nominated or agreed to by the administering authority to investigate any complaint of environmental harm. The results of the investigation (including an analysis and interpretation of the monitoring results) and abatement measures, where implemented, must be provided to the administering authority within 10 business days of completion of the investigation, or no later than 10 business days after the end of the timeframe nominated by the administering authority to undertake the investigation.

Third-party reporting

A13 The holder of this environmental authority must:

a) Within one (1) year of the commencement of this environmental authority, obtain from an appropriately qualified person a report on compliance with the conditions of this environmental authority;

b) Obtain further such reports at regular intervals, not exceeding three (3) yearly intervals, from the completion of the report referred to above; and

c) Provide each report to the administering authority within 90 days of its completion.

A14 Where a condition of this environmental authority requires compliance with a standard, policy or guideline published externally to this environmental authority and the standard is amended or changed subsequent to the issue of this environmental authority, the holder of this environmental authority must:

a) Comply with the amended or changed standard, policy or guideline within two years of the amendment or change being made, unless a different period is specified in the amended standard or relevant legislation, or where the amendment or change relates specifically to regulated structures referred to in Schedule I, the time specified in that condition; and

b) Until compliance with the amended or changed standard, policy or guideline is achieved, continue to remain in compliance with the corresponding provision that was current immediately prior to the relevant amendment or change.

Exploration

A15 All exploration activities carried out on the mining lease must comply with each of the standard environmental conditions contained in the latest version of the *Eligibility criteria and standard conditions for exploration and mineral development projects*.

END OF CONDITIONS FOR SCHEDULE A

Schedule B – Air

B1 The activities must not cause an exceedance of the air quality objectives specified in *Table B1* beyond the boundaries of any mining lease/s listed on this environmental authority.

Table B1 - Air quality objectives ('Table B1')

Contaminant	Measurement period	Air Quality Objective
Dust Deposition		
Arsenic and its compounds as arsenic[3]	Annual average over the calendar year	Must not exceed background concentration[4]
Cadmium and its compounds as cadmium[3]		
Copper and its compounds as copper[3]		
Lead and its compounds as lead[3]		250 µg/m^2/day
Dust deposition (total insoluble matter)[1]		120 mg/m^2/day

[1] The dust deposition limit is calculated over a nominal month as per AS/NZS3580.10.1 of 2003 (or more recent editions) unless an appropriately qualified person recommends and justifies an alternative frequency.

[3] Metal analysis is to be carried out in accordance with a methodology, sufficient to produce representative results capable of comparison against the respective trigger values.

[4] The background concentration must be determined in accordance with condition B2 of this environmental authority and include sufficient background dust deposition monitoring locations that are not potentially impacted by the mining activities.

B2 Prior to commencing the mining activity, the environmental authority holder must ensure that an air quality monitoring program is developed and implemented by an appropriately qualified person that is capable of determining compliance with condition B1 of this environmental authority.

END OF CONDITIONS FOR SCHEDULE B

Schedule C - Waste management

C1 All waste generated as part of the mining activities must be disposed of in a lawful manner at an off-site facility, with the exception of:

a) Treated sewage effluent, which may only be released via sub-surface infiltration trench and must be undertaken in accordance with condition C2 of this environmental authority; and

b) Waste rock, which must be characterised, handled and disposed of in accordance with condition C3 of this environmental authority.

C2 The only contaminant permitted to be released to land is treated sewage effluent released in accordance with condition C1 (a) and the release limits specified in *Table C1.*

Table C1 - Contaminant release limits to land ('Table C1')

Contaminant	Unit	Release Limit	Limit Type	Frequency
5 day Biochemical oxygen demand (BOD)1	mg/L	20	Maximum	Monthly
Total suspended solids	mg/L	30	Maximum	Monthly
Nitrogen	mg/L	30	Maximum	Monthly
Phosphorus	mg/L	15	Maximum	Monthly
E-coli	Organisms/100ml	1000	Maximum	Monthly
pH	pH units	6.0-9.0	Range	Monthly

C3 All potentially acid forming waste rock must be:

(a) Identified and disposed of in a manner that minimises the potential generation and/or release of contaminants to the receiving environment;

(b) Where the characteristics of waste rock in regards to acid producing potential is uncertain, this material must be treated as potentially acid forming until demonstrated otherwise; and

(c) Details pertaining to meeting the requirements of this condition must be recorded and retained until this environmental authority is surrendered.

END OF CONDITIONS FOR SCHEDULE C

Schedule D – Noise

Noise limits

D1 The holder of this environmental authority must ensure that noise generated by the mining activities does not cause the criteria in *Table D1* to be exceeded at a sensitive place or commercial place.

Table D1 – Noise limits ('Table D1')

Sensitive place						
Noise level dB(A) measured as:	**Monday to Saturday**			**Sundays and public holidays**		
	7am to 6pm	**6pm to 10pm**	**10pm to 7am**	**9am to 6pm**	**6pm to 10pm**	**10pm to 9am**
$L_{Aeq, adj, 15 mins}$	CV = 50 AV = 5	CV = 45 AV = 5	CV = 40 AV = 0	CV = 45 AV = 5	CV = 40 AV = 5	CV = 35 AV = 0
$L_{A1, adj, 15 mins}$	CV = 55 AV = 10	CV = 50 AV = 10	CV = 45 AV = 5	CV = 50 AV = 10	CV = 45 AV = 10	CV = 40 AV = 5

Notes:

a) CV: Critical Value, AV: Adjustment Value
b) To calculate noise limits;
If bg ≤ (CV-AV): Noise limit = bg + AV
If (CV-AV) < bg ≤ CV: Noise limit = CV
If bg > CV: Noise limit = bg+0
c) In the event that measured bg (LA90,adj, 15 mins) is less than 30 dB(A), then 30 dB(A) can be substituted for the measured background level.
d) Bg = background noise level (LA90, adj, 15 mins) measured over 3 – 5 days at the nearest sensitive receptor.
e) If the project is unable to meet the noise limits as calculated above alternative limits may be calculated using the process outlined in the 'Planning for Noise Control' guideline.

Airblast overpressure nuisance

D2 The holder of this environmental authority must ensure that blasting does not cause the limits for peak particle velocity and air blast overpressure in *Table D2* to be exceeded at a sensitive place or commercial place.

Table D2 – Blasting noise limits ('Table D2')

Blasting noise limits	Sensitive or commercial blasting noise limits place limits	
	7am to 6pm	**6pm to 7am**
Airblast overpressure	115 dB (Linear) Peak for 9 out of 10 consecutive blasts initiated and not greater than 120 dB (Linear) Peak at any time	No blasting
Ground vibration peak particle velocity	5mm/second peak particle velocity for 9 out of 10 consecutive blasts and not greater than 10 mm/second peak particle velocity at any time	No blasting

Monitoring and reporting

D3 Noise monitoring and recording must include the following descriptor characteristics and matters:

a) $L_{AN,T}$ (where N equals the statistical levels of 1, 10 and 90 and T = 15 mins)

b) background noise LA90

c) the level and frequency of occurrence of impulsive or tonal noise and any adjustment and penalties to statistical levels

d) atmospheric conditions including temperature, relative humidity and wind speed and directions

e) effects due to any extraneous factors such as traffic noise

f) location, date and time of monitoring

g) if the complaint concerns low frequency noise, Max LpLIN,T and one third octave band measurements in dB(LIN) for centre frequencies in the 10 – 200 Hz range.

END OF CONDITIONS FOR SCHEDULE D

Schedule E – Water

Contaminant release

E1 Contaminants must not be released to receiving waters unless there are natural flows in the receiving water of at least twenty times the volume of the release.

E2 Contaminants may only be released to receiving waters from a location specified in *Table E1* and must not exceed any release limit specified in *Table E2*.

Table E1 – Authorised contaminant release points ('Table E1')

Release point	Location		Release source	Monitoring Point	Receiving waters description
	Easting (GDA94 – Zone 54)	Northing (GDA94 – Zone 54)			
RP01	379862	7742050	North Pit (Mine water dam)	Pit	Drainage of unnamed tributary
RP02	380153	7741260	South Pit	Pit	Drainage of unnamed tributary
RP03	380007	7741120	WRD Dam	Dam Spillway	Drainage of unnamed tributary
RP04	380309	7741040	ROM Dam	Dam Spillway	Drainage of unnamed tributary

E3 Contaminated water released from a release point specified in *Table E1* must be monitored at the release point for all contaminants and at the frequency specified in *Table E2*.

Table E2 – Contaminant release limits ('Table E2)

Contaminant	Release limit[1, 2]	Monitoring frequency
pH (pH units)	6.0 or 20th percentile[3] of reference site[4] value, whichever is lower	- One sample must be taken within 2 hours of any release event commencing; and - For release events with duration of greater than twenty-four hours, samples must be taken daily for one week and once a week thereafter until the release event ceases.
	7.5 or 80th percentile[3] of reference site[4] value, whichever is higher	
EC (µs/cm)	1,500 or 20 times the 80th percentile[3] of reference site value[4], whichever is higher	
Turbidity (NTU)	20 x 80th percentile of reference site value[3]	
Sulfate	1,000 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Fluoride	2 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Arsenic	0.14 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Barium	20 x 80th percentile[3] of reference site[4] concentration	
Bismuth	20 x 80th percentile[3] of reference site[4] concentration	
Chromium	0.02 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Cobalt	0.056 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Copper	0.028 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Molybdenum	0.15 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	

Nickel	0.22 or 20 x 80th or percentile[3] of reference site[4] concentration, whichever is higher	
Selenium	0.22 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Uranium	0.4 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	

[1] All metals and metalloids must be measured as both 'total' (from analysis of an unfiltered sample) and 'dissolved' (from analysis of a field filtered sample).

[2] Measured and reported in mg/L unless specified otherwise.

[3] The relevant reference site is specified in *Table E3*.

[4] Site-specific trigger levels and water quality objectives for water quality (20th, 80th and 95th percentile of reference site concentration) must be calculated in accordance with QWQG (2009) and ANZECC (2000) methodology if sufficient monitoring data is available. The environmental authority holder must maintain a database documenting all relevant water quality monitoring data and calculation of percentiles adopted as water quality trigger levels and water quality objectives.

E4 The environmental authority holder must notify the administering authority within twenty-four hours of any contaminant release commencing or ceasing.

Surface waters

E5 The quality of receiving waters must be monitored at the locations specified in *Table E3,* for the contaminants and at the frequency specified in *Table E4.*

Table E3 - Receiving waters reference and compliance monitoring sites ('Table E3')

Monitoring sites	Monitoring site description and purpose	Location	
		Easting (GDA94 – Zone 54)	Northing (GDA94 – Zone 54)
Reference sites			
BASW09	Drainage feature outside and northeast of disturbance footprint catchment	377540	7738673
BASW05	Drainage feature southwest and outside of disturbance footprint catchment	380736	7742273
Compliance sites			
BASW01	Watercourse at Mining Lease west boundary	378513	7743286
BASW04	Watercourse downstream of North Pit	379491	7742440
BASW08	Drainage feature at the top of catchment (Mining Lease entry)	380776	7740396
BASW11	Drainage feature upstream of junction with watercourse	379884	7743040

Table E4 - Receiving waters trigger levels and quality objectives ('Table E4')

Contaminant	Water quality[1, 3]		Sediment quality[7, 4]		Monitoring frequency
	Trigger levels	Water quality objectives	Trigger levels[2]	Sediment quality objectives[2]	
pH (pH units)	6.0 (minimum)	5.0 (minimum)	Not applicable		- For water quality: a) At least daily during release events, the first sample must be taken within two hours of the release event commencing; and b) At least once every three months (if surface water is present). - For sediment quality, at least twice per year, once at the end of the wet season and once at the end of the dry season.
	7.5 (maximum)	9.0 (maximum)	Not applicable		
Electrical conductivity (µS/cm)	500 or 80th percentile[6] of reference site[5], whichever is higher	1,000 or 95th percentile[6] of reference site[5], whichever is lower	Not applicable		
Turbidity (NTU)	80th percentile[6] of reference site[5]	25 or 95th percentile[6] of reference site[5], whichever is lower	Not applicable		
Sulfate	80th percentile[6] of reference site[5]	1,000 or 95th percentile[6] of reference site[5], whichever is lower	Not applicable		
Fluoride	80th percentile[6] of reference site[5]	2 or 95th percentile[6] of reference site[5], whichever is lower	Not applicable		
Arsenic	0.007 or 80th percentile[6] of reference site[5], whichever is higher	0.5 (total) or 95th percentile[6] of reference site[5] (dissolved), whichever is lower	20 or two times the reference site[5] value, whichever is higher	70 or two times the reference site[5] value, whichever is lower	
Barium	80th percentile of reference site[5]	95th percentile[6] of reference site[5] (dissolved)	Two times the reference site[5] value	Three times the reference site[5] value	
Bismuth	80th percentile[6] of reference site[5]	95th percentile[6] of reference site[5] (dissolved)	Two times the reference site[5] value	Three times the reference site[5] value	
Cobalt	0.0028 or 80th percentile[6] of reference site[5], whichever is higher	1 (total) or 95th percentile[6] of reference site[5] (dissolved), whichever is lower	Two times the reference site[5] value	Three times the reference site[5] value	
Chromium	0.001 or 80th percentile[6] of reference site[5], whichever is higher	1 (total) or 95th percentile[6] of reference site[5] (dissolved), whichever is lower	80 or two times the reference site[5] value, whichever is higher	370 or two times the reference site[5] value, whichever is lower	
Copper	0.0014 or 80th percentile[6] of reference site[5], whichever is higher	1 or (total) or 95th percentile[6] of reference site[5] (dissolved), whichever is lower	65 or two times the reference site[5] value, whichever is higher	270 or two times the reference site[5] value, whichever is lower	
Molybdenum	0.034 or 80th percentile[6] of reference site[5], whichever is higher	0.15 (total) and 95th percentile[6] of reference site[5] (dissolved), whichever is lower	Two times the reference site[5] value	Three times the reference site[5] value	
Nickel	0.011 or 80th percentile[6] of reference site[5], whichever is higher	1 (total) or 95th percentile[6] of reference site[5] (dissolved), whichever is lower	21 or two times the reference site[5] value, whichever is higher	52 or two times the reference site[5] value, whichever is lower	
Selenium	0.011 or 80th percentile[6] of reference site[5], whichever is higher	0.02 (total) and 95th percentile[6] of reference site[5] (dissolved), whichever is lower	Two times the reference site[5] value	Three times the reference site[5] value	

Uranium	0.02 or 80th percentile[6] of reference site[5], whichever is higher	0.2 (total) or 95th percentile[6] of reference site[5] (dissolved), whichever is lower	Two times the reference site[5] value, whichever is higher	Three times the reference site[5] value, whichever is lower
Major cations	For interpretation only		Not applicable	
Major anions	For interpretation only		Not applicable	
Total hardness	For interpretation only		Not applicable	
Total organic carbon	Not applicable		For interpretation only	

[1] For water quality, all metals and metalloids must be measured as both 'total' (from analysis of an unfiltered sample) and 'dissolved' (from analysis of a field filtered sample). All trigger levels are based on dissolved metal concentrations; for water quality objectives, the relevant method is specified in brackets for each contaminant where applicable.

[2] Analysis for metals/metalloids concentrations in sediment must be conducted on the <2mm fraction of the sample and measured as a dilute acid extractable concentration in a manner consistent with the *Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines*, CSIRO (May 2013).

[3] Measured and reported in mg/L unless specified otherwise.

[4] Measured and reported in mg/kg dry weight.

[5] The relevant reference site is specified in *Table E3*.

[6] Site-specific trigger levels and water quality objectives for water quality (80th and 95th percentile of reference site concentration) must be calculated in accordance with QWQG (2009) and ANZECC (2000) methodology if sufficient monitoring data is available. The environmental authority holder must maintain a database documenting all relevant water quality monitoring data and calculation of percentiles adopted as water quality trigger levels and water quality objectives.

[7] For sediment quality, compliance site monitoring results are to be compared:

a) Directly to the guideline values from the *Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines*, CSIRO (May 2013), if insufficient reference site monitoring data is available; or

b) The relevant reference site monitoring data, which must be normalised to account for any difference in particle size distribution (*i.e.* conduct a fractionated sediment analysis based on comparing the metals concentrations of the <63µm sediment fraction with the >63µm to <2mm sediment fraction).

E6 The contaminant concentrations measured in receiving waters including any compliance site specified in *Table E3* must not exceed a water quality objective or sediment quality objective specified in *Table E4*.

E7 If a contaminant concentration measured at a compliance site specified in *Table E3* exceeds any trigger level specified in *Table E4*, the environmental authority holder must compare this result to the applicable reference site; and

a) If the contaminant concentration measured at the compliance site is equal to or less than the contaminant concentration measured at the applicable reference site, no further action is required for this event; or

b) If the contaminant concentration measured at the compliance site is greater than the contaminant concentration measured at the applicable reference site:

i. Notify the administering authority within twenty-four hours of becoming aware of the trigger level exceedance; and

ii. Undertake further sampling of potentially impacted receiving waters for all contaminants specified in *Table E4*; and

iii. Complete an investigation into the potential for environmental harm to occur in accordance with ANZECC (2000) methodology, within three months of identifying this exceedance or the alternative timeframe specified by the administering authority; and

iv. Within one week of completing the investigation, provide a written report to the administering authority detailing all pertinent aspects of the investigation (such as objectives, applied methodology, investigation outcomes, assumptions relied upon and justification for any assertions made) and any actions undertaken and/or proposed to prevent or minimise environmental harm.

Note: Where a contaminant trigger level exceedance has occurred and is under investigation in accordance with condition E7, no further reporting is required for subsequent exceedance events of that contaminant during the course of the investigation.

Groundwater

E8 The holder of this environmental authority must not release contaminants to groundwater.

E9 The extraction of groundwater must not cause environmental harm to any groundwater dependent ecosystems.

E10 Groundwater quality and levels must be monitored:

a) at the locations specified in *Table E5 (Groundwater monitoring bore locations); and*

b) at the frequencies specified in *Table E5 (Groundwater monitoring bore locations); and*

c) for the quality characteristics identified in *Table E6 (Groundwater Quality Objectives)*.

Table E5 - Groundwater monitoring bore locations ('Table E5')

Monitoring Point	Location (GDA94 – Zone 54)		Surface RL (m)[1]	Total Depth (mbgl[2])	Screened interval (mbgl)	Monitoring Frequency	
	Easting	Northing				Standing water level	Groundwater quality
Compliance bores							
BAWB05	380948	7740252	377.32	102	35-102	Monthly	3 monthly
Bore E	380022	7738827	334.23	85	28-83		
BAWB01	380432	7742097	352.68	104	20-101	Monthly	3 monthly
BAWB02	379480	7742395	310.59	104	96-102		
BAWB03	379834	7741692	329.50	104	50-102		
BAWB04	380043	7742054	329.14	100	94-100		
BAWB07	379849	7741936	328.74	127	18-146		
BAWBR1	380292	7740939	334.49	14	5-6		
BAWBR2	379912	7741279	322.98	14	2-3		
BAWBR3	379991	7741485	326.02	14	3-4		
Seepage monitoring bores							
Seepage Bore 1a	380084	7741046	336.819	6	1-5	Monthly	3 monthly

Seepage Bore 1b	380084	7741048	336.487	16	5-15		
Seepage Bore 2a	380025	7741117	331.218	6	1-5		
Seepage Bore 2b	380023	7741116	331.342	16	5-15		
Seepage Bore 3a	379985	7741133	332.189	6	1-5		
Seepage Bore 3b	379986	7741135	331.962	16	5-15		
Seepage Bore 4a	380711	7740798	355.061	6	1-5		
Seepage Bore 4b	380711	7740800	355.111	16	5-15		

Notes:
1. RL must be measured to the nearest 5cm from the top of the bore casing.
2. Metres below ground level

Table E6 – Groundwater quality objectives ('Table E6')

Contaminant[1]	Units	Limit type	Bore(s)	Limit A[3]	Limit B[4]
pH	pH	Range	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	7.0-8.5
Electrical conductivity (EC)	µS/cm	Maximum	BAWB01, BAWB02, BAWB07	1260	1365
			BAWB03, BAWB04, BAWB05, BAWBR1, BAWBR2, BAWBR3, Bore E	950	1010
Sulfate	mg/L	Maximum	BAWB01, BAWB03, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	65	73
			BAWB02	190	200
			BAWB04	16	21
Fluoride	mg/L	Maximum	BAWB02, BAWB03, BAWB04, BAWB05, BAWBR1, BAWBR2, BAWBR3	0.8	0.9
			BAWB01, BAWB07, Bore E	1.6	1.7
Arsenic	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.013[2]
Barium	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	0.140	0.170
			BAWB04	0.400	0.420
			BAWB05	0.2	0.3
Bismuth	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.0007[5]
Cobalt	mg/L	Maximum	BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.0014[5]

			BAWB01	-	0.0028
Chromium	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.001[2]
Copper	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	0.003	0.008
Molybdenum	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.034[2]
Nickel	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.011[2]
Selenium	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.011[2]
Uranium	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	0.006	0.007
Major cations			BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	For interpretation only	
Major anions			BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	For interpretation only	
Total Hardness			BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	For interpretation only	

Notes:
1. All metals and metalloids must be measured as 'dissolved' (from analysis of a field filtered sample)
2. Contaminant limit based on ANZECC (2000), Table 3.4.1, 95% aquatic species protection level for slightly to moderately disturbed ecosystem.
3. Derived from site-specific values, based off dissolved concentration of metals (80th percentiles).
4. Derived from site-specific values, based off dissolved concentration of metals (95th percentiles).
5. Based off ANZECC (2000) low reliability metals and metalloids, Section 8.3.7.1

E11 Groundwater measured from any compliance bore specified in **Table E5** must not exceed the corresponding Limit A specified in **Table E6** on any five consecutive sampling occasions**.**

E12 Groundwater measured from any compliance bore specified in **Table E5** must not exceed the corresponding Limit B specified in **Table E6** on any three consecutive sampling occasions**.**

E13 If groundwater measured from any compliance bore specified in **Table E5** exceeds the corresponding Limit B specified in **Table E6** on any one sampling occasion the environmental authority holder must resample the groundwater within the compliance bore for all exceeding parameters within ten business days of receipt of results.

Bore construction and maintenance and decommissioning

E14 The construction, maintenance and decommissioning of groundwater monitoring bores must be undertaken in a manner that:

a) prevents contaminants entering the groundwater; and

b) ensures the integrity of the bores to obtain representative groundwater samples from the target aquifer; and

c) maintains the hydrogeological environment within the aquifer.

E15 A bore drill log must be kept for each reference, compliance and observation groundwater monitoring bore which includes:

a) bore identification reference and geographic coordinate location;

b) specific construction information including but not limited to depth of bore, depth and length of casing, depth and length of screening and bore sealing details;

c) standing groundwater level and water quality parameters including physical parameters and results of laboratory analysis for the possible trigger parameters;

d) lithological data and stratigraphic interpretation by an appropriately qualified person to identify important features associated with groundwater monitoring; and

e) target aquifer formation of the bore.

Groundwater Management Program

E16 A Groundwater Management Program must be developed, documented and implemented by appropriately qualified persons.

E17 The Groundwater Management Program required by Condition E16 must:

a) identify potential sources of contamination to groundwater from the activity; and

b) ensure that all potential groundwater impacts due to the activity are identified, monitored and mitigated; and

c) document sampling and monitoring methodology; and

d) ensure that adequate groundwater monitoring and data analysis is undertaken to achieve the following objectives:

i. detect any impacts to groundwater levels due to the activity;

ii. detect any impacts to groundwater quality due to the activity;

iii. determine compliance with condition E11 and E12; and

iv. determine trends in groundwater quality; and

e) include an appropriate quality assurance and quality control program; and

f) include a conceptual groundwater model; and

g) include a review process to identify improvements to the program that includes addresses any comments provided by the administering authority.

E18 The Groundwater Management Program must be reviewed on an annual basis by an appropriately qualified person to determine if it continues to meet the requirements stated in condition E17.

E19 Monitoring and sampling must be carried out in accordance with written procedures and must address the requirements of the latest version of the following documents unless otherwise approved by the administering authority:

a) for waters and aquatic environments, the Queensland Government's Monitoring and Sampling Manual – Environmental Protection (Water) Policy;

b) for groundwater, Groundwater Sampling and Analysis – A Field Guide (2009:27 GeoCat#6890.1) and Australian Standard AS/NZS 5667.11:1998 Water Quality – Sampling – Guidance on sampling of groundwaters;

c) for subterranean aquatic fauna, the Guideline for the Environmental Assessment of Subterranean Aquatic Fauna.

Receiving environment monitoring program

E20 The environmental authority holder must develop, document and implement a Receiving Environment Monitoring Program (REMP) to monitor, identify and describe any adverse impacts to environmental values of receiving waters by 5 October 2016. The REMP must include at minimum:

a) Monitoring the effects of the mining activities on the receiving environment periodically under natural flow conditions and while contaminants are being released (if applicable);

b) Encompass the waters of Leichardt River and connected or surrounding waterways within 10km downstream of the mining activities;

c) Identification of all environmental values of receiving waters;

d) An assessment of background reference water quality, the condition of downstream water quality compared against water quality objectives, and the suitability of current environmental authority conditions to protect downstream environmental values; and

e) Application of biological monitoring if required to determine whether the mining activities are being conducted in a manner that enhances or protects the environmental values of receiving waters;

E21 A report outlining the findings of the REMP that addresses all requirements specified under condition E20, including all monitoring results and any interpretations or assumptions relied upon, must be completed annually.

Water management

E22 A Water Management Plan must be developed by an appropriately qualified person, documented and implemented for all stages of the mining activity.

Erosion and sediment control

E23 An Erosion and Sediment Control Plan must be developed, documented and implemented by an appropriately qualified person for all stages of the mining activities to minimise erosion and the release of sediment to receiving waters.

END OF CONDITIONS FOR SCHEDULE E

Schedule F – Biodiversity

Biodiversity offsets

F1 Impacts to prescribed environmental matters, other than by low impact activities, are only authorised to occur if the impacts do not exceed the maximum extent of impact specified for that prescribed environmental matter specified in *Table F1 – Authorised impacts to prescribed environmental matters*.

F2 An environmental offset made under the *Environmental Offsets Act 2014* must be delivered for each impact specified in *Table F1 – Authorised impacts to prescribed environmental matters* as requiring an environmental offset.

F3 A notice of election must be provided to the administering authority no less than three months before the proposed commencement of the prescribed activities.

Table F1 – Authorised impacts to prescribed environmental matters ('Table F1')

Prescribed environmental matter	Location of prescribed environmental matter (GDA94 – Zone 54)	Maximum extent of impact	Environmental offset required
Protected wildlife habitat			
Habitat for an animal that is vulnerable wildlife – Purple-necked rock wallaby *Petrogale purpuriecollis*	379910 E, 7740390 N	5 ha	Yes

F4 Prior to the commencement of any impacts to a prescribed environmental matter for which an offset is required by condition F2, the authority holder must enter into an Agreed Delivery Arrangement with the administering authority

END OF CONDITIONS FOR SCHEDULE F

Schedule G – Land and Rehabilitation

G1 The environmental authority holder must rehabilitate all significantly disturbed land caused by the mining activities in a manner that ensures rehabilitated areas achieve the following rehabilitation objectives:

a) Safe for humans and wildlife;

b) Non-polluting;

c) Stable;

d) Able to sustain a post-mining land-use agreed to by the administering authority and any underlying landholders;

e) Revegetated with species endemic to the area with no declared pest species; and

f) Compliant with all conditions of this environmental authority.

G2 Two years from commencement of mining[1] the environmental authority holder must develop and document a Post Mine Land-use Plan ('PMLUP') that describes how the rehabilitation objectives in condition G1 will be achieved. The PMLUP must at minimum include:

a) Schematic representation of the proposed final land form inclusive of site drainage features;

b) Details of proposed slope design and erosion and sediment controls;

c) Proposed cover designs for encapsulation of waste material, including performance criteria;

d) Proposed re-vegetation methods inclusive of plant species selection, propagation methods and establishment of suitable plant growth medium (*i.e.* top soil);

e) Materials balance for all rehabilitation requirements including available top soil and material suitable for encapsulating waste in accordance with the proposed encapsulation methodology;

f) Geotechnical, geochemical and hydrological studies necessary to demonstrate likely success of proposed rehabilitation methodology to achieve the required rehabilitation outcomes;

g) An investigation of proposed residual voids including potential for generation/mobilisation of contaminants, potential pathways for release of contaminants to waters (including groundwater) and a long-term void water balance model; and

h) A rehabilitation monitoring program sufficient to identify if required rehabilitation outcomes have been achieved.

Note: Commencement of mining is taken to be the date that extraction of material from the pit commences.

G3 Rehabilitation must commence progressively in accordance with the Plan of Operations.

G4 Residual voids (including open pits and underground workings) must not cause any serious or material environmental harm, other than the environmental harm constituted by the existence of the residual void itself, subject to any other condition within this environmental authority.

G5 All explosives, flammable or corrosive substances, hazardous chemicals, toxic substances, gases and dangerous goods must be stored and handled in accordance with:

a) The current Australian Standard where applicable; or

b) Where no relevant Australian Standard exists, store such materials within an on-site containment system sufficient to prevent release to the receiving environment.

END OF CONDITIONS FOR SCHEDULE G

Schedule H – Regulated Dams

H1 The consequence category of any structure must be assessed by a suitably qualified and experienced person in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* at the following times:

a) prior to the design and construction of the structure, if it is not an existing structure; or

b) if it is an existing structure, prior to the adoption of this schedule; or

c) prior to any change in its purpose or the nature of its stored contents.

H2 A consequence assessment report and certification must be prepared for each structure assessed and the report may include a consequence assessment for more than one structure.

H3 Certification must be provided by the suitably qualified and experienced person who undertook the assessment, in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

Design and construction of a regulated structure

H4 Conditions H5 to H9 inclusive do not apply to existing structures.

H5 All regulated structures must be designed by, and constructed under the supervision of, a suitably qualified and experienced person in accordance with the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

H6 Construction of a regulated structure is prohibited unless the holder has submitted a consequence category assessment report and certification to the administering authority has been certified by a suitably qualified and experienced person for the design and design plan and the associated operating procedures in compliance with the relevant condition of this authority.

H7 Certification must be provided by the suitably qualified and experienced person who oversees the preparation of the design plan in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*, and must be recorded in the Regulated Dams/Levees register.

H8 Regulated structures must:

a) be designed and constructed in accordance with and conform to the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635);*

b) be designed and constructed with due consideration given to ensuring that the design integrity would not be compromised on account of:

i) floodwaters from entering the regulated dam from any watercourse or drainage line; and

ii) possible erosion by floodwaters arising from any watercourse or drainage line.

H9 Certification by the suitably qualified and experienced person who supervises the construction must be submitted to the administering authority on the completion of construction of the regulated structure, and state that:

a) the 'as constructed' drawings and specifications meet the original intent of the design plan for that regulated structure;

b) construction of the regulated structure is in accordance with the design plan.

Operation of a regulated structure

H10 Operation of a regulated structure**,** except for an existing structure, is prohibited unless:

a) the holder has submitted to the administering authority:

i) one paper copy and one electronic copy of the design plan and certification of the 'design plan' in accordance with condition H8, and

ii) a set of 'as constructed' drawings and specifications, and

iii) certification of those 'as constructed drawings and specifications' in accordance with condition H9, and

iv) where the regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, a copy of the certified system design plan.

v) the requirements of this authority relating to the construction of the regulated structure have been met;

vi) the holder has entered the details required under this authority, into a Register of Regulated Dams; and

vii) there is a current operational plan for the regulated structures.

H11 Each regulated structure must be maintained and operated, for the duration of its operational life until decommissioned and rehabilitated, in a manner that is consistent with the current operational plan and, if applicable, the current design plan and associated certified 'as constructed' drawings.

Mandatory reporting level

H12 Conditions H14 to H17 inclusive only apply to Regulated Structures which have not been certified as low consequence category for 'failure to contain – overtopping'.

H13 The Mandatory Reporting Level (the MRL) specified in *Table H1* must be marked on a regulated dam in such a way that during routine inspections of that dam, it is clearly observable.

H14 The holder must, as soon as practical and within forty-eight (48) hours of becoming aware, notify the administering authority when the level of the contents of a regulated dam reaches the MRL.

H15 The holder must, immediately on becoming aware that the MRL has been reached, act to prevent the occurrence of any unauthorised discharge from the regulated dam.

H16 The holder must record any changes to the MRL in the Register of Regulated Structures.

Design storage allowance

H17 The holder must assess the performance of each regulated dam or linked containment system over the preceding November to May period based on actual observations of the available storage in each regulated dam or linked containment system taken prior to 1 July of each year.

H18 By 1 November of each year, storage capacity must be available in each regulated dam (or network of linked containment systems with a shared DSA volume), to meet the Design Storage Allowance (DSA) volume for the dam (or network of linked containment systems), as specified in *Table H1*.

H19 The holder must, as soon as possible and within forty-eight (48) hours of becoming aware that the regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on 1 November of any year, notify the administering authority.

H20 The holder must, immediately on becoming aware that a regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on 1 November of any year, act to prevent the occurrence of any unauthorised discharge from the regulated dam or linked containment systems.

Annual inspection report

H21 Each regulated structure must be inspected each calendar year by a suitably qualified and experienced person.

H22 At each annual inspection, the condition and adequacy of all components of the regulated structure must be assessed and a suitably qualified and experienced person must prepare an annual inspection report containing details of the assessment and include recommended actions to ensure the integrity of the regulated structure.

H23 The suitably qualified and experienced person who prepared the annual inspection report must certify the report in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

H24 The holder must:

a) Within 20 business days of receipt of the annual inspection report, provide to the administering authority:

i) The recommendations section of the annual inspection report; and

ii) If applicable, any actions being taken in response to those recommendations; and

b) If, following receipt of the recommendations and (if applicable) actions, the administering authority requests a full copy of the annual inspection report from the holder, provide this to the administering authority within 10 business days[6] of receipt of the request.

Transfer arrangements

H25 The holder must provide a copy of any reports, documentation and certifications prepared under this authority, including but not limited to any Register of Regulated Structures, consequence assessment, design plan and other supporting documentation, to a new holder on transfer of this authority.

Decommissioning and rehabilitation

H26 Dams must not be abandoned but be either:

a) decommissioned and rehabilitated to achieve compliance with condition H27; or

b) be left in-situ for a beneficial use(s) provided that:

i) it no longer contains contaminants that will migrate into the environment; and

ii) it contains water of a quality that is demonstrated to be suitable for its intended beneficial use(s); and

iii) the administering authority, the holder of the environmental authority and the landholder agree in writing that the dam will be used by the landholder following the cessation of the environmentally relevant activity(ies).

H27 After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria:

a) the landform is safe for humans and fauna;

b) the landform is stable with no subsidence or significant erosion gullies for at least three (3) years;

c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated;

d) not allowing for acid mine drainage; or

e) there is no ongoing contamination to waters (including groundwater);

f) rehabilitation is undertaken in a manner such that any actual or potential acid sulfate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the Instructions for the treatment and management of acid sulfate soils (2001);

g) all significantly disturbed land is reinstated to the pre-disturbed soil suitability class;

h) for land that is not being cultivated by the landholder:

i. groundcover, that is not a declared pest species is established and self-sustaining

ii. vegetation of similar species richness and species diversity to pre-selected analogue sites is established and suited to the post mine land use, and

iii. the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the petroleum activity(ies).

i) for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within 3 months of petroleum activities being completed.

Register of Regulated Dams

H30 A Register of Regulated Dams must be established and maintained by the holder for each regulated dam.

H31 The holder must provisionally enter the required information in the Register of Regulated Dams when a design plan for a regulated dam is submitted to the administering authority.

H32 The holder must make a final entry of the required information in the Register of Regulated Dams once compliance with condition H10 and H11 has been achieved.

H33 The holder must ensure that the information contained in the Register of Regulated Dams is current and complete on any given day.

H34 All entries in the Register of Regulated Dams must be approved by the chief executive officer for the holder of this authority, or their delegate, as being accurate and correct.

H35 The holder must, at the same time as providing the annual return, supply to the administering authority a copy of the records contained in the Register of Regulated Dams, in the electronic format required by the administering authority.

Hydraulic performance of regulated dams

H36 All regulated dams must meet the hydraulic performance criteria specified in *Table H1*.

Table H1 – Hydraulic performance criteria ('Table H1')

Name of dam	Consequence category	Hydraulic performance criteria		
		Spillway capacity	Design Storage Allowance	Mandatory Reporting Level
North Pit	Significant	1:100 to 1:1000 AEP 72 hour duration storm event	1:20 AEP 2 month wet season	1:10 AEP 72 hour duration storm event
South Pit	Significant	1:100 to 1:1000 AEP72 hour duration storm event	1:20 AEP 2 month wet season	1:10 AEP 72 hour duration storm event
WRD Dam	Significant	1:100 to 1:1000 AEP72 hour duration storm event	1:20 AEP 2 month wet season	1:10 AEP 72 hour duration storm event
ROM Dam	Significant	1:100 to 1:1000 AEP72 hour duration storm event	1:20 AEP 2 month wet season	1:10 AEP 72 hour duration storm event

END OF CONDITIONS FOR SCHEDULE H

Schedule I – Definitions

Definitions

Key terms and/or phrases used in this document are defined in this section and bolded throughout this document. Applicants should note that where a term is not defined, the definition in the *Environmental Protection Act 1994*, its regulations or environmental protection policies must be used. If a word remains undefined it has its ordinary meaning.

Acid rock drainage means any contaminated discharge emanating from a mining activity formed through a series of chemical and biological reactions, when geological strata is disturbed and exposed to oxygen and moisture.

Administering Authority is the agency that administers the environmental authority provisions under the *Environmental Protection Act 1994*.

Affected person is someone whose drinking water can potentially be impacted as a result of discharges from a dam or their life can be put at risk due to dwellings or workplaces being in the path of a dam break flood.

Airblast overpressure means energy transmitted from the blast site within the atmosphere in the form of pressure waves. The maximum excess pressure in this wave, above ambient pressure is the peak airblast overpressure measured in decibels linear (dBL).

Annual inspection report means an assessment prepared by a suitably qualified and experienced person containing details of the assessment against the most recent consequence assessment report and design plan (or system design plan);

(a) against recommendations contained in previous annual inspections reports;

(b) against recognised dam safety deficiency indicators;

(c) for changes in circumstances potentially leading to a change in consequence category;

(d) for conformance with the conditions of this authority;

(e) for conformance with the 'as constructed' drawings;

(f) for the adequacy of the available storage in each regulated dam, based on an actual observation or observations taken after 31 May each year but prior to 1 November of that year, of accumulated sediment, state of the containment barrier and the level of liquids in the dam (or network of linked containment systems);

(g) for evidence of conformance with the current operational plan.

Annual exceedance probability or AEP the probability that at least one event in excess of a particular magnitude will occur in any given year.

Appropriately qualified person means a person who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relating to the subject matter using the relevant protocols, standards, methods or literature.

Assessed or **assessment** by a suitably qualified and experienced person in relation to a consequence assessment of a dam, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit of the assessment:

(a) exactly what has been assessed and the precise nature of that determination;

(b) the relevant legislative, regulatory and technical criteria on which the assessment has been based;

(c) the relevant data and facts on which the assessment has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and

(d) the reasoning on which the assessment has been based using the relevant data and facts, and the relevant criteria.

Associated works in relation to a dam, means:

(a) operations of any kind and all things constructed, erected or installed for that dam; and

(b) any land used for those operations.

Authority means an environmental authority or a development approval.

Background, with reference to the water schedule means the average of samples taken prior to the commencement of mining from the same waterway that the current sample has been taken.

Blasting means the use of explosive materials to fracture:

(a) rock, coal and other minerals for later recovery, or

(b) structural components or other items to facilitate removal from a site or for reuse.

Certification means assessment and approval must be undertaken by a suitably qualified and experienced person in relation to any assessment or documentation required by this Manual, including design plans, 'as constructed' drawings and specifications, construction, operation or an annual report regarding regulated structures, undertaken in accordance with the Board of Professional Engineers of Queensland Policy Certification by RPEQs (ID: 1.4 (2A)).

Certification, Certifying or **Certified** by an appropriately qualified and experienced person in relation to a design plan or an annual report regarding dams/structures, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit at any time:

a) exactly what is being certified and the precise nature of that certification

b) the relevant legislative, regulatory and technical criteria on which the certification has been based

c) the relevant data and facts on which the certification has been based, the source of that material, and the efforts made to obtain all relevant data and facts

d) the reasoning on which the certification has been based using the relevant data and facts, and the relevant criteria.

Chemical means:

a) an agricultural chemical product or veterinary chemical product within the meaning of the Agricultural and *Veterinary Chemicals Code Act 1994* (Commonwealth), or

b) a dangerous good under the Australian Code for the Transport of Dangerous Goods by Road and Rail approved by the Australian Transport Council, or

c) a lead hazardous substance within the meaning of the Workplace Health and Safety Regulation 1997, or

d) a drug or poison in the Standard for the Uniform Scheduling of Drugs and Poisons prepared by the Australian Health Ministers' Advisory Council and published by the Commonwealth, or

e) any substance used as, or intended for use as:

i. a pesticide, insecticide, fungicide, herbicide, rodenticide, nematocide, miticide, fumigant or related product, or

ii. a surface active agent, including, for example, soap or related detergent, or

iii. a paint solvent, pigment, dye, printing ink, industrial polish, adhesive, sealant, food additive, bleach, sanitiser, disinfectant, or biocide, or

iv. a fertiliser for agricultural, horticultural or garden use, or

v. a substance used for, or intended for use for mineral processing or treatment of metal, pulp and paper, textile, timber, water or wastewater, or

vi. manufacture of plastic or synthetic rubber.

Commercial place means a workplace used as an office or for business or commercial purposes, which is not part of the mining activity and does not include employees' accommodation or public roads.

Construction or constructed in relation to a regulated structure includes building a new regulated structure and lifting or otherwise modifying an existing regulated structure, but does not include investigations and testing necessary for the purpose of preparing a design plan.

Coal seam gas water means groundwater that is necessarily or unavoidably brought to the surface in the process of coal seam gas exploration or production.

Coal seam gas water concentrate means the concentrated saline water waste stream from a water treatment process that does not exceed a total dissolved solid concentration of 40 000 mg/L.

Coal seam gas evaporation dam is defined as a impoundment, enclosure or structure that is designed to be used to hold coal seam gas water for evaporation.

Consequence in relation to a structure as defined, means the potential for environmental harm resulting from the collapse or failure of the structure to perform its primary purpose of containing, diverting or controlling flowable substances.

Consequence category means a category, either low, significant or high, into which a dam is assessed as a result of the application of tables and other criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

Dam means a land-based structure or a void that contains, diverts or controls flowable substances, and includes any substances that are thereby contained, diverted or controlled by that land-based structure or void and **associated works**.

Dam crest volume means the volume of material (liquids and/or solids) that could be within the walls of a dam at any time when the upper level of that material is at the crest level of that dam. That is, the instantaneous maximum volume within the walls, without regard to flows entering or leaving (for example, via spillway).

Design plan is a document that contains the design, operation, monitoring and revegetation criteria of a watercourse diversion that addresses the outcomes stated in conditions on the environmental authority relating to the diversion. The document should include, but not be limited to:

a) required information under a functional design
b) the location, function and description of geomorphic and riparian vegetation features within the proposed watercourse diversion
c) results from hydrologic, hydraulic and sediment transportation modelling used in the design of the diversion
d) a revegetation and vegetation management plan (a revegetation plan) for the diversion
e) engineering drawings depicting the physical attributes and dimensions of the diversion
f) (if relevant) the staged development of a permanent watercourse diversion including the proposed use of temporary watercourse diversions with identified lifespans
g) all investigation and other reports relied on by the design
h) plans and specifications sufficient to complete construction and revegetation in accordance with the design.

Design storage allowance or DSA means an available volume, estimated in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority, must be provided in a dam as at 1 November each year in order to prevent a discharge from that dam to an annual exceedance probability (AEP) specified in that Manual.

Designer for the purposes of a regulated dam, means the certifier of the design plan for the regulated dam.

Development approval means a development approval under the *Integrated Planning Act 1997* or the *Sustainable Planning Act 2009* in relation to a matter that involves an environmentally relevant activity under the *Environmental Protection Act 1994*.

Disturbance of land includes:

a) compacting, removing, covering, exposing or stockpiling of earth
b) removal or destruction of vegetation or topsoil or both to an extent where the land has been made susceptible to erosion
c) carrying out mining within a watercourse, waterway, wetland or lake
d) the submersion of areas by tailings or hazardous contaminant storage and dam/structure walls

e) temporary infrastructure, including any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc) which is to be removed after the mining activity has ceased
f) releasing of contaminants into the soil, or underlying geological strata.

However, the following areas are not included when calculating areas of 'disturbance':

a) areas off lease (e.g. roads or tracks which provide access to the mining lease)
b) areas previously disturbed which have achieved the rehabilitation outcomes
c) by agreement with the administering authority, areas previously disturbed which have not achieved the rehabilitation objective(s) due to circumstances beyond the control of the mine operator (such as climatic conditions)
d) areas under permanent infrastructure. Permanent infrastructure includes any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc) which is to be left by agreement with the landowner
e) disturbance that pre-existed the grant of the tenure.

EC means electrical conductivity.

Effluent treated waste water released from sewage treatment plants.

Emergency action plan means documentation forming part of the operational plan held by the holder or a nominated responsible officer, that identifies emergency conditions that sets out procedures and actions that will be followed and taken by the dam owner and operating personnel in the event of an emergency. The actions are to minimise the risk and consequences of failure, and ensure timely warning to downstream communities and the implementation of protection measures. The plan must require dam owners to annually update contact.

Equilibrium: A state where 'balance' is achieved despite changing variables.

Existing structure means a structure that was in existence prior to the adoption of this schedule of conditions under the authority.

Extreme Storm Storage – means a storm storage allowance determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority

Flare pit means containment area where any hydrocarbon that is discovered in an over-pressured reservoir during a drilling operation is diverted to, and combusted. The flare pit is only used during the drilling and work over process on a petroleum well.

Flowable substance means matter or a mixture of materials which can flow under any conditions potentially affecting that substance. Constituents of a flowable substance can include water, other liquids fluids or solids, or a mixture that includes water and any other liquids fluids or solids either in solution or suspension.
Functional design is a document that contains 'conceptual' information about the design, operation and revegetation criteria of a watercourse diversion that addresses the outcomes stated in the conditions on the environmental authority relating to the diversion. The document should include, but not be limited to:

a) geomorphic and vegetation assessment of the existing watercourse

b) hydrologic conditions of the existing watercourse

c) the proposed watercourse diversion route

d) results from hydrologic, hydraulic and sediment transportation modelling used in the design of the diversion.

Functionality: the purpose that something is designed or expected to fulfil.

Holder means:

a) where this document is an environmental authority, any person who is the holder of, or is acting under, that environmental authority; or

b) where this document is a development approval, any person who is the registered operator for that development approval.

Hazard category means a category, either low significant or high, into which a dam is assessed as a result of the application of tables and other criteria in 'Manual for Assessing Hazard Categories and Hydraulic Performance of Dams'.

Holder, for a mining tenement, means a holder of the tenement under the *Mineral Resources Act 1989*, and the holder of the associated environmental authority under the *Environmental Protection Act 1994.*

Hydraulic performance means the capacity of a regulated dam to contain or safely pass flowable substances based on the design criteria specified for the relevant consequence category in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

Infrastructure means water storage dams, levees,, roads and tracks, buildings and other structures built for the purpose of the mining activity.

Land in the 'land schedule' of this document means land excluding waters and the atmosphere, that is, the term has a different meaning from the term as defined in the *Environmental Protection Act 1994*. For the purposes of the *Acts Interpretation Act 1954*, it is expressly noted that the term 'land' in this environmental authority relates to physical land and not to interests in land.

Land use means the selected post mining use of the land, which is planned to occur after the cessation of mining operations.

Leachate means a liquid that has passed through or emerged from, or is likely to have passed through or emerged from, a material stored, processed or disposed of at the operational land, which contains soluble, suspended or miscible contaminants likely to have been derived from the said material.

Levee means an embankment that only provides for the containment and diversion of stormwater or flood flows from a contributing catchment, or containment and diversion of flowable materials resulting from releases from other works, during the progress of those stormwater or flood flows or those releases; and does not store any significant volume of water or flowable substances at any other times.

Licensed place means the mining activities carried out at the mining tenements.

Low consequence dam means any dam that is not a high or significant consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

Low impact activities means activities which do not result in the clearing of native vegetation, cause disruption to soil profiles through earthworks or excavation, or result in significant disturbance to land which cannot be rehabilitated immediately using hand tools after the activity is completed. Examples of such activities include but are not necessarily limited to soil surveys (excluding test pits), topographic surveys, cadastral surveys and ecological surveys, the installation of monitoring equipment provided that it is within the meaning of low impact and traversing land by car or foot via existing access tracks or routes or in such a way that does not result in permanent damage to vegetation.

Mandatory reporting level or MRL means a warning and reporting level determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

Manual means the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

Maximum extent of impacts means the total maximum, unabated, impact to a prescribed environmental matter that could to occur over the whole-of-project life.

Minimise is to reduce to the smallest possible amount or degree.

Modification or modifying (see definition of 'construction')

NATA means National Association of Testing Authorities, Australia.

Natural flow means the flow of water through waters caused by natural processes (*i.e.* rainfall in the catchment area and subsequent runoff into watercourses).

Non polluting means having no adverse impacts upon the receiving environment.

Notice of election has the meaning in section 18(2) *Environmental Offsets Act 2014* by which an authority holder elects to deliver an environmental offset.

Operational plan includes:

(a) Normal operating procedures and rules (including clear documentation and definition of process inputs in the DSA allowance);

(b) Contingency and emergency action plans including operating procedures designed to avoid and/or minimise environmental impacts including threats to human life resulting from any overtopping or loss of structural integrity of the regulated structure.

Peak particle velocity (ppv) means a measure of ground vibration magnitude which is the maximum rate of change of ground displacement with time, usually measured in millimetres/second (mm/s).

Permanent watercourse diversion is a man-made structure that incorporates the geomorphologic, hydraulic, hydrologic and ecological components of a local watercourse and is designed, constructed, operated and maintained according to an engineering standard that ultimately achieves a self-sustaining watercourse able to function without features or characteristics that rely on ongoing maintenance or that impose a financial or other burden on the proponent, government or the community.

Pre-existing watercourse is the section of watercourse from which the flow of water will be diverted as a result of the construction and operation of a watercourse diversion.

Prescribed environmental matters has the meaning in section 10 of the *Environmental Offsets Act 2014*, limited to the matters of State environmental significant listed in schedule 2 of the *Environmental Offsets Regulation 2014*.

Protected area means **–** a protected area under the *Nature Conservation Act 1992*, or

a) a marine park under the *Marine Parks Act 1992*, or

b) a World Heritage Area.

Receiving environment in relation to an activity that causes or may cause environmental harm, means the part of the environment to which the harm is, or may be, caused. The receiving environment includes (but is not limited to):

a) Waters;

b) Land;

c) Air; and

d) Any area that is not specified in Table A1 of this environmental authority.

Receiving waters means the waters into which this environmental authority authorises releases of contaminated water.

Regulated dam means any dam in the significant or high consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

Register of Regulated Dams includes**:**

a) Date of entry in the register;

b) Name of the dam, its purpose and intended/actual contents;

c) The consequence category of the dam as assessed using the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635);

d) Dates, names, and reference for the design plan plus dates, names, and reference numbers of all document(s) lodged as part of a design plan for the dam;

e) Name and qualifications of the suitably qualified and experienced person who certified the design plan and 'as constructed' drawings;

f) For the regulated dam, other than in relation to any levees **–**

   i. The dimensions (metres) and surface area (hectares) of the dam measured at the footprint of the dam;

   ii. Coordinates (latitude and longitude in GDA94) within five metres at any point from the outside of the dam including its storage area

   iii. Dam crest volume (megalitres);

   iv. Spillway crest level (metres AHD).

   v. Maximum operating level (metres AHD);

   vi. Storage rating table of stored volume versus level (metres AHD);

   vii. Design storage allowance (megalitres) and associated level of the dam (metres AHD);

   viii. Mandatory reporting level (metres AHD);

g) The design plan title and reference relevant to the dam;

h) The date construction was certified as compliant with the design plan;

i) The name and details of the suitably qualified and experienced person who certified that the constructed dam was compliant with the design plan;

j) Details of the composition and construction of any liner;

k) The system for the detection of any leakage through the floor and sides of the dam;

l) Dates when the regulated dam underwent an annual inspection for structural and operational adequacy, and to ascertain the available storage volume for 1 November of any year;

m) Dates when recommendations and actions arising from the annual inspection were provided to the administering authority;

n) Dam water quality as obtained from any monitoring required under this authority as at 1 November of each year.

Regulated structure includes land-based containment structures, levees, bunds and voids, but not a tank or container designed and constructed to an Australian Standard that deals with strength and structural integrity.

Rehabilitation means the process of reshaping and revegetating land to restore it to a stable landform.

Release event means a discharge of water contaminated by the mining activity.

Representative means a sample set which covers the variance in monitoring or other data either due to natural changes or operational phases of the mining activities.

Residual drilling material means waste drilling materials including muds and cuttings or cement returns from well holes and which have been left behind after the drilling fluids are pumped out.

Revegetation is the re-establishment of vegetation[1] of a species and density of cover similar to surrounding undisturbed areas or the landform that existed before mining activities on soil surfaces associated with the construction or rehabilitation of a watercourse diversion.

RL means reduced level, relative to mean sea level as distinct from depths to water.

Saline drainage The movement of waters, contaminated with salts, as a result of the mining activity.

Self-sustaining means not requiring on-going intervention and maintenance to maintain functional riverine processes and characteristics

Sensitive place means:

a) a dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises, or

b) a motel, hotel or hostel, or

c) an educational institution, or

d) a medical centre or hospital, or

e) a protected area under the *Nature Conservation Act 1992*, the *Marine Parks Act 1992* or a World Heritage Area, or

f) a public park or gardens.

Significant residual impact has the meaning in section 8 *Environmental Offsets Act 2014.*

Spillway means a weir, channel, conduit, tunnel, gate or other structure designed to permit discharges form the dam, normally under flood conditions or in anticipation of flood conditions.

Structure means dam or levee.

Suitably qualified and experienced person in relation to regulated structures means a person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the *Professional Engineers Act 2002*, and has demonstrated competency and relevant experience:

- for regulated dams, an RPEQ who is a civil engineer with the required qualifications in dam safety and dam design.
- for regulated levees, an RPEQ who is a civil engineer with the required qualifications in the design of flood protection embankments.

Note: It is permissible that a suitably qualified and experienced person obtain subsidiary certification from an RPEQ who has demonstrated competence and relevant experience in either geomechanics, hydraulic design or engineering hydrology.

System design plan means a plan that manages an integrated containment system that shares the required DSA and/or ESS volume across the integrated containment system.

Temporary watercourse diversion is a man-made structure that may incorporate geomorphologic, hydraulic, hydrologic and ecological components of a local watercourse and is designed, constructed, operated and maintained to an engineering standard that ensures the diversion does not compromise the equilibrium and performance of the diversion and adjoining watercourses. A temporary diversion is replaced by a permanent diversion, or the re-establishment of the pre-existing watercourse, within the timeframe specified in the design plan.

the Act means the *Environmental Protection Act 1994*.

Void means any constructed, open excavation in the ground.

Water is defined under Schedule 4 of the *Water Act 2000.*

Watercourse has the meaning in Schedule 4 of the *Environmental Protection Act 1994* and means a river, creek or stream in which water flows permanently or intermittently—

(a) in a natural channel, whether artificially improved or not; or

(b) in an artificial channel that has changed the course of the watercourse.

Watercourse includes the bed and banks and any other element of a river, creek or stream confining or containing water.

Water quality means the chemical, physical and biological condition of water.

Waters includes all or any part of a river, stream, lake, lagoon, pond, swamp, wetland, unconfined surface water, unconfined water in natural or artificial watercourses, bed and banks of a watercourse, dams, non-tidal or tidal waters (including the sea), stormwater channel, stormwater drain, roadside gutter, stormwater run-off, and groundwater.

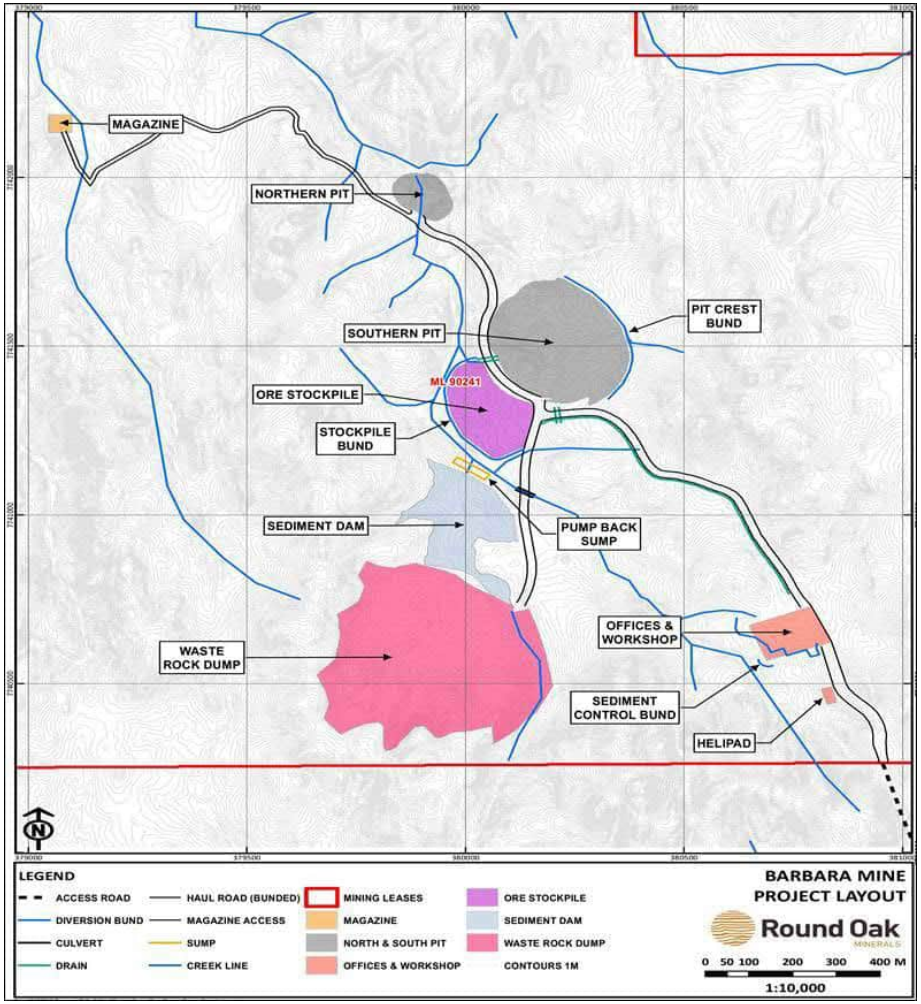
Water year means the 12-month period from 1 July to 30 June.

Wet season means the time of year, covering one or more months, when most of the average annual rainfall in a region occurs. For the purposes of DSA determination this time of year is deemed to extend from 1 November in one year to 31 May in the following year inclusive.

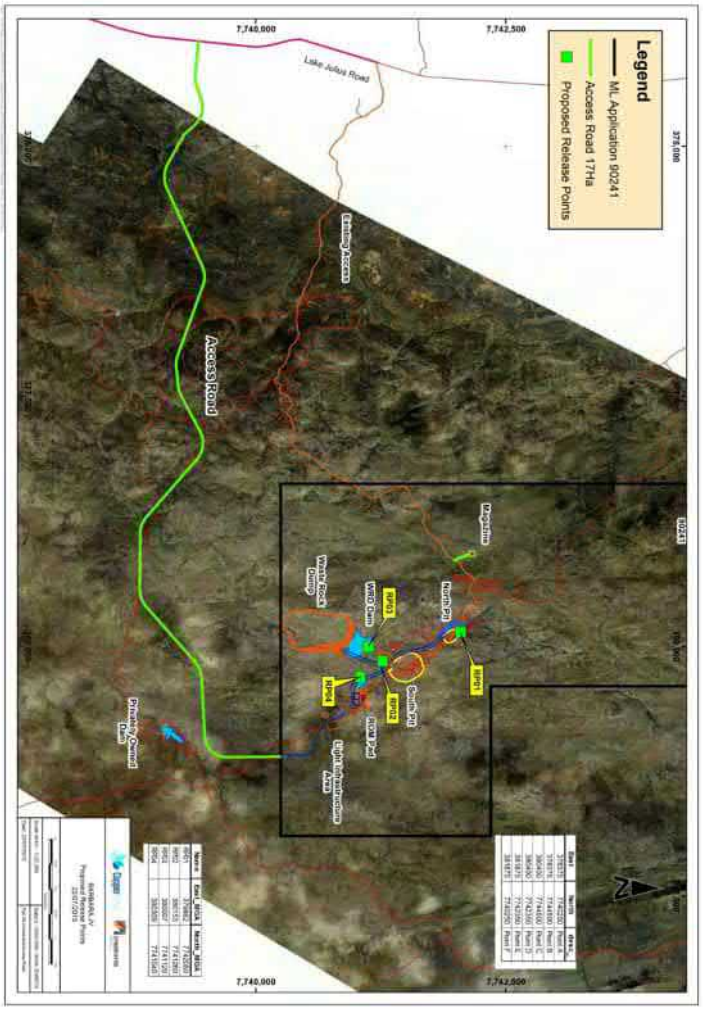
END OF SCHEDULE I

Schedule J – Maps and Plans

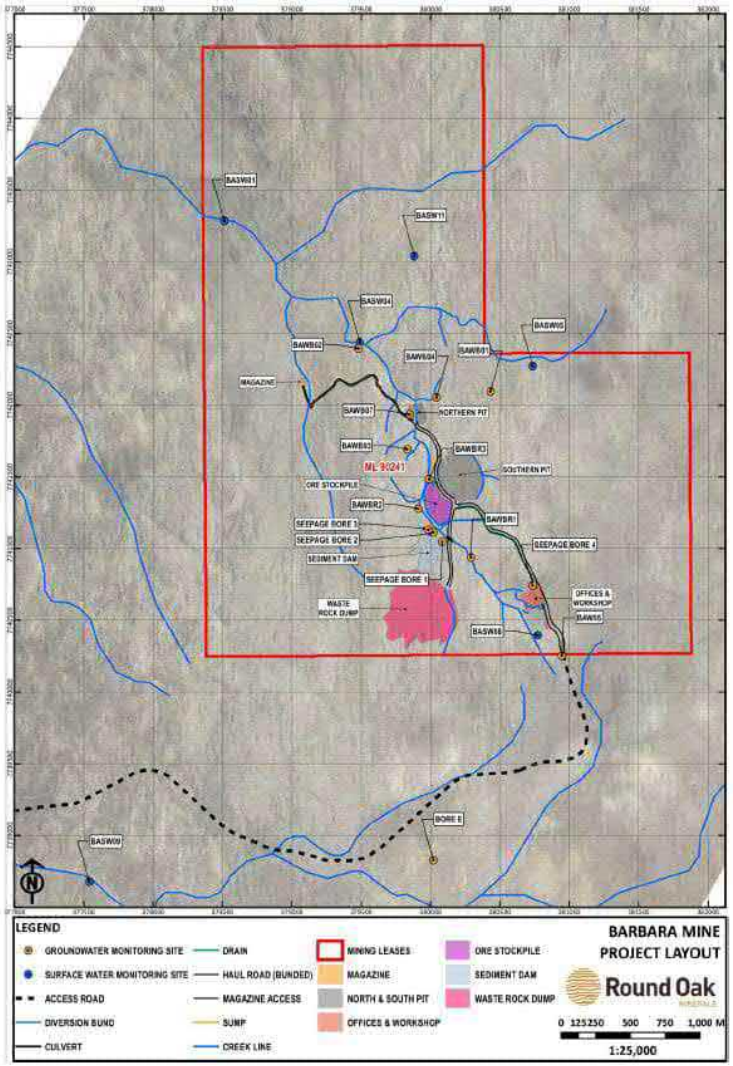
Map 1 – Location of authorised disturbance



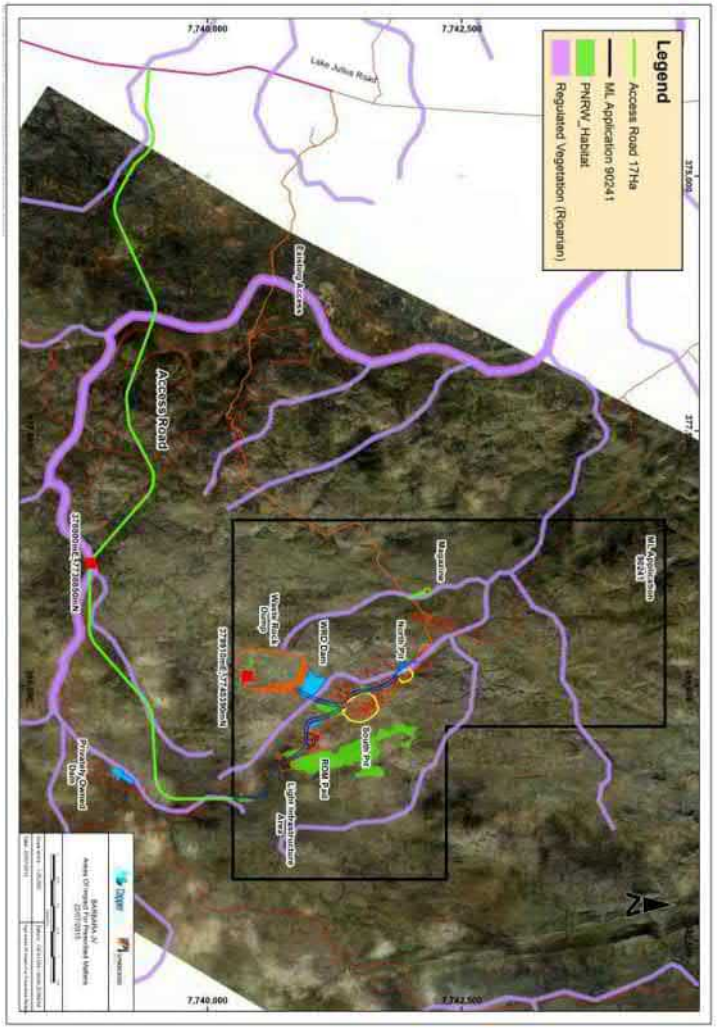
Map 2—Release points



Map 3—Monitoring and reference sites



Map 4—Areas of impact for prescribed matters



End of Schedule J

END OF PERMIT

Appendix B Bore construction logs

Drill log form

Queensland Government

1028888

Authorisation details
Registered number _____ Development permit number _____ Works reference number BOWBR 1

SECTION A—LOCATION DETAILS
Name of landholder SYNDICATED METALS LTD Phone No. _____
Postal address GPO BOX 2810, PERTH WA Postcode 6000
Real property address MT ISA BERRA, MT ISA QLD Postcode 4825
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 380292 Northing 7740939 Zone 54K

SECTION B—BORE COMPLETION DETAILS
Date commenced 4/10/14
Date completed 4/10/14

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☑ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
203	0	14

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	100	CLASS 12	0	6

SECTION F—CENTRALISERS TYPE

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
SLOTS	100	2.5	5	6

SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
CEMENT	203	100	0	4
BENTONITE	203	100	4	5
4-8mm SAND	203	100	5	6

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) MINING

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	2	RIVER STONE	
2	14	DOLERITE.	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
			DRY

Conductivity(EC) pH

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres) Depth to pump suction or bottom of drill stem (metres)
Type of test used ☐ Air ☐ Bail ☐ Pump
Est. supply (litres/second) Duration of test (hours) Drawdown level from surface (metres)

SECTION M—ARTESIAN BORE ON COMPLETION
Pressure (kPa) Free flow (litres/second) Temperature (°C)

SECTION N—REMARKS
MONITORING BORE.
HOLE COLLAPSE DUE TO RIVER STONE

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided in sections A to E and section H above is true, accurate and complete to the best of my knowledge and belief.
Driller MARK SERRA Driller's Licence No. 3250
Trainee Driller _____ Driller's Licence No. _____
Signature of Driller _____ Date 4/10/14
Contractor SERRA DRILLING PTY LTD

Department of Environment and Resource Management

White — forward to the Department of Environment and Resource Management. Pink — provide to landholder. Blue — Driller to retain.

The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 315 of the Water Act 2000. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the Public Records Act 2002 (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.derm.qld.gov.au/privacy

Drill log form

Queensland Government

1028887

Authorisation details
Registered number _____ Development permit number _____ Works reference number BAWBR 2.

SECTION A—LOCATION DETAILS
Name of landholder SYNDICATED METALS LTD Phone No. _____
Postal address GPO BOX 2810, PERTH WA Postcode 6000
Real property address MT BARBERA, MT ISA QLD Postcode 4825
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 379912 Northing 7741279 Zone 54K

SECTION B—BORE COMPLETION DETAILS
Date commenced 4/10/14
Date completed 4/10/14

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☑ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
203	0	14

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	100	CLASS 12	0	3

SECTION F—CENTRALISERS TYPE

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
SLOTS	100	2.5	2	3

SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
CEMENT	203	100	0	1
BENTONITE	203	100	1	2
4-8mm SAND	203	100	2	3

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) MINING

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	1	RIVER STONE	
1	14	DOLERITE	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
			DRY

Conductivity(EC) pH

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres) Depth to pump suction or bottom of drill stem (metres)
Type of test used ☑ Air ☐ Bail ☐ Pump
Est. supply (litres/second) Duration of test (hours) Drawdown level from surface (metres)

SECTION M—ARTESIAN BORE ON COMPLETION
Pressure (kPa) Free flow (litres/second) Temperature (°C)

SECTION N—REMARKS
MONITORING BORE
HOLE COLLAPSE DUE TO RIVER STONE.

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided in sections A to E and section H above is true, accurate and complete to the best of my knowledge and belief.
Driller MARK SERRA Driller's Licence No. 3250
Trainee Driller _____ Driller's Licence No. _____
Signature of Driller _____ Date 4/10/14
Contractor SERRA DRILLING PTY LTD

Department of Environment and Resource Management

White — forward to the Department of Environment and Resource Management. Pink — provide to landholder. Blue — Driller to retain.

The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 315 of the Water Act 2000. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the Public Records Act 2002 (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.derm.qld.gov.au/privacy

Drill log form

Queensland Government

1028886

Authorisation details
Registered number _____ Development permit number _____ Works reference number BAWBR 3

SECTION A—LOCATION DETAILS
Name of landholder SYNDICATED METALS LTD Phone No. _____
Postal address GPO BOX 2810, PERTH WA Postcode 6000
Real property address MT BARUSERRA, MT ISA QLD Postcode 4825
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 379991 Northing 7264485 Zone 54K

SECTION B—BORE COMPLETION DETAILS
Date commenced 4/10/14
Date completed 4/10/14

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☑ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
203	0	14

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	100	CLASS 12	0	4

SECTION F—CENTRALISERS TYPE

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
SLOTS	100	2.5	3	4

SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
CEMENT	203	100	0	2
BENTONITE	203	100	2	3
4-8 mm SAND	203	100	3	4

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) MINING

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	1	RIVER STONE	
1	14	DOLERITE.	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
			DRY

Conductivity(EC) _____ pH _____

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level _____ (metres) Depth to pump suction or bottom of drill stem _____ (metres)
Type of test used ☐ Air ☐ Bail ☐ Pump
Est. supply _____ (litres/second) Duration of test _____ (hours) Drawdown level from surface _____ (metres)

SECTION M—ARTESIAN BORE ON COMPLETION
Pressure _____ (kPa) Free flow _____ (litres/second) Temperature _____ (°C)

SECTION N—REMARKS
MONITORING BORE.
HOLE COLLAPSE DUE TO RIVER STONE

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided in sections A to E and section H above is true, accurate and complete to the best of my knowledge and belief.
Driller MARK SERRA Driller's Licence No. 3250
Trainee Driller _____ Driller's Licence No. _____
Signature of Driller _____ Date 4/10/14
Contractor SERRA DRILLING PTY LTD

White — forward to the Department of Environment and Resource Management. Pink — provide to landholder. Blue — Driller to retain.

epartment of Environment and Resource Management
e information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 315 of the Water Act 2000. Your personal details will be accessed only by authorised officers within this department. It will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the Public Records Act 2002 (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please at www.derm.qld.gov.au/privacy.

Drill log form

Queensland Government

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sampled

Authorisation details
Registered number _____ Development permit number _____ Works reference number WB "E"

SECTION A—LOCATION DETAILS
Name of landholder SYNDICATED METALS LTD Phone No. _____
Postal address GPO BOX 2810, PERTH WA Postcode 6000
Real property address MT BARUSERRA, MT ISA QLD Postcode 4825
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 380026 Northing 7739835 Zone 54K

SECTION B—BORE COMPLETION DETAILS
Date commenced 26/9/14
Date completed 26/9/14

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☑ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
203	0	83

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	142	CLASS 12	0	85

SECTION F—CENTRALISERS TYPE

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
SLOTS	142	2.5	28	83

SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
CEMENT	203	142	0	12
BENTONITE	203	142	12	14
4-8 mm SAND	203	142	14	83

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) MINING

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	11	DECOMPOSED SCHIST	
11	29	BANDED BASALT	
29	31	FRACTURED BASALT	0.5
31	46	BASALT	
46	47	FRACTURED BASALT	0.3
47	83	BASALT / DOLERITE.	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
29	28.1	0.5	
46		0.3	

Conductivity(EC) 1162 pH _____

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level 28.1 (metres) Depth to pump suction or bottom of drill stem 83 (metres)
Type of test used ☑ Air ☐ Bail ☐ Pump
Est. supply 0.8 (litres/second) Duration of test 2 (hours) Drawdown level from surface _____ (metres)

SECTION M—ARTESIAN BORE ON COMPLETION
Pressure _____ (kPa) Free flow _____ (litres/second) Temperature _____ (°C)

SECTION N—REMARKS
PLACE PUMP SUCTION
@ 60 m

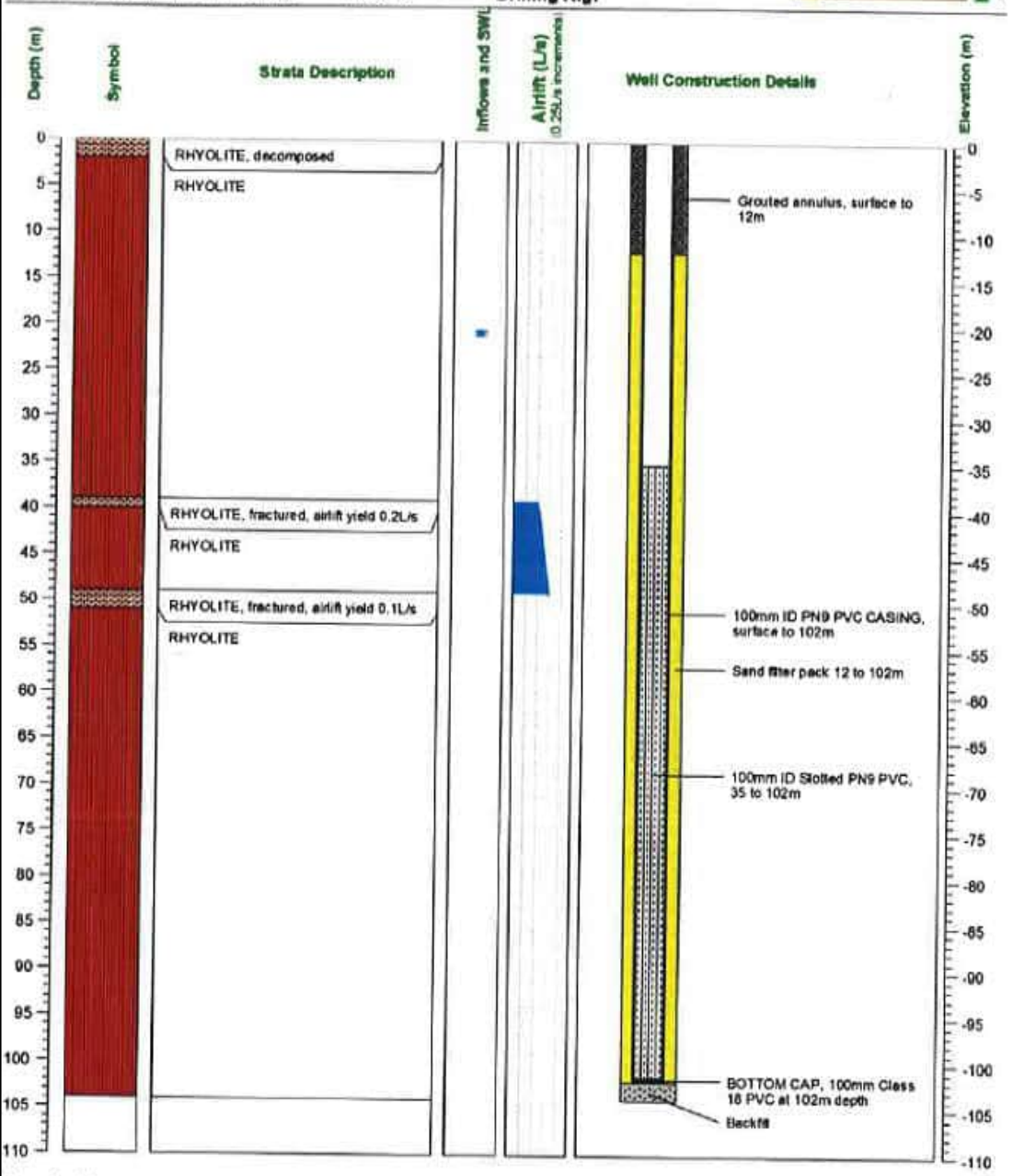
SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided in sections A to E and section H above is true, accurate and complete to the best of my knowledge and belief.
Driller MARK SERRA Driller's Licence No. 3250
Trainee Driller PETER SERRA / MORGAN GUNN Driller's Licence No. _____
Signature of Driller _____ Date 26/9/14
Contractor SERRA DRILLING PTY LTD

White — forward to the Department of Environment and Resource Management. Pink — provide to landholder. Blue — Driller to retain.

epartment of Environment and Resource Management
e information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 315 of the Water Act 2000. Your personal details will be accessed only by authorised officers within this department. It will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the Public Records Act 2002 (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please at www.derm.qld.gov.au/privacy.

Borehole No: BAWB05
Location: Barbara **Date Drilled:** 1/2/2014
Easting: 380948 **Northing:** 7740252
Method: Rotary Air Blast **Driller:** M Serra

Client: Syndicated Metals/Copperchem
Project:
GL Elev (m):
Drilling Rig:



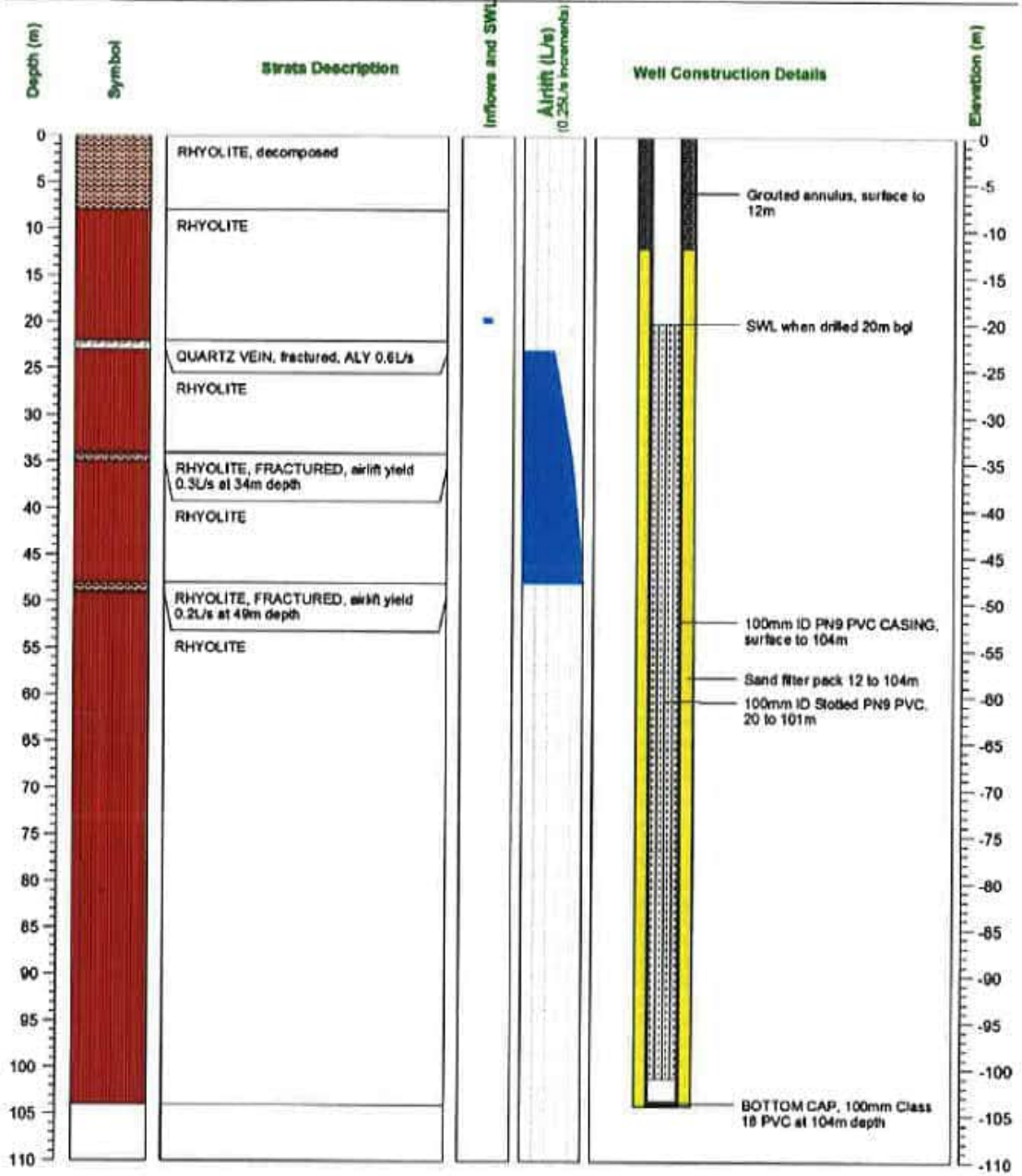
Page 1 of 1 **Notes:**

Datum:GDA94

Barbara Project
Strata description compiled by driller

Borehole No: BAWB01
Location: Barbara **Date Drilled:** 31/1/2014
Easting: 380432 **Northing:** 7741097
Method: Rotary Air Blast **Driller:** M Serra

Client: Syndicated Metals/Copperchem
Project:
GL Elev (m):
Drilling Rig:



Page 1 of 1 **Notes:**

Datum:GDA94

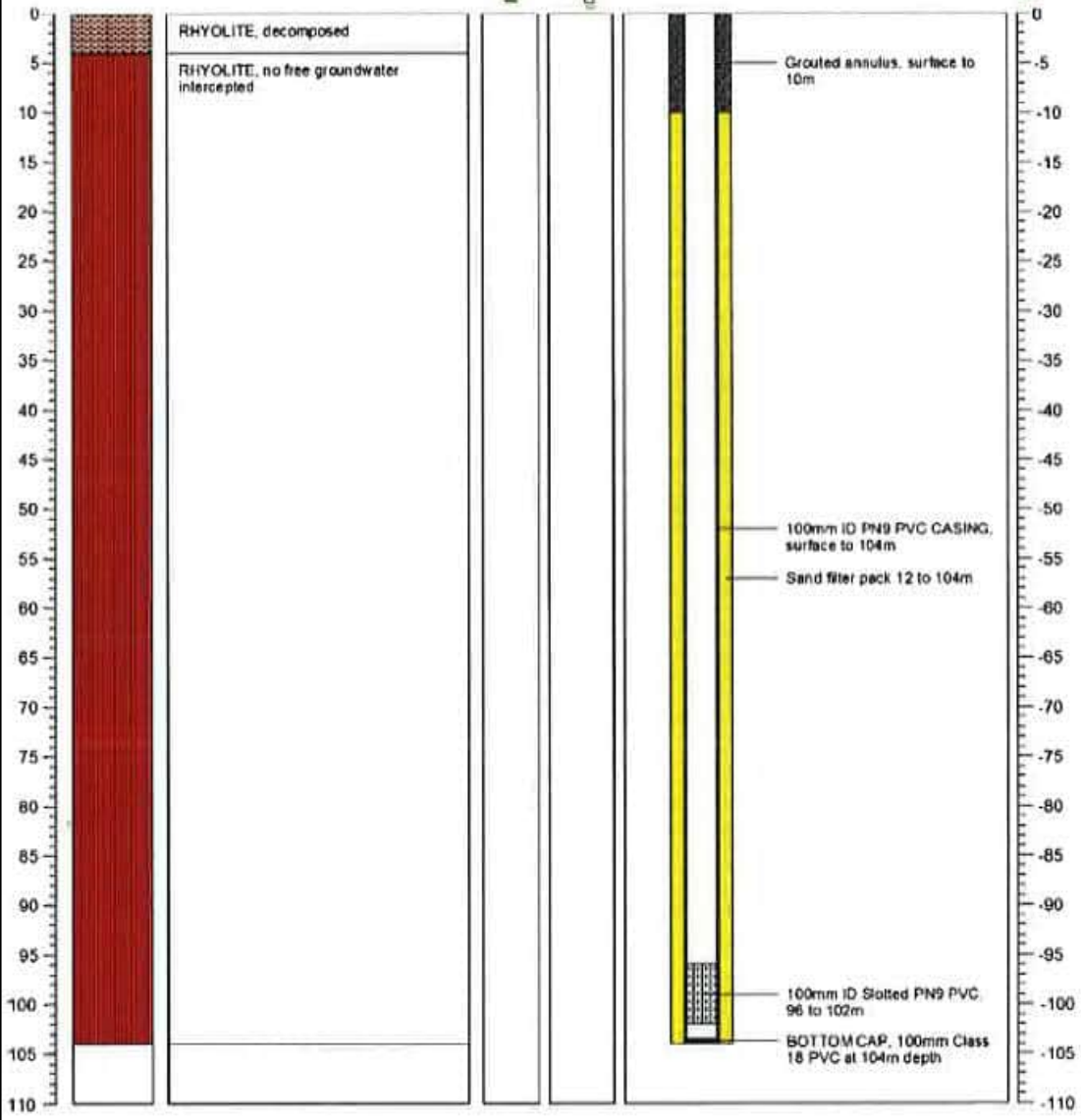
Barbara Project
Strata description compiled by driller

Borehole No: BAWB02

Client: Syndicated Metals/Copperchem

Location: Barbara **Date Drilled:** 2/2/2014
Easting: 379480 **Northing:** 7742395
Method: Rotary Air Blast **Driller:** M Serra

Project:
GL Elev (m):
Drilling Rig:



Page 1 of 1

Notes:

Datum:GDA94

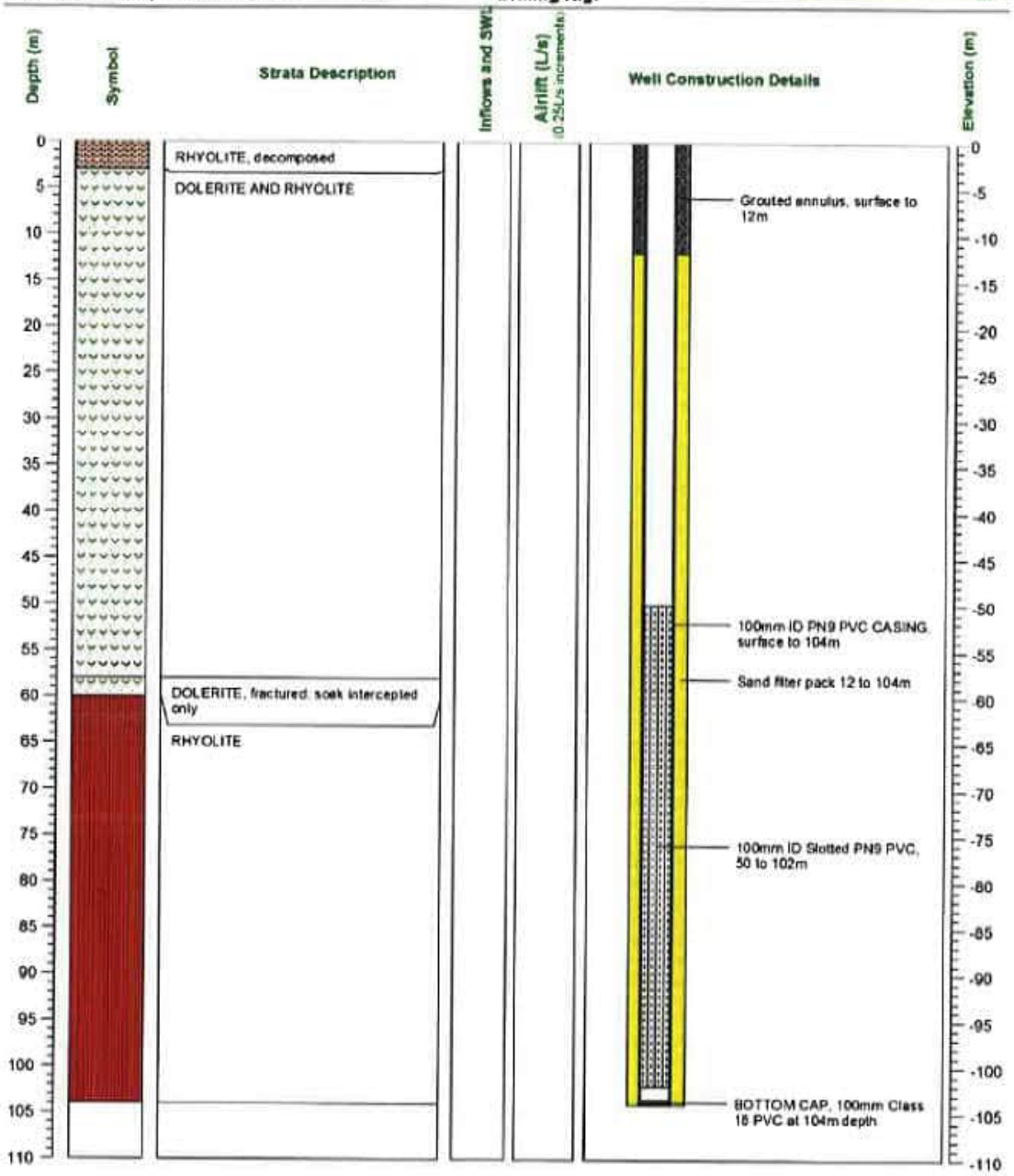
Barbara Project
Strata description compiled by driller

Borehole No: BAWB03

Client: Syndicated Metals/Copperchem

Location: Barbara **Date Drilled:** 26/1/2014
Easting: 379834 **Northing:** 7741692
Method: Rotary Air Blast **Driller:** M Serra

Project:
GL Elev (m):
Drilling Rig:



Page 1 of 1

Notes:

Datum:GDA94

Barbara Project
Strata description compiled by driller

Borehole No: BAWB04

Location: Barbara **Date Drilled:** 301/2014

Easting: 380043 **Northing:** 7742054

Method: Rotary Air Blast **Driller:** M Serra

Client: Syndicated Metals/Copperchem

Project:

GL Elev (m):

Drilling Rig:

Depth (m)	Symbol	Strata Description	Inflows and Swell	AirWR (L/s) (0.25L/s increments)	Well Construction Details	Elevation (m)
0		RHYOLITE, decomposed				0
5		RHYOLITE, weathered				-5
10		RHYOLITE, no free groundwater intercepted				-10
15						-15
20						-20
25						-25
30						-30
35						-35
40						-40
45						-45
50					100mm ID PN9 PVC CASING, surface to 100m	-50
55					Gravel filter pack 12 to 104m	-55
60						-60
65						-65
70						-70
75						-75
80						-80
85						-85
90						-90
95					100mm ID Slotted PN9 PVC, 94 to 100m	-95
100					BOTTOM CAP, 100mm Class 18 PVC at 100m depth	-100
105					Backfill	-105
110						-110

Grouted annulus, surface to 12m

Notes:

Datum:GDA94

Barbara Project
Strata description compiled by driller

Drill log form

1028993

Queensland Government

Authorisation details

Registered number ..... Development permit number ..... Works reference number BAR 065

SECTION A—LOCATION DETAILS

Name of landholder SYNDICATED METALS LTD Phone No. 6000

Postal address GPO BOX 2810, PERTH WA Postcode 4825

Real property address MT BARBARA, MT ISA QLD Postcode

Real property description Lot ..... Plan ..... or Bore location GPS. Latitude ..... Longitude ..... Datum .....

Easting 038082 Northing 7741711 Zone 54K

SECTION B—BORE COMPLETION DETAILS

Date commenced 4/2/14

Date completed 5/2/14

SECTION C—DRILLING METHOD

☐ Rotary mud ☐ Cable tool

☐ Auger ☑ Rotary air

☐ Other .....

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
200	0	127

SECTION I—BORE PURPOSE

☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial

☐ Urban ☑ Industrial Other (please specify) MINING

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	1	DECOMPOSED RHYOLITE	
1	33	RHYOLITE	
33	35	FRACTURED RHYOLITE	* 0.6
35	38	FRACTURED RHYOLITE	* 4
38	127	RHYOLITE.	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
33	21M	0.6	POTABLE
35		4	

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	142	CLASS 12	0	127

SECTION L—SUB ARTESIAN BORE ON COMPLETION

Conductivity(EC) 960 µS pH

Depth to standing water level from ground level 21 (metres) Depth to pump suction or bottom of drill stem 127 (metres)

Type of test used ☑ Air ☐ Bail ☐ Pump

Est. supply (litres/second) Duration of test (hours) Drawdown level from surface (metres)

SECTION M—ARTESIAN BORE ON COMPLETION

Pressure (kPa) Free flow (litres/second) Temperature (°C)

SECTION F—CENTRALISERS

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
SLOTS	142	3	30	127

SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
~~CEMENT~~	200	142	0	6
FOAM				

SECTION N—REMARKS

NOT FOR PERMANENT WATER SUPPLY, PLACE PUMP SECTION @ 60m.

SECTION O—CERTIFICATION

I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided in sections A to E and section H above is true, accurate and complete to the best of my knowledge and belief.

Driller MARK SERRA Driller's Licence No. 3250

Trainee Driller ..... Driller's Licence No. .....

Signature of Driller ..... Date 5/2/14

Contractor SERRA DRILLING PTY LTD

Department of Environment and Resource Management

White — forward to the Department of Environment and Resource Management. Pink — provide to landholder. Blue — Driller to retain

The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 193 of the Water Act 2000. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the Public Records Act 2002 (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.derm.qld.gov.au/privacy

Drill log form

Queensland Government

1028992

Authorisation details
Registered number: Development permit number: Works reference number: BARC 071

SECTION A—LOCATION DETAILS
Name of landholder: SYNDICATED METALS LTD Phone No.:
Postal address: GPO BOX 2810, PERTH WA Postcode: 6000
Real property address: MT BARBARA, MT ISA QLD Postcode: 4825
Real property description Lot: Plan: or Bore location GPS. Latitude: Longitude: Datum:
Easting: 0379859 Northing: 7741935 Zone: 54K

SECTION B—BORE COMPLETION DETAILS
Date commenced: 3/2/14
Date completed: 4/2/14

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☑ Rotary air
☐ Other

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
200	0	146

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	142	CLASS 18	0	146

SECTION F—CENTRALISERS TYPE

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
SLOTS	142	3	18	146

SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
Form	200	142	0	6

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☑ Industrial Other (please specify): MINING

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	3	DECOMPOSED RHORLITE	
3	19	RHORLITE	
19	22	FRACTURED RHORLITE	* 0.5
22	108	RHORLITE	
108	109	FRACTURED RHORLITE	* 0.3
109	146	RHORLITE.	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
19	15m	0.5	POTABLE.
108		0.3	

Conductivity(EC): 980 ms pH:

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level: 15 (metres)
Depth to pump suction or bottom of drill stem: 146 (metres)
Type of test used: ☑ Air ☐ Bail ☐ Pump
Est. supply: 0.7 (litres/second) Duration of test: 2 (hours) Drawdown level from surface: (metres)

SECTION M—ARTESIAN BORE ON COMPLETION
Pressure: (kPa) Free flow: (litres/second) Temperature: (°C)

SECTION N—REMARKS
NOT FOR PERMANANT WATER SOURCE, PLACE PUMP SUCTION @ 120 m

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided in sections A to E and section H above is true, accurate and complete to the best of my knowledge and belief.
Driller: MARK SERRA Driller's Licence No.: 3250
Trainee Driller: Driller's Licence No.:
Signature of Driller: Date: 4/2/14
Contractor: SERRA DRILLING PTY LTD

The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 313 of the *Water Act 2000*. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the *Public Records Act 2002* (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.derm.qld.gov.au/privacy.

Drill log form

Queensland Government

1028991

Authorisation details
Registered number: Development permit number: Works reference number: BAWB 02

SECTION A—LOCATION DETAILS
Name of landholder: SYNDICATED METAL LTD Phone No.:
Postal address: GPO BOX 2810 PERTH WA Postcode: 6000
Real property address: MT BARBARA, MT ISA QLD Postcode: 4825
Real property description Lot: Plan: or Bore location GPS. Latitude: Longitude: Datum:
Easting: 0379480 Northing: 7742395 Zone: 54K

SECTION B—BORE COMPLETION DETAILS
Date commenced: 2/2/14
Date completed: 2/2/14

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☑ Rotary air
☐ Other

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
200	0	104

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	142	CLASS 12	0	102

SECTION F—CENTRALISERS TYPE

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
SLOTS	142	3	96	102

SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
CEMENT	200	142	0	10
4-8 mm GRAVEL/SAND	200	142	10	102

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☑ Industrial Other (please specify): MINING.

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	4	DECOMPOSED RHORLITE	
4	104	RHORLITE	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)

Conductivity(EC): pH:

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level: (metres)
Depth to pump suction or bottom of drill stem: 102 (metres)
Type of test used: ☑ Air ☐ Bail ☐ Pump
Est. supply: (litres/second) Duration of test: (hours) Drawdown level from surface: (metres)

SECTION M—ARTESIAN BORE ON COMPLETION
Pressure: (kPa) Free flow: (litres/second) Temperature: (°C)

SECTION N—REMARKS
DRY MONITORING BORE

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided in sections A to E and section H above is true, accurate and complete to the best of my knowledge and belief.
Driller: MARK SERRA Driller's Licence No.: 3250
Trainee Driller: Driller's Licence No.:
Signature of Driller: Date: 2/2/14
Contractor: SERRA DRILLING PTY LTD

The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 313 of the *Water Act 2000*. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the *Public Records Act 2002* (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.derm.qld.gov.au/privacy.

Drill log form

Queensland Government

1028990

Authorisation details
Registered number: Development permit number: Works reference number: BAWB05

SECTION A—LOCATION DETAILS
Name of landholder: SYNDICATED METALS LTD Phone No.:
Postal address: GPO BOX 2810, PERTH WA Postcode: 6000
Real property address: MT BARBARA', MT ISA QLD Postcode: 4825
Real property description Lot: Plan: or Bore location GPS. Latitude: Longitude: Datum:
Easting: 0380948 Northing: 7740252 Zone: 54K

SECTION B—BORE COMPLETION DETAILS
Date commenced: 1/12/14
Date completed: 1/12/14

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☑ Rotary air
☐ Other

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
200	0	104

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	100	CLASS 18	0	102

SECTION F—CENTRALISERS TYPE

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
SLOTS	100	3	35	102

SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
CEMENT	200	100	0	12
4-8mm SAND	200	100	12	102

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☑ Industrial Other (please specify): MINING.

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	2	DECOMPOSED RHOKLITE	
2	39	RHOKLITE	
39	40	FRACTURED RHOKLITE	* 0.2
40	49	RHOKLITE	
49	51	FRACTURED RHOKLITE	* 0.1
51	104	RHOKLITE.	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
39	21m	0.2	
49		0.1	

Conductivity(EC): 960 mS pH:

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres): Depth to pump suction or bottom of drill stem: 102 (metres)
Type of test used: ☑ Air ☐ Bail ☐ Pump
Est. supply: 0.3 (litres/second) Duration of test: 2 (hours) Drawdown level from surface (metres):

SECTION M—ARTESIAN BORE ON COMPLETION
Pressure (kPa): Free flow (litres/second): Temperature (°C):

SECTION N—REMARKS
MONITORING BORE.

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided in sections A to E and section H above is true, accurate and complete to the best of my knowledge and belief.
Driller: MARK SERRA Driller's Licence No.: 3250
Trainee Driller: Driller's Licence No.:
Signature of Driller: Date: 1/12/14
Contractor: SERRA DRILLING PTY LTD.

Department of Environment and Resource Management

White — forward to the Department of Environment and Resource Management. Pink — provide to landholder. Blue — Driller to retain.

The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 313 of the Water Act 2000. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the Public Records Act 2002 (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.derm.qld.gov.au/privacy.

Drill log form

Queensland Government

1028989

Authorisation details
Registered number: Development permit number: Works reference number: BAWB 01

SECTION A—LOCATION DETAILS
Name of landholder: SYNDICATED METALS PTY LTD Phone No.:
Postal address: GPO BOX 2810, PERTH WA Postcode: 6000
Real property address: MT BARBARA, MT ISA QLD Postcode: 4825
Real property description Lot: Plan: or Bore location GPS. Latitude: Longitude: Datum:
Easting: 0380432 Northing: 7741097 Zone: 54K

SECTION B—BORE COMPLETION DETAILS
Date commenced: 30/01/14
Date completed: 31/01/14

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☑ Rotary air
☐ Other

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
200	0	104

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	100	CLASS 9	0	104

SECTION F—CENTRALISERS TYPE

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
SLOTS	100	3	20	101

SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
CEMENT	200	100	0	12
4-8mm SAND	200	100	12	101

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☑ Industrial Other (please specify): MINING.

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	8	DECOMPOSED RHOKLITE	
8	22	RHOKLITE	
22	23	FRACTURED QUARTZ	* 0.5
23	34	RHOKLITE	
34	35	FRACTURED RHOKLITE	* 0.3
35	48	RHOKLITE	
48	49	FRACTURED RHOKLITE	* 0.2
49	104	RHOKLITE.	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
23		0.5	
34	20m	0.3	POTABLE
48		0.2	

Conductivity(EC): 920 mS pH:

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level: 20 (metres) Depth to pump suction or bottom of drill stem: 101 (metres)
Type of test used: ☑ Air ☐ Bail ☐ Pump
Est. supply: 1 (litres/second) Duration of test: 2 (hours) Drawdown level from surface (metres):

SECTION M—ARTESIAN BORE ON COMPLETION
Pressure (kPa): Free flow (litres/second): Temperature (°C):

SECTION N—REMARKS
MONITORING BORE.

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided in sections A to E and section H above is true, accurate and complete to the best of my knowledge and belief.
Driller: MARK SERRA Driller's Licence No.: 3250
Trainee Driller: Driller's Licence No.:
Signature of Driller: Date: 31/01/14
Contractor: SERRA DRILLING PTY LTD

Department of Environment and Resource Management

White — forward to the Department of Environment and Resource Management. Pink — provide to landholder. Blue — Driller to retain.

The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 313 of the Water Act 2000. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the Public Records Act 2002 (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.derm.qld.gov.au/privacy.

Drill log form

Queensland Government

1028988

Authorisation details
Registered number ____ Development permit number ____ Works reference number BAWB04

SECTION A—LOCATION DETAILS
Name of landholder: SYNDICATED METALS LTD — Phone No.
Postal address: GPO BOX 2810, PERTH WA — Postcode 6000
Real property address: MT BARBARA, MT ISA — Postcode 4825
Real property description Lot ____ Plan ____ or Bore location GPS. Latitude ____ Longitude ____ Datum ____
Easting 0380043 Northing 7242054 Zone 54K

SECTION B—BORE COMPLETION DETAILS
Date commenced 29/01/14
Date completed 30/01/14

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☑ Rotary air
☐ Other

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
200	0	104

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	100	CLASS 9	0	100

SECTION F—CENTRALISERS TYPE

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
SLOTS	100	3	94	100

SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
CEMENT	200	100	0	12
4-8mm RIVER GRAVEL	200	100	12	100

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☑ Industrial Other (please specify) MINING.

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	2	DECOMPOSED RHOMLITE	
2	6	WEATHERED RHOMLITE	
6	104	RHOMLITE.	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)

Conductivity(EC) pH

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres) — Depth to pump suction or bottom of drill stem 100 (metres)
Type of test used ☑ Air ☐ Bail ☐ Pump
Est. supply (litres/second) — Duration of test (hours) — Drawdown level from surface (metres)

SECTION M—ARTESIAN BORE ON COMPLETION
Pressure (kPa) — Free flow (litres/second) — Temperature (°C)

SECTION N—REMARKS
DRY MONITORING BORE.

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided in sections A to E and section H above is true, accurate and complete to the best of my knowledge and belief.
Driller MARK SERRA Driller's Licence No. 3250
Trainee Driller ____ Driller's Licence No. ____
Signature of Driller ____ Date 30/01/14
Contractor SERRA DRILLING PTY LTD

Department of Environment and Resource Management

White — forward to the Department of Environment and Resource Management. Pink — provide to landholder. Blue — Driller to retain.

The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 313 of the *Water Act 2000*. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the *Public Records Act 2002* (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.derm.qld.gov.au/privacy.

Drill log form

Queensland Government

1028987

Authorisation details
Registered number ____ Development permit number ____ Works reference number BAWB03

SECTION A—LOCATION DETAILS
Name of landholder: SYNDICATED METALS LTD — Phone No.
Postal address: GPO BOX 2810, PERTH WA — Postcode 6000
Real property address: MT BARBARA, MT ISA — Postcode 4825
Real property description Lot ____ Plan ____ or Bore location GPS. Latitude ____ Longitude ____ Datum ____
Easting 0379834 Northing 7241692 Zone 54K

SECTION B—BORE COMPLETION DETAILS
Date commenced 26/01/2014
Date completed / /

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☑ Rotary air
☐ Other

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
200	0	104

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	100	CLASS 9	0	102

SECTION F—CENTRALISERS TYPE

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
SLOTS	100	3	50	102

SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
CEMENT	200	100	0	12
4-8 mm RIVER GRAVEL	200	100	12	102

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☑ Industrial Other (please specify) MINING

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	3	DECOMPOSED ROLLITE/ DOLLARITE.	
3	58	DOLLARITE/RHOMOLITE	
58	60	FRACTURED DOLLARITE * SOAK	
60	104	RHOMOLITE.	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)

Conductivity(EC) pH

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres) — Depth to pump suction or bottom of drill stem 102 (metres)
Type of test used ☑ Air ☐ Bail ☐ Pump
Est. supply (litres/second) — Duration of test 4 (hours) — Drawdown level from surface (metres)

SECTION M—ARTESIAN BORE ON COMPLETION
Pressure (kPa) — Free flow (litres/second) — Temperature (°C)

SECTION N—REMARKS
MONITORING BORE. DRY

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided in sections A to E and section H above is true, accurate and complete to the best of my knowledge and belief.
Driller MARK SERRA Driller's Licence No. 3250
Trainee Driller ____ Driller's Licence No. ____
Signature of Driller ____ Date 26/01/14
Contractor SERRA DRILLING PTY LTD

Department of Environment and Resource Management

White — forward to the Department of Environment and Resource Management. Pink — provide to landholder. Blue — Driller to retain.

The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 313 of the *Water Act 2000*. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the *Public Records Act 2002* (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.derm.qld.gov.au/privacy.

Water bore drilling log

Barbara Seepage Bores

Queensland Government

2003994

Authorisation details
Registered number _____ Development permit number _____ Works reference number _____

SECTION A—LOCATION DETAILS
Name of landholder: Round Oak — Phone No. _____
Postal address _____ Postcode _____
Real property address: Barbara Copper Project — Postcode 4825
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 340085 Northing 7241042 Zone _____

SECTION B—BORE COMPLETION DETAILS
Date commenced 12/7/19
Date completed 16/7/19

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☒ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
195	0	6

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	125	4.19	0	6

SECTION F—CENTRALISERS

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
PVC	125	1.0	1	5

SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
Cement	195	125	0	0.5
Bentonite	195	125	0.5	1
Gravel Pack	195	125	1	6
		Top Cement Pad		

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) Seepage Bore

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	6	Granite	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
	Dry		

Conductivity (µS/cm) _____ pH _____

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres) _____ Depth to pump suction or bottom of drill stem (metres) _____
Type of test used ☐ Air ☐ Bail ☐ Pump
Estimated supply (litres/second) _____ Duration of test (hours) _____ Drawdown level from surface (metres) _____

SECTION M—ARTESIAN BORE ON COMPLETION
Shut-in pressure (kPa) _____ Free flow (litres/second) _____ Temperature (°C) _____

SECTION N—REMARKS
SB1A

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.
Driller R Watkins Driller's licence no. 3740
Trainee driller _____ Driller's licence no. _____
Signature of driller _____ Date 22/7/19
Contractor Kelly drilling

Department of Natural Resources and Mines

White — foward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain

The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 313 of the *Water Act 2000*. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the *Public Records Act 2002 (Qld)* and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.dnrm.qld.gov.au.

Water bore drilling log

Queensland Government

2003995

Authorisation details
Registered number _____ Development permit number _____ Works reference number _____

SECTION A—LOCATION DETAILS
Name of landholder: Round Oak — Phone No. _____
Postal address _____ Postcode _____
Real property address: Barbara Copper Project — Postcode 4825
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 340085 Northing 7241042 Zone _____

SECTION B—BORE COMPLETION DETAILS
Date commenced 16/7/19
Date completed 16/7/19

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☒ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
195	0	16

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	125	4.19	0	11

SECTION F—CENTRALISERS

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
PVC	125	1.0	5	15

SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
Cement	195	125	0	3
Bentonite	195	125	3	5
Gravel Pack	195	125	5	16
		Top Cement Pad		

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) _____

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	11	Granite	
11	11.5	Granite (water)	*
11.5	16	Granite	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
11	2	6.2	

Conductivity (µS/cm) 600 pH 6.5

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres) _____ Depth to pump suction or bottom of drill stem (metres) _____
Type of test used ☐ Air ☐ Bail ☐ Pump
Estimated supply (litres/second) _____ Duration of test (hours) _____ Drawdown level from surface (metres) _____

SECTION M—ARTESIAN BORE ON COMPLETION
Shut-in pressure (kPa) _____ Free flow (litres/second) _____ Temperature (°C) _____

SECTION N—REMARKS
SB1B

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.
Driller R Watkins Driller's licence no. 3740
Trainee driller _____ Driller's licence no. _____
Signature of driller _____ Date 19/7/19
Contractor Kelly drilling

Department of Natural Resources and Mines

White — foward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain

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Water bore drilling log

Queensland Government

2003992

Authorisation details
Registered number _____ Development permit number _____ Works reference number _____

SECTION A—LOCATION DETAILS
Name of landholder: Round Oak — Phone No. _____
Postal address _____ Postcode _____
Real property address: Barbara copper Project — Postcode 4825
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 280011 Northing 7741115 Zone _____

SECTION B—BORE COMPLETION DETAILS
Date commenced 15 / 7 / 19
Date completed 16 / 7 / 19

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☒ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
195	0	6

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	125	PN9	0	6

SECTION F—CENTRALISERS

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
PVC	125	1.0	1	5

SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
Cement	195	125	0	0.5
Bentonite	195	125	0.5	1
Gravel Pack	195	125	1	6

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) Seepage Bore

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	6	Granite	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
		Dry	

Conductivity (µS/cm) _____ pH _____

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres) _____ Depth to pump suction or bottom of drill stem (metres) _____
Type of test used ☐ Air ☐ Bail ☐ Pump
Estimated supply (litres/second) _____ Duration of test (hours) _____ Drawdown level from surface (metres) _____

SECTION M—ARTESIAN BORE ON COMPLETION
Shut-in pressure (kPa) _____ Free flow (litres/second) _____ Temperature (°C) _____

SECTION N—REMARKS
SB2A

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.
Driller R Watkins Driller's licence no. 3470
Trainee driller _____ Driller's licence no. _____
Signature of driller _____ Date 25 / 7 / 19
Contractor Kelly drilling

Department of Natural Resources and Mines

White — foward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain

The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 313 of the *Water Act 2000*. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the *Public Records Act 2002 (Qld)* and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.dnrm.qld.gov.au.

Water bore drilling log

Queensland Government

2003993

Authorisation details
Registered number _____ Development permit number _____ Works reference number _____

SECTION A—LOCATION DETAILS
Name of landholder: Round Oak — Phone No. _____
Postal address _____ Postcode _____
Real property address: Barbara copper Project — Postcode 4825
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 280011 Northing 7741115 Zone _____

SECTION B—BORE COMPLETION DETAILS
Date commenced 15 / 7 / 19
Date completed 16 / 7 / 19

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☒ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
195	0	16

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	125	PN9	0	16

SECTION F—CENTRALISERS

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
PVC	125	1.0	5	16

SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
Cement	195	125	0	4
Bentonite	195	125	4	5
Gravel Pack	195	125	5	16
		TOP Cement		

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) _____

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	10	Granite	
10	10.5	Granite (Water)	*
10.5	16	Granite	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
10	5	0.7	

Conductivity (µS/cm) 500 pH 7.0

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres) _____ Depth to pump suction or bottom of drill stem (metres) _____
Type of test used ☐ Air ☐ Bail ☐ Pump
Estimated supply (litres/second) _____ Duration of test (hours) _____ Drawdown level from surface (metres) _____

SECTION M—ARTESIAN BORE ON COMPLETION
Shut-in pressure (kPa) _____ Free flow (litres/second) _____ Temperature (°C) _____

SECTION N—REMARKS
SB2B

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.
Driller R Watkins Driller's licence no. 3470
Trainee driller _____ Driller's licence no. _____
Signature of driller _____ Date 25 / 7 / 19
Contractor Kelly drilling

Department of Natural Resources and Mines

White — foward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain

The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 313 of the *Water Act 2000*. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the *Public Records Act 2002 (Qld)* and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.dnrm.qld.gov.au.

Water bore drilling log

Queensland Government

2003990

Authorisation details
Registered number _____ Development permit number _____ Works reference number _____

SECTION A—LOCATION DETAILS
Name of landholder: Round oak — Phone No. _____
Postal address: Po Box 28 Clancurry — Postcode 4824
Real property address: Barbara Copper project — Postcode 4825
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 279989 Northing 7274131 Zone _____

SECTION B—BORE COMPLETION DETAILS
Date commenced 14 / 7 / 19
Date completed 15 / 7 / 19

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☒ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
141	0	6

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	125	4MM	0	6

SECTION F—CENTRALISERS

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
PVC	125	1.0	1	5

SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
Cement	141	125	0	1
Bentonite	141	125	1	3
Gravel pack	141	125	3	6

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) Secondary Bore

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	6	Granite	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
		Dry	

Conductivity (µS/cm) _____ pH _____

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres) _____ Depth to pump suction or bottom of drill stem (metres) _____
Type of test used ☐ Air ☐ Bail ☐ Pump
Estimated supply (litres/second) _____ Duration of test (hours) _____ Drawdown level from surface (metres) _____

SECTION M—ARTESIAN BORE ON COMPLETION
Shut-in pressure (kPa) _____ Free flow (litres/second) _____ Temperature (°C) _____

SECTION N—REMARKS
SB3A

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.
Driller R Wetton Driller's licence no. 3740
Trainee driller _____ Driller's licence no. _____
Signature of driller _____ Date 15 / 7 / 19
Contractor Kelly drilling

Department of Natural Resources and Mines

White — foward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain

The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 313 of the *Water Act 2000*. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the *Public Records Act 2002 (Qld)* and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.dnrm.qld.gov.au.

Water bore drilling log

Queensland Government

2003991

Authorisation details
Registered number _____ Development permit number _____ Works reference number _____

SECTION A—LOCATION DETAILS
Name of landholder: Round oak — Phone No. _____
Postal address _____ Postcode _____
Real property address: Barbara copper project — Postcode 4825
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 279989 Northing 7274131 Zone _____

SECTION B—BORE COMPLETION DETAILS
Date commenced 14 / 7 / 19
Date completed 15 / 7 / 19

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☒ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
141	0	16

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	125	4MM	0	16

SECTION F—CENTRALISERS

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
PVC	125	1.0	5	15

SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
Cement	141	125	0	2
Bentonite	141	125	2	5
Gravel pack	141	125	5	16
top cement				

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) Secondary Bore

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	10	Granite	
10	14.5	Granite Water	*
14.5	16	Granite	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
14	2.8	0.7	

Conductivity (µS/cm) 300 pH 6.4

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres) _____ Depth to pump suction or bottom of drill stem (metres) _____
Type of test used ☐ Air ☐ Bail ☐ Pump
Estimated supply (litres/second) _____ Duration of test (hours) _____ Drawdown level from surface (metres) _____

SECTION M—ARTESIAN BORE ON COMPLETION
Shut-in pressure (kPa) _____ Free flow (litres/second) _____ Temperature (°C) _____

SECTION N—REMARKS
SB3B

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.
Driller R Watkins Driller's licence no. 3430
Trainee driller _____ Driller's licence no. _____
Signature of driller _____ Date 19 / 7 / 19
Contractor Kelly drilling

Department of Natural Resources and Mines

White — foward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain

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Water bore drilling log

Queensland Government

2003996

Authorisation details
Registered number _____ Development permit number _____ Works reference number _____

SECTION A—LOCATION DETAILS
Name of landholder: Round Oak
Phone No. _____
Postal address _____ Postcode _____
Real property address: Barbara copper Project Postcode 4825
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 280736 Northing 7740742 Zone _____

SECTION B—BORE COMPLETION DETAILS
Date commenced 25/7/19
Date completed 26/7/19

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☒ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
193	0	6

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	125	PN9	0	6

SECTION F—CENTRALISERS

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
PVC	125	1.0	1	5

SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
Cement	193	125	0	0.5
Bentonite	193	125	0.5	1
Sand pack	193	125	1	6
	193	125		

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) Seepage Bore

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	6	Granite	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
Dry			

Conductivity (µS/cm) _____ pH _____

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres) _____ Depth to pump suction or bottom of drill stem (metres) _____
Type of test used ☐ Air ☐ Bail ☐ Pump
Estimated supply (litres/second) _____ Duration of test (hours) _____ Drawdown level from surface (metres) _____

SECTION M—ARTESIAN BORE ON COMPLETION
Shut-in pressure (kPa) _____ Free flow (litres/second) _____ Temperature (°C) _____

SECTION N—REMARKS
SB4A

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.
Driller R Watkins Driller's licence no. 3470
Trainee driller _____ Driller's licence no. _____
Signature of driller _____ Date 29/7/19
Contractor Kelly drilling

Department of Natural Resources and Mines

White — foward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain

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Water bore drilling log

Queensland Government

2003997

Authorisation details
Registered number _____ Development permit number _____ Works reference number _____

SECTION A—LOCATION DETAILS
Name of landholder: Round Oak
Phone No. _____
Postal address _____ Postcode _____
Real property address: Barbara copper Project Postcode 4825
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 280736 Northing 7740742 Zone _____

SECTION B—BORE COMPLETION DETAILS
Date commenced 25/7/19
Date completed 26/7/19

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☒ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
193	0	16

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	125	PN9	0	14

SECTION F—CENTRALISERS

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
PVC	125	1.0	5	14

SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
Cement	193	125	0	0.5
Bentonite	193	125	0.5	1
Sand pack	193	125	1	16
	193	125		

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) Seepage Bore

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	9	Granite	
9	9.5	Granite (Water)	*
9.5	16	Granite	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
9	6	1.5	

Conductivity (µS/cm) 500 pH 7.0

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres) _____ Depth to pump suction or bottom of drill stem (metres) _____
Type of test used ☐ Air ☐ Bail ☐ Pump
Estimated supply (litres/second) _____ Duration of test (hours) _____ Drawdown level from surface (metres) _____

SECTION M—ARTESIAN BORE ON COMPLETION
Shut-in pressure (kPa) _____ Free flow (litres/second) _____ Temperature (°C) _____

SECTION N—REMARKS
SB4B

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.
Driller R Watkins Driller's licence no. 3470
Trainee driller _____ Driller's licence no. _____
Signature of driller _____ Date 29/7/19
Contractor Kelly drilling

Department of Natural Resources and Mines

White — foward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain

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Water bore drilling log

Queensland Government

2003998

Authorisation details
Registered number _____ Development permit number _____ Works reference number _____

SECTION A—LOCATION DETAILS
Name of landholder: Mound Oak
Phone No. _____
Postal address _____ Postcode _____
Real property address: Pacharca Copper Area, ect. Postcode 4825
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 138° 50' 54" Northing 22° 24' 32" Zone _____

SECTION B—BORE COMPLETION DETAILS
Date commenced 28 / 7 / 19
Date completed 28 / 7 / 19

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☐ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
400	0	6
250	6	110

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	300	6.4	0	8

SECTION F—CENTRALISERS

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
PVC	300	1.0	40	89

SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
Cement	400	300	0	6
Bentonite	250	300	6	8
Bentonite	250	300	8	9
Sand Pack	250	300	9	110

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) Dewatering Bore

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	2	Broken Granite	
2	11	Granite	
11	12	Granite Water	*
12	end	Granite	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
11	8	0.1	

Conductivity (µS/cm) 500 pH 6.9

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres)
Depth to pump suction or bottom of drill stem (metres)
Type of test used ☐ Air ☐ Bail ☐ Pump
Estimated supply (litres/second)
Duration of test (hours)
Drawdown level from surface (metres)

SECTION M—ARTESIAN BORE ON COMPLETION
Shut-in pressure (kPa)
Free flow (litres/second)
Temperature (°C)

SECTION N—REMARKS
Dewatering Bore

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.
Driller R. Watkins Driller's licence no. 3470
Trainee driller _____ Driller's licence no. _____
Signature of driller _____ Date 29 / 7 / 19
Contractor Kelly Drilling

Department of Natural Resources and Mines

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Water bore drilling log

Queensland Government

2003973

Authorisation details
Registered number _____ Development permit number _____ Works reference number _____

SECTION A—LOCATION DETAILS
Name of landholder: Copper Chase
Phone No. _____
Postal address _____ Postcode _____
Real property address: West Leichhardt Station Burke mine Lake Julianne Road Postcode 4825
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 138° 46' 00.5" Northing 20° 28' 30.0" Zone _____

SECTION B—BORE COMPLETION DETAILS
Date commenced 20 / 3 / 19
Date completed 25 / 3 / 19

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool
☐ Auger ☐ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	Location (metres) From	To
150	0	15
150	15	50

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	200	4.0	0	15
PVC	165	6.3	0	50

SECTION F—CENTRALISERS

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
Slots	165	1.0	26	50

SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
Cement	150	165	0	10
Bentonite	150	165	10	26
Cement				
Sand Pack				

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) _____

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed thus(*)
0	1	Brown Clay	
1	3	Brown Rock Sand	
3	4	Clay Sand Rock	
4	10	Brown Clay	
10	15	Brown Clay Sand Sandstone Pebbles	
15	17	Sand Salt Sand Stone	*
17	30	Broken Sand Stone	*
30	50	Sand Stone	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)
17	5	1.0	Potable

Conductivity (µS/cm) 100 pH 6.9

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level (metres)
Depth to pump suction or bottom of drill stem (metres)
Type of test used ☐ Air ☐ Bail ☐ Pump
Estimated supply (litres/second)
Duration of test (hours)
Drawdown level from surface (metres)

SECTION M—ARTESIAN BORE ON COMPLETION
Shut-in pressure (kPa)
Free flow (litres/second)
Temperature (°C)

SECTION N—REMARKS

SECTION O—CERTIFICATION
I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.
Driller Robert Watkins Driller's licence no. 3470
Trainee driller _____ Driller's licence no. _____
Signature of driller _____ Date / /
Contractor Kelly Drilling

Department of Natural Resources and Mines

White — foward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain

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Appendix C Registered bore reports

Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
37655	Sub-Artesian Facility	Abandoned and Destroyed	18/10/1971	Longreach	5300 - MT ISA C.

Details

Description	PALMERSON NO1		
Parish	1090 - CLACHAN		
Original Name	GOANNA HOLE		
Driller Name			
Drill Company			
Const Method	CABLE TOOL - E M JONES		
Bore Line			
D/O File No	515/010(152)	Polygon	
R/O File No	17/10/W/05	Equipment	NE
H/O File No	L39386B	RN of Bore Replaced	
Log Received Date		Data Owner	
Roles			

Location

Latitude	20-24-25	Basin	9130
Longitude	139-48-49	Sub-area	
GIS Latitude	-20.40682537	Lot	
GIS Longitude	139.8136911	Plan	
Easting	376213		
Northing	7743038	Map Scale	254 - 1: 250 000
Zone	54	Map Series	M - Metric Series
Accuracy		Map No	SF54-2
GPS Accuracy		Map Name	CLONCURRY
Checked	No	Prog Section	

Casing

2 *records for RN* 37655

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	18/10/1971	1	0.00	47.90	Steel Casing		WT - Wall Thickness	127
A	18/10/1971	2	13.10	47.20	Perforated or Slotted Casing		AP - Aperture Size	

Strata Logs

5 *records for RN* 37655

Rec	Top (m)	Bottom (m)	Strata Description

Bore Report

From Year:

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	47.24	SCHIST,SAND & METAPHORIC ROCKS
2			WITH FRACTURES
902			18/10/1971 SWL 50FT/15.24M
903			18/10/1971 DISCH: 400GPH
910	15.24	32.00	QUALITY DESCRIP/CONDUCT: POTABLE

Stratigraphies

1 *records for RN* 37655

Source	Rec	Top (m)	Bottom (m)	Strata Description
DNR	1			NOT RECORDED

Aquifers

1 *records for RN* 37655

Rec	Top (m)	Bottom (m)	Lithology	Date	SWL (m)	Flow	Quality	Yield (L/s)	Contr	Cond	Formation Name
1	15.30	32.00	CONG - Conglomerate							FR	NOT RECORDED

Pump Tests Part 1

0 *records for RN* 37655

Pump Tests Part 2

0 *records for RN* 37655

Bore Conditions

0 *records for RN* 37655

Elevations

0 *records for RN* 37655

Water Analysis Part 1

0 *records for RN* 37655

Water Analysis Part 2

0 *records for RN* 37655

Water Levels

1 *records for RN* 37655

Bore Report

From Year:

Pipe	Date	Time	Measure (m)	Meas	Point	Remark	Meas	Type	Coll Auth	Coll	Method	Project		Quality
A	18/10/1971		-15.24	N	Natural Surface		NR	Not Recorded	NR	NR	Not Recorded		130	Data is of unknown quality

Wire Line Logs

0 *records for RN* 37655

Field Measurements

0 *records for RN* 37655

Special Water Analysis

0 *records for RN* 37655

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
146948	Sub-Artesian Facility	Existing	26/01/2014	Longreach	5300 - MT ISA C.

Details

Description			
Parish	1090 - CLACHAN		
Original Name	BAWB03		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	LON/515/010 (0152)	Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	19/02/2014	Data Owner	DNR
Roles	Mine Monitoring		

Location

Latitude	20-24-37	Basin	9130
Longitude	139-50-54	Sub-area	
GIS Latitude	-20.41030732	Lot	1
GIS Longitude	139.8482889	Plan	AA29
Easting	379834		
Northing	7742692	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

4 *records for RN* 146948

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	26/01/2014	1	0.00	102.00	Polyvinyl Chloride			100
A	26/01/2014	2	50.00	102.00	Perforated or Slotted Casing	3.000	AP - Aperture Size	100
X	26/01/2014	3	0.00	12.00	Grout			200
X	26/01/2014	4	12.00	102.00	Gravel Pack	8.000	GR - Gravel Size	200

Bore Report

From Year:

Strata Logs

4 *records for RN* 146948

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	3.00	DECOMPOSED RHYOLITE AND DOLOMITE
2	3.00	58.00	DOLERITE AND RHYOLITE
3	58.00	60.00	FRACTURED RHYOLITE
4	60.00	104.00	RHYOLITE

Stratigraphies

0 *records for RN* 146948

Aquifers

0 *records for RN* 146948

Pump Tests Part 1

1 *records for RN* 146948

Pipe	Date	Rec	RN of Pumped Bore	Top (m)	Bottom (m)	Dist (m)	Meth	Test Types	Pump Type	Suction Set (m)	Q Prior to Test (l/s)	Dur of Q PR (mins)	Pres on Arriv (m)	Q on Arriv (l/s/)
A	26/01/2014	1	146948				PUM		AIR	102.00				

Pump Tests Part 2

1 *records for RN* 146948

Pipe	Date	Rec	Test Dur (mins)	SWL(m)	Recov Time (mins)	Resid DD (m)	Max DD or P RED (m)	Q at Max DD (l/s)	Time to Max DD (mins)	Max Q (l/s)	Calc Stat HD (m)	Design Yield (l/s)	Design BP (m)	Suct. Set (m)	Tmsy (m2/Day)	Stor
A	26/01/2014	1	240											102.00		

Bore Conditions

0 *records for RN* 146948

Elevations

0 *records for RN* 146948

Water Analysis Part 1

0 *records for RN* 146948

Bore Report

From Year:

Water Analysis Part 2	**0**	***records for RN***	**146948**
Water Levels	**0**	***records for RN***	**146948**
Wire Line Logs	**0**	***records for RN***	**146948**
Field Measurements	**0**	***records for RN***	**146948**
Special Water Analysis	**0**	***records for RN***	**146948**

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
146949	Sub-Artesian Facility	Existing	30/01/2014	Longreach	5300 - MT ISA C.

Details

Description			
Parish	1090 - CLACHAN		
Original Name	BAWB04		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	LON/515/010 (0152)	Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	19/02/2014	Data Owner	DNR
Roles	Mine Monitoring		

Location

Latitude	20-24-58	Basin	9130
Longitude	139-51-01	Sub-area	
GIS Latitude	-20.41608411	Lot	1
GIS Longitude	139.8502509	Plan	AA29
Easting	380043		
Northing	7742054	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

4 *records for RN* 146949

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	30/01/2014	1	0.00	100.00	Polyvinyl Chloride			100
A	30/01/2014	2	94.00	100.00	Perforated or Slotted Casing	3.000	AP - Aperture Size	100
X	30/01/2014	3	0.00	12.00	Grout			200
X	30/01/2014	4	12.00	100.00	Gravel Pack	4.000	GR - Gravel Size	200

Bore Report

From Year:

Strata Logs

3 *records for RN* 146949

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	2.00	DECOMPOSE RHYOLITE
2	2.00	6.00	WEATHERED RHYOLITE
3	6.00	104.00	RHYOLITE

Stratigraphies

0 *records for RN* 146949

Aquifers

0 *records for RN* 146949

Pump Tests Part 1

1 *records for RN* 146949

Pipe	Date	Rec	RN of Pumped Bore	Top (m)	Bottom (m)	Dist (m)	Meth	Test Types	Pump Type	Suction Set (m)	Q Prior to Test (l/s)	Dur of Q PR (mins)	Pres on Arriv (m)	Q on Arriv (l/s/)
A	30/01/2014	1	146949						AIR	100.00				

Pump Tests Part 2

1 *records for RN* 146949

Pipe	Date	Rec	Test Dur (mins)	SWL(m)	Recov Time (mins)	Resid DD (m)	Max DD or P RED (m)	Q at Max DD (l/s)	Time to Max DD (mins)	Max Q (l/s)	Calc Stat HD (m)	Design Yield (l/s)	Design BP (m)	Suct. Set (m)	Tmsy (m2/Day)	Stor
A	30/01/2014	1												100.00		

Bore Conditions

0 *records for RN* 146949

Elevations

0 *records for RN* 146949

Water Analysis Part 1

0 *records for RN* 146949

Water Analysis Part 2

0 *records for RN* 146949

Bore Report

From Year:

Water Levels	**0**	***records for RN***	**146949**
Wire Line Logs	**0**	***records for RN***	**146949**
Field Measurements	**0**	***records for RN***	**146949**
Special Water Analysis	**0**	***records for RN***	**146949**

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
146950	Sub-Artesian Facility	Existing	31/01/2014	Longreach	5300 - MT ISA C.

Details

Description			
Parish	1090 - CLACHAN		
Original Name	BAWB01		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	LON/515/010 (0152)	Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	19/02/2014	Data Owner	DNR
Roles	Mine Monitoring		

Location

Latitude	20-25-29	Basin	9130
Longitude	139-51-14	Sub-area	
GIS Latitude	-20.4247508	Lot	1
GIS Longitude	139.8539149	Plan	AA29
Easting	380432		
Northing	7741097	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

4 *records for RN* 146950

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	31/01/2014	1	0.00	104.00	Polyvinyl Chloride			100
A	31/01/2014	2	20.00	101.00	Perforated or Slotted Casing	3.000	AP - Aperture Size	100
X	31/01/2014	3	0.00	12.00	Grout			200
X	31/01/2014	4	12.00	101.00	Gravel Pack	8.000	GR - Gravel Size	200

Bore Report

From Year:

Strata Logs

8 *records for RN* 146950

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	8.00	DECOMPOSED RHYOLITE
2	8.00	22.00	RHYOLITE
3	22.00	23.00	FRACTURED QUARTZ
4	23.00	34.00	RHYOLITE
5	34.00	35.00	FRACTURED RHYOLITE
6	35.00	48.00	RHYOLITE
7	48.00	49.00	FRACTURED RHYOLITE
8	49.00	104.00	RHYOLITE

Stratigraphies

0 *records for RN* 146950

Aquifers

3 *records for RN* 146950

Rec	Top (m)	Bottom (m)	Lithology	Date	SWL (m)	Flow	Quality	Yield (L/s)	Contr	Cond	Formation Name
1	23.00		QUAR - Quartz	31/01/2014	-20.00	N	POTABLE	0.50	Y	FR	LEICHHARDT VOLCANICS
2	34.00		RHYO - Rhyolite, Acid Volcanic	31/01/2014	-20.00	N	POTABLE	0.50	Y	FR	
3	48.00		RHYO - Rhyolite, Acid Volcanic	31/01/2014	-20.00	N	POTABLE	0.20	Y	FR	

Pump Tests Part 1

1 *records for RN* 146950

Pipe	Date	Rec	RN of Pumped Bore	Top (m)	Bottom (m)	Dist (m)	Meth	Test Types	Pump Type	Suction Set (m)	Q Prior to Test (l/s)	Dur of Q PR (mins)	Pres on Arriv (m)	Q on Arriv (l/s/)
A	31/01/2014	1	146950				PUM		AIR	101.00				

Pump Tests Part 2

1 *records for RN* 146950

Bore Report

From Year:

Pipe	Date	Rec	Test Dur (mins)	SWL(m)	Recov Time (mins)	Resid DD (m)	Max DD or P RED (m)	Q at Max DD (l/s)	Time to Max DD (mins)	Max Q (l/s)	Calc Stat HD (m)	Design Yield (l/s)	Design BP (m)	Suct. Set (m)	Tmsy (m2/Day)	Stor
A	31/01/2014	1	120	-20.00				1.00						101.00		

Bore Conditions 0 *records for RN* 146950

Elevations 0 *records for RN* 146950

Water Analysis Part 1 0 *records for RN* 146950

Water Analysis Part 2 0 *records for RN* 146950

Water Levels 0 *records for RN* 146950

Wire Line Logs 0 *records for RN* 146950

Field Measurements 0 *records for RN* 146950

Special Water Analysis 0 *records for RN* 146950

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
146951	Sub-Artesian Facility	Existing	01/02/2014	Longreach	5300 - MT ISA C.

Details

Description			
Parish	1090 - CLACHAN		
Original Name	BAWB05		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	LON/515/010 (0152)	Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	19/02/2014	Data Owner	DNR
Roles	Mine Monitoring		

Location

Latitude	20-25-57	Basin	9130
Longitude	139-51-32	Sub-area	
GIS Latitude	-20.43242127	Lot	1
GIS Longitude	139.8588008	Plan	AA29
Easting	380948		
Northing	7740252	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

4 *records for RN* 146951

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	01/12/2014	1	0.00	102.00	Polyvinyl Chloride			100
A	01/12/2014	2	35.00	102.00	Perforated or Slotted Casing	3.000	AP - Aperture Size	100
X	01/12/2014	3	0.00	12.00	Grout			200
X	01/12/2014	4	12.00	102.00	Gravel Pack	8.000	GR - Gravel Size	200

Bore Report

From Year:

Strata Logs

6 *records for RN* 146951

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	2.00	DECOMPOSED RHYOLITE
2	2.00	39.00	RHYOLITE
3	39.00	40.00	FRACTURED RHYOLITE
4	40.00	49.00	RHYOLITE
5	49.00	51.00	FRACTURED RHYOLITE
6	51.00	104.00	RHYOLITE

Stratigraphies

0 *records for RN* 146951

Aquifers

2 *records for RN* 146951

Rec	Top (m)	Bottom (m)	Lithology	Date	SWL (m)	Flow	Quality	Yield (L/s)	Contr	Cond	Formation Name
1	39.00		RHYO - Rhyolite, Acid Volcanic	01/02/2014	-21.00	N		0.20	Y	FR	
2	49.00		RHYO - Rhyolite, Acid Volcanic	01/02/2014	-21.00	N		0.10	Y	FR	

Pump Tests Part 1

0 *records for RN* 146951

Pump Tests Part 2

0 *records for RN* 146951

Bore Conditions

0 *records for RN* 146951

Elevations

0 *records for RN* 146951

Water Analysis Part 1

0 *records for RN* 146951

Water Analysis Part 2

0 *records for RN* 146951

Bore Report

From Year:

Water Levels	**0**	***records for RN***	**146951**
Wire Line Logs	**0**	***records for RN***	**146951**
Field Measurements	**0**	***records for RN***	**146951**
Special Water Analysis	**0**	***records for RN***	**146951**

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
146952	Sub-Artesian Facility	Existing	02/02/2014	Longreach	5300 - MT ISA C.

Details

Description			
Parish	1090 - CLACHAN		
Original Name	BAWB02		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	LON/515/010 (0152)	Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	19/02/2014	Data Owner	DNR
Roles	Mine Monitoring		

Location

Latitude	20-24-47	Basin	9130
Longitude	139-50-42	Sub-area	
GIS Latitude	-20.41297048	Lot	1
GIS Longitude	139.8448793	Plan	AA29
Easting	379480		
Northing	7742395	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

4 *records for RN* 146952

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	02/02/2014	1	0.00	102.00	Polyvinyl Chloride			142
A	02/02/2014	2	96.00	102.00	Perforated or Slotted Casing	3.000	AP - Aperture Size	142
X	02/02/2014	3	0.00	10.00	Grout			200
X	02/02/2014	4	10.00	102.00	Gravel Pack	8.000	GR - Gravel Size	200

Bore Report

From Year:

Strata Logs

2 *records for RN* 146952

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	4.00	DECOMPOSED RHYOLITE
2	4.00	104.00	RHYOLITE

Stratigraphies

0 *records for RN* 146952

Aquifers

0 *records for RN* 146952

Pump Tests Part 1

1 *records for RN* 146952

Pipe	Date	Rec	RN of Pumped Bore	Top (m)	Bottom (m)	Dist (m)	Meth	Test Types	Pump Type	Suction Set (m)	Q Prior to Test (l/s)	Dur of Q PR (mins)	Pres on Arriv (m)	Q on Arriv (l/s/)
A	02/02/2014	1	146952						AIR	102.00				

Pump Tests Part 2

1 *records for RN* 146952

Pipe	Date	Rec	Test Dur (mins)	SWL(m)	Recov Time (mins)	Resid DD (m)	Max DD or P RED (m)	Q at Max DD (l/s)	Time to Max DD (mins)	Max Q (l/s)	Calc Stat HD (m)	Design Yield (l/s)	Design BP (m)	Suct. Set (m)	Tmsy (m2/Day)	Stor
A	02/02/2014	1												102.00		

Bore Conditions

0 *records for RN* 146952

Elevations

0 *records for RN* 146952

Water Analysis Part 1

0 *records for RN* 146952

Water Analysis Part 2

0 *records for RN* 146952

Bore Report

From Year:

Water Levels	**0**	***records for RN***	**146952**
Wire Line Logs	**0**	***records for RN***	**146952**
Field Measurements	**0**	***records for RN***	**146952**
Special Water Analysis	**0**	***records for RN***	**146952**

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
146953	Sub-Artesian Facility	Existing	04/02/2014	Longreach	5300 - MT ISA C.

Details

Description			
Parish	1090 - CLACHAN		
Original Name	BARC071		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	LON/515/010 (0152)	Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	19/02/2014	Data Owner	DNR
Roles	Water Supply		

Location

Latitude	20-25-02	Basin	9130
Longitude	139-50-55	Sub-area	
GIS Latitude	-20.41714711	Lot	1
GIS Longitude	139.8484773	Plan	AA29
Easting	379859		
Northing	7741935	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

2 *records for RN* 146953

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	04/02/2014	1	0.00	146.00	Polyvinyl Chloride			142
A	04/02/2014	2	18.00	146.00	Perforated or Slotted Casing	3.000	AP - Aperture Size	142

Strata Logs

6 *records for RN* 146953

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	3.00	DECOMPOSED RHYOLITE
2	3.00	19.00	RHYOLITE
3	19.00	22.00	FRACTURED RHYOLITE
4	22.00	108.00	RHYOLITE
5	108.00	109.00	FRACTURED RHYOLITE
6	109.00	146.00	RHYOLITE

Bore Report

From Year:

Stratigraphies

0 *records for RN* 146953

Aquifers

2 *records for RN* 146953

Rec	Top (m)	Bottom (m)	Lithology	Date	SWL (m)	Flow	Quality	Yield (L/s)	Contr	Cond	Formation Name
1	19.00		RHYO - Rhyolite, Acid Volcanic	04/02/2014	-15.00	N	POTABLE	0.50	Y	FR	
2	108.00		RHYO - Rhyolite, Acid Volcanic	04/02/2014	-15.00	N	POTABLE	0.30	Y	FR	

Pump Tests Part 1

1 *records for RN* 146953

Pipe	Date	Rec	RN of Pumped Bore	Top (m)	Bottom (m)	Dist (m)	Meth	Test Types	Pump Type	Suction Set (m)	Q Prior to Test (l/s)	Dur of Q PR (mins)	Pres on Arriv (m)	Q on Arriv (l/s/)
A	04/02/2014	1	146953				PUM		AIR	146.00				

Pump Tests Part 2

1 *records for RN* 146953

Pipe	Date	Rec	Test Dur (mins)	SWL(m)	Recov Time (mins)	Resid DD (m)	Max DD or P RED (m)	Q at Max DD (l/s)	Time to Max DD (mins)	Max Q (l/s)	Calc Stat HD (m)	Design Yield (l/s)	Design BP (m)	Suct. Set (m)	Tmsy (m2/Day)	Stor
A	04/02/2014	1	120	-15.00				0.70						146.00		

Bore Report

From Year:

Bore Conditions	0	*records for RN*	146953
Elevations	0	*records for RN*	146953
Water Analysis Part 1	0	*records for RN*	146953
Water Analysis Part 2	0	*records for RN*	146953
Water Levels	0	*records for RN*	146953
Wire Line Logs	0	*records for RN*	146953
Field Measurements	0	*records for RN*	146953
Special Water Analysis	0	*records for RN*	146953

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
146954	Sub-Artesian Facility	Existing	05/02/2014	Longreach	5300 - MT ISA C.

Details

Description			
Parish	1090 - CLACHAN		
Original Name	BARC065		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	LON/515/010 (0152)	Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	19/02/2014	Data Owner	DNR
Roles	Water Supply		

Location

Latitude	20-25-09	Basin	9130
Longitude	139-51-01	Sub-area	
GIS Latitude	-20.41918265	Lot	1
GIS Longitude	139.850315	Plan	AA29
Easting	380052		
Northing	7741711	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

2 *records for RN* 146954

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	05/02/2014	1	0.00	127.00	Polyvinyl Chloride			142
A	05/02/2014	2	30.00	127.00	Perforated or Slotted Casing	3.000	AP - Aperture Size	142

Strata Logs

5 *records for RN* 146954

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	1.00	DECOMPOSED RHYOLITE
2	1.00	33.00	RHYOLITE
3	33.00	35.00	FRACTURED RHYOLITE
4	35.00	38.00	FRACTURED RHYOLITE
5	38.00	127.00	RHYOLITE

Bore Report

From Year:

Stratigraphies

0 *records for RN* 146954

Aquifers

2 *records for RN* 146954

Rec	Top (m)	Bottom (m)	Lithology	Date	SWL (m)	Flow	Quality	Yield (L/s)	Contr	Cond	Formation Name
1	33.00		RHYO - Rhyolite, Acid Volcanic	05/02/2014	-21.00	N	POTABLE	0.60	Y	FR	
2	35.00		RHYO - Rhyolite, Acid Volcanic	05/02/2014	-21.00	N	POTABLE	4.00	Y	FR	

Pump Tests Part 1

1 *records for RN* 146954

Pipe	Date	Rec	RN of Pumped Bore	Top (m)	Bottom (m)	Dist (m)	Meth	Test Types	Pump Type	Suction Set (m)	Q Prior to Test (l/s)	Dur of Q PR (mins)	Pres on Arriv (m)	Q on Arriv (l/s/)
A	05/02/2014	1	146954						AIR	127.00				

Pump Tests Part 2

1 *records for RN* 146954

Pipe	Date	Rec	Test Dur (mins)	SWL(m)	Recov Time (mins)	Resid DD (m)	Max DD or P RED (m)	Q at Max DD (l/s)	Time to Max DD (mins)	Max Q (l/s)	Calc Stat HD (m)	Design Yield (l/s)	Design BP (m)	Suct. Set (m)	Tmsy (m2/Day)	Stor
A	05/02/2014	1		-21.00										127.00		

Bore Conditions

0 *records for RN* 146954

Bore Report

From Year:

Elevations	**0**	***records for RN***	**146954**
Water Analysis Part 1	**0**	***records for RN***	**146954**
Water Analysis Part 2	**0**	***records for RN***	**146954**
Water Levels	**0**	***records for RN***	**146954**
Wire Line Logs	**0**	***records for RN***	**146954**
Field Measurements	**0**	***records for RN***	**146954**
Special Water Analysis	**0**	***records for RN***	**146954**

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
163352	Sub-Artesian Facility	Existing	04/10/2014	Longreach	5300 - MT ISA C.

Details

Description	BOWBR1		
Parish	1090 - CLACHAN		
Original Name	BOWBR1		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING PTY LTD		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	LON/515/010 (0152)	Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	04/10/2014	Data Owner	
Roles	Mine Monitoring		

Location

Latitude	20-25-34	Basin	9130
Longitude	139-51-09	Sub-area	
GIS Latitude	-20.42617182	Lot	1
GIS Longitude	139.85255988	Plan	AA29
Easting	380292		
Northing	7740939	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

5 *records for RN* 163352

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	04/10/2014	1	0.00	6.00	Polyvinyl Chloride	6.300	WT - Wall Thickness	114
A	04/10/2014	2	5.00	6.00	Perforated or Slotted Casing	2.500	AP - Aperture Size	114
A	04/10/2014	3	5.00	6.00	Gravel Pack	6.000	GR - Gravel Size	203
X	04/10/2014	4	0.00	4.00	Grout			203
X	04/10/2014	5	4.00	5.00	Bentonite Seal			203

Bore Report

From Year:

Strata Logs

2 *records for RN* 163352

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	2.00	RIVER STONE
2	2.00	14.00	DOLERITE

Stratigraphies

0 *records for RN* 163352

Aquifers

0 *records for RN* 163352

Pump Tests Part 1

0 *records for RN* 163352

Pump Tests Part 2

0 *records for RN* 163352

Bore Conditions

0 *records for RN* 163352

Elevations

0 *records for RN* 163352

Water Analysis Part 1

0 *records for RN* 163352

Water Analysis Part 2

0 *records for RN* 163352

Water Levels

0 *records for RN* 163352

Wire Line Logs

0 *records for RN* 163352

Field Measurements

0 *records for RN* 163352

Special Water Analysis

0 *records for RN* 163352

From Year:

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From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
163353	Sub-Artesian Facility	Abandoned and Destroyed	25/09/2014	Longreach	5300 - MT ISA C.

Details

Description	WBA		
Parish	1090 - CLACHAN		
Original Name			
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING PTY LTD		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	LON/515/010 (0152)	**Polygon**	
R/O File No		**Equipment**	
H/O File No		**RN of Bore Replaced**	
Log Received Date	25/09/2014	**Data Owner**	
Roles	Mine Monitoring		

Location

Latitude	20-24-56	**Basin**	9130
Longitude	139-50-34	**Sub-area**	
GIS Latitude	-20.4156453	**Lot**	1
GIS Longitude	139.84286255	**Plan**	AA29
Easting	379272		
Northing	7742097	**Map Scale**	
Zone	54	**Map Series**	
Accuracy		**Map No**	
GPS Accuracy		**Map Name**	
Checked	Yes	**Prog Section**	

Casing

2 *records for RN* 163353

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
X	25/09/2014	1	0.00	6.00	Cement or Grout Plug			203
X	25/09/2014	2	6.00	83.00	Cuttings or other fill between casing and hole wall			203

Strata Logs

2 *records for RN* 163353

Rec	Top (m)	Bottom	Strata Description

From Year:

		(m)	
1	0.00	13.00	SCHIST, DECOMPOSED
2	13.00	83.00	DOLERITE

Stratigraphies
0 *records for RN* 163353

Aquifers
0 *records for RN* 163353

Pump Tests Part 1
0 *records for RN* 163353

Pump Tests Part 2
0 *records for RN* 163353

Bore Conditions
0 *records for RN* 163353

Elevations
0 *records for RN* 163353

Water Analysis Part 1
0 *records for RN* 163353

Water Analysis Part 2
0 *records for RN* 163353

Water Levels
0 *records for RN* 163353

Wire Line Logs
0 *records for RN* 163353

Field Measurements
0 *records for RN* 163353

Special Water Analysis
0 *records for RN* 163353

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
163354	Sub-Artesian Facility	Existing	26/09/2014	Longreach	5300 - MT ISA C.

Details

Description	WB E		
Parish	1090 - CLACHAN		
Original Name	WBE		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING PTY LTD		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	LON/515/010 (0152)	Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	26/09/2014	Data Owner	
Roles	Mine Monitoring		

Location

Latitude	20-26-43	Basin	9130
Longitude	139-50-59	Sub-area	
GIS Latitude	-20.44516341	Lot	1
GIS Longitude	139.84986922	Plan	AA29
Easting	380026		
Northing	7738835	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

5 *records for RN* 163354

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	26/09/2014	1	0.00	83.00	Polyvinyl Chloride	7.650	WT - Wall Thickness	140
A	26/09/2014	2	28.00	83.00	Perforated or Slotted Casing	2.500	AP - Aperture Size	140
A	26/09/2014	3	14.00	83.00	Gravel Pack	6.000	GR - Gravel Size	203
X	26/09/2014	4	0.00	12.00	Grout			203
X	26/09/2014	5	12.00	14.00	Cuttings or other fill between casing and hole wall			203

Bore Report

From Year:

Strata Logs

6 *records for RN* 163354

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	11.00	SCHIST, DECOMPOSED
2	11.00	29.00	BASALT, BAKED
3	29.00	31.00	BASALT, FRACTURED
4	31.00	46.00	BASALT
5	46.00	47.00	BASALT, FRACTURED
6	47.00	83.00	BASALT / DOLERITE

Stratigraphies

0 *records for RN* 163354

Aquifers

1 *records for RN* 163354

Rec	Top (m)	Bottom (m)	Lithology	Date	SWL (m)	Flow	Quality	Yield (L/s)	Contr	Cond	Formation Name
1	29.00		BSLT - Basic Volcanic	26/09/2014	-28.10	N	1162US/CM	0.80	Y	FR	ARGYLLA FORMATION

Pump Tests Part 1

1 *records for RN* 163354

Pipe	Date	Rec	RN of Pumped Bore	Top (m)	Bottom (m)	Dist (m)	Meth	Test Types	Pump Type	Suction Set (m)	Q Prior to Test (l/s)	Dur of Q PR (mins)	Pres on Arriv (m)	Q on Arriv (l/s/)
A	26/09/2014	1	163354	29.00	47.00		PUM		AIR LIFT	60.00				

Pump Tests Part 2

1 *records for RN* 163354

Pipe	Date	Rec	Test Dur (mins)	SWL(m)	Recov Time (mins)	Resid DD (m)	Max DD or P RED (m)	Q at Max DD (l/s)	Time to Max DD (mins)	Max Q (l/s)	Calc Stat HD (m)	Design Yield (l/s)	Design BP (m)	Suct. Set (m)	Tmsy (m2/Day)	Stor
A	26/09/2014	1	120	-28.10				0.80						60.00		

Bore Report

From Year:

Bore Conditions

0 *records for RN* 163354

Elevations

0 *records for RN* 163354

Water Analysis Part 1

0 *records for RN* 163354

Water Analysis Part 2

0 *records for RN* 163354

Water Levels

0 *records for RN* 163354

Wire Line Logs

0 *records for RN* 163354

Field Measurements

1 *records for RN* 163354

Pipe	Date	Depth (m)	Conduct (uS/cm)	pH	Temp (C)	NO3 (mg/L)	DO2 (mg/L)	Eh (mV)	Alkalinity (mV)	Samp	Method	Samp	Source
A	26/09/2014		1162							AI	Air Lifting	GB	Groundwater - from Bore

Special Water Analysis

0 *records for RN* 163354

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
163355	Sub-Artesian Facility	Abandoned and Destroyed	27/09/2014	Longreach	5300 - MT ISA C.

Details

Description	WBF		
Parish	1090 - CLACHAN		
Original Name	WBF		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING PTY LTD		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	LON/515/010 (0152)	Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	27/09/2014	Data Owner	
Roles	Mine Monitoring		

Location

Latitude	20-26-49	Basin	9130
Longitude	139-51-01	Sub-area	
GIS Latitude	-20.44690112	Lot	1
GIS Longitude	139.85032598	Plan	AA29
Easting	380075		
Northing	7738643	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

2 *records for RN* 163355

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
X	27/09/2014	1	0.00	6.00	Cement or Grout Plug			203
X	27/09/2014	2	6.00	73.00	Cuttings or other fill between casing and hole wall			203

Strata Logs

3 *records for RN* 163355

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	6.00	SCHIST, DECOMPOSED (RUBBLE)
2	6.00	17.00	SCHIST, DECOMPOSED
3	17.00	75.00	DOLERITE

Bore Report

From Year:

Stratigraphies

0 *records for RN* 163355

Aquifers

0 *records for RN* 163355

Pump Tests Part 1

0 *records for RN* 163355

Pump Tests Part 2

0 *records for RN* 163355

Bore Conditions

0 *records for RN* 163355

Elevations

0 *records for RN* 163355

Water Analysis Part 1

0 *records for RN* 163355

Water Analysis Part 2

0 *records for RN* 163355

Water Levels

0 *records for RN* 163355

Wire Line Logs

0 *records for RN* 163355

Field Measurements

0 *records for RN* 163355

Special Water Analysis

0 *records for RN* 163355

From Year:

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From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
163356	Sub-Artesian Facility	Abandoned and Destroyed	28/09/2014	Longreach	5300 - MT ISA C.

Details

Description	WBO		
Parish	1090 - CLACHAN		
Original Name	WBO		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING PTY LTD		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	LON/515/010 (0152)	**Polygon**	
R/O File No		**Equipment**	
H/O File No		**RN of Bore Replaced**	
Log Received Date	28/09/2014	**Data Owner**	
Roles	Mine Monitoring		

Location

Latitude	20-26-36	**Basin**	9130
Longitude	139-51-34	**Sub-area**	
GIS Latitude	-20.4433479	**Lot**	1
GIS Longitude	139.85955441	**Plan**	AA29
Easting	381035		
Northing	7739043	**Map Scale**	
Zone	54	**Map Series**	
Accuracy		**Map No**	
GPS Accuracy		**Map Name**	
Checked	Yes	**Prog Section**	

Casing

2 *records for RN* 163356

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
X	28/09/2014	1	0.00	6.00	Cement or Grout Plug			203
X	28/09/2014	2	6.00	83.00	Cuttings or other fill between casing and hole wall			203

Strata Logs

3 *records for RN* 163356

Rec	Top (m)	Bottom	Strata Description

From Year:

		(m)	
1	0.00	13.00	SCHIST, DECOMPOSED
2	13.00	40.00	DOLERITE
3	40.00	83.00	CALCITE / DOLERITE

Stratigraphies
0 *records for RN* 163356

Aquifers
0 *records for RN* 163356

Pump Tests Part 1
0 *records for RN* 163356

Pump Tests Part 2
0 *records for RN* 163356

Bore Conditions
0 *records for RN* 163356

Elevations
0 *records for RN* 163356

Water Analysis Part 1
0 *records for RN* 163356

Water Analysis Part 2
0 *records for RN* 163356

Water Levels
0 *records for RN* 163356

Wire Line Logs
0 *records for RN* 163356

Field Measurements
0 *records for RN* 163356

Special Water Analysis
0 *records for RN* 163356

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
163358	Sub-Artesian Facility	Abandoned and Destroyed	03/10/2014	Longreach	5300 - MT ISA C.

Details

Description	CK NEAR CORE SHED		
Parish	3750 - PARKSIDE		
Original Name			
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING PTY LTD		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	515/010(0152)	Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	03/10/2014	Data Owner	
Roles	Mine Monitoring		

Location

Latitude	20-25-43	Basin	9130
Longitude	139-48-42	Sub-area	
GIS Latitude	-20.42857183	Lot	1
GIS Longitude	139.81166442	Plan	AA29
Easting	376027		
Northing	7740643	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

2 *records for RN* 163358

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
X	03/10/2014	1	0.00	6.00	Cement or Grout Plug			203
X	03/10/2014	2	6.00	30.00	Cuttings or other fill between casing and hole wall			203

Strata Logs

3 *records for RN* 163358

Rec	Top (m)	Bottom (m)	Strata Description

Bore Report

From Year:

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	8.00	RIVER STONE
2	8.00	21.00	GRANITE, DECOMPOSED
3	21.00	30.00	GRANITE

Stratigraphies

0 *records for RN* 163358

Aquifers

0 *records for RN* 163358

Pump Tests Part 1

0 *records for RN* 163358

Pump Tests Part 2

0 *records for RN* 163358

Bore Conditions

0 *records for RN* 163358

Elevations

0 *records for RN* 163358

Water Analysis Part 1

0 *records for RN* 163358

Water Analysis Part 2

0 *records for RN* 163358

Water Levels

0 *records for RN* 163358

Wire Line Logs

0 *records for RN* 163358

Field Measurements

0 *records for RN* 163358

Special Water Analysis

0 *records for RN* 163358

From Year:

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From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
163359	Sub-Artesian Facility	Abandoned and Destroyed	04/10/2014	Longreach	5300 - MT ISA C.

Details

Description	BAWBR 3		
Parish	1090 - CLACHAN		
Original Name	BAWBR 3		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING PTY LTD		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	515/010(0152)	**Polygon**	
R/O File No		**Equipment**	
H/O File No		**RN of Bore Replaced**	
Log Received Date	04/10/2014	**Data Owner**	
Roles	Mine Monitoring		

Location

Latitude	20-25-16	**Basin**	9130
Longitude	139-50-59	**Sub-area**	
GIS Latitude	-20.42122	**Lot**	1
GIS Longitude	139.84971179	**Plan**	AA29
Easting	379991		
Northing	7741485	**Map Scale**	
Zone	54	**Map Series**	
Accuracy		**Map No**	
GPS Accuracy		**Map Name**	
Checked	Yes	**Prog Section**	

Casing

5 *records for RN* 163359

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	04/10/2014	1	0.00	4.00	Polyvinyl Chloride	6.300	WT - Wall Thickness	114
A	04/10/2014	2	3.00	4.00	Perforated or Slotted Casing	2.500	AP - Aperture Size	114
A	04/10/2014	3	3.00	4.00	Gravel Pack	6.000	GR - Gravel Size	203
X	04/10/2014	4	0.00	2.00	Grout			203
X	04/10/2014	5	2.00	3.00	Bentonite Seal			203

Bore Report

From Year:

Strata Logs — 2 records for RN 163359

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	1.00	RIVERSTONE
2	1.00	14.00	DOLERITE

Stratigraphies — 0 records for RN 163359

Aquifers — 0 records for RN 163359

Pump Tests Part 1 — 0 records for RN 163359

Pump Tests Part 2 — 0 records for RN 163359

Bore Conditions — 0 records for RN 163359

Elevations — 0 records for RN 163359

Water Analysis Part 1 — 0 records for RN 163359

Water Analysis Part 2 — 0 records for RN 163359

Water Levels — 0 records for RN 163359

Wire Line Logs — 0 records for RN 163359

Field Measurements — 0 records for RN 163359

Special Water Analysis — 0 records for RN 163359

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
163360	Sub-Artesian Facility	Abandoned and Destroyed	04/10/2014	Longreach	5300 - MT ISA C.

Details

Description	BAWBR 2		
Parish	1090 - CLACHAN		
Original Name	BAWBR 2		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING PTY LTD		
Const Method	ROTARY AIR		
Bore Line			
D/O File No	515/010(0152)	Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	04/10/2014	Data Owner	
Roles	Mine Monitoring		

Location

Latitude	20-25-23	Basin	9130
Longitude	139-50-56	Sub-area	
GIS Latitude	-20.42307609	Lot	1
GIS Longitude	139.84894085	Plan	AA29
Easting	379912		
Northing	7741279	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

5 *records for RN* 163360

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	04/10/2014	1	0.00	3.00	Polyvinyl Chloride	6.300	WT - Wall Thickness	114
A	04/10/2014	2	2.00	3.00	Perforated or Slotted Casing	2.500	AP - Aperture Size	114
A	04/10/2014	3	2.00	3.00	Gravel Pack	6.000	GR - Gravel Size	203
X	04/10/2014	4	0.00	1.00	Grout			203
X	04/10/2014	5	1.00	2.00	Bentonite Seal			203

Bore Report

From Year:

Strata Logs

2 *records for RN* 163360

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	1.00	RIVER STONE
2	1.00	14.00	DOLERITE

Stratigraphies

0 *records for RN* 163360

Aquifers

0 *records for RN* 163360

Pump Tests Part 1

0 *records for RN* 163360

Pump Tests Part 2

0 *records for RN* 163360

Bore Conditions

0 *records for RN* 163360

Elevations

0 *records for RN* 163360

Water Analysis Part 1

0 *records for RN* 163360

Water Analysis Part 2

0 *records for RN* 163360

Water Levels

0 *records for RN* 163360

Wire Line Logs

0 *records for RN* 163360

Field Measurements

0 *records for RN* 163360

Special Water Analysis

0 *records for RN* 163360

From Year:

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From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
163368	Sub-Artesian Facility	Abandoned and Destroyed	28/09/2014	Longreach	5300 - MT ISA C.

Details

Description			
Parish	1090 - CLACHAN		
Original Name	WB "C"		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING PTY TLD		
Const Method	ROTARY AIR		
Bore Line			
D/O File No		**Polygon**	
R/O File No		**Equipment**	
H/O File No		**RN of Bore Replaced**	
Log Received Date	14/11/2014	**Data Owner**	
Roles	Mine Monitoring		

Location

Latitude	20-26-36	**Basin**	9130
Longitude	139-51-34	**Sub-area**	
GIS Latitude	-20.4433573804	**Lot**	1
GIS Longitude	139.859394844	**Plan**	AA29
Easting	381018		
Northing	7739042	**Map Scale**	
Zone	54	**Map Series**	
Accuracy		**Map No**	
GPS Accuracy		**Map Name**	
Checked	Yes	**Prog Section**	

Casing

2 *records for RN* 163368

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
X	28/09/2014	1	0.00	6.00	Grout			203
X	28/09/2014	2	6.00	60.00	Cuttings or other fill between casing and hole wall			203

Strata Logs

3 *records for RN* 163368

Rec	Top (m)	Bottom (m)	Strata Description

Bore Report

From Year:

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	21.00	DECOMPOSED SCHIST
2	21.00	46.00	DOLERITE/CALCITE
3	46.00	60.00	DOLERITE

Stratigraphies
0 *records for RN* 163368

Aquifers
0 *records for RN* 163368

Pump Tests Part 1
0 *records for RN* 163368

Pump Tests Part 2
0 *records for RN* 163368

Bore Conditions
0 *records for RN* 163368

Elevations
0 *records for RN* 163368

Water Analysis Part 1
0 *records for RN* 163368

Water Analysis Part 2
0 *records for RN* 163368

Water Levels
0 *records for RN* 163368

Wire Line Logs
0 *records for RN* 163368

Field Measurements
0 *records for RN* 163368

Special Water Analysis
0 *records for RN* 163368

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
163369	Sub-Artesian Facility	Abandoned and Destroyed	29/09/2014	Longreach	5300 - MT ISA C.

Details

Description			
Parish	1090 - CLACHAN		
Original Name	WB "B"		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING PTY LTD		
Const Method	ROTARY AIR		
Bore Line			
D/O File No		Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	14/11/2014	Data Owner	
Roles	Mine Monitoring		

Location

Latitude	20-25-38	Basin	9130
Longitude	139-51-20	Sub-area	
GIS Latitude	-20.4272295428	Lot	1
GIS Longitude	139.8556071493	Plan	AA29
Easting	380611		
Northing	7740824	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

2 *records for RN* 163369

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
X	29/09/2014	1	0.00	6.00	Grout			203
X	29/09/2014	2	6.00	83.00	Cuttings or other fill between casing and hole wall			203

Strata Logs

3 *records for RN* 163369

Rec	Top (m)	Bottom (m)	Strata Description

Bore Report

From Year:

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	26.00	DECOMPOSED SCHIST
2	26.00	32.00	DOLERITE
3	32.00	83.00	DOLERITE/CALCITE

Stratigraphies

0 *records for RN* 163369

Aquifers

0 *records for RN* 163369

Pump Tests Part 1

0 *records for RN* 163369

Pump Tests Part 2

0 *records for RN* 163369

Bore Conditions

0 *records for RN* 163369

Elevations

0 *records for RN* 163369

Water Analysis Part 1

0 *records for RN* 163369

Water Analysis Part 2

0 *records for RN* 163369

Water Levels

0 *records for RN* 163369

Wire Line Logs

0 *records for RN* 163369

Field Measurements

0 *records for RN* 163369

Special Water Analysis

0 *records for RN* 163369

From Year:

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From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
163370	Sub-Artesian Facility	Existing	01/10/2014	Longreach	5300 - MT ISA C.

Details

Description			
Parish	3750 - PARKSIDE		
Original Name	WB "G"		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING PTY LTD		
Const Method	ROTARY AIR		
Bore Line			
D/O File No		**Polygon**	
R/O File No		**Equipment**	
H/O File No		**RN of Bore Replaced**	
Log Received Date	14/11/2014	**Data Owner**	
Roles	Mine Monitoring		

Location

Latitude	20-23-27	**Basin**	9130
Longitude	139-49-11	**Sub-area**	
GIS Latitude	-20.3908894854	**Lot**	1
GIS Longitude	139.8197002792	**Plan**	AA29
Easting	376835		
Northing	7744820	**Map Scale**	
Zone	54	**Map Series**	
Accuracy		**Map No**	
GPS Accuracy		**Map Name**	
Checked	Yes	**Prog Section**	

Casing

5 *records for RN* 163370

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	01/10/2014	1	0.00	120.00	Polyvinyl Chloride	7.650	WT - Wall Thickness	142
A	01/10/2014	2	32.00	120.00	Perforated or Slotted Casing	2.500	AP - Aperture Size	142
X	01/10/2014	3	0.00	12.00	Grout			203
X	01/10/2014	4	12.00	14.00	Bentonite Seal			203
X	01/10/2014	5	14.00	120.00	Gravel Pack	8.000	GR - Gravel Size	203

From Year:

Strata Logs

5 records for RN 163370

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	34.00	DECOMPOSED SCHIST
2	34.00	38.00	FRACTURED SCHIST
3	38.00	86.00	SCHIST
4	86.00	87.00	FRACTURED SCHIST
5	87.00	120.00	SCHIST

Stratigraphies

0 records for RN 163370

Aquifers

2 records for RN 163370

Rec	Top (m)	Bottom (m)	Lithology	Date	SWL (m)	Flow	Quality	Yield (L/s)	Contr	Cond	Formation Name
1	34.00		SCHT - Schist	01/10/2014	-28.60	N	2492 US/CM	0.50	Y	FR	ARGYLLA FORMATION
2	86.00		SCHT - Schist	01/10/2014	-28.60	N	2492 US/CM	0.40	Y	FR	ARGYLLA FORMATION

Pump Tests Part 1

1 records for RN 163370

Pipe	Date	Rec	RN of Pumped Bore	Top (m)	Bottom (m)	Dist (m)	Meth	Test Types	Pump Type	Suction Set (m)	Q Prior to Test (l/s)	Dur of Q PR (mins)	Pres on Arriv (m)	Q on Arriv (l/s/)
A	01/10/2014	1	163370				PUM		AIR	120.00				

Pump Tests Part 2

1 records for RN 163370

Pipe	Date	Rec	Test Dur (mins)	SWL(m)	Recov Time (mins)	Resid DD (m)	Max DD or P RED (m)	Q at Max DD (l/s)	Time to Max DD (mins)	Max Q (l/s)	Calc Stat HD (m)	Design Yield (l/s)	Design BP (m)	Suct. Set (m)	Tmsy (m2/Day)	Stor

From Year:

Pipe	Date	Rec	Test Dur (mins)	SWL(m)	Recov Time (mins)	Resid DD (m)	Max DD or P RED (m)	Q at Max DD (l/s)	Time to Max DD (mins)	Max Q (l/s)	Calc Stat HD (m)	Design Yield (l/s)	Design BP (m)	Suct. Set (m)	Tmsy (m2/Day)	Stor
A	01/10/2014	1	120	-28.60				0.90						120.00		

Bore Conditions

0 records for RN 163370

Elevations

0 records for RN 163370

Water Analysis Part 1

0 records for RN 163370

Water Analysis Part 2

0 records for RN 163370

Water Levels

0 records for RN 163370

Wire Line Logs

0 records for RN 163370

Field Measurements

0 records for RN 163370

Special Water Analysis

0 records for RN 163370

From Year:

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From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
163371	Sub-Artesian Facility	Abandoned and Destroyed	02/10/2014	Longreach	5300 - MT ISA C.

Details

Description			
Parish	3750 - PARKSIDE		
Original Name	STOCK YARDS		
Driller Name	SERRA, MARK ANTHONY		
Drill Company	SERRA DRILLING PTY LTD		
Const Method	ROTARY AIR		
Bore Line			
D/O File No		**Polygon**	
R/O File No		**Equipment**	
H/O File No		**RN of Bore Replaced**	
Log Received Date	14/11/2014	**Data Owner**	
Roles	Mine Monitoring		

Location

Latitude	20-22-53	**Basin**	9130
Longitude	139-48-23	**Sub-area**	
GIS Latitude	-20.3815216251	**Lot**	1
GIS Longitude	139.8064050628	**Plan**	AA29
Easting	375440		
Northing	7745847	**Map Scale**	
Zone	54	**Map Series**	
Accuracy		**Map No**	
GPS Accuracy		**Map Name**	
Checked	Yes	**Prog Section**	

Casing

2 *records for RN* 163371

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
X	02/10/2014	1	0.00	6.00	Grout			203
X	02/10/2014	2	6.00	30.00	Cuttings or other fill between casing and hole wall			203

Strata Logs

4 *records for RN* 163371

Rec	Top (m)	Bottom (m)	Strata Description

Bore Report

From Year:

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	1.00	TOPSOIL (RED)
2	1.00	20.00	GRANITE
3	20.00	22.00	SCHIST
4	22.00	30.00	GRANITE

Stratigraphies
0 *records for RN* **163371**

Aquifers
0 *records for RN* **163371**

Pump Tests Part 1
0 *records for RN* **163371**

Pump Tests Part 2
0 *records for RN* **163371**

Bore Conditions
0 *records for RN* **163371**

Elevations
0 *records for RN* **163371**

Water Analysis Part 1
0 *records for RN* **163371**

Water Analysis Part 2
0 *records for RN* **163371**

Water Levels
0 *records for RN* **163371**

Wire Line Logs
0 *records for RN* **163371**

Field Measurements
0 *records for RN* **163371**

Special Water Analysis
0 *records for RN* **163371**

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
184209	Sub-Artesian Facility	Existing	11/04/2014	Longreach	5300 - MT ISA C.

Details

Description			
Parish	6000 - NO LONGER USED		
Original Name			
Driller Name	SERRA, MARK		
Drill Company	SERRA DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No		Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	01/04/2019	Data Owner	
Roles	Water Supply		

Location

Latitude	20-21-46	Basin	9130
Longitude	139-48-10	Sub-area	
GIS Latitude	-20.3627074728	Lot	1
GIS Longitude	139.8028399982	Plan	AA29
Easting	375053		
Northing	7747926	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

4 *records for RN* 184209

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	11/09/2014	1	0.00	28.00	Polyvinyl Chloride	7.650	WT - Wall Thickness	142
A	11/09/2014	2	12.00	28.00	Perforated or Slotted Casing	2.500	AP - Aperture Size	142
X	11/09/2014	3	0.00	6.00	Grout			203
X	11/09/2014	4	6.00	28.00	Cuttings or other fill between casing and hole wall			203

Strata Logs

5 *records for RN* 184209

Bore Report

From Year:

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	12.00	DECOMPOSED IRONSTONE
2	12.00	13.00	FRACTURED IRONSTONE*
3	13.00	15.00	DOLERITE & IRONSTONE
4	15.00	16.00	FRACTURED DOLERITE*
5	16.00	28.00	DOLERITE & IRONSTONE

Stratigraphies

0 *records for RN* 184209

Aquifers

2 *records for RN* 184209

Rec	Top (m)	Bottom (m)	Lithology	Date	SWL (m)	Flow	Quality	Yield (L/s)	Contr	Cond	Formation Name
1	12.00			11/09/2014	-9.10	N	POTABLE	0.15	Y	FR	
2	15.00		DOLE - Dolerite SEDI - Sedimentary	11/09/2014	-9.10	N	POTABLE	0.10	Y	FR	

Pump Tests Part 1

0 *records for RN* 184209

Pump Tests Part 2

0 *records for RN* 184209

Bore Conditions

0 *records for RN* 184209

Elevations

0 *records for RN* 184209

Water Analysis Part 1

0 *records for RN* 184209

Water Analysis Part 2

0 *records for RN* 184209

Water Levels

0 *records for RN* 184209

Wire Line Logs

0 *records for RN* 184209

Bore Report

From Year:

Field Measurements

0 *records for RN* **184209**

Special Water Analysis

0 *records for RN* **184209**

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
184264	Sub-Artesian Facility	Existing	15/07/2019	Longreach	5300 - MT ISA C.

Details

Description			
Parish	6000 - NO LONGER USED		
Original Name	SB3A		
Driller Name	WATKINS, ROBERT		
Drill Company	KELLY DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No		Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	11/09/2019	Data Owner	
Roles	Mine Monitoring		

Location

Latitude	20-25-28	Basin	9130
Longitude	139-50-59	Sub-area	
GIS Latitude	-20.42441774	Lot	1
GIS Longitude	139.84962094	Plan	AA29
Easting	379984		
Northing	7741131	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

5 *records for RN* 184264

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	15/07/2019	1	0.00	6.00	Polyvinyl Chloride			125
A	15/07/2019	2	1.00	5.00	Perforated or Slotted Casing	1.000	AP - Aperture Size	125
X	15/07/2019	3	0.00	0.50	Grout			190
X	15/07/2019	4	0.50	1.00	Bentonite Seal			190
X	15/07/2019	5	1.00	6.00	Gravel Pack			190

Bore Report

From Year:

Strata Logs

1 *records for RN* 184264

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	6.00	GRANITE

Stratigraphies

0 *records for RN* 184264

Aquifers

0 *records for RN* 184264

Pump Tests Part 1

0 *records for RN* 184264

Pump Tests Part 2

0 *records for RN* 184264

Bore Conditions

0 *records for RN* 184264

Elevations

0 *records for RN* 184264

Water Analysis Part 1

0 *records for RN* 184264

Water Analysis Part 2

0 *records for RN* 184264

Water Levels

0 *records for RN* 184264

Wire Line Logs

0 *records for RN* 184264

Field Measurements

0 *records for RN* 184264

Special Water Analysis

0 *records for RN* 184264

From Year:

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From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
184265	Sub-Artesian Facility	Existing	15/07/2019	Longreach	5300 - MT ISA C.

Details

Description			
Parish	6000 - NO LONGER USED		
Original Name	SB3B		
Driller Name	WATKINS, ROBERT		
Drill Company	KELLY DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No		**Polygon**	
R/O File No		**Equipment**	
H/O File No		**RN of Bore Replaced**	
Log Received Date	11/09/2019	**Data Owner**	
Roles	Mine Monitoring		

Location

Latitude	20-25-28	**Basin**	9130
Longitude	139-50-59	**Sub-area**	
GIS Latitude	-20.42441774	**Lot**	1
GIS Longitude	139.84962094	**Plan**	AA29
Easting	379984		
Northing	7741131	**Map Scale**	
Zone	54	**Map Series**	
Accuracy		**Map No**	
GPS Accuracy		**Map Name**	
Checked	Yes	**Prog Section**	

Casing

5 *records for RN* 184265

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	15/07/2019	1	0.00	16.00	Polyvinyl Chloride			125
A	15/07/2019	2	5.00	15.00	Perforated or Slotted Casing	1.000	AP - Aperture Size	125
X	15/07/2019	3	0.00	4.00	Grout			190
X	15/07/2019	4	4.00	5.00	Bentonite Seal			190
X	15/07/2019	5	5.00	16.00	Gravel Pack			190

From Year:

Strata Logs

3 *records for RN* 184265

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	14.00	GRANITE
2	14.00	14.50	GRANITE: WATER
3	14.50	16.00	GRANITE

Stratigraphies

0 *records for RN* 184265

Aquifers

1 *records for RN* 184265

Rec	Top (m)	Bottom (m)	Lithology	Date	SWL (m)	Flow	Quality	Yield (L/s)	Contr	Cond	Formation Name
1	14.00	14.50	GNTE - Acid Intrusive, Granite	15/07/2019	-2.80	N		0.70	Y	PS	

Pump Tests Part 1

0 *records for RN* 184265

Pump Tests Part 2

0 *records for RN* 184265

Bore Conditions

0 *records for RN* 184265

Elevations

0 *records for RN* 184265

Water Analysis Part 1

0 *records for RN* 184265

Water Analysis Part 2

0 *records for RN* 184265

Water Levels

0 *records for RN* 184265

Wire Line Logs

0 *records for RN* 184265

Field Measurements

1 *records for RN* 184265

From Year:

Pipe	Date	Depth (m)	Conduct (uS/cm)	pH	Temp (C)	NO3 (mg/L)	DO2 (mg/L)	Eh (mV)	Alkalinity (mV)	Samp	Method	Samp	Source
A	15/07/2019		500	6.9						XX	Unknown	GB	Groundwater - from Bore

Special Water Analysis

0 *records for RN* 184265

From Year:

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From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
184266	Sub-Artesian Facility	Existing	16/07/2019	Longreach	5300 - MT ISA C.

Details

Description			
Parish	6000 - NO LONGER USED		
Original Name	SB2A		
Driller Name	WATKINS, ROBERT		
Drill Company	KELLY DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No		**Polygon**	
R/O File No		**Equipment**	
H/O File No		**RN of Bore Replaced**	
Log Received Date	11/09/2019	**Data Owner**	
Roles	Mine Monitoring		

Location

Latitude	20-25-28	**Basin**	9130
Longitude	139-50-59	**Sub-area**	
GIS Latitude	-20.4245647	**Lot**	1
GIS Longitude	139.84998405	**Plan**	AA29
Easting	380022		
Northing	7741115	**Map Scale**	
Zone	54	**Map Series**	
Accuracy		**Map No**	
GPS Accuracy		**Map Name**	
Checked	Yes	**Prog Section**	

Casing

5 *records for RN* **184266**

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	16/07/2019	1	0.00	6.00	Polyvinyl Chloride			125
A	16/07/2019	2	1.00	5.00	Perforated or Slotted Casing	1.000	AP - Aperture Size	125
X	16/07/2019	3	0.00	0.50	Grout			193
X	16/07/2019	4	0.50	1.00	Bentonite Seal			193
X	16/07/2019	5	1.00	6.00	Gravel Pack			193

Bore Report

From Year:

Strata Logs — 1 *records for RN* 184266

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	6.00	GRANITE

Stratigraphies — 0 *records for RN* 184266

Aquifers — 0 *records for RN* 184266

Pump Tests Part 1 — 0 *records for RN* 184266

Pump Tests Part 2 — 0 *records for RN* 184266

Bore Conditions — 0 *records for RN* 184266

Elevations — 0 *records for RN* 184266

Water Analysis Part 1 — 0 *records for RN* 184266

Water Analysis Part 2 — 0 *records for RN* 184266

Water Levels — 0 *records for RN* 184266

Wire Line Logs — 0 *records for RN* 184266

Field Measurements — 0 *records for RN* 184266

Special Water Analysis — 0 *records for RN* 184266

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
184267	Sub-Artesian Facility	Existing	16/07/2019	Longreach	5300 - MT ISA C.

Details

Description			
Parish	6000 - NO LONGER USED		
Original Name	SB2B		
Driller Name	WALKER, ADAM		
Drill Company	KELLY DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No		Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	11/09/2019	Data Owner	
Roles	Mine Monitoring		

Location

Latitude	20-25-28	Basin	9130
Longitude	139-50-59	Sub-area	
GIS Latitude	-20.4245647	Lot	1
GIS Longitude	139.84998405	Plan	AA29
Easting	380022		
Northing	7741115	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

5 *records for RN* 184267

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	16/07/2019	1	0.00	16.00	Polyvinyl Chloride			125
A	16/07/2019	2	5.00	15.00	Perforated or Slotted Casing	1.000	AP - Aperture Size	125
X	16/07/2019	3	0.00	4.00	Grout			193
X	16/07/2019	4	4.00	5.00	Bentonite Seal			193
X	16/07/2019	5	5.00	16.00	Gravel Pack			193

Bore Report

From Year:

Strata Logs

3 *records for RN* 184267

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	10.00	GRANITE
2	10.00	10.50	GRANITE: WATER
3	10.50	16.00	GRANITE

Stratigraphies

0 *records for RN* 184267

Aquifers

1 *records for RN* 184267

Rec	Top (m)	Bottom (m)	Lithology	Date	SWL (m)	Flow	Quality	Yield (L/s)	Contr	Cond	Formation Name
1	10.00	10.50	GNTE - Acid Intrusive, Granite	16/07/2019	-3.00	N		0.70	Y	PS	

Pump Tests Part 1

0 *records for RN* 184267

Pump Tests Part 2

0 *records for RN* 184267

Bore Conditions

0 *records for RN* 184267

Elevations

0 *records for RN* 184267

Water Analysis Part 1

0 *records for RN* 184267

Water Analysis Part 2

0 *records for RN* 184267

Water Levels

0 *records for RN* 184267

Wire Line Logs

0 *records for RN* 184267

Field Measurements

1 *records for RN* 184267

Bore Report

From Year:

Pipe	Date	Depth (m)	Conduct (uS/cm)	pH	Temp (C)	NO3 (mg/L)	DO2 (mg/L)	Eh (mV)	Alkalinity (mV)	Samp	Method	Samp	Source
A	16/07/2019		500	7.0						XX	Unknown	GB	Groundwater - from Bore

Special Water Analysis

0 *records for RN* **184267**

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
184268	Sub-Artesian Facility	Existing	16/07/2019	Longreach	5300 - MT ISA C.

Details

Description			
Parish	6000 - NO LONGER USED		
Original Name	SB1A		
Driller Name	WATKINS, ROBERT		
Drill Company	KELLY DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No		Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	11/09/2019	Data Owner	
Roles	Mine Monitoring		

Location

Latitude	20-25-31	Basin	9130
Longitude	139-51-02	Sub-area	
GIS Latitude	-20.42518302	Lot	1
GIS Longitude	139.85058326	Plan	AA29
Easting	380085		
Northing	7741047	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

5 *records for RN* 184268

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	16/07/2019	1	0.00	6.00	Polyvinyl Chloride			125
A	16/07/2019	2	1.00	5.00	Perforated or Slotted Casing	1.000	AP - Aperture Size	125
X	16/07/2019	3	0.00	0.50	Grout			193
X	16/07/2019	4	0.50	1.00	Bentonite Seal			193
X	16/07/2019	5	1.00	6.00	Gravel Pack			193

Bore Report

From Year:

Strata Logs

1 *records for RN* 184268

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	6.00	GRANITE

Stratigraphies

0 *records for RN* 184268

Aquifers

0 *records for RN* 184268

Pump Tests Part 1

0 *records for RN* 184268

Pump Tests Part 2

0 *records for RN* 184268

Bore Conditions

0 *records for RN* 184268

Elevations

0 *records for RN* 184268

Water Analysis Part 1

0 *records for RN* 184268

Water Analysis Part 2

0 *records for RN* 184268

Water Levels

0 *records for RN* 184268

Wire Line Logs

0 *records for RN* 184268

Field Measurements

0 *records for RN* 184268

Special Water Analysis

0 *records for RN* 184268

From Year:

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From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
184269	Sub-Artesian Facility	Existing	16/07/2019	Longreach	5300 - MT ISA C.

Details

Description			
Parish	6000 - NO LONGER USED		
Original Name	SB1B		
Driller Name	WATKINS, ROBERT		
Drill Company	KELLY DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No		**Polygon**	
R/O File No		**Equipment**	
H/O File No		**RN of Bore Replaced**	
Log Received Date	11/09/2019	**Data Owner**	
Roles	Mine Monitoring		

Location

Latitude	20-25-31	**Basin**	9130
Longitude	139-51-02	**Sub-area**	
GIS Latitude	-20.42518302	**Lot**	1
GIS Longitude	139.85058326	**Plan**	AA29
Easting	380085		
Northing	7741047	**Map Scale**	
Zone	54	**Map Series**	
Accuracy		**Map No**	
GPS Accuracy		**Map Name**	
Checked	Yes	**Prog Section**	

Casing

5 *records for RN* **184269**

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	16/07/2019	1	0.00	16.00	Polyvinyl Chloride			125
A	16/07/2019	2	5.00	15.00	Perforated or Slotted Casing	1.000	AP - Aperture Size	125
X	16/07/2019	3	0.00	4.00	Grout			193
X	16/07/2019	4	4.00	5.00	Bentonite Seal			193
X	16/07/2019	5	5.00	16.00	Gravel Pack			193

From Year:

Strata Logs

3 *records for RN* 184269

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	11.00	GRANITE
2	11.00	11.50	GRANITE: WATER
3	11.50	16.00	GRANITE

Stratigraphies

0 *records for RN* 184269

Aquifers

1 *records for RN* 184269

Rec	Top (m)	Bottom (m)	Lithology	Date	SWL (m)	Flow	Quality	Yield (L/s)	Contr	Cond	Formation Name
1	11.00	11.50	GNTE - Acid Intrusive, Granite	16/07/2019	-7.00	N		0.70	Y	PS	

Pump Tests Part 1

0 *records for RN* 184269

Pump Tests Part 2

0 *records for RN* 184269

Bore Conditions

0 *records for RN* 184269

Elevations

0 *records for RN* 184269

Water Analysis Part 1

0 *records for RN* 184269

Water Analysis Part 2

0 *records for RN* 184269

Water Levels

0 *records for RN* 184269

Wire Line Logs

0 *records for RN* 184269

Field Measurements

1 *records for RN* 184269

From Year:

Pipe	Date	Depth (m)	Conduct (uS/cm)	pH	Temp (C)	NO3 (mg/L)	DO2 (mg/L)	Eh (mV)	Alkalinity (mV)	Samp	Method	Samp	Source
A	16/07/2019		500	6.9						XX	Unknown	GB	Groundwater - from Bore

Special Water Analysis

0 *records for RN* 184269

From Year:

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From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
184270	Sub-Artesian Facility	Existing	26/07/2019	Longreach	5300 - MT ISA C.

Details

Description			
Parish	6000 - NO LONGER USED		
Original Name	SB4A		
Driller Name	WATKINS, ROBERT		
Drill Company	KELLY DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No		**Polygon**	
R/O File No		**Equipment**	
H/O File No		**RN of Bore Replaced**	
Log Received Date	11/09/2019	**Data Owner**	
Roles	Mine Monitoring		

Location

Latitude	20-25-41	**Basin**	9130
Longitude	139-51-24	**Sub-area**	
GIS Latitude	-20.4279796	**Lot**	1
GIS Longitude	139.85680197	**Plan**	AA29
Easting	380736		
Northing	7740742	**Map Scale**	
Zone	54	**Map Series**	
Accuracy		**Map No**	
GPS Accuracy		**Map Name**	
Checked	Yes	**Prog Section**	

Casing

5 *records for RN* **184270**

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	26/07/2019	1	0.00	6.00	Polyvinyl Chloride			125
A	26/07/2019	2	1.00	5.00	Perforated or Slotted Casing	1.000	AP - Aperture Size	125
X	26/07/2019	3	0.00	0.50	Grout			193
X	26/07/2019	4	0.50	1.00	Bentonite Seal			193
X	26/07/2019	5	1.00	6.00	Gravel Pack			193

Bore Report

From Year:

Strata Logs — 1 *records for RN* 184270

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	6.00	GRANITE

Stratigraphies — 0 *records for RN* 184270

Aquifers — 0 *records for RN* 184270

Pump Tests Part 1 — 0 *records for RN* 184270

Pump Tests Part 2 — 0 *records for RN* 184270

Bore Conditions — 0 *records for RN* 184270

Elevations — 0 *records for RN* 184270

Water Analysis Part 1 — 0 *records for RN* 184270

Water Analysis Part 2 — 0 *records for RN* 184270

Water Levels — 0 *records for RN* 184270

Wire Line Logs — 0 *records for RN* 184270

Field Measurements — 0 *records for RN* 184270

Special Water Analysis — 0 *records for RN* 184270

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
184271	Sub-Artesian Facility	Existing	26/07/2019	Longreach	5300 - MT ISA C.

Details

Description			
Parish	6000 - NO LONGER USED		
Original Name	SB4B		
Driller Name	WATKINS, ROBERT		
Drill Company	KELLY DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No		Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	11/09/2019	Data Owner	
Roles	Mine Monitoring		

Location

Latitude	20-25-41	Basin	9130
Longitude	139-51-24	Sub-area	
GIS Latitude	-20.4279796	Lot	1
GIS Longitude	139.85680197	Plan	AA29
Easting	380736		
Northing	7740742	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

5 *records for RN* 184271

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	26/07/2019	1	0.00	14.00	Polyvinyl Chloride			125
A	26/07/2019	2	5.00	14.00	Perforated or Slotted Casing	1.000	AP - Aperture Size	125
X	26/07/2019	3	0.00	4.00	Grout			193
X	26/07/2019	4	4.00	5.00	Bentonite Seal			193
X	26/07/2019	5	5.00	16.00	Gravel Pack			193

Bore Report

From Year:

Strata Logs

3 *records for RN* 184271

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	9.00	GRANITE
2	9.00	9.50	GRANITE: WATER
3	9.50	16.00	GRANITE

Stratigraphies

0 *records for RN* 184271

Aquifers

1 *records for RN* 184271

Rec	Top (m)	Bottom (m)	Lithology	Date	SWL (m)	Flow	Quality	Yield (L/s)	Contr	Cond	Formation Name
1	9.00	9.50	GNTE - Acid Intrusive, Granite	26/07/2019	-6.00	N		1.50	Y	PS	

Pump Tests Part 1

0 *records for RN* 184271

Pump Tests Part 2

0 *records for RN* 184271

Bore Conditions

0 *records for RN* 184271

Elevations

0 *records for RN* 184271

Water Analysis Part 1

0 *records for RN* 184271

Water Analysis Part 2

0 *records for RN* 184271

Water Levels

0 *records for RN* 184271

Wire Line Logs

0 *records for RN* 184271

Field Measurements

1 *records for RN* 184271

Bore Report

From Year:

Pipe	Date	Depth (m)	Conduct (uS/cm)	pH	Temp (C)	NO3 (mg/L)	DO2 (mg/L)	Eh (mV)	Alkalinity (mV)	Samp	Method	Samp	Source
A	16/07/2019		500	7.0						XX	Unknown	GB	Groundwater - from Bore

Special Water Analysis

0 *records for RN* **184271**

Bore Report

From Year:

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Bore Report

From Year:

Registered Number	Facility Type	Facility Status	Drilled Date	Office	Shire
184272	Sub-Artesian Facility	Existing	28/07/2019	Longreach	5300 - MT ISA C.

Details

Description			
Parish	6000 - NO LONGER USED		
Original Name			
Driller Name	WATKINS, ROBERT		
Drill Company	KELLY DRILLING		
Const Method	ROTARY AIR		
Bore Line			
D/O File No		Polygon	
R/O File No		Equipment	
H/O File No		RN of Bore Replaced	
Log Received Date	11/09/2019	Data Owner	
Roles	Water Supply		

Location

Latitude	20-24-58	Basin	9130
Longitude	139-50-54	Sub-area	
GIS Latitude	-20.4160441975	Lot	1
GIS Longitude	139.8483438702	Plan	AA29
Easting	379844		
Northing	7742057	Map Scale	
Zone	54	Map Series	
Accuracy		Map No	
GPS Accuracy		Map Name	
Checked	Yes	Prog Section	

Casing

7 *records for RN* 184272

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
A	28/07/2019	1	0.00	39.00	Polyvinyl Chloride			200
A	28/07/2019	2	27.00	39.00	Perforated or Slotted Casing	1.000	AP - Aperture Size	200
X	28/07/2019	3	0.00	6.00	Polyvinyl Chloride			300
X	28/07/2019	4	0.00	6.00	Grout			400
X	28/07/2019	5	0.00	6.00	Grout			270

Bore Report

From Year:

Pipe	Date	Rec	Top (m)	Bottom (m)	Material Description	Mat Size (mm)	Size Desc	Outside Diameter (mm)
X	28/07/2019	6	6.00	8.00	Bentonite Seal			270
X	28/07/2019	7	8.00	40.00	Gravel Pack			270

Strata Logs

4 *records for RN* 184272

Rec	Top (m)	Bottom (m)	Strata Description
1	0.00	2.00	BROKEN GRANITE, SAND
2	2.00	11.00	GRANITE
3	11.00	12.00	GRANITE: WATER
4	12.00	40.00	GRANITE

Stratigraphies

0 *records for RN* 184272

Aquifers

1 *records for RN* 184272

Rec	Top (m)	Bottom (m)	Lithology	Date	SWL (m)	Flow	Quality	Yield (L/s)	Contr	Cond	Formation Name
1	11.00	12.00	GNTE - Acid Intrusive, Granite	28/07/2019	-6.00	N		0.80	Y	PS	

Pump Tests Part 1

0 *records for RN* 184272

Pump Tests Part 2

0 *records for RN* 184272

Bore Conditions

0 *records for RN* 184272

Elevations

0 *records for RN* 184272

Water Analysis Part 1

0 *records for RN* 184272

From Year:

Water Analysis Part 2

0 *records for RN* 184272

Water Levels

0 *records for RN* 184272

Wire Line Logs

0 *records for RN* 184272

Field Measurements

1 *records for RN* 184272

Pipe	Date	Depth (m)	Conduct (uS/cm)	pH	Temp (C)	NO3 (mg/L)	DO2 (mg/L)	Eh (mV)	Alkalinity (mV)	Samp	Method	Samp	Source
A	28/07/2019		500	6.9						XX	Unknown	GB	Groundwater - from Bore

Special Water Analysis

0 *records for RN* 184272

From Year:

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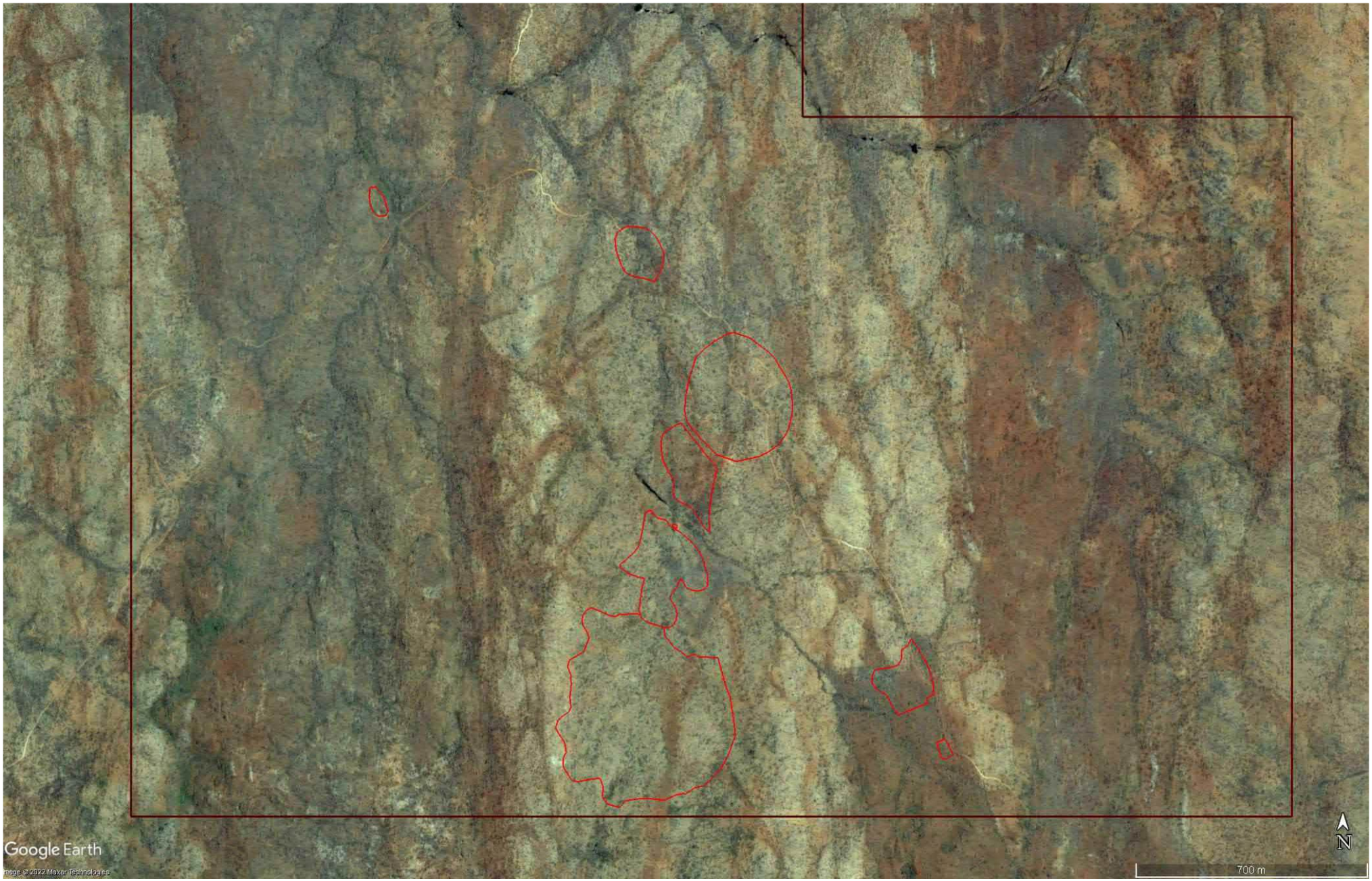
Appendix D Google Earth images of BCP Spring



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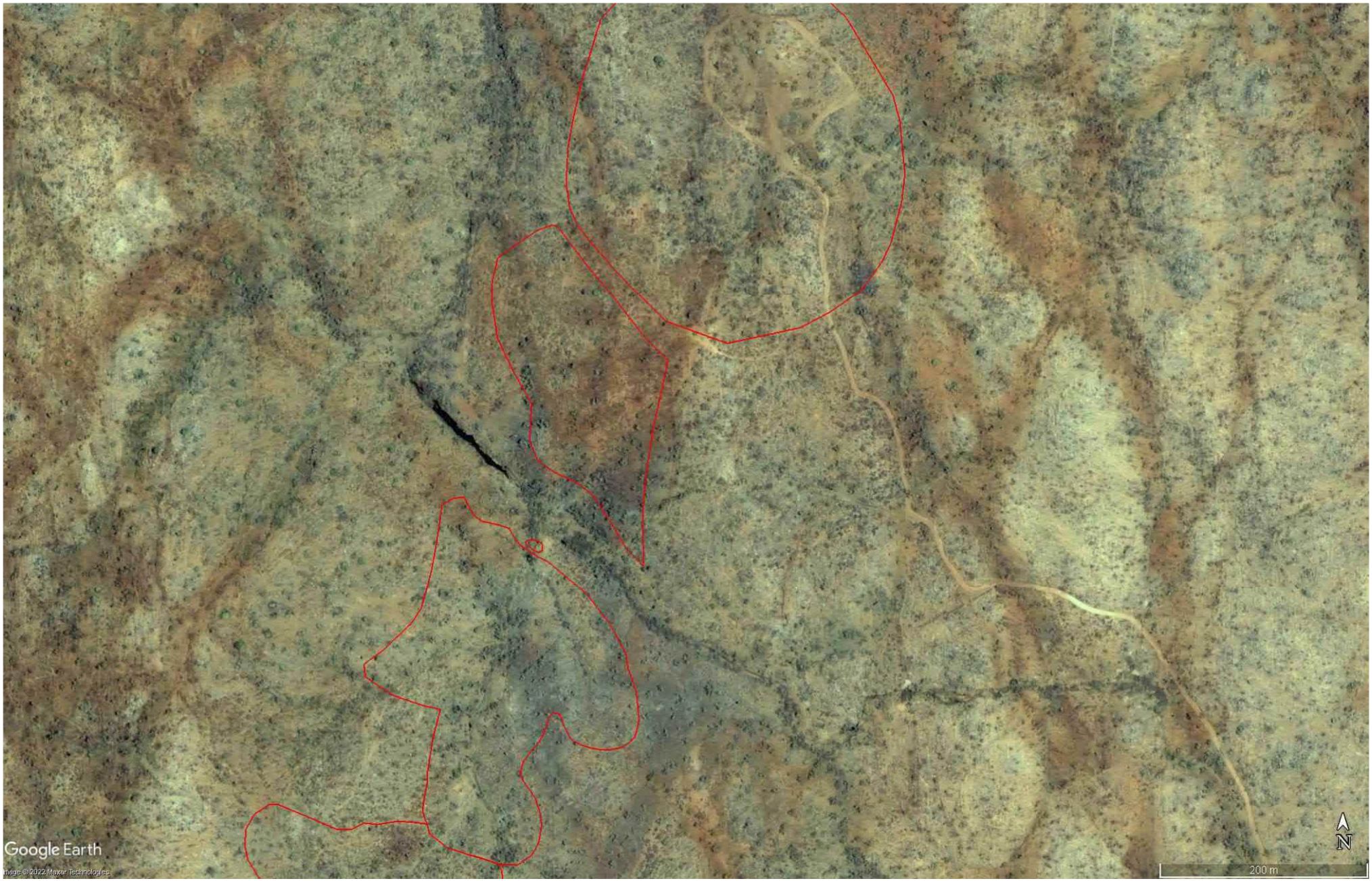

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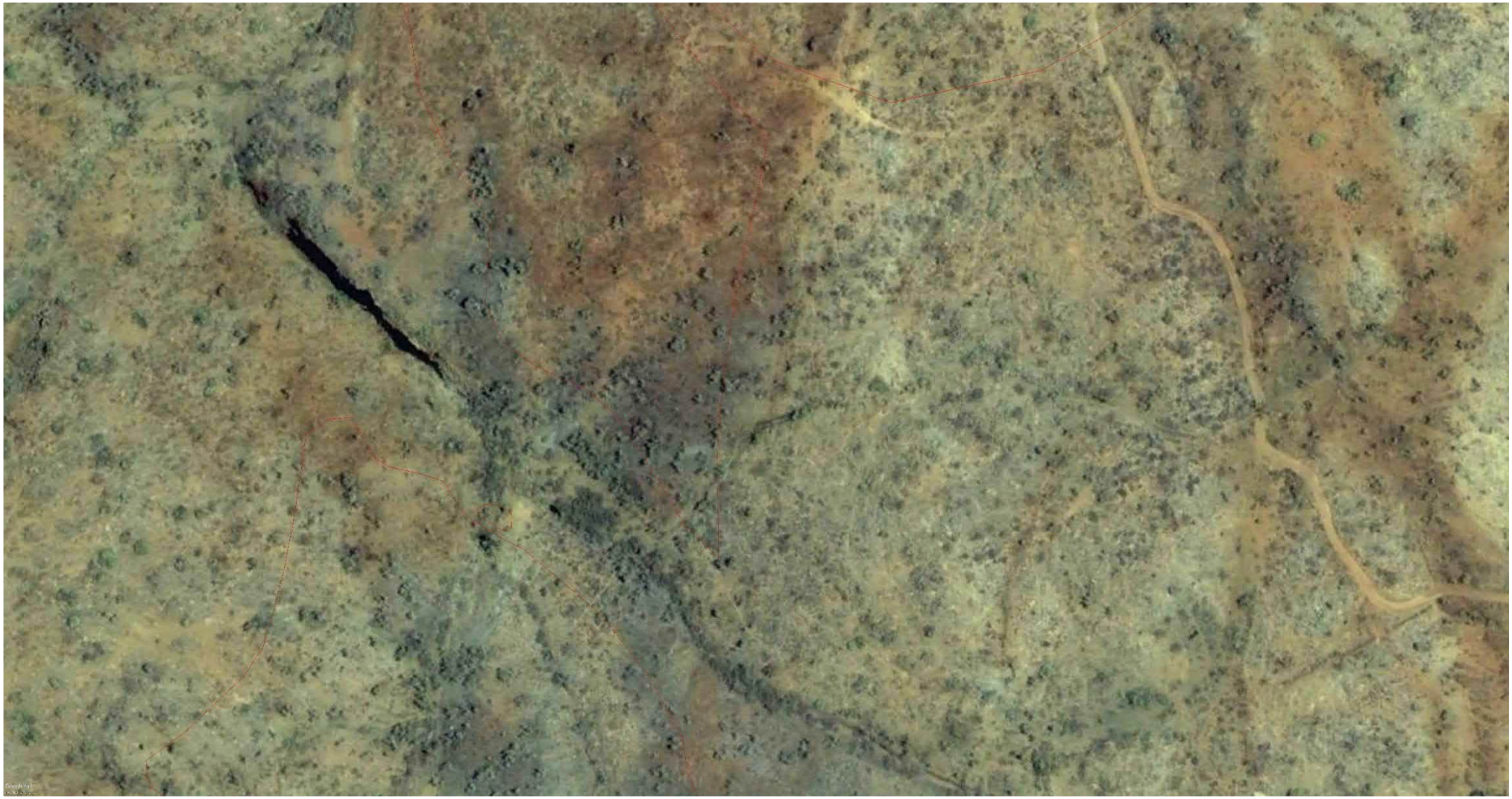

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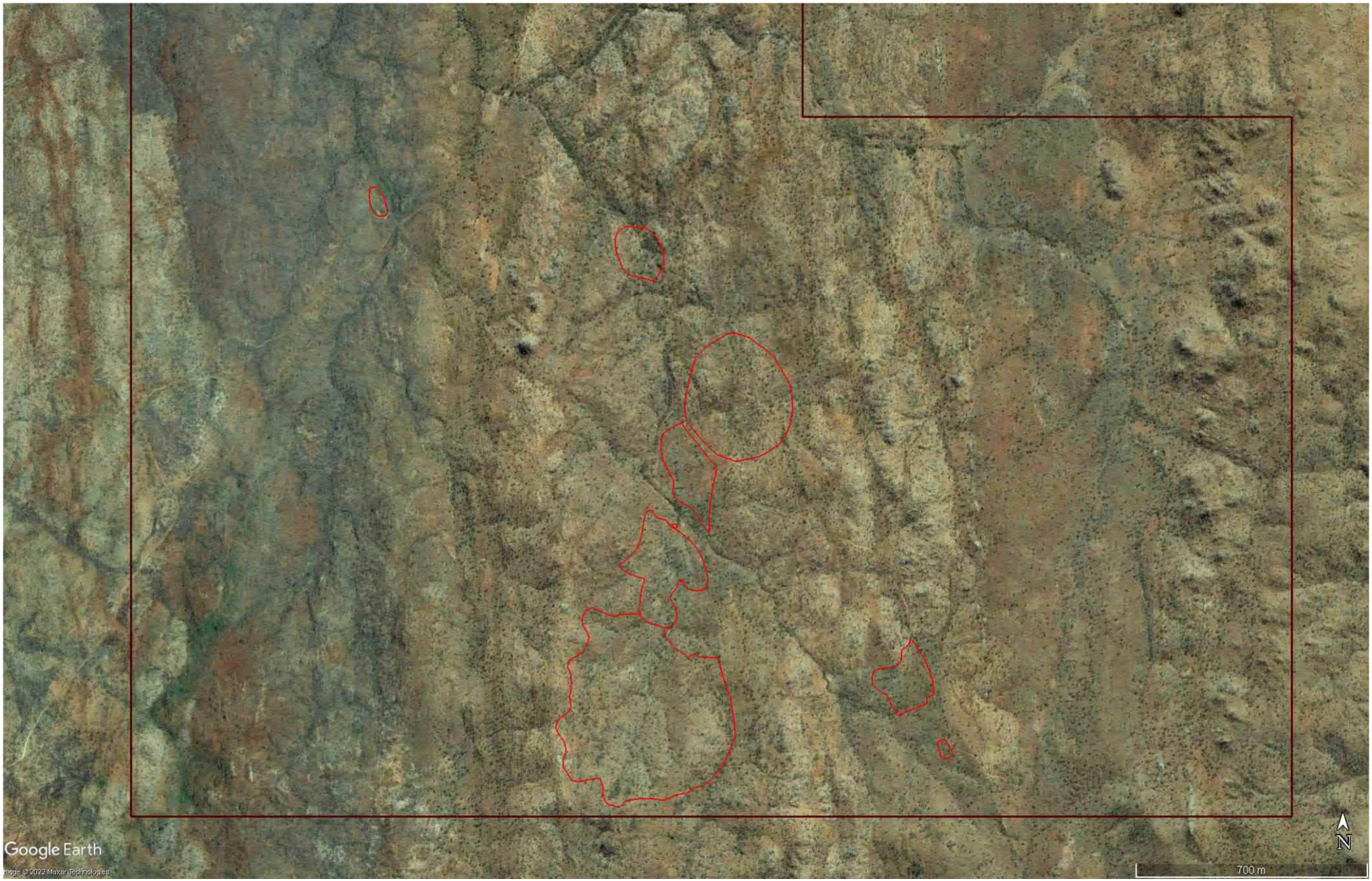

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GE_2005_07 (b)

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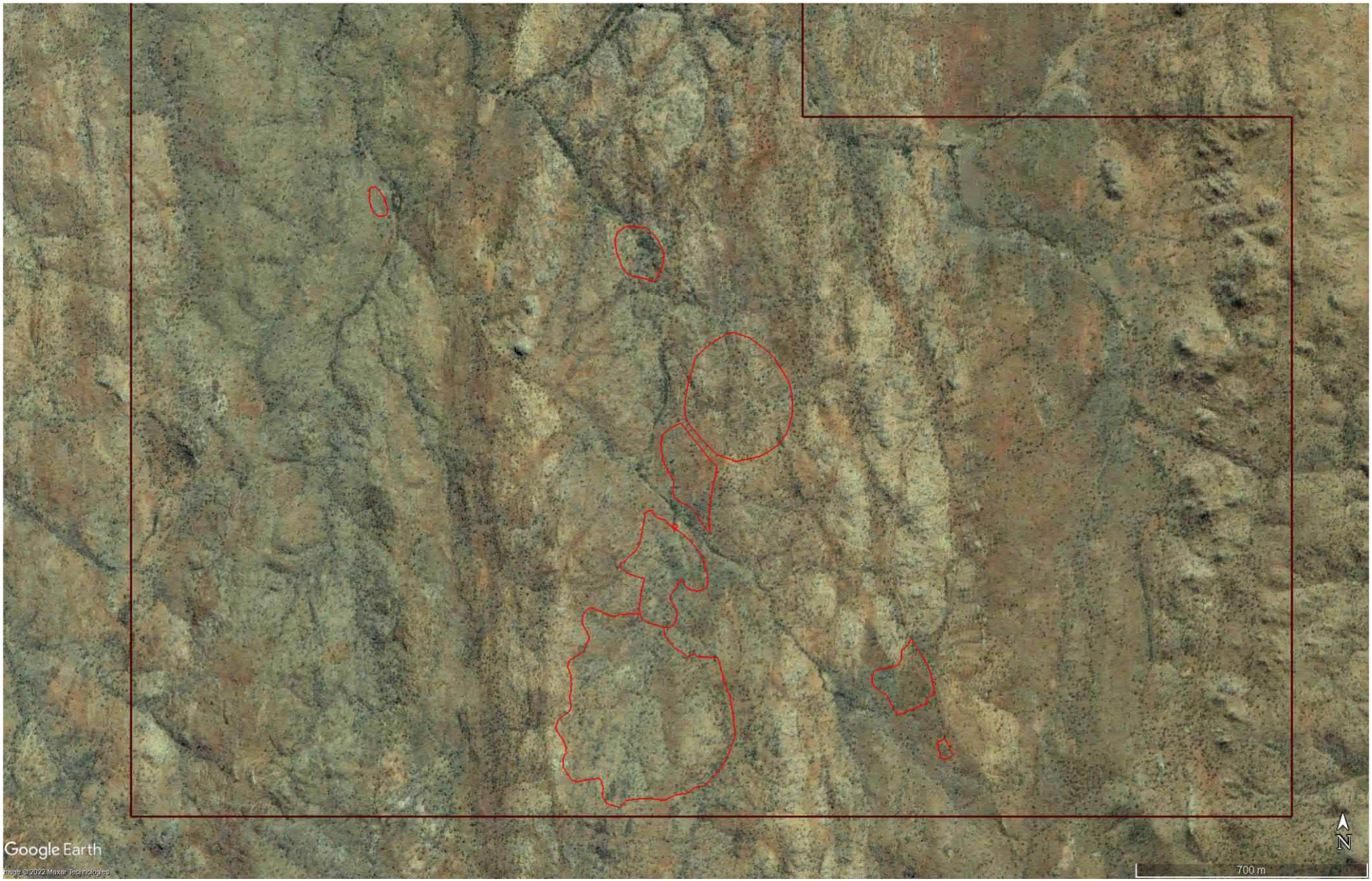

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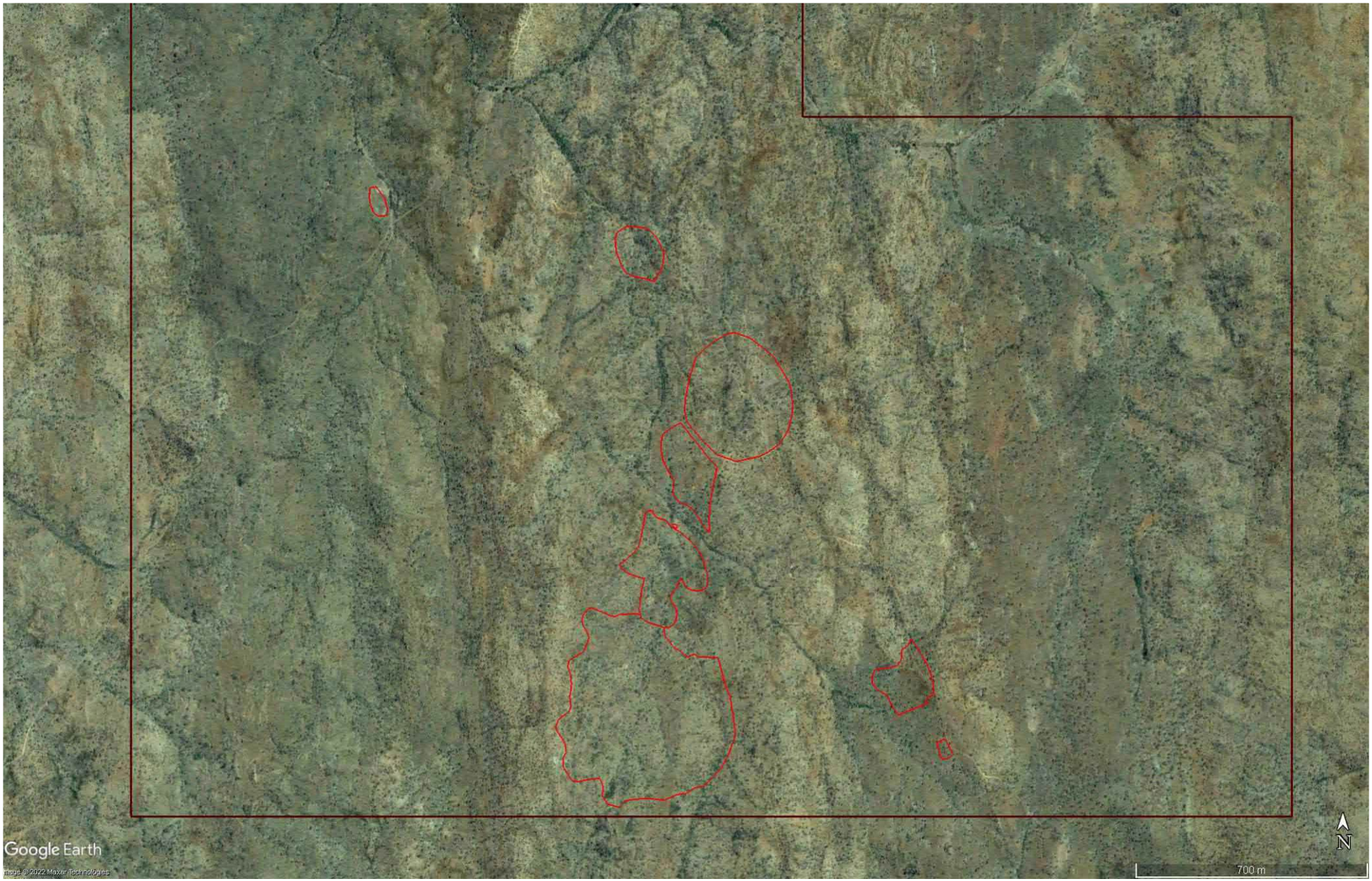
GE_2005_08 (b)

GE_2005_08 (c)



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GE_2006_09 (b)

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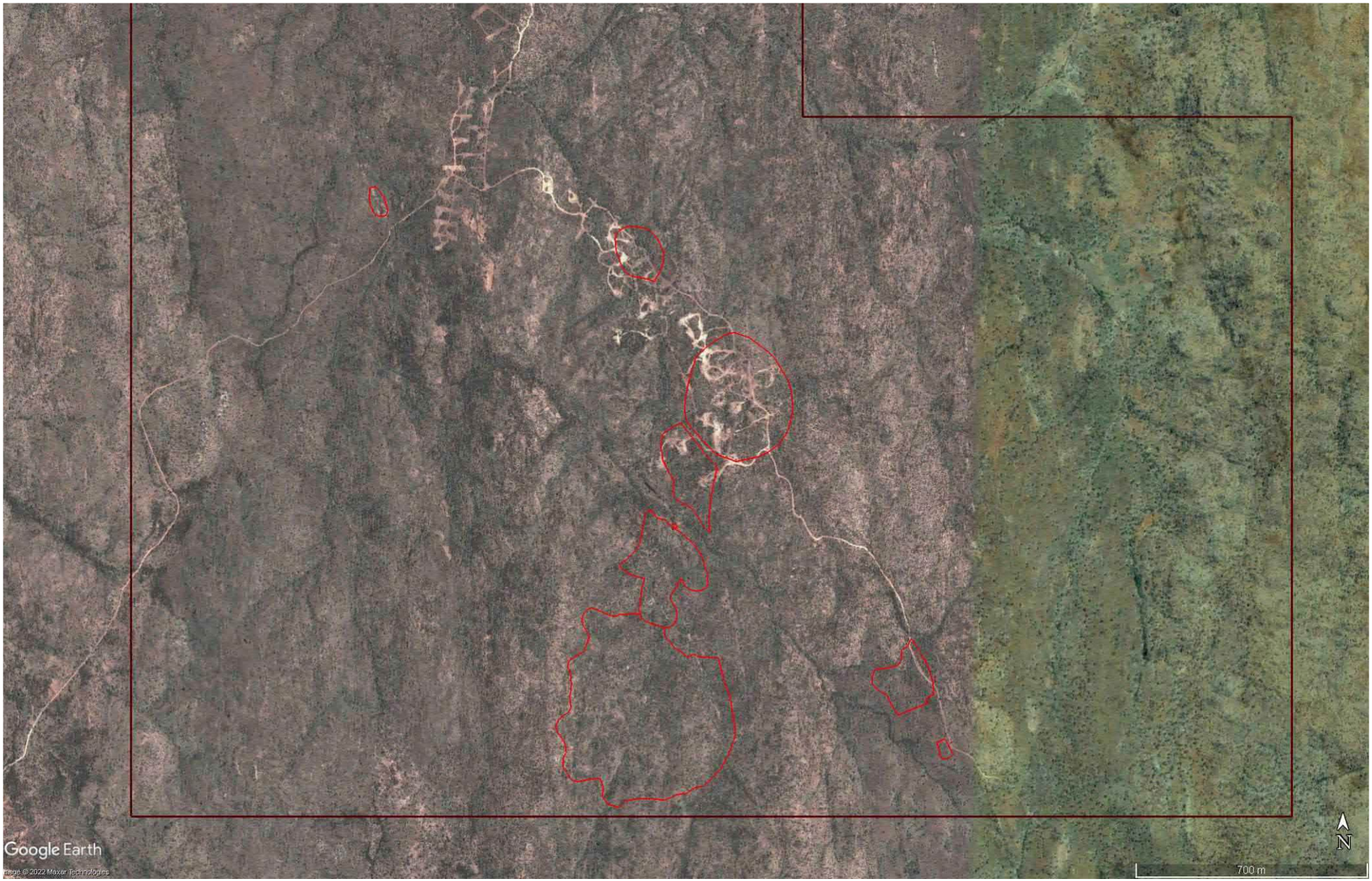

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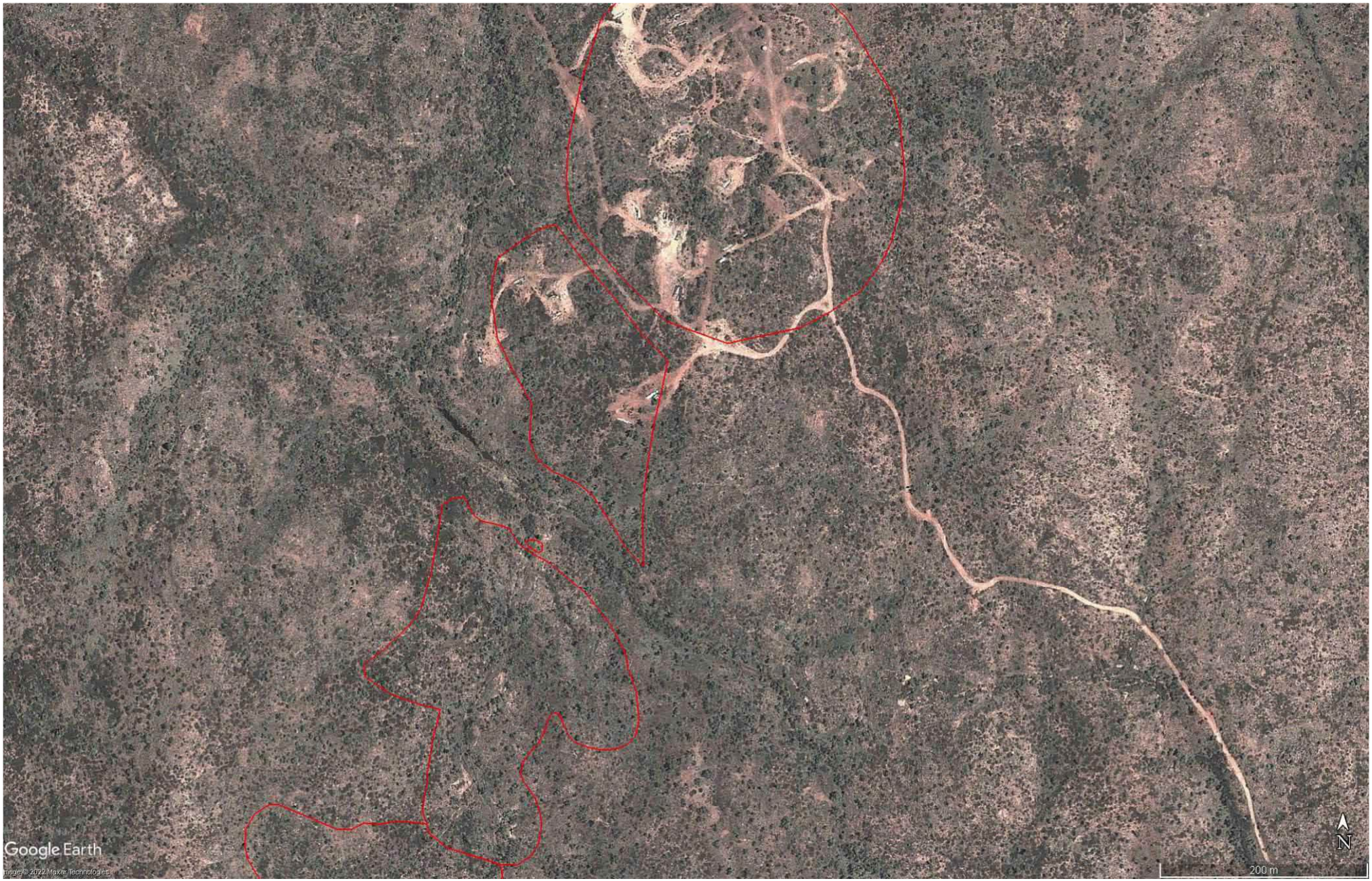

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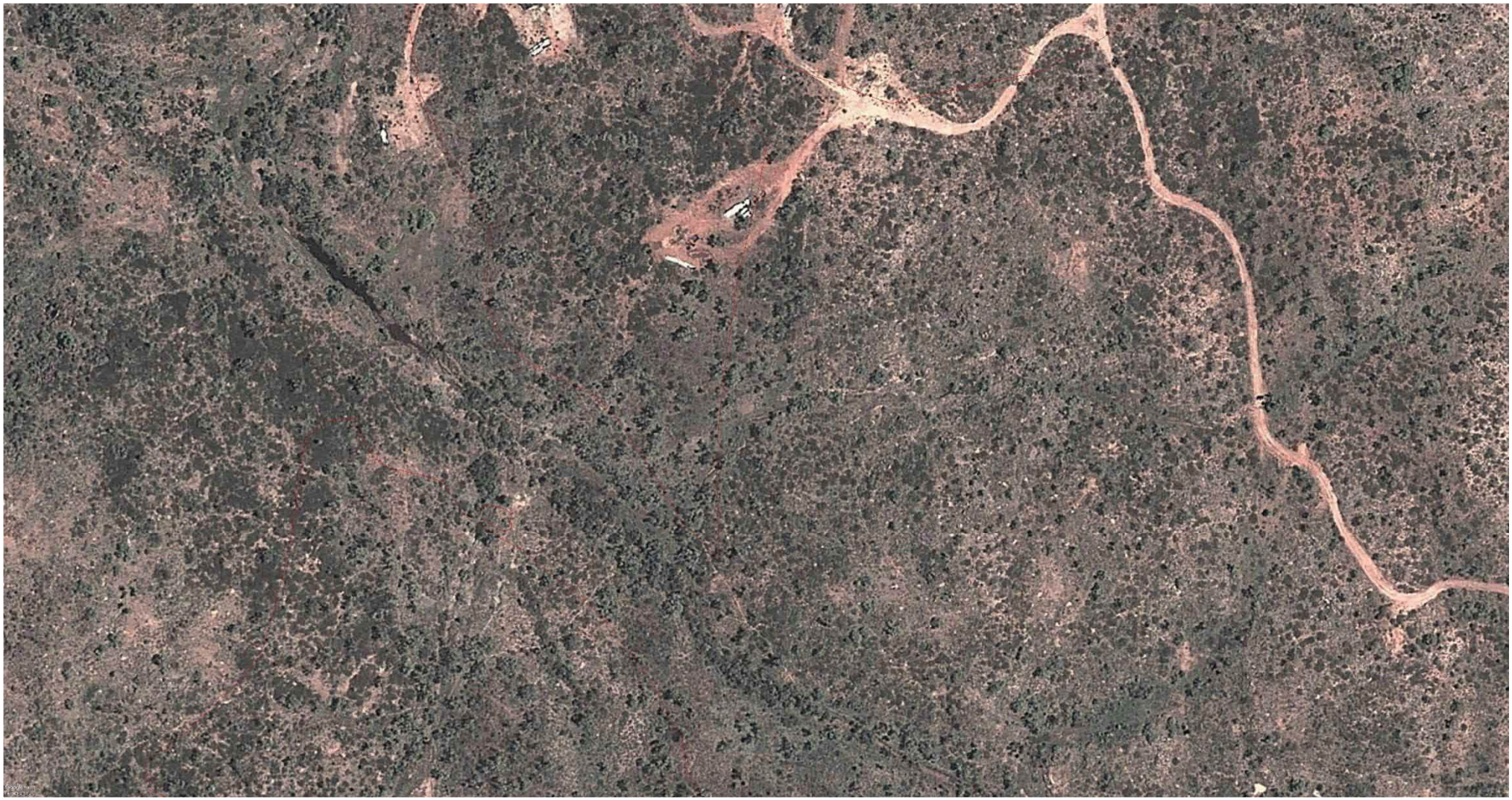

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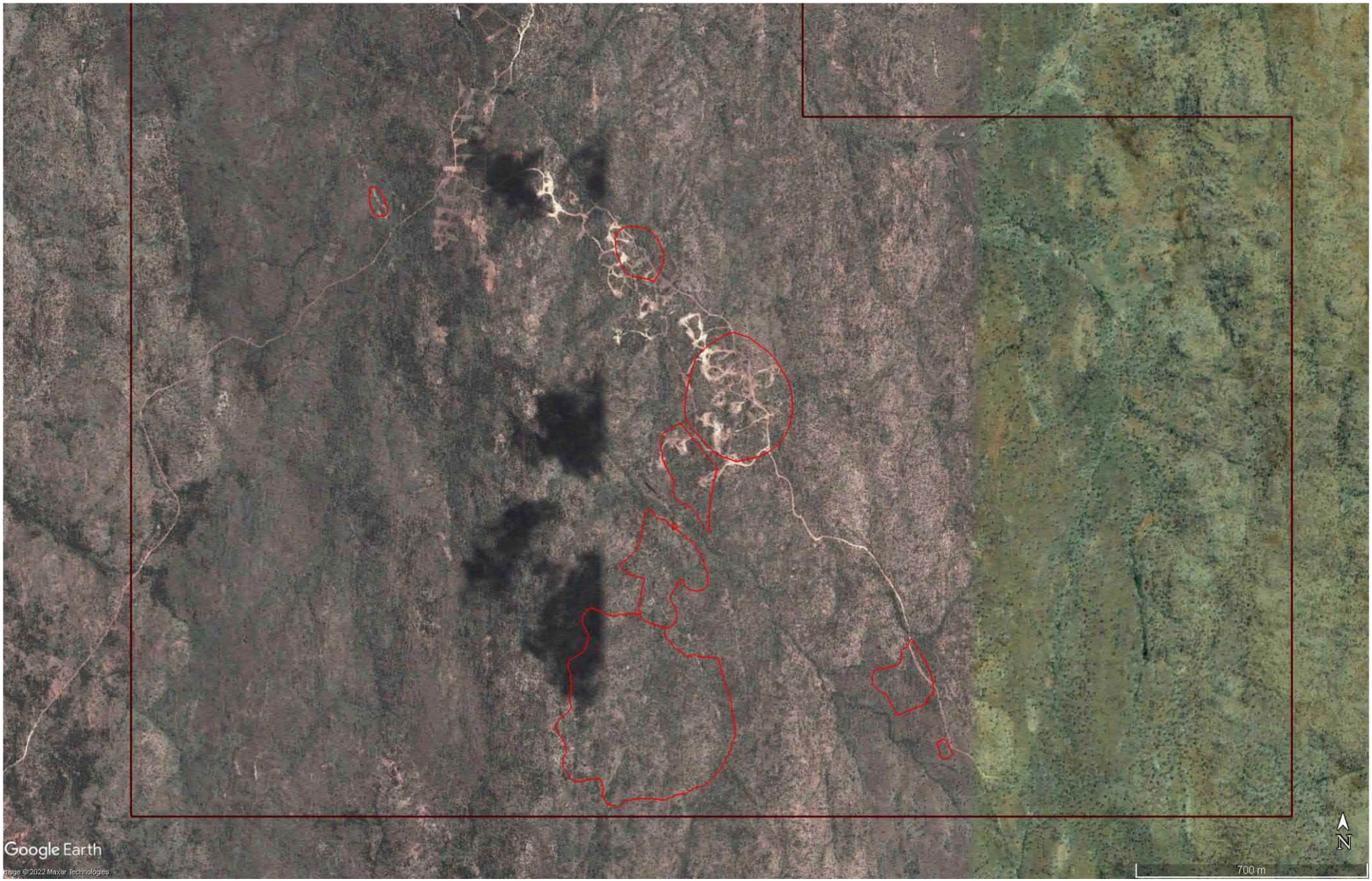

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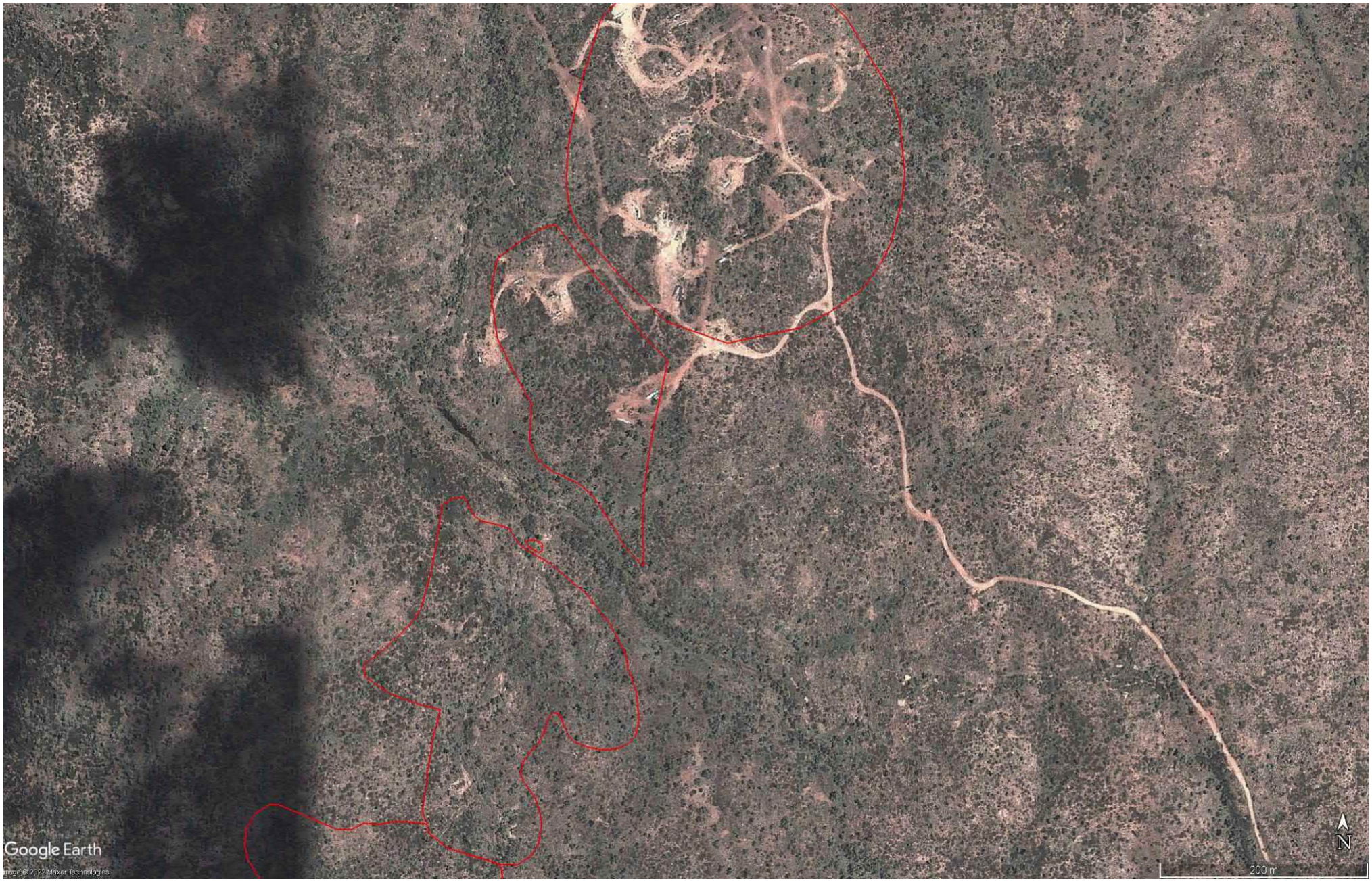
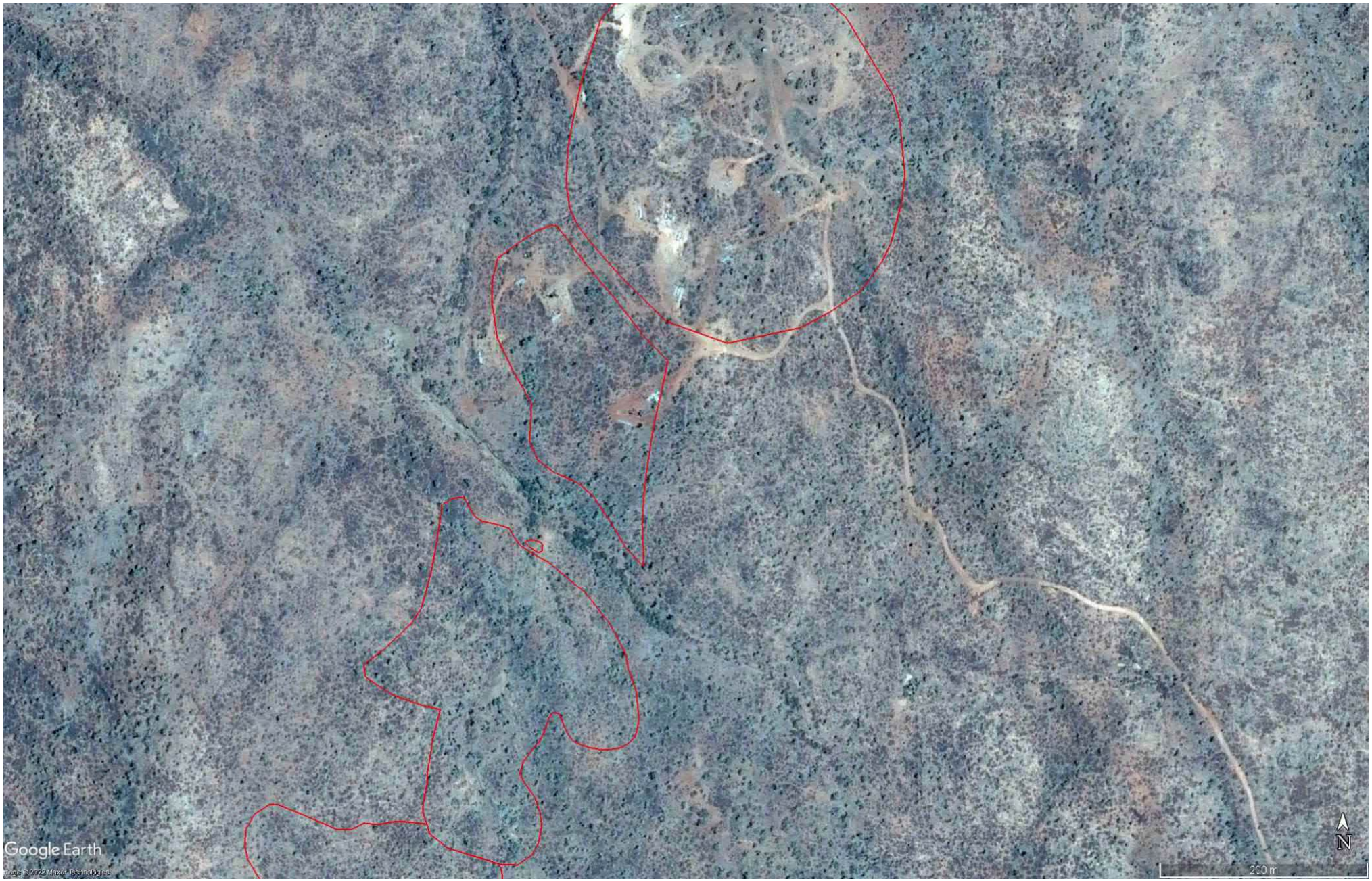


GE_2013_01 (b)

GE_2013_10 (a)



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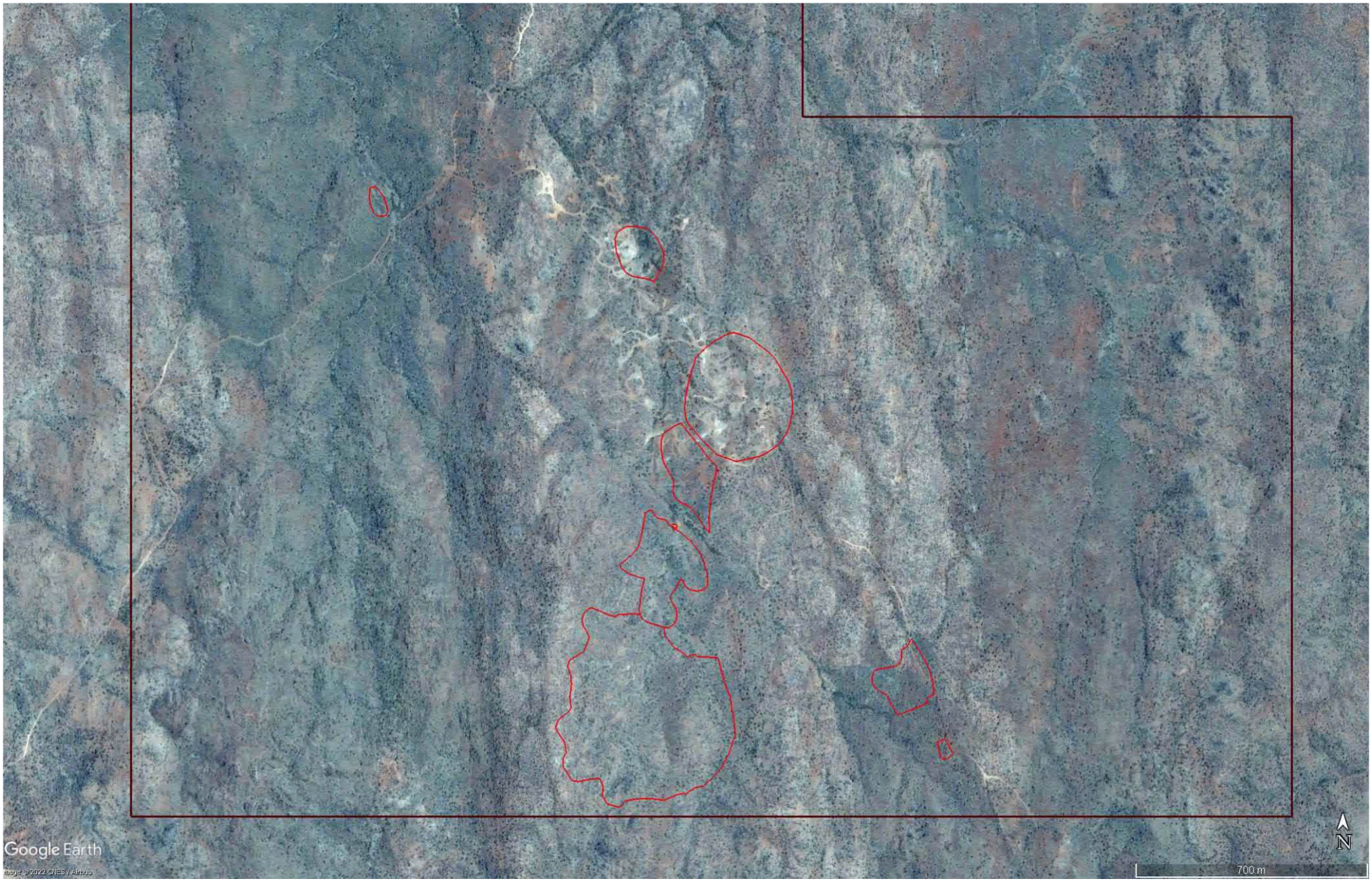
GE_2013_10 (c)



GE_2015_10 (a)

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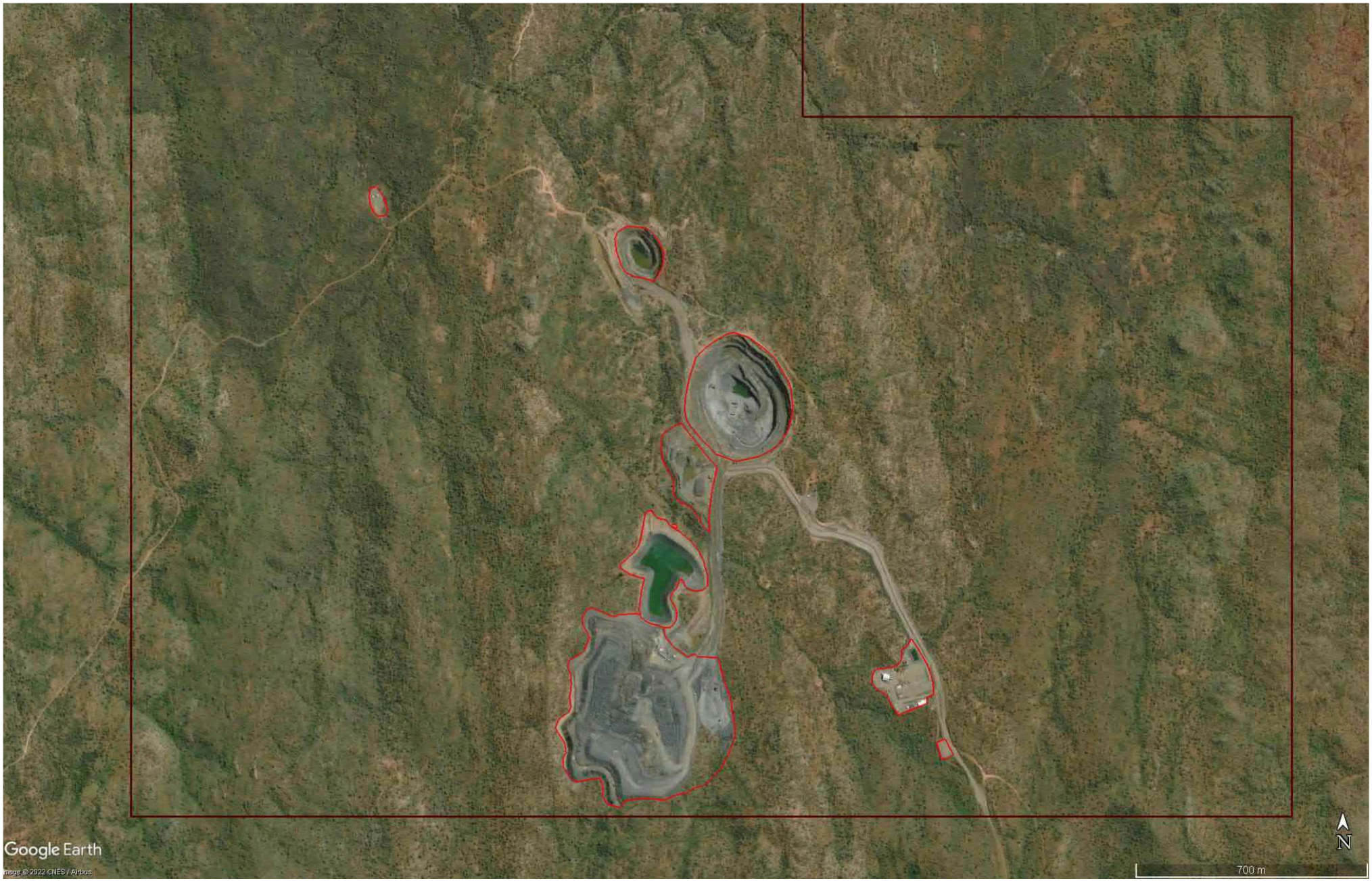


GE_2020_03 (a)

GE_2020_03 (b)

GE_2020_03 (c)

GE_2020_05 (a)

GE_2020_05 (b)

GE_2020_05 (c)

GE_2023_04 (a)

GE_2023_04 (b)

GE_2023_04 (c)

2021_05_01 (Orthomosaic)

Appendix E REMP and EA surface water monitoring data

E.1 Surface water data tables

Table D.1 REMP and EA surface water monitoring events

Year/ Month	B3	B4	B6	B7	B8	B9	BASW01	BASW04	BASW05	BASW08	BASW09	BASW11
2017												
11								✓				
2018												
3								✓		✓		
11								✓				
2019												
1							✓	✓		✓	✓	✓
2							✓	✓				✓
3								✓			✓	
4							✓	✓	✓	✓	✓	✓
5							✓	✓	✓	✓	✓	✓
6							✓	✓	✓	✓	✓	✓
7								✓	✓	✓		✓
8									✓		✓	✓
9												✓
10												✓
11							✓		✓		✓	✓
2020												
2							✓	✓	✓		✓	✓
2021												
1							✓	✓	✓		✓	✓
2								✓			✓	
3	✓		✓	✓	✓	✓						
4							✓	✓	✓		✓	✓
5							✓		✓		✓	✓
8	✓											
11							✓	✓				✓
2022												
2							✓	✓	✓		✓	✓
3	✓		✓	✓	✓							
6							✓	✓	✓	✓		✓
8	✓				✓							
11							✓	✓	✓		✓	✓
2023												
1							✓	✓	✓		✓	✓
4	✓	✓	✓	✓	✓	✓						

Table D.2 Descriptive statistics – all surface water monitoring results

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	No. distinct values (>LOR)	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	10%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	80%ile	90%ile (> LOR)	95%ile (>LOR)	99%ile (>LOR)
Alkalinity																				
Bicarbonate Alkalinity as CaCO3 (mg/L)	91	91			70	17	163.09	156.08	824	807	30.5	35	49	62	103	197	259	400	449.5	748.4
Carbonate Alkalinity as CaCO3 (mg/L)	91	13	78	85.7%	13	3	25.46	22.00	81	78	3.6	4.8	10	13	19	30	31.2	57.6	70.8	78.96
Hydroxide Alkalinity as CaCO3 (mg/L)	91		91	100.0%	1															
Total Alkalinity as CaCO3 (mg/L)	91	91			72	17	166.74	160.89	824	807	30.5	35	49	62	103	199.5	259	416	466	748.4
Carbon																				
Total Non-Purgeable Organic Carbon(mg/L)	6	6			4	7.1	10.33	2.12	13	5.9	7.55	8	8.9	9.175	10	12.25	13	13	13	13
Field Measurements																				
Depth to Water (mbRL)	2	2			2	0.3	0.65	0.35	1	0.7	0.335	0.37	0.44	0.475	0.65	0.825	0.86	0.93	0.965	0.993
Dissolved Oxygen (field) (% sat))	50	50			38	0	34.37	38.13	179.6	179.6	0	0	8.84	9.95	27.35	42.675	48.42	59.64	119.555	171.466
Electrical Conductivity (field) (µS/cm)	53	53			46	49	457.23	419.18	1723	1674	60	79.4	103.2	126	248	716	928.8	1055	1293	1505.64
ORP (field) (mV)	51	51			45	-133.6	78.76	81.43	231.7	365.3	-33.45	-8.4	25.1	28.5	76.3	136.8	168	186.5	206.45	230.25
pH (field)	53	53			42	5.34	7.90	0.84	9.52	4.18	6.34	7.01	7.294	7.43	7.9	8.61	8.63	8.778	8.97	9.2964
Salinity (field) (PSU)	52	52			29	0.02	0.23	0.21	0.87	0.85	0.03	0.04	0.052	0.06	0.13	0.355	0.468	0.519	0.65	0.7578
Temperature (field) (°C)	52	52			46	15	26.23	5.87	35.99	20.99	16.739	17.528	20.804	21.785	25.9	30.83	33.264	33.933	34.499	35.4035
Total Dissolved Solids (field) (ppm)	51	51			44	0.07	232.79	212.96	861	860.93	28.5	35	48	63	154	371	490	531	647	757
Turbidity (field) (FNU)	33	33			27	0	45.48	62.67	272	272	4.06	7.68	10.42	11.2	16.2	51.6	80.12	141.4	170	239.36
Hardness																				
Total Hardness (mg CaCO3/L)	91	91			66	9	94.44	82.10	402	393	19.5	26	35	41	60	111.5	140	230	275	321
Ion Balance																				
Ion Balance (%)	18	18			17	-10	-5.79	3.57	0.9	10.9	-10	-9.86	-9.08	-8.8	-6.9	-2.625	-2.02	-0.61	-0.205	0.679
Ionic Balance (%)	30	30			29	0.28	2.77	1.66	6.46	6.18	0.369	0.902	1.27	1.3725	2.65	3.715	3.806	5.419	5.931	6.3875
Total Anions (meq/L)	91	91			82	0.37	4.20	4.21	20	19.63	0.695	0.78	1.15	1.54	2.59	4.945	6.16	10.7	13	17.57
Total Cations (meq/L)	91	91			79	0.3	4.23	4.22	19.5	19.2	0.74	0.81	1.33	1.46	2.54	4.96	6.86	11.6	13	17.79
Major Ions																				
Calcium (mg/L)	139	139			38	2	16.79	12.35	73	71	4	5	8	9	13	19.5	22.4	36	40.4	59.16
Chloride (mg/L)	91	90	1	1.1%	42	1	22.01	25.67	111	110	2.45	3	4	6	10	27.75	30.8	59.1	79.85	110.11
Fluoride (mg/L)	88	63	25	28.4%	10	0.1	0.30	0.33	1.6	1.5	0.1	0.1	0.1	0.1	0.2	0.4	0.4	0.5	0.96	1.6
Magnesium (mg/L)	139	139			45	1	10.94	13.10	76	75	2	2.56	3	4	6	10.5	14.4	30	39.3	62.64
Potassium (mg/L)	139	139			39	2	10.55	16.89	160	158	3	3.48	4	4	6	9.95	12	17.6	30.2	68.86
Sodium (mg/L)	139	138	1	0.7%	70	1	42.30	53.13	270	269	3	4	8	10	22.5	43.75	57.6	114.4	149.4	232.52
Sulfate (as SO4)	91	68	23	25.3%	38	1	16.62	29.96	230	229	1.445	2	2.08	3	7	20	23.6	37.9	51	120.12
Metals (dissolved)																				
Aluminium - dissolved (mg/L)	18	9	9	50.0%	9	0.006	0.044	0.087	0.29	0.284	0.0064	0.0068	0.0082	0.009	0.013	0.02	0.024	0.082	0.186	0.2692
Arsenic - dissolved (mg/L)	92	32	60	65.2%	5	0.001	0.002	0.001	0.004	0.003	0.001	0.001	0.001	0.001	0.002	0.003	0.003	0.0039	0.004	0.004

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	No. distinct values (>LOR)	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	10%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	80%ile	90%ile (> LOR)	95%ile (>LOR)	99%ile (>LOR)
Barium - dissolved (mg/L)	91	91			52	0.005	0.052	0.060	0.419	0.414	0.015	0.017	0.02	0.021	0.034	0.0495	0.07	0.099	0.1545	0.3029
Bismuth - dissolved (mg/L)	91		91	100.0%	1															
Chromium - dissolved (mg/L)	92	3	89	96.7%	3	0.001	0.001	0.000	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.0015	0.0016	0.0018	0.0019	0.00198
Cobalt - dissolved (mg/L)	92	25	67	72.8%	6	0.001	0.003	0.001	0.005	0.004	0.001	0.001	0.001	0.001	0.002	0.003	0.004	0.005	0.005	0.005
Copper - dissolved (mg/L)	92	85	7	7.6%	21	0.001	0.011	0.031	0.208	0.207	0.001	0.001	0.002	0.002	0.004	0.009	0.0112	0.0172	0.0276	0.208
Molybdenum - dissolved (mg/L)	92	34	58	63.0%	8	0.0006	0.002	0.001	0.003	0.0024	0.0007	0.00093	0.001	0.001	0.00155	0.003	0.003	0.003	0.003	0.003
Nickel - dissolved (mg/L)	92	16	76	82.6%	7	0.001	0.003	0.002	0.008	0.007	0.001	0.001	0.001	0.001	0.002	0.00325	0.004	0.0055	0.00725	0.00785
Selenium - dissolved (mg/L)	92		92	100.0%	1															
Uranium - dissolved (mg/L)	91	23	68	74.7%	11	0.0005	0.003	0.002	0.012	0.0115	0.00091	0.001	0.001	0.0014	0.002	0.003	0.0036	0.0048	0.005	0.01046
Zinc - dissolved (mg/L)	6		6	100.0%	1															
Metals (total)																				
Aluminium - total (mg/L)	18	18			18	0.02	0.442	1.098	4.9	4.88	0.02255	0.0265	0.032	0.04275	0.09	0.2825	0.314	0.61	1.3725	4.1945
Arsenic - total (mg/L)	92	41	51	55.4%	7	0.001	0.002	0.001	0.006	0.005	0.001	0.001	0.001	0.001	0.002	0.003	0.003	0.004	0.004	0.0056
Barium - total (mg/L)	91	91			59	0.012	0.064	0.069	0.38	0.368	0.0185	0.02	0.026	0.0285	0.044	0.066	0.074	0.103	0.2095	0.3764
Bismuth - total (mg/L)	91		91	100.0%	1															
Chromium - total (mg/L)	92	10	82	89.1%	7	0.001	0.004	0.004	0.016	0.015	0.001	0.001	0.0018	0.002	0.002	0.00345	0.00368	0.0052	0.0106	0.01492
Cobalt - total (mg/L)	92	41	51	55.4%	9	0.001	0.003	0.002	0.011	0.01	0.001	0.001	0.001	0.001	0.002	0.003	0.004	0.005	0.006	0.0094
Copper - total (mg/L)	92	88	4	4.3%	29	0.001	0.017	0.046	0.311	0.31	0.002	0.002	0.002	0.00275	0.0055	0.014	0.015	0.033	0.0416	0.311
Molybdenum - total (mg/L)	92	32	60	65.2%	9	0	0.002	0.001	0.004	0.004	0.000655	0.00082	0.001	0.001	0.002	0.003	0.003	0.0039	0.004	0.004
Nickel - total (mg/L)	92	25	67	72.8%	7	0.001	0.003	0.002	0.009	0.008	0.001	0.001	0.001	0.001	0.002	0.003	0.003	0.004	0.0064	0.00852
Selenium - total (mg/L)	92		92	100.0%	1															
Uranium - total (mg/L)	91	24	67	73.6%	13	0.0005	0.003	0.002	0.012	0.0115	0.001	0.001	0.001	0.001075	0.002	0.00325	0.004	0.00507	0.005865	0.01062
Nutrients																				
Nitrite + Nitrate as N (mg/L)	1		1	100.0%	1															
Total Kjeldahl Nitrogen as N (mg/L)	1	1			1	0.9	0.90	0.00	0.9	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Total Nitrogen as N (mg/L)	1	1			1	0.9	0.90	0.00	0.9	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Total Phosphorus as P (mg/L)	1	1			1	0.07	0.07	0.00	0.07	0	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Physico-Chemical Parameters																				
Electrical Conductivity (µS/cm)	89	89			78	39	374.22	356.91	1710	1671	74	85	127.8	136	244	460	553.8	935.4	1040	1613.2
pH (lab)	85	85			63	6.47	7.72	0.54	8.97	2.5	6.878	7.122	7.29	7.36	7.7	8.04	8.192	8.5	8.596	8.9448
Turbidity (NTU)	78	78			69	1.1	25.57	36.62	205	203.9	1.87	2.74	4.08	5.4	11.9	28.4	37.16	59.68	129.15	152.64

Table D.3 Descriptive statistics of surface water monitoring results – by location

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
B3														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	5	5			74	126.6	56.0771	200	126	75.8	83	86	190	198
Carbonate Alkalinity as CaCO3 (mg/L)	5	1	4	80.0%	8	8	0	8	0	8	8	8	8	8
Total Alkalinity as CaCO3 (mg/L)	5	5			74	128.2	54.9123	200	126	76.4	86	91	190	198
Hardness														
Total Hardness (mg CaCO3/L)	5	5			26	59.2	30.4985	110	84	28.4	38	45	77	103.4
Major Ions														
Calcium (mg/L)	5	5			6	12.3	4.9558	19	13	6.5	8.5	11	17	18.6
Chloride (mg/L)	5	5			7	15.2	10.1863	34	27	7.2	8	9	18	30.8
Fluoride (mg/L)	5	4	1	20.0%	0.1	0.15	0.0866	0.3	0.2	0.1	0.1	0.1	0.15	0.27
Magnesium (mg/L)	5	5			2.7	6.68	4.09067	14	11.3	2.96	4	4.5	8.2	12.84
Potassium (mg/L)	5	5			3.6	6.56	3.09877	12	8.4	3.64	3.8	5.7	7.7	11.14
Sodium (mg/L)	5	5			15	31.8	19.1353	66	51	15.2	16	23	39	60.6
Sulfate (as SO4)	5	5			1.9	4.64	3.75798	12	10.1	1.96	2.2	3	4.1	10.42
Metals (dissolved)														
Aluminium - dissolved (mg/L)	5	4	1	20.0%	0.007	0.0148	0.00907	0.03	0.023	0.0073	0.0085	0.011	0.0173	0.02745
Arsenic - dissolved (mg/L)	6		6	100.0%										
Barium - dissolved (mg/L)	5	5			0.015	0.028	0.01145	0.047	0.032	0.0158	0.019	0.025	0.034	0.0444
Bismuth - dissolved (mg/L)	5		5	100.0%										
Chromium - dissolved (mg/L)	6		6	100.0%										
Cobalt - dissolved (mg/L)	6		6	100.0%										
Copper - dissolved (mg/L)	6	6			0.001	0.0025	0.00096	0.004	0.003	0.0013	0.002	0.0025	0.003	0.00375
Molybdenum - dissolved (mg/L)	6	1	5	83.3%	7E-04	0.0007	0	0.0007	0	0.0007	0.0007	0.0007	0.0007	0.0007

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Nickel - dissolved (mg/L)	6		6	100.0%										
Selenium - dissolved (mg/L)	6		6	100.0%										
Uranium - dissolved (mg/L)	5	1	4	80.0%	0.001	0.001	0	0.001	0	0.001	0.001	0.001	0.001	0.001
Zinc - dissolved (mg/L)	1		1	100.0%										
Metals (total)														
Aluminium - total (mg/L)	5	5			0.067	0.2814	0.16307	0.55	0.483	0.0876	0.17	0.29	0.33	0.506
Arsenic - total (mg/L)	6		6	100.0%										
Barium - total (mg/L)	5	5			0.02	0.035	0.01753	0.068	0.048	0.0202	0.021	0.03	0.036	0.0616
Bismuth - total (mg/L)	5		5	100.0%										
Chromium - total (mg/L)	6		6	100.0%										
Cobalt - total (mg/L)	6	1	5	83.3%	0.001	0.001	0	0.001	0	0.001	0.001	0.001	0.001	0.001
Copper - total (mg/L)	6	6			0.002	0.0035	0.0015	0.006	0.004	0.002	0.00225	0.003	0.0045	0.00575
Molybdenum - total (mg/L)	6		6	100.0%										
Nickel - total (mg/L)	6	1	5	83.3%	0.001	0.001	0	0.001	0	0.001	0.001	0.001	0.001	0.001
Selenium - total (mg/L)	6		6	100.0%										
Uranium - total (mg/L)	5	1	4	80.0%	0.001	0.0011	0	0.0011	0	0.0011	0.0011	0.0011	0.0011	0.0011
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	4	4			130	247.5	147.203	500	370	137.5	167.5	180	260	452
pH (lab)	4	4			7.3	7.675	0.43229	8.4	1.1	7.315	7.375	7.5	7.8	8.28
B4														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	1	1			460	460	0	460	0	460	460	460	460	460
Carbonate Alkalinity as CaCO3 (mg/L)	1		1	100.0%										
Total Alkalinity as CaCO3 (mg/L)	1	1			460	460	0	460	0	460	460	460	460	460
Hardness														

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Total Hardness (mg CaCO3/L)	1	1			270	270	0	270	0	270	270	270	270	270
Major Ions														
Calcium (mg/L)	1	1			40	40	0	40	0	40	40	40	40	40
Chloride (mg/L)	1	1			110	110	0	110	0	110	110	110	110	110
Fluoride (mg/L)	1	1			0.5	0.5	0	0.5	0	0.5	0.5	0.5	0.5	0.5
Magnesium (mg/L)	1	1			42	42	0	42	0	42	42	42	42	42
Potassium (mg/L)	1	1			9	9	0	9	0	9	9	9	9	9
Sodium (mg/L)	1	1			270	270	0	270	0	270	270	270	270	270
Sulfate (as SO4)	1	1			230	230	0	230	0	230	230	230	230	230
Metals (dissolved)														
Aluminium - dissolved (mg/L)	1		1	100.0%										
Arsenic - dissolved (mg/L)	1		1	100.0%										
Barium - dissolved (mg/L)	1	1			0.08	0.08	0	0.08	0	0.08	0.08	0.08	0.08	0.08
Bismuth - dissolved (mg/L)	1		1	100.0%										
Chromium - dissolved (mg/L)	1		1	100.0%										
Cobalt - dissolved (mg/L)	1		1	100.0%										
Copper - dissolved (mg/L)	1	1			0.005	0.005	0	0.005	0	0.005	0.005	0.005	0.005	0.005
Molybdenum - dissolved (mg/L)	1	1			0.002	0.002	0	0.002	0	0.002	0.002	0.002	0.002	0.002
Nickel - dissolved (mg/L)	1		1	100.0%										
Selenium - dissolved (mg/L)	1		1	100.0%										
Uranium - dissolved (mg/L)	1	1			0.005	0.005	0	0.005	0	0.005	0.005	0.005	0.005	0.005
Zinc - dissolved (mg/L)	1		1	100.0%										
Metals (total)														
Aluminium - total (mg/L)	1	1			0.066	0.066	0	0.066	0	0.066	0.066	0.066	0.066	0.066
Arsenic - total (mg/L)	1		1	100.0%										

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Barium - total (mg/L)	1	1			0.085	0.085	0	0.085	0	0.085	0.085	0.085	0.085	0.085
Bismuth - total (mg/L)	1		1	100.0%										
Chromium - total (mg/L)	1		1	100.0%										
Cobalt - total (mg/L)	1	1			0.001	0.001	0	0.001	0	0.001	0.001	0.001	0.001	0.001
Copper - total (mg/L)	1	1			0.006	0.006	0	0.006	0	0.006	0.006	0.006	0.006	0.006
Molybdenum - total (mg/L)	1	1			0.002	0.002	0	0.002	0	0.002	0.002	0.002	0.002	0.002
Nickel - total (mg/L)	1		1	100.0%										
Selenium - total (mg/L)	1		1	100.0%										
Uranium - total (mg/L)	1	1			0.005	0.0051	0	0.0051	0	0.0051	0.0051	0.0051	0.0051	0.0051
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	1	1			1600	1600	0	1600	0	1600	1600	1600	1600	1600
B6														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	3	3			130	173.33	36.8179	220	90	134	150	170	195	215
Carbonate Alkalinity as CaCO3 (mg/L)	3		3	100.0%										
Total Alkalinity as CaCO3 (mg/L)	3	3			130	173.33	36.8179	220	90	134	150	170	195	215
Hardness														
Total Hardness (mg CaCO3/L)	3	3			55	88.333	23.9212	110	55	59.5	77.5	100	105	109
Major Ions														
Calcium (mg/L)	3	3			12	20.333	6.01849	26	14	13.1	17.5	23	24.5	25.7
Chloride (mg/L)	3	3			10	16.667	8.05536	28	18	10.2	11	12	20	26.4
Fluoride (mg/L)	3	3			0.1	0.1	#NUM!	0.1	0	0.1	0.1	0.1	0.1	0.1
Magnesium (mg/L)	3	3			5.7	9.3	2.98105	13	7.3	6.05	7.45	9.2	11.1	12.62
Potassium (mg/L)	3	3			4.1	4.8667	0.57927	5.5	1.4	4.19	4.55	5	5.25	5.45
Sodium (mg/L)	3	3			22	34	15.5778	56	34	22.2	23	24	40	52.8

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Sulfate (as SO4)	3	3			1.2	2.8	1.1431	3.8	2.6	1.42	2.3	3.4	3.6	3.76
Metals (dissolved)														
Aluminium - dissolved (mg/L)	3	2	1	33.3%	0.011	0.0155	0.0045	0.02	0.009	0.0115	0.01325	0.0155	0.0178	0.01955
Arsenic - dissolved (mg/L)	3	1	2	66.7%	0.002	0.002	0	0.002	0	0.002	0.002	0.002	0.002	0.002
Barium - dissolved (mg/L)	3	3			0.026	0.037	0.0086	0.047	0.021	0.0272	0.032	0.038	0.0425	0.0461
Bismuth - dissolved (mg/L)	3		3	100.0%										
Chromium - dissolved (mg/L)	3		3	100.0%										
Cobalt - dissolved (mg/L)	3		3	100.0%										
Copper - dissolved (mg/L)	3	1	2	66.7%	0.002	0.002	0	0.002	0	0.002	0.002	0.002	0.002	0.002
Molybdenum - dissolved (mg/L)	3	1	2	66.7%	6E-04	0.0006	0	0.0006	0	0.0006	0.0006	0.0006	0.0006	0.0006
Nickel - dissolved (mg/L)	3		3	100.0%										
Selenium - dissolved (mg/L)	3		3	100.0%										
Uranium - dissolved (mg/L)	3	1	2	66.7%	5E-04	0.0005	0	0.0005	0	0.0005	0.0005	0.0005	0.0005	0.0005
Zinc - dissolved (mg/L)	1		1	100.0%										
Metals (total)														
Aluminium - total (mg/L)	3	3			0.02	0.0237	0.0033	0.028	0.008	0.0203	0.0215	0.023	0.0255	0.0275
Arsenic - total (mg/L)	3	1	2	66.7%	0.002	0.002	0	0.002	0	0.002	0.002	0.002	0.002	0.002
Barium - total (mg/L)	3	3			0.026	0.043	0.01203	0.052	0.026	0.0285	0.0385	0.051	0.0515	0.0519
Bismuth - total (mg/L)	3		3	100.0%										
Chromium - total (mg/L)	3		3	100.0%										
Cobalt - total (mg/L)	3	1	2	66.7%	0.002	0.002	0	0.002	0	0.002	0.002	0.002	0.002	0.002
Copper - total (mg/L)	3	2	1	33.3%	0.001	0.0015	0.0005	0.002	0.001	0.0011	0.00125	0.0015	0.0018	0.00195
Molybdenum - total (mg/L)	3	1	2	66.7%	6E-04	0.0006	0	0.0006	0	0.0006	0.0006	0.0006	0.0006	0.0006
Nickel - total (mg/L)	3		3	100.0%										
Selenium - total (mg/L)	3		3	100.0%										

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Uranium - total (mg/L)	3	1	2	66.7%	5E-04	0.0005	0	0.0005	0	0.0005	0.0005	0.0005	0.0005	0.0005
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	3	3			230	336.67	94.6338	460	230	239	275	320	390	446
pH (lab)	2	2			7.8	7.9	0.1	8	0.2	7.81	7.85	7.9	7.95	7.99
B7														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	3	3			130	290	192.007	560	430	135	155	180	370	522
Carbonate Alkalinity as CaCO3 (mg/L)	3	1	2	66.7%	19	19	0	19	0	19	19	19	19	19
Total Alkalinity as CaCO3 (mg/L)	3	3			150	296.67	186.607	560	410	153	165	180	370	522
Hardness														
Total Hardness (mg CaCO3/L)	3	3			62	126.33	80.6074	240	178	63.5	69.5	77	158.5	223.7
Major Ions														
Calcium (mg/L)	3	3			15	23	10.6145	38	23	15.1	15.5	16	27	35.8
Chloride (mg/L)	3	3			12	44.333	37.5618	97	85	13.2	18	24	60.5	89.7
Fluoride (mg/L)	3	3			0.2	0.3	0.08165	0.4	0.2	0.21	0.25	0.3	0.35	0.39
Magnesium (mg/L)	3	3			6.1	16.3	12.5642	34	27.9	6.37	7.45	8.8	21.4	31.48
Potassium (mg/L)	3	3			5.6	7.8667	1.7632	9.9	4.3	5.85	6.85	8.1	9	9.72
Sodium (mg/L)	3	3			32	106.67	87.8534	230	198	34.6	45	58	144	212.8
Sulfate (as SO4)	3	3			8.9	28.967	26.2171	66	57.1	9.21	10.45	12	39	60.6
Metals (dissolved)														
Aluminium - dissolved (mg/L)	3	1	2	66.7%	0.013	0.013	0	0.013	0	0.013	0.013	0.013	0.013	0.013
Arsenic - dissolved (mg/L)	3	1	2	66.7%	0.002	0.002	0	0.002	0	0.002	0.002	0.002	0.002	0.002
Barium - dissolved (mg/L)	3	3			0.031	0.0477	0.01759	0.072	0.041	0.0319	0.0355	0.04	0.056	0.0688
Bismuth - dissolved (mg/L)	3		3	100.0%										
Chromium - dissolved (mg/L)	3		3	100.0%										

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Cobalt - dissolved (mg/L)	3		3	100.0%										
Copper - dissolved (mg/L)	3	3			0.002	0.0067	0.00411	0.012	0.01	0.0024	0.004	0.006	0.009	0.0114
Molybdenum - dissolved (mg/L)	3	3			0.001	0.0017	0.00092	0.003	0.002	0.001	0.00105	0.0011	0.0021	0.00281
Nickel - dissolved (mg/L)	3		3	100.0%										
Selenium - dissolved (mg/L)	3		3	100.0%										
Uranium - dissolved (mg/L)	3	2	1	33.3%	9E-04	0.0065	0.00555	0.012	0.011	0.0015	0.003675	0.00645	0.0092	0.011445
Zinc - dissolved (mg/L)	1		1	100.0%										
Metals (total)														
Aluminium - total (mg/L)	3	3			0.03	0.2933	0.32417	0.75	0.72	0.037	0.065	0.1	0.425	0.685
Arsenic - total (mg/L)	3	1	2	66.7%	0.002	0.002	0	0.002	0	0.002	0.002	0.002	0.002	0.002
Barium - total (mg/L)	3	3			0.033	0.054	0.01715	0.075	0.042	0.0351	0.0435	0.054	0.0645	0.0729
Bismuth - total (mg/L)	3		3	100.0%										
Chromium - total (mg/L)	3		3	100.0%										
Cobalt - total (mg/L)	3	1	2	66.7%	0.001	0.001	0	0.001	0	0.001	0.001	0.001	0.001	0.001
Copper - total (mg/L)	3	3			0.003	0.0097	0.00478	0.014	0.011	0.0039	0.0075	0.012	0.013	0.0138
Molybdenum - total (mg/L)	3	3			0.001	0.0017	0.00094	0.003	0.002	0.001	0.001	0.001	0.002	0.0028
Nickel - total (mg/L)	3	1	2	66.7%	0.001	0.001	0	0.001	0	0.001	0.001	0.001	0.001	0.001
Selenium - total (mg/L)	3		3	100.0%										
Uranium - total (mg/L)	3	2	1	33.3%	0.001	0.0065	0.0055	0.012	0.011	0.0016	0.00375	0.0065	0.0093	0.01145
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	3	3			280	700	498.264	1400	1120	294	350	420	910	1302
pH (lab)	2	2			8	8.2	0.2	8.4	0.4	8.02	8.1	8.2	8.3	8.38
B8														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	4	4			100	345	255.49	740	640	106	130	270	485	689

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Carbonate Alkalinity as CaCO3 (mg/L)	4		4	100.0%										
Total Alkalinity as CaCO3 (mg/L)	4	4			100	345	255.49	740	640	106	130	270	485	689
Hardness														
Total Hardness (mg CaCO3/L)	4	4			57	154.5	101.623	310	253	59.1	67.5	125.5	212.5	290.5
Major Ions														
Calcium (mg/L)	4	4			15	34.25	23.0367	73	58	15.6	18	24.5	40.75	66.55
Chloride (mg/L)	4	4			7	33.5	23.6907	60	53	7.9	11.5	33.5	55.5	59.1
Fluoride (mg/L)	4	4			0.1	0.2	0.12247	0.4	0.3	0.1	0.1	0.15	0.25	0.37
Magnesium (mg/L)	4	4			4.9	17	11.5566	30	25.1	5.08	5.8	16.55	27.75	29.55
Potassium (mg/L)	4	4			7	46.225	65.6945	160	153	7.195	7.975	8.95	47.2	137.44
Sodium (mg/L)	4	4			17	63.25	49.1089	140	123	18.05	22.25	48	89	129.8
Sulfate (as SO4)	4	4			2.6	13.95	13.6509	37	34.4	2.99	4.55	8.1	17.5	33.1
Metals (dissolved)														
Aluminium - dissolved (mg/L)	4	2	2	50.0%	0.006	0.148	0.142	0.29	0.284	0.0202	0.077	0.148	0.219	0.2758
Arsenic - dissolved (mg/L)	4	1	3	75.0%	0.004	0.004	0	0.004	0	0.004	0.004	0.004	0.004	0.004
Barium - dissolved (mg/L)	4	4			0.032	0.1063	0.10656	0.29	0.258	0.0337	0.04025	0.0515	0.1175	0.2555
Bismuth - dissolved (mg/L)	4		4	100.0%										
Chromium - dissolved (mg/L)	4		4	100.0%										
Cobalt - dissolved (mg/L)	4	1	3	75.0%	0.005	0.005	0	0.005	0	0.005	0.005	0.005	0.005	0.005
Copper - dissolved (mg/L)	4	4			0.001	0.0025	0.00112	0.004	0.003	0.0012	0.00175	0.0025	0.0033	0.00385
Molybdenum - dissolved (mg/L)	4	4			9E-04	0.0012	0.00045	0.002	0.001	0.0009	0.000975	0.001	0.0013	0.00185
Nickel - dissolved (mg/L)	4	1	3	75.0%	0.003	0.003	0	0.003	0	0.003	0.003	0.003	0.003	0.003
Selenium - dissolved (mg/L)	4		4	100.0%										
Uranium - dissolved (mg/L)	4	2	2	50.0%	0.002	0.0024	0.00055	0.0029	0.001	0.0019	0.002075	0.00235	0.0026	0.002845
Zinc - dissolved (mg/L)	1		1	100.0%										

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Metals (total)														
Aluminium - total (mg/L)	4	4			0.035	1.2988	2.07984	4.9	4.865	0.0418	0.06875	0.13	1.36	4.192
Arsenic - total (mg/L)	4	1	3	75.0%	0.006	0.006	0	0.006	0	0.006	0.006	0.006	0.006	0.006
Barium - total (mg/L)	4	4			0.036	0.1325	0.14326	0.38	0.344	0.038	0.04575	0.057	0.1438	0.33275
Bismuth - total (mg/L)	4		4	100.0%										
Chromium - total (mg/L)	4	1	3	75.0%	0.004	0.0036	0	0.0036	0	0.0036	0.0036	0.0036	0.0036	0.0036
Cobalt - total (mg/L)	4	1	3	75.0%	0.011	0.011	0	0.011	0	0.011	0.011	0.011	0.011	0.011
Copper - total (mg/L)	4	4			0.002	0.0113	0.0127	0.033	0.031	0.0022	0.00275	0.005	0.0135	0.0291
Molybdenum - total (mg/L)	4	4			0	0.0007	0.00041	0.001	0.001	0.0001	0.0006	0.0009	0.001	0.001
Nickel - total (mg/L)	4	1	3	75.0%	0.007	0.007	0	0.007	0	0.007	0.007	0.007	0.007	0.007
Selenium - total (mg/L)	4		4	100.0%										
Uranium - total (mg/L)	4	2	2	50.0%	0.002	0.0025	0.00045	0.0029	9E-04	0.002	0.002225	0.00245	0.0027	0.002855
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	3	3			200	466.67	328.87	930	730	207	235	270	600	864
pH (lab)	3	3			7.4	7.6333	0.16997	7.8	0.4	7.43	7.55	7.7	7.75	7.79
B9														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	2	2			160	230	70	300	140	167	195	230	265	293
Carbonate Alkalinity as CaCO3 (mg/L)	2		2	100.0%										
Total Alkalinity as CaCO3 (mg/L)	2	2			160	230	70	300	140	167	195	230	265	293
Hardness														
Total Hardness (mg CaCO3/L)	2	2			82	136	54	190	108	87.4	109	136	163	184.6
Major Ions														
Calcium (mg/L)	2	2			19	27.5	8.5	36	17	19.85	23.25	27.5	31.75	35.15
Chloride (mg/L)	2	2			7	41.5	34.5	76	69	10.45	24.25	41.5	58.75	72.55

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Fluoride (mg/L)	2	2			0.1	0.1	0	0.1	0	0.1	0.1	0.1	0.1	0.1
Magnesium (mg/L)	2	2			8.5	16.75	8.25	25	16.5	9.325	12.625	16.75	20.875	24.175
Potassium (mg/L)	2	2			8.7	10.85	2.15	13	4.3	8.915	9.775	10.85	11.925	12.785
Sodium (mg/L)	2	2			19	58.5	39.5	98	79	22.95	38.75	58.5	78.25	94.05
Sulfate (as SO4)	2	2			2	18	16	34	32	3.6	10	18	26	32.4
Metals (dissolved)														
Aluminium - dissolved (mg/L)	2		2	100.0%										
Arsenic - dissolved (mg/L)	2		2	100.0%										
Barium - dissolved (mg/L)	2	2			0.035	0.0525	0.0175	0.07	0.035	0.0368	0.04375	0.0525	0.0613	0.06825
Bismuth - dissolved (mg/L)	2		2	100.0%										
Chromium - dissolved (mg/L)	2		2	100.0%										
Cobalt - dissolved (mg/L)	2		2	100.0%										
Copper - dissolved (mg/L)	2	2			0.002	0.0025	0.0005	0.003	0.001	0.0021	0.00225	0.0025	0.0028	0.00295
Molybdenum - dissolved (mg/L)	2	1	1	50.0%	7E-04	0.0007	0	0.0007	0	0.0007	0.0007	0.0007	0.0007	0.0007
Nickel - dissolved (mg/L)	2		2	100.0%										
Selenium - dissolved (mg/L)	2		2	100.0%										
Uranium - dissolved (mg/L)	2	1	1	50.0%	0.002	0.0018	0	0.0018	0	0.0018	0.0018	0.0018	0.0018	0.0018
Zinc - dissolved (mg/L)	1		1	100.0%										
Metals (total)														
Aluminium - total (mg/L)	2	2			0.07	0.165	0.095	0.26	0.19	0.0795	0.1175	0.165	0.2125	0.2505
Arsenic - total (mg/L)	2		2	100.0%										
Barium - total (mg/L)	2	2			0.039	0.057	0.018	0.075	0.036	0.0408	0.048	0.057	0.066	0.0732
Bismuth - total (mg/L)	2		2	100.0%										
Chromium - total (mg/L)	2		2	100.0%										
Cobalt - total (mg/L)	2		2	100.0%										

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Copper - total (mg/L)	2	2			0.004	0.004	0	0.004	0	0.004	0.004	0.004	0.004	0.004
Molybdenum - total (mg/L)	2	1	1	50.0%	7E-04	0.0007	0	0.0007	0	0.0007	0.0007	0.0007	0.0007	0.0007
Nickel - total (mg/L)	2		2	100.0%										
Selenium - total (mg/L)	2		2	100.0%										
Uranium - total (mg/L)	2	1	1	50.0%	0.002	0.0019	0	0.0019	0	0.0019	0.0019	0.0019	0.0019	0.0019
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	2	2			260	550	290	840	580	289	405	550	695	811
pH (lab)	1	1			7.8	7.8	0	7.8	0	7.8	7.8	7.8	7.8	7.8
BASW01														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	14	14			24	86.643	58.8771	242	218	25.3	37.25	78	102.25	190.65
Carbonate Alkalinity as CaCO3 (mg/L)	14		14	100.0%										
Total Alkalinity as CaCO3 (mg/L)	14	14			24	86.643	58.8771	242	218	25.3	37.25	78	102.25	190.65
Field Measurements														
Depth to Water (mbRL)	1	1			1	1	0	1	0	1	1	1	1	1
Dissolved Oxygen (field) (% sat)	9	9			0	20.9	17.8651	53.4	53.4	0	9	14.4	32.7	49.36
Electrical Conductivity (field) (µS/cm)	10	10			60	330.7	356.263	1293	1233	64.05	100.5	208	340.75	977.55
ORP (field) (mV)	10	10			22.2	99.73	53.3547	185.8	163.6	29.175	55.45	96.05	140.03	179.05
pH (field)	10	10			5.87	7.642	0.81672	8.61	2.74	6.3605	7.2175	7.66	8.345	8.574
Salinity (field) (PSU)	10	10			0.03	0.16	0.18022	0.65	0.62	0.03	0.0425	0.1	0.1575	0.488
TDS (field) (ppm)	10	10			30	165.4	178.236	647	617	32.25	50.25	104	170.25	489.05
Temperature (field) (°C)	10	10			15	26.515	5.75156	34.13	19.13	18.15	22.2825	27.585	30.438	33.851
Hardness														
Total Hardness (mg CaCO3/L)	14	14			16	53.286	29.1288	126	110	19.25	35	42	69	105.2
Major Ions														

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Calcium (mg/L)	24	24			3	11	4.66369	19	16	4.15	8.5	10.5	14.25	18
Chloride (mg/L)	14	14			2	10.929	9.06693	30	28	2	4	9	13.5	29.35
Fluoride (mg/L)	14	9	5	35.7%	0.1	0.1667	0.06667	0.3	0.2	0.1	0.1	0.2	0.2	0.26
Magnesium (mg/L)	24	24			2	5.5	3.77492	19	17	2	3	4.5	6.25	11.55
Potassium (mg/L)	24	24			2	6.4583	5.02477	21	19	3	4	4	6	19.65
Sodium (mg/L)	24	24			4	24.25	20.4863	93	89	4	6	20	34.25	52.75
Sulfate (as SO4)	14	9	5	35.7%	4	13.778	12.1177	44	40	4.8	6	8	16	35.6
Metals (dissolved)														
Arsenic - dissolved (mg/L)	14	4	10	71.4%	0.001	0.001	0	0.001	0	0.001	0.001	0.001	0.001	0.001
Barium - dissolved (mg/L)	14	14			0.009	0.0304	0.01537	0.07	0.061	0.0149	0.02025	0.024	0.0405	0.0557
Bismuth - dissolved (mg/L)	14		14	100.0%										
Chromium - dissolved (mg/L)	14	1	13	92.9%	0.002	0.002	0	0.002	0	0.002	0.002	0.002	0.002	0.002
Cobalt - dissolved (mg/L)	14	4	10	71.4%	0.001	0.002	0.00071	0.003	0.002	0.0012	0.00175	0.002	0.0023	0.00285
Copper - dissolved (mg/L)	14	14			0.002	0.0098	0.00899	0.039	0.037	0.0027	0.00475	0.007	0.0105	0.02405
Molybdenum - dissolved (mg/L)	14	2	12	85.7%	0.001	0.0015	0.0005	0.002	0.001	0.0011	0.00125	0.0015	0.0018	0.00195
Nickel - dissolved (mg/L)	14	2	12	85.7%	0.002	0.005	0.003	0.008	0.006	0.0023	0.0035	0.005	0.0065	0.0077
Selenium - dissolved (mg/L)	14		14	100.0%										
Uranium - dissolved (mg/L)	14	1	13	92.9%	0.001	0.001	0	0.001	0	0.001	0.001	0.001	0.001	0.001
Metals (total)														
Arsenic - total (mg/L)	14	7	7	50.0%	0.001	0.0011	0.00035	0.002	0.001	0.001	0.001	0.001	0.001	0.0017
Barium - total (mg/L)	14	14			0.017	0.0382	0.01784	0.074	0.057	0.017	0.02325	0.0365	0.044	0.0701
Bismuth - total (mg/L)	14		14	100.0%										
Chromium - total (mg/L)	14	3	11	78.6%	0.001	0.0017	0.00094	0.003	0.002	0.001	0.001	0.001	0.002	0.0028
Cobalt - total (mg/L)	14	5	9	64.3%	0.001	0.002	0.00089	0.003	0.002	0.001	0.001	0.002	0.003	0.003
Copper - total (mg/L)	14	14			0.002	0.0129	0.0134	0.046	0.044	0.002	0.004	0.0075	0.0138	0.0408

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Molybdenum - total (mg/L)	14	2	12	85.7%	0.001	0.0015	0.0005	0.002	0.001	0.0011	0.00125	0.0015	0.0018	0.00195
Nickel - total (mg/L)	14	4	10	71.4%	0.002	0.0025	0.00087	0.004	0.002	0.002	0.002	0.002	0.0025	0.0037
Selenium - total (mg/L)	14		14	100.0%										
Uranium - total (mg/L)	14	1	13	92.9%	0.001	0.001	0	0.001	0	0.001	0.001	0.001	0.001	0.001
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	14	14			57	218.07	142.926	573	516	66.75	90.25	195.5	303.25	459.25
pH (lab)	14	14			6.48	7.4614	0.53461	8.43	1.95	6.7205	7.03	7.44	7.885	8.287
BASW04														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	17	17			40	195.47	153.065	499	459	47.2	99	130	294	451
Carbonate Alkalinity as CaCO3 (mg/L)	17	3	14	82.4%	22	25.333	4.71405	32	10	22	22	22	27	31
Total Alkalinity as CaCO3 (mg/L)	17	17			40	199.94	161.026	531	491	47.2	99	130	294	475
Field Measurements														
Depth to Water (mbRL)	1	1			0.3	0.3	0	0.3	0	0.3	0.3	0.3	0.3	0.3
Dissolved Oxygen (field) (% sat)	9	9			4.8	41.667	52.1629	179.6	174.8	6.32	8.9	16.1	48.5	131.04
Electrical Conductivity (field) (µS/cm)	9	9			126	571.89	428.157	1293	1167	140.4	198	307	980	1201.8
ORP (field) (mV)	7	7			1.8	70.586	65.9529	168.4	166.6	2.55	18.15	43.3	122.15	168.28
pH (field)	9	9			6.78	7.97	0.70312	8.89	2.11	6.968	7.42	8.24	8.61	8.782
Salinity (field) (PSU)	9	9			0.06	0.2778	0.21745	0.65	0.59	0.06	0.09	0.14	0.48	0.602
TDS (field) (ppm)	7	7			63	338.57	215.581	647	584	73.8	126.5	384	511.5	612.8
Temperature (field) (°C)	9	9			22.09	29.766	4.43648	35.99	13.9	23.49	26.21	30.83	33.7	35.098
Hardness														
Total Hardness (mg CaCO3/L)	17	17			30	126.53	96.306	312	282	38.8	49	76	199	286.4
Major Ions														
Calcium (mg/L)	24	24			7	24.292	15.5764	66	59	7.45	13	17	34.25	48

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Chloride (mg/L)	17	17			4	25.765	26.636	86	82	4	7	13	24	83.6
Fluoride (mg/L)	14	10	4	28.6%	0.1	0.68	0.63056	1.6	1.5	0.1	0.2	0.25	1.375	1.6
Magnesium (mg/L)	24	24			3	12.5	12.6326	49	46	3.15	4.75	6.5	12.25	39
Potassium (mg/L)	24	24			4	7.75	4.013	20	16	4	5	6	10.25	14.55
Sodium (mg/L)	24	24			4	50.5	51.2778	212	208	4.9	21.5	34.5	41.5	145
Sulfate (as SO4)	17	14	3	17.6%	1	20.429	19.2603	55	54	2.3	6	11.5	36	52.4
Metals (dissolved)														
Arsenic - dissolved (mg/L)	17	13	4	23.5%	0.001	0.0023	0.00114	0.004	0.003	0.001	0.001	0.002	0.003	0.004
Barium - dissolved (mg/L)	17	17			0.019	0.088	0.09779	0.419	0.4	0.0206	0.034	0.049	0.099	0.2742
Bismuth - dissolved (mg/L)	17		17	100.0%										
Chromium - dissolved (mg/L)	17		17	100.0%										
Cobalt - dissolved (mg/L)	17	8	9	52.9%	0.001	0.0029	0.00176	0.005	0.004	0.001	0.001	0.0025	0.005	0.005
Copper - dissolved (mg/L)	17	16	1	5.9%	0.004	0.0384	0.06456	0.208	0.204	0.004	0.01	0.012	0.0238	0.208
Molybdenum - dissolved (mg/L)	17	10	7	41.2%	0.001	0.0021	0.00094	0.003	0.002	0.001	0.001	0.0025	0.003	0.003
Nickel - dissolved (mg/L)	17	4	13	76.5%	0.001	0.0028	0.00249	0.007	0.006	0.001	0.001	0.0015	0.0033	0.00625
Selenium - dissolved (mg/L)	17		17	100.0%										
Uranium - dissolved (mg/L)	17	5	12	70.6%	0.002	0.0028	0.00075	0.004	0.002	0.002	0.002	0.003	0.003	0.0038
Metals (total)														
Arsenic - total (mg/L)	17	14	3	17.6%	0.001	0.0026	0.00117	0.005	0.004	0.001	0.002	0.003	0.003	0.00435
Barium - total (mg/L)	17	17			0.02	0.0921	0.08806	0.376	0.356	0.0256	0.037	0.061	0.098	0.2672
Bismuth - total (mg/L)	17		17	100.0%										
Chromium - total (mg/L)	17	3	14	82.4%	0.002	0.002	0	0.002	0	0.002	0.002	0.002	0.002	0.002
Cobalt - total (mg/L)	17	13	4	23.5%	0.001	0.0027	0.00186	0.006	0.005	0.001	0.001	0.002	0.004	0.006
Copper - total (mg/L)	17	17			0.003	0.0538	0.09459	0.311	0.308	0.0078	0.013	0.017	0.033	0.311
Molybdenum - total (mg/L)	17	8	9	52.9%	0.001	0.0029	0.00105	0.004	0.003	0.0014	0.002	0.003	0.004	0.004

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Nickel - total (mg/L)	17	7	10	58.8%	0.001	0.0023	0.00088	0.004	0.003	0.0013	0.002	0.002	0.0025	0.0037
Selenium - total (mg/L)	17		17	100.0%										
Uranium - total (mg/L)	17	5	12	70.6%	0.002	0.003	0.00063	0.004	0.002	0.0022	0.003	0.003	0.003	0.0038
Nutrients														
Nitrite + Nitrate as N (mg/L)	1		1	100.0%										
Total Kjeldahl Nitrogen as N (mg/L)	1	1			0.9	0.9	0	0.9	0	0.9	0.9	0.9	0.9	0.9
Total Nitrogen as N (mg/L)	1	1			0.9	0.9	0	0.9	0	0.9	0.9	0.9	0.9	0.9
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	17	17			120	456.76	360.353	1260	1140	124.8	194	274	746	1084
pH (lab)	17	17			7.17	7.8182	0.43797	8.58	1.41	7.218	7.41	7.76	8.01	8.58
BASW05														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	9	9			23	115.33	93.6542	295	272	29	40	92	140	280.6
Carbonate Alkalinity as CaCO3 (mg/L)	9		9	100.0%										
Total Alkalinity as CaCO3 (mg/L)	9	9			23	115.33	93.6542	295	272	29	40	92	140	280.6
Field Measurements														
Dissolved Oxygen (field) (% sat)	7	7			0	20.914	26.5333	72.6	72.6	0	0	0.8	36.5	63.33
Electrical Conductivity (field) (µS/cm)	8	8			79	413.5	304.395	1027	948	106.3	169.75	333.5	584.5	890.5
ORP (field) (mV)	8	8			-133.6	54.438	129.074	231.7	365.3	-129.09	-10.975	41.95	147.05	230.685
pH (field)	8	8			5.34	7.5125	0.90155	8.63	3.29	6.047	7.42	7.73	7.9175	8.399
Salinity (field) (PSU)	8	8			0.04	0.2013	0.15186	0.51	0.47	0.0505	0.0775	0.16	0.2875	0.44
TDS (field) (ppm)	8	8			40	206.88	152.372	514	474	53.3	84.75	166.5	292.75	445.75
Temperature (field) (°C)	8	8			15.31	22.956	4.73227	28.99	13.68	16.49	19.715	22.145	28.04	28.7835
Hardness														
Total Hardness (mg CaCO3/L)	9	9			18	74.222	53.4016	165	147	22	32	48	114	162.2

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Major Ions														
Calcium (mg/L)	17	17			4	17.176	11.8433	37	33	4	8	13	31	37
Chloride (mg/L)	9	8	1	11.1%	2	11.25	9.18899	27	25	2.35	3.75	6.5	20.25	24.9
Fluoride (mg/L)	9	5	4	44.4%	0.1	0.16	0.04899	0.2	0.1	0.1	0.1	0.2	0.2	0.2
Magnesium (mg/L)	17	17			2	7.1765	5.91345	21	19	2	3	5	9	20.2
Potassium (mg/L)	17	17			2	14.235	17.7185	60	58	2.8	4	7	12	56
Sodium (mg/L)	17	17			2	18.647	17.2693	57	55	2	5	13	26	52.2
Sulfate (as SO4)	9	4	5	55.6%	1	2.75	1.92029	6	5	1.15	1.75	2	3	5.4
Metals (dissolved)														
Arsenic - dissolved (mg/L)	9	4	5	55.6%	0.001	0.002	0.001	0.003	0.002	0.001	0.001	0.002	0.003	0.003
Barium - dissolved (mg/L)	9	9			0.015	0.063	0.05431	0.176	0.161	0.0166	0.021	0.04	0.088	0.1588
Bismuth - dissolved (mg/L)	9		9	100.0%										
Chromium - dissolved (mg/L)	9		9	100.0%										
Cobalt - dissolved (mg/L)	9	4	5	55.6%	0.001	0.003	0.00122	0.004	0.003	0.0013	0.0025	0.0035	0.004	0.004
Copper - dissolved (mg/L)	9	9			0.001	0.0062	0.00609	0.018	0.017	0.0014	0.002	0.003	0.008	0.0172
Molybdenum - dissolved (mg/L)	9	2	7	77.8%	0.002	0.002	0	0.002	0	0.002	0.002	0.002	0.002	0.002
Nickel - dissolved (mg/L)	9	3	6	66.7%	0.001	0.0017	0.00047	0.002	0.001	0.0011	0.0015	0.002	0.002	0.002
Selenium - dissolved (mg/L)	9		9	100.0%										
Uranium - dissolved (mg/L)	9	1	8	88.9%	0.001	0.001	0	0.001	0	0.001	0.001	0.001	0.001	0.001
Metals (total)														
Arsenic - total (mg/L)	9	7	2	22.2%	0.001	0.002	0.00107	0.004	0.003	0.001	0.001	0.002	0.0025	0.0037
Barium - total (mg/L)	9	9			0.026	0.0846	0.06289	0.215	0.189	0.0284	0.035	0.063	0.094	0.199
Bismuth - total (mg/L)	9		9	100.0%										
Chromium - total (mg/L)	9	2	7	77.8%	0.004	0.01	0.006	0.016	0.012	0.0046	0.007	0.01	0.013	0.0154
Cobalt - total (mg/L)	9	6	3	33.3%	0.003	0.0043	0.00137	0.007	0.004	0.003	0.00325	0.004	0.0048	0.0065

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Copper - total (mg/L)	9	9			0.002	0.0157	0.01321	0.039	0.037	0.0028	0.004	0.013	0.026	0.037
Molybdenum - total (mg/L)	9	3	6	66.7%	0.001	0.0017	0.00047	0.002	0.001	0.0011	0.0015	0.002	0.002	0.002
Nickel - total (mg/L)	9	5	4	44.4%	0.001	0.0036	0.0028	0.009	0.008	0.0012	0.002	0.003	0.003	0.0078
Selenium - total (mg/L)	9		9	100.0%										
Uranium - total (mg/L)	9	2	7	77.8%	0.001	0.001	0	0.001	0	0.001	0.001	0.001	0.001	0.001
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	9	9			58	254.33	203.169	666	608	65.6	102	200	282	616
pH (lab)	9	9			6.47	7.4122	0.49492	8.21	1.74	6.702	7.14	7.36	7.55	8.154
BASW08														
Field Measurements														
Dissolved Oxygen (field) (% sat)	1	1			48.4	48.4	0	48.4	0	48.4	48.4	48.4	48.4	48.4
Electrical Conductivity (field) (µS/cm)	1	1			1305	1305	0	1305	0	1305	1305	1305	1305	1305
ORP (field) (mV)	1	1			-21.1	-21.1	0	-21.1	0	-21.1	-21.1	-21.1	-21.1	-21.1
pH (field)	1	1			9.09	9.09	0	9.09	0	9.09	9.09	9.09	9.09	9.09
Salinity (field) (PSU)	1	1			0.65	0.65	0	0.65	0	0.65	0.65	0.65	0.65	0.65
TDS (field) (ppm)	1	1			653	653	0	653	0	653	653	653	653	653
Temperature (field) (°C)	1	1			20.94	20.94	0	20.94	0	20.94	20.94	20.94	20.94	20.94
BASW09														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	14	14			17	198.79	216.118	824	807	28.05	64.5	86	325.5	541.9
Carbonate Alkalinity as CaCO3 (mg/L)	14	4	10	71.4%	15	47.5	26.2536	81	66	17.25	26.25	47	68.25	78.45
Total Alkalinity as CaCO3 (mg/L)	14	14			17	212.36	227.899	824	807	28.05	64.5	86	351.75	594.55
Field Measurements														
Dissolved Oxygen (field) (% sat)	8	8			0	54.325	52.4341	163	163	7.455	21.3	32.15	65.425	146.62
Electrical Conductivity (field) (µS/cm)	9	9			49	560.22	577.104	1723	1674	61.8	84	127	980	1458.6

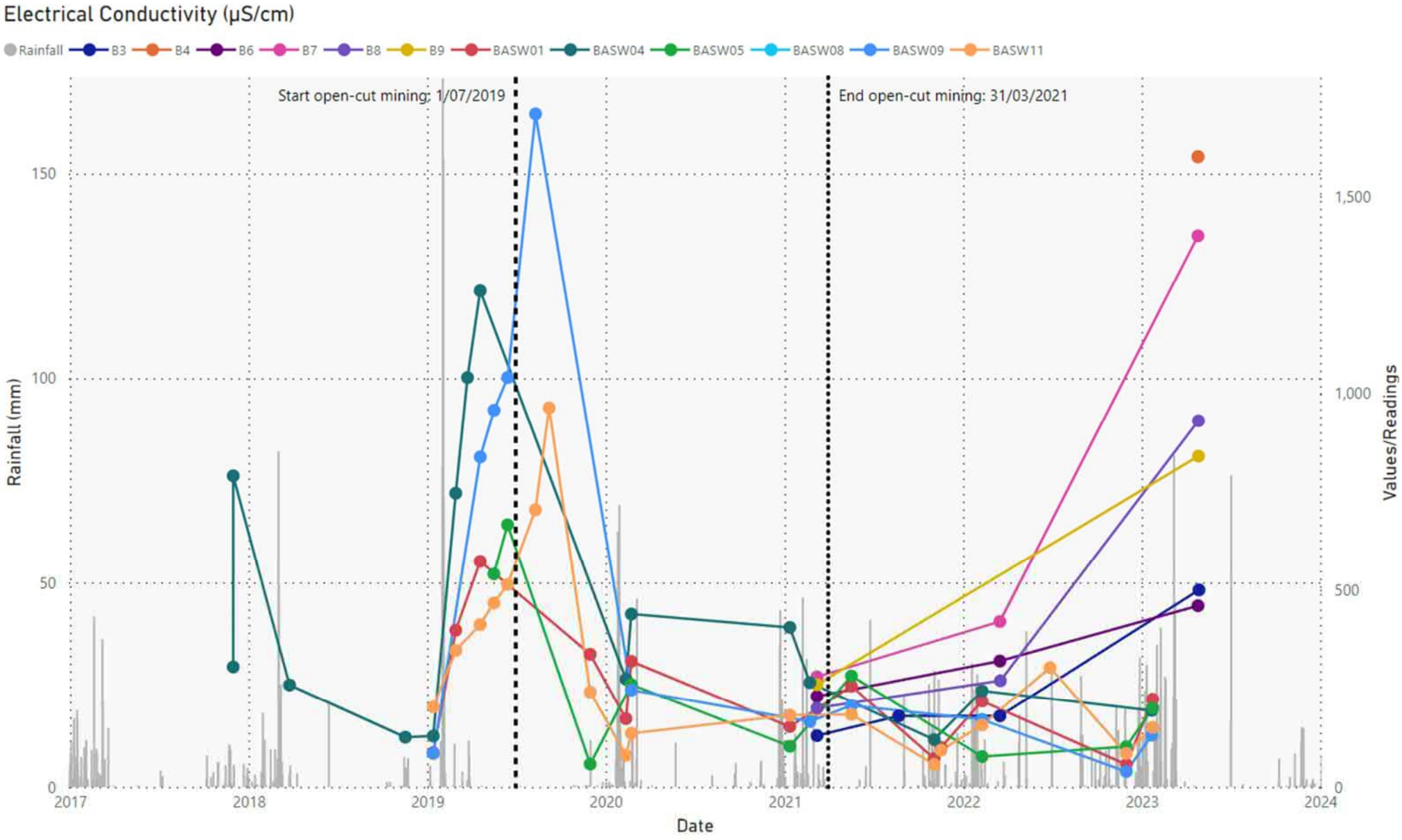
Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
ORP (field) (mV)	9	9			-45.8	68.789	62.488	170	215.8	-17.44	27.7	62.6	111	152.2
pH (field)	9	9			6.6	8.1833	0.82562	9.52	2.92	6.968	7.52	8.17	8.69	9.268
Salinity (field) (PSU)	8	8			0.02	0.3063	0.29389	0.87	0.85	0.027	0.04	0.24	0.49	0.7475
TDS (field) (ppm)	9	9			0.07	275.45	292.526	861	860.9	9.242	42	64	490	729
Temperature (field) (°C)	8	8			20.77	27.608	4.54958	34.84	14.07	22.405	25.4625	26.21	29.02	34.84
Hardness														
Total Hardness (mg CaCO3/L)	14	14			9	119.71	109.934	402	393	19.4	48	66.5	203.5	291.5
Major Ions														
Calcium (mg/L)	23	23			2	16.043	10.6464	44	42	3.2	10	12	20	42.1
Chloride (mg/L)	14	14			1	27	33.6261	111	110	2.3	4	6	49.75	86.95
Fluoride (mg/L)	14	10	4	28.6%	0.1	0.31	0.1578	0.5	0.4	0.1	0.2	0.3	0.475	0.5
Magnesium (mg/L)	23	23			1	19.174	22.2352	76	75	2.1	5	7	33	68.7
Potassium (mg/L)	23	23			3	14.13	18.3381	70	67	4	4.5	6	11	63.2
Sodium (mg/L)	23	22	1	4.3%	1	59.636	77.2125	234	233	2	8.25	15.5	118.75	222.25
Sulfate (as SO4)	14	9	5	35.7%	2	13.333	10.3387	30	28	2	2	20	20	26.4
Metals (dissolved)														
Arsenic - dissolved (mg/L)	14	5	9	64.3%	0.001	0.0018	0.00075	0.003	0.002	0.001	0.001	0.002	0.002	0.0028
Barium - dissolved (mg/L)	14	14			0.005	0.0421	0.04245	0.18	0.175	0.0122	0.018	0.0285	0.0443	0.115
Bismuth - dissolved (mg/L)	14		14	100.0%										
Chromium - dissolved (mg/L)	14	2	12	85.7%	0.001	0.001	0	0.001	0	0.001	0.001	0.001	0.001	0.001
Cobalt - dissolved (mg/L)	14	5	9	64.3%	0.001	0.0016	0.00049	0.002	0.001	0.001	0.001	0.002	0.002	0.002
Copper - dissolved (mg/L)	14	10	4	28.6%	0.001	0.0024	0.0012	0.005	0.004	0.001	0.002	0.002	0.0028	0.00455
Molybdenum - dissolved (mg/L)	14	5	9	64.3%	0.001	0.0024	0.0008	0.003	0.002	0.0012	0.002	0.003	0.003	0.003
Nickel - dissolved (mg/L)	14	1	13	92.9%	0.001	0.001	0	0.001	0	0.001	0.001	0.001	0.001	0.001
Selenium - dissolved (mg/L)	14		14	100.0%										

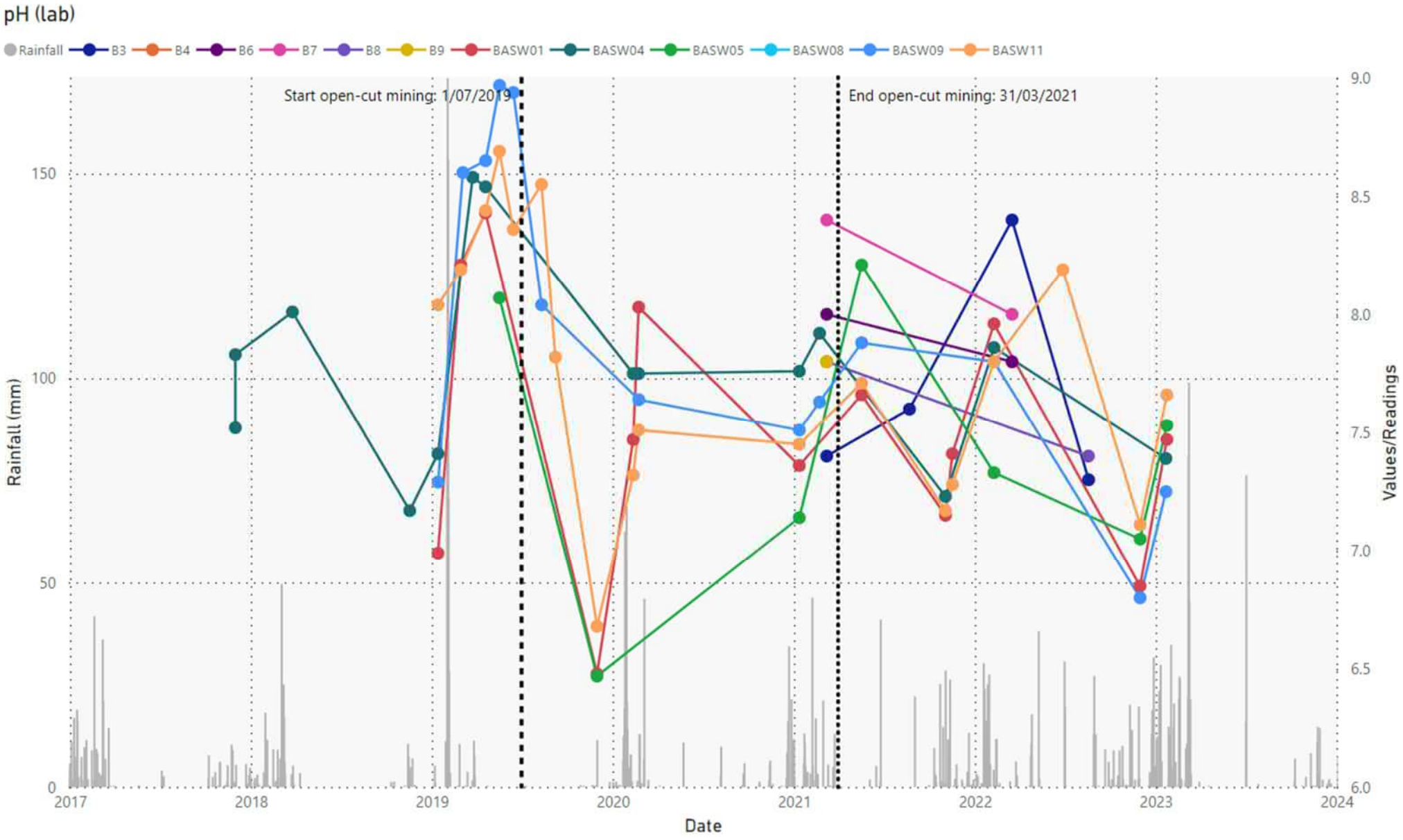
Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Uranium - dissolved (mg/L)	14	5	9	64.3%	0.002	0.0034	0.00102	0.005	0.003	0.0022	0.003	0.003	0.004	0.0048
Metals (total)														
Arsenic - total (mg/L)	14	6	8	57.1%	0.001	0.002	0.001	0.004	0.003	0.001	0.00125	0.002	0.002	0.0035
Barium - total (mg/L)	14	14			0.012	0.0656	0.08315	0.316	0.304	0.0172	0.025	0.033	0.0515	0.2432
Bismuth - total (mg/L)	14		14	100.0%										
Chromium - total (mg/L)	14	1	13	92.9%	0.002	0.002	0	0.002	0	0.002	0.002	0.002	0.002	0.002
Cobalt - total (mg/L)	14	7	7	50.0%	0.001	0.0023	0.00139	0.005	0.004	0.001	0.001	0.002	0.003	0.0044
Copper - total (mg/L)	14	13	1	7.1%	0.001	0.0029	0.0022	0.009	0.008	0.001	0.002	0.002	0.003	0.0072
Molybdenum - total (mg/L)	14	5	9	64.3%	0.002	0.0028	0.00075	0.004	0.002	0.002	0.002	0.003	0.003	0.0038
Nickel - total (mg/L)	14	2	12	85.7%	0.001	0.002	0.001	0.003	0.002	0.0011	0.0015	0.002	0.0025	0.0029
Selenium - total (mg/L)	14		14	100.0%										
Uranium - total (mg/L)	14	5	9	64.3%	0.002	0.004	0.00141	0.006	0.004	0.0022	0.003	0.004	0.005	0.0058
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	14	14			39	465.5	485.28	1710	1671	68.9	133	189	804.25	1274.5
pH (lab)	14	14			6.8	7.8779	0.65309	8.97	2.17	7.0925	7.345	7.72	8.46	8.9505
BASW11														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	19	19			27	113.74	93.7386	407	380	34.2	48.5	79	150.5	285.5
Carbonate Alkalinity as CaCO3 (mg/L)	19	4	15	78.9%	3	9.5	6.26498	18	15	3.15	3.75	8.5	14.25	17.25
Total Alkalinity as CaCO3 (mg/L)	19	19			27	115.74	96.1183	407	380	34.2	48.5	79	152	301.7
Field Measurements														
Dissolved Oxygen (field) (% sat)	16	16			0	32.869	26.9279	122.3	122.3	7.275	15	30.95	37.825	70.55
Electrical Conductivity (field) (µS/cm)	16	16			54	382.75	301.891	994	940	58.5	139.5	277	541	994
ORP (field) (mV)	16	16			-16.2	93.256	73.7353	216.1	232.3	-10.35	37.1	80.05	172.63	201.625
pH (field)	16	16			5.95	7.9681	0.78173	9.09	3.14	6.925	7.43	8.02	8.63	8.865

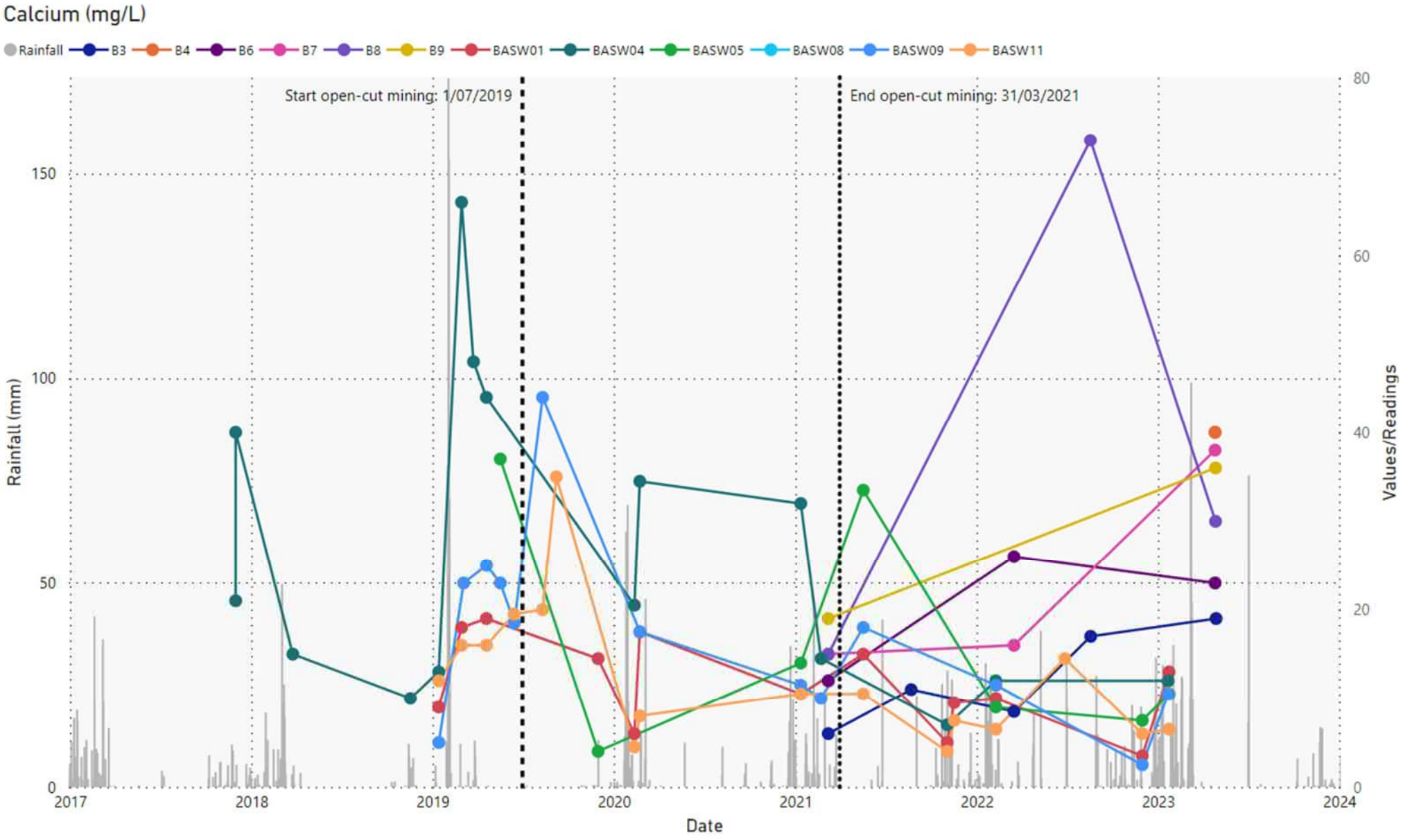
Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Salinity (field) (PSU)	16	16			0.02	0.1844	0.14975	0.49	0.47	0.0275	0.0675	0.13	0.26	0.49
TDS (field) (ppm)	16	16			27	191.31	150.929	497	470	29.25	69.75	138	270.75	497
Temperature (field) (°C)	16	16			16.2	25.353	6.53305	34.22	18.02	16.935	19.4625	24.355	31.47	34.01
Hardness														
Total Hardness (mg CaCO3/L)	19	19			18	65.947	50.6157	226	208	18	32.5	46	85	148.6
Major Ions														
Calcium (mg/L)	33	33			4	12.212	7.62276	36	32	4	7	11	16	26.2
Chloride (mg/L)	19	19			3	17.684	17.1527	70	67	3	6	9	26.5	46.6
Fluoride (mg/L)	19	12	7	36.8%	0.1	0.275	0.17381	0.6	0.5	0.1	0.1	0.25	0.4	0.545
Magnesium (mg/L)	33	33			2	8.2424	8.30126	33	31	2	3	4	10	26
Potassium (mg/L)	33	33			2	8.2424	7.12669	32	30	2.6	4	5	9	22.2
Sodium (mg/L)	33	33			3	36.182	37.9477	145	142	3.6	10	21	46	119.4
Sulfate (as SO4)	19	14	5	26.3%	1	10.643	9.18545	27	26	1.65	2.25	8	14.75	25.7
Metals (dissolved)														
Arsenic - dissolved (mg/L)	19	3	16	84.2%	0.001	0.0017	0.00094	0.003	0.002	0.001	0.001	0.001	0.002	0.0028
Barium - dissolved (mg/L)	19	19			0.01	0.0341	0.02529	0.127	0.117	0.01	0.0185	0.029	0.0395	0.0613
Bismuth - dissolved (mg/L)	19		19	100.0%										
Chromium - dissolved (mg/L)	19		19	100.0%										
Cobalt - dissolved (mg/L)	19	3	16	84.2%	0.002	0.0023	0.00047	0.003	0.001	0.002	0.002	0.002	0.0025	0.0029
Copper - dissolved (mg/L)	19	19			0.001	0.0037	0.00397	0.018	0.017	0.001	0.0015	0.002	0.004	0.0099
Molybdenum - dissolved (mg/L)	19	4	15	78.9%	0.001	0.0015	0.00087	0.003	0.002	0.001	0.001	0.001	0.0015	0.0027
Nickel - dissolved (mg/L)	19	5	14	73.7%	0.001	0.0026	0.00136	0.004	0.003	0.001	0.001	0.003	0.004	0.004
Selenium - dissolved (mg/L)	19		19	100.0%										
Uranium - dissolved (mg/L)	19	3	16	84.2%	0.001	0.0017	0.00047	0.002	0.001	0.0011	0.0015	0.002	0.002	0.002
Metals (total)														

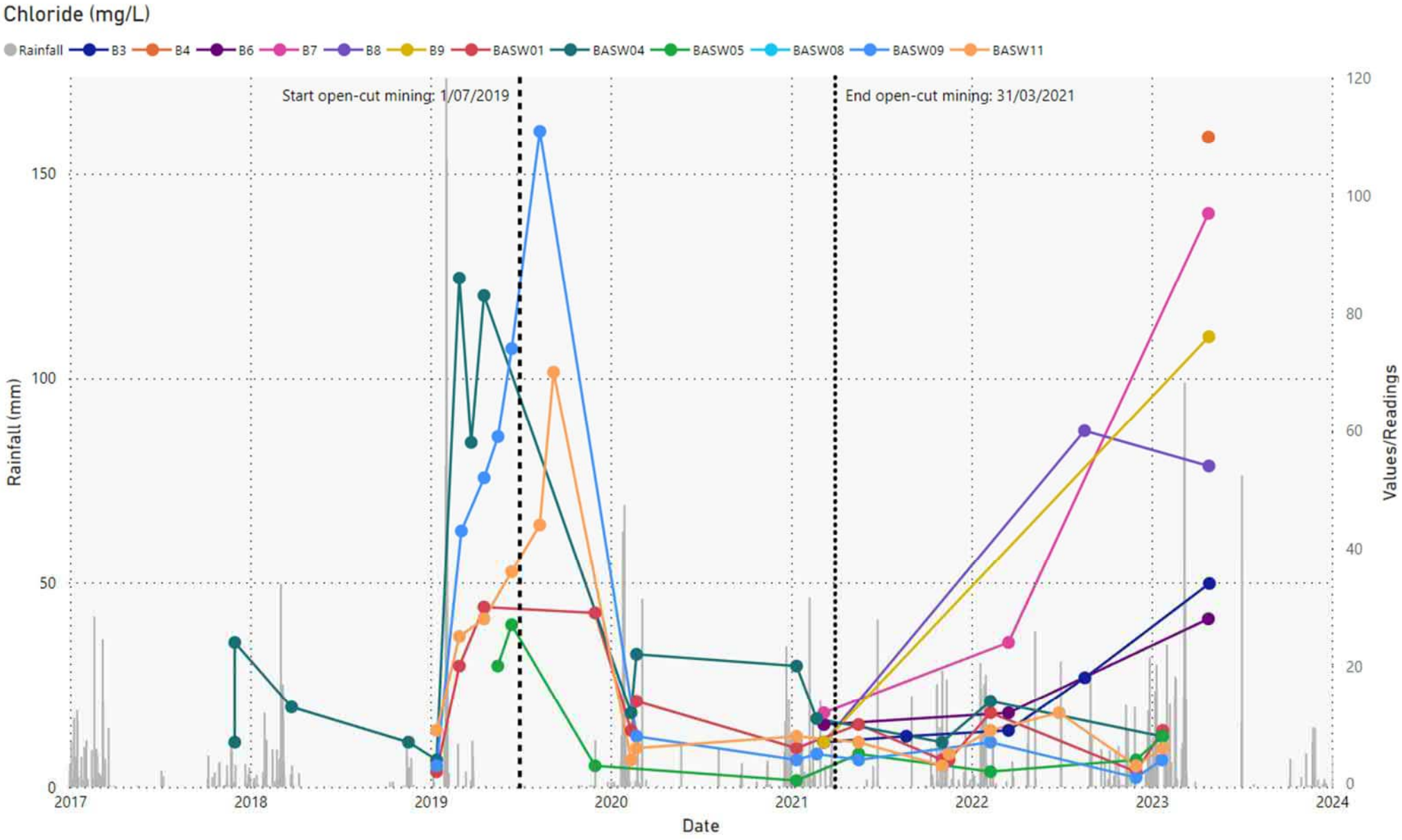
Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Arsenic - total (mg/L)	19	4	15	78.9%	0.001	0.0018	0.00083	0.003	0.002	0.001	0.001	0.0015	0.0023	0.00285
Barium - total (mg/L)	19	19			0.013	0.0432	0.03174	0.16	0.147	0.0139	0.026	0.033	0.05	0.079
Bismuth - total (mg/L)	19		19	100.0%										
Chromium - total (mg/L)	19		19	100.0%										
Cobalt - total (mg/L)	19	5	14	73.7%	0.001	0.0022	0.00075	0.003	0.002	0.0012	0.002	0.002	0.003	0.003
Copper - total (mg/L)	19	17	2	10.5%	0.002	0.0063	0.00593	0.024	0.022	0.002	0.002	0.004	0.008	0.0168
Molybdenum - total (mg/L)	19	4	15	78.9%	0.001	0.0013	0.00043	0.002	0.001	0.001	0.001	0.001	0.0013	0.00185
Nickel - total (mg/L)	19	4	15	78.9%	0.001	0.0015	0.0005	0.002	0.001	0.001	0.001	0.0015	0.002	0.002
Selenium - total (mg/L)	19		19	100.0%										
Uranium - total (mg/L)	19	3	16	84.2%	0.001	0.0017	0.00047	0.002	0.001	0.0011	0.0015	0.002	0.002	0.002
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	19	19			57	288.53	229.929	963	906	77.7	143.5	203	379.5	729.9
pH (lab)	19	19			6.68	7.79	0.53105	8.69	2.01	7.067	7.385	7.8	8.19	8.564

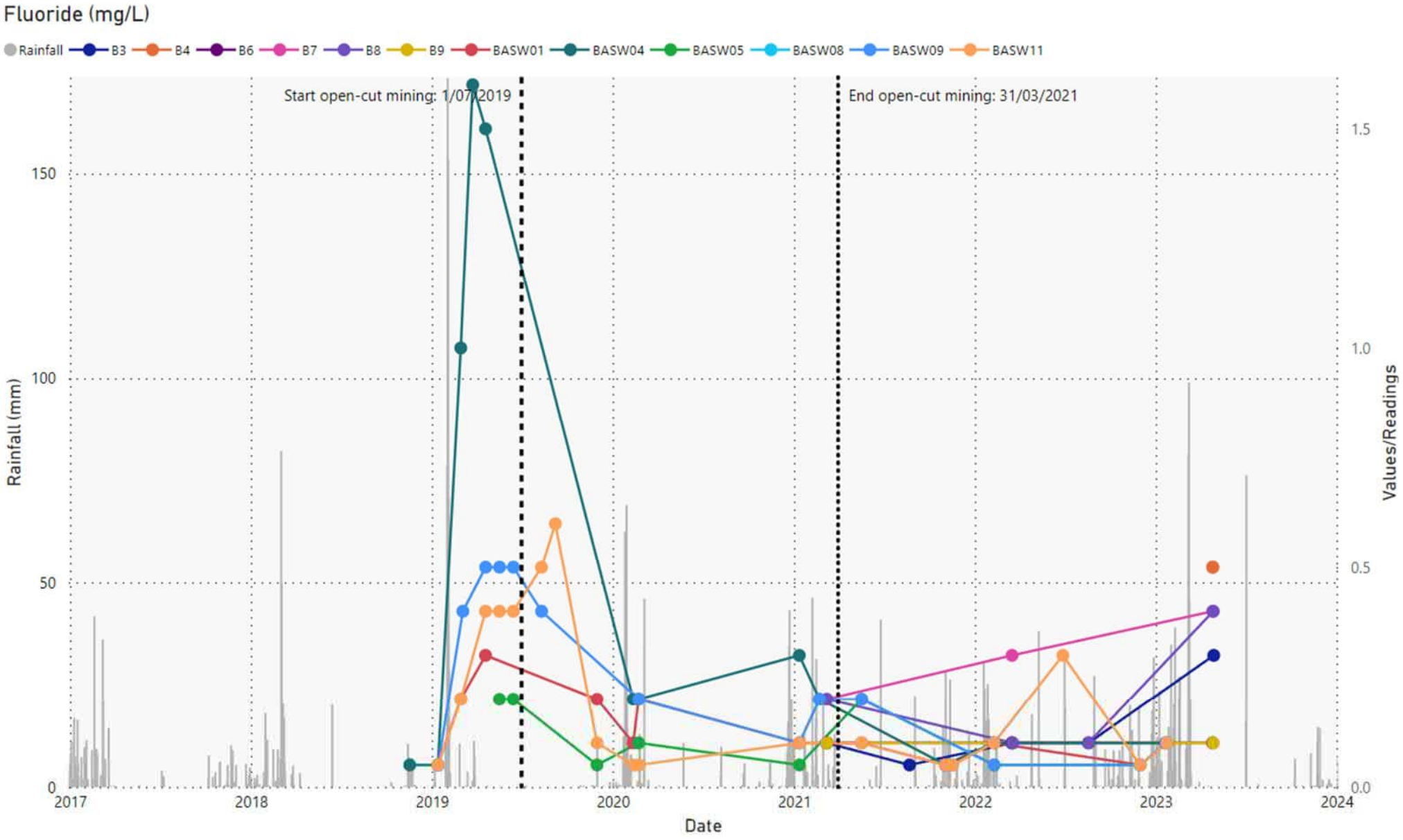
E.2 Water quality time series

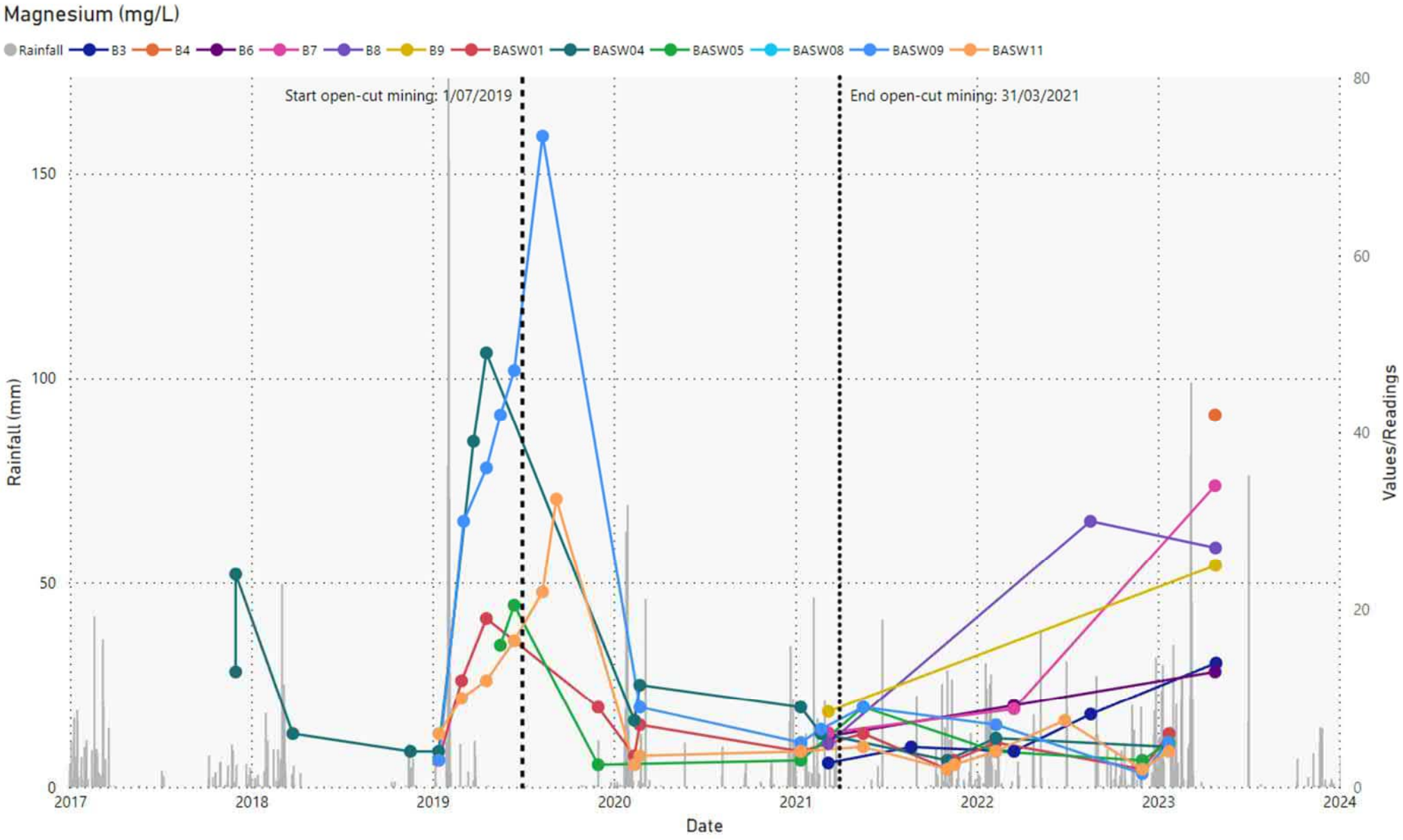

Electrical Conductivity (µS/cm)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0
500
1,000
1,500
2017
2018
2019
2020
2021
2022
2023
2024

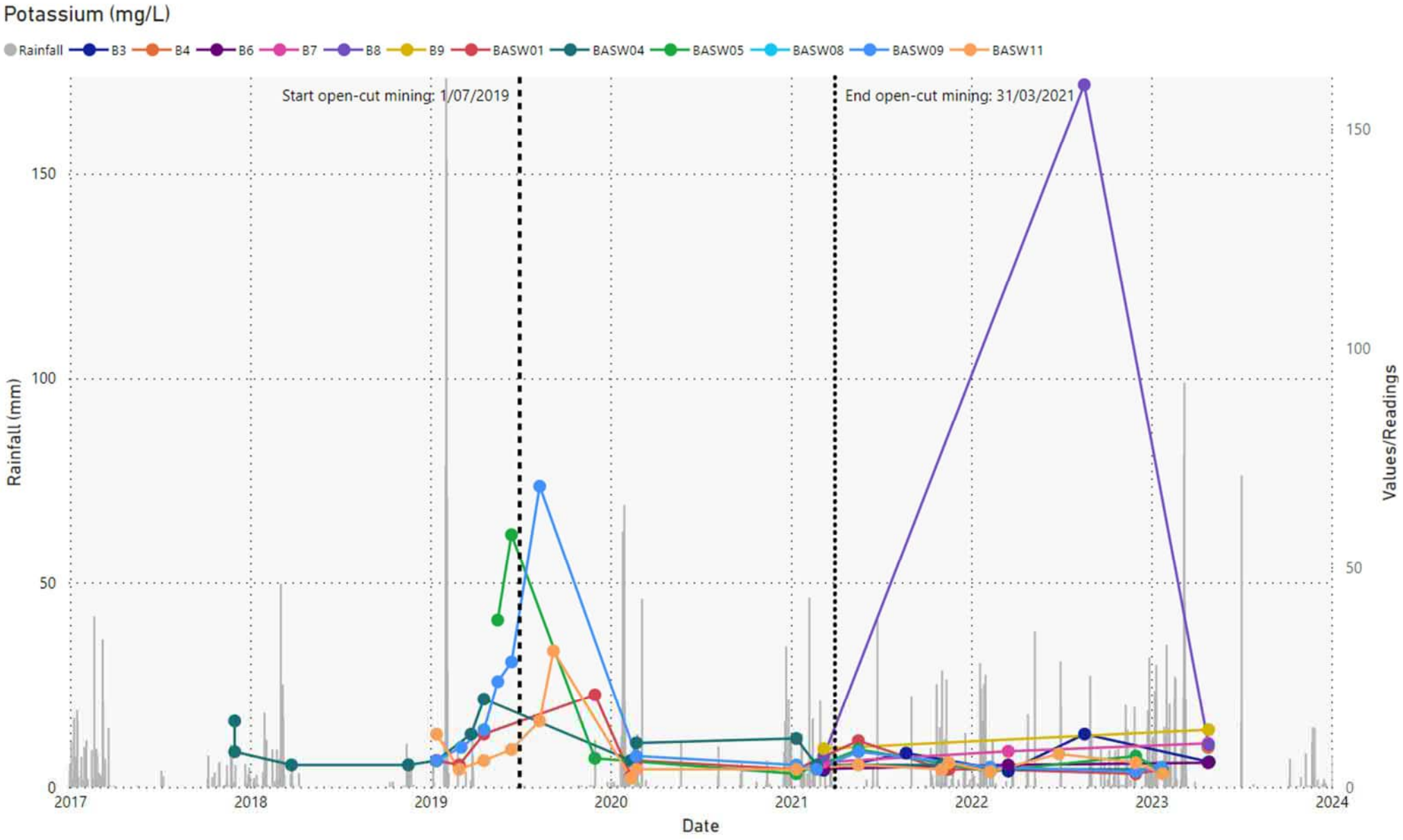

pH (lab)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
6.0
6.5
7.0
7.5
8.0
8.5
9.0
2017
2018
2019
2020
2021
2022
2023
2024

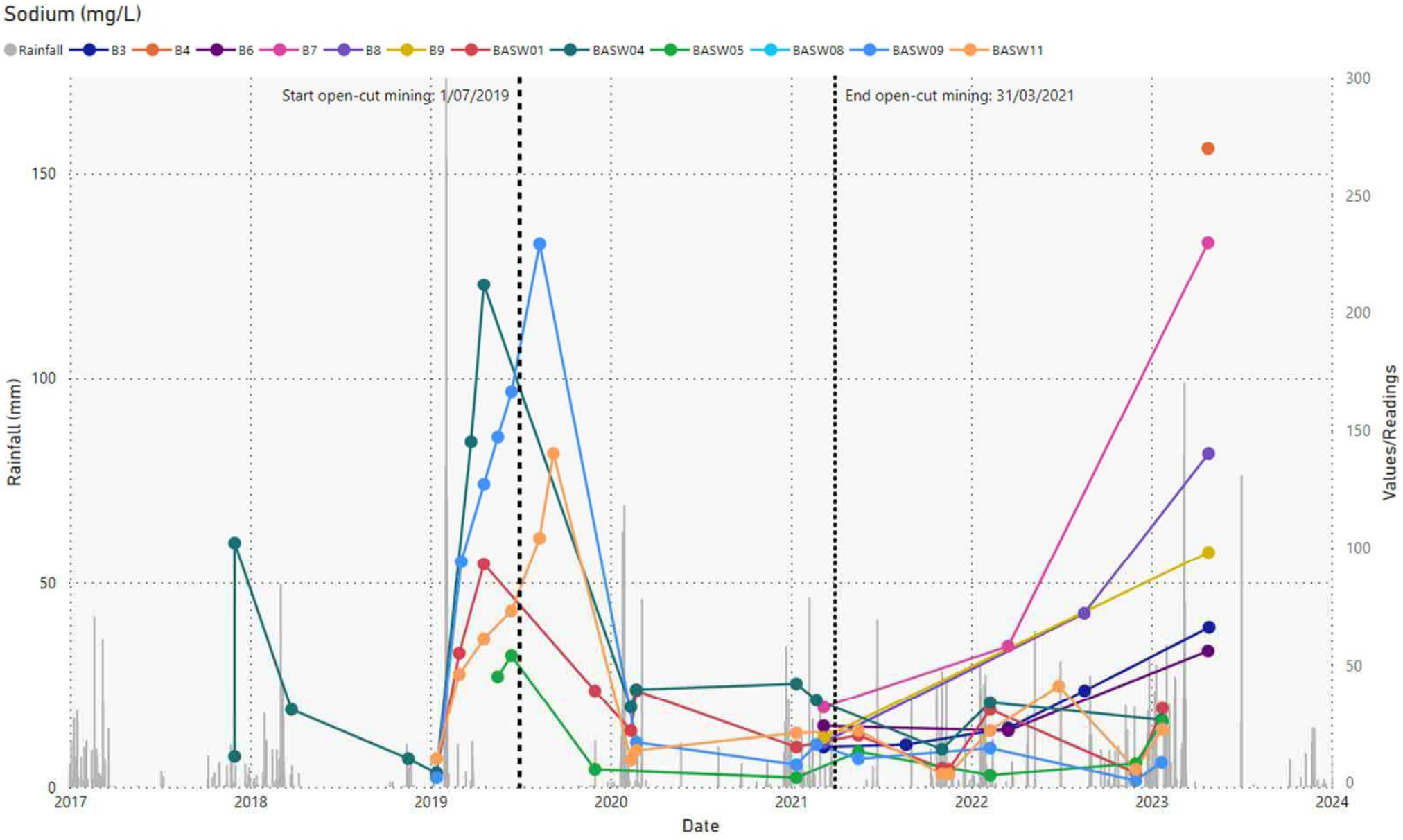

Calcium (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0
20
40
60
80
2017
2018
2019
2020
2021
2022
2023
2024

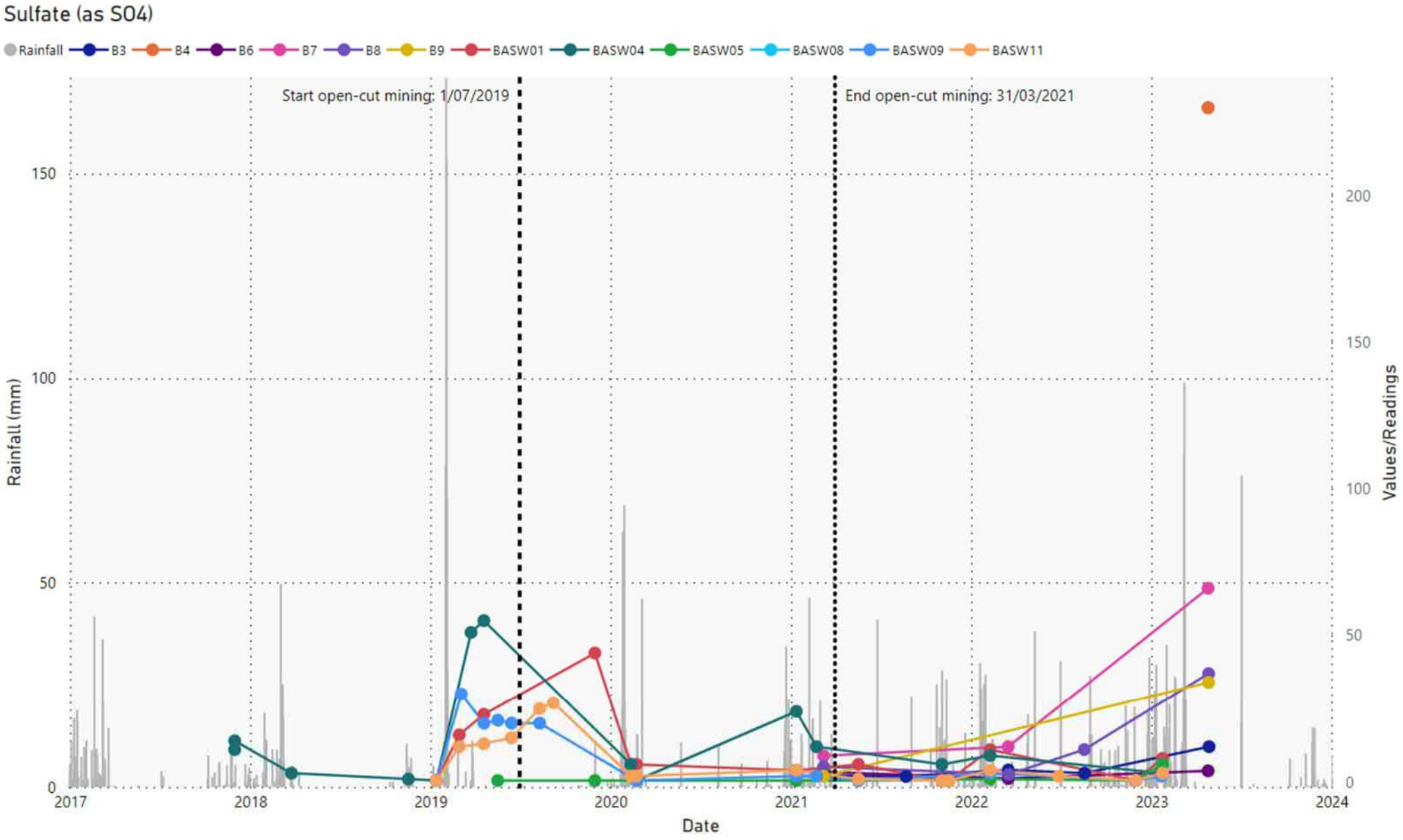

Chloride (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0
20
40
60
80
100
120
2017
2018
2019
2020
2021
2022
2023
2024

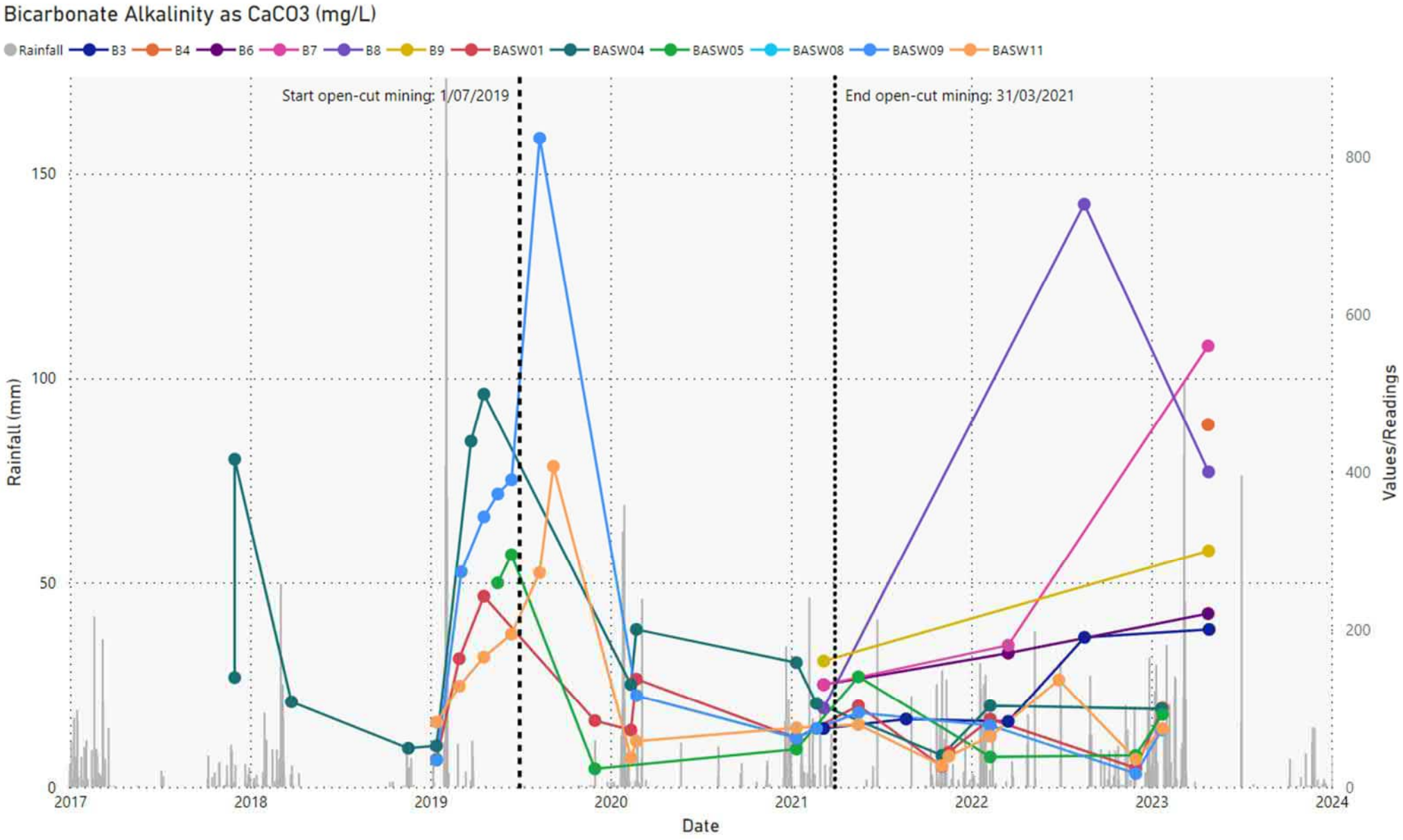

Fluoride (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0.0
0.5
1.0
1.5
2017
2018
2019
2020
2021
2022
2023
2024

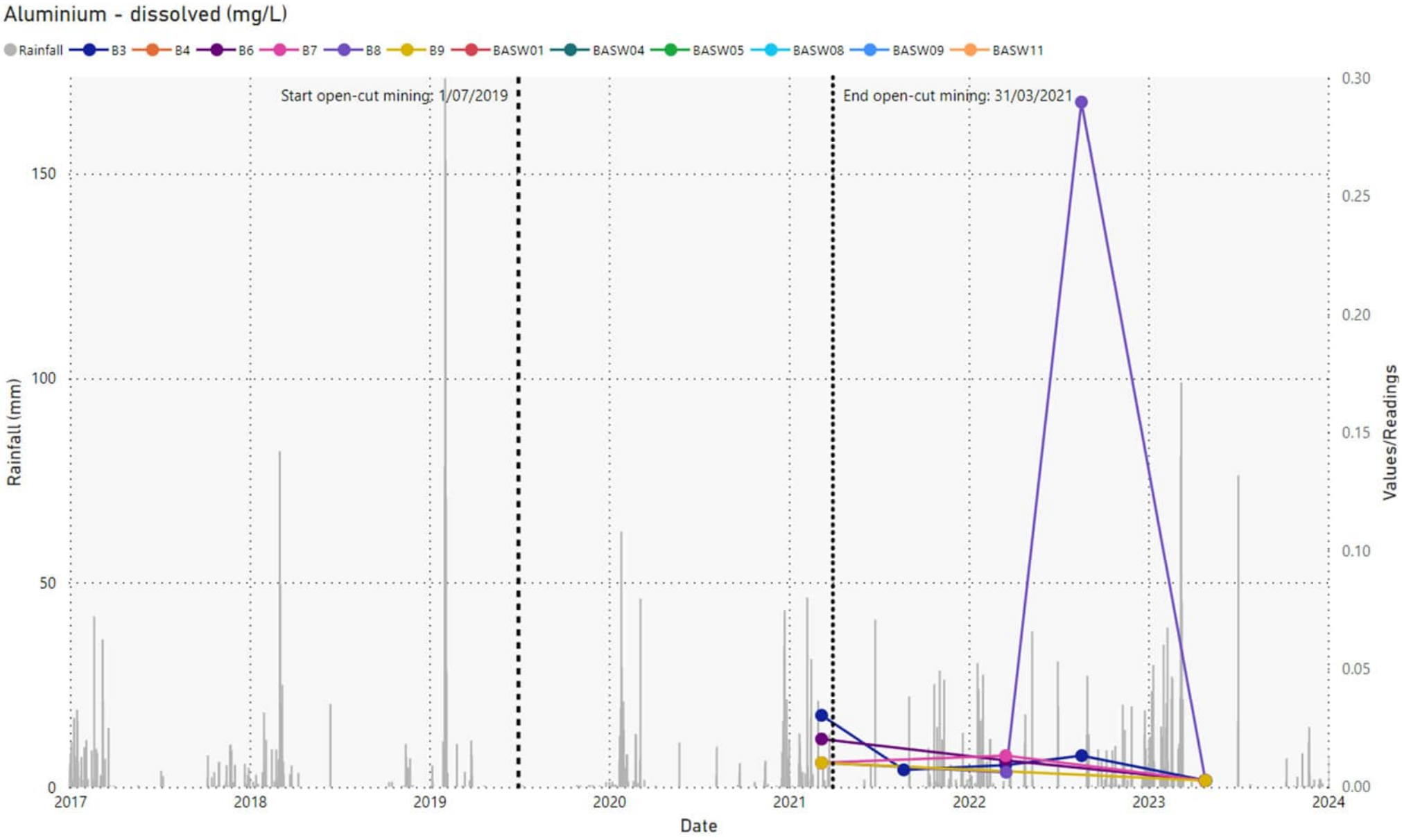

Magnesium (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0
20
40
60
80
2017
2018
2019
2020
2021
2022
2023
2024

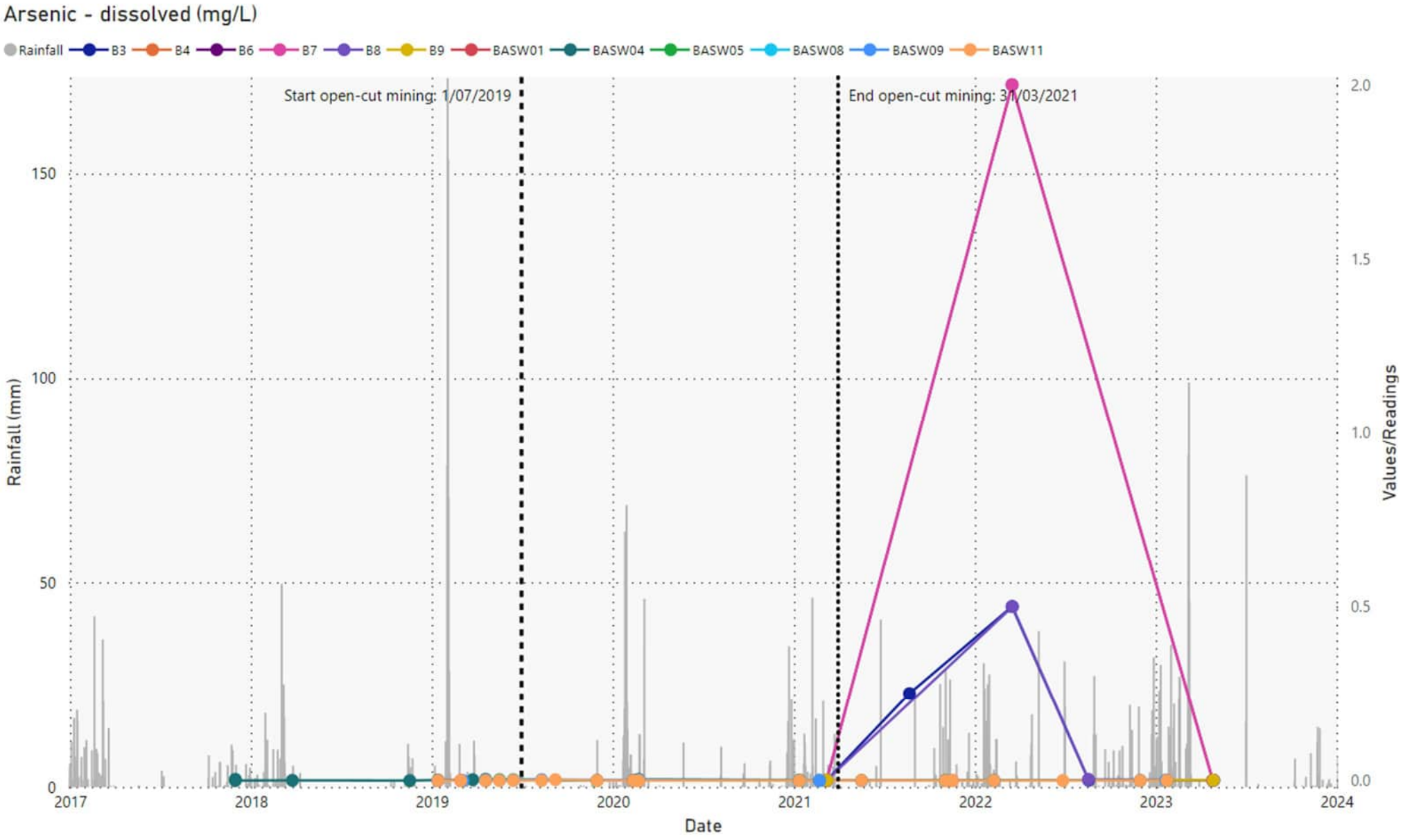

Potassium (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
2017
2018
2019
2020
2021
2022
2023
2024

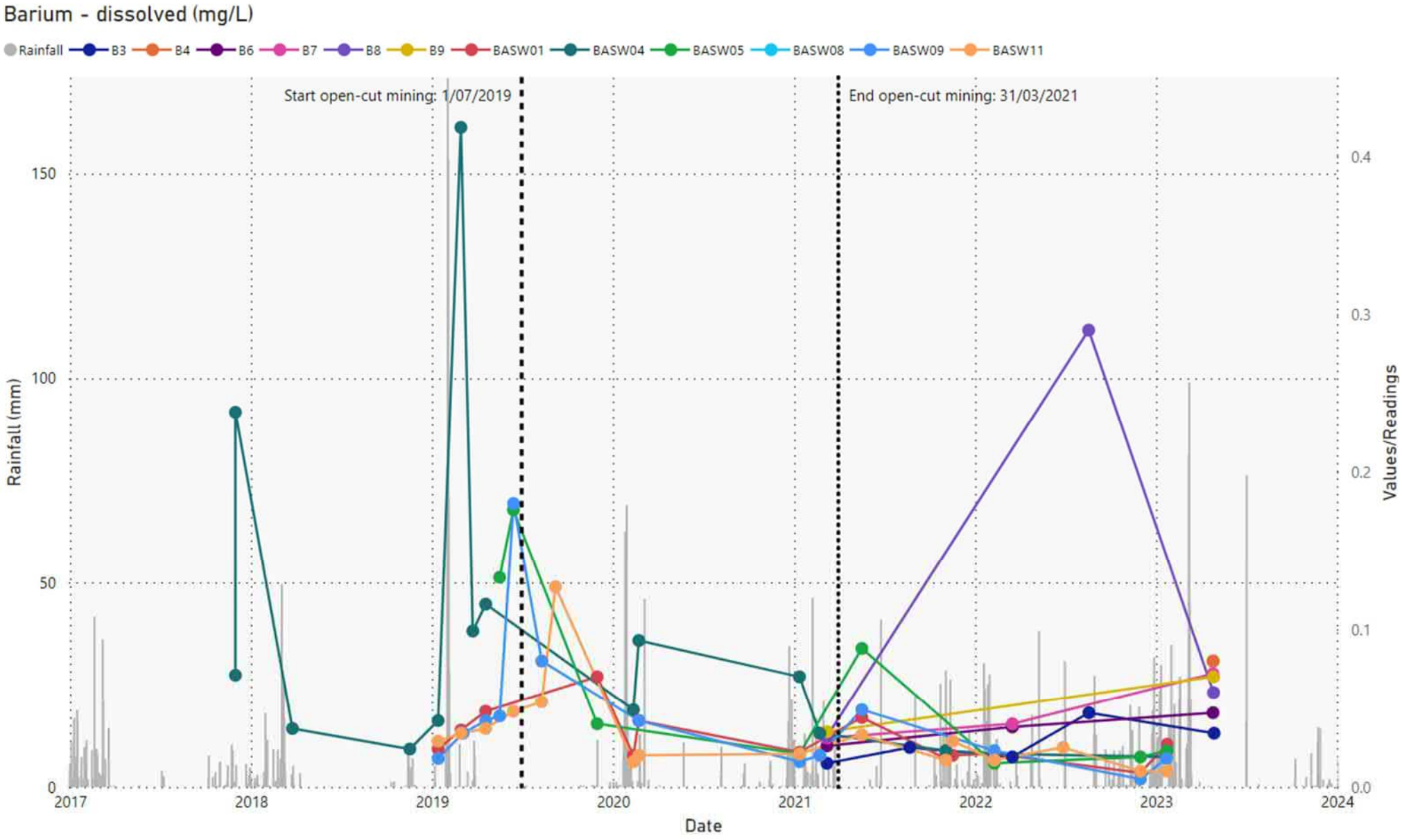

Sodium (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0
50
100
150
200
250
300
2017
2018
2019
2020
2021
2022
2023
2024

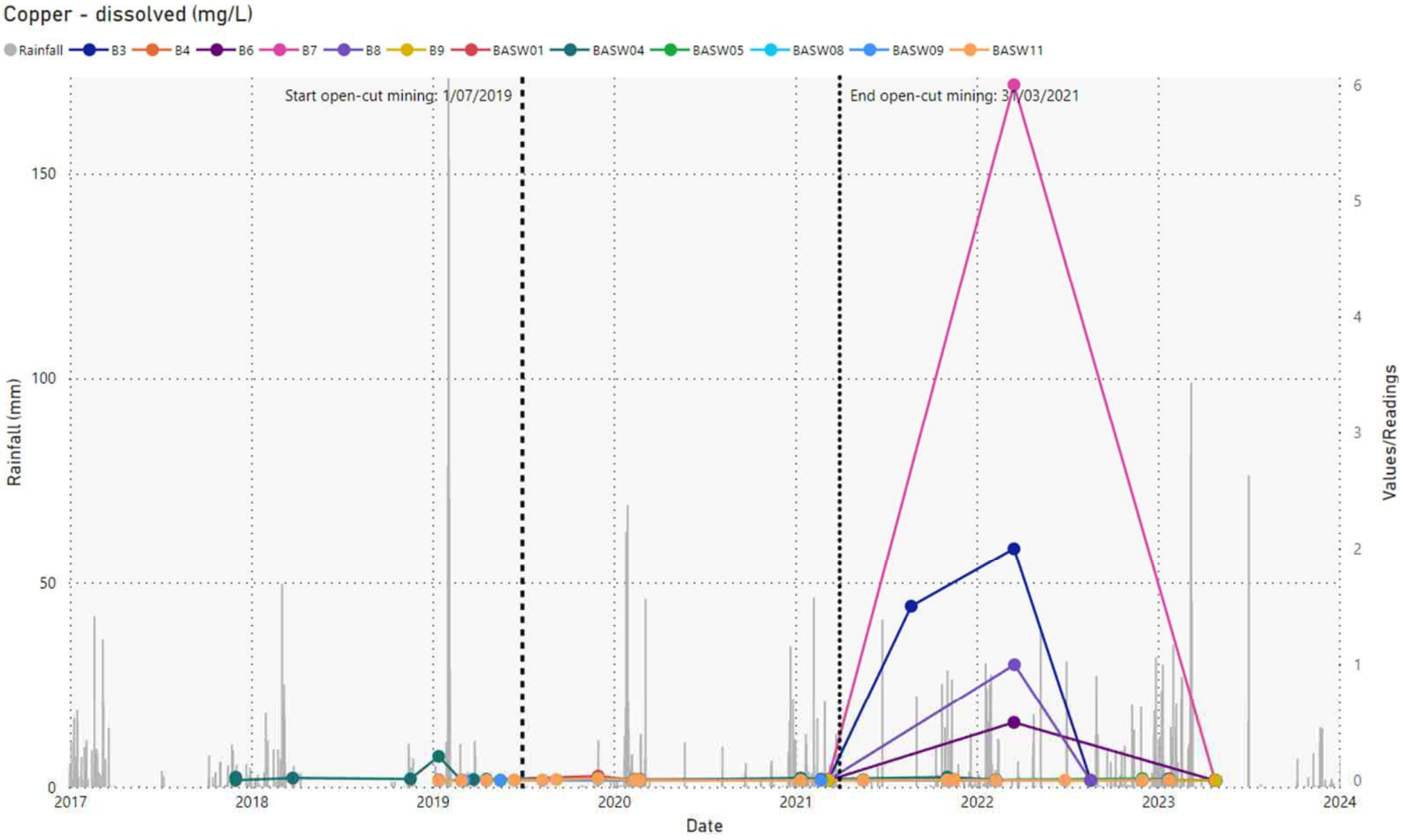

Sulfate (as SO4)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
200
2017
2018
2019
2020
2021
2022
2023
2024

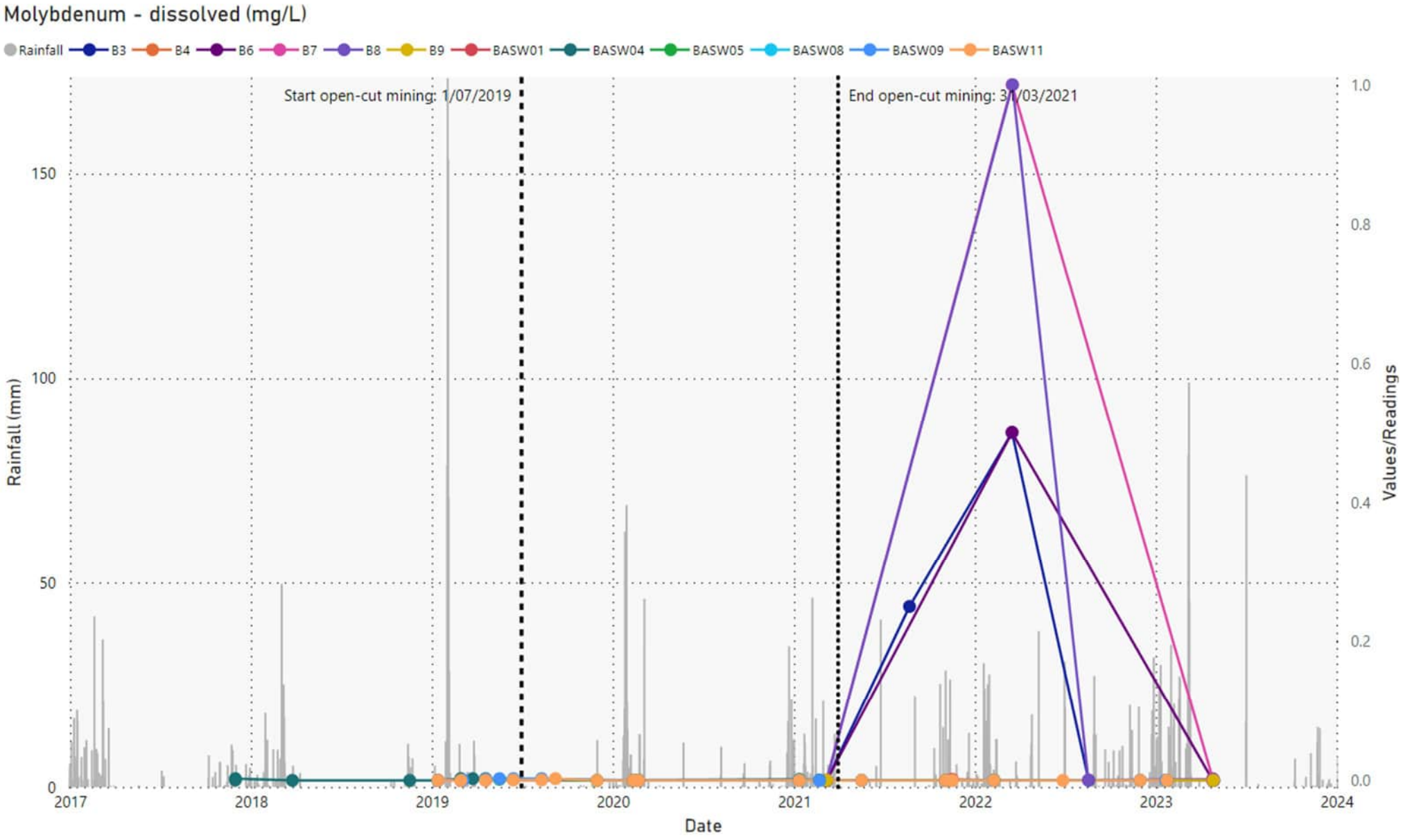

Bicarbonate Alkalinity as CaCO3 (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0
200
400
600
800
2017
2018
2019
2020
2021
2022
2023
2024

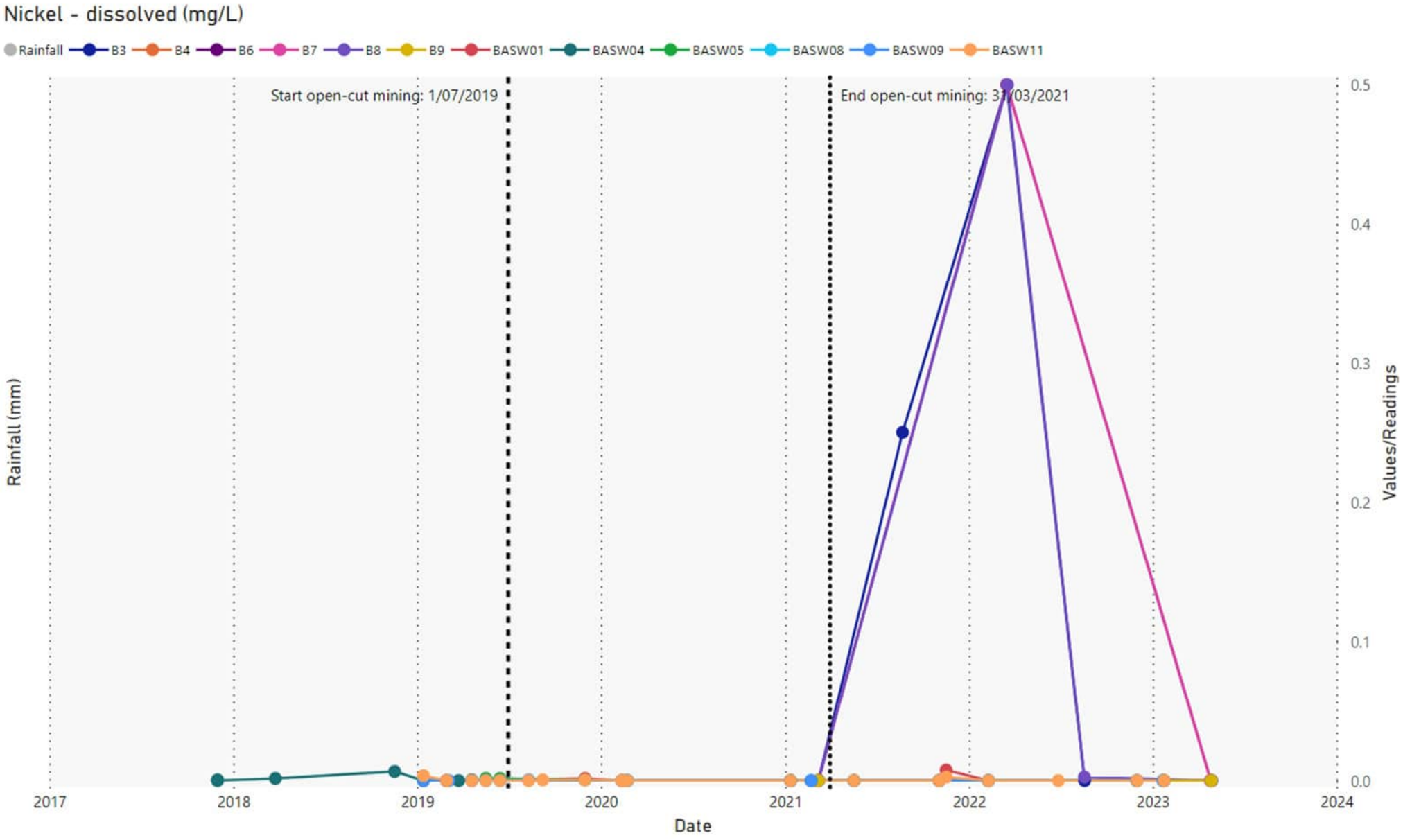

Aluminium - dissolved (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0.00
0.05
0.10
0.15
0.20
0.25
0.30
2017
2018
2019
2020
2021
2022
2023
2024

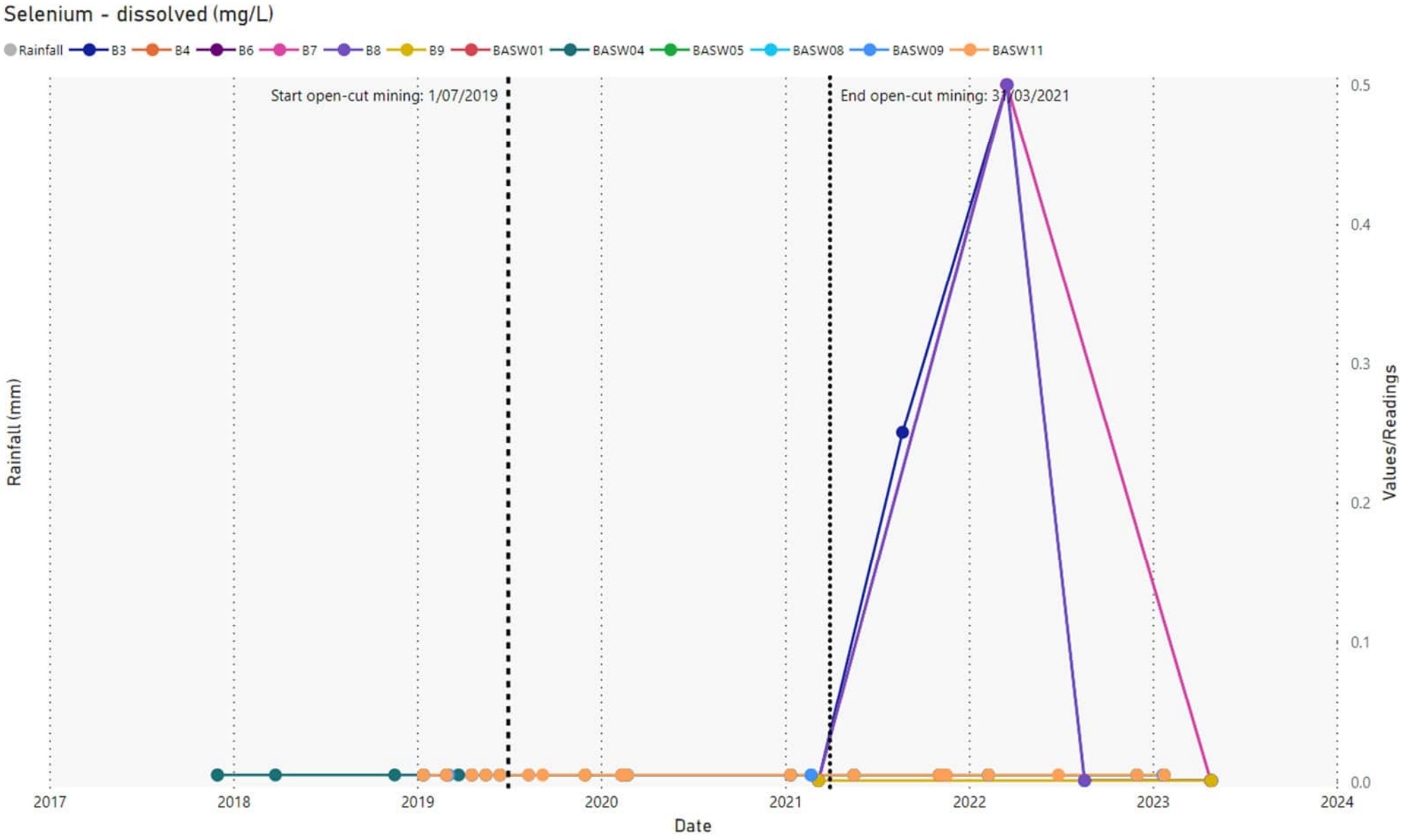

Arsenic - dissolved (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0.0
0.5
1.0
1.5
2.0
2017
2018
2019
2020
2021
2022
2023
2024

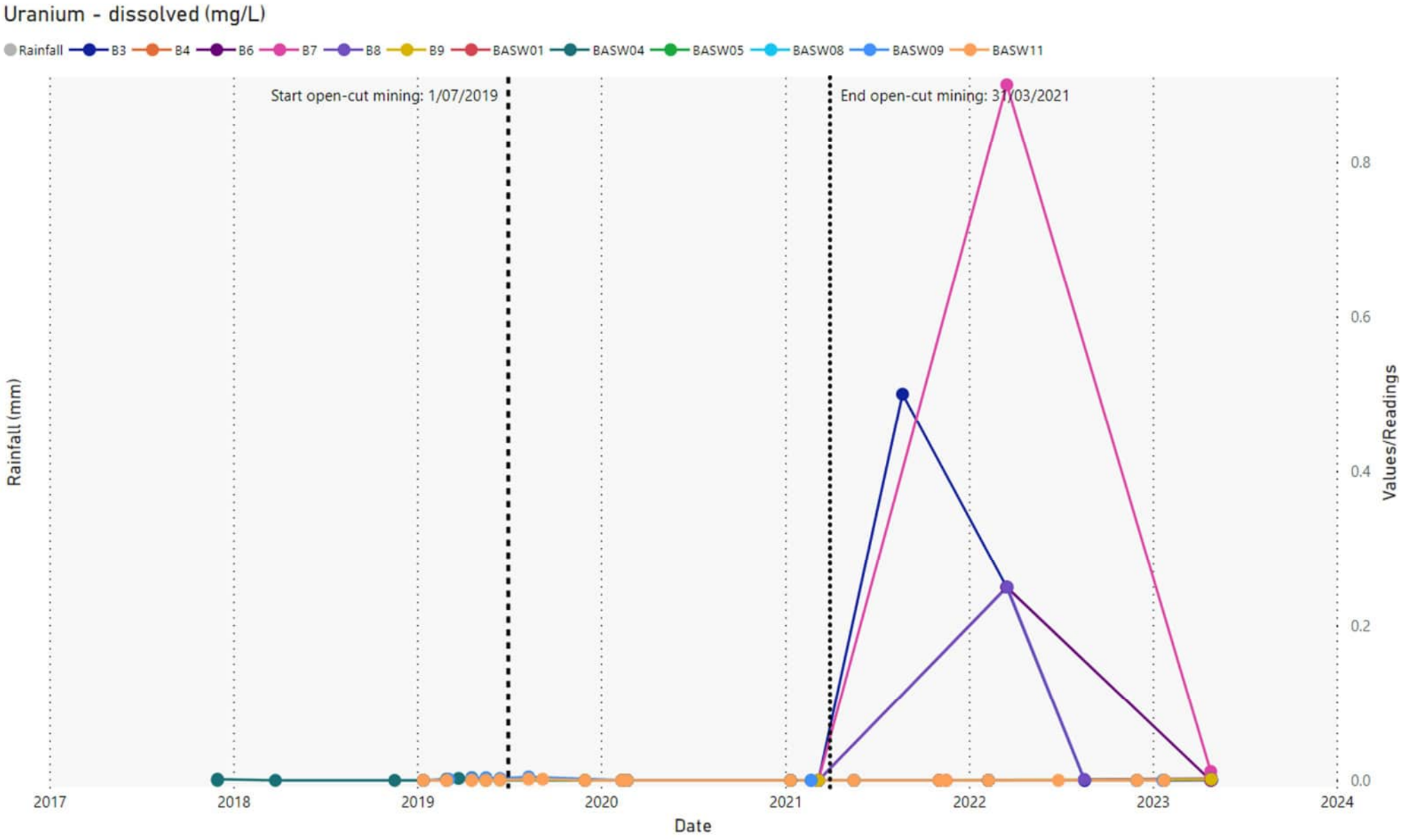

Barium - dissolved (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0.0
0.1
0.2
0.3
0.4
2017
2018
2019
2020
2021
2022
2023
2024

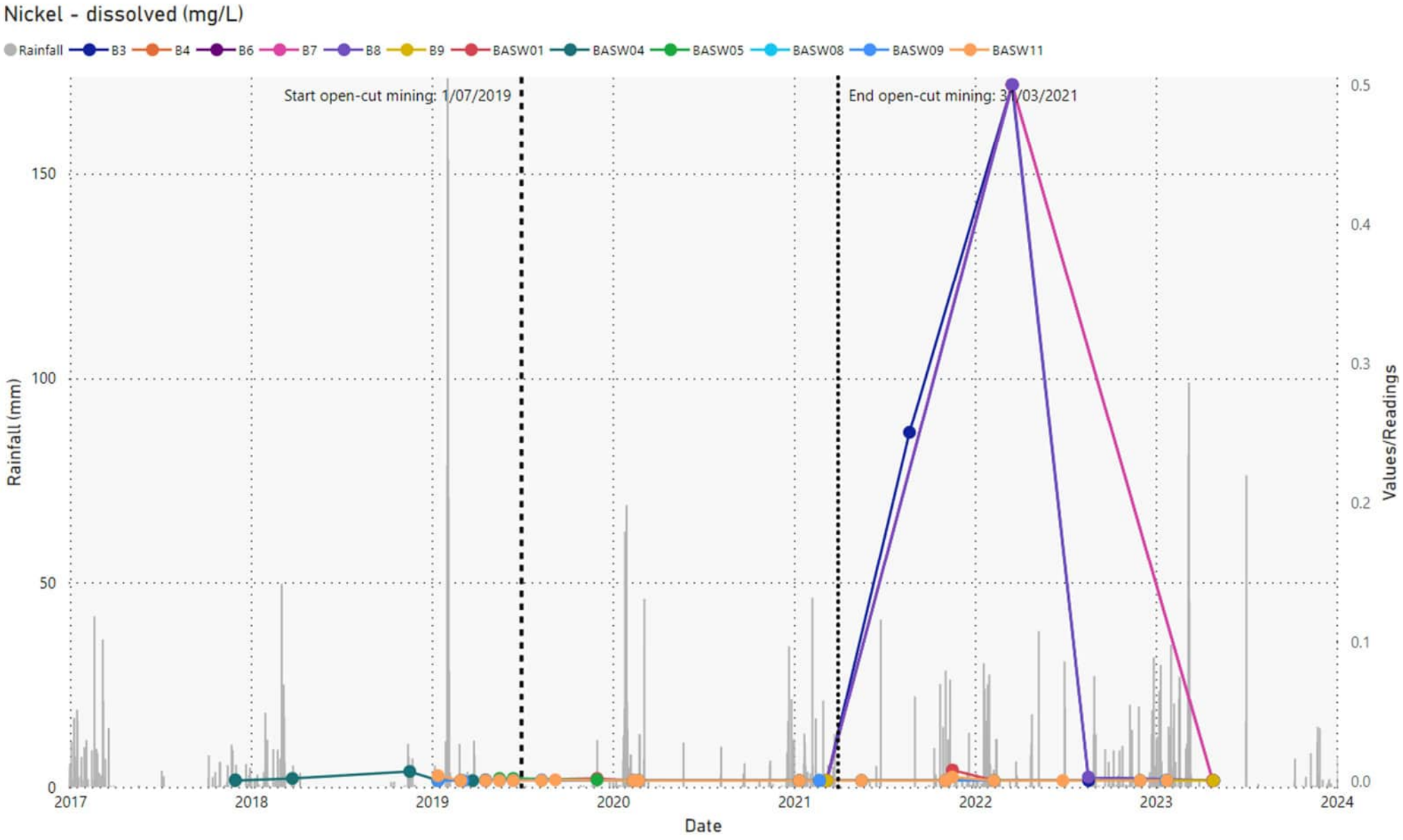

Copper - dissolved (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0
1
2
3
4
5
6
2017
2018
2019
2020
2021
2022
2023
2024

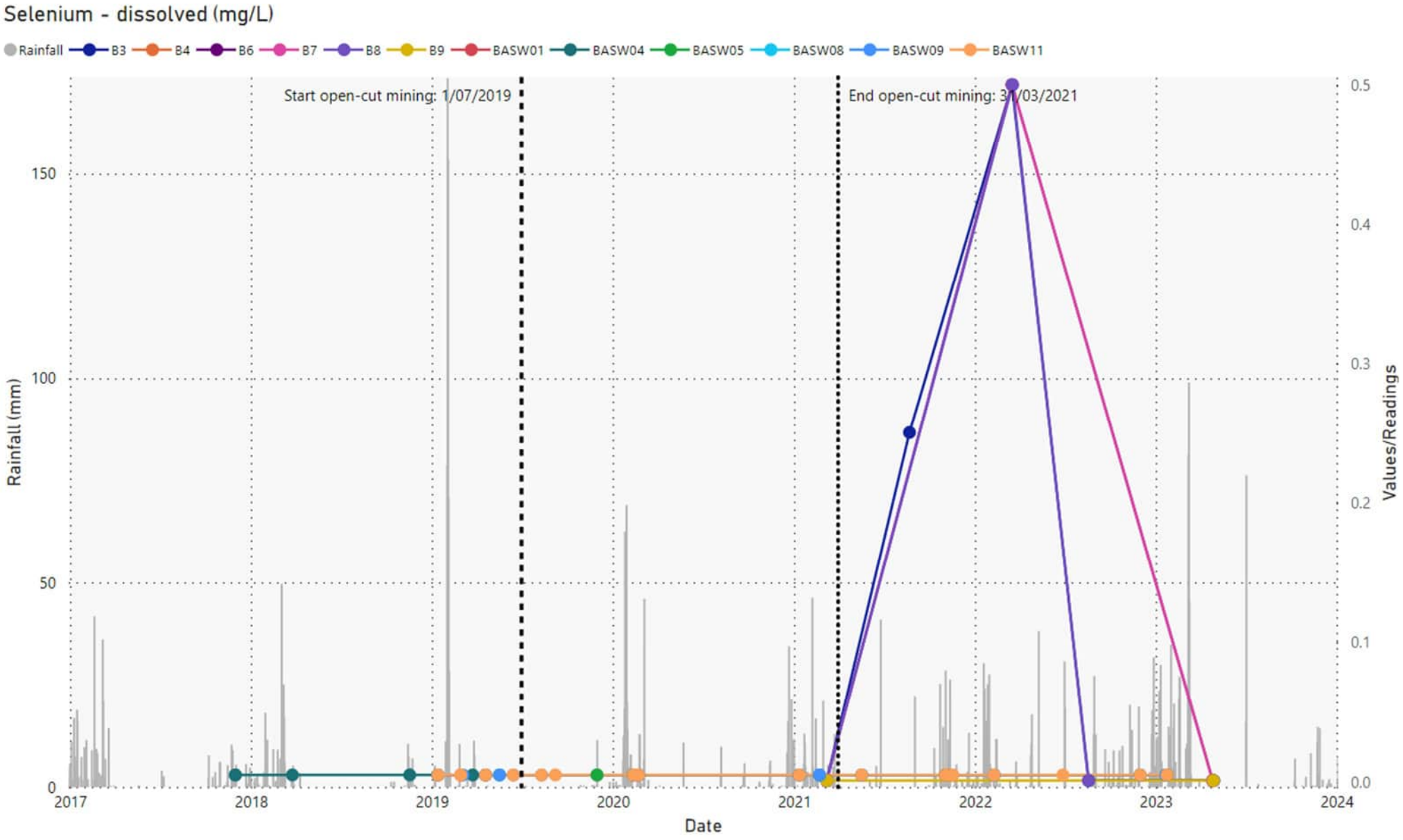

Molybdenum - dissolved (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0.0
0.2
0.4
0.6
0.8
1.0
2017
2018
2019
2020
2021
2022
2023
2024

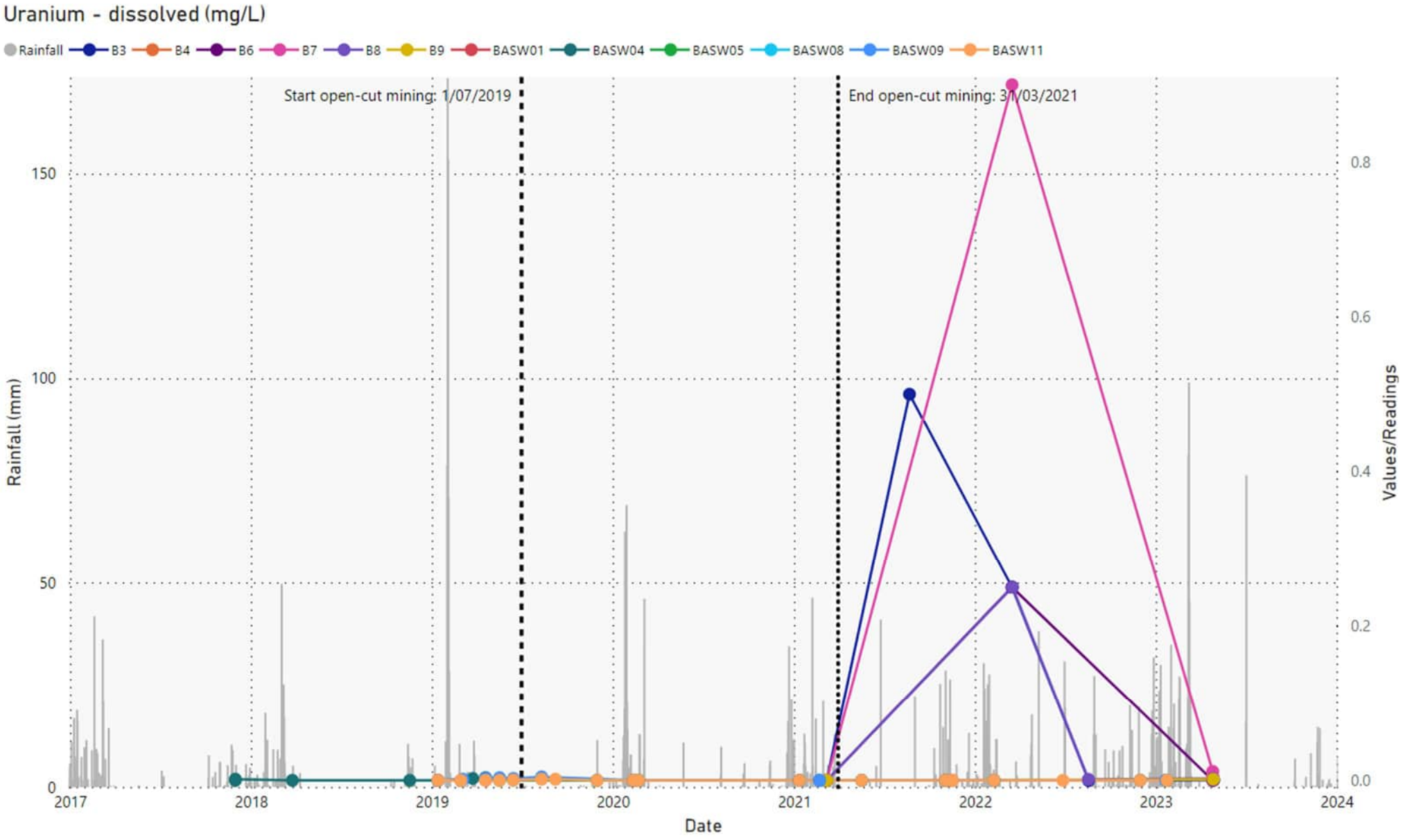

Nickel - dissolved (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
0.5
0.4
0.3
0.2
0.1
0.0
2017
2018
2019
2020
2021
2022
2023
2024
Date


Selenium - dissolved (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
0.5
0.4
0.3
0.2
0.1
0.0
2017
2018
2019
2020
2021
2022
2023
2024
Date


Uranium - dissolved (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
0.0
0.2
0.4
0.6
0.8
2017
2018
2019
2020
2021
2022
2023
2024
Date

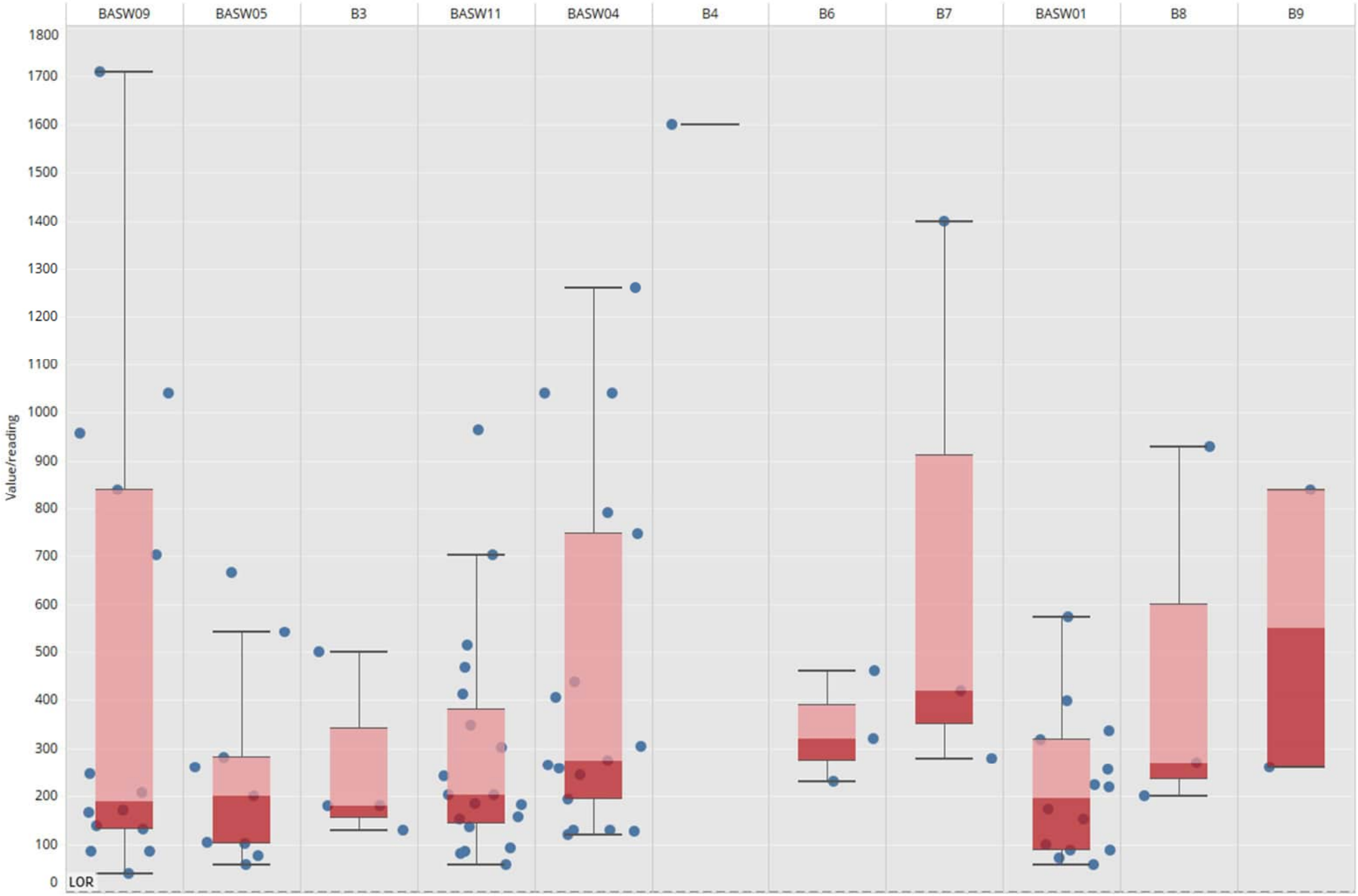

Nickel - dissolved (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0.0
0.1
0.2
0.3
0.4
0.5
2017
2018
2019
2020
2021
2022
2023
2024


Selenium - dissolved (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0.0
0.1
0.2
0.3
0.4
0.5
2017
2018
2019
2020
2021
2022
2023
2024

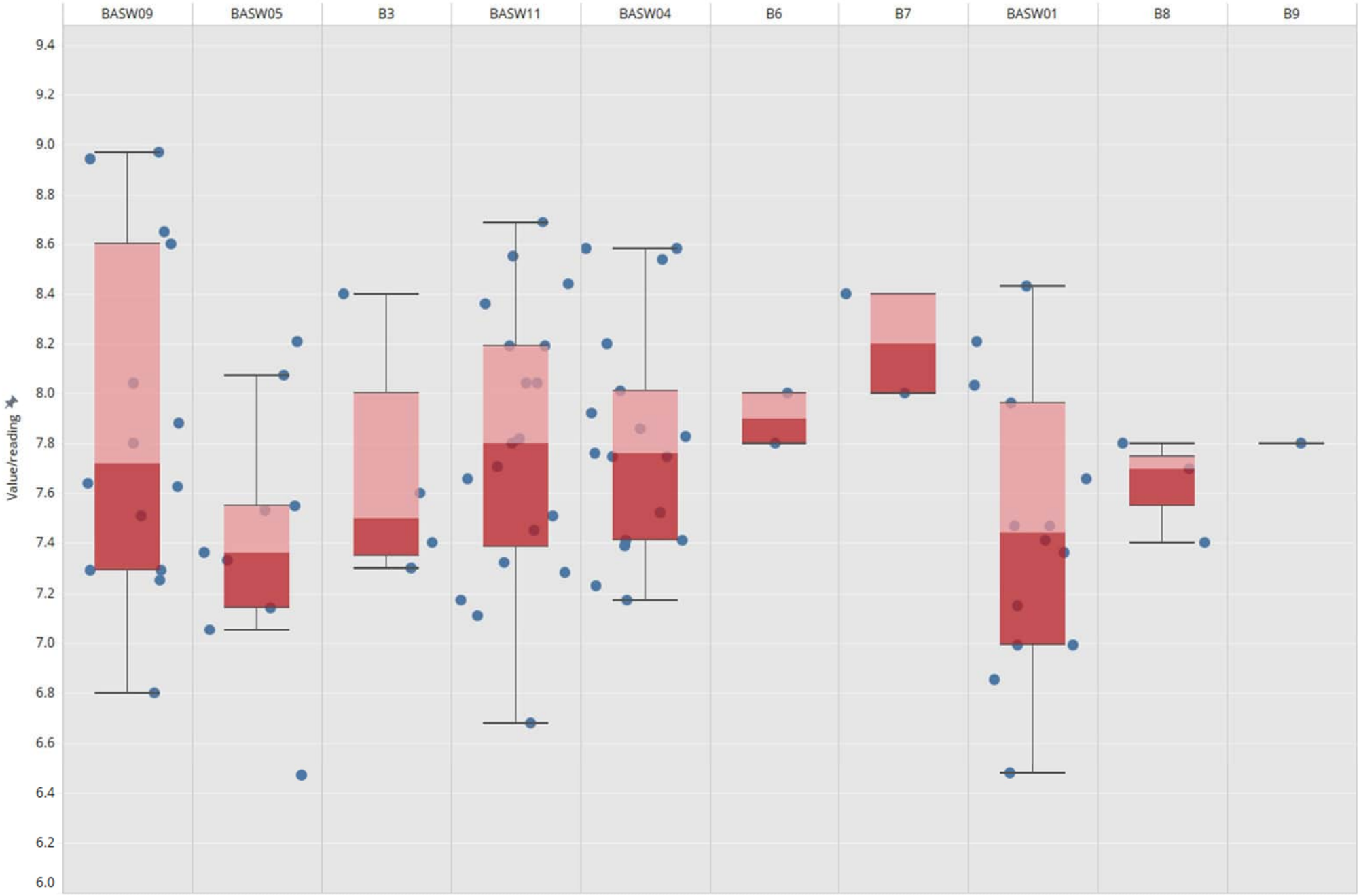

Uranium - dissolved (mg/L)
Rainfall
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW08
BASW09
BASW11
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings
Date
0
50
100
150
0.0
0.2
0.4
0.6
0.8
2017
2018
2019
2020
2021
2022
2023
2024

E.3 Water quality box & whisker plots

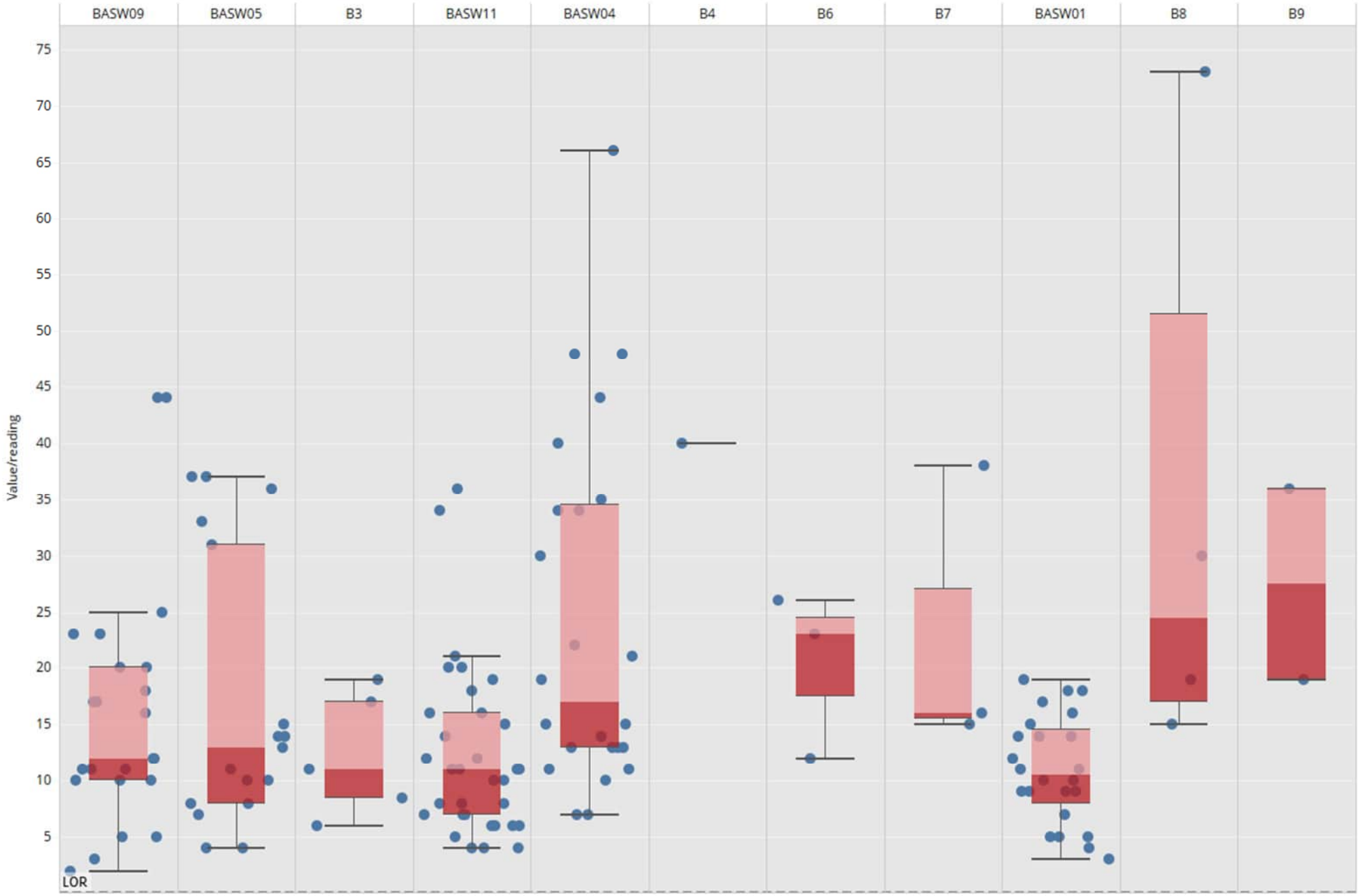
Electrical Conductivity (µS/cm)



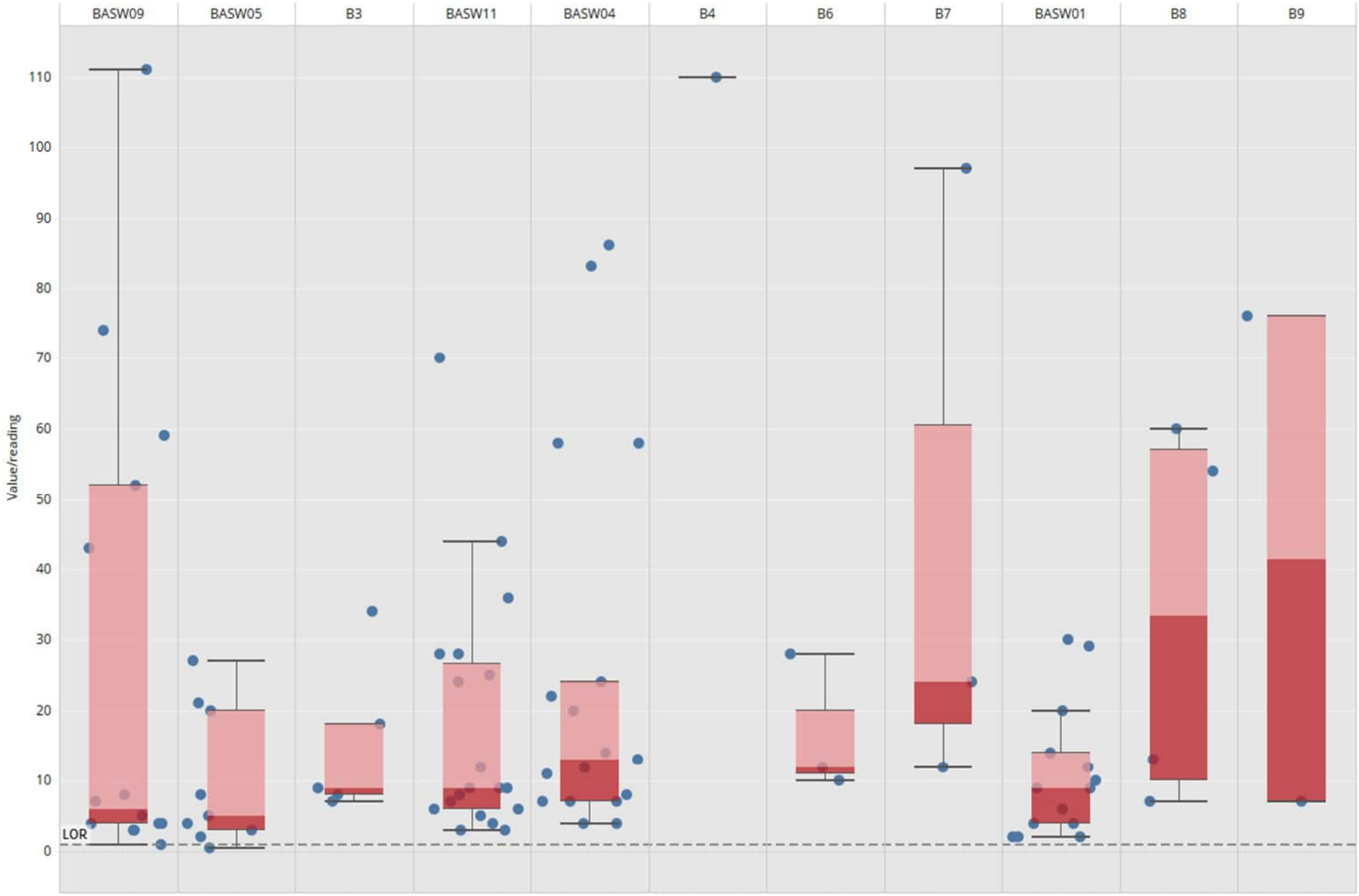
pH (lab)


BASW09
BASW05
B3
BASW11
BASW04
B6
B7
BASW01
B8
B9
Value/reading
9.4
9.2
9.0
8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
6.2
6.0

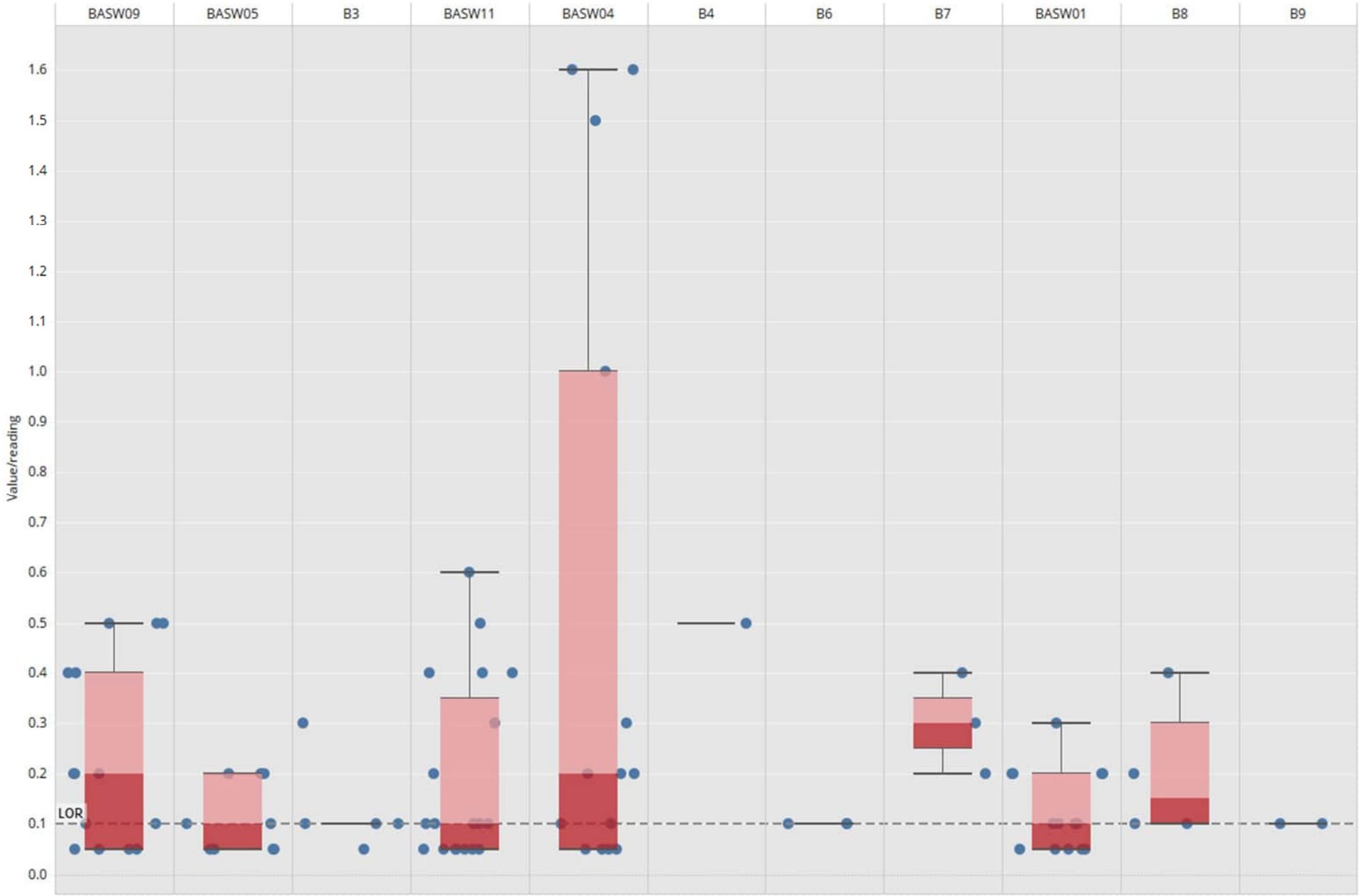
Calcium (mg/L)


BASW09
BASW05
B3
BASW11
BASW04
B4
B6
B7
BASW01
B8
B9
Value/reading
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
LOR

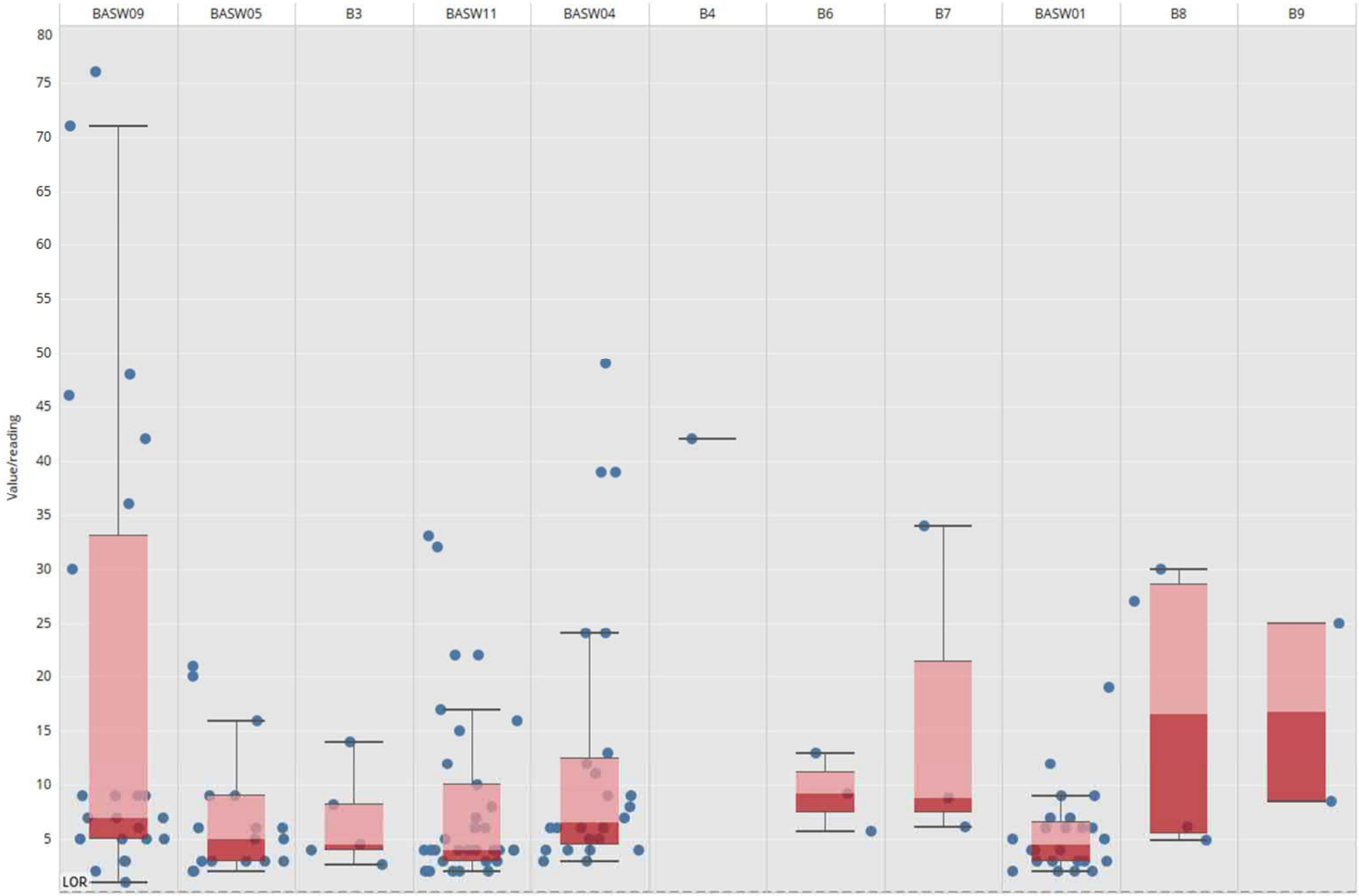
Chloride (mg/L)



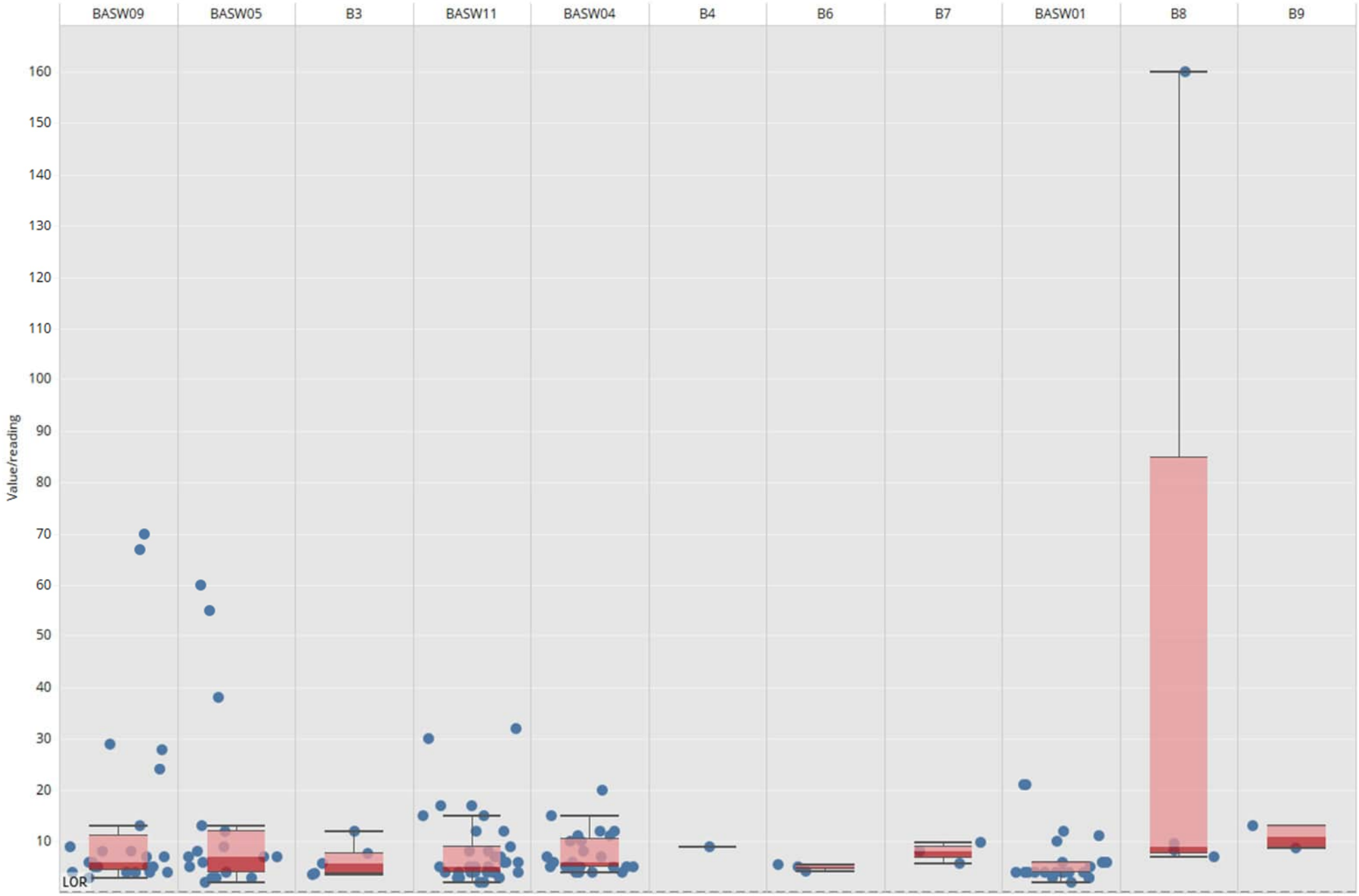
Fluoride (mg/L)



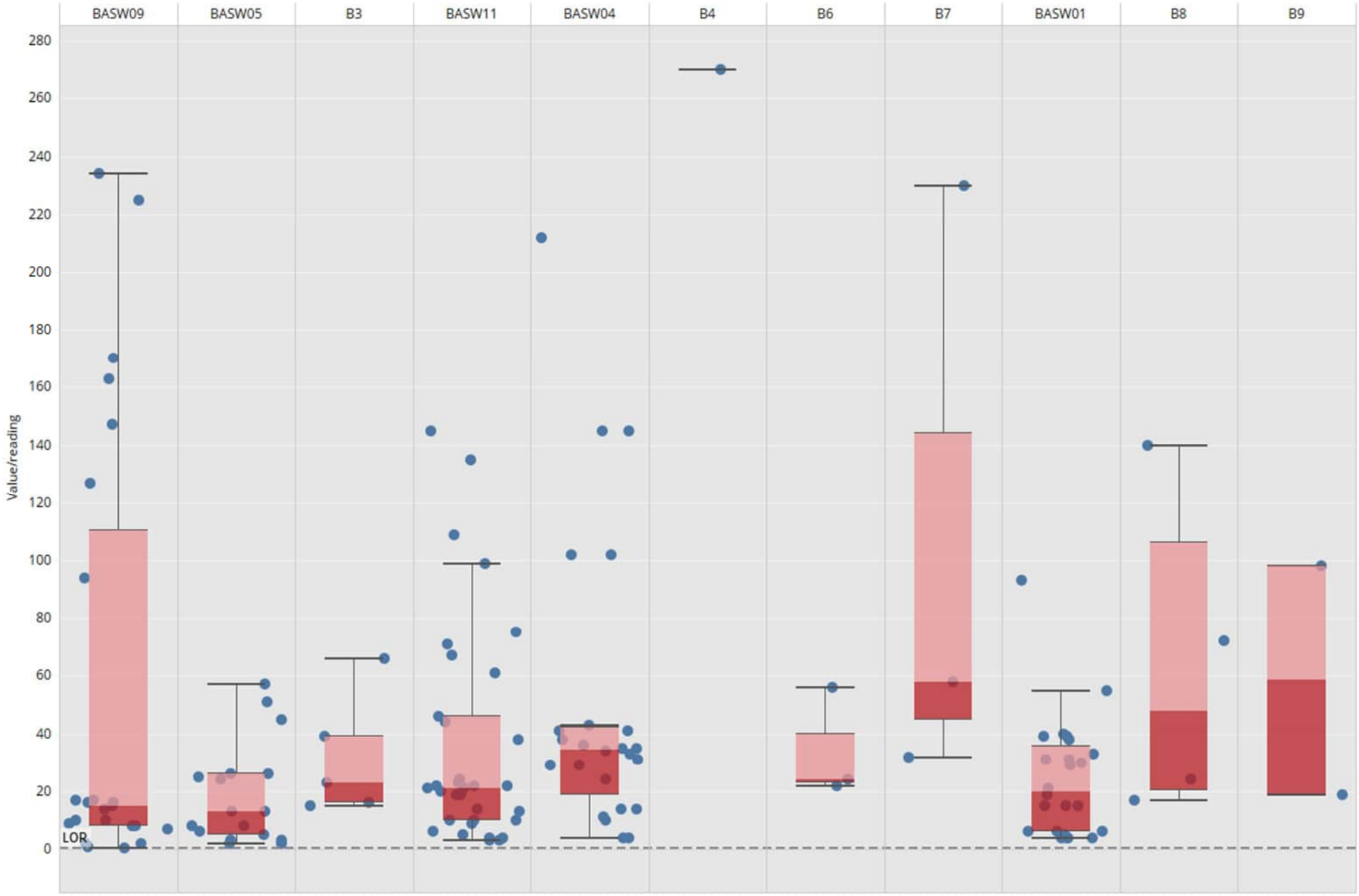
Magnesium (mg/L)



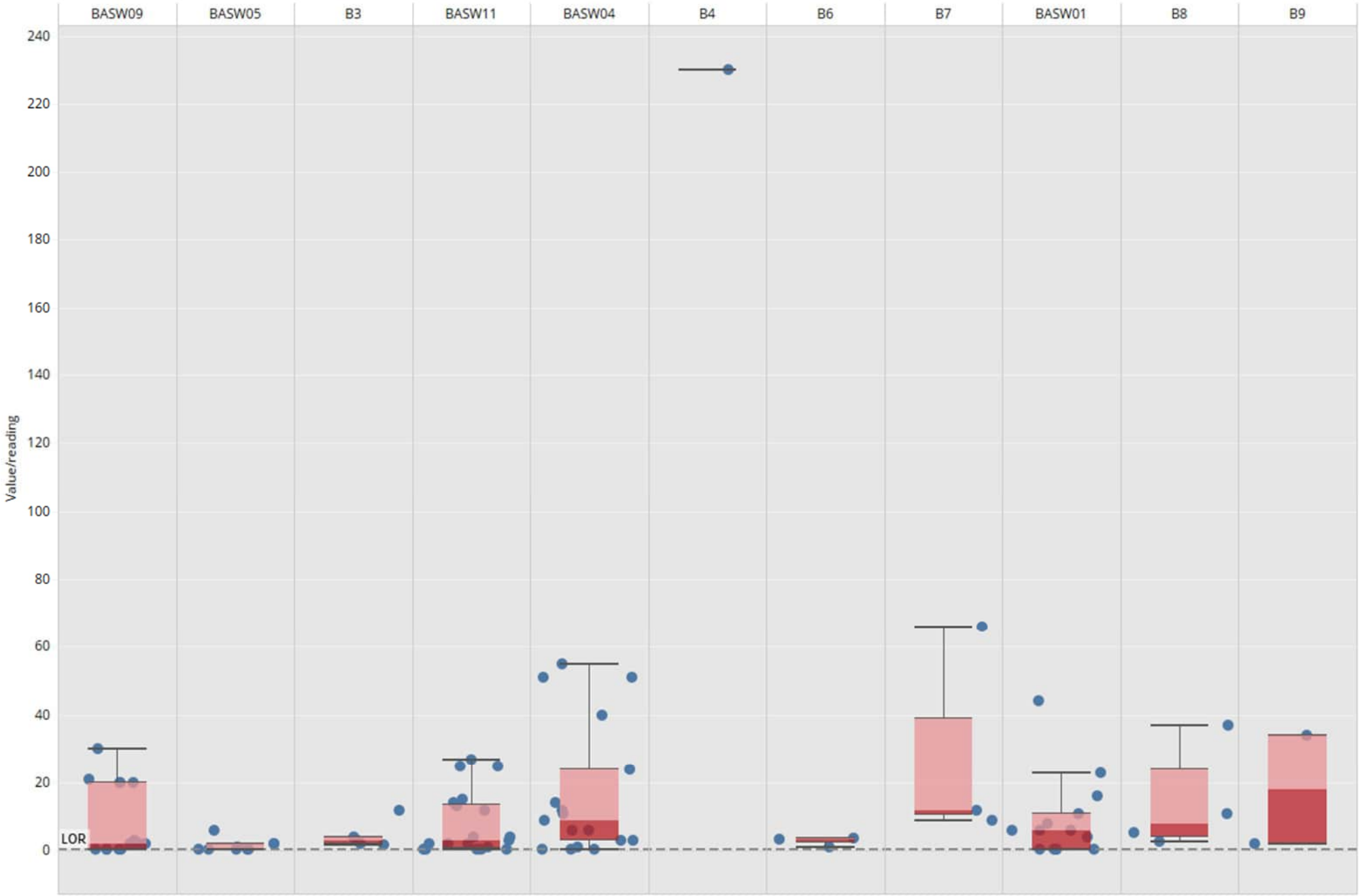
Potassium (mg/L)



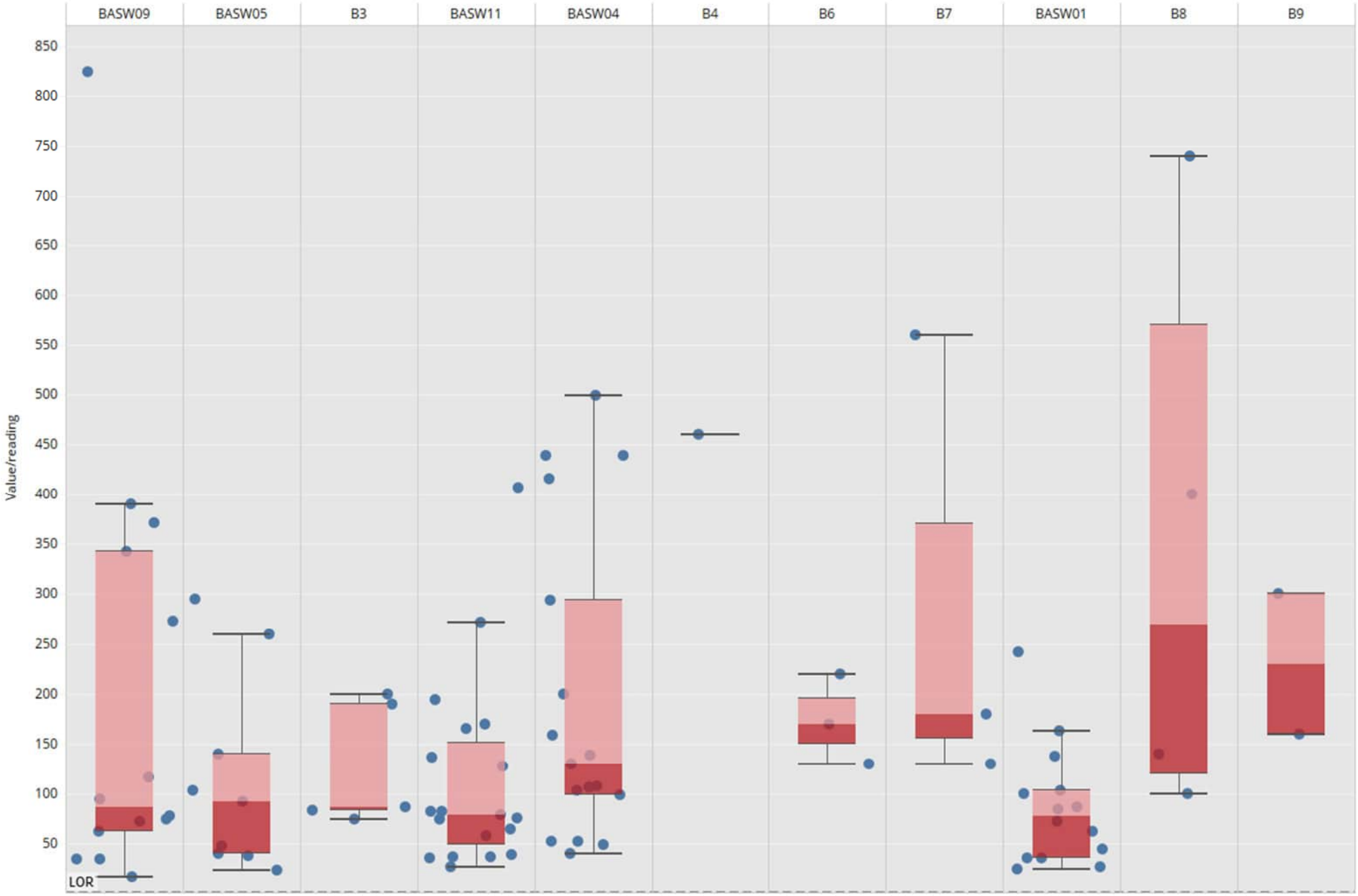
Sodium (mg/L)


BASW09
BASW05
B3
BASW11
BASW04
B4
B6
B7
BASW01
B8
B9
Value/reading
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
LOR

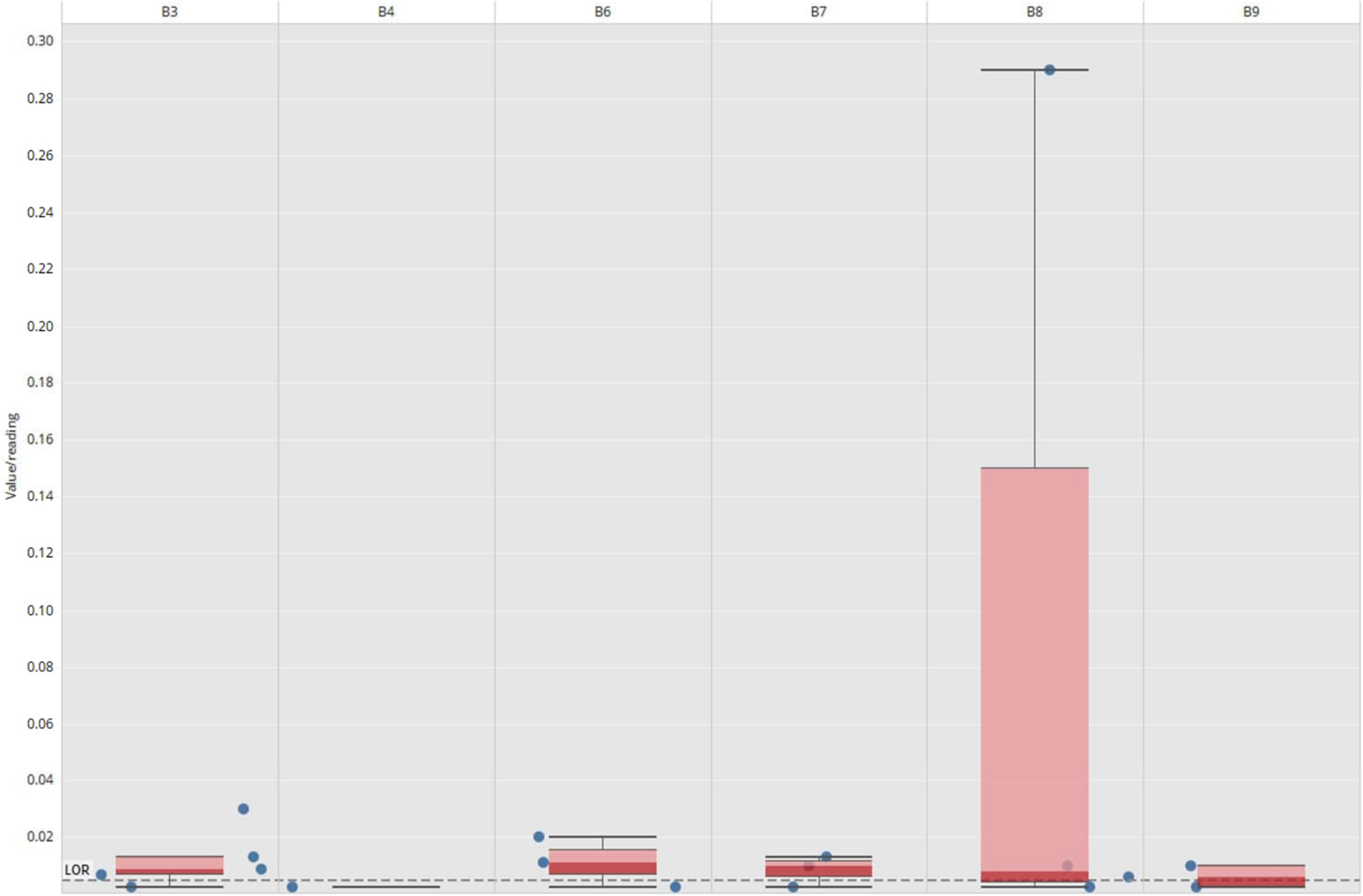
Sulfate (as SO4)



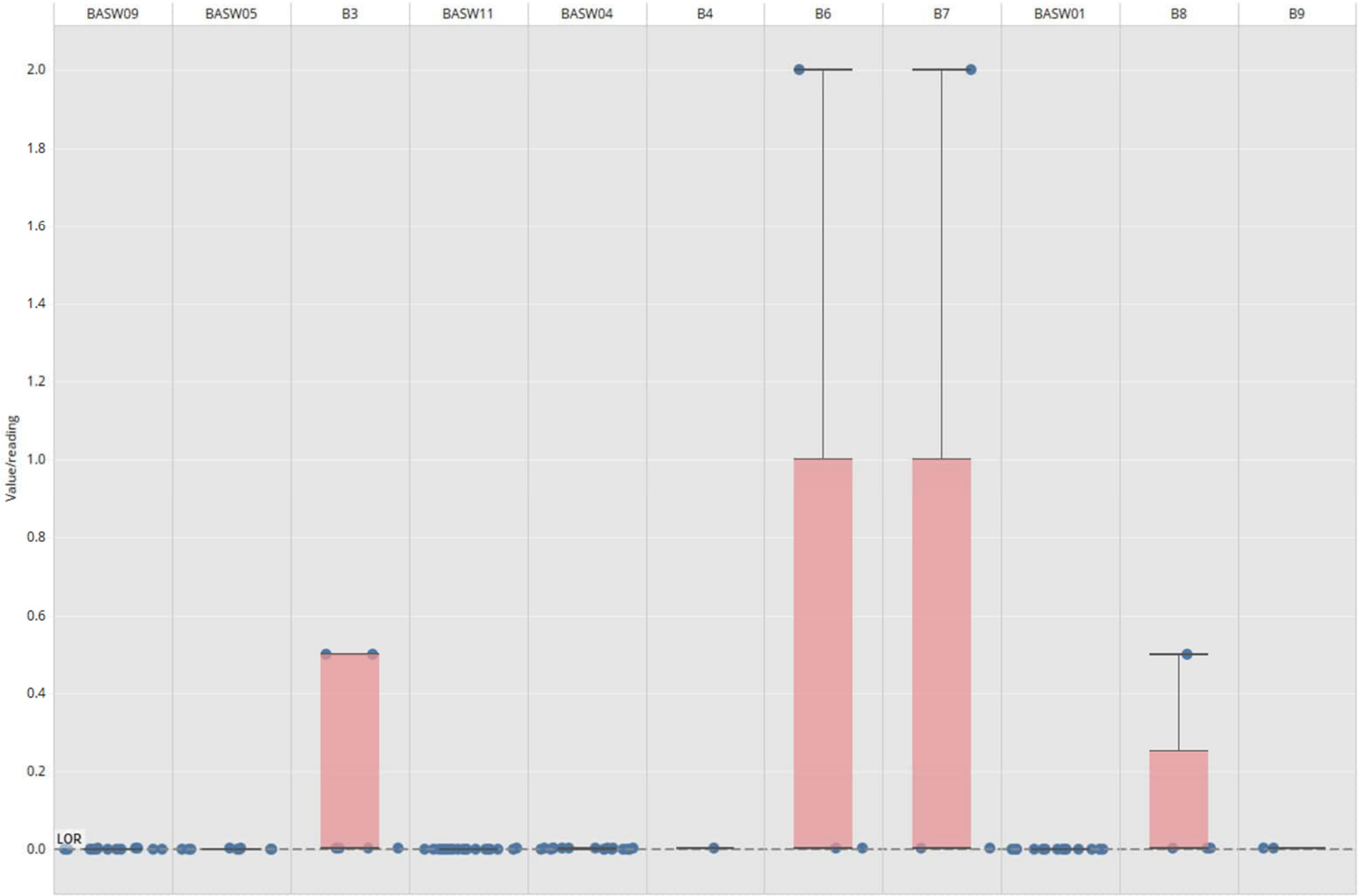
Bicarbonate Alkalinity as CaCO3 (mg/L)



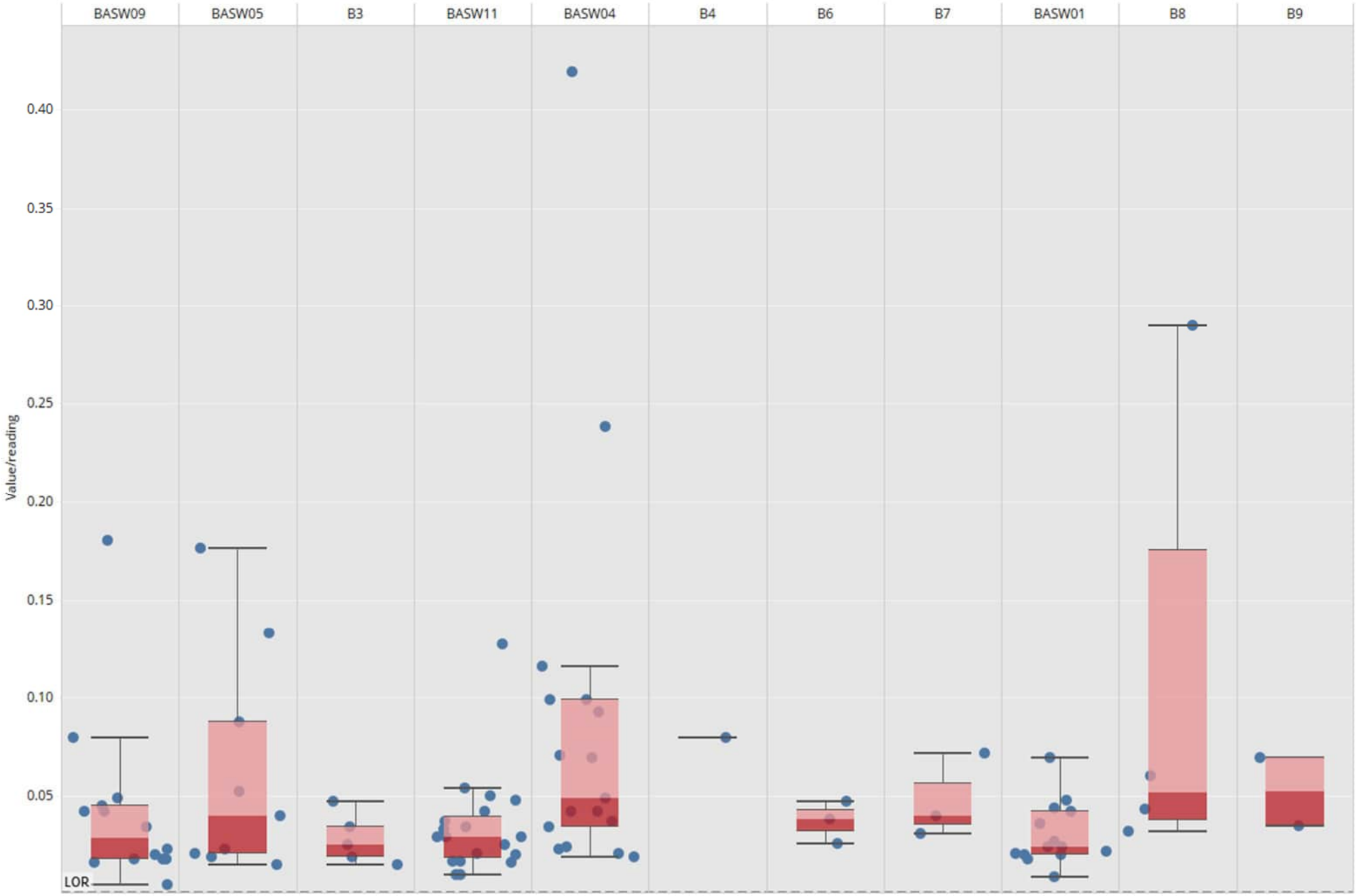
Aluminium - dissolved (mg/L)



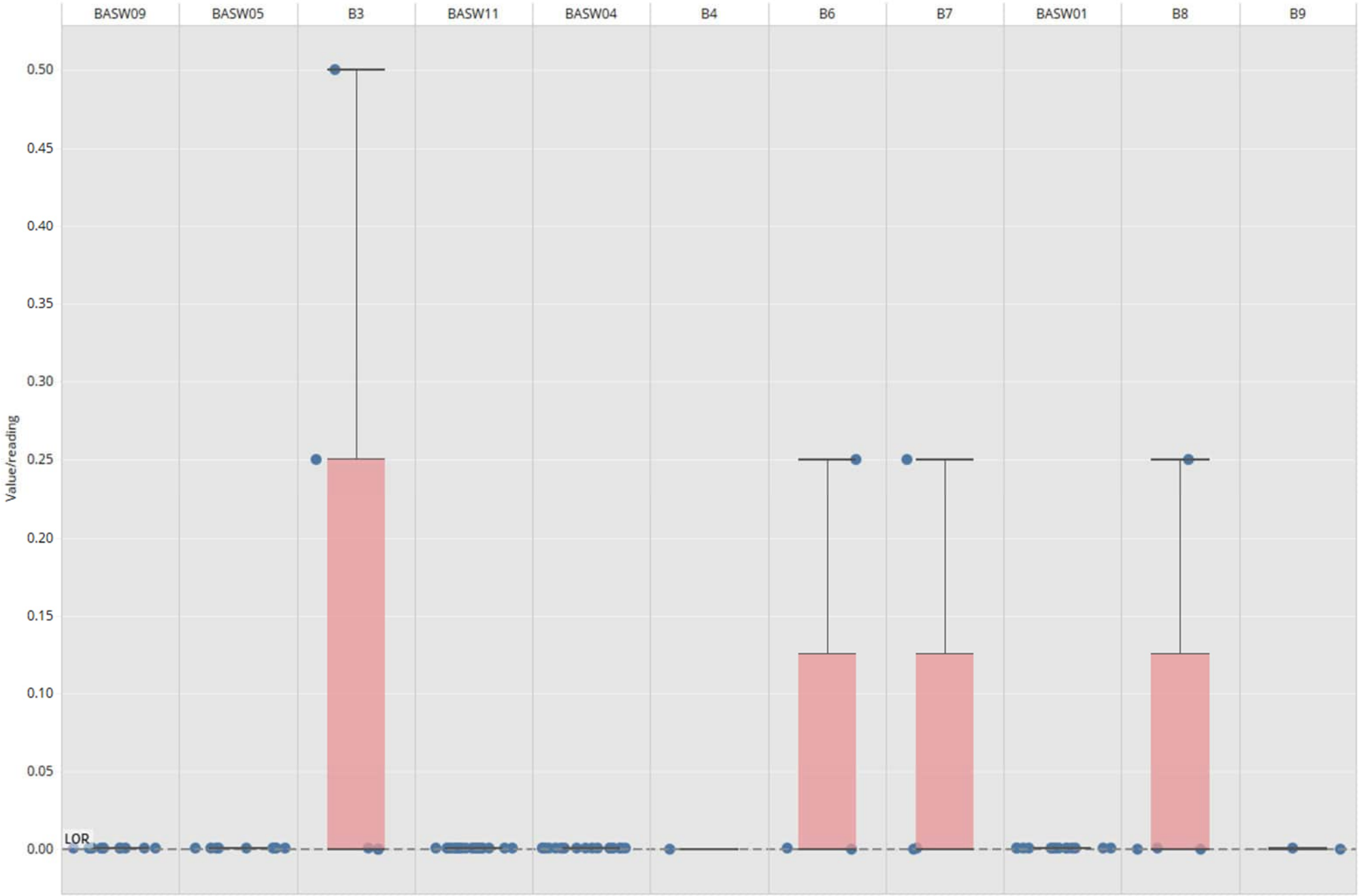
Arsenic - dissolved (mg/L)



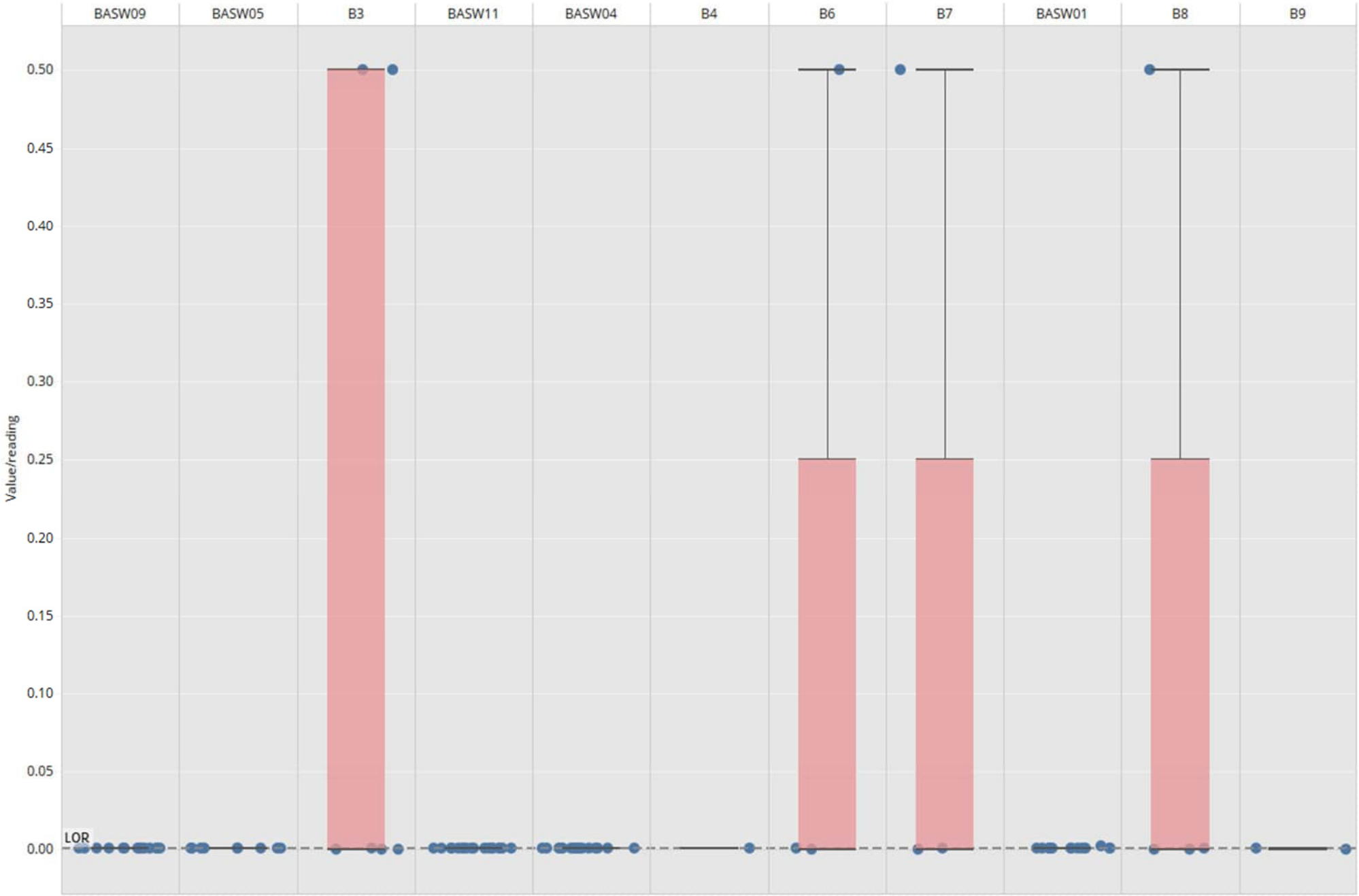
Barium - dissolved (mg/L)



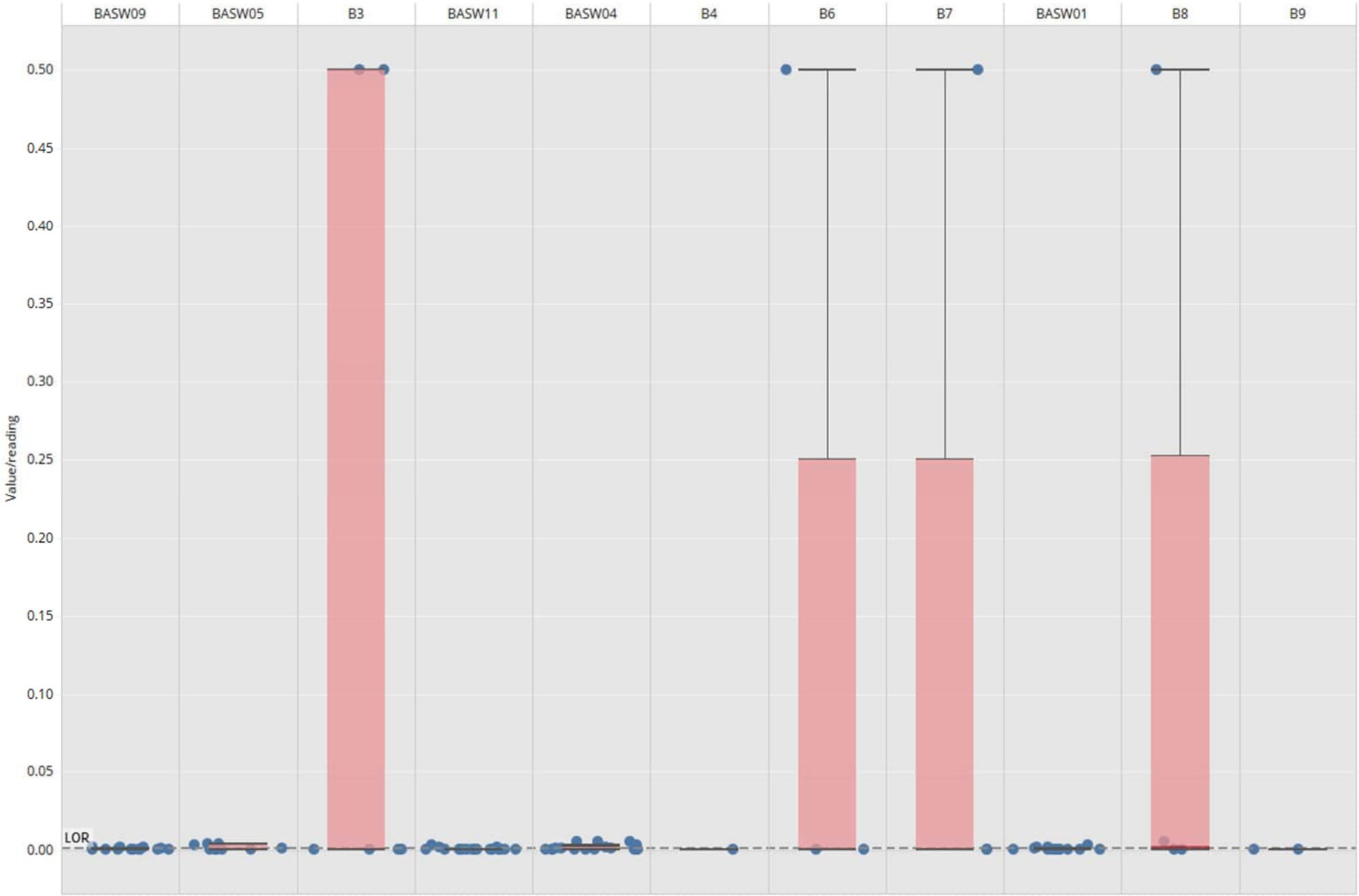
Bismuth - dissolved (mg/L)



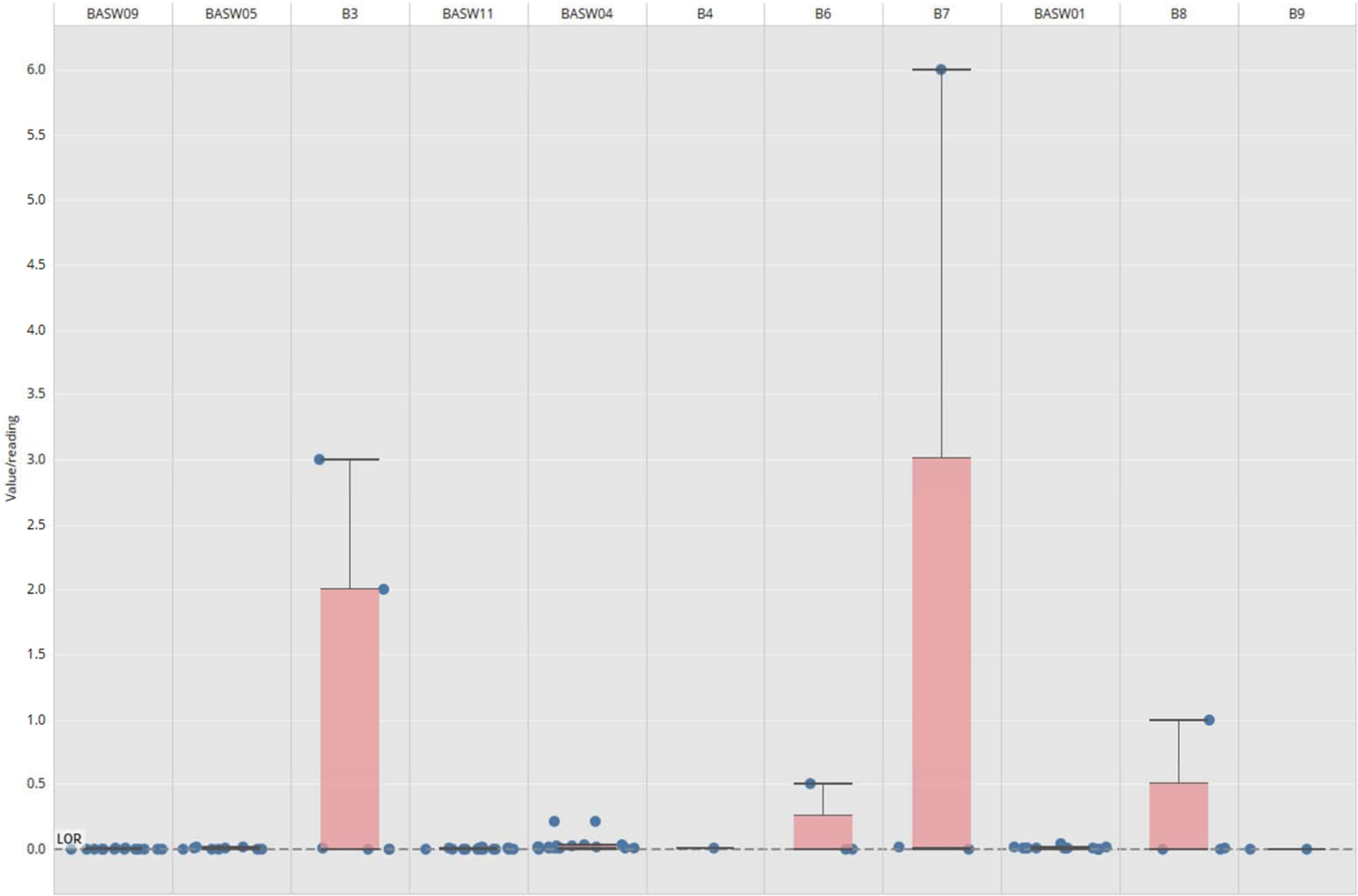
Chromium - dissolved (mg/L)



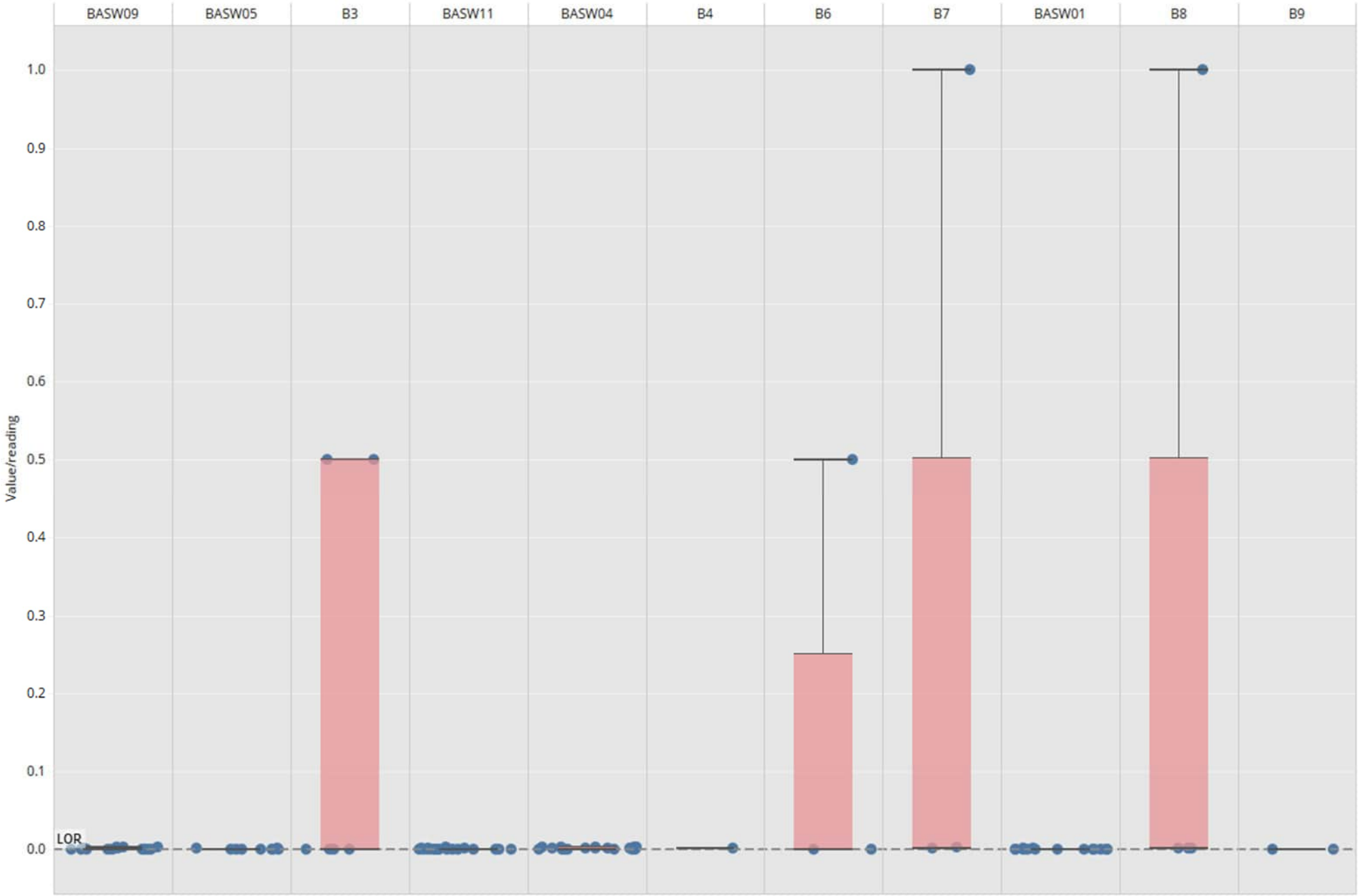
Cobalt - dissolved (mg/L)



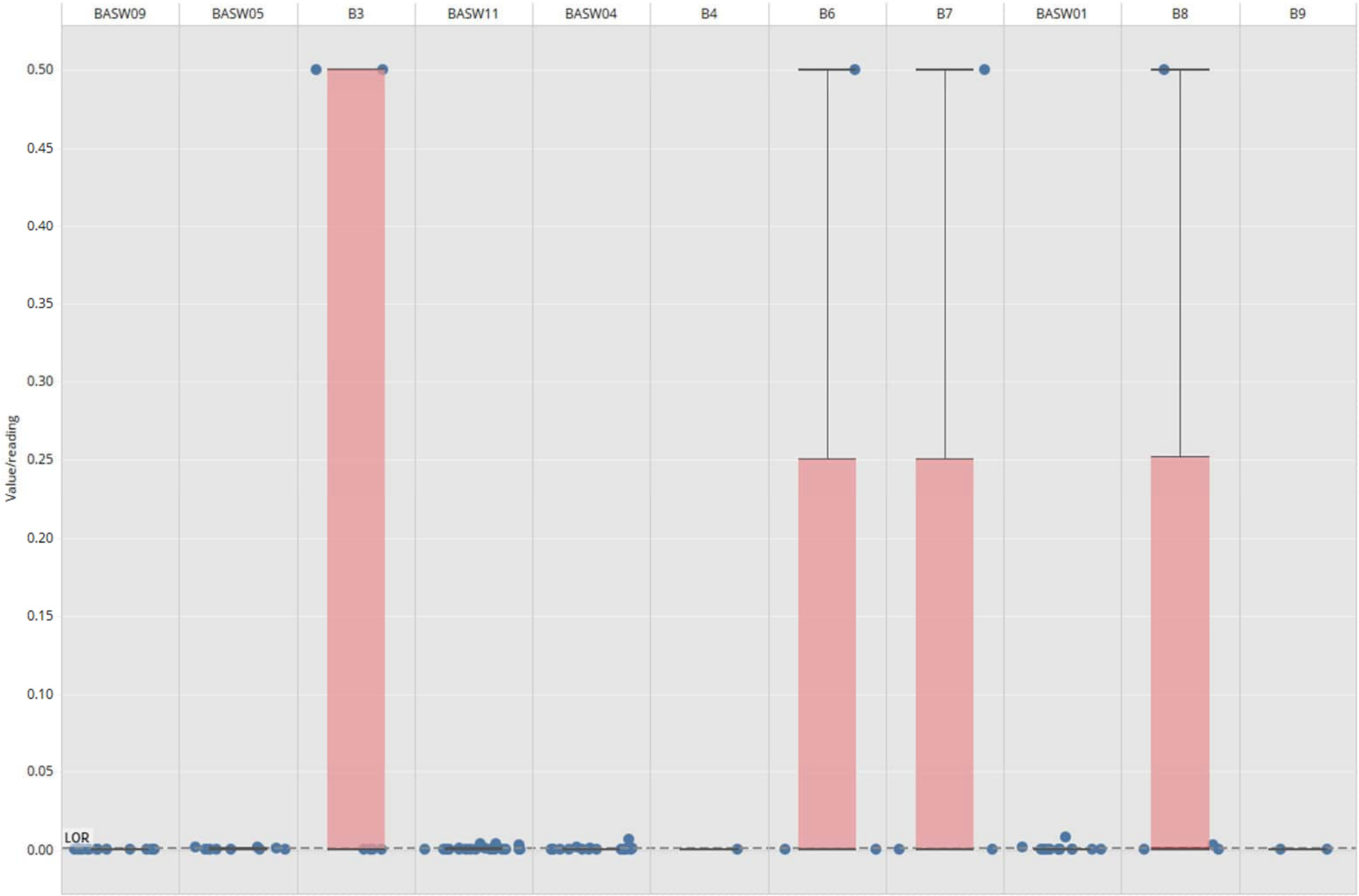
Copper - dissolved (mg/L)



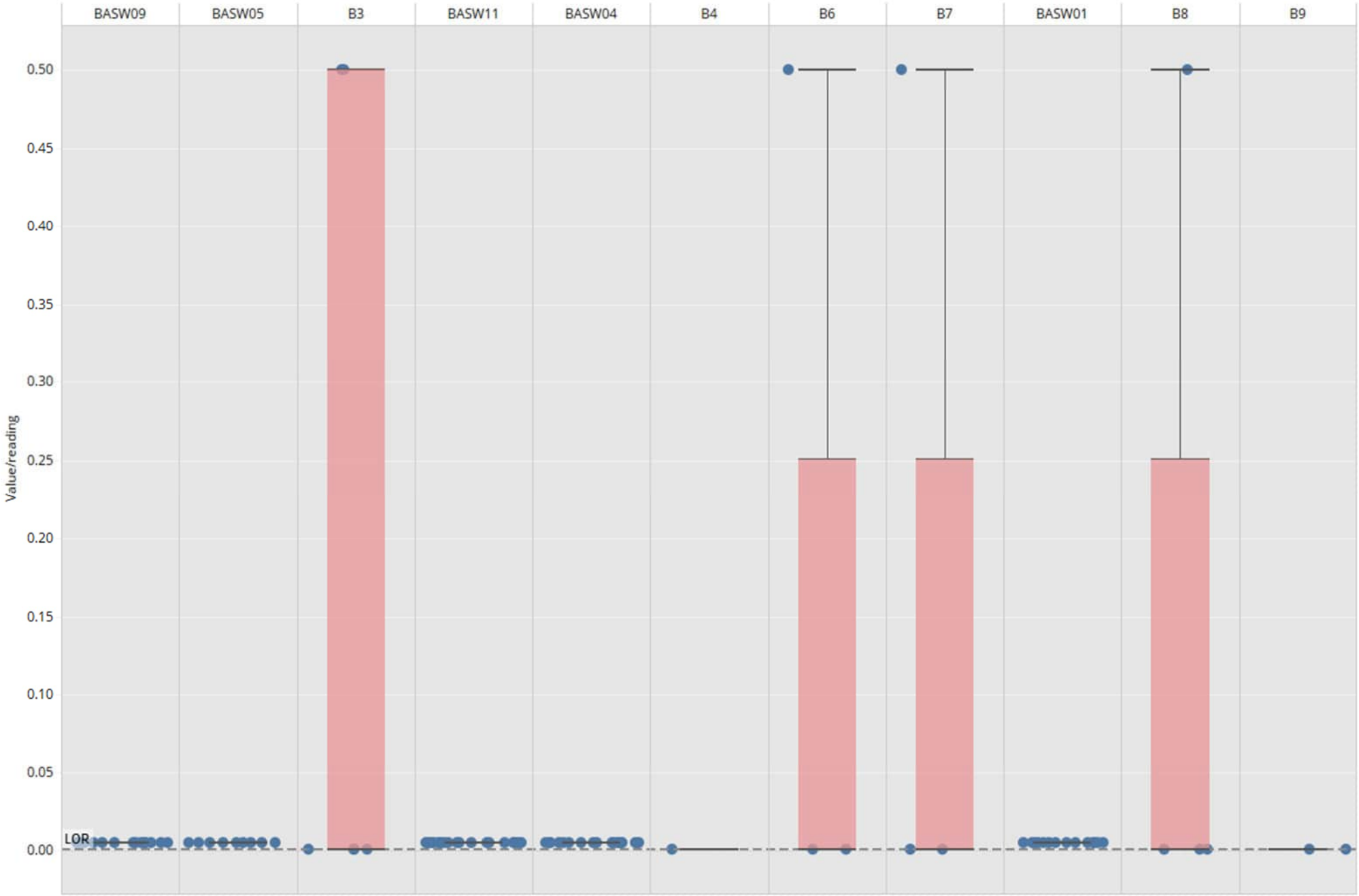
Molybdenum - dissolved (mg/L)



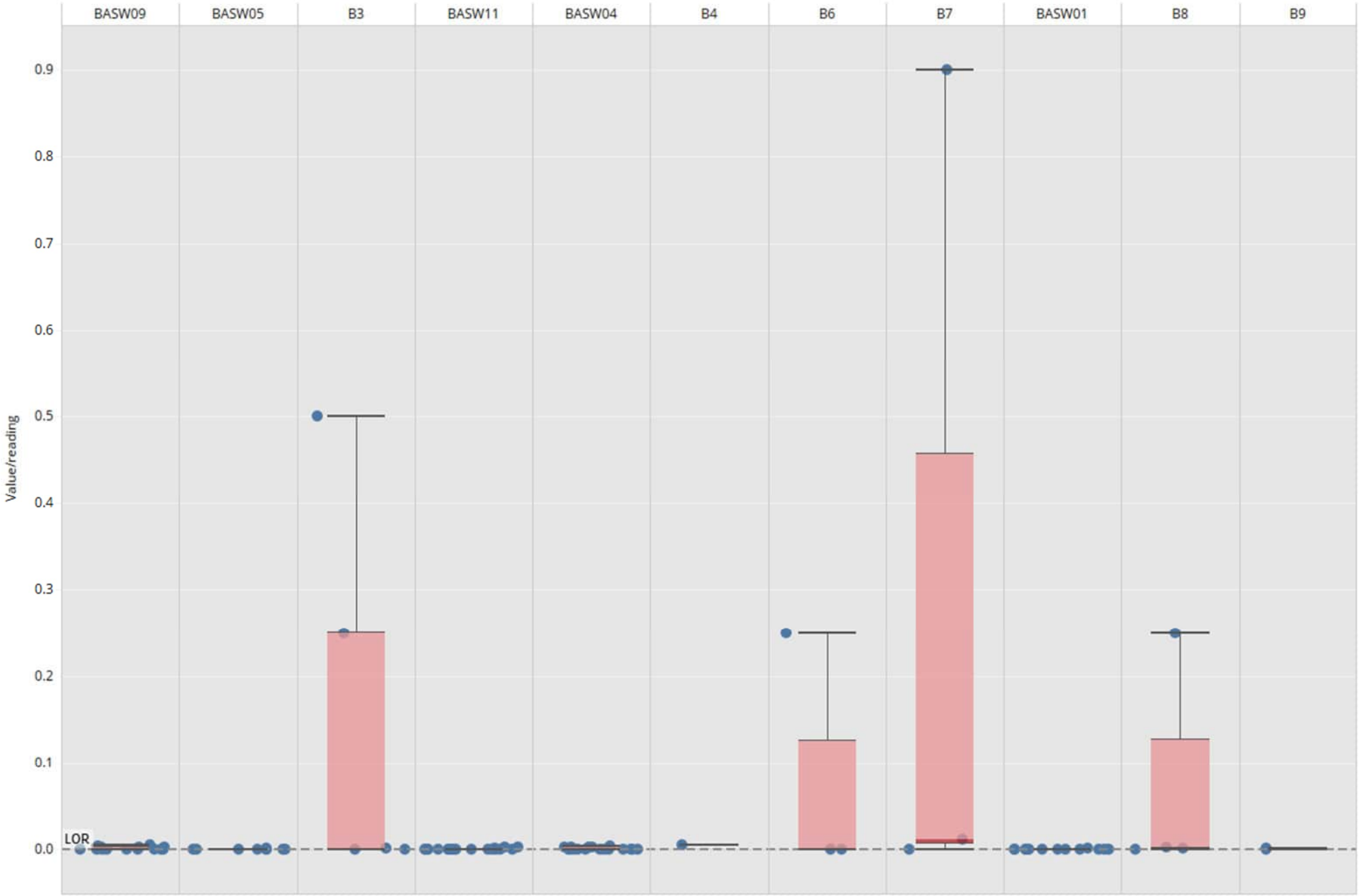
Nickel - dissolved (mg/L)



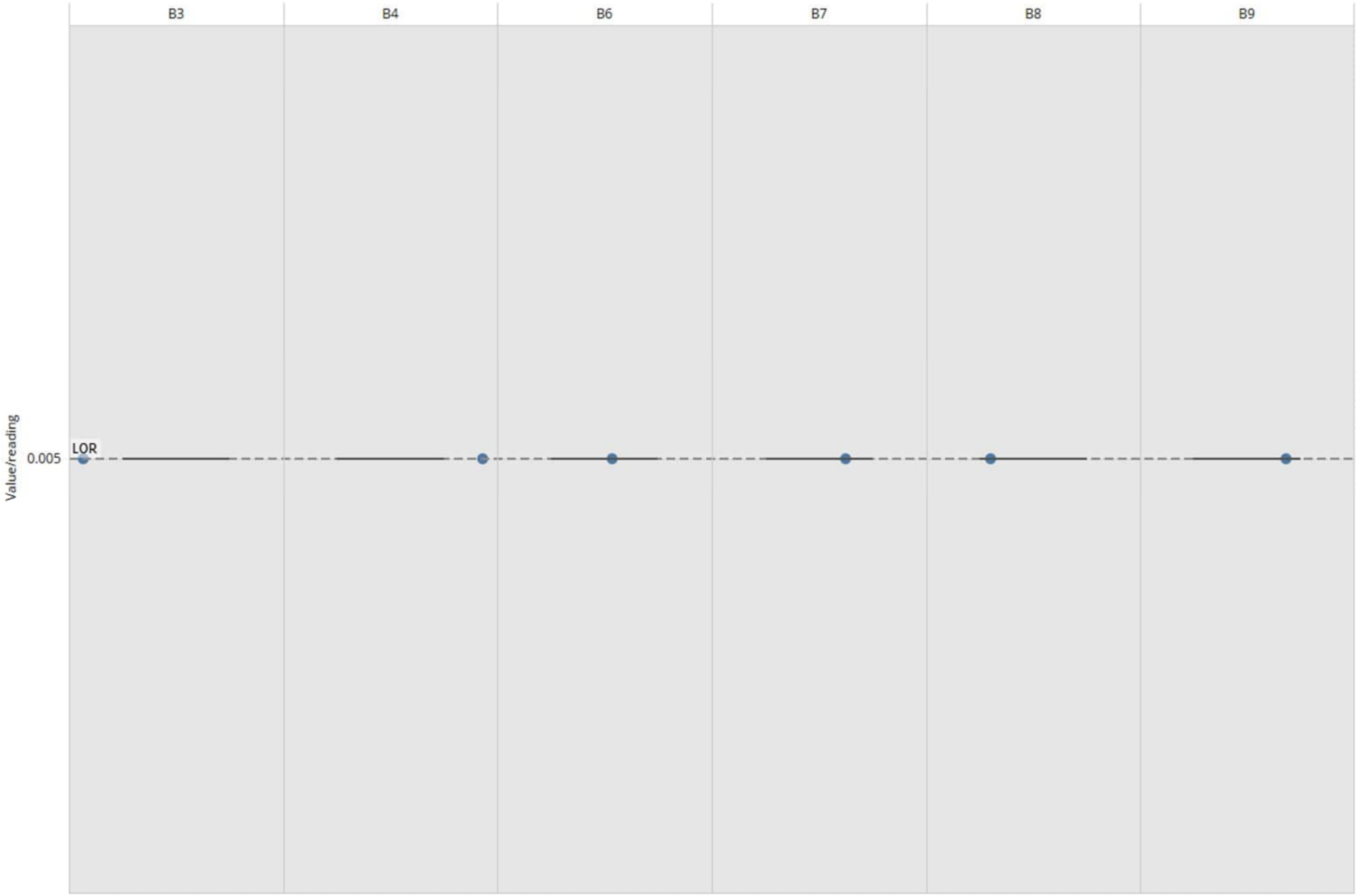
Selenium - dissolved (mg/L)



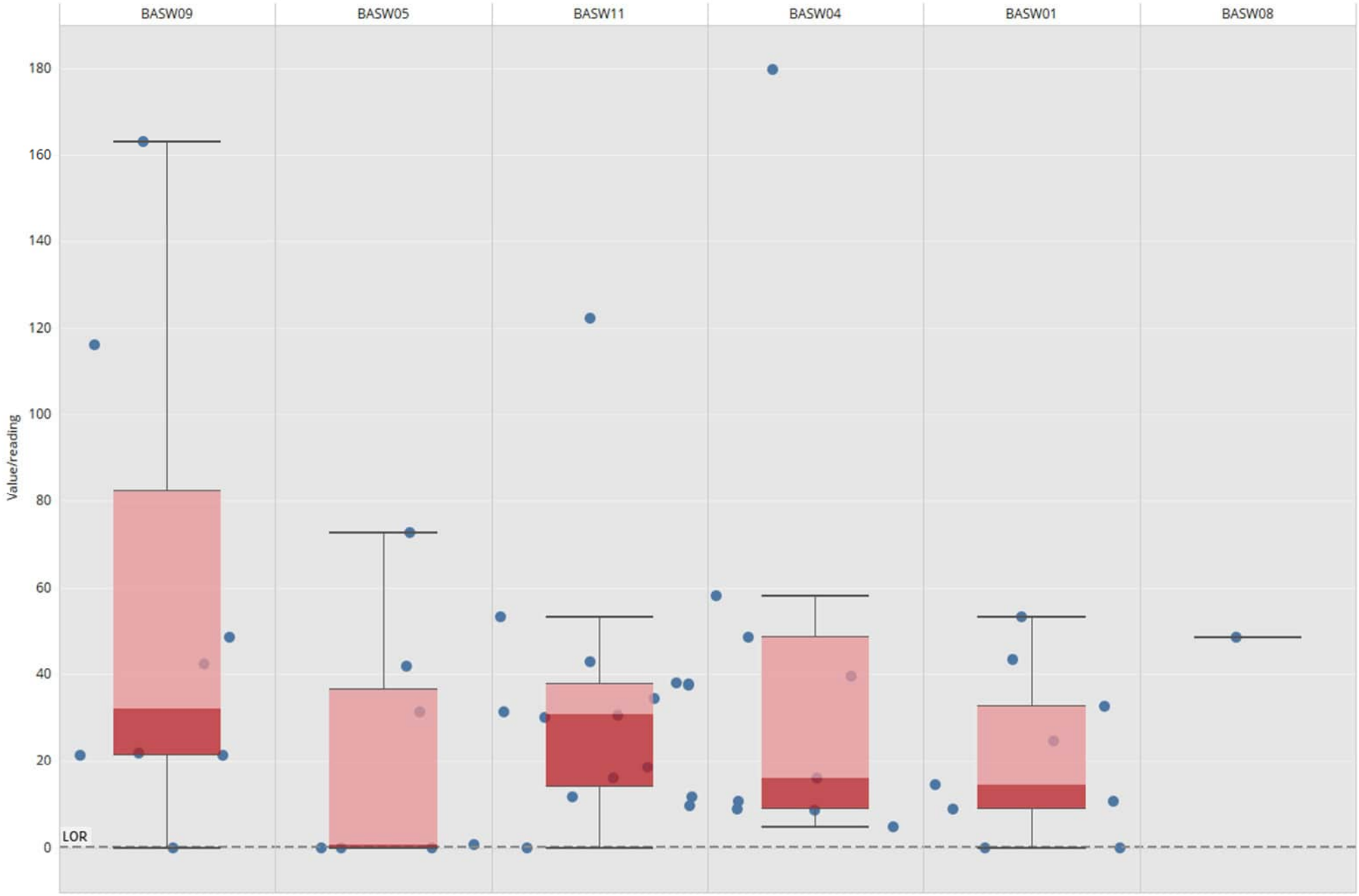
Uranium - dissolved (mg/L)



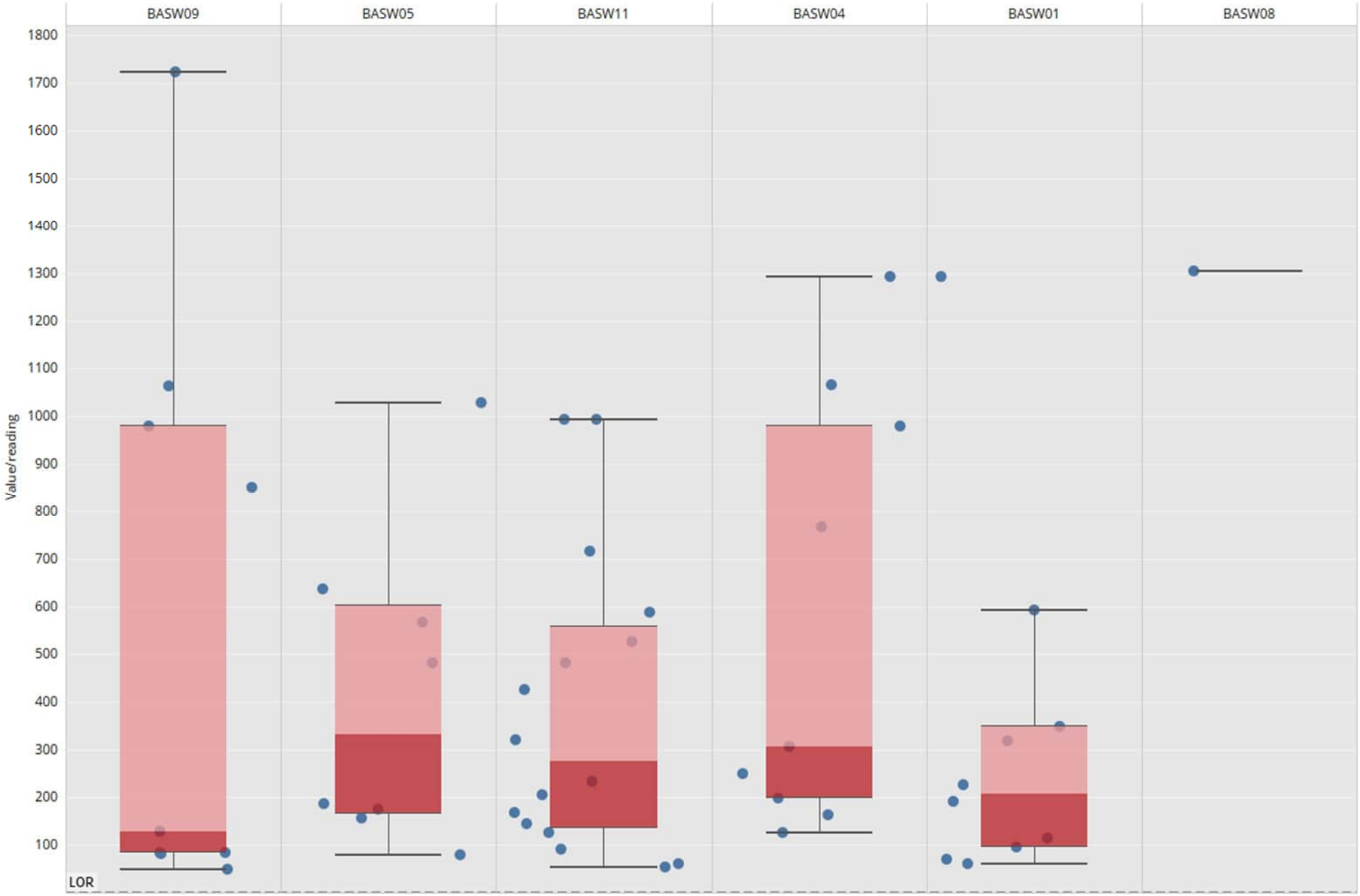
Zinc - dissolved (mg/L)



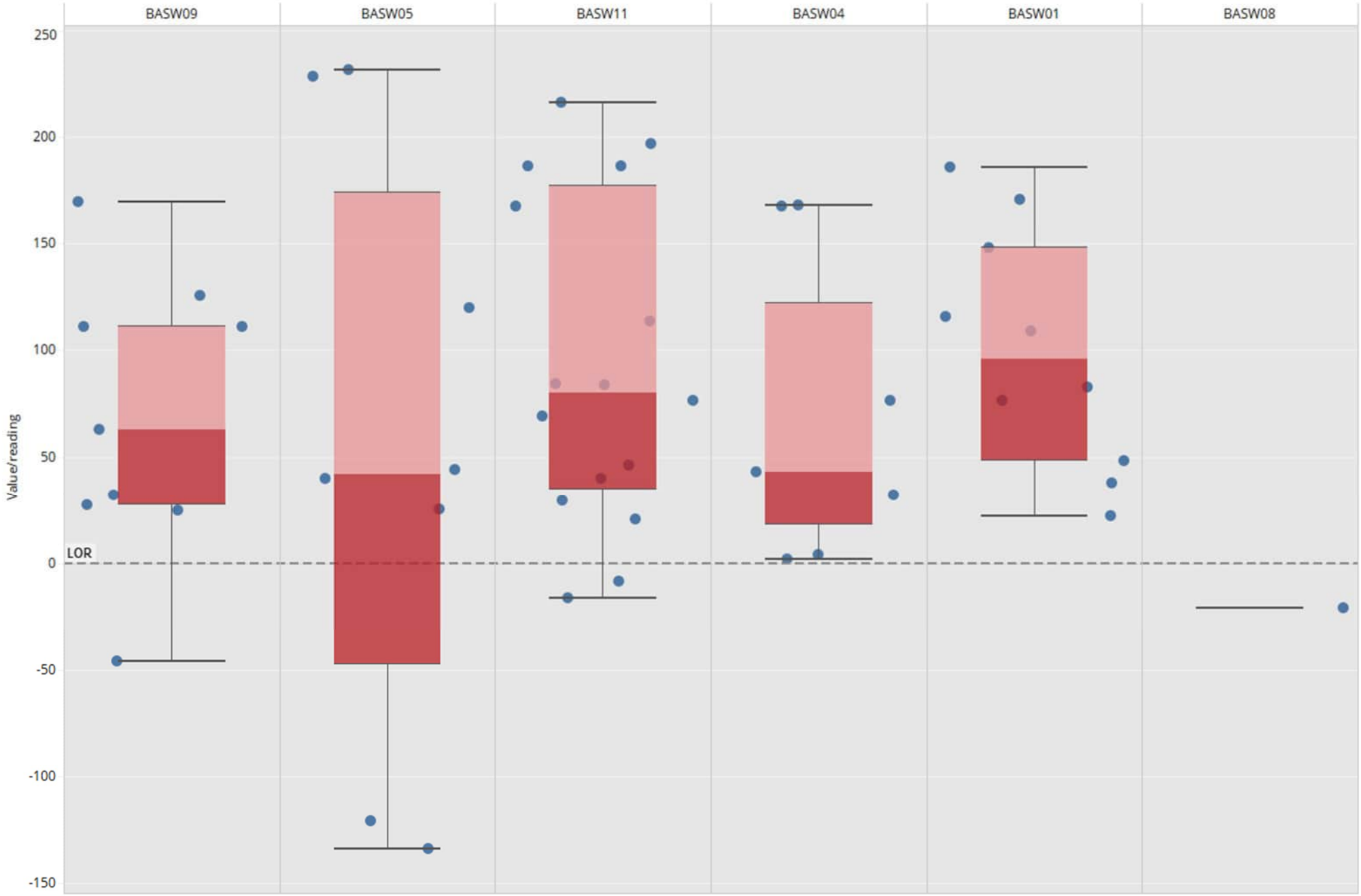
Dissolved Oxygen (field) (% sat)



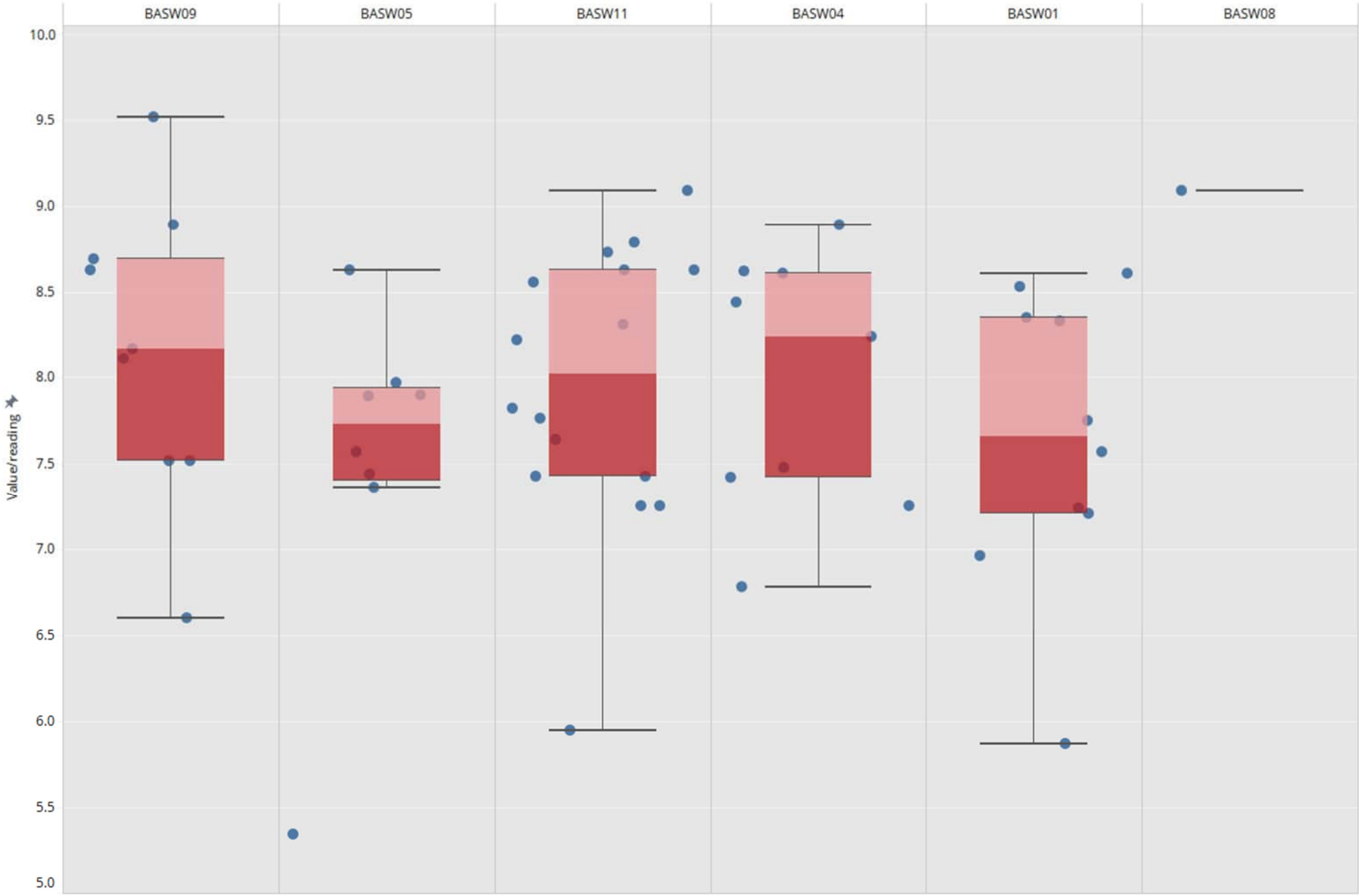
Electrical Conductivity (field) (µS/cm)



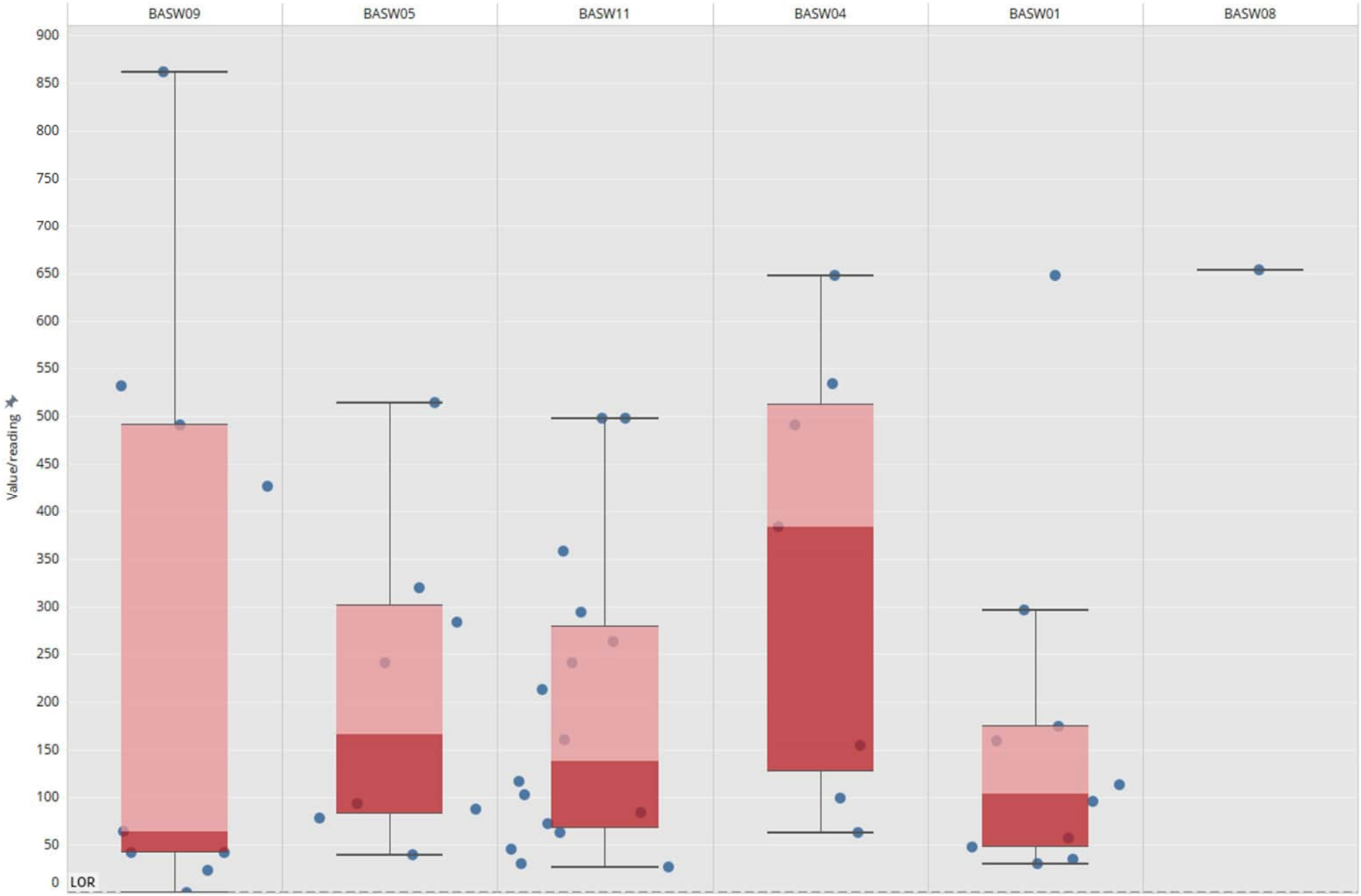
ORP (field) (mV)


BASW09
BASW05
BASW11
BASW04
BASW01
BASW08
250
200
150
100
50
0
-50
-100
-150
Value/reading
LOR

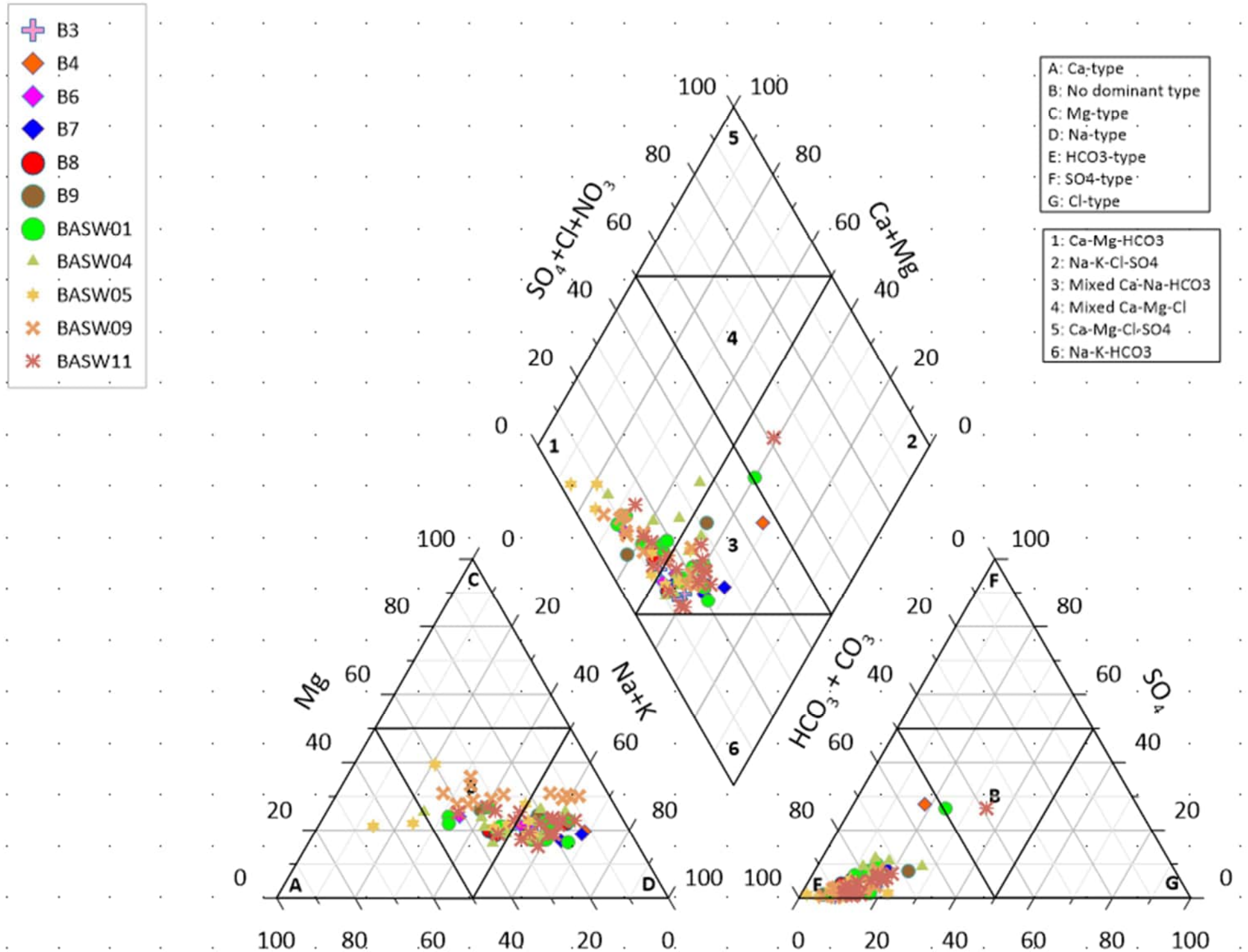
pH (field)

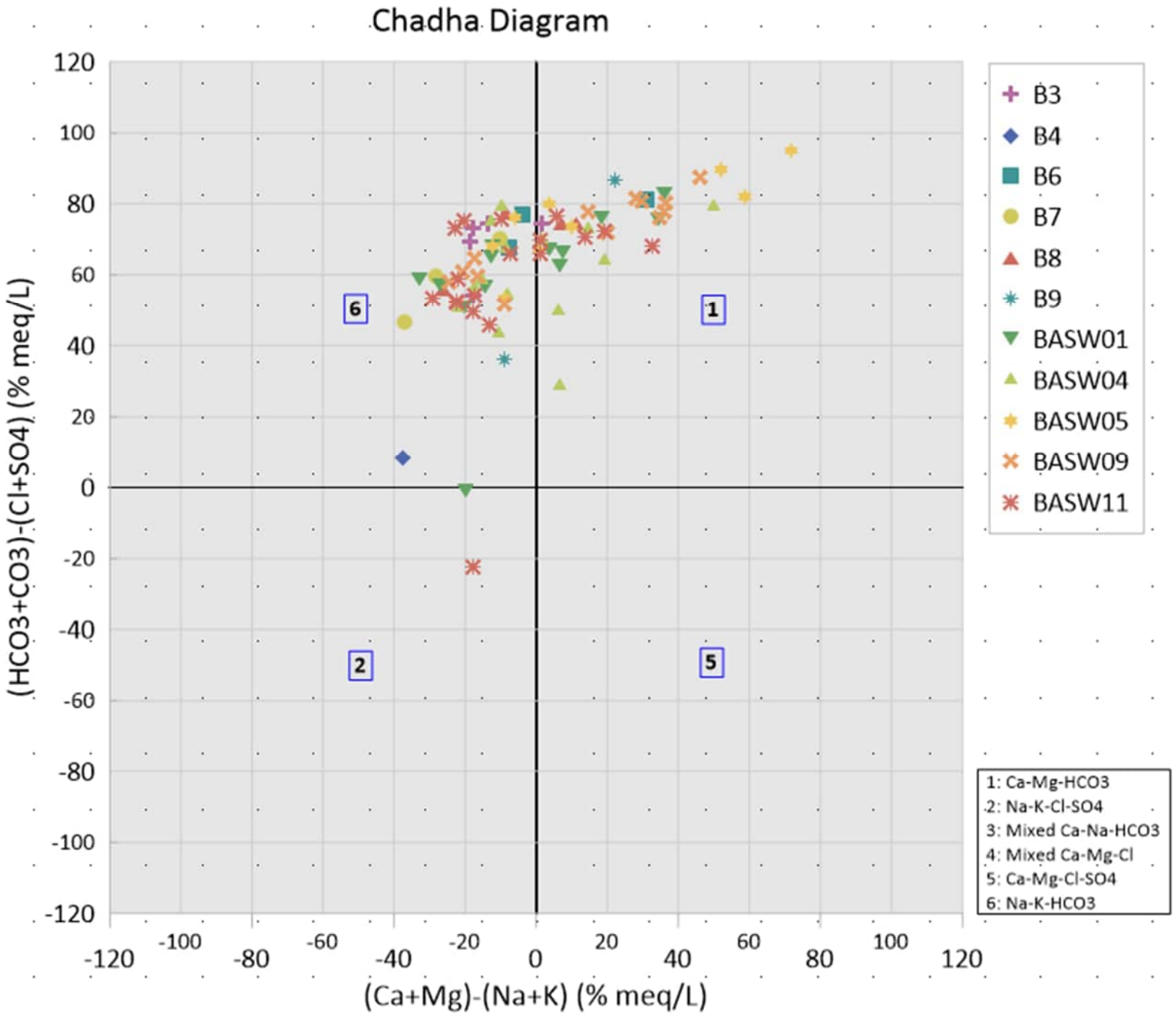

BASW09
BASW05
BASW11
BASW04
BASW01
BASW08
Value/reading
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0

TDS (field) (ppm)

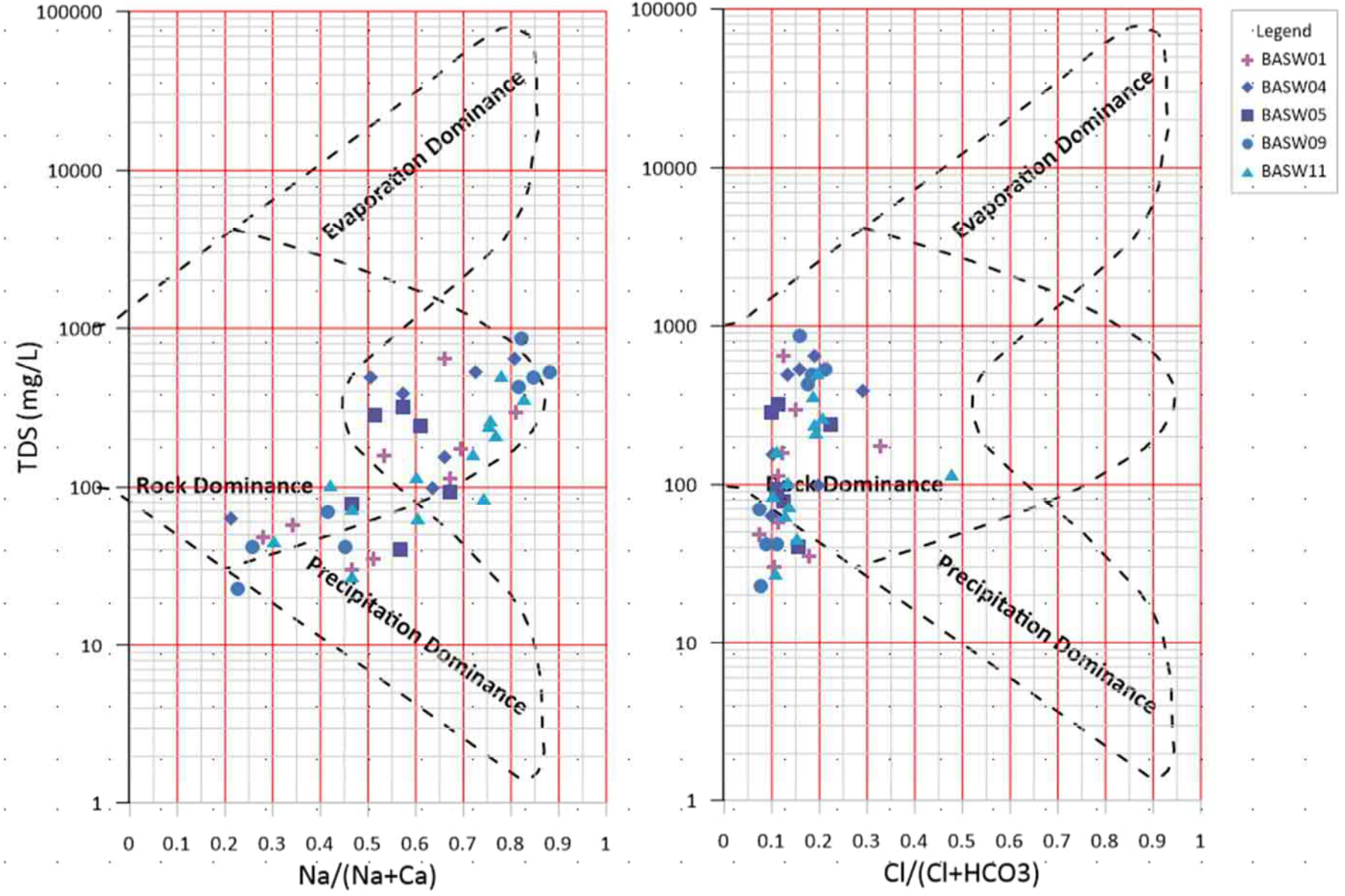


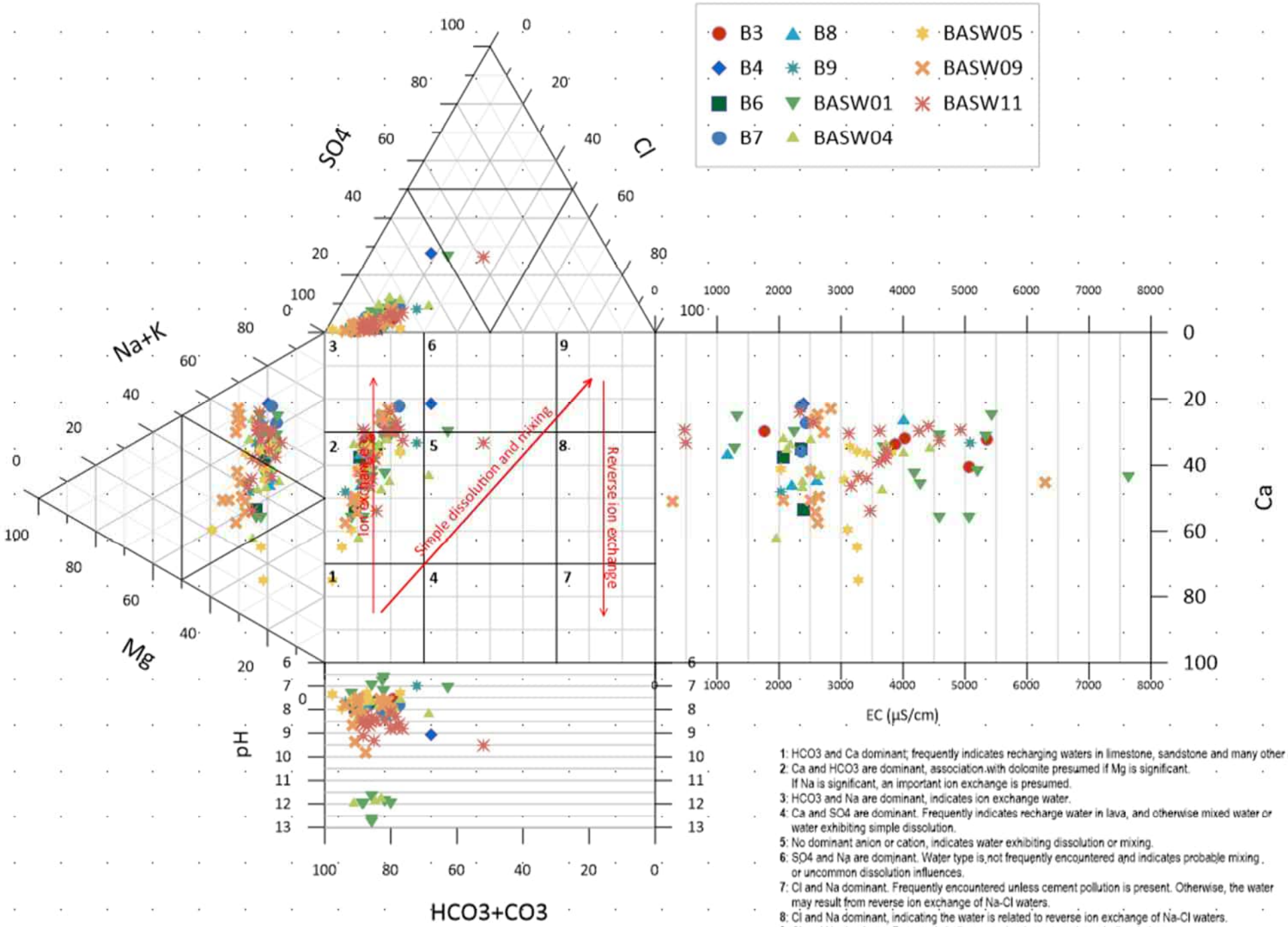
E.4 Hydrogeochemistry plots


B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW09
BASW11
A: Ca-type
B: No dominant type
C: Mg-type
D: Na-type
E: HCO3-type
F: SO4-type
G: Cl-type
1: Ca-Mg-HCO3
2: Na-K-Cl-SO4
3: Mixed Ca-Na-HCO3
4: Mixed Ca-Mg-Cl
5: Ca-Mg-Cl-SO4
6: Na-K-HCO3
SO4+Cl+NO3
Ca+Mg
Mg
Na+K
HCO3+CO3
SO4


Chadha Diagram
(HCO3+CO3)-(Cl+SO4) (% meq/L)
(Ca+Mg)-(Na+K) (% meq/L)
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
1
2
5
6
B3
B4
B6
B7
B8
B9
BASW01
BASW04
BASW05
BASW09
BASW11
1: Ca-Mg-HCO3
2: Na-K-Cl-SO4
3: Mixed Ca-Na-HCO3
4: Mixed Ca-Mg-Cl
5: Ca-Mg-Cl-SO4
6: Na-K-HCO3

Gibbs Diagram





1: HCO3 and Ca dominant; frequently indicates recharging waters in limestone, sandstone and many other aquifers.
2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant.
If Na is significant, an important ion exchange is presumed.
3: HCO3 and Na are dominant, indicates ion exchange water.
4: Ca and SO4 are dominant. Frequently indicates recharge water in lava, and otherwise mixed water or water exhibiting simple dissolution.
5: No dominant anion or cation, indicates water exhibiting dissolution or mixing.
6: SO4 and Na are dominant. Water type is not frequently encountered and indicates probable mixing, or uncommon dissolution influences.
7: Cl and Na dominant. Frequently encountered unless cement pollution is present. Otherwise, the water may result from reverse ion exchange of Na-Cl waters.
8: Cl and Na dominant, indicating the water is related to reverse ion exchange of Na-Cl waters.
9: Cl and Na dominant. Frequently indicates end-point waters through dissolution.

Appendix F Mine site surface water monitoring data

F.1 Mine site surface water data tables

Table F.1 Mine site surface water monitoring events

Year/ Month	BCP North Pit	BCP South Pit	BCP Spring	BCP Spring (N)	BCP Spring (S)	Pooled water S of sediment dam	Sediment Dam	Seepage	Sump
2019									
9								✓	
2020									
2	✓						✓		
10	✓						✓		
2021									
1	✓						✓		
4	✓	✓					✓		
7	✓	✓							
8			✓				✓		
9							✓		
10			✓				✓		✓
11	✓	✓	✓				✓		✓
2022									
2			✓				✓		✓
3	✓		✓				✓		✓
6	✓	✓	✓				✓		✓
7			✓						✓
8			✓	✓	✓		✓		✓
9	✓	✓	✓	✓			✓		✓
10				✓	✓		✓		✓
2023									
1	✓	✓		✓	✓		✓		✓
4	✓	✓	✓	✓	✓	✓	✓		✓
5				✓	✓	✓	✓		✓
6	✓	✓		✓	✓	✓	✓		✓
7				✓	✓	✓	✓		✓
8				✓	✓	✓	✓		✓
9				✓	✓				✓

Year/ Month	BCP North Pit	BCP South Pit	BCP Spring	BCP Spring (N)	BCP Spring (S)	Pooled water S of sediment dam	Sediment Dam	Seepage	Sump
10				✓	✓		✓		✓
11				✓	✓		✓		✓
12	✓			✓	✓		✓		✓

Table F.2 Descriptive statistics: mine site surface water monitoring results (all sites)

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	No. distinct values (>LOR)	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	10%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	80%ile	90%ile (> LOR)	95%ile (>LOR)	99%ile (>LOR)
Alkalinity																				
Bicarbonate Alkalinity as CaCO3 (mg/L)	101	101			87	38	532.149	471.345	1700	1662	56	70	87	93	473	884	913	1220	1450	1570
Carbonate Alkalinity as CaCO3 (mg/L)	101	50	51	50.5%	49	10	220.520	254.595	1400	1390	14.45	24.9	35.8	46	107	301	390.6	515.5	595.95	1096.2
Hydroxide Alkalinity as CaCO3 (mg/L)	101		101	100.0%	1															
Total Alkalinity as CaCO3 (mg/L)	101	101			82	50	640.842	637.433	2950	2900	62	73	87	93	526	950	1140	1500	1960	2200
Carbon																				
Total Non-Purgeable Organic Carbon(mg/L)	1	1			1	300	300.000	0.000	300	0	300	300	300	300	300	300	300	300	300	300
Field Measurements																				
Dissolved Oxygen (field) (% sat)	44	44			39	0	96.645	86.833	315.9	315.9	0	0.33	1.56	3.85	94.85	164.325	173.58	187.86	209.09	314.051
Electrical Conductivity (field) (µS/cm)	48	48			47	65	2423.500	1869.688	9392	9327	621.35	870.3	986.2	1014	1761	3246.75	3913.2	4951.9	5298.4	8120.18
ORP (field) (mV)	48	48			47	-58.8	37.127	85.281	252.9	311.7	-57.92	-51.54	-32.98	-27.925	3.7	86.825	110.44	180.8	200.61	245.521
pH (field)	48	48			40	7.76	8.710	0.503	10.06	2.3	7.9705	8.14	8.308	8.4125	8.66	8.9025	9.026	9.432	9.6025	9.9566
Salinity (field) (PSU)	48	48			43	0.03	1.231	1.002	5.24	5.21	0.287	0.414	0.484	0.5	0.88	1.68	1.988	2.488	2.682	4.488
TDS (field) (ppm)	48	48			47	32	1212.354	934.463	4695	4663	310.7	437.6	493.4	506	880.5	1623.75	1956.8	2475.2	2649.55	4059.56
Temperature (field) (°C)	48	48			47	19.72	27.471	3.466	33.96	14.24	21.894	22.557	24.226	25.7325	27.89	29.315	30.094	32.11	33.1325	33.8848
Turbidity (field) (FNU)	2	2			2	2.1	2.550	0.450	3	0.9	2.145	2.19	2.28	2.325	2.55	2.775	2.82	2.91	2.955	2.991
Hardness																				
Total Hardness (mg CaCO3/L)	61	61			56	37	742.246	682.970	3550	3513	138	215	324	348	522	834	916	1590	2100	3190
Ion Balance																				
Ion Balance (%)	4	4			4	-0.3	5.150	4.019	11	11.3	0.405	1.11	2.52	3.225	4.95	6.875	7.7	9.35	10.175	10.835
Ionic Balance (%)	96	96			90	0.63	6.282	6.359	32.3	31.67	0.8475	1.055	1.62	1.7525	3.7	9.2375	9.66	17.2	18.2	25.935
Total Anions (meq/L)	101	101			95	2.8	33.150	22.023	101	98.2	6.41	9.21	12.9	13.7	31	44.9	52.3	65	78.1	86.2
Total Cations (meq/L)	101	101			95	2.88	37.207	25.070	114	111.12	7.86	9.05	14.2	15.8	34.9	52.4	56.6	70.6	88.9	107
Major Ions																				
Bromide (mg/L)	7	7			7	0.086	0.761	0.828	2.36	2.274	0.0932	0.1004	0.112	0.115	0.21	1.22	1.424	1.88	2.12	2.312
Calcium (mg/L)	158	158			103	10	106.956	141.064	754	744	15	17.7	23.4	30.5	58.5	97.5	126.8	242.6	464.8	665.91
Chloride (mg/L)	101	101			84	14	198.168	184.513	912	898	17	18	28	39	178	263	326	474	554	721
Fluoride (mg/L)	101	101			22	0.2	1.173	0.479	2.6	2.4	0.4	0.6	0.8	0.8	1.1	1.6	1.6	1.8	1.9	2.5
Iodide (mg/L)	7	2	5	71.4%	3	0.62	0.650	0.030	0.68	0.06	0.623	0.626	0.632	0.635	0.65	0.665	0.668	0.674	0.677	0.6794
Magnesium (mg/L)	158	158			105	3	99.652	77.044	406	403	16	22	34	43	88.5	129	138.6	188.7	249	368.64
Potassium (mg/L)	158	158			38	2	16.753	11.639	84	82	4	5	7	8	14	22.75	25	34	36.3	42
Sodium (mg/L)	158	158			142	41	547.861	440.571	2260	2219	68.7	78.4	109.2	136.75	518.5	739.25	771.2	1140	1481.5	1786
Sulfate (as SO4)	101	101			99	32	709.079	518.658	3220	3188	142	227	390	431	604	820	920	1150	1710	2660
Metals (dissolved)																				
Aluminium - dissolved (mg/L)	4	3	1	25.0%	3	0.011	0.012	0.001	0.013	0.002	0.0112	0.0114	0.0118	0.012	0.013	0.013	0.013	0.013	0.013	0.013
Arsenic - dissolved (mg/L)	102	100	2	2.0%	20	0	0.005	0.005	0.035	0.035	0.001	0.001	0.002	0.002	0.0035	0.00725	0.01	0.012	0.01305	0.02114

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	No. distinct values (>LOR)	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	10%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	80%ile	90%ile (> LOR)	95%ile (>LOR)	99%ile (>LOR)
Barium - dissolved (mg/L)	101	101			65	0.021	0.088	0.031	0.176	0.155	0.04	0.046	0.06	0.067	0.089	0.109	0.11	0.127	0.139	0.15
Beryllium - dissolved (mg/L)	6		6	100.0%	1															
Bismuth - dissolved (mg/L)	101		101	100.0%	1															
Boron - dissolved (mg/L)	6	5	1	16.7%	5	0.06	0.082	0.026	0.13	0.07	0.06	0.06	0.06	0.06	0.07	0.09	0.098	0.114	0.122	0.1284
Chromium - dissolved (mg/L)	102	2	100	98.0%	2	0.002	0.002	0.000	0.002	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cobalt - dissolved (mg/L)	102	63	39	38.2%	10	0.001	0.003	0.003	0.014	0.013	0.001	0.001	0.001	0.001	0.002	0.002	0.0026	0.0058	0.007	0.01276
Copper - dissolved (mg/L)	102	102			39	0.001	0.022	0.027	0.196	0.195	0.005	0.006	0.009	0.01	0.013	0.02375	0.027	0.0409	0.0539	0.1624
Iron - dissolved (mg/L)	6	1	5	83.3%	2	0.09	0.090	0.000	0.09	0	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Molybdenum - dissolved (mg/L)	102	102			38	0.001	0.017	0.019	0.146	0.145	0.003	0.004	0.005	0.006	0.008	0.02175	0.0248	0.0424	0.05	0.06097
Nickel - dissolved (mg/L)	102	58	44	43.1%	15	0.001	0.005	0.005	0.027	0.026	0.001	0.001	0.0014	0.002	0.002	0.005	0.006	0.0086	0.0163	0.02529
Selenium - dissolved (mg/L)	102	33	69	67.6%	17	0.002	0.062	0.071	0.28	0.278	0.0076	0.01	0.01	0.01	0.03	0.07	0.104	0.16	0.224	0.264
Uranium - dissolved (mg/L)	101	101			36	0.002	0.016	0.012	0.076	0.074	0.003	0.004	0.006	0.007	0.014	0.024	0.025	0.031	0.036	0.057
Vanadium - dissolved (mg/L)	6	1	5	83.3%	2	0.03	0.030	0.000	0.03	0	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Zinc - dissolved (mg/L)	1		1	100.0%	1															
Metals (total)																				
Aluminium - total (mg/L)	4	4			4	0.11	0.555	0.314	0.99	0.88	0.1685	0.227	0.344	0.4025	0.56	0.7125	0.768	0.879	0.9345	0.9789
Arsenic - total (mg/L)	102	102			21	0.001	0.006	0.008	0.066	0.065	0.001	0.0011	0.002	0.003	0.004	0.007	0.009	0.0129	0.01495	0.03387
Barium - total (mg/L)	101	101			69	0.024	0.097	0.035	0.188	0.164	0.041	0.049	0.064	0.076	0.098	0.117	0.123	0.142	0.163	0.179
Beryllium - total (mg/L)	6		6	100.0%	1															
Bismuth - total (mg/L)	101		101	100.0%	1															
Boron - total (mg/L)	6	5	1	16.7%	4	0.07	0.090	0.028	0.14	0.07	0.07	0.07	0.07	0.07	0.07	0.1	0.108	0.124	0.132	0.1384
Chromium - total (mg/L)	102	11	91	89.2%	6	0.0009	0.002	0.001	0.005	0.0041	0.00095	0.001	0.001	0.001	0.001	0.002	0.002	0.004	0.0045	0.0049
Cobalt - total (mg/L)	102	76	26	25.5%	11	0.001	0.003	0.003	0.016	0.015	0.001	0.001	0.002	0.002	0.002	0.003	0.003	0.006	0.00725	0.01525
Copper - total (mg/L)	102	102			48	0.006	0.034	0.048	0.392	0.386	0.009	0.0101	0.013	0.014	0.0215	0.034	0.0376	0.051	0.0967	0.22845
Iron - total (mg/L)	6	2	4	66.7%	3	0.3	0.680	0.380	1.06	0.76	0.338	0.376	0.452	0.49	0.68	0.87	0.908	0.984	1.022	1.0524
Molybdenum - total (mg/L)	102	102			41	0	0.019	0.022	0.156	0.156	0.00305	0.004	0.006	0.00625	0.01	0.02475	0.027	0.0447	0.0599	0.06894
Nickel - total (mg/L)	102	70	32	31.4%	15	0.001	0.004	0.004	0.025	0.024	0.001	0.001	0.001	0.002	0.002	0.005	0.006	0.0081	0.012	0.01948
Selenium - total (mg/L)	102	30	72	70.6%	16	0.002	0.069	0.073	0.28	0.278	0.0067	0.01	0.018	0.02	0.035	0.07	0.116	0.166	0.231	0.2684
Uranium - total (mg/L)	101	101			37	0.002	0.018	0.015	0.091	0.089	0.004	0.005	0.006	0.007	0.014	0.026	0.029	0.034	0.041	0.083
Vanadium - total (mg/L)	6	2	4	66.7%	3	0.01	0.025	0.015	0.04	0.03	0.0115	0.013	0.016	0.0175	0.025	0.0325	0.034	0.037	0.0385	0.0397
Nutrients																				
Nitrate as N (mg/L)	9	7	2	22.2%	8	0.09	14.979	14.185	34.6	34.51	0.105	0.12	0.176	0.23	17.3	26.2	30.64	34	34.3	34.54
Nitrite + Nitrate as N (mg/L)	9	7	2	22.2%	8	0.09	15.266	14.442	35.3	35.21	0.108	0.126	0.184	0.235	17.6	26.7	31.14	34.58	34.94	35.228
Nitrite as N (mg/L)	9	5	4	44.4%	6	0.01	0.392	0.225	0.65	0.64	0.066	0.122	0.234	0.29	0.46	0.55	0.57	0.61	0.63	0.646
Physico-Chemical Parameters																				
Electrical Conductivity (µS/cm)	100	100			91	279	3149.890	2003.047	9460	9181	759.9	948.9	1258	1435	3080	4270	4876	5975	7170	8856.1
pH (lab)	100	100			72	7.51	8.386	0.422	9.3	1.79	7.849	7.92	8.04	8.06	8.295	8.7225	8.782	8.971	9.1425	9.2802
Turbidity (NTU)	97	97			62	0.2	8.671	18.077	155	154.8	0.5	0.66	0.9	1	2	10.3	14.32	19.78	33.7	61.208

Table F.3 Descriptive statistics: mine site surface water monitoring results – by location

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
BCP North Pit														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	11	11			98	139.455	77.700	382	284	98	103	120	130	256.5
Carbonate Alkalinity as CaCO3 (mg/L)	11		11	100.0%										
Total Alkalinity as CaCO3 (mg/L)	11	11			98	139.455	77.700	382	284	98	103	120	130	256.5
Field Measurements														
Dissolved Oxygen (field) (% sat)	6	6			0	66.350	73.534	196	196	0	0.475	43.95	107.15	175.55
Electrical Conductivity (field) (µS/cm)	7	7			738	1038.571	194.327	1386	648	794.7	930.5	1014	1135.5	1332.6
ORP (field) (mV)	7	7			-34.1	59.743	86.179	237.2	271.3	-33.17	-3.95	43.2	89.9	193.97
pH (field)	7	7			7.89	8.413	0.303	8.86	0.97	7.965	8.235	8.44	8.615	8.803
Salinity (field) (PSU)	7	7			0.3	0.504	0.111	0.68	0.38	0.345	0.46	0.5	0.565	0.656
TDS (field) (ppm)	7	7			369	520.429	96.590	693	324	398.4	469	507	568	666.3
Temperature (field) (°C)	7	7			19.82	27.263	4.356	32.84	13.02	20.978	24.01	29.31	30.425	32.303
Hardness														
Total Hardness (mg CaCO3/L)	4	4			157	216.250	37.732	249	92	164.95	196.75	229.5	249	249
Major Ions														
Bromide (mg/L)	1	1			0.12	0.120	0.000	0.12	0	0.12	0.12	0.12	0.12	0.12
Calcium (mg/L)	15	15			38	65.800	23.302	128	90	38.7	51.5	60	75.5	107
Chloride (mg/L)	11	11			16	32.909	38.611	153	137	16	17	20	21.5	97.5
Fluoride (mg/L)	11	11			1	1.318	0.252	1.9	0.9	1	1.2	1.2	1.4	1.75
Iodide (mg/L)	1		1	100.0%										

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Magnesium (mg/L)	15	15			15	27.133	7.873	43	28	15.7	22	26	32	40.9
Potassium (mg/L)	15	15			9	18.333	6.204	33	24	9.7	15	17	22.5	28.1
Sodium (mg/L)	15	15			54	84.133	23.194	156	102	56.8	74.5	79	89	124.5
Sulfate (as SO4)	11	11			142	313.455	124.126	583	441	147.5	235.5	304	379	515.5
Metals (dissolved)														
Arsenic - dissolved (mg/L)	11	9	2	18.2%	0.001	0.002	0.001	0.003	0.002	0.001	0.002	0.002	0.002	0.0026
Barium - dissolved (mg/L)	11	11			0.041	0.058	0.017	0.093	0.052	0.0425	0.0465	0.05	0.0675	0.0865
Beryllium - dissolved (mg/L)	1		1	100.0%										
Bismuth - dissolved (mg/L)	11		11	100.0%										
Boron - dissolved (mg/L)	1		1	100.0%										
Chromium - dissolved (mg/L)	11		11	100.0%										
Cobalt - dissolved (mg/L)	11	5	6	54.5%	0.001	0.002	0.001	0.004	0.003	0.001	0.001	0.002	0.002	0.0036
Copper - dissolved (mg/L)	11	11			0.005	0.026	0.013	0.054	0.049	0.01	0.0175	0.024	0.0335	0.0475
Iron - dissolved (mg/L)	1		1	100.0%										
Molybdenum - dissolved (mg/L)	11	11			0.006	0.013	0.005	0.02	0.014	0.006	0.009	0.013	0.017	0.019
Nickel - dissolved (mg/L)	11	11			0.001	0.007	0.005	0.018	0.017	0.0015	0.0035	0.005	0.009	0.0145
Selenium - dissolved (mg/L)	11	4	7	63.6%	0.01	0.020	0.007	0.03	0.02	0.0115	0.0175	0.02	0.0225	0.0285
Uranium - dissolved (mg/L)	11	11			0.002	0.005	0.003	0.014	0.012	0.0025	0.004	0.004	0.0045	0.0105
Vanadium - dissolved (mg/L)	1		1	100.0%										
Metals (total)														
Arsenic - total (mg/L)	11	11			0.001	0.002	0.001	0.003	0.002	0.001	0.001	0.002	0.003	0.003
Barium - total (mg/L)	11	11			0.035	0.062	0.018	0.088	0.053	0.0405	0.049	0.056	0.081	0.0875
Beryllium - total (mg/L)	1		1	100.0%										

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Bismuth - total (mg/L)	11		11	100.0%										
Boron - total (mg/L)	1		1	100.0%										
Chromium - total (mg/L)	11		11	100.0%										
Cobalt - total (mg/L)	11	6	5	45.5%	0.001	0.003	0.001	0.004	0.003	0.00125	0.00225	0.003	0.003	0.00375
Copper - total (mg/L)	11	11			0.008	0.033	0.014	0.065	0.057	0.015	0.024	0.031	0.0395	0.056
Iron - total (mg/L)	1		1	100.0%										
Molybdenum - total (mg/L)	11	11			0.007	0.015	0.005	0.022	0.015	0.008	0.012	0.013	0.019	0.0215
Nickel - total (mg/L)	11	11			0.002	0.007	0.005	0.017	0.015	0.002	0.0035	0.005	0.009	0.0145
Selenium - total (mg/L)	11	3	8	72.7%	0.02	0.023	0.005	0.03	0.01	0.02	0.02	0.02	0.025	0.029
Uranium - total (mg/L)	11	11			0.003	0.006	0.003	0.016	0.013	0.0035	0.004	0.005	0.005	0.011
Vanadium - total (mg/L)	1		1	100.0%										
Nutrients														
Nitrate as N (mg/L)	1	1			0.09	0.090	0.000	0.09	0	0.09	0.09	0.09	0.09	0.09
Nitrite + Nitrate as N (mg/L)	1	1			0.09	0.090	0.000	0.09	0	0.09	0.09	0.09	0.09	0.09
Nitrite as N (mg/L)	1		1	100.0%										
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	11	11			556	945.455	216.313	1360	804	658.5	821	885	1055	1300
pH (lab)	11	11			7.85	8.097	0.099	8.26	0.41	7.955	8.06	8.09	8.15	8.225
BCP South Pit														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	5	5			78	86.000	6.603	93	15	78	78	90	91	92.6
Carbonate Alkalinity as CaCO3 (mg/L)	5		5	100.0%										
Total Alkalinity as CaCO3 (mg/L)	5	5			78	86.000	6.603	93	15	78	78	90	91	92.6

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Field Measurements														
Dissolved Oxygen (field) (% sat)	5	5			0	62.020	70.341	162.8	162.8	0.36	1.8	14.1	131.4	156.52
Electrical Conductivity (field) (µS/cm)	5	5			977	1245.800	230.741	1591	614	981.6	1000	1327	1334	1539.6
ORP (field) (mV)	5	5			-40.3	60.560	82.960	207.4	247.7	-28.24	20	35.3	80.4	182
pH (field)	5	5			8.14	8.540	0.321	9.12	0.98	8.2	8.44	8.45	8.55	9.006
Salinity (field) (PSU)	5	5			0.47	0.614	0.122	0.8	0.33	0.474	0.49	0.65	0.66	0.772
TDS (field) (ppm)	5	5			489	623.200	115.439	796	307	491.2	500	664	667	770.2
Temperature (field) (°C)	5	5			22.41	27.788	4.857	33.96	11.55	22.726	23.99	25.29	33.29	33.826
Major Ions														
Calcium (mg/L)	5	5			103	122.800	17.792	153	50	104.8	112	114	132	148.8
Chloride (mg/L)	5	5			14	17.200	2.993	22	8	14	14	18	18	21.2
Fluoride (mg/L)	5	5			0.8	0.940	0.120	1.1	0.3	0.8	0.8	1	1	1.08
Magnesium (mg/L)	5	5			53	55.800	2.315	60	7	53.4	55	55	56	59.2
Potassium (mg/L)	5	5			15	19.200	3.600	25	10	15.2	16	19	21	24.2
Sodium (mg/L)	5	5			72	89.000	12.426	101	29	72.8	76	96	100	100.8
Sulfate (as SO4)	5	5			481	566.800	78.288	713	232	490.2	527	549	564	683.2
Metals (dissolved)														
Arsenic - dissolved (mg/L)	5	5			0.006	0.009	0.002	0.012	0.006	0.0062	0.007	0.008	0.011	0.0118
Barium - dissolved (mg/L)	5	5			0.037	0.044	0.006	0.052	0.015	0.0376	0.04	0.041	0.052	0.052
Bismuth - dissolved (mg/L)	5		5	100.0%										
Chromium - dissolved (mg/L)	5		5	100.0%										
Cobalt - dissolved (mg/L)	5	3	2	40.0%	0.001	0.008	0.005	0.012	0.011	0.0021	0.0065	0.012	0.012	0.012
Copper - dissolved (mg/L)	5	5			0.011	0.023	0.023	0.069	0.058	0.011	0.011	0.012	0.012	0.0576

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Molybdenum - dissolved (mg/L)	5	5			0.024	0.031	0.007	0.043	0.019	0.0242	0.025	0.029	0.034	0.0412
Nickel - dissolved (mg/L)	5	5			0.007	0.012	0.007	0.024	0.017	0.007	0.007	0.008	0.016	0.0224
Selenium - dissolved (mg/L)	5	2	3	60.0%	0.01	0.010	0.000	0.01	0	0.01	0.01	0.01	0.01	0.01
Uranium - dissolved (mg/L)	5	5			0.006	0.007	0.001	0.008	0.002	0.0062	0.007	0.007	0.007	0.0078
Metals (total)														
Arsenic - total (mg/L)	5	5			0.007	0.009	0.002	0.012	0.005	0.007	0.007	0.008	0.011	0.0118
Barium - total (mg/L)	5	5			0.037	0.045	0.007	0.053	0.016	0.0372	0.038	0.046	0.052	0.0528
Bismuth - total (mg/L)	5		5	100.0%										
Chromium - total (mg/L)	5		5	100.0%										
Cobalt - total (mg/L)	5	4	1	20.0%	0.001	0.008	0.006	0.015	0.014	0.00115	0.00175	0.0075	0.0135	0.0147
Copper - total (mg/L)	5	5			0.012	0.028	0.023	0.072	0.06	0.0124	0.014	0.015	0.026	0.0628
Molybdenum - total (mg/L)	5	5			0.026	0.035	0.009	0.051	0.025	0.0262	0.027	0.036	0.037	0.0482
Nickel - total (mg/L)	5	5			0.007	0.012	0.007	0.025	0.018	0.007	0.007	0.008	0.014	0.0228
Selenium - total (mg/L)	5	2	3	60.0%	0.01	0.010	0.000	0.01	0	0.01	0.01	0.01	0.01	0.01
Uranium - total (mg/L)	5	5			0.007	0.008	0.000	0.008	0.001	0.007	0.007	0.008	0.008	0.008
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	5	5			1250	1328.000	99.076	1520	270	1252	1260	1290	1320	1480
pH (lab)	5	5			7.92	8.082	0.092	8.17	0.25	7.948	8.06	8.09	8.17	8.17
BCP Spring														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	12	12			321	1166.917	406.726	1700	1379	448.05	1012.5	1255	1482.5	1628.5
Carbonate Alkalinity as CaCO3 (mg/L)	12	11	1	8.3%	66	511.636	348.685	1400	1334	108	283	515	590.5	1090
Total Alkalinity as CaCO3 (mg/L)	12	12			470	1630.667	699.329	2950	2480	551.4	1260	1735	2085	2537.5

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Field Measurements														
Dissolved Oxygen (field) (% sat)	4	4			1.2	79.950	133.756	311.6	310.4	1.2	1.2	3.5	82.25	265.73
Electrical Conductivity (field) (µS/cm)	5	5			2278	4832.200	2568.608	9392	7114	2315.6	2466	4945	5080	8529.6
ORP (field) (mV)	5	5			-31.3	17.640	62.025	131.5	162.8	-30.36	-26.6	-21.9	36.5	112.5
pH (field)	5	5			8.78	9.378	0.487	10.06	1.28	8.796	8.86	9.57	9.62	9.972
Salinity (field) (PSU)	5	5			1.15	2.552	1.483	5.24	4.09	1.162	1.21	2.53	2.63	4.718
TDS (field) (ppm)	5	5			1139	2415.800	1283.956	4695	3556	1157.8	1233	2471	2541	4264.2
Temperature (field) (°C)	5	5			27.42	29.022	1.654	32.05	4.63	27.464	27.64	28.88	29.12	31.464
Hardness														
Total Hardness (mg CaCO3/L)	4	4			390	472.500	64.177	570	180	400.5	442.5	465	495	555
Major Ions														
Bromide (mg/L)	2	2			0.88	1.620	0.740	2.36	1.48	0.954	1.25	1.62	1.99	2.286
Calcium (mg/L)	12	12			12	21.250	7.907	39	27	13.1	15.75	18	26	35.15
Chloride (mg/L)	12	12			170	478.417	209.115	912	742	181	314.5	495.5	619	771.2
Fluoride (mg/L)	12	12			0.6	1.458	0.486	2.5	1.9	0.71	1.225	1.5	1.725	2.115
Iodide (mg/L)	2	1	1	50.0%	0.62	0.620	0.000	0.62	0	0.62	0.62	0.62	0.62	0.62
Magnesium (mg/L)	12	12			24	97.333	32.597	140	116	39.4	85.75	100	124.5	134.5
Potassium (mg/L)	12	12			7	20.167	11.253	42	35	7	13.25	16.5	24	40.35
Sodium (mg/L)	12	12			375	1247.083	563.806	2260	1885	421.75	830	1255	1647.5	2062
Sulfate (as SO4)	12	12			227	666.000	256.487	1040	813	280.9	484.5	714.5	868.5	987.2
Metals (dissolved)														
Aluminium - dissolved (mg/L)	4	3	1	25.0%	0.011	0.012	0.001	0.013	0.002	0.0112	0.012	0.013	0.013	0.013
Arsenic - dissolved (mg/L)	13	13			0	0.012	0.008	0.035	0.035	0.0018	0.01	0.012	0.014	0.0266

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Barium - dissolved (mg/L)	12	12			0.059	0.089	0.017	0.118	0.059	0.06175	0.079	0.0885	0.10175	0.1136
Beryllium - dissolved (mg/L)	1		1	100.0%										
Bismuth - dissolved (mg/L)	12		12	100.0%										
Boron - dissolved (mg/L)	1	1			0.09	0.090	0.000	0.09	0	0.09	0.09	0.09	0.09	0.09
Chromium - dissolved (mg/L)	13	1	12	92.3%	0.002	0.002	0.000	0.002	0	0.002	0.002	0.002	0.002	0.002
Cobalt - dissolved (mg/L)	13	9	4	30.8%	0.001	0.003	0.004	0.014	0.013	0.001	0.001	0.002	0.002	0.01
Copper - dissolved (mg/L)	13	13			0.011	0.059	0.057	0.196	0.185	0.0116	0.022	0.041	0.052	0.1762
Iron - dissolved (mg/L)	1	1			0.09	0.090	0.000	0.09	0	0.09	0.09	0.09	0.09	0.09
Molybdenum - dissolved (mg/L)	13	13			0.005	0.009	0.003	0.016	0.011	0.005	0.007	0.008	0.009	0.0148
Nickel - dissolved (mg/L)	13	12	1	7.7%	0.001	0.003	0.002	0.006	0.005	0.001	0.002	0.002	0.005	0.006
Selenium - dissolved (mg/L)	13	3	10	76.9%	0.002	0.012	0.012	0.029	0.027	0.0022	0.003	0.004	0.0165	0.0265
Uranium - dissolved (mg/L)	12	12			0.015	0.030	0.011	0.057	0.042	0.0161	0.023	0.0255	0.03725	0.0471
Vanadium - dissolved (mg/L)	1	1			0.03	0.030	0.000	0.03	0	0.03	0.03	0.03	0.03	0.03
Zinc - dissolved (mg/L)	1		1	100.0%										
Metals (total)														
Aluminium - total (mg/L)	4	4			0.11	0.555	0.314	0.99	0.88	0.1685	0.4025	0.56	0.7125	0.9345
Arsenic - total (mg/L)	13	13			0.004	0.017	0.016	0.066	0.062	0.004	0.009	0.013	0.016	0.0468
Barium - total (mg/L)	12	12			0.059	0.102	0.026	0.165	0.106	0.0656	0.087	0.099	0.112	0.1419
Beryllium - total (mg/L)	1		1	100.0%										
Bismuth - total (mg/L)	12		12	100.0%										
Boron - total (mg/L)	1	1			0.1	0.100	0.000	0.1	0	0.1	0.1	0.1	0.1	0.1
Chromium - total (mg/L)	13	4	9	69.2%	0.0009	0.002	0.002	0.005	0.0041	0.000915	0.000975	0.001	0.002	0.0044
Cobalt - total (mg/L)	13	12	1	7.7%	0.001	0.004	0.004	0.016	0.015	0.00155	0.002	0.002	0.00325	0.0116

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Copper - total (mg/L)	13	13			0.017	0.105	0.102	0.392	0.375	0.0284	0.048	0.051	0.13	0.2942
Iron - total (mg/L)	1	1			1.06	1.060	0.000	1.06	0	1.06	1.06	1.06	1.06	1.06
Molybdenum - total (mg/L)	13	13			0	0.010	0.006	0.025	0.025	0.003	0.008	0.01	0.011	0.0196
Nickel - total (mg/L)	13	12	1	7.7%	0.001	0.005	0.003	0.012	0.011	0.00155	0.002	0.003	0.00625	0.01035
Selenium - total (mg/L)	13	3	10	76.9%	0.002	0.020	0.024	0.054	0.052	0.0022	0.003	0.004	0.029	0.049
Uranium - total (mg/L)	12	12			0.016	0.037	0.020	0.091	0.075	0.01655	0.02275	0.0325	0.04175	0.07285
Vanadium - total (mg/L)	1	1			0.04	0.040	0.000	0.04	0	0.04	0.04	0.04	0.04	0.04
Nutrients														
Nitrate as N (mg/L)	2	1	1	50.0%	0.14	0.140	0.000	0.14	0	0.14	0.14	0.14	0.14	0.14
Nitrite + Nitrate as N (mg/L)	2	1	1	50.0%	0.15	0.150	0.000	0.15	0	0.15	0.15	0.15	0.15	0.15
Nitrite as N (mg/L)	2	1	1	50.0%	0.01	0.010	0.000	0.01	0	0.01	0.01	0.01	0.01	0.01
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	11	11			1890	5164.545	2116.650	8850	6960	2030	3700	5070	6865	8125
pH (lab)	11	11			8.61	9.021	0.223	9.3	0.69	8.67	8.89	9.05	9.235	9.29
BCP Spring (N)														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	12	12			243	987.000	321.112	1470	1227	532.85	848.25	894.5	1205	1459
Carbonate Alkalinity as CaCO3 (mg/L)	12	11	1	8.3%	93	245.818	129.342	490	397	96	107	278	300	455.5
Total Alkalinity as CaCO3 (mg/L)	12	12			243	1214.000	451.715	1960	1717	584.55	974.75	1140	1500	1910.5
Field Measurements														
Dissolved Oxygen (field) (% sat)	5	5			23.8	146.480	94.657	315.9	292.1	43.24	121	126.6	145.1	281.74
Electrical Conductivity (field) (µS/cm)	5	5			968	3808.600	1668.209	5416	4448	1347.8	2867	4824	4968	5326.4
ORP (field) (mV)	5	5			-58.8	-6.920	75.836	142.5	201.3	-58.68	-58.2	-34.4	-25.7	108.86

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
pH (field)	5	5			8.55	8.768	0.145	8.94	0.39	8.572	8.66	8.8	8.89	8.93
Salinity (field) (PSU)	5	5			0.48	1.896	0.834	2.71	2.23	0.668	1.42	2.4	2.47	2.662
TDS (field) (ppm)	5	5			484	1904.400	834.300	2708	2224	673.8	1433	2412	2485	2663.4
Temperature (field) (°C)	5	5			22.65	26.212	2.124	29.33	6.68	23.344	26.12	26.44	26.52	28.768
Hardness														
Total Hardness (mg CaCO3/L)	11	11			138	555.545	184.923	885	747	274.5	516	548	599.5	845.5
Major Ions														
Calcium (mg/L)	23	23			15	27.217	10.636	45	30	16.1	18.5	21	38	44
Chloride (mg/L)	12	12			52	320.083	149.631	554	502	134.5	210.5	285	434.5	536.4
Fluoride (mg/L)	12	12			0.6	1.533	0.332	1.9	1.3	0.985	1.4	1.6	1.7	1.9
Magnesium (mg/L)	23	23			21	121.174	44.882	204	183	28.7	103.5	115	138	200.1
Potassium (mg/L)	23	23			4	11.304	5.520	21	17	4.2	7	8	16	20.9
Sodium (mg/L)	23	23			174	920.522	415.032	1660	1486	218.2	638	747	1190	1582
Sulfate (as SO4)	12	12			112	839.083	407.548	1640	1528	358.4	589.25	708.5	1008.5	1546.5
Metals (dissolved)														
Arsenic - dissolved (mg/L)	12	12			0.002	0.008	0.004	0.017	0.015	0.0031	0.00475	0.008	0.012	0.0148
Barium - dissolved (mg/L)	12	12			0.046	0.077	0.017	0.109	0.063	0.0548	0.06625	0.076	0.0805	0.10845
Bismuth - dissolved (mg/L)	12		12	100.0%										
Chromium - dissolved (mg/L)	12		12	100.0%										
Cobalt - dissolved (mg/L)	12	6	6	50.0%	0.001	0.001	0.000	0.001	0	0.001	0.001	0.001	0.001	0.001
Copper - dissolved (mg/L)	12	12			0.014	0.024	0.014	0.067	0.053	0.014	0.01675	0.019	0.024	0.0472
Molybdenum - dissolved (mg/L)	12	12			0.004	0.006	0.002	0.012	0.008	0.004	0.005	0.006	0.007	0.0109
Nickel - dissolved (mg/L)	12	6	6	50.0%	0.001	0.002	0.000	0.002	0.001	0.00125	0.002	0.002	0.002	0.002

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Selenium - dissolved (mg/L)	12		12	100.0%										
Uranium - dissolved (mg/L)	12	12			0.005	0.021	0.007	0.033	0.028	0.0116	0.017	0.018	0.02475	0.03245
Metals (total)														
Arsenic - total (mg/L)	12	12			0.002	0.009	0.005	0.018	0.016	0.00365	0.005	0.0085	0.01225	0.0158
Barium - total (mg/L)	12	12			0.046	0.085	0.018	0.118	0.072	0.0581	0.07875	0.0825	0.0905	0.1147
Bismuth - total (mg/L)	12		12	100.0%										
Chromium - total (mg/L)	12	1	11	91.7%	0.001	0.001	0.000	0.001	0	0.001	0.001	0.001	0.001	0.001
Cobalt - total (mg/L)	12	11	1	8.3%	0.001	0.001	0.000	0.002	0.001	0.001	0.001	0.001	0.002	0.002
Copper - total (mg/L)	12	12			0.023	0.039	0.020	0.098	0.075	0.02465	0.02775	0.0315	0.03825	0.076
Molybdenum - total (mg/L)	12	12			0.004	0.008	0.003	0.013	0.009	0.00455	0.00575	0.0065	0.00925	0.01135
Nickel - total (mg/L)	12	8	4	33.3%	0.001	0.002	0.001	0.004	0.003	0.001	0.00175	0.002	0.0025	0.004
Selenium - total (mg/L)	12		12	100.0%										
Uranium - total (mg/L)	12	12			0.005	0.024	0.010	0.044	0.039	0.0116	0.01875	0.019	0.03	0.04015
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	12	12			956	4319.667	1545.528	7080	6124	2223.2	3397.5	4280	5305	6453
pH (lab)	12	12			8.27	8.836	0.226	9.19	0.92	8.4845	8.71	8.92	8.9725	9.0855
BCP Spring (S)														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	12	12			227	808.083	182.714	938	711	521.25	806.25	856.5	898.25	931.95
Carbonate Alkalinity as CaCO3 (mg/L)	12	5	7	58.3%	24	124.400	157.232	438	414	29	49	54	57	361.8
Total Alkalinity as CaCO3 (mg/L)	12	12			227	860.083	220.877	1230	1003	521.25	838.25	899	929	1099.1
Field Measurements														
Dissolved Oxygen (field) (% sat)	4	4			1.2	78.475	46.900	127.6	126.4	14.46	67.5	92.55	103.525	122.785

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Electrical Conductivity (field) (µS/cm)	4	4			674	2379.750	1011.387	3324	2650	984.65	2227.25	2760.5	2913	3241.8
ORP (field) (mV)	4	4			-58.6	-20.500	24.916	2.3	60.9	-53.845	-34.825	-12.85	1.475	2.135
pH (field)	4	4			8.3	8.503	0.135	8.64	0.34	8.324	8.42	8.535	8.6175	8.6355
Salinity (field) (PSU)	4	4			0.33	1.203	0.517	1.68	1.35	0.4845	1.1025	1.4	1.5	1.644
TDS (field) (ppm)	4	4			338	1190.000	505.227	1662	1324	493.1	1113.5	1380	1456.5	1620.9
Temperature (field) (°C)	4	4			22.62	26.628	2.512	28.88	6.26	23.1825	25.4325	27.505	28.7	28.844
Hardness														
Total Hardness (mg CaCO3/L)	11	11			110	680.273	209.599	916	806	315	645	709	807	887
Major Ions														
Calcium (mg/L)	23	23			15	69.565	20.192	93	78	19.4	63.5	76	81.5	90
Chloride (mg/L)	12	12			26	173.833	57.320	278	252	93.1	159	171.5	191.25	256.55
Fluoride (mg/L)	12	12			0.5	1.483	0.443	2.1	1.6	0.775	1.175	1.6	1.8	2.045
Magnesium (mg/L)	23	23			16	125.913	41.155	179	163	24.6	116	126	155.5	176.2
Potassium (mg/L)	23	23			4	5.522	1.347	8	4	4	4	5	6	8
Sodium (mg/L)	23	23			106	467.087	143.111	744	638	133.6	419	467	538.5	671.1
Sulfate (as SO4)	12	12			55	521.500	196.549	767	712	185.9	442.5	538.5	664.5	754.9
Metals (dissolved)														
Arsenic - dissolved (mg/L)	12	12			0.001	0.002	0.001	0.004	0.003	0.001	0.001	0.002	0.003	0.004
Barium - dissolved (mg/L)	12	12			0.033	0.121	0.039	0.176	0.143	0.0539	0.10625	0.1365	0.14175	0.1617
Bismuth - dissolved (mg/L)	12		12	100.0%										
Chromium - dissolved (mg/L)	12		12	100.0%										
Cobalt - dissolved (mg/L)	12	9	3	25.0%	0.001	0.002	0.000	0.002	0.001	0.001	0.001	0.002	0.002	0.002
Copper - dissolved (mg/L)	12	12			0.003	0.008	0.003	0.012	0.009	0.003	0.00475	0.0075	0.01025	0.012

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Molybdenum - dissolved (mg/L)	12	12			0.002	0.004	0.001	0.006	0.004	0.00255	0.003	0.0035	0.004	0.006
Nickel - dissolved (mg/L)	12	1	11	91.7%	0.002	0.002	0.000	0.002	0	0.002	0.002	0.002	0.002	0.002
Selenium - dissolved (mg/L)	12		12	100.0%										
Uranium - dissolved (mg/L)	12	12			0.002	0.011	0.003	0.014	0.012	0.0053	0.011	0.0115	0.014	0.014
Metals (total)														
Arsenic - total (mg/L)	12	12			0.001	0.002	0.001	0.004	0.003	0.001	0.00175	0.002	0.003	0.004
Barium - total (mg/L)	12	12			0.041	0.139	0.044	0.188	0.147	0.0619	0.1155	0.1605	0.16475	0.18305
Bismuth - total (mg/L)	12		12	100.0%										
Chromium - total (mg/L)	12		12	100.0%										
Cobalt - total (mg/L)	12	11	1	8.3%	0.001	0.002	0.001	0.003	0.002	0.0015	0.002	0.002	0.002	0.003
Copper - total (mg/L)	12	12			0.006	0.014	0.005	0.021	0.015	0.006	0.0105	0.015	0.01725	0.01935
Molybdenum - total (mg/L)	12	12			0.003	0.004	0.001	0.007	0.004	0.003	0.00375	0.004	0.00525	0.00645
Nickel - total (mg/L)	12	5	7	58.3%	0.001	0.002	0.001	0.004	0.003	0.001	0.001	0.001	0.001	0.0034
Selenium - total (mg/L)	12		12	100.0%										
Uranium - total (mg/L)	12	12			0.003	0.013	0.004	0.018	0.015	0.0052	0.012	0.013	0.0155	0.01745
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	12	12			619	2823.250	707.182	3420	2801	1741.55	2770	2930	3230	3370.5
pH (lab)	12	12			7.85	8.182	0.225	8.54	0.69	7.883	8.0275	8.105	8.3675	8.518
Pooled water S of sediment dam														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	5	5			73	104.000	35.287	152	79	73.4	75	78	142	150
Carbonate Alkalinity as CaCO3 (mg/L)	5		5	100.0%										
Total Alkalinity as CaCO3 (mg/L)	5	5			73	104.000	35.287	152	79	73.4	75	78	142	150

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Field Measurements														
Dissolved Oxygen (field) (% sat)	1	1			94.2	94.200	0.000	94.2	0	94.2	94.2	94.2	94.2	94.2
Electrical Conductivity (field) (µS/cm)	1	1			4632	4632.000	0.000	4632	0	4632	4632	4632	4632	4632
ORP (field) (mV)	1	1			-54.2	-54.200	0.000	-54.2	0	-54.2	-54.2	-54.2	-54.2	-54.2
pH (field)	1	1			8.23	8.230	0.000	8.23	0	8.23	8.23	8.23	8.23	8.23
Salinity (field) (PSU)	1	1			2.3	2.300	0.000	2.3	0	2.3	2.3	2.3	2.3	2.3
TDS (field) (ppm)	1	1			2315	2315.000	0.000	2315	0	2315	2315	2315	2315	2315
Temperature (field) (°C)	1	1			21.88	21.880	0.000	21.88	0	21.88	21.88	21.88	21.88	21.88
Hardness														
Total Hardness (mg CaCO3/L)	5	5			2100	2696.000	549.785	3550	1450	2100	2100	2780	2950	3430
Major Ions														
Calcium (mg/L)	10	10			430	574.500	107.239	754	324	444.85	477.25	591.5	606.5	749.5
Chloride (mg/L)	5	5			136	235.000	62.000	326	190	151	211	246	256	312
Fluoride (mg/L)	5	5			0.4	0.460	0.080	0.6	0.2	0.4	0.4	0.4	0.5	0.58
Magnesium (mg/L)	10	10			229	310.500	59.441	406	177	238	252	314	345.75	401.5
Potassium (mg/L)	10	10			21	28.100	4.415	34	13	21	25.5	29	30.75	34
Sodium (mg/L)	10	10			482	717.300	150.864	958	476	504.95	599.75	751	771.5	948.55
Sulfate (as SO4)	5	5			1540	2318.000	601.146	3220	1680	1592	1800	2370	2660	3108
Metals (dissolved)														
Arsenic - dissolved (mg/L)	5	5			0.001	0.001	0.000	0.002	0.001	0.001	0.001	0.001	0.001	0.0018
Barium - dissolved (mg/L)	5	5			0.069	0.088	0.019	0.12	0.051	0.0694	0.071	0.086	0.096	0.1152
Bismuth - dissolved (mg/L)	5		5	100.0%										
Chromium - dissolved (mg/L)	5		5	100.0%										

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Cobalt - dissolved (mg/L)	5	5			0.005	0.006	0.001	0.007	0.002	0.0052	0.006	0.007	0.007	0.007
Copper - dissolved (mg/L)	5	5			0.012	0.016	0.007	0.03	0.018	0.012	0.012	0.013	0.013	0.0266
Molybdenum - dissolved (mg/L)	5	5			0.009	0.013	0.003	0.018	0.009	0.0096	0.012	0.014	0.014	0.0172
Nickel - dissolved (mg/L)	5	2	3	60.0%	0.001	0.001	0.000	0.001	0	0.001	0.001	0.001	0.001	0.001
Selenium - dissolved (mg/L)	5	5			0.16	0.210	0.046	0.28	0.12	0.16	0.16	0.22	0.23	0.27
Uranium - dissolved (mg/L)	5	5			0.003	0.017	0.011	0.036	0.033	0.005	0.013	0.014	0.018	0.0324
Metals (total)														
Arsenic - total (mg/L)	5	5			0.001	0.001	0.001	0.003	0.002	0.001	0.001	0.001	0.001	0.0026
Barium - total (mg/L)	5	5			0.073	0.093	0.020	0.128	0.055	0.0736	0.076	0.085	0.104	0.1232
Bismuth - total (mg/L)	5		5	100.0%										
Chromium - total (mg/L)	5	2	3	60.0%	0.001	0.002	0.001	0.002	0.001	0.00105	0.00125	0.0015	0.00175	0.00195
Cobalt - total (mg/L)	5	5			0.005	0.007	0.001	0.007	0.002	0.0054	0.007	0.007	0.007	0.007
Copper - total (mg/L)	5	5			0.013	0.017	0.006	0.03	0.017	0.013	0.013	0.014	0.016	0.0272
Molybdenum - total (mg/L)	5	5			0.01	0.014	0.002	0.017	0.007	0.0106	0.013	0.015	0.016	0.0168
Nickel - total (mg/L)	5	3	2	40.0%	0.001	0.002	0.000	0.002	0.001	0.0011	0.0015	0.002	0.002	0.002
Selenium - total (mg/L)	5	5			0.16	0.212	0.047	0.28	0.12	0.16	0.16	0.22	0.24	0.272
Uranium - total (mg/L)	5	5			0.004	0.017	0.011	0.038	0.034	0.0058	0.013	0.014	0.018	0.034
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	5	5			5690	7232.000	1287.205	9460	3770	5814	6310	7170	7530	9074
pH (lab)	5	5			7.89	7.970	0.061	8.04	0.15	7.896	7.92	7.96	8.04	8.04
Sediment Dam														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	23	23			38	75.739	21.937	129	91	42.8	59	75	92	101.9

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Carbonate Alkalinity as CaCO3 (mg/L)	23	6	17	73.9%	10	18.000	6.904	28	18	11	14	14.5	24	27.75
Total Alkalinity as CaCO3 (mg/L)	23	23			50	80.435	21.930	129	79	52	64.5	78	94.5	122.2
Field Measurements														
Dissolved Oxygen (field) (% sat)	10	10			0	112.240	78.122	211.4	211.4	0.135	30.975	138.75	173.625	201.05
Electrical Conductivity (field) (µS/cm)	11	11			65	1386.091	654.250	2752	2687	502.5	1032.5	1282	1761	2338
ORP (field) (mV)	11	11			-22.1	88.945	93.203	252.9	275	-20.15	8.25	75.7	182.4	220.45
pH (field)	11	11			7.76	8.555	0.490	9.38	1.62	7.805	8.2	8.56	8.93	9.215
Salinity (field) (PSU)	11	11			0.03	0.696	0.343	1.43	1.4	0.24	0.51	0.63	0.88	1.215
TDS (field) (ppm)	11	11			32	695.091	329.146	1375	1343	251.5	514.5	641	880.5	1181
Temperature (field) (°C)	11	11			19.72	27.696	3.886	33.8	14.08	20.82	25.9	28.86	30.3	32.2
Hardness														
Total Hardness (mg CaCO3/L)	14	14			215	791.214	471.910	1720	1505	249.45	357.75	741	1070	1635.5
Major Ions														
Bromide (mg/L)	2	2			0.11	0.160	0.050	0.21	0.1	0.115	0.135	0.16	0.185	0.205
Calcium (mg/L)	37	37			42	155.622	86.961	358	316	55.6	80	128	218	308.4
Chloride (mg/L)	23	23			15	63.217	42.096	186	171	26	35	44	76	146.1
Fluoride (mg/L)	23	23			0.6	1.057	0.439	2.6	2	0.7	0.75	0.9	1.3	1.59
Iodide (mg/L)	2		2	100.0%										
Magnesium (mg/L)	37	37			19	91.297	61.213	248	229	26	44	61	124	216.6
Potassium (mg/L)	37	37			13	29.081	11.953	84	71	18.4	22	25	36	40.4
Sodium (mg/L)	37	37			42	227.784	163.701	690	648	56.8	115	180	282	572
Sulfate (as SO4)	23	23			168	740.130	452.957	2140	1972	189.4	472	639	930.5	1654
Metals (dissolved)														

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Arsenic - dissolved (mg/L)	23	23			0.002	0.003	0.001	0.006	0.004	0.0021	0.003	0.003	0.004	0.005
Barium - dissolved (mg/L)	23	23			0.06	0.098	0.015	0.139	0.079	0.0793	0.0915	0.101	0.104	0.11
Beryllium - dissolved (mg/L)	3		3	100.0%										
Bismuth - dissolved (mg/L)	23		23	100.0%										
Boron - dissolved (mg/L)	3	3			0.06	0.063	0.005	0.07	0.01	0.06	0.06	0.06	0.065	0.069
Chromium - dissolved (mg/L)	23		23	100.0%										
Cobalt - dissolved (mg/L)	23	8	15	65.2%	0.001	0.002	0.001	0.003	0.002	0.001	0.001	0.002	0.002	0.00265
Copper - dissolved (mg/L)	23	23			0.004	0.013	0.007	0.027	0.023	0.0051	0.008	0.011	0.02	0.0267
Iron - dissolved (mg/L)	3		3	100.0%										
Molybdenum - dissolved (mg/L)	23	23			0.019	0.042	0.026	0.146	0.127	0.0211	0.024	0.036	0.05	0.0607
Nickel - dissolved (mg/L)	23	16	7	30.4%	0.001	0.005	0.006	0.027	0.026	0.001	0.002	0.003	0.005	0.0105
Selenium - dissolved (mg/L)	23	12	11	47.8%	0.01	0.058	0.039	0.13	0.12	0.01	0.0175	0.06	0.0725	0.1245
Uranium - dissolved (mg/L)	23	23			0.002	0.008	0.004	0.021	0.019	0.0041	0.0055	0.007	0.008	0.0145
Vanadium - dissolved (mg/L)	3		3	100.0%										
Metals (total)														
Arsenic - total (mg/L)	23	23			0.002	0.003	0.001	0.005	0.003	0.0021	0.003	0.003	0.004	0.0049
Barium - total (mg/L)	23	23			0.057	0.102	0.017	0.142	0.085	0.0773	0.095	0.103	0.109	0.129
Beryllium - total (mg/L)	3		3	100.0%										
Bismuth - total (mg/L)	23		23	100.0%										
Boron - total (mg/L)	3	3			0.07	0.070	0.000	0.07	0	0.07	0.07	0.07	0.07	0.07
Chromium - total (mg/L)	23		23	100.0%										
Cobalt - total (mg/L)	23	7	16	69.6%	0.001	0.002	0.001	0.003	0.002	0.001	0.0015	0.002	0.002	0.0027
Copper - total (mg/L)	23	23			0.008	0.017	0.008	0.036	0.028	0.0091	0.0105	0.014	0.0195	0.0308

Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Iron - total (mg/L)	3		3	100.0%										
Molybdenum - total (mg/L)	23	23			0.022	0.048	0.028	0.156	0.134	0.0231	0.0275	0.039	0.059	0.0684
Nickel - total (mg/L)	23	15	8	34.8%	0.001	0.003	0.002	0.006	0.005	0.001	0.002	0.003	0.0045	0.006
Selenium - total (mg/L)	23	10	13	56.5%	0.01	0.066	0.036	0.14	0.13	0.0145	0.06	0.06	0.07	0.1265
Uranium - total (mg/L)	23	23			0.004	0.009	0.004	0.023	0.019	0.005	0.0065	0.008	0.009	0.0154
Vanadium - total (mg/L)	3		3	100.0%										
Nutrients														
Nitrate as N (mg/L)	4	4			17.3	26.075	8.050	34.6	17.3	17.525	18.425	26.2	33.85	34.45
Nitrite + Nitrate as N (mg/L)	4	4			17.6	26.575	8.158	35.3	17.7	17.855	18.875	26.7	34.4	35.12
Nitrite as N (mg/L)	4	4			0.29	0.488	0.132	0.65	0.36	0.3155	0.4175	0.505	0.575	0.635
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	23	23			739	2204.739	1185.648	5280	4541	997	1365	1680	3060	4507
pH (lab)	23	23			7.51	8.142	0.321	8.73	1.22	7.555	7.97	8.17	8.305	8.645
Seepage														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	1	1			744	744.000	0.000	744	0	744	744	744	744	744
Carbonate Alkalinity as CaCO3 (mg/L)	1		1	100.0%										
Total Alkalinity as CaCO3 (mg/L)	1	1			744	744.000	0.000	744	0	744	744	744	744	744
Hardness														
Total Hardness (mg CaCO3/L)	1	1			450	450.000	0.000	450	0	450	450	450	450	450
Major Ions														
Calcium (mg/L)	2	2			50	54.000	4.000	58	8	50.4	52	54	56	57.6
Chloride (mg/L)	1	1			49	49.000	0.000	49	0	49	49	49	49	49

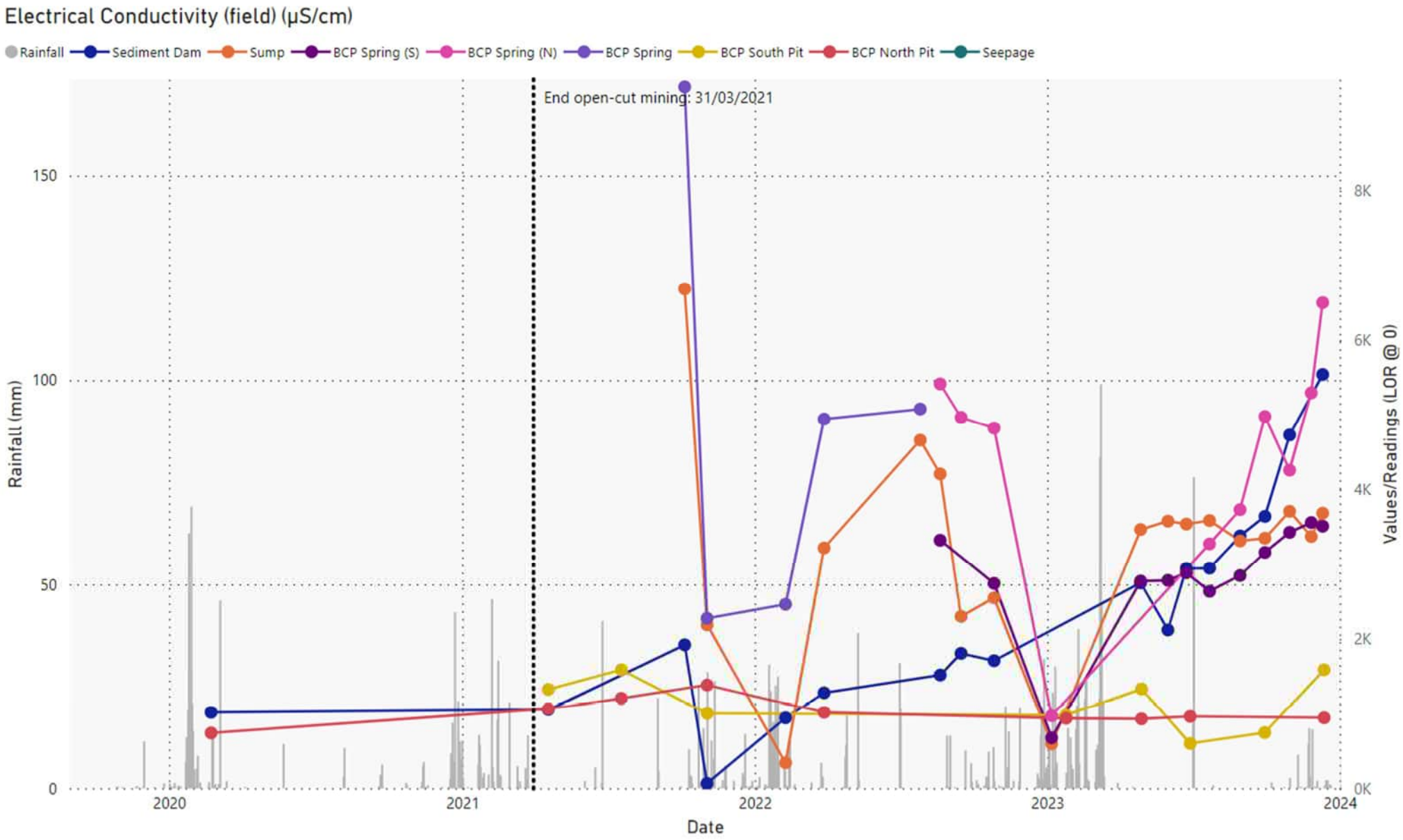
Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Fluoride (mg/L)	1	1			1.9	1.900	0.000	1.9	0	1.9	1.9	1.9	1.9	1.9
Magnesium (mg/L)	2	2			78	78.500	0.500	79	1	78.05	78.25	78.5	78.75	78.95
Potassium (mg/L)	2	2			6	6.500	0.500	7	1	6.05	6.25	6.5	6.75	6.95
Sodium (mg/L)	2	2			195	204.000	9.000	213	18	195.9	199.5	204	208.5	212.1
Sulfate (as SO4)	1	1			79	79.000	0.000	79	0	79	79	79	79	79
Metals (dissolved)														
Arsenic - dissolved (mg/L)	1	1			0.003	0.003	0.000	0.003	0	0.003	0.003	0.003	0.003	0.003
Barium - dissolved (mg/L)	1	1			0.124	0.124	0.000	0.124	0	0.124	0.124	0.124	0.124	0.124
Bismuth - dissolved (mg/L)	1		1	100.0%										
Chromium - dissolved (mg/L)	1		1	100.0%										
Cobalt - dissolved (mg/L)	1	1			0.001	0.001	0.000	0.001	0	0.001	0.001	0.001	0.001	0.001
Copper - dissolved (mg/L)	1	1			0.001	0.001	0.000	0.001	0	0.001	0.001	0.001	0.001	0.001
Molybdenum - dissolved (mg/L)	1	1			0.014	0.014	0.000	0.014	0	0.014	0.014	0.014	0.014	0.014
Nickel - dissolved (mg/L)	1		1	100.0%										
Selenium - dissolved (mg/L)	1		1	100.0%										
Uranium - dissolved (mg/L)	1	1			0.011	0.011	0.000	0.011	0	0.011	0.011	0.011	0.011	0.011
Metals (total)														
Arsenic - total (mg/L)	1	1			0.003	0.003	0.000	0.003	0	0.003	0.003	0.003	0.003	0.003
Barium - total (mg/L)	1	1			0.133	0.133	0.000	0.133	0	0.133	0.133	0.133	0.133	0.133
Bismuth - total (mg/L)	1		1	100.0%										
Chromium - total (mg/L)	1	1			0.001	0.001	0.000	0.001	0	0.001	0.001	0.001	0.001	0.001
Cobalt - total (mg/L)	1	1			0.002	0.002	0.000	0.002	0	0.002	0.002	0.002	0.002	0.002
Copper - total (mg/L)	1	1			0.007	0.007	0.000	0.007	0	0.007	0.007	0.007	0.007	0.007

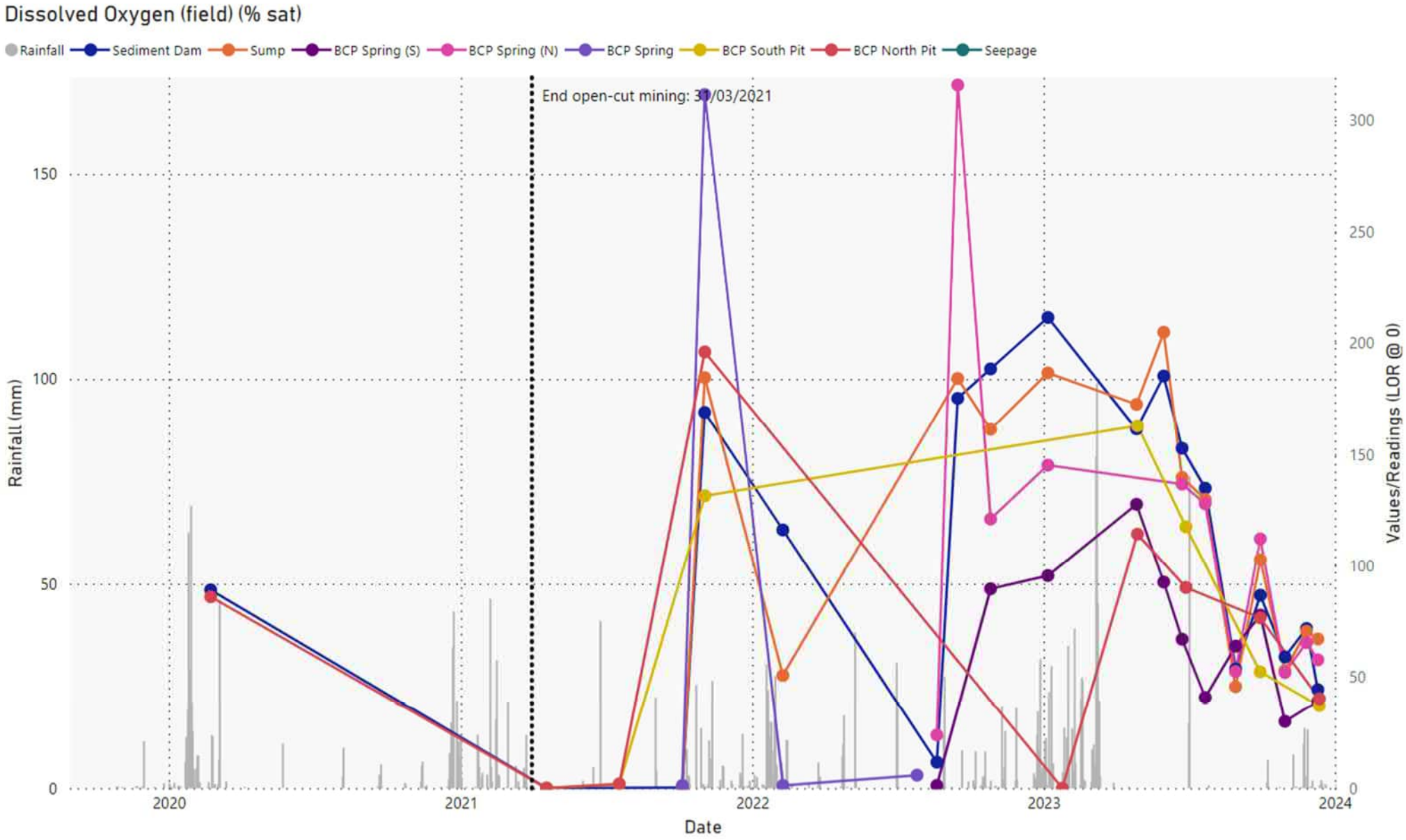
Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Molybdenum - total (mg/L)	1	1			0.018	0.018	0.000	0.018	0	0.018	0.018	0.018	0.018	0.018
Nickel - total (mg/L)	1	1			0.002	0.002	0.000	0.002	0	0.002	0.002	0.002	0.002	0.002
Selenium - total (mg/L)	1		1	100.0%										
Uranium - total (mg/L)	1	1			0.012	0.012	0.000	0.012	0	0.012	0.012	0.012	0.012	0.012
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	1	1			1500	1500.000	0.000	1500	0	1500	1500	1500	1500	1500
pH (lab)	1	1			7.73	7.730	0.000	7.73	0	7.73	7.73	7.73	7.73	7.73
Sump														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	20	20			83	661.650	293.321	1300	1217	121.95	502.75	650.5	872	1008.35
Carbonate Alkalinity as CaCO3 (mg/L)	20	17	3	15.0%	25	115.529	101.945	331	306	29.8	42	64	182	303.8
Total Alkalinity as CaCO3 (mg/L)	20	20			83	759.500	354.590	1420	1337	121.95	539.25	756	987	1258.5
Field Measurements														
Dissolved Oxygen (field) (% sat)	9	9			0.4	106.833	80.733	186.6	186.2	2.04	16.9	161.2	184.1	185.76
Electrical Conductivity (field) (µS/cm)	10	10			340	3022.700	1796.789	6686	6346	453.85	2219.25	2886.5	4024.5	5775.2
ORP (field) (mV)	10	10			-57.4	16.530	65.835	133	190.4	-54.25	-33.825	-3.8	57.8	128.05
pH (field)	10	10			8.12	8.941	0.528	9.84	1.72	8.21	8.6625	8.77	9.3775	9.7005
Salinity (field) (PSU)	10	10			0.16	1.550	0.965	3.64	3.48	0.214	1.1175	1.475	2.03	3.037
TDS (field) (ppm)	10	10			171	1511.200	898.332	3343	3172	227.25	1109	1443.5	2012.75	2887.15
Temperature (field) (°C)	10	10			24.15	27.959	2.008	32.25	8.1	25.1625	26.87	27.89	28.8975	30.8775
Hardness														
Total Hardness (mg CaCO3/L)	11	11			37	356.455	158.778	546	509	63.5	325	348	465.5	544.5
Major Ions														

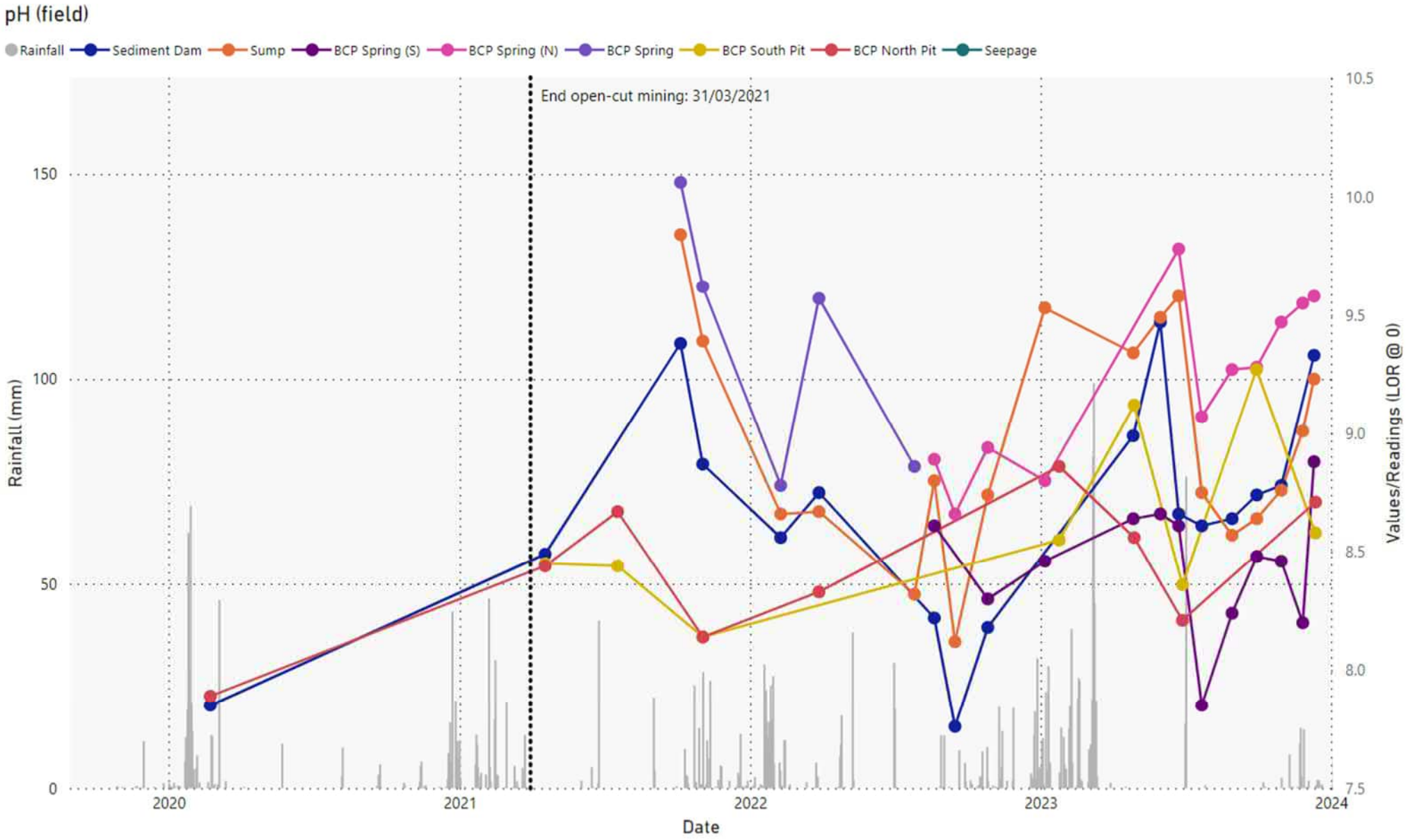
Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Bromide (mg/L)	2	2			0.086	0.823	0.737	1.56	1.474	0.1597	0.4545	0.823	1.1915	1.4863
Calcium (mg/L)	31	31			10	38.903	18.655	75	65	12	21	45	52	65.5
Chloride (mg/L)	20	20			17	261.050	143.215	721	704	27.45	193.5	244.5	311	402.75
Fluoride (mg/L)	20	20			0.2	0.855	0.304	1.2	1	0.2	0.75	1	1	1.2
Iodide (mg/L)	2	1	1	50.0%	0.68	0.680	0.000	0.68	0	0.68	0.68	0.68	0.68	0.68
Magnesium (mg/L)	31	31			3	50.581	29.575	96	93	3	30.5	51	79.5	93
Potassium (mg/L)	31	31			2	8.935	2.602	12	10	4	8	9	11	12
Sodium (mg/L)	31	31			41	708.581	288.949	1410	1369	96	651.5	703	780.5	1145
Sulfate (as SO4)	20	20			32	616.200	244.181	970	938	63.35	471.25	687	804.25	841.75
Metals (dissolved)														
Arsenic - dissolved (mg/L)	20	20			0.001	0.005	0.003	0.012	0.011	0.00195	0.003	0.004	0.008	0.01105
Barium - dissolved (mg/L)	20	20			0.021	0.090	0.035	0.15	0.129	0.0286	0.0725	0.099	0.11375	0.13955
Beryllium - dissolved (mg/L)	1		1	100.0%										
Bismuth - dissolved (mg/L)	20		20	100.0%										
Boron - dissolved (mg/L)	1	1			0.13	0.130	0.000	0.13	0	0.13	0.13	0.13	0.13	0.13
Chromium - dissolved (mg/L)	20	1	19	95.0%	0.002	0.002	0.000	0.002	0	0.002	0.002	0.002	0.002	0.002
Cobalt - dissolved (mg/L)	20	17	3	15.0%	0.001	0.002	0.001	0.003	0.002	0.001	0.001	0.002	0.002	0.003
Copper - dissolved (mg/L)	20	20			0.008	0.016	0.009	0.04	0.032	0.008	0.01	0.012	0.018	0.0343
Iron - dissolved (mg/L)	1		1	100.0%										
Molybdenum - dissolved (mg/L)	20	20			0.001	0.006	0.002	0.008	0.007	0.00195	0.00475	0.0065	0.007	0.008
Nickel - dissolved (mg/L)	20	5	15	75.0%	0.001	0.001	0.000	0.002	0.001	0.001	0.001	0.001	0.002	0.002
Selenium - dissolved (mg/L)	20	7	13	65.0%	0.01	0.026	0.009	0.04	0.03	0.013	0.02	0.03	0.03	0.037
Uranium - dissolved (mg/L)	20	20			0.002	0.026	0.014	0.076	0.074	0.00485	0.02275	0.0255	0.02925	0.03325

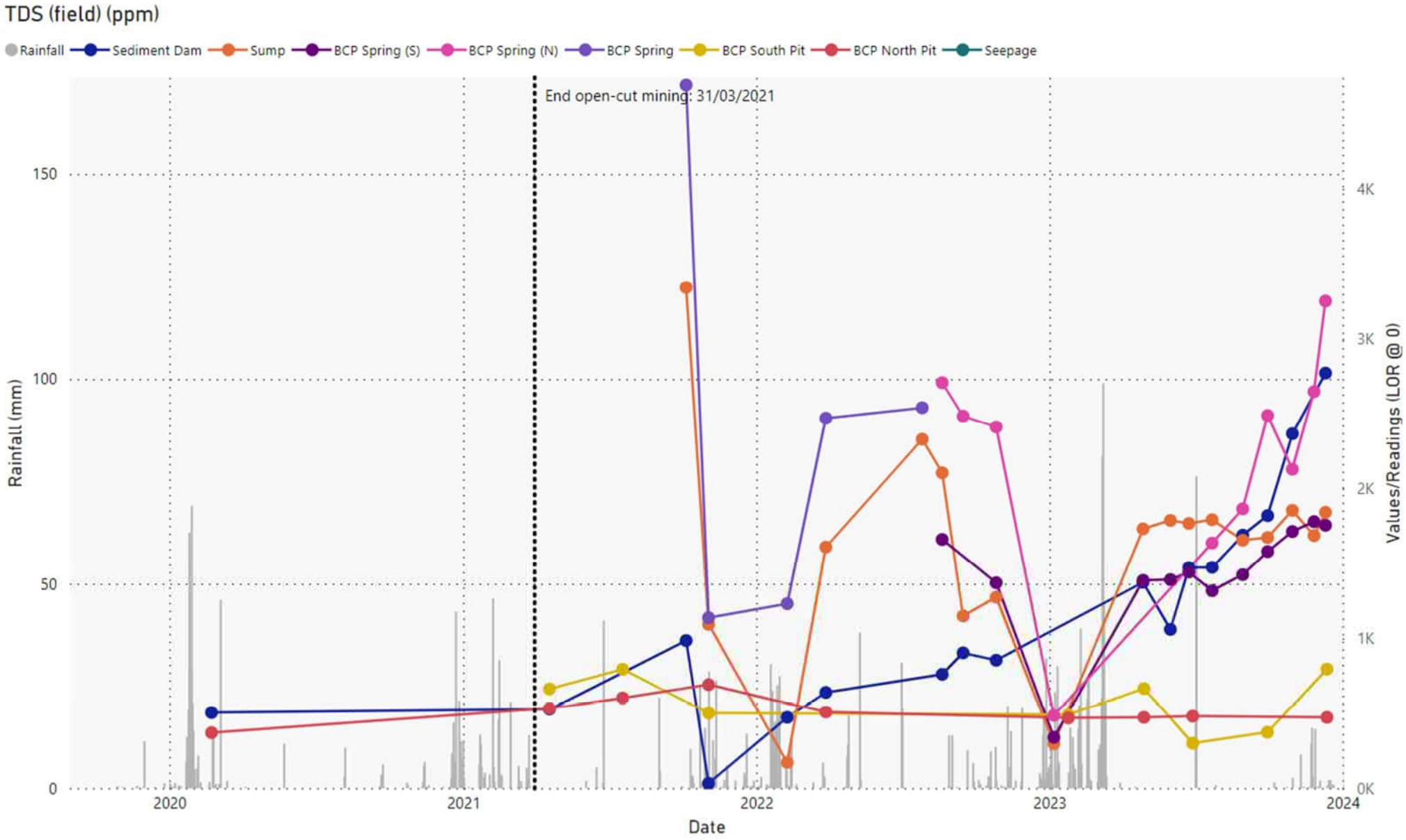
Analyte/Parameter	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Vanadium - dissolved (mg/L)	1		1	100.0%										
Metals (total)														
Arsenic - total (mg/L)	20	20			0.002	0.006	0.003	0.013	0.011	0.002	0.003	0.004	0.009	0.01205
Barium - total (mg/L)	20	20			0.024	0.100	0.037	0.163	0.139	0.03635	0.0775	0.109	0.12575	0.13925
Beryllium - total (mg/L)	1		1	100.0%										
Bismuth - total (mg/L)	20		20	100.0%										
Boron - total (mg/L)	1	1			0.14	0.140	0.000	0.14	0	0.14	0.14	0.14	0.14	0.14
Chromium - total (mg/L)	20	3	17	85.0%	0.001	0.002	0.001	0.004	0.003	0.0011	0.0015	0.002	0.003	0.0038
Cobalt - total (mg/L)	20	19	1	5.0%	0.001	0.002	0.001	0.004	0.003	0.001	0.002	0.002	0.003	0.0031
Copper - total (mg/L)	20	20			0.011	0.024	0.011	0.051	0.04	0.0129	0.015	0.02	0.02875	0.05005
Iron - total (mg/L)	1	1			0.3	0.300	0.000	0.3	0	0.3	0.3	0.3	0.3	0.3
Molybdenum - total (mg/L)	20	20			0.001	0.007	0.002	0.009	0.008	0.00195	0.006	0.0075	0.008	0.009
Nickel - total (mg/L)	20	10	10	50.0%	0.001	0.002	0.001	0.003	0.002	0.001	0.001	0.001	0.002	0.00255
Selenium - total (mg/L)	20	7	13	65.0%	0.01	0.027	0.009	0.04	0.03	0.013	0.025	0.03	0.03	0.037
Uranium - total (mg/L)	20	20			0.002	0.028	0.015	0.083	0.081	0.00485	0.02475	0.0285	0.032	0.03645
Vanadium - total (mg/L)	1	1			0.01	0.010	0.000	0.01	0	0.01	0.01	0.01	0.01	0.01
Nutrients														
Nitrate as N (mg/L)	2	1	1	50.0%	0.32	0.320	0.000	0.32	0	0.32	0.32	0.32	0.32	0.32
Nitrite + Nitrate as N (mg/L)	2	1	1	50.0%	0.32	0.320	0.000	0.32	0	0.32	0.32	0.32	0.32	0.32
Nitrite as N (mg/L)	2		2	100.0%										
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	20	20			279	3352.750	1346.902	6290	6011	475.65	2975	3540	3870	5007.5
pH (lab)	20	20			8	8.544	0.280	9.14	1.14	8.0095	8.44	8.5	8.765	8.9215

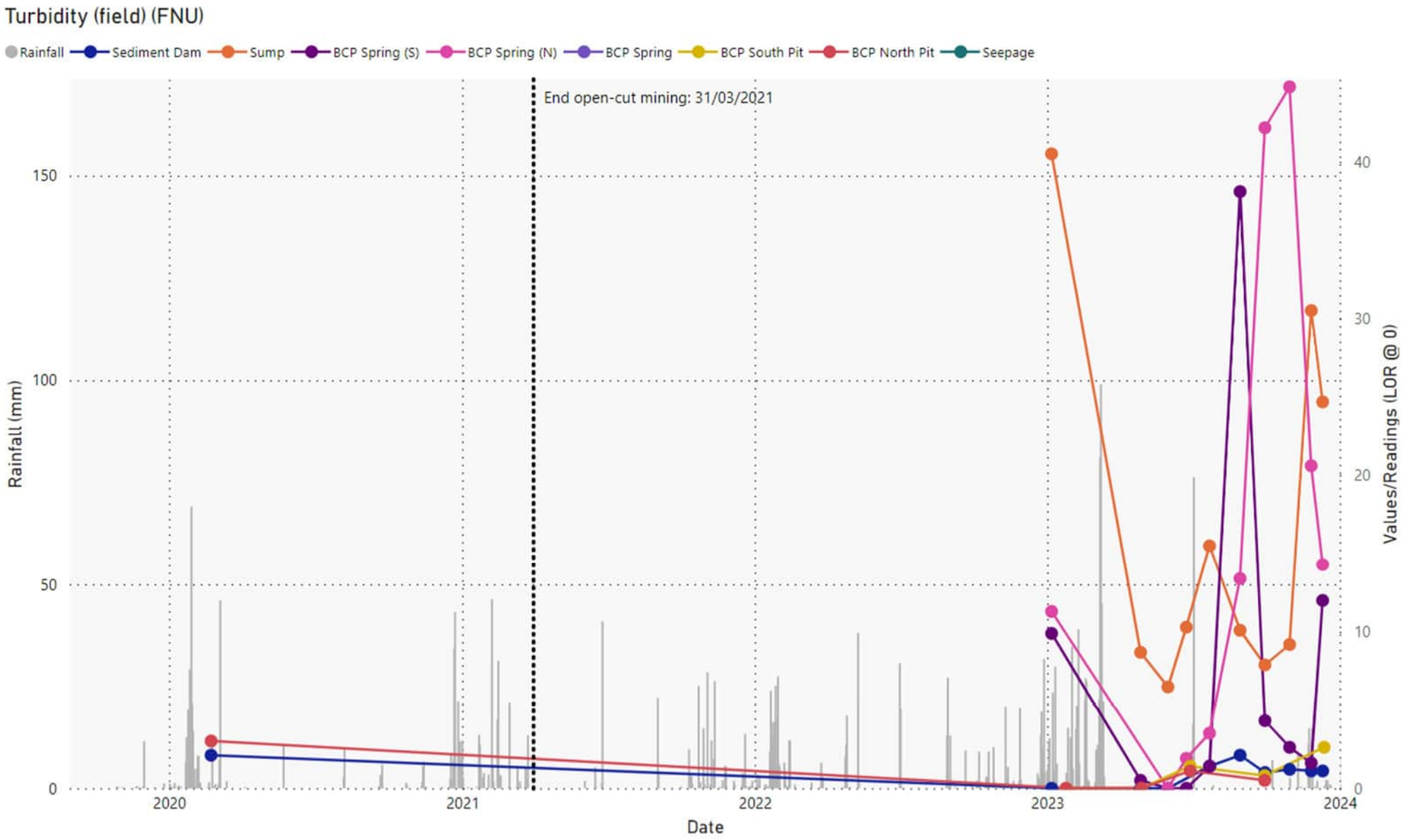
F.2 Water quality time series

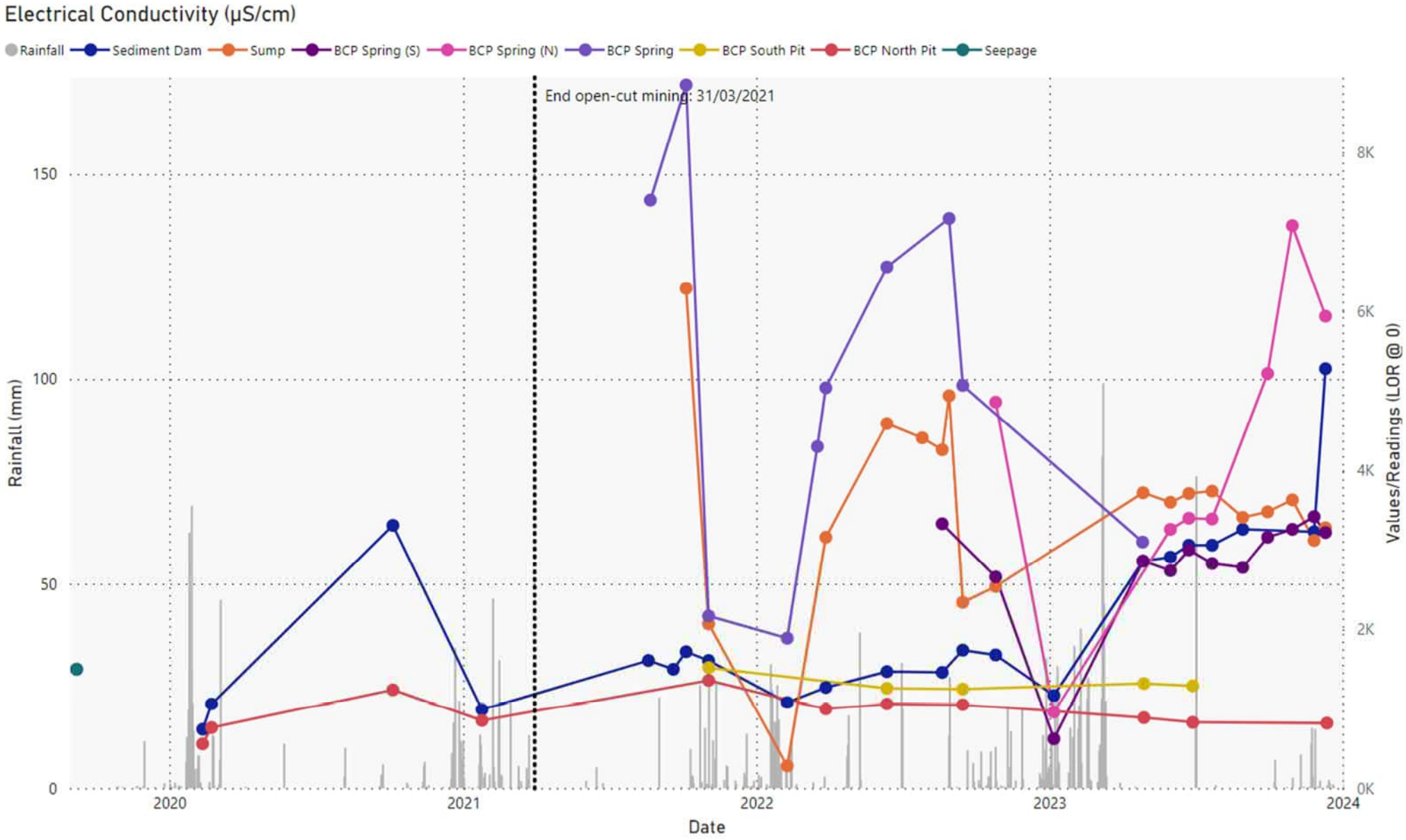

Electrical Conductivity (field) (µS/cm)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
Values/Readings (LOR @ 0)
8K
6K
4K
2K
0K
2020
2021
2022
2023
2024
Date

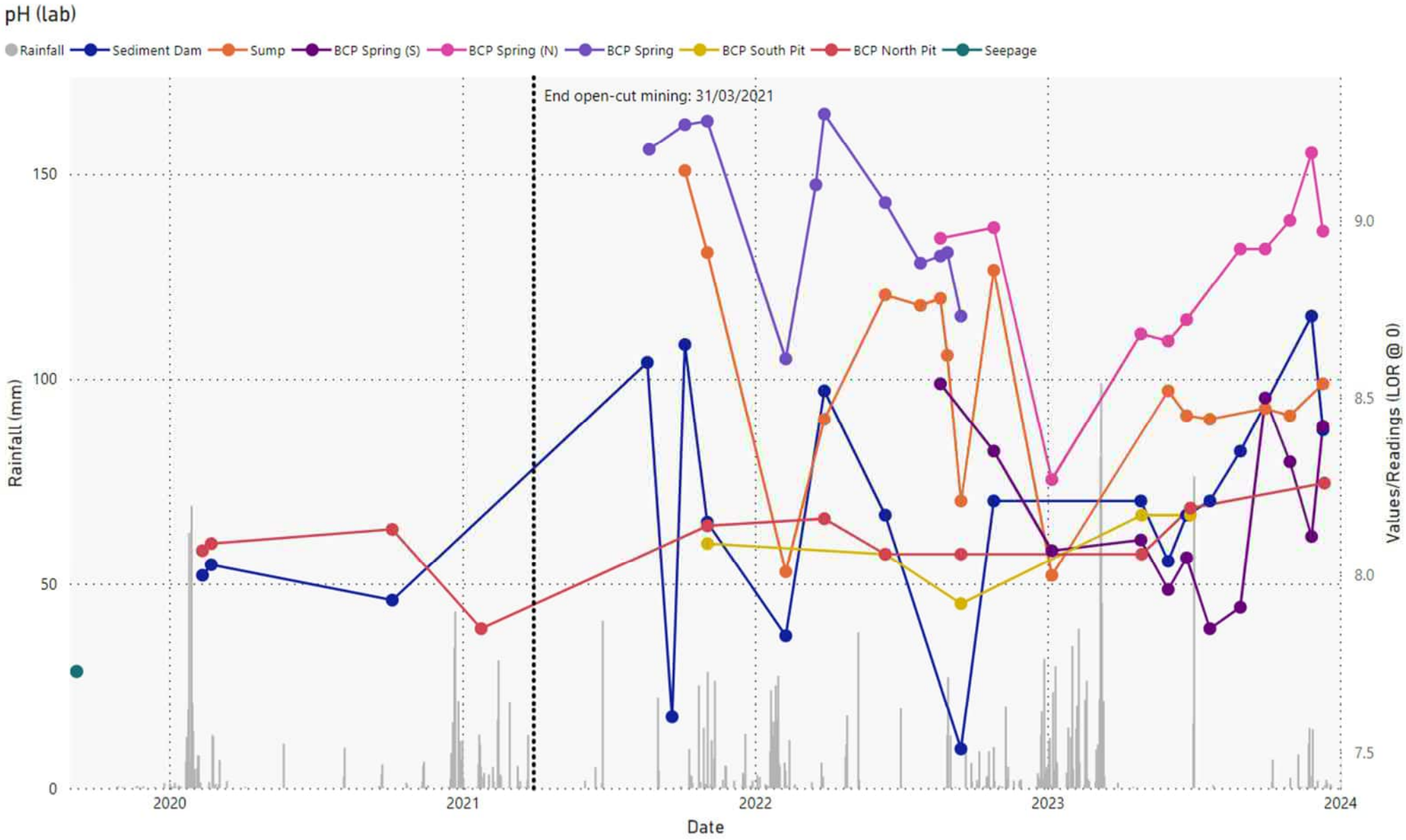

Dissolved Oxygen (field) (% sat)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
50
100
150
200
250
300
2020
2021
2022
2023
2024

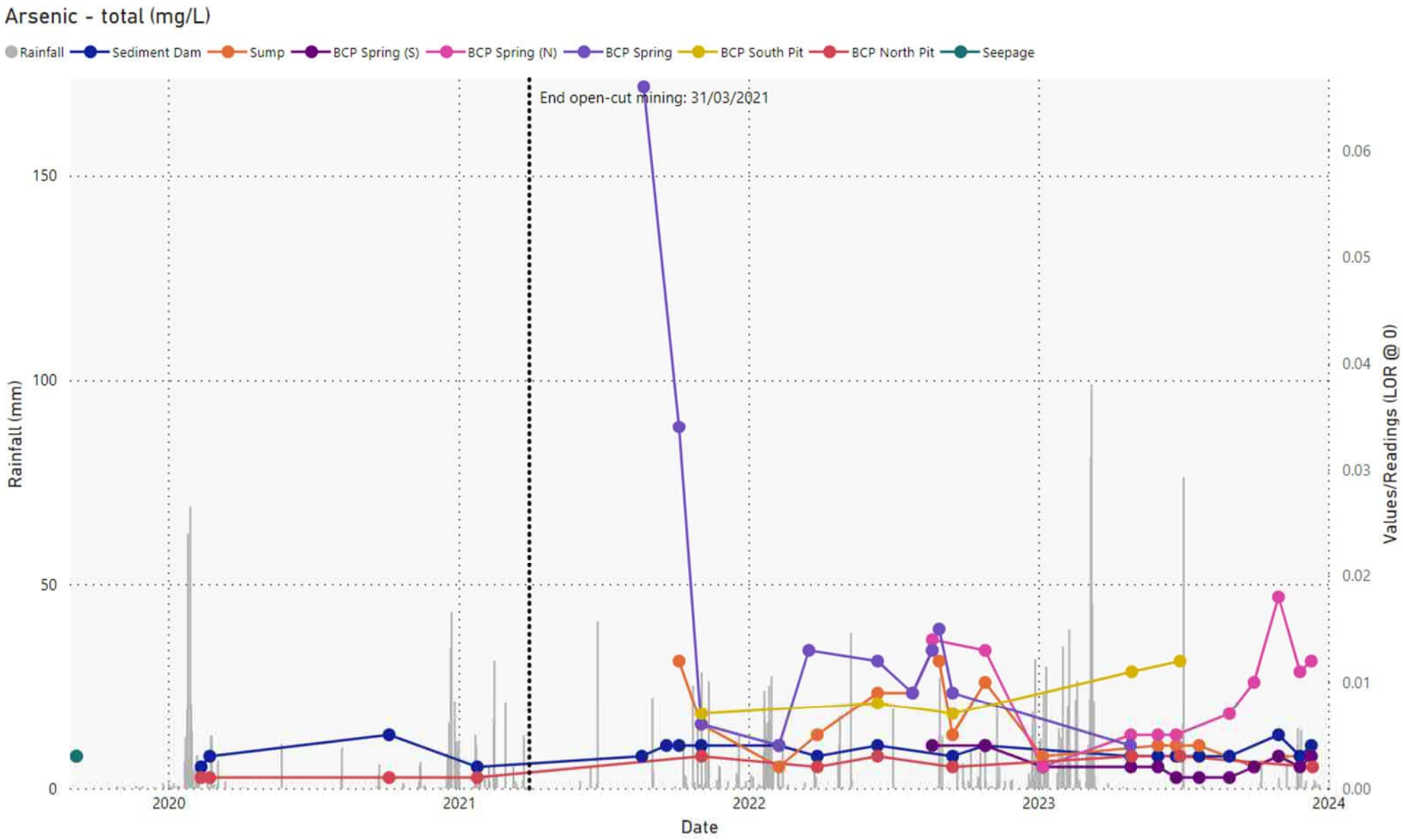

pH (field)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
7.5
8.0
8.5
9.0
9.5
10.0
10.5
2020
2021
2022
2023
2024

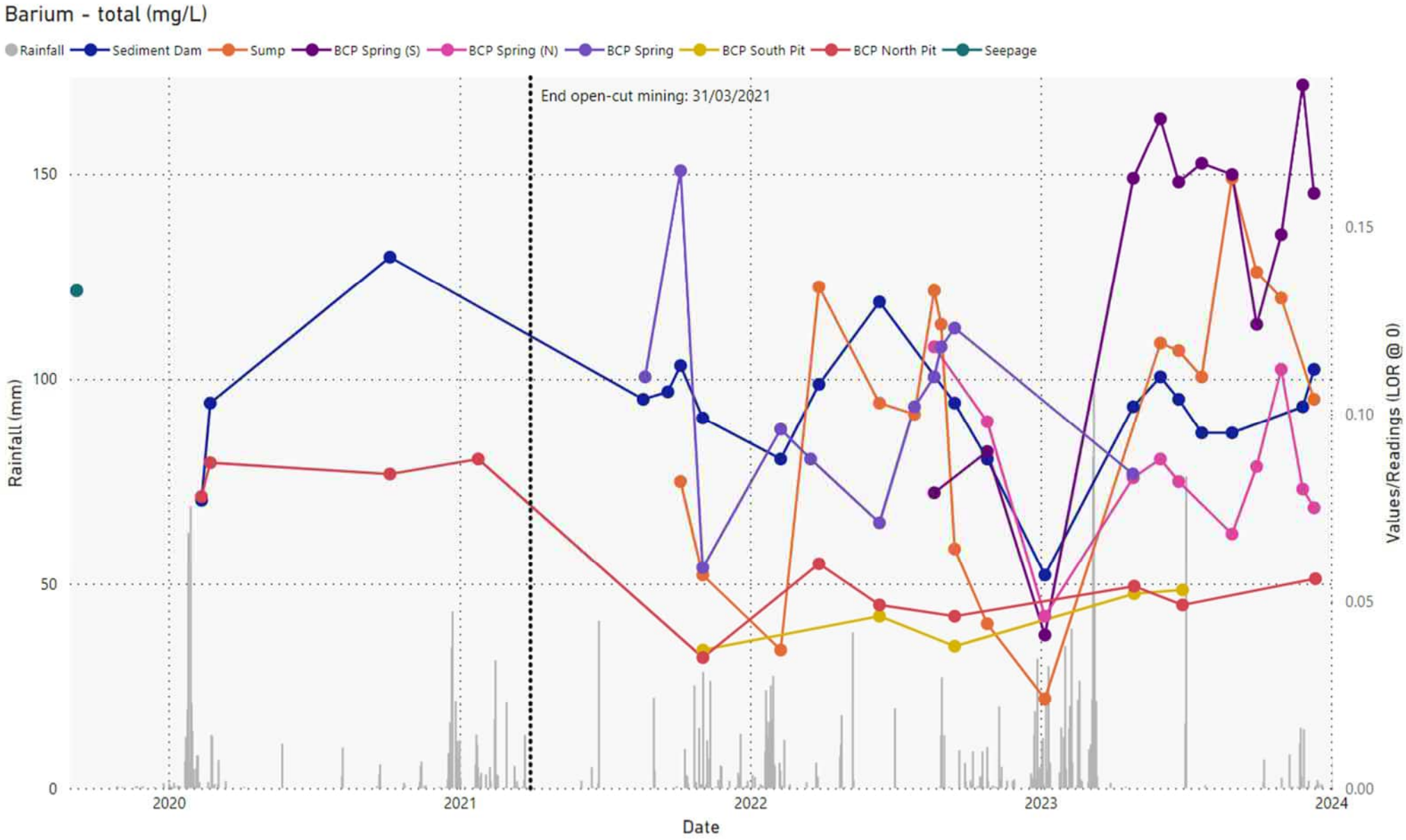

TDS (field) (ppm)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
Values/Readings (LOR @ 0)
4K
3K
2K
1K
0K
2020
2021
2022
2023
2024
Date

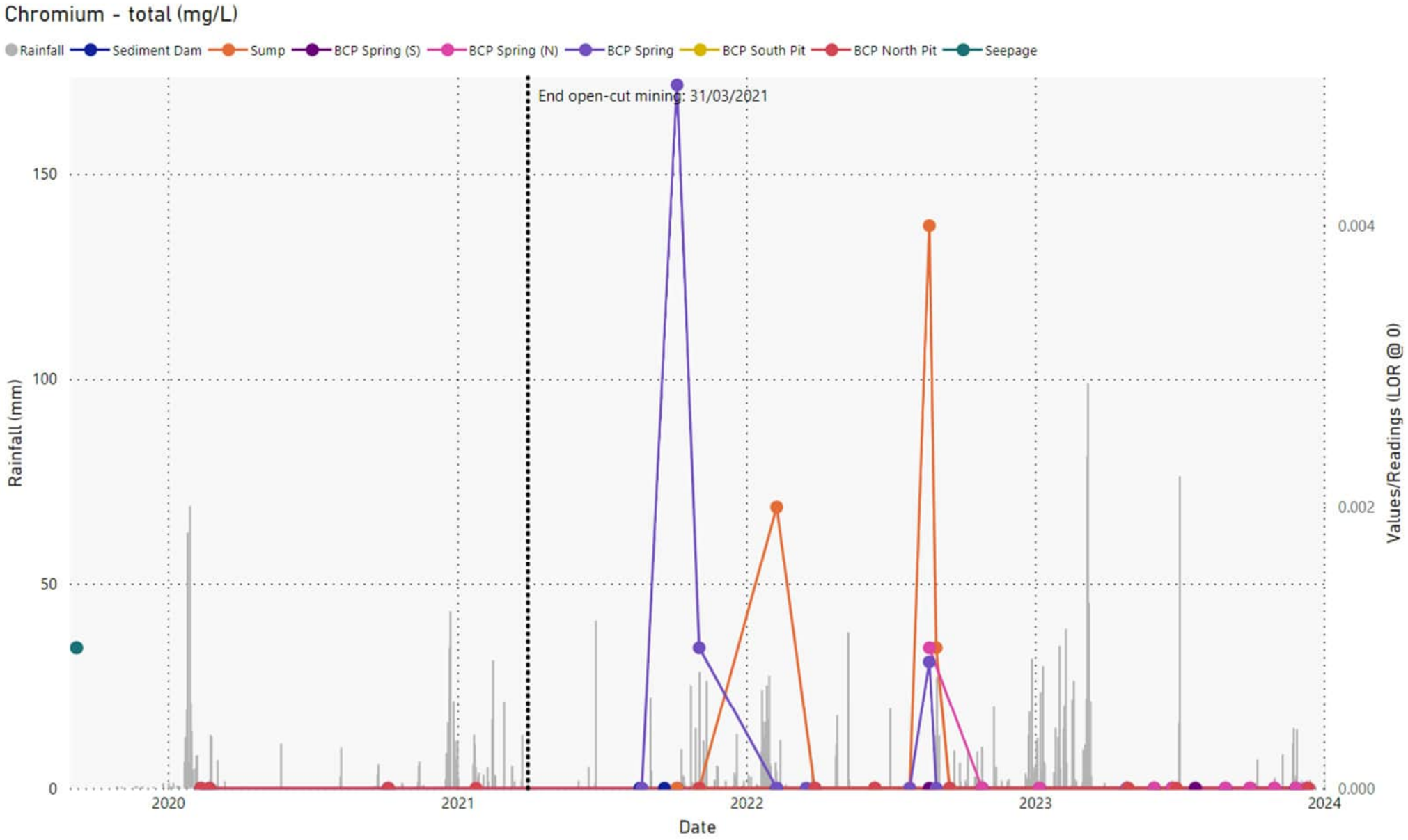

Turbidity (field) (FNU)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
10
20
30
40
2020
2021
2022
2023
2024

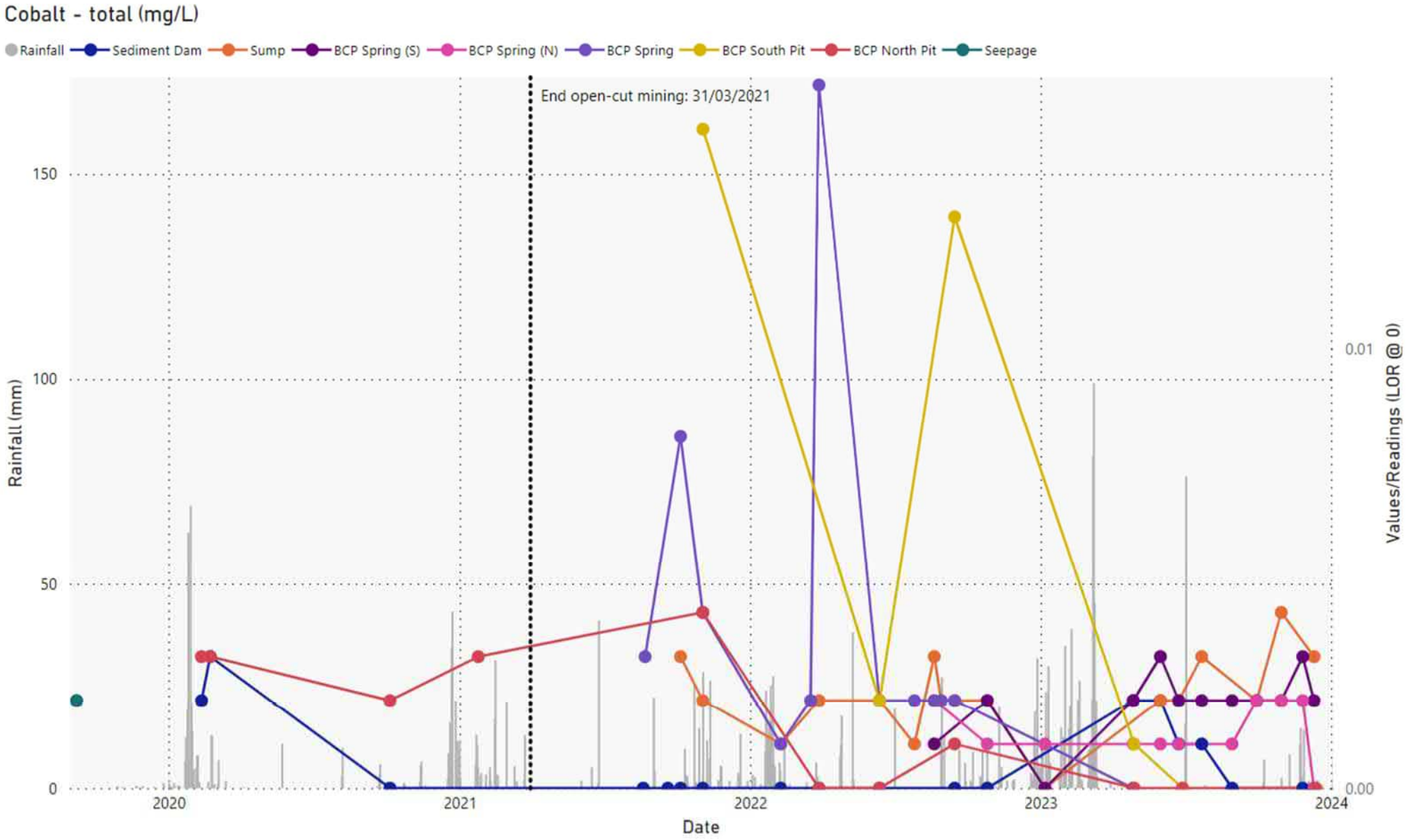

Electrical Conductivity (µS/cm)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
Values/Readings (LOR @ 0)
8K
6K
4K
2K
0K
2020
2021
2022
2023
2024
Date

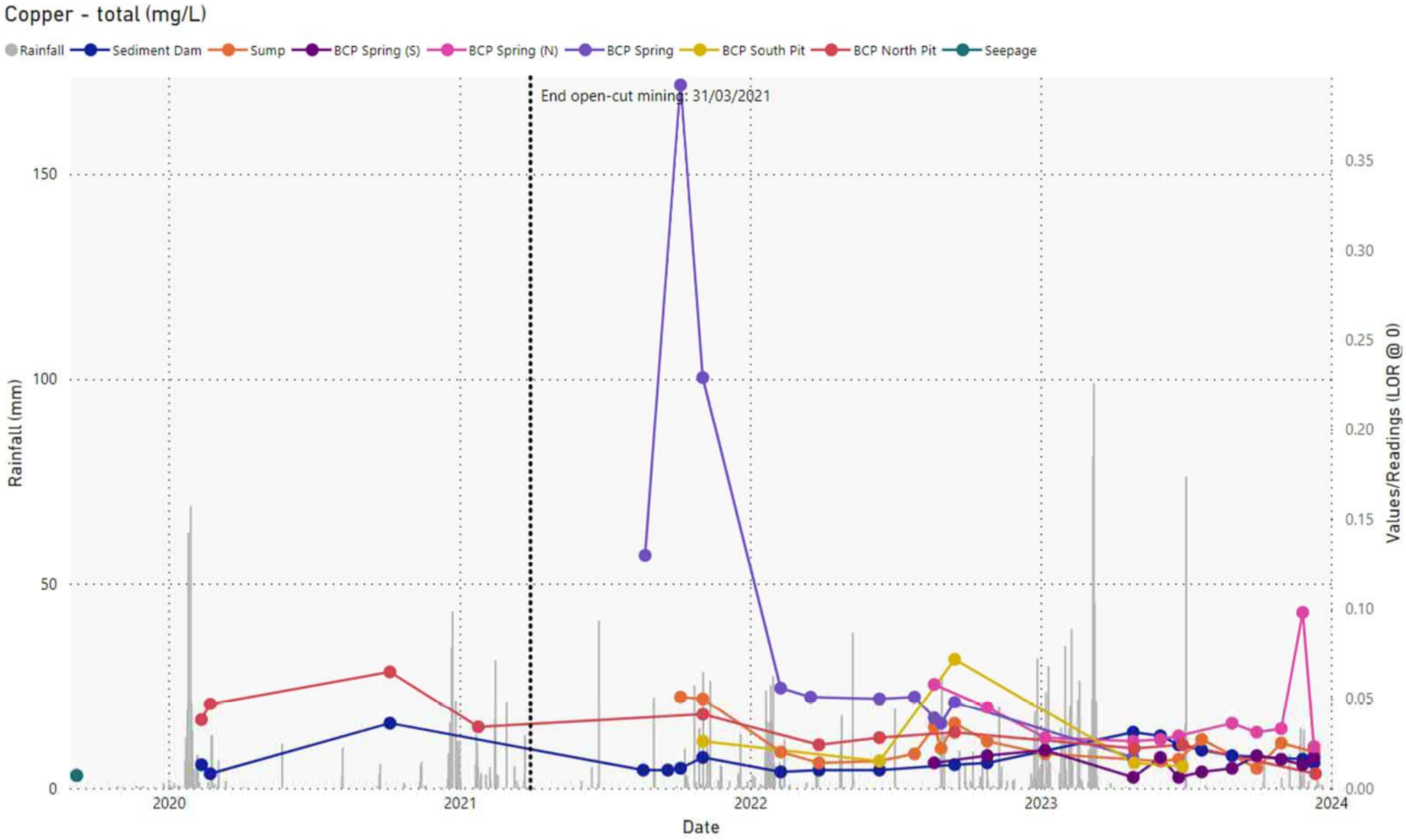

pH (lab)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
7.5
8.0
8.5
9.0
2020
2021
2022
2023
2024

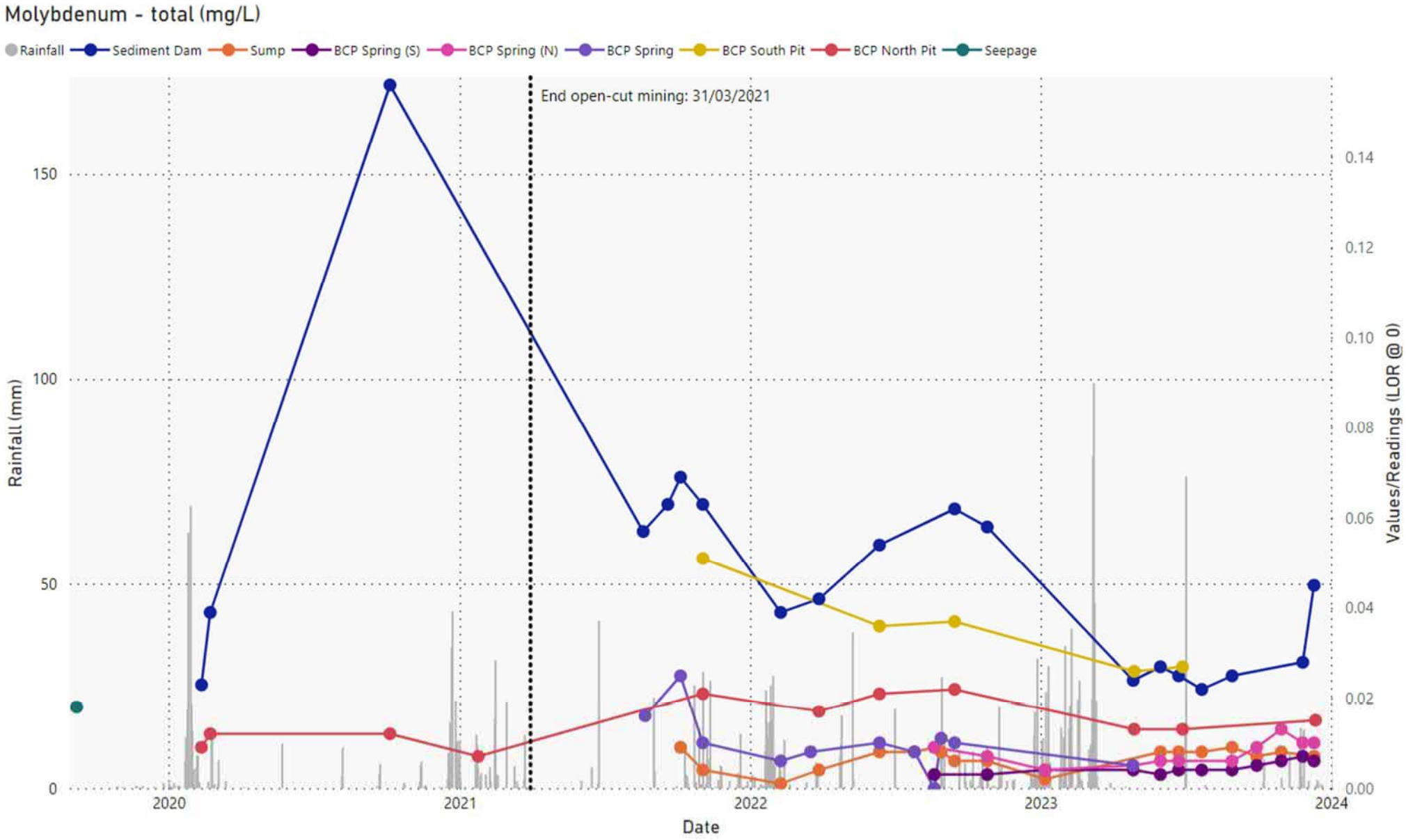

Arsenic - total (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.01
0.02
0.03
0.04
0.05
0.06
2020
2021
2022
2023
2024

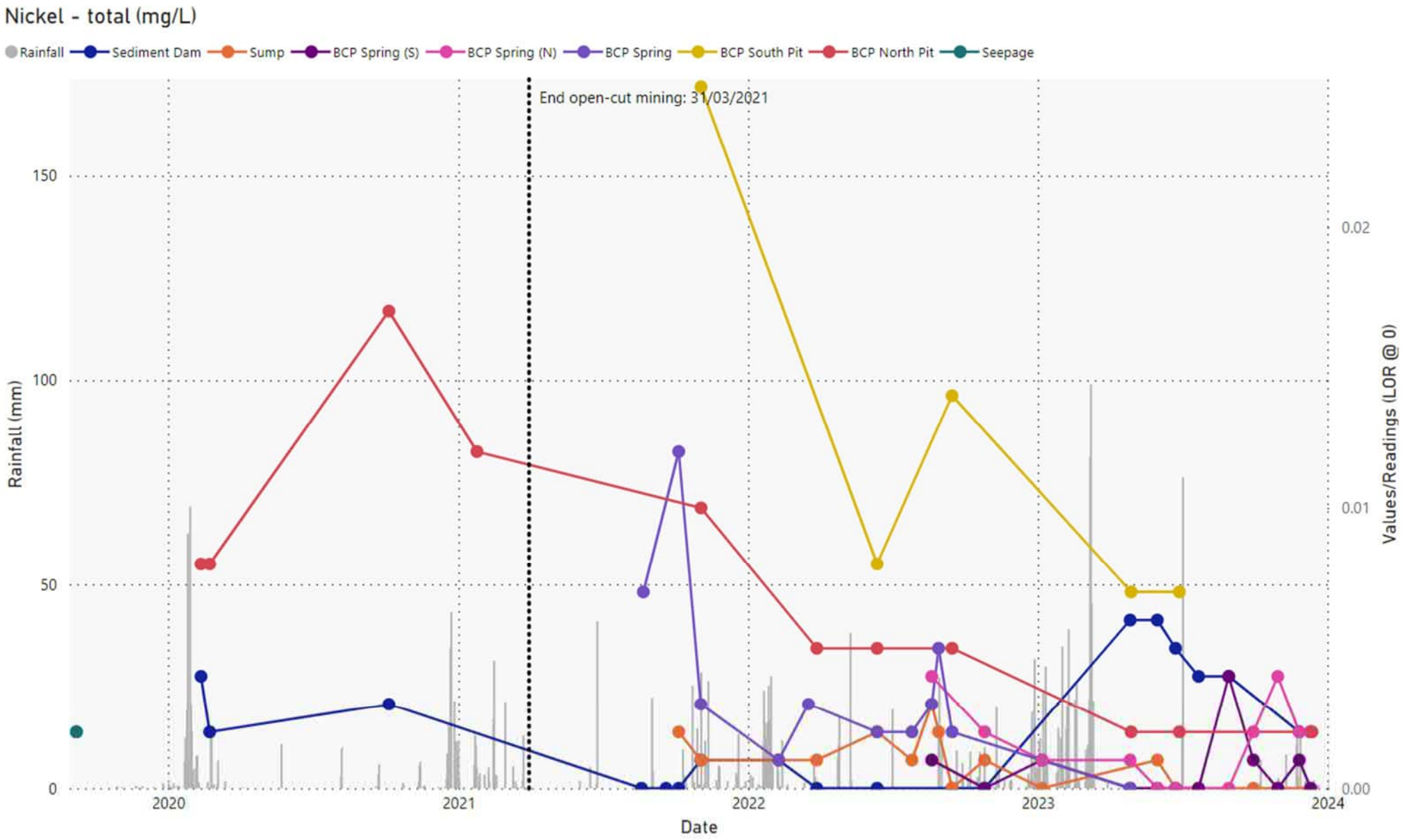

Barium - total (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.05
0.10
0.15
2020
2021
2022
2023
2024

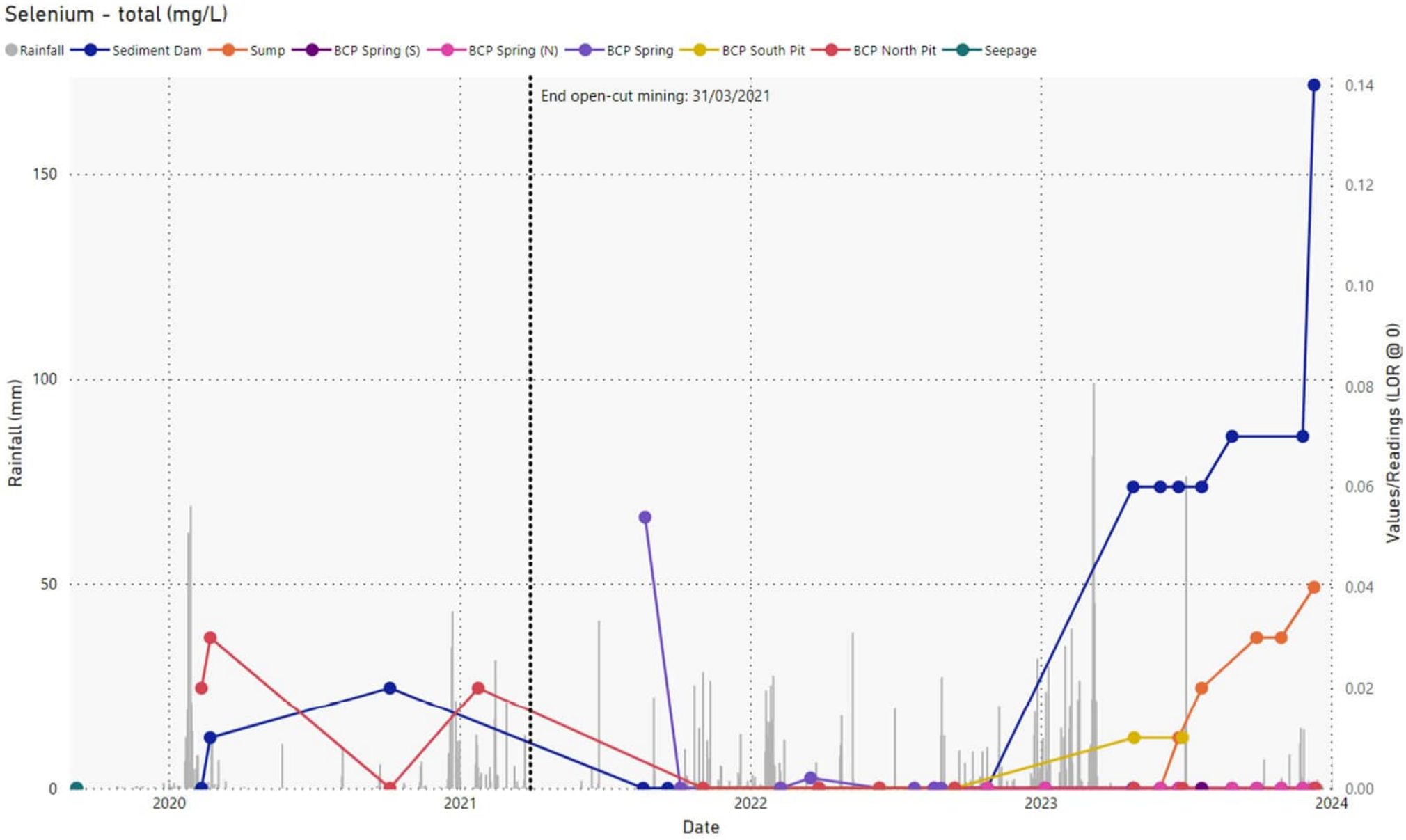

Chromium - total (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
0.004
0.002
0.000
Values/Readings (LOR @ 0)
2020
2021
2022
2023
2024
Date

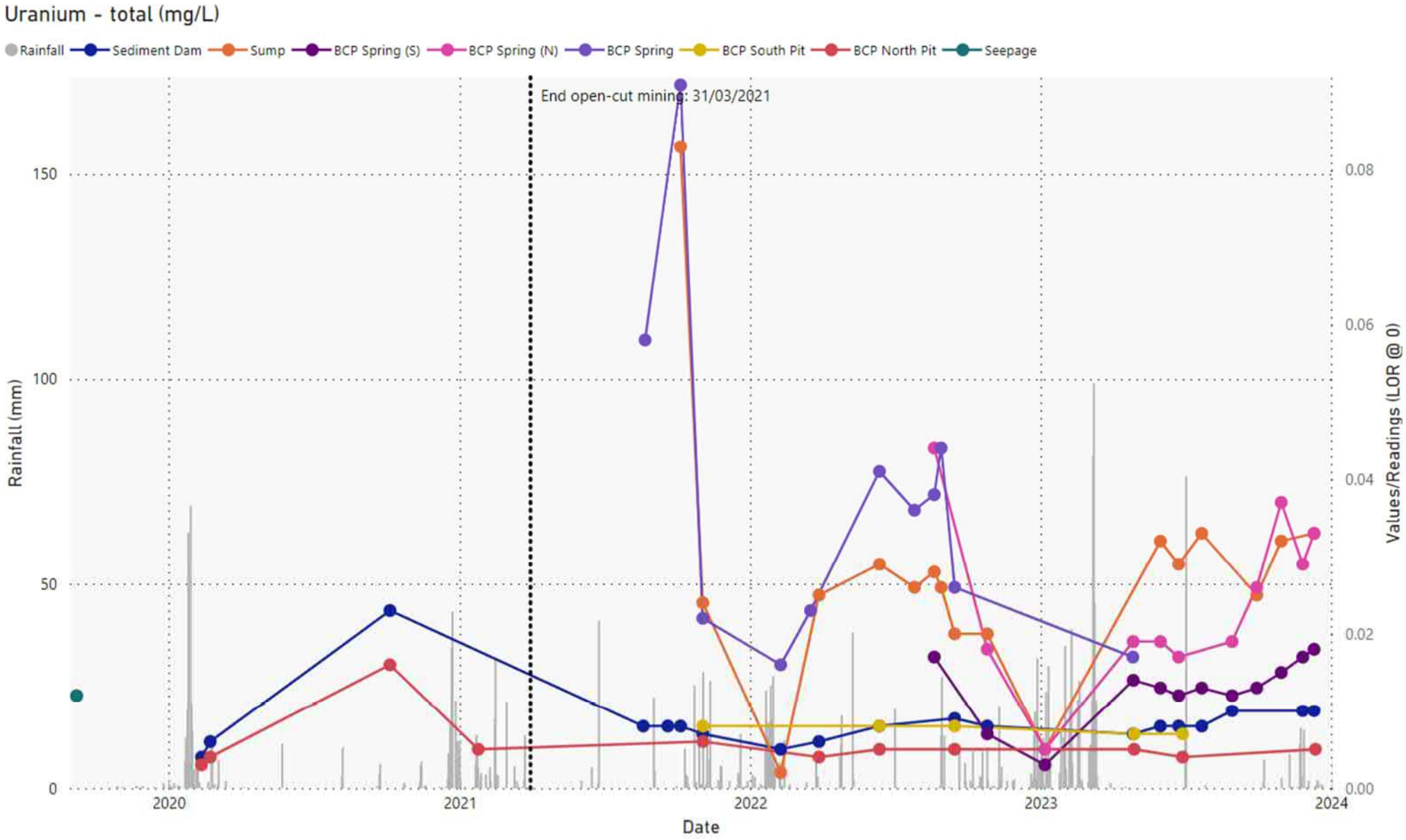

Cobalt - total (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
0.01
0.00
Values/Readings (LOR @ 0)
2020
2021
2022
2023
2024
Date

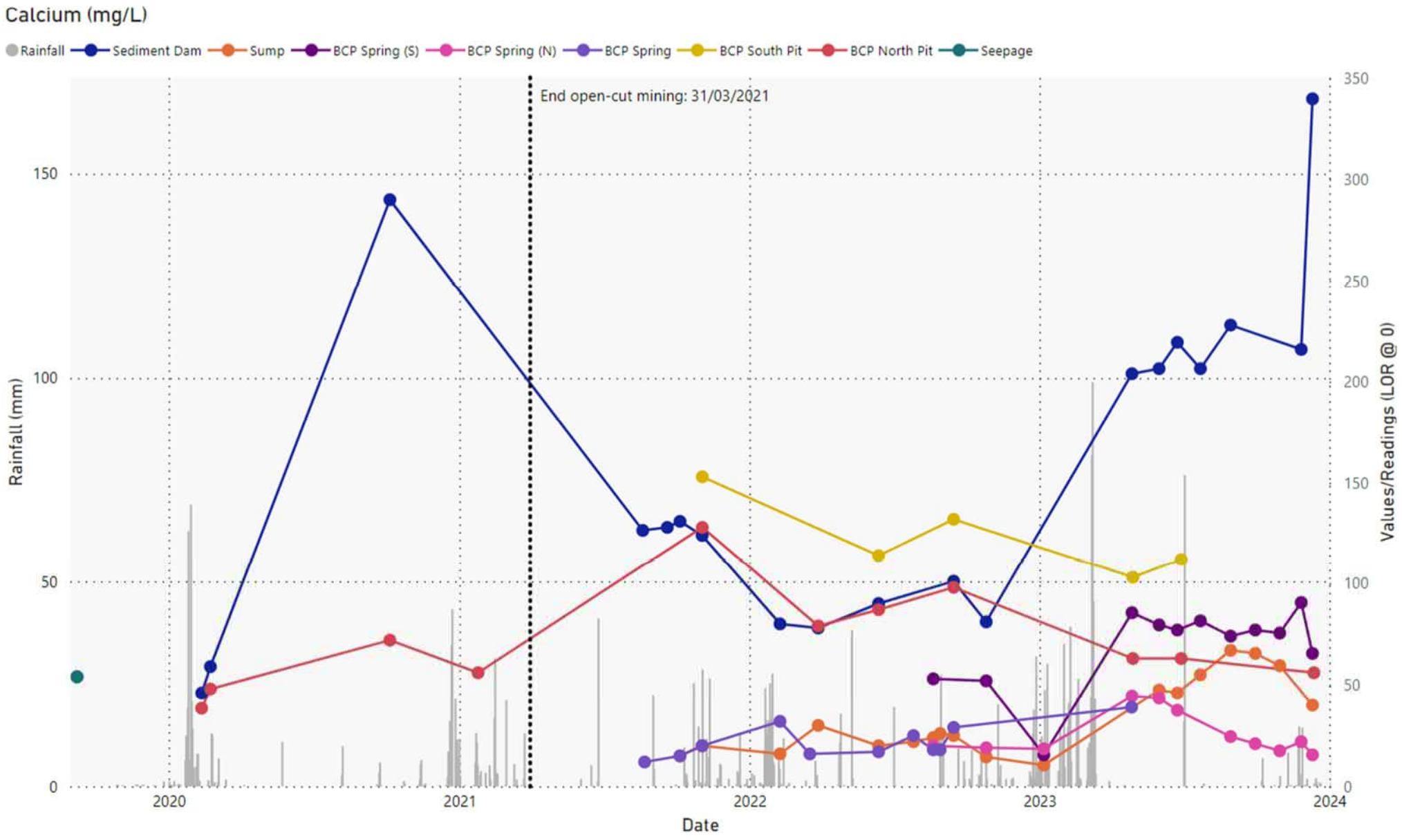

Copper - total (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
2020
2021
2022
2023
2024

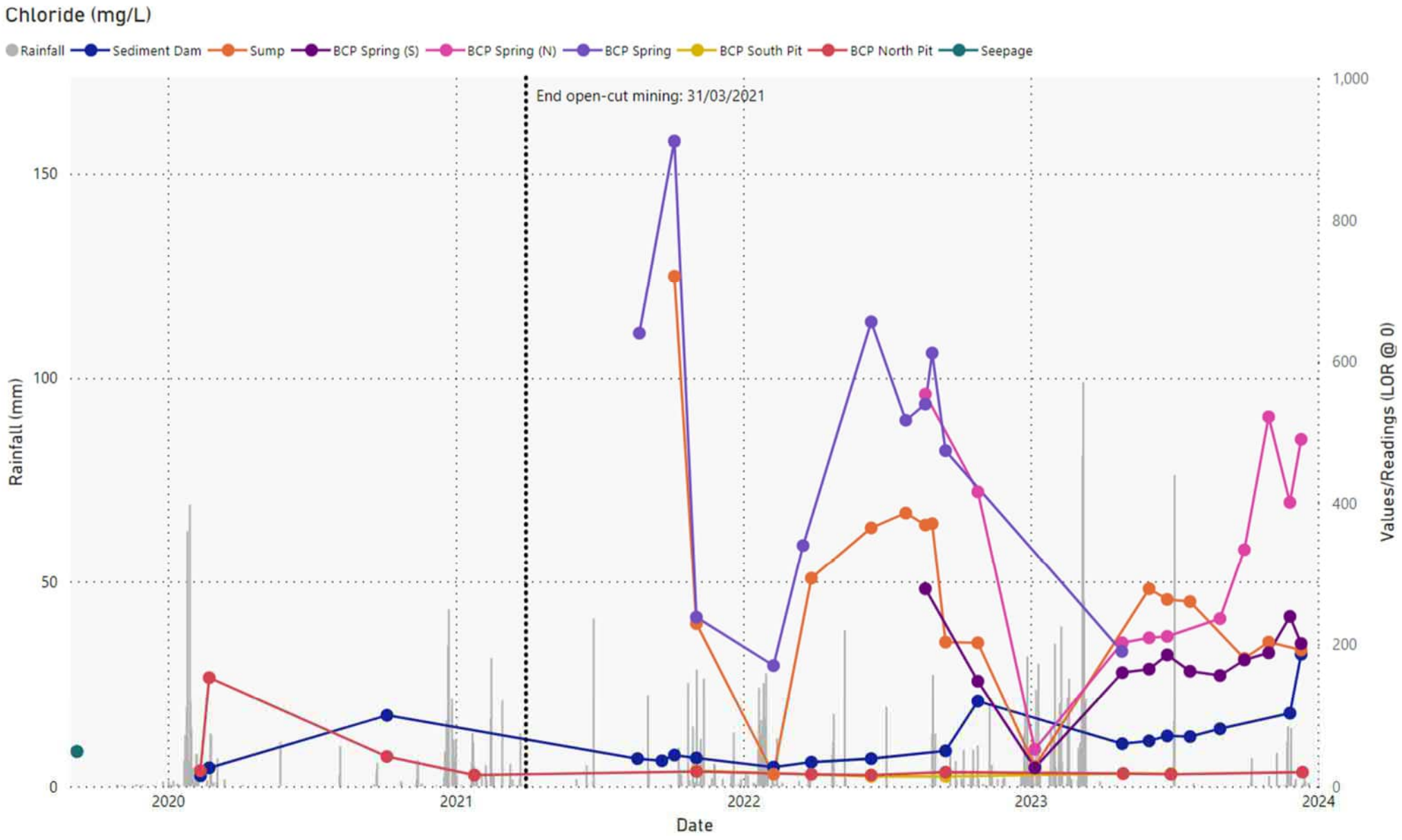

Molybdenum - total (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
2020
2021
2022
2023
2024

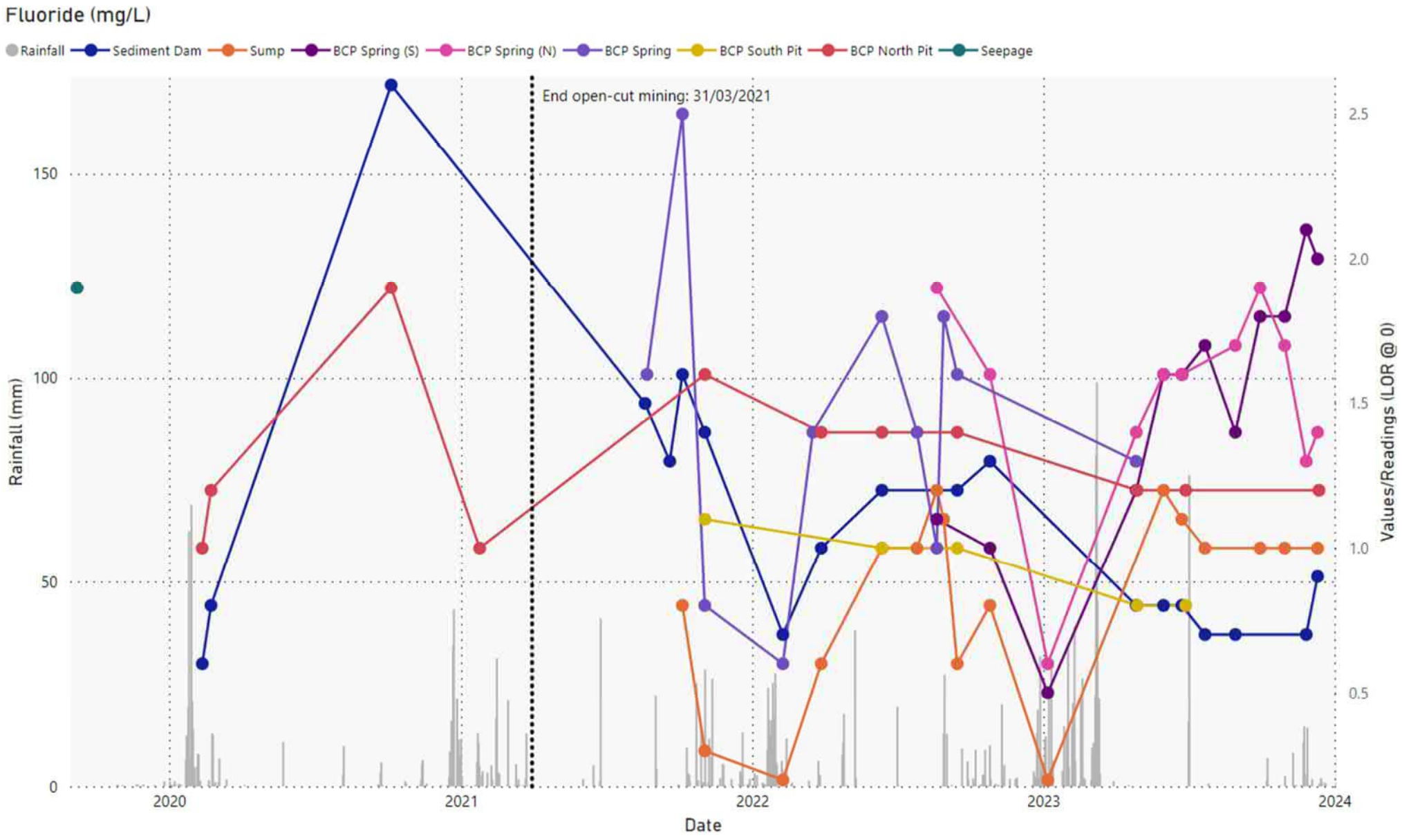

Nickel - total (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
Values/Readings (LOR @ 0)
0.02
0.01
0.00
2020
2021
2022
2023
2024
Date

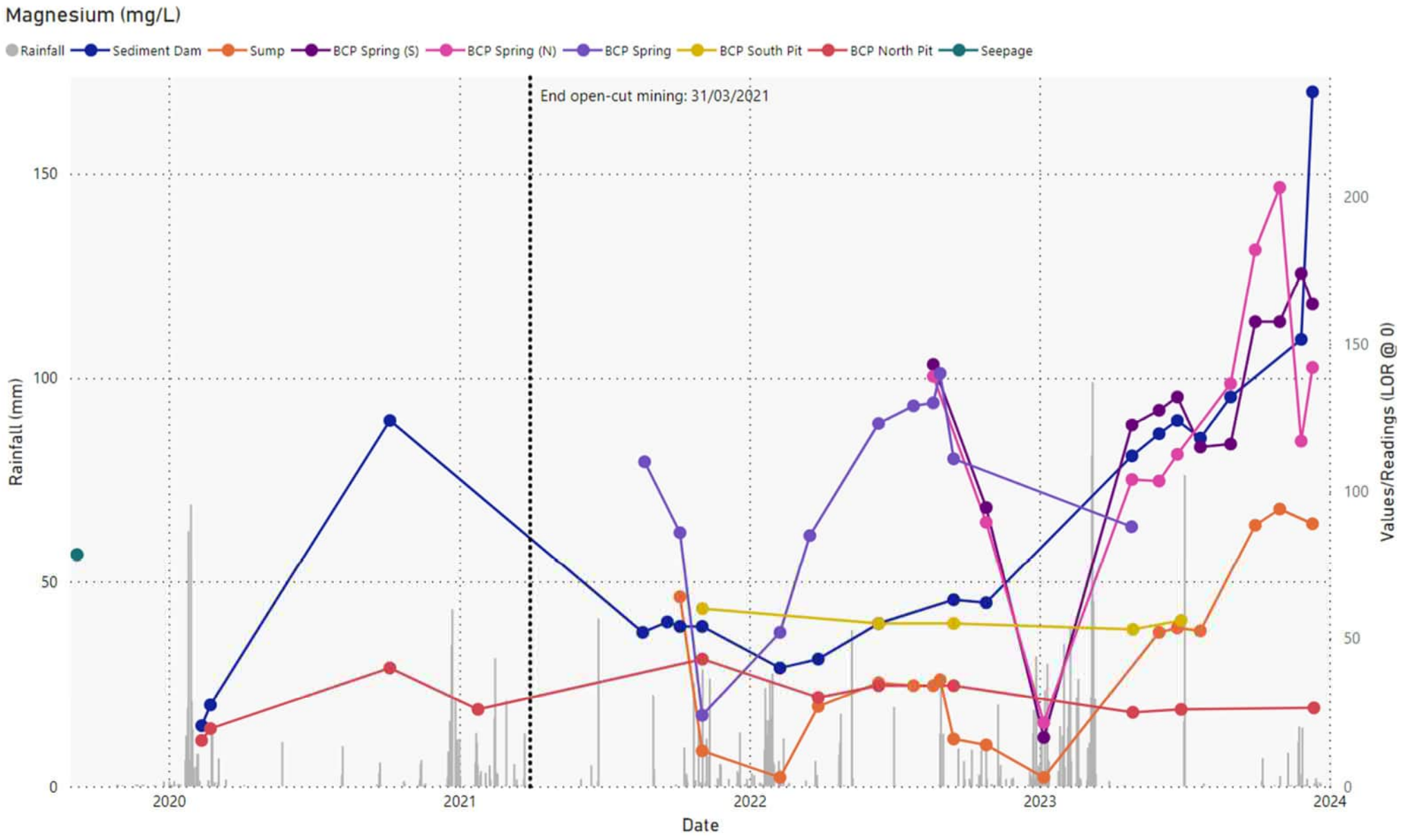

Selenium - total (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
2020
2021
2022
2023
2024

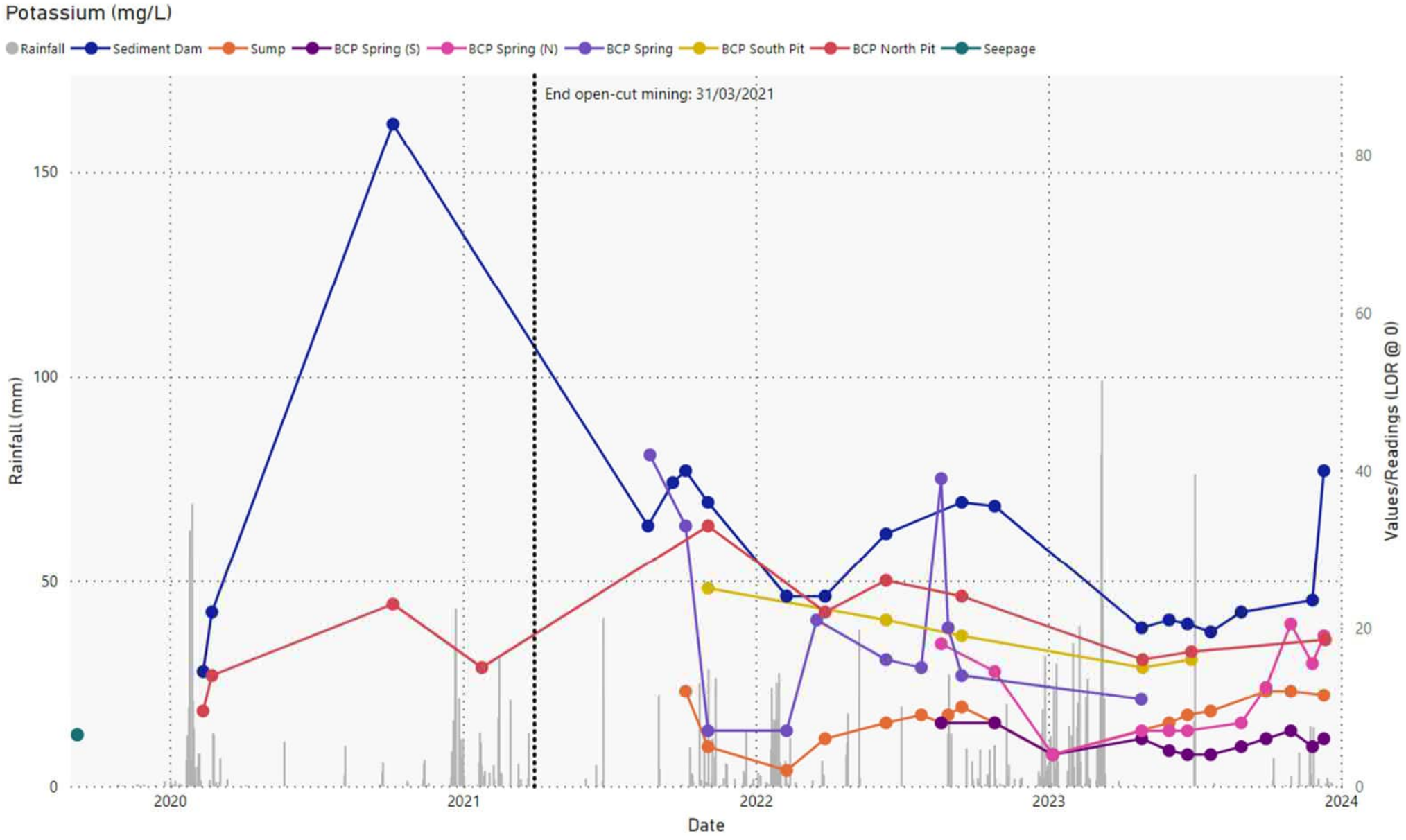

Uranium - total (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.02
0.04
0.06
0.08
2020
2021
2022
2023
2024

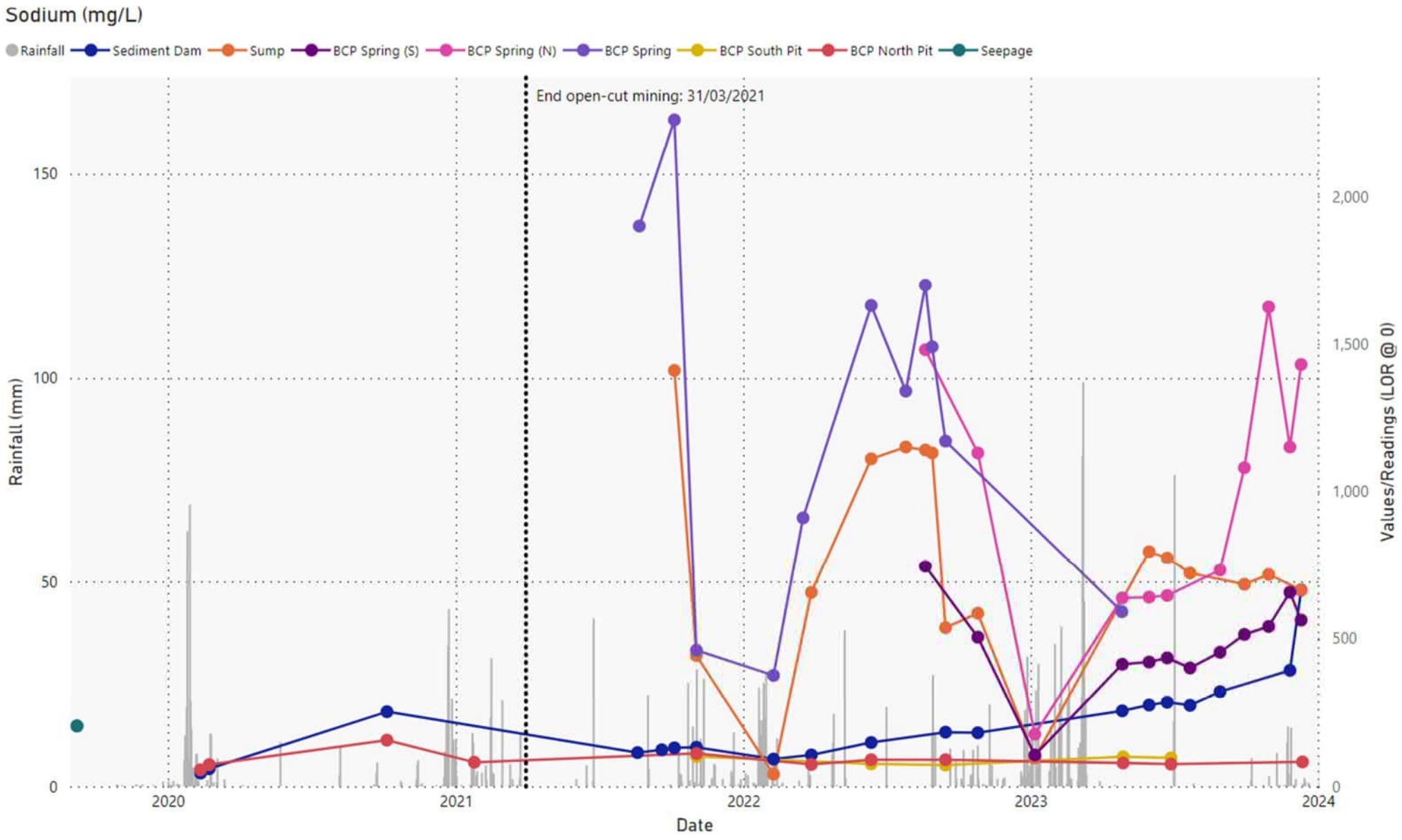

Calcium (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
50
100
150
200
250
300
350
2020
2021
2022
2023
2024

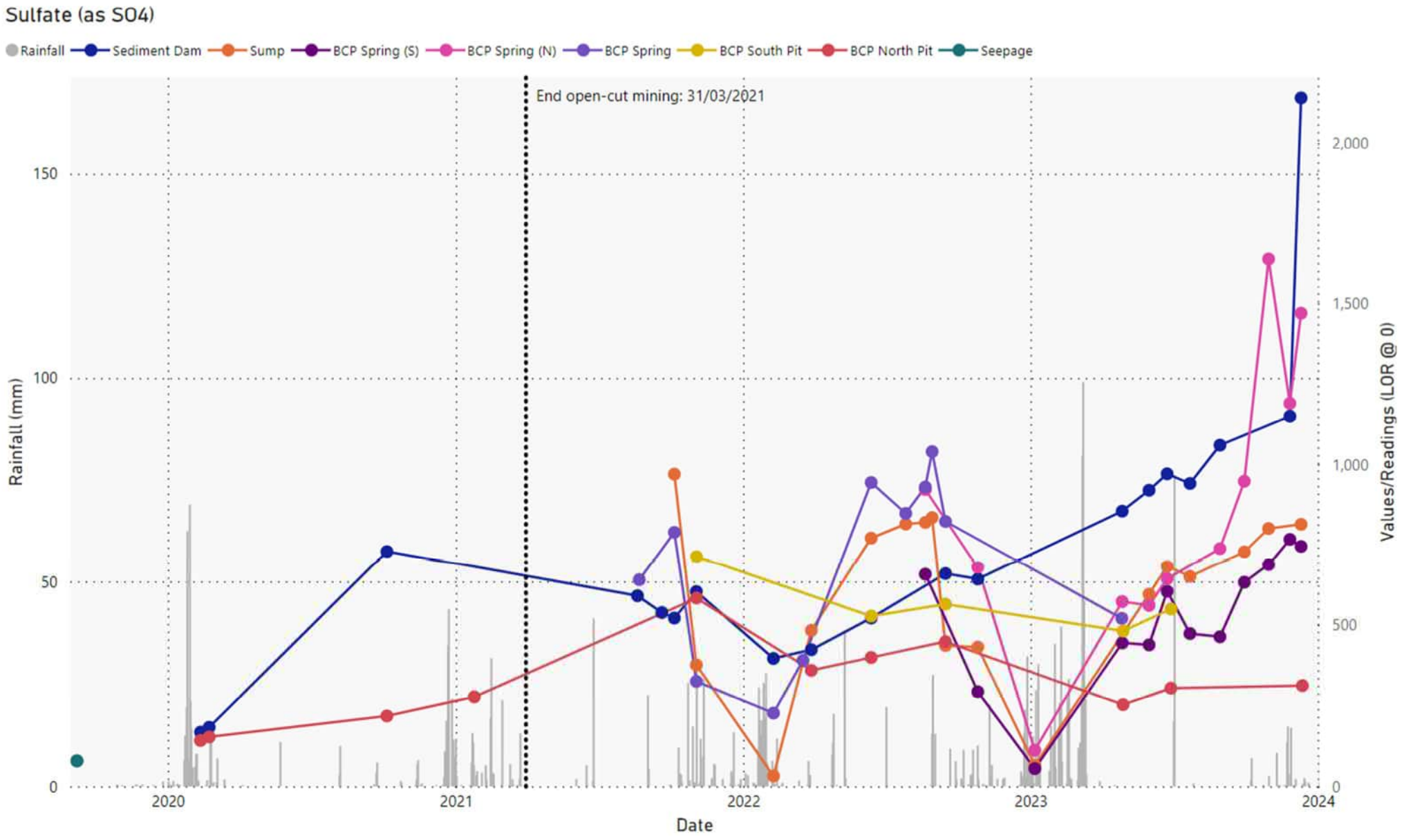

Chloride (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
200
400
600
800
1,000
2020
2021
2022
2023
2024

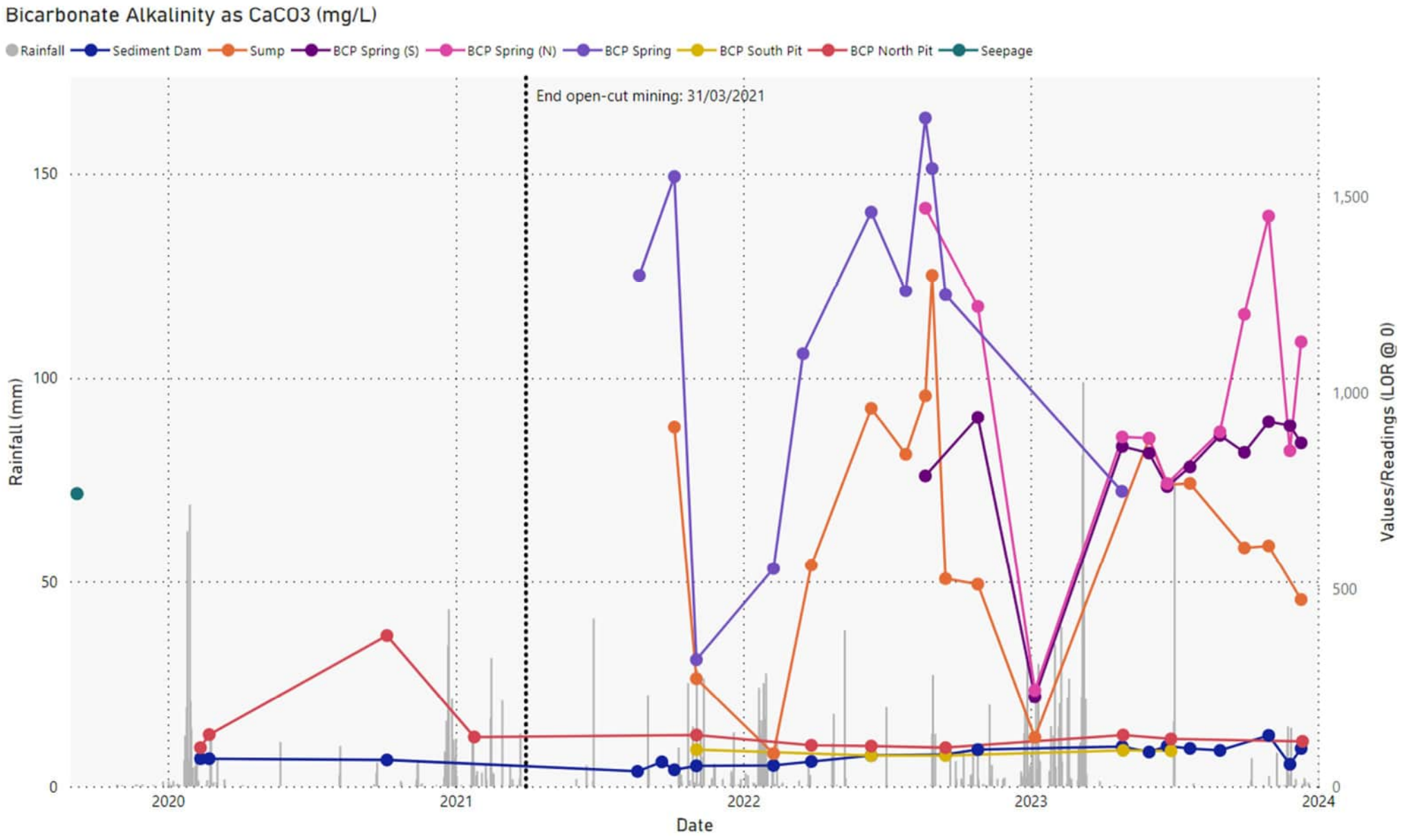

Fluoride (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.5
1.0
1.5
2.0
2.5
2020
2021
2022
2023
2024

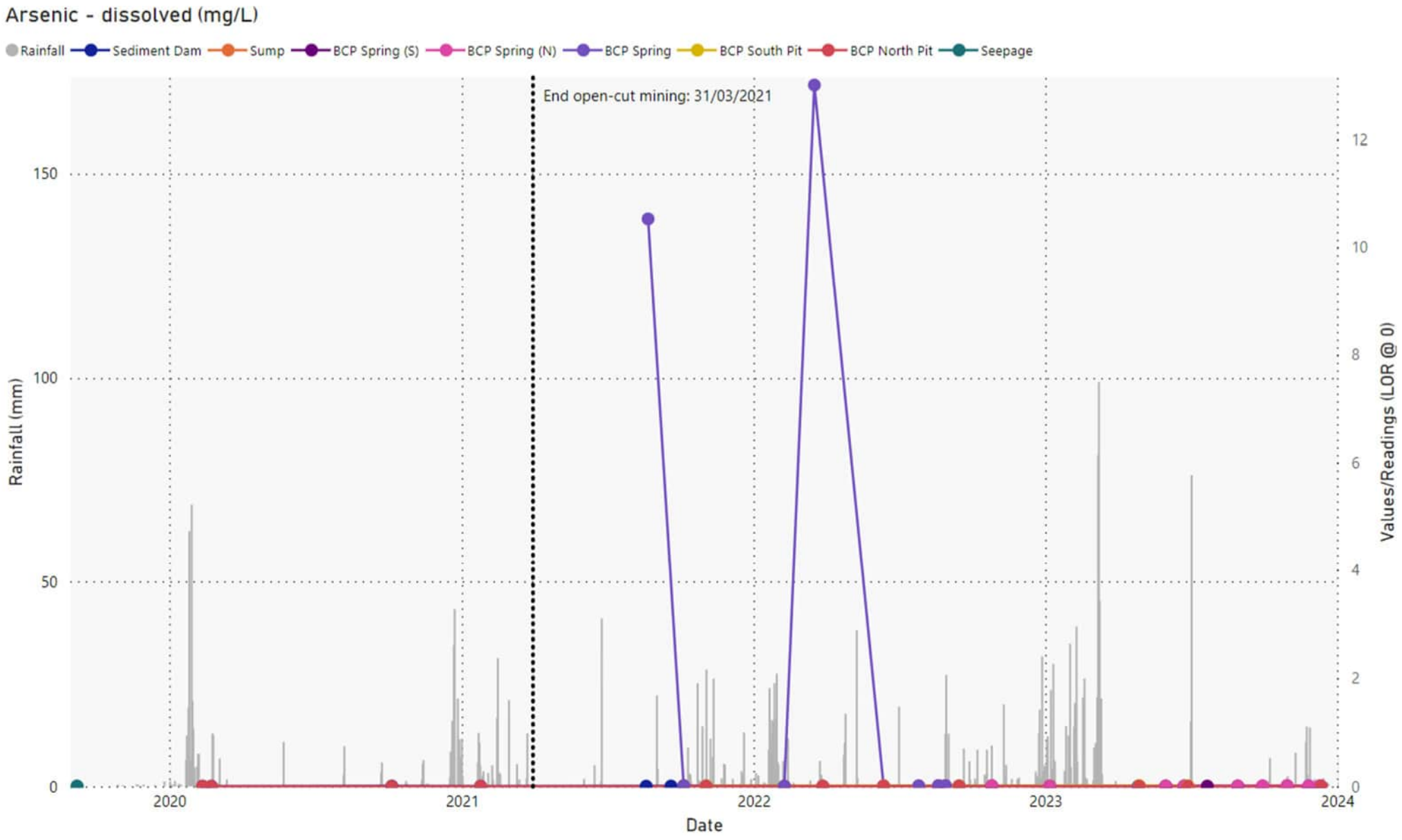

Magnesium (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
200
2020
2021
2022
2023
2024

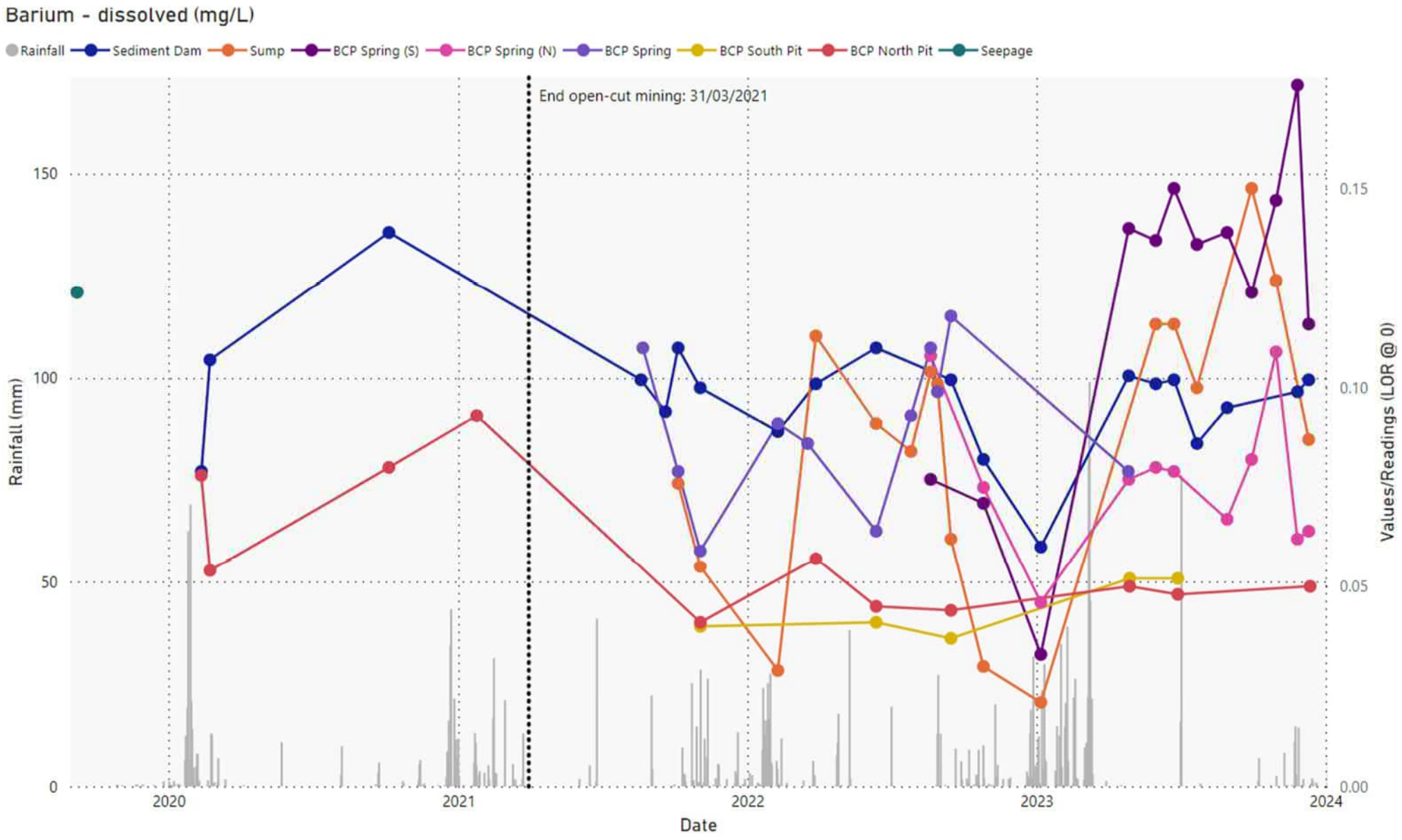

Potassium (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
20
40
60
80
2020
2021
2022
2023
2024

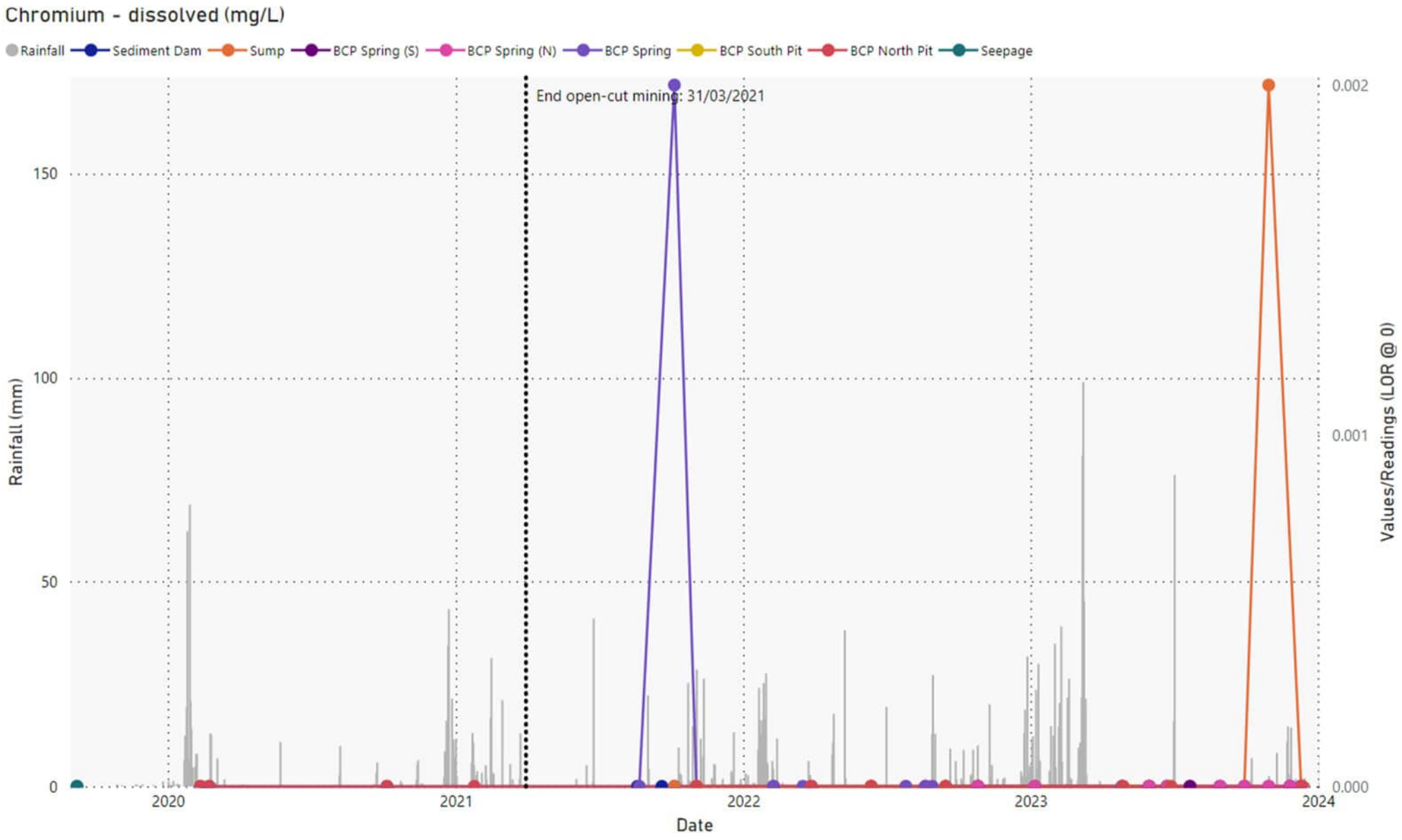

Sodium (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
500
1,000
1,500
2,000
2020
2021
2022
2023
2024

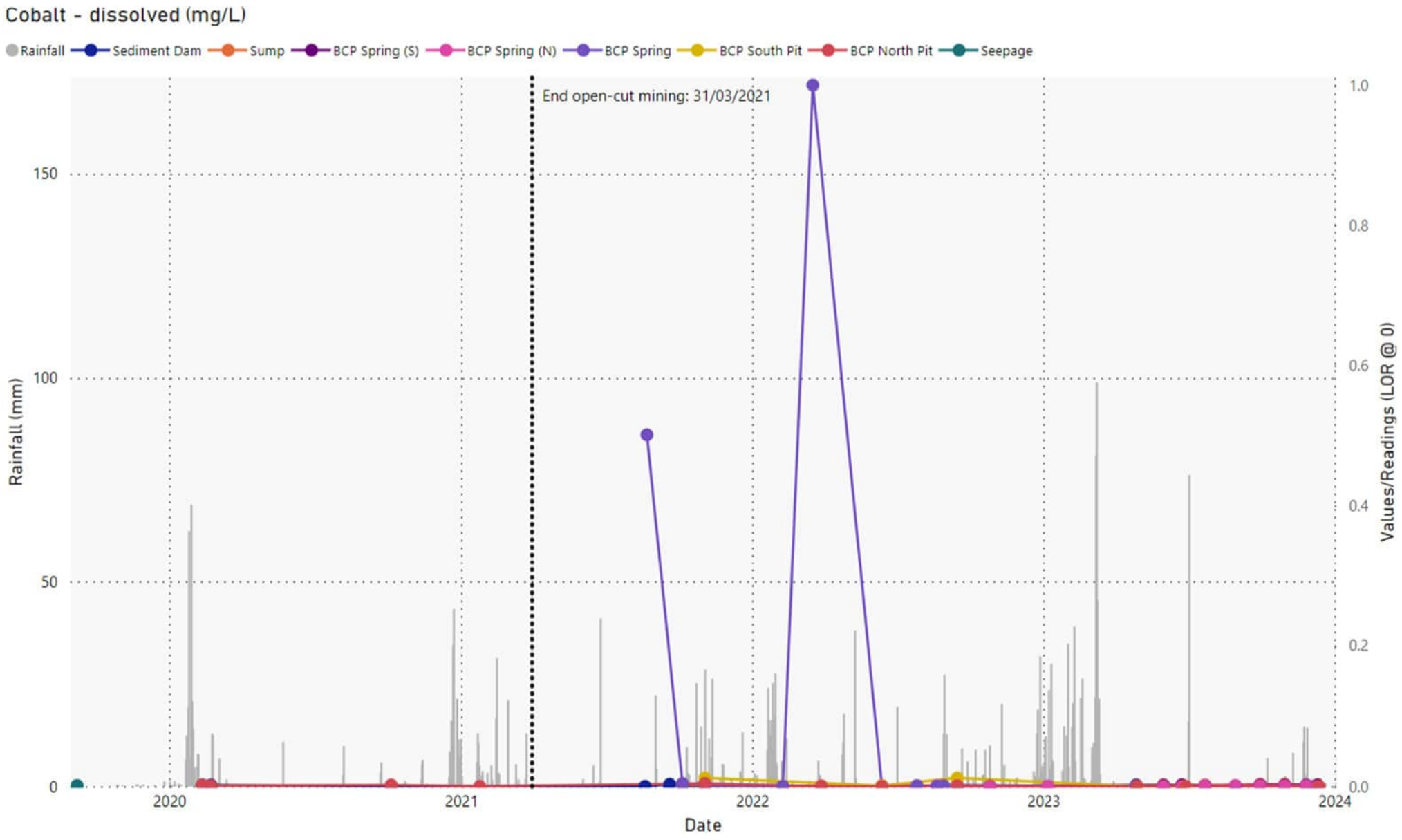

Sulfate (as SO4)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
500
1,000
1,500
2,000
2020
2021
2022
2023
2024

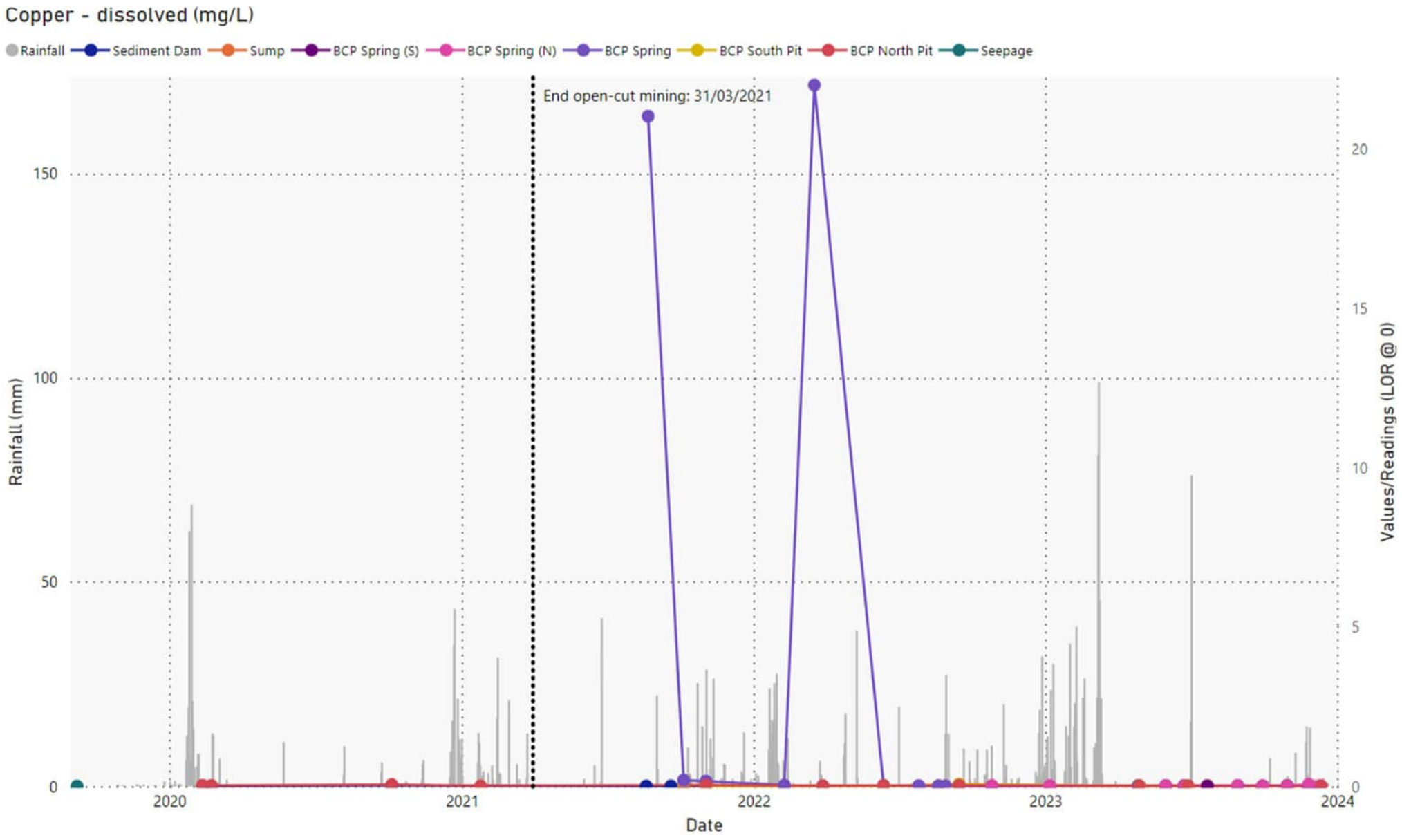

Bicarbonate Alkalinity as CaCO3 (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
500
1,000
1,500
2020
2021
2022
2023
2024

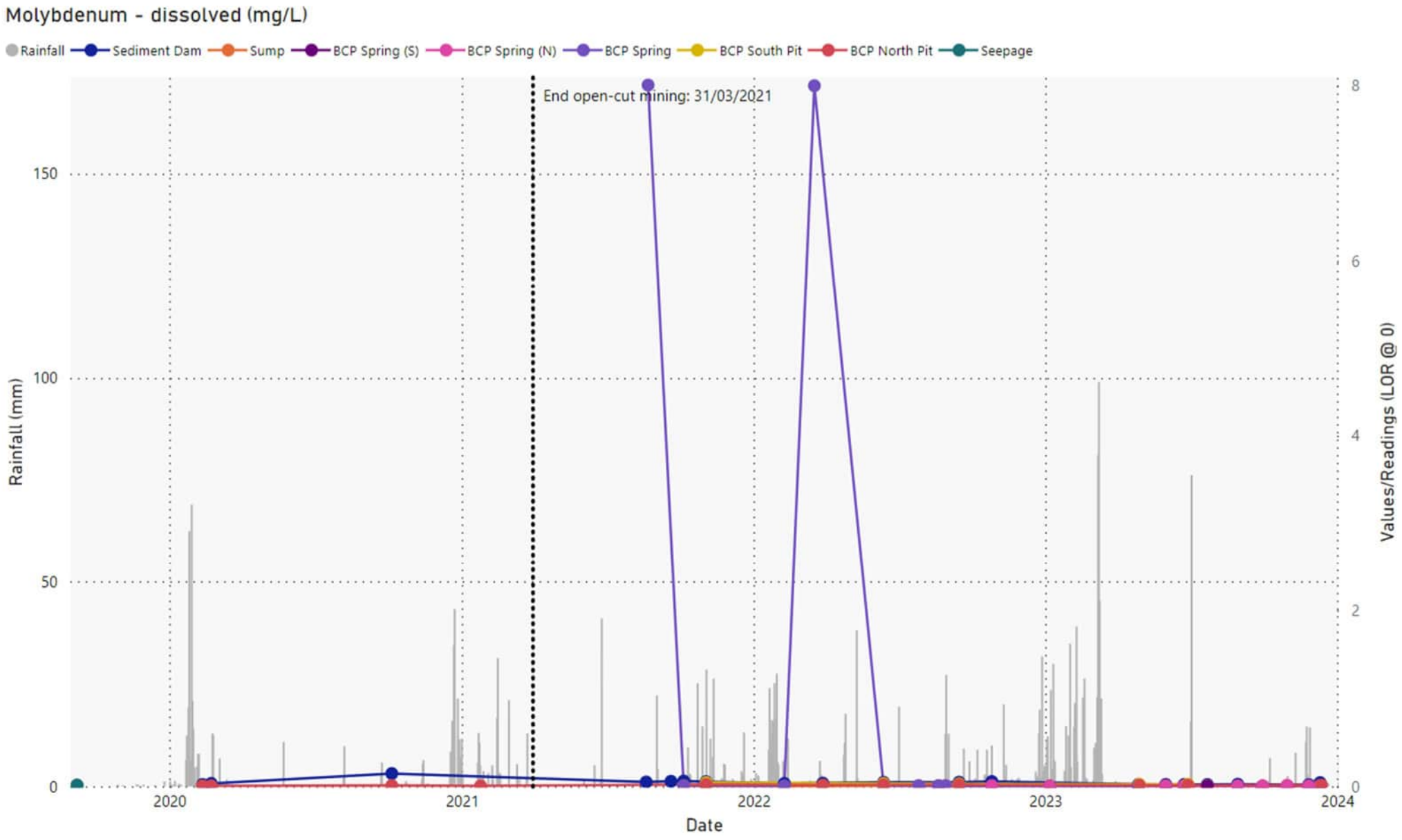

Arsenic - dissolved (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
2
4
6
8
10
12
2020
2021
2022
2023
2024

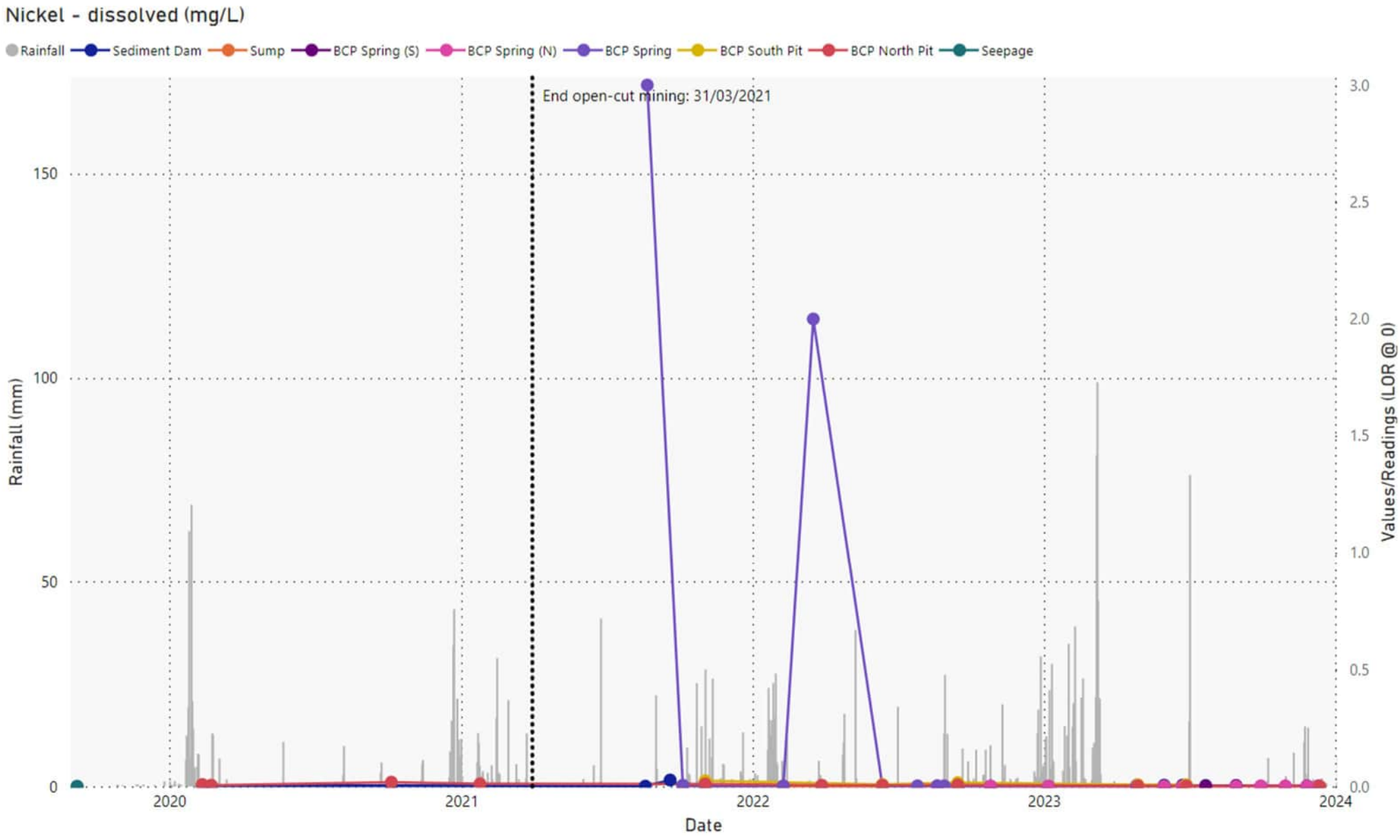

Barium - dissolved (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.05
0.10
0.15
2020
2021
2022
2023
2024

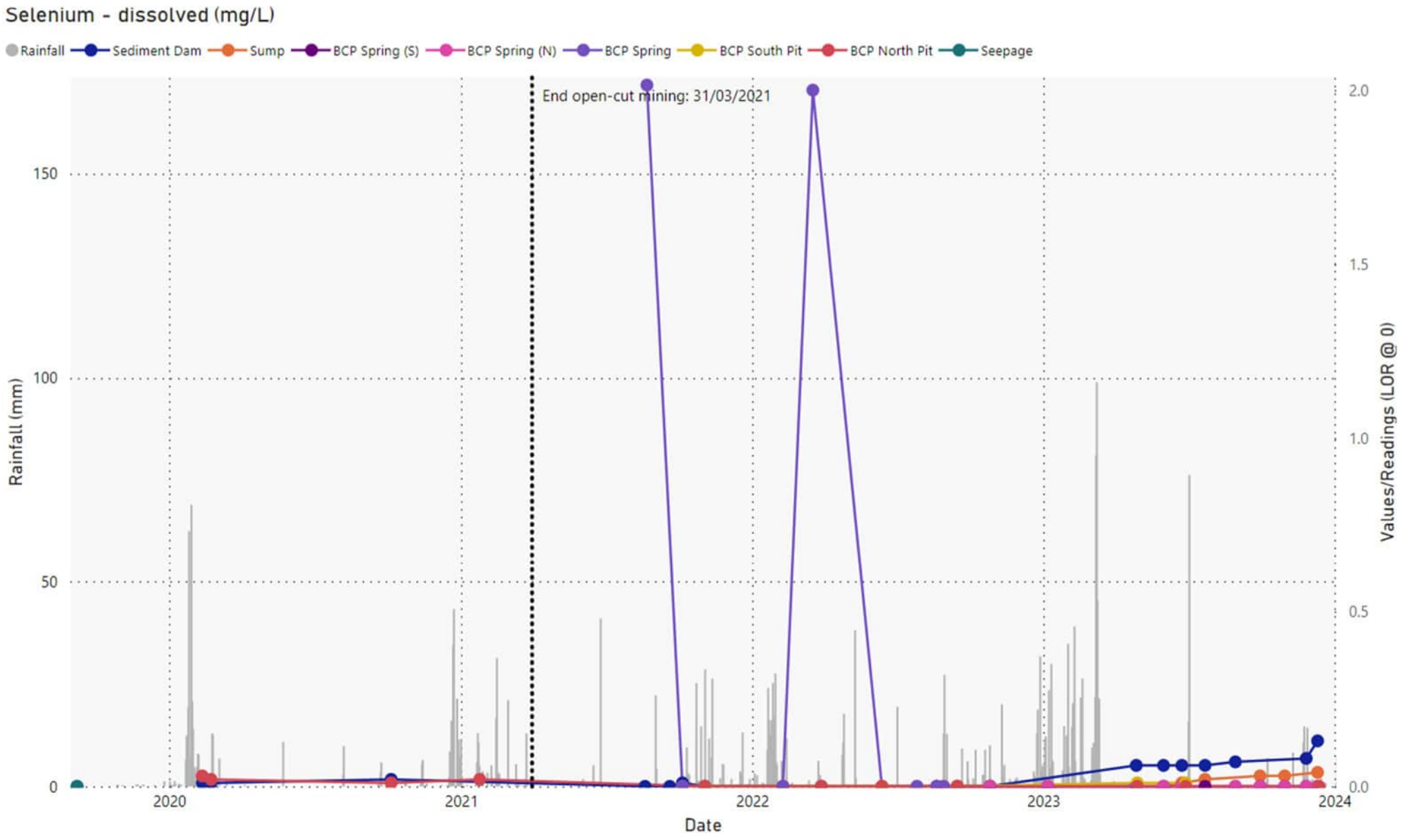

Chromium - dissolved (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
0.002
0.001
0.000
Values/Readings (LOR @ 0)
2020
2021
2022
2023
2024
Date

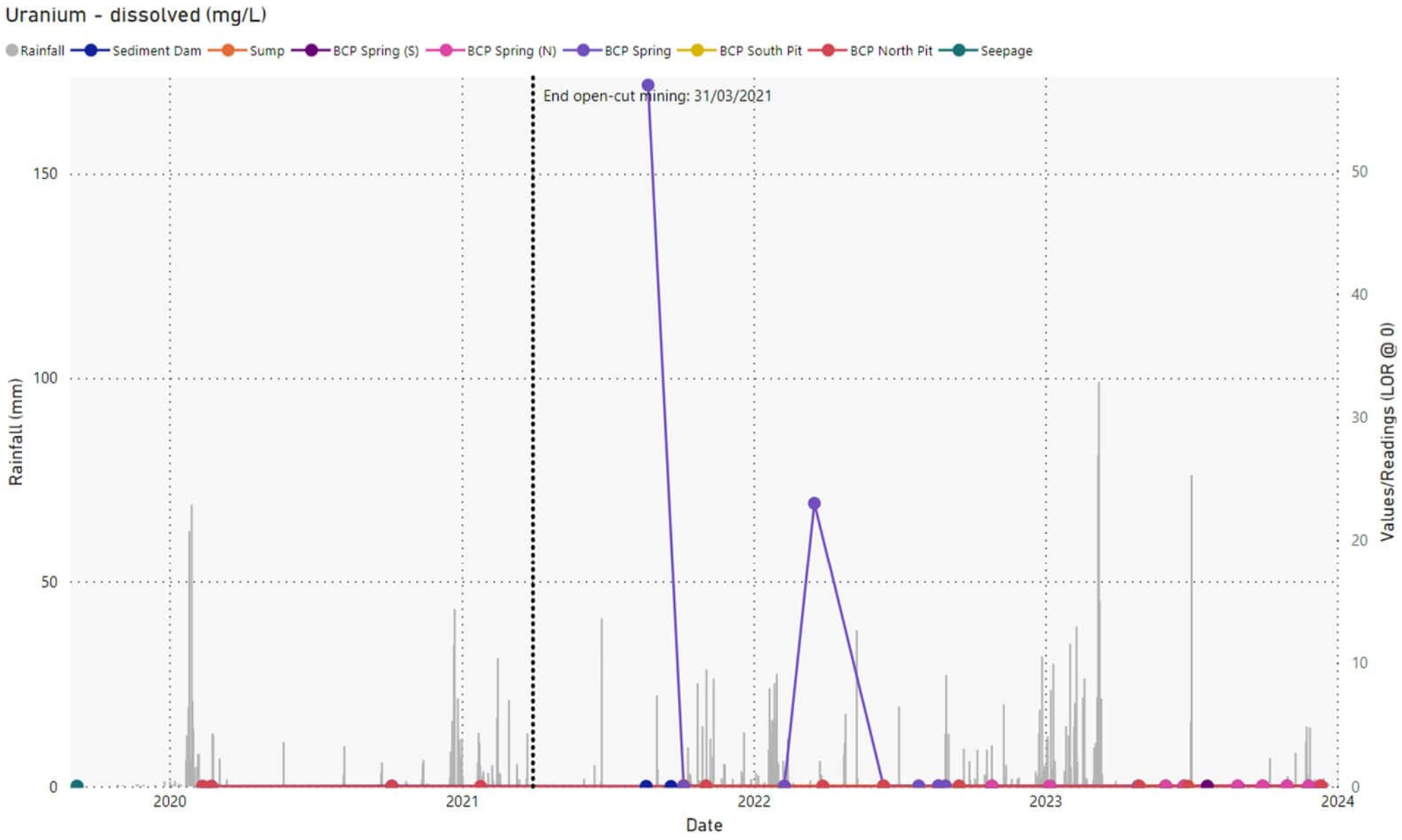

Cobalt - dissolved (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.0
0.2
0.4
0.6
0.8
1.0
2020
2021
2022
2023
2024


Copper - dissolved (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
5
10
15
20
2020
2021
2022
2023
2024


Molybdenum - dissolved (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
2
4
6
8
2020
2021
2022
2023
2024

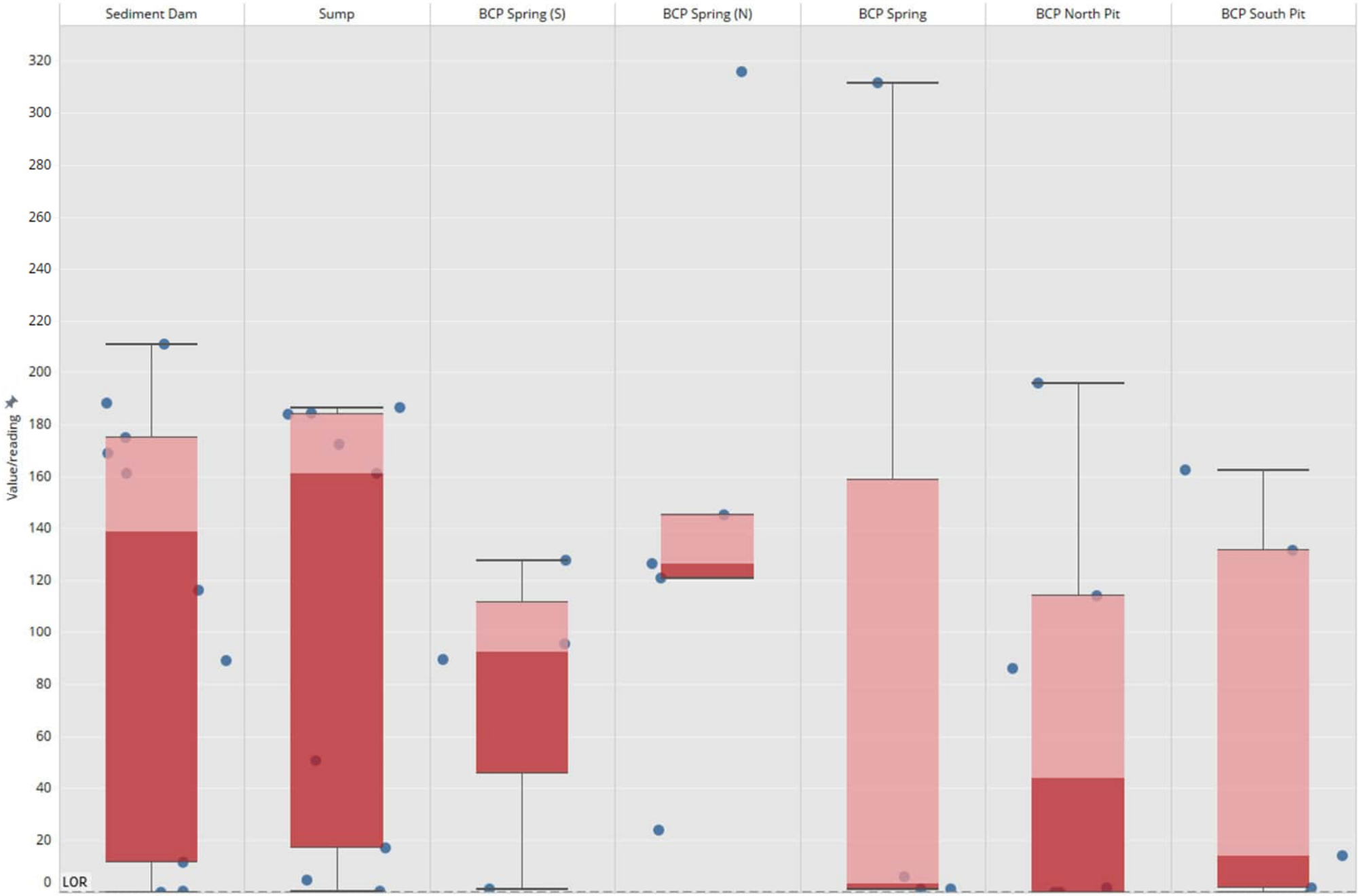

Nickel - dissolved (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.0
0.5
1.0
1.5
2.0
2.5
3.0
2020
2021
2022
2023
2024


Selenium - dissolved (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.0
0.5
1.0
1.5
2.0
2020
2021
2022
2023
2024

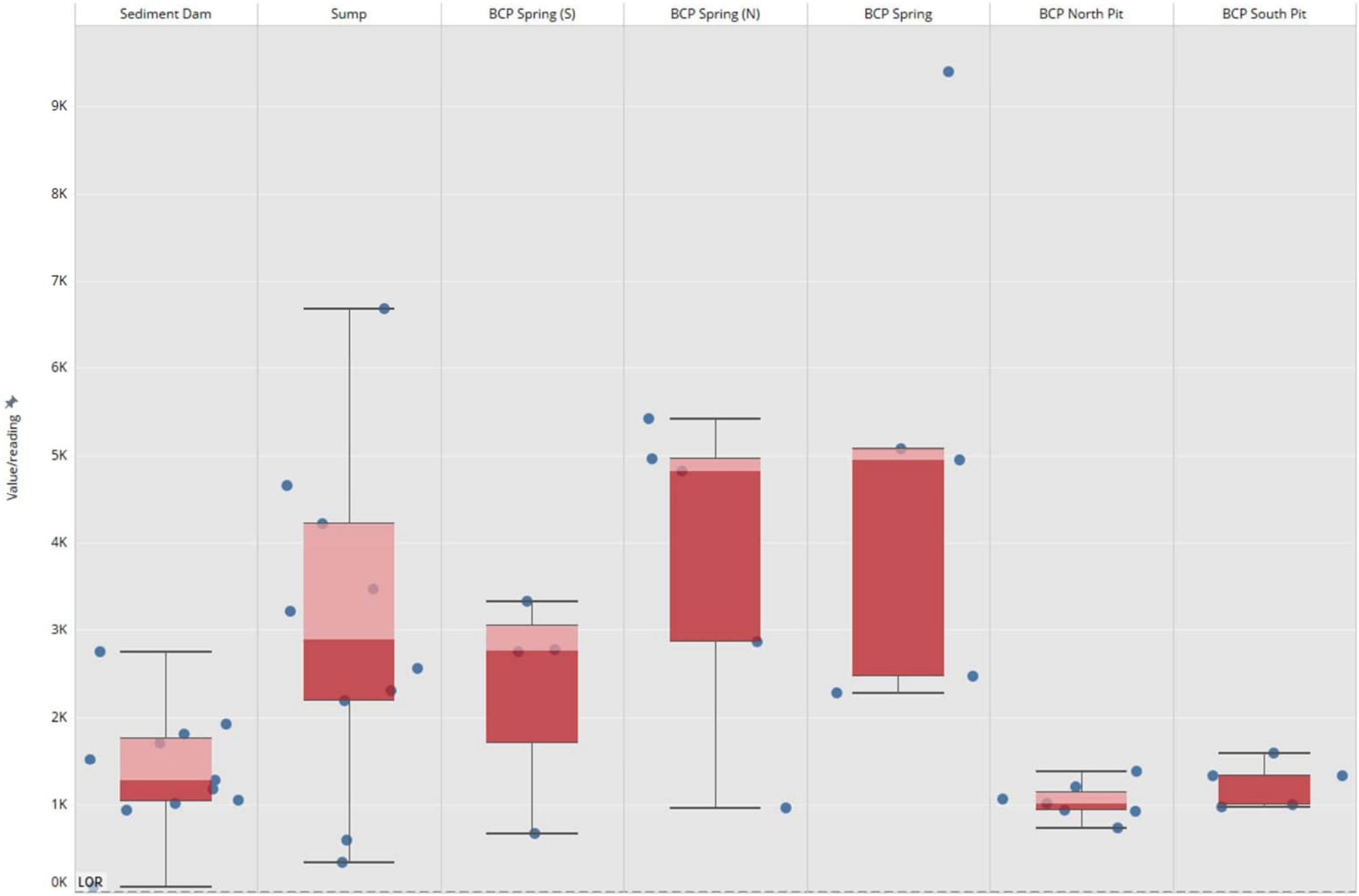

Uranium - dissolved (mg/L)
Rainfall
Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP South Pit
BCP North Pit
Seepage
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
10
20
30
40
50
2020
2021
2022
2023
2024

F.3 Water quality box & whisker plots

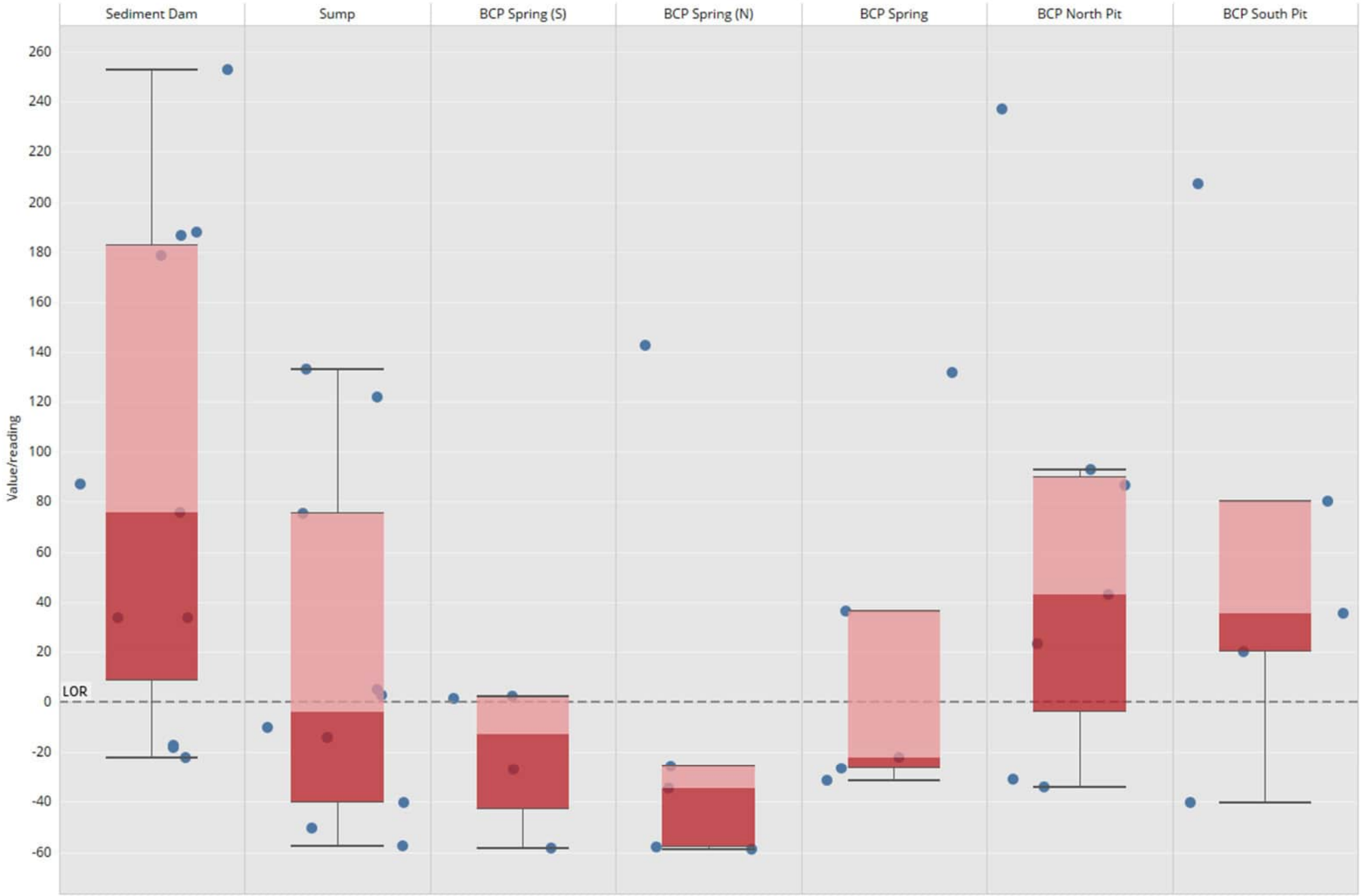
Dissolved Oxygen (field) (% sat)



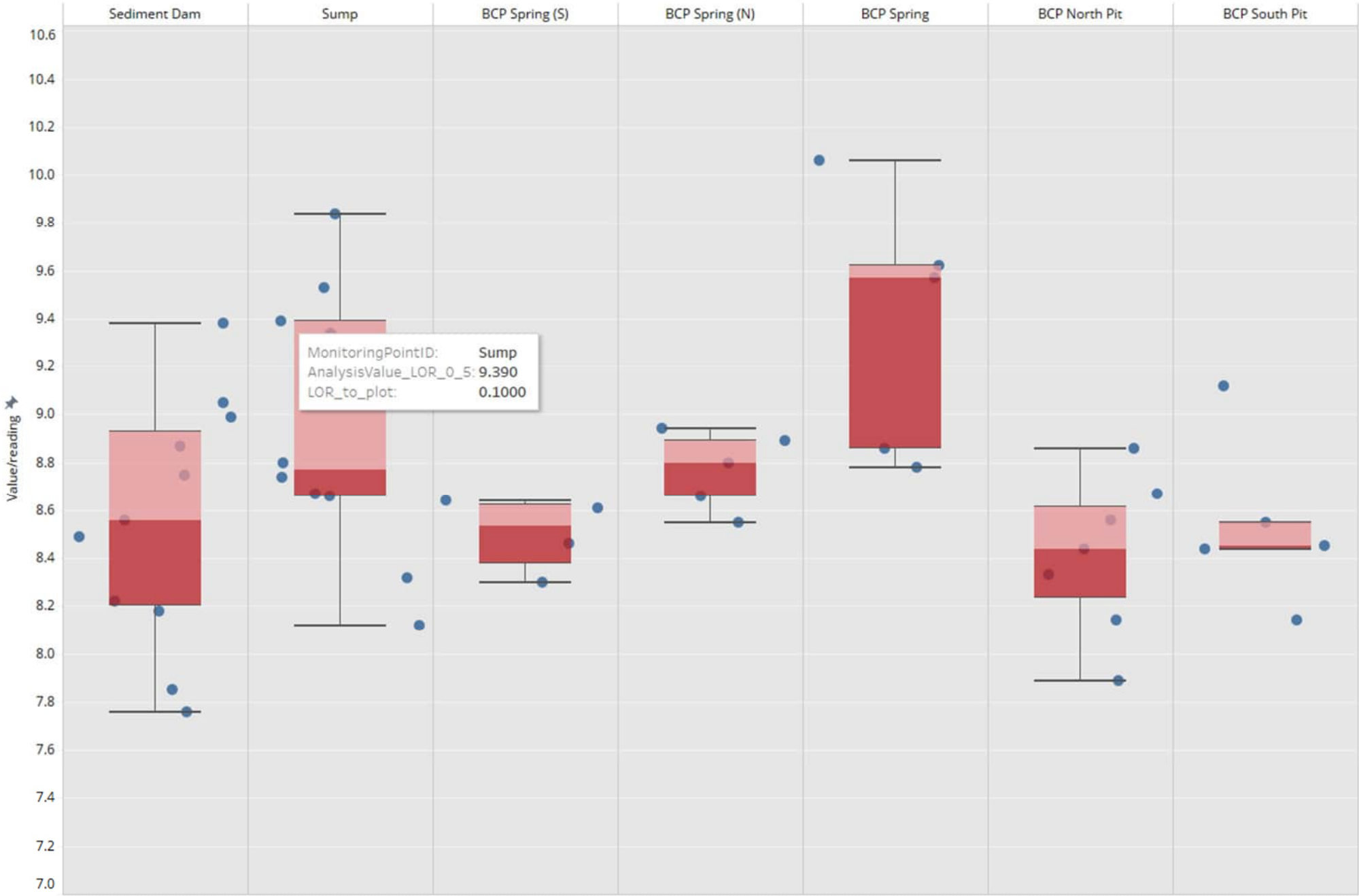
Electrical Conductivity (field) (µS/cm)



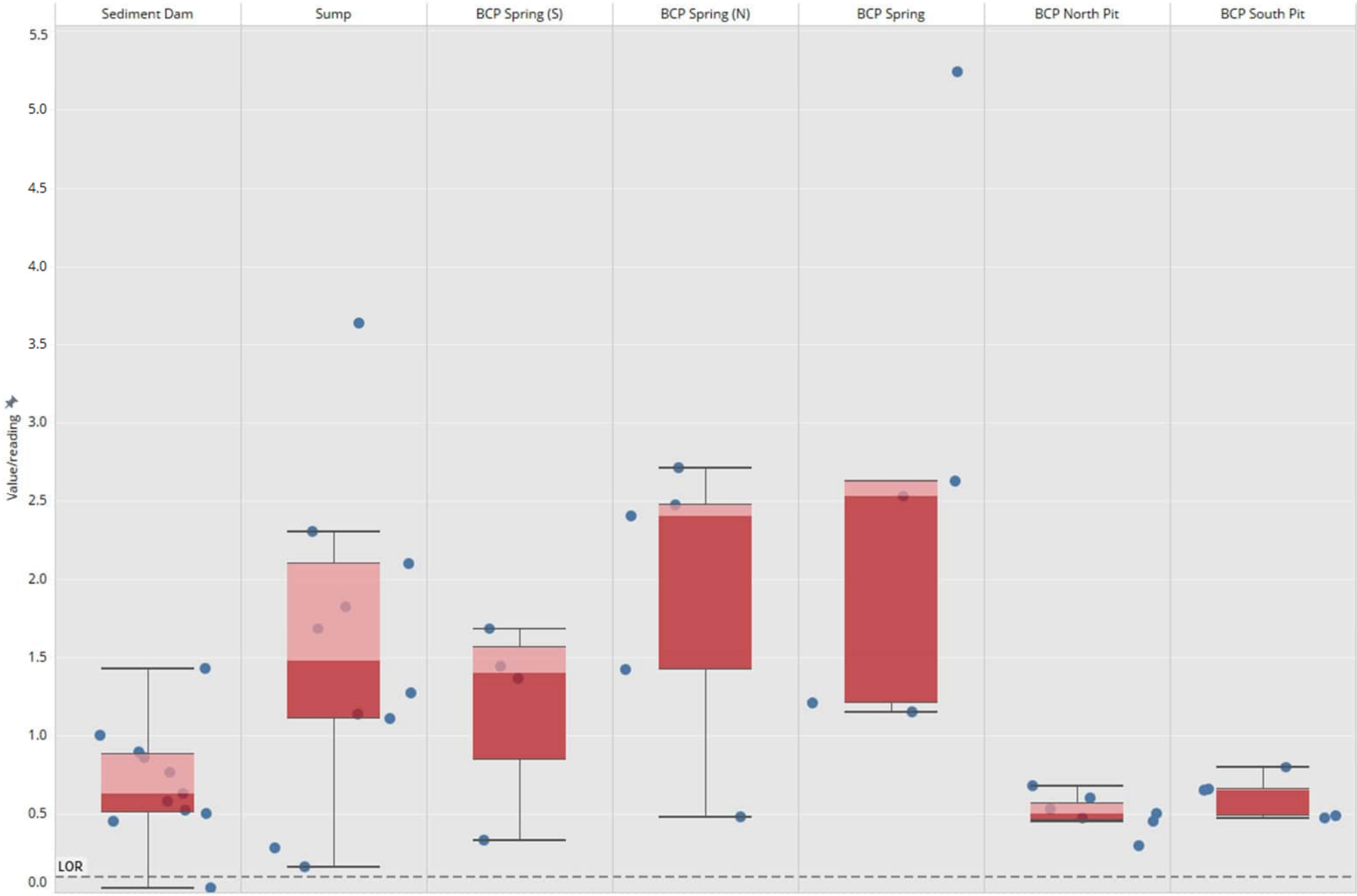
ORP (field) (mV)


Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP North Pit
BCP South Pit
Value/reading
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
LOR

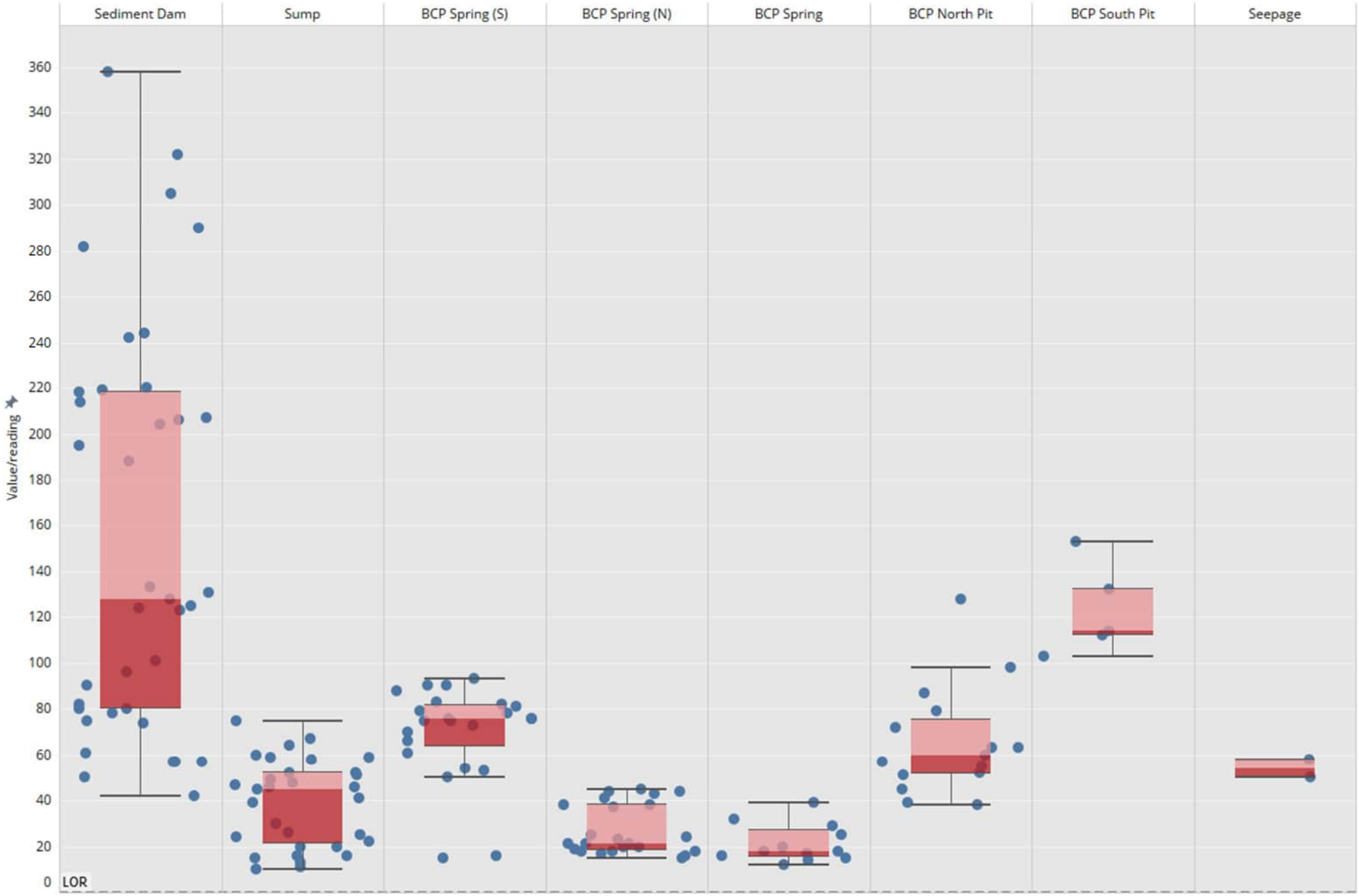
pH (field)


Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP North Pit
BCP South Pit
Value/reading
10.6
10.4
10.2
10.0
9.8
9.6
9.4
9.2
9.0
8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
MonitoringPointID: Sump
AnalysisValue_LOR_0_5: 9.390
LOR_to_plot: 0.1000

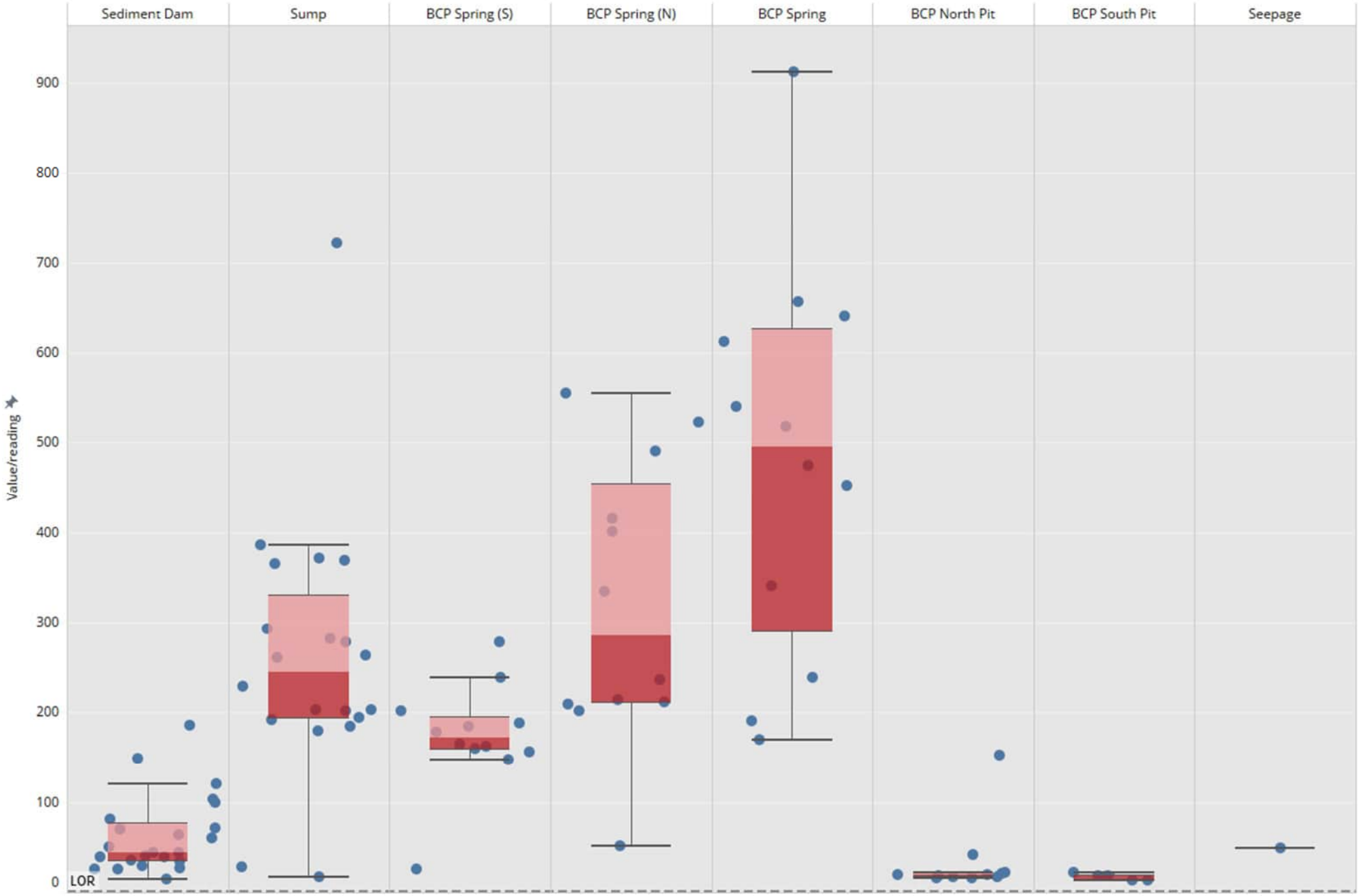
Salinity (field) (PSU)



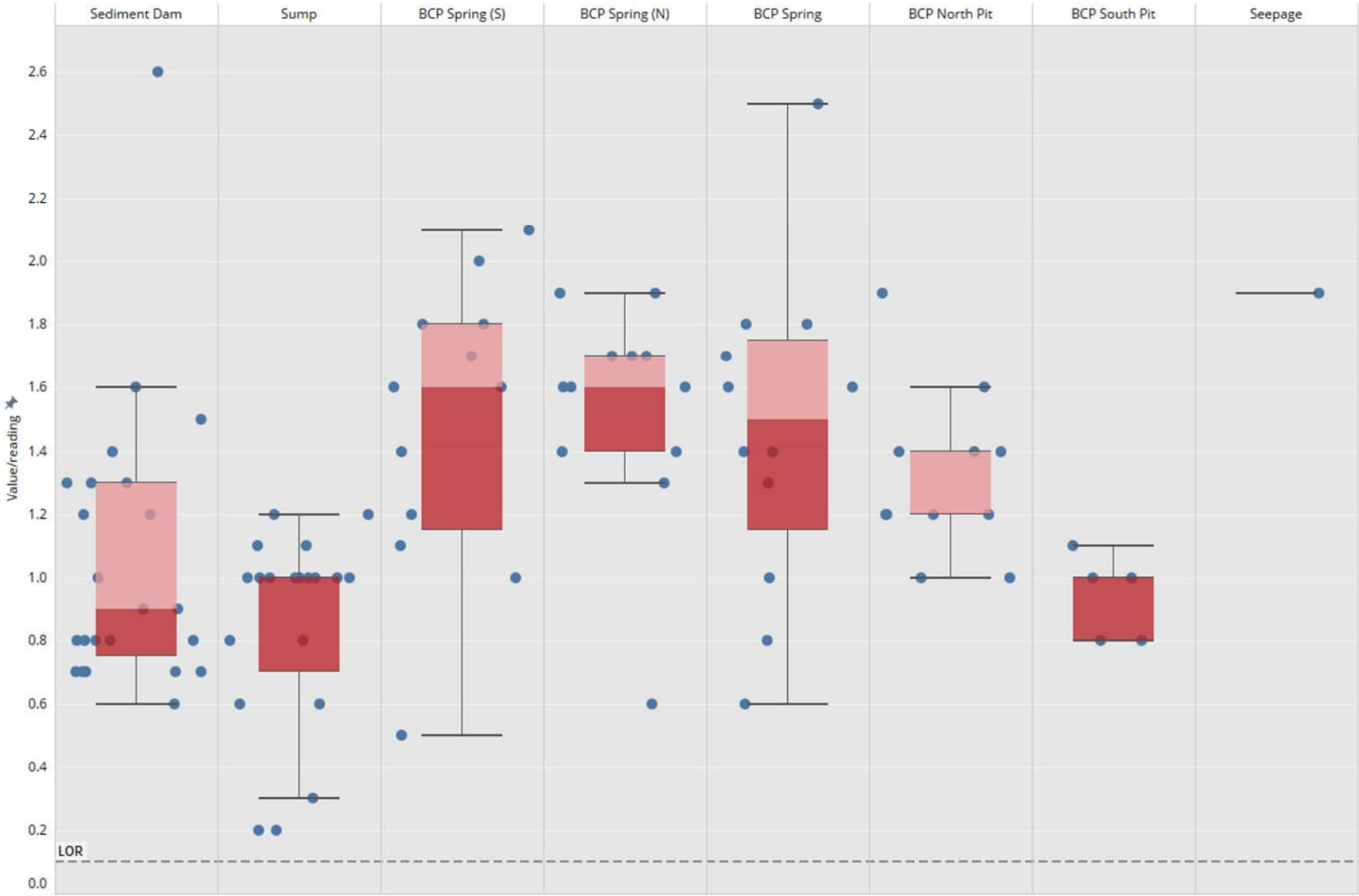
Calcium (mg/L)


Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP North Pit
BCP South Pit
Seepage
Value/reading
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
LOR

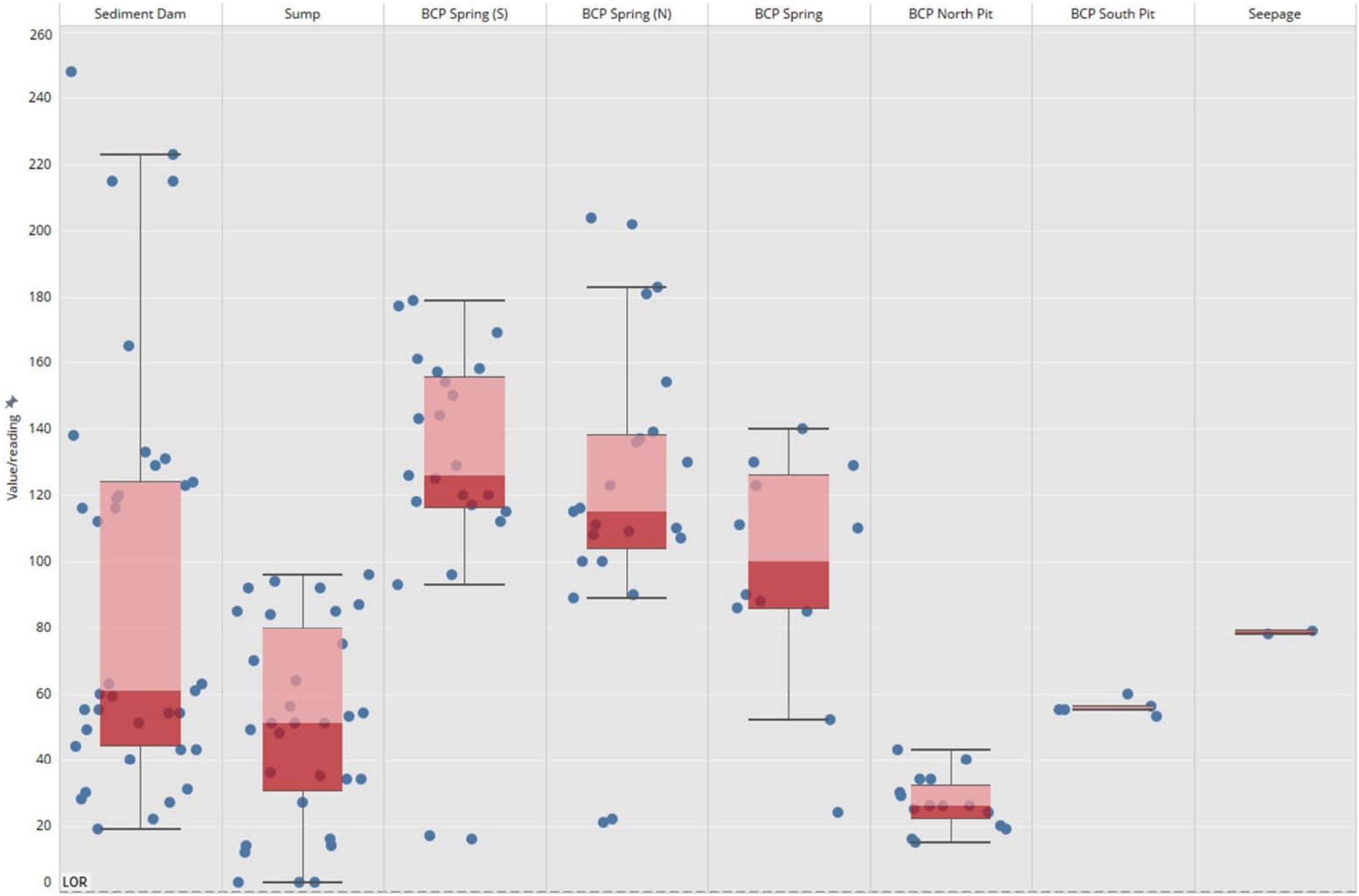
Chloride (mg/L)



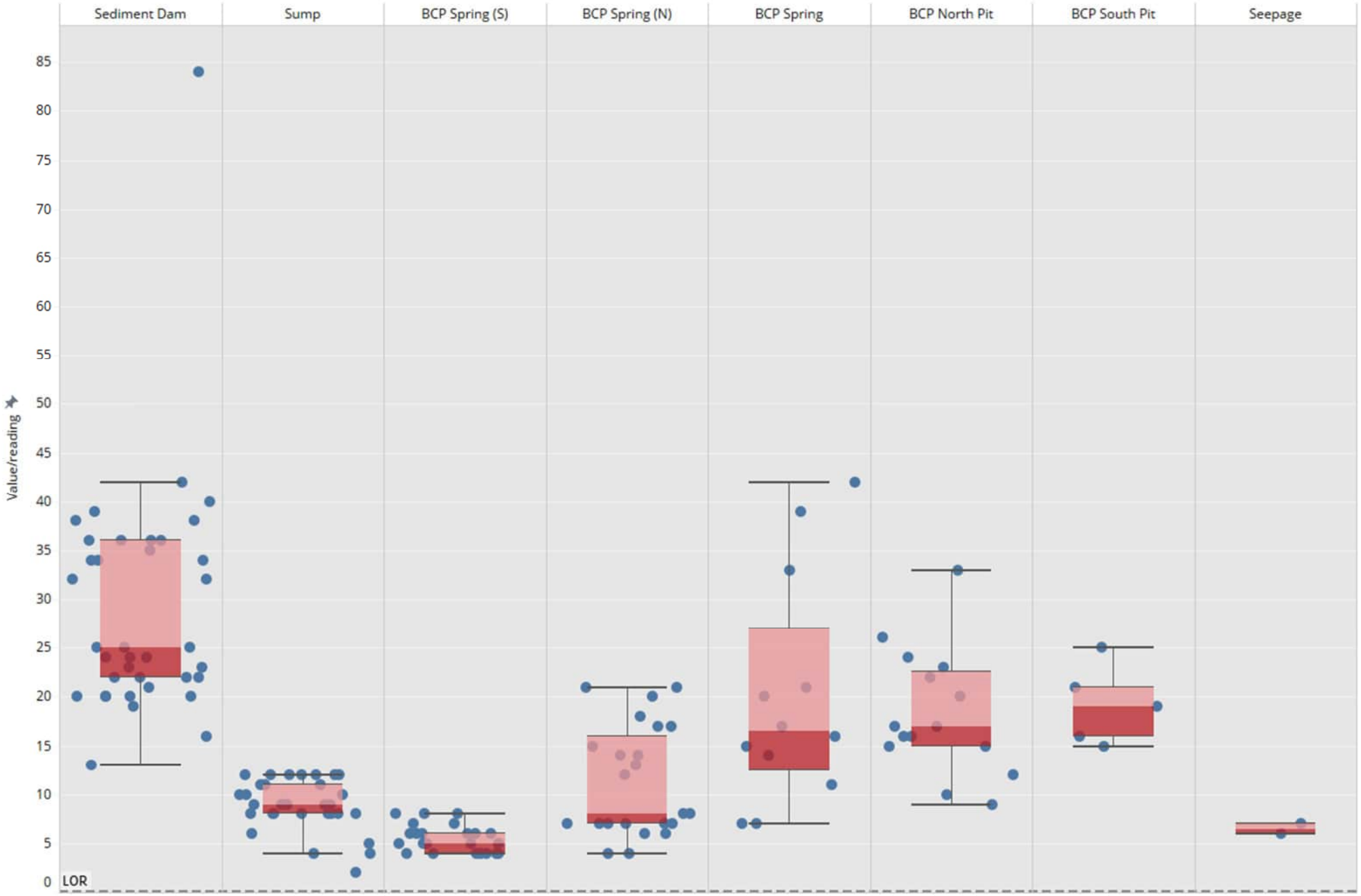
Fluoride (mg/L)



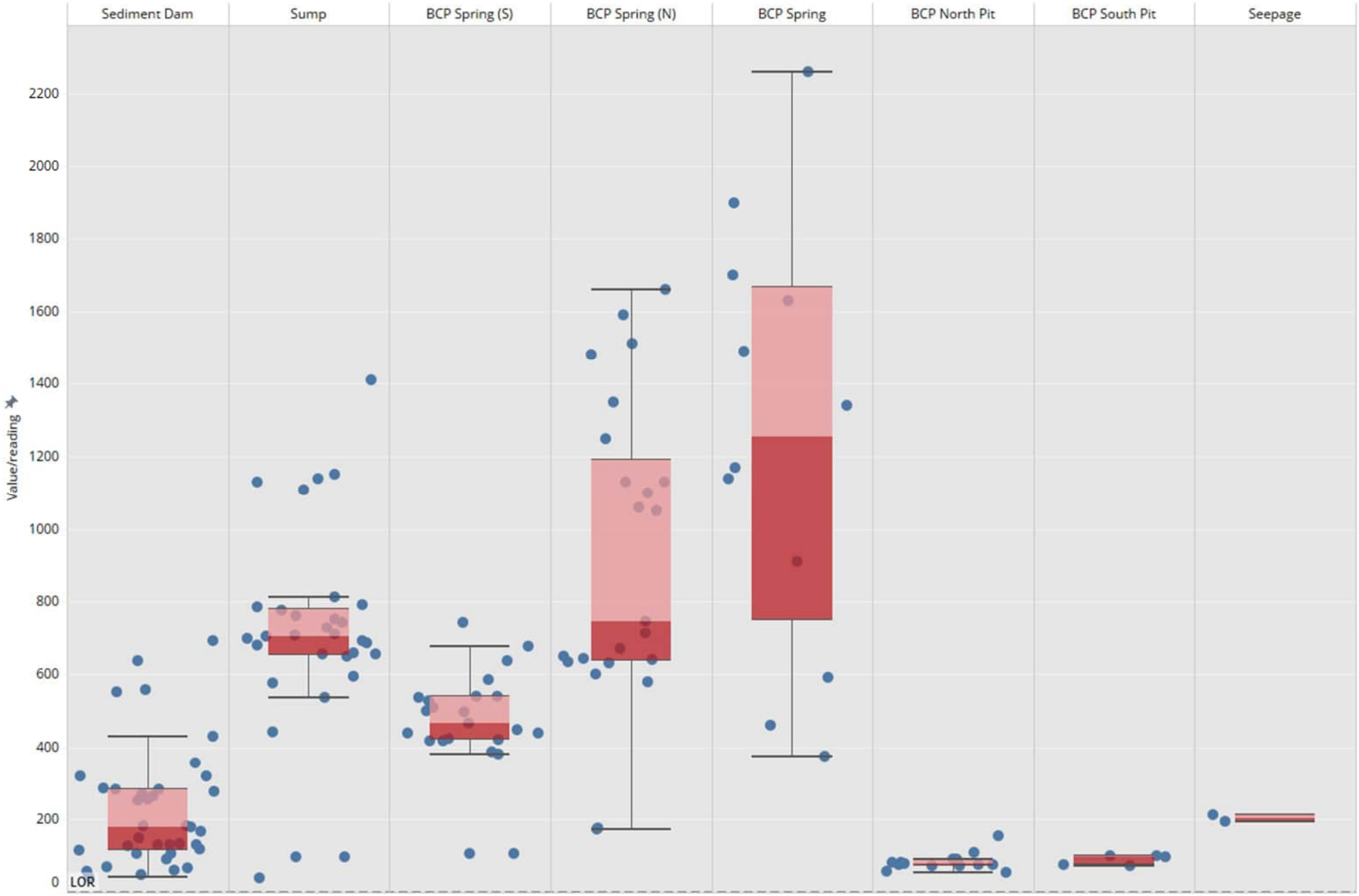
Magnesium (mg/L)



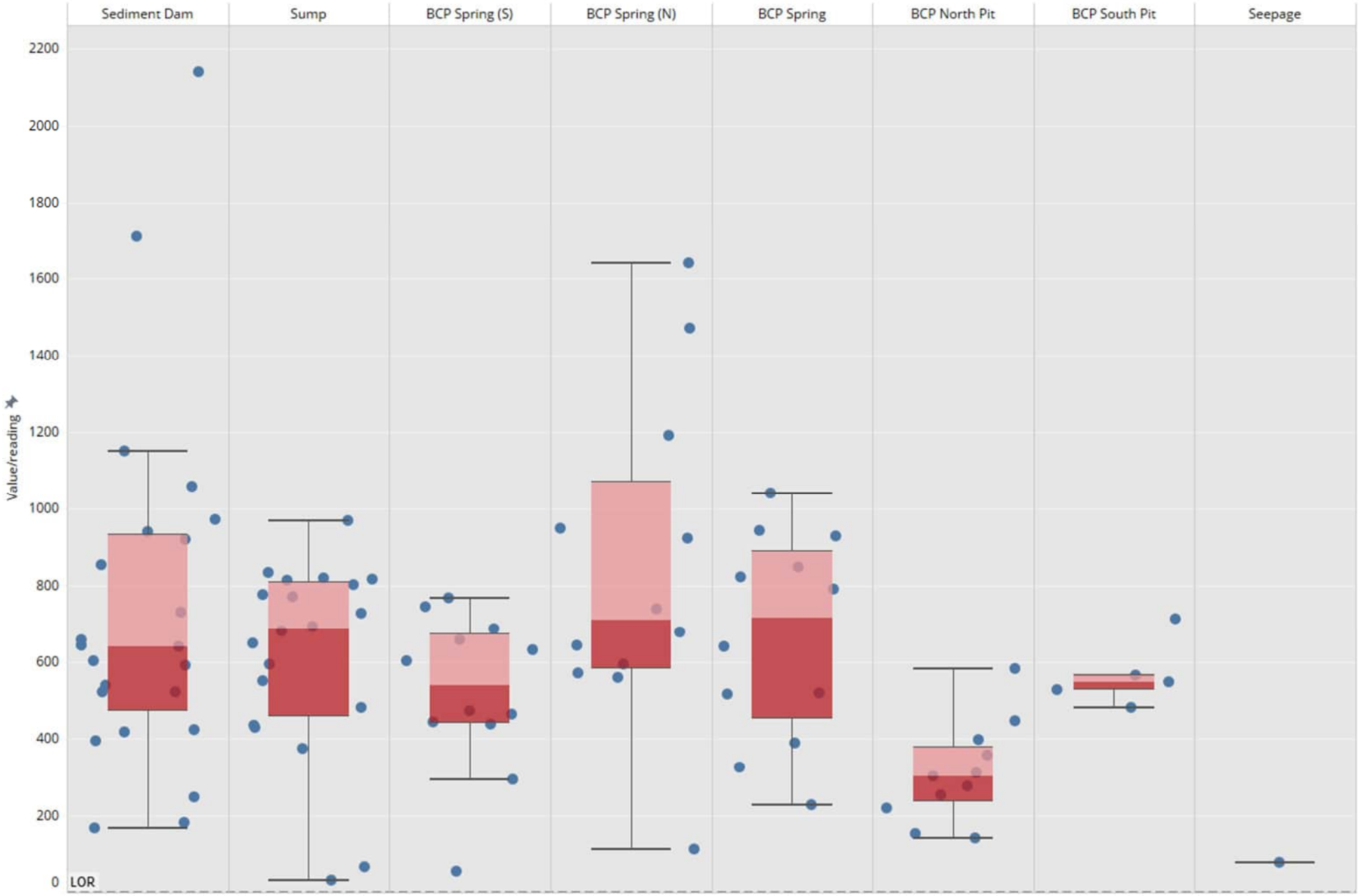
Potassium (mg/L)



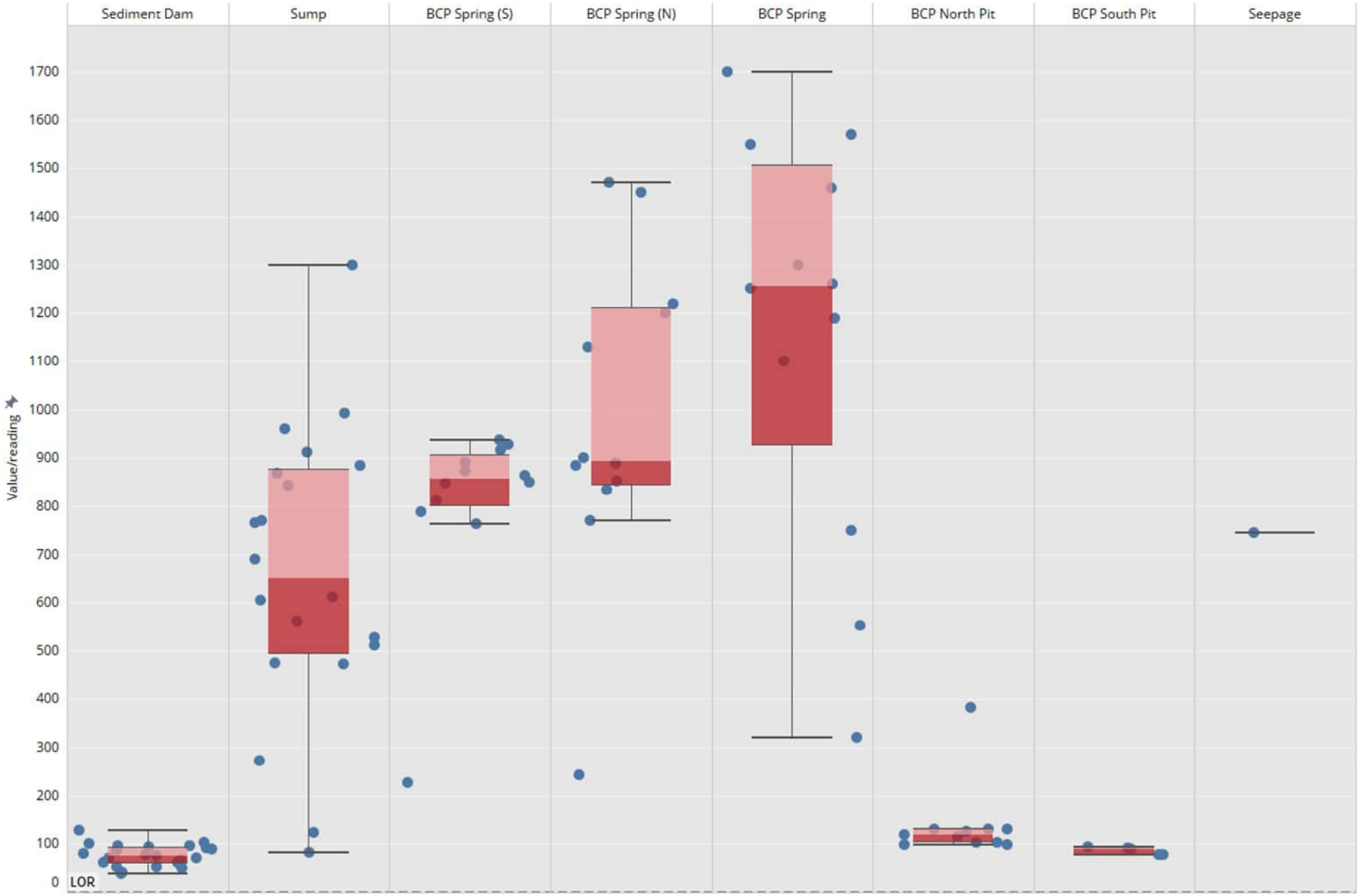
Sodium (mg/L)


Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP North Pit
BCP South Pit
Seepage
Value/reading
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
LOR

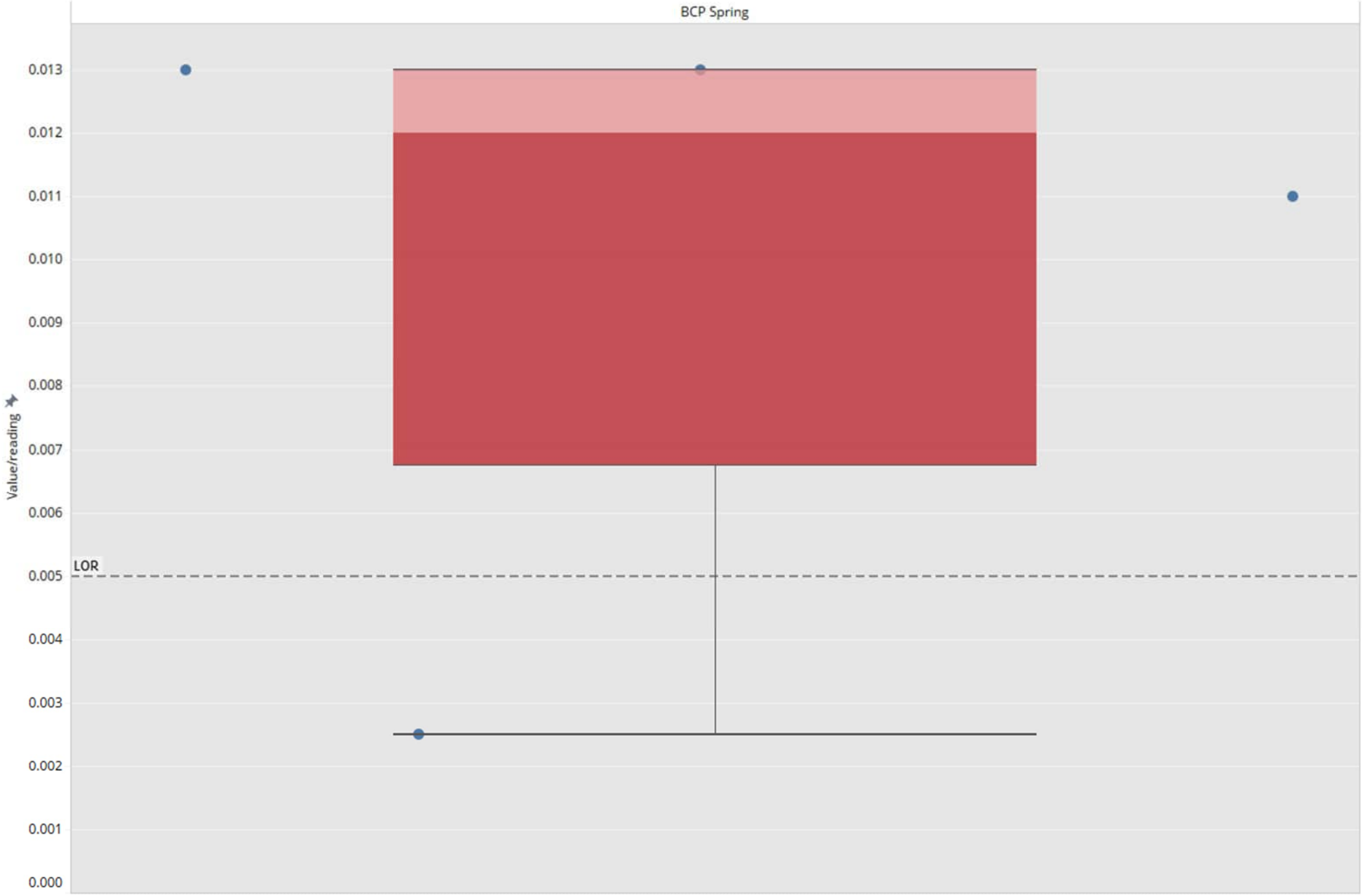
Sulfate (as SO4)



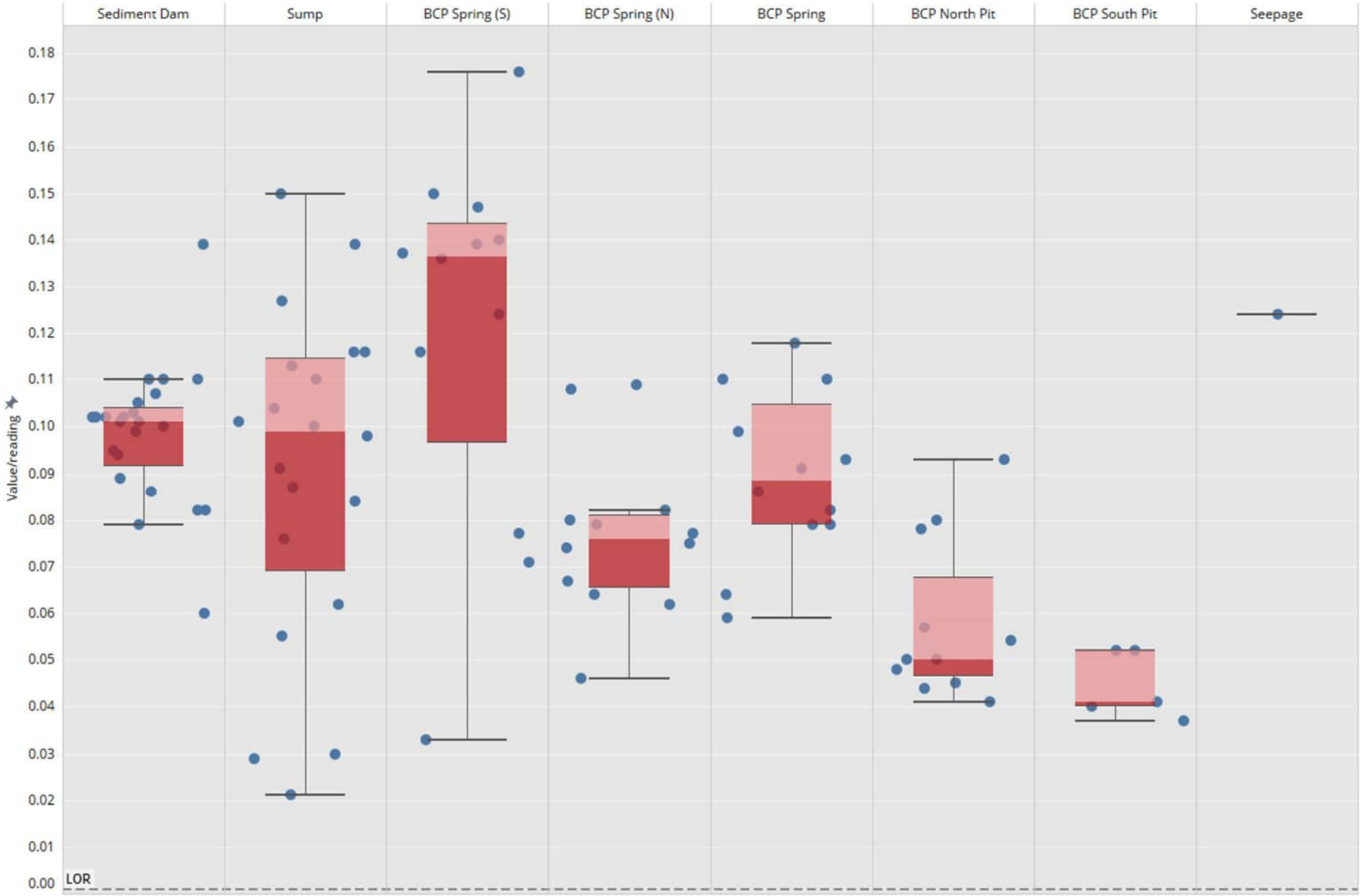
Bicarbonate Alkalinity as CaCO3 (mg/L)



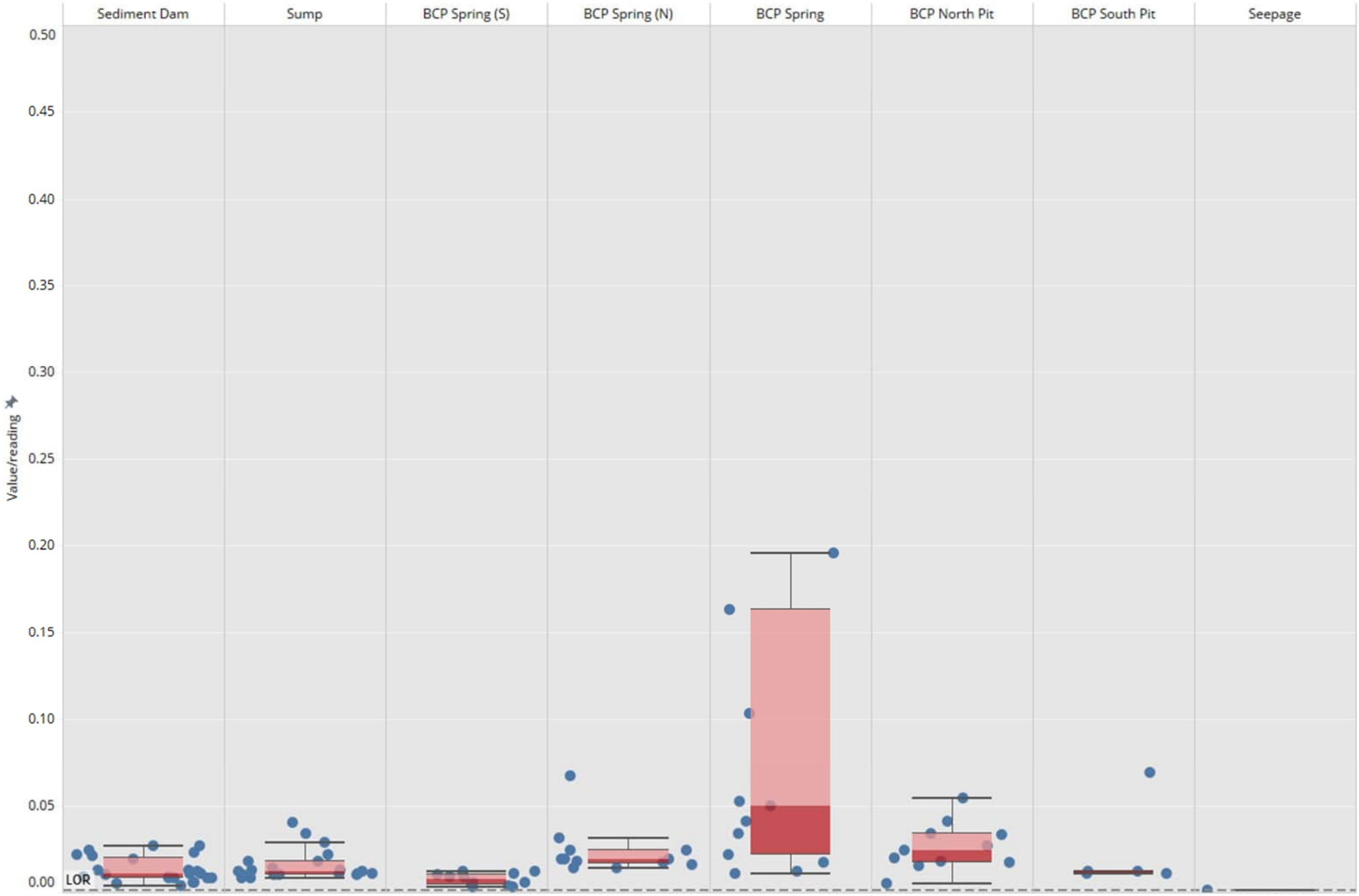
Aluminium - dissolved (mg/L)



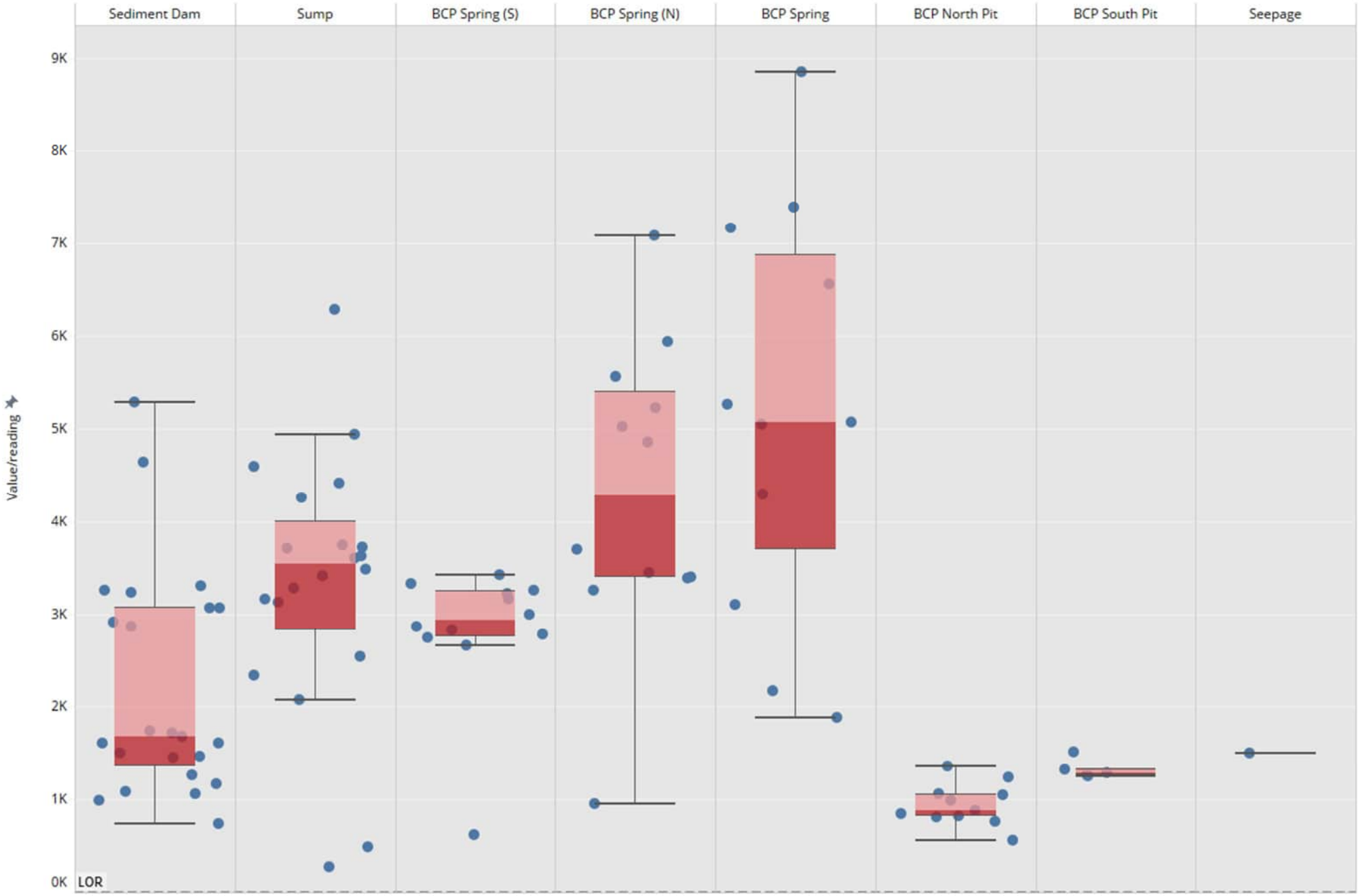
Barium - dissolved (mg/L)



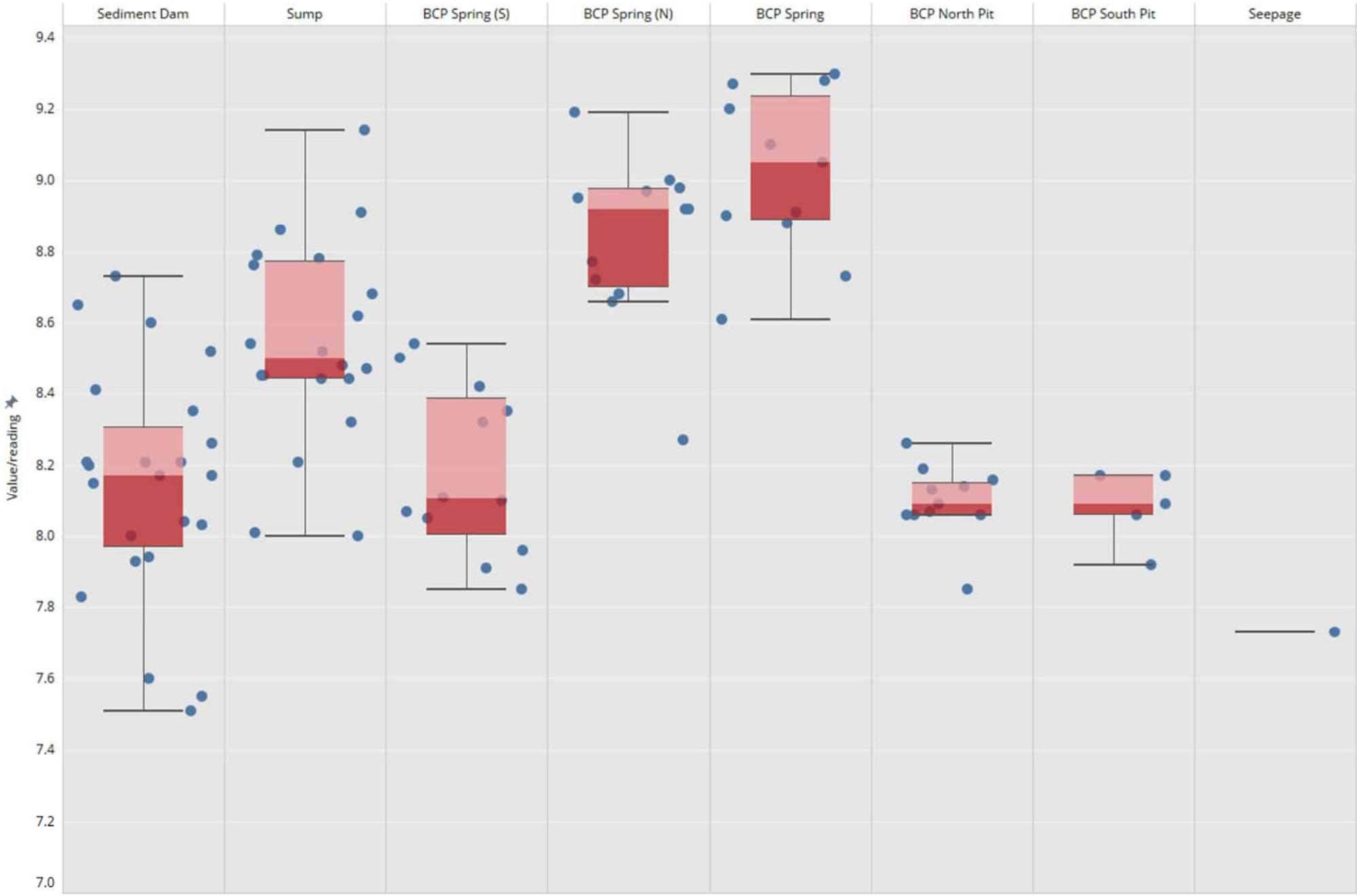
Copper - dissolved (mg/L)



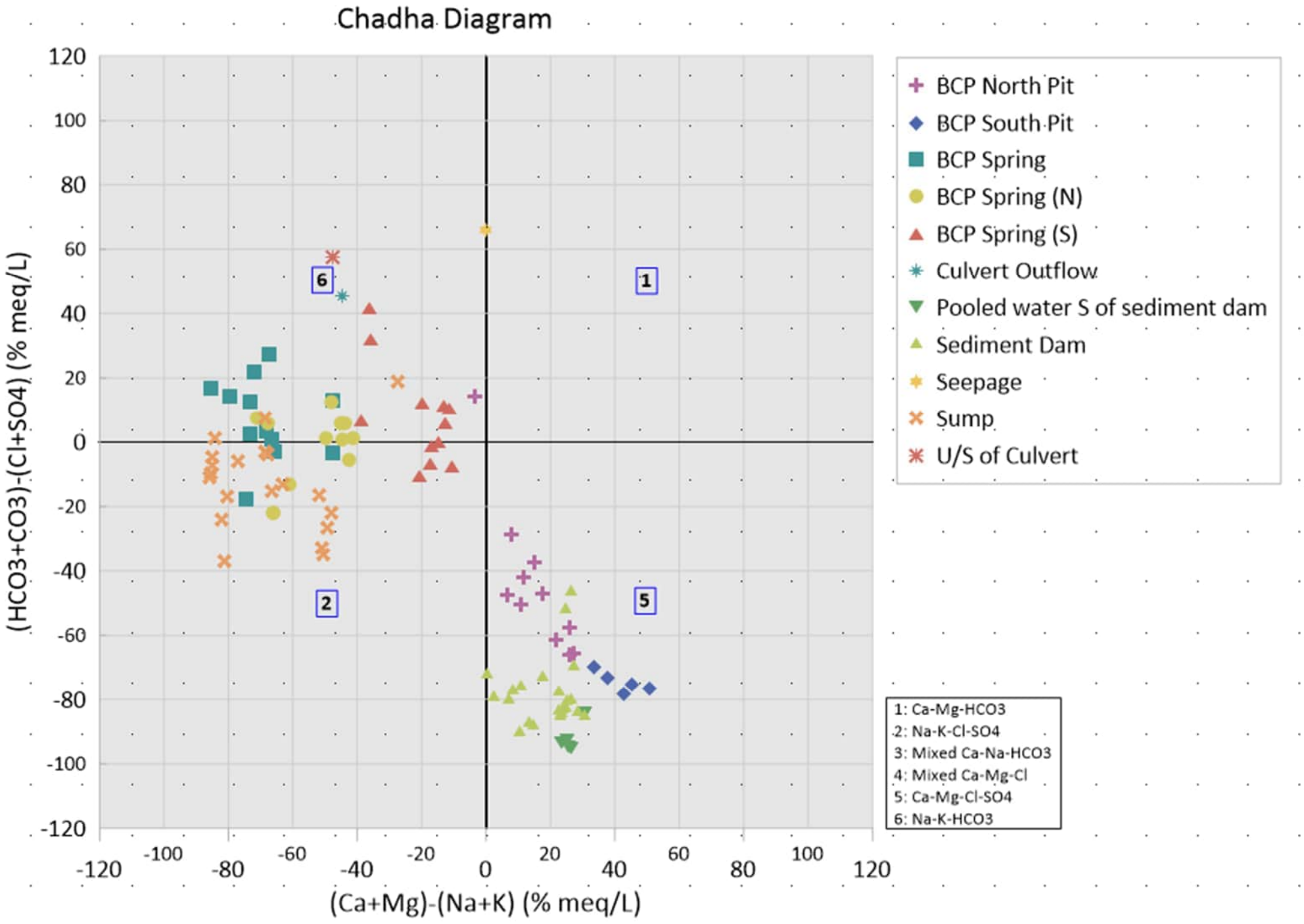
Electrical Conductivity (µS/cm)



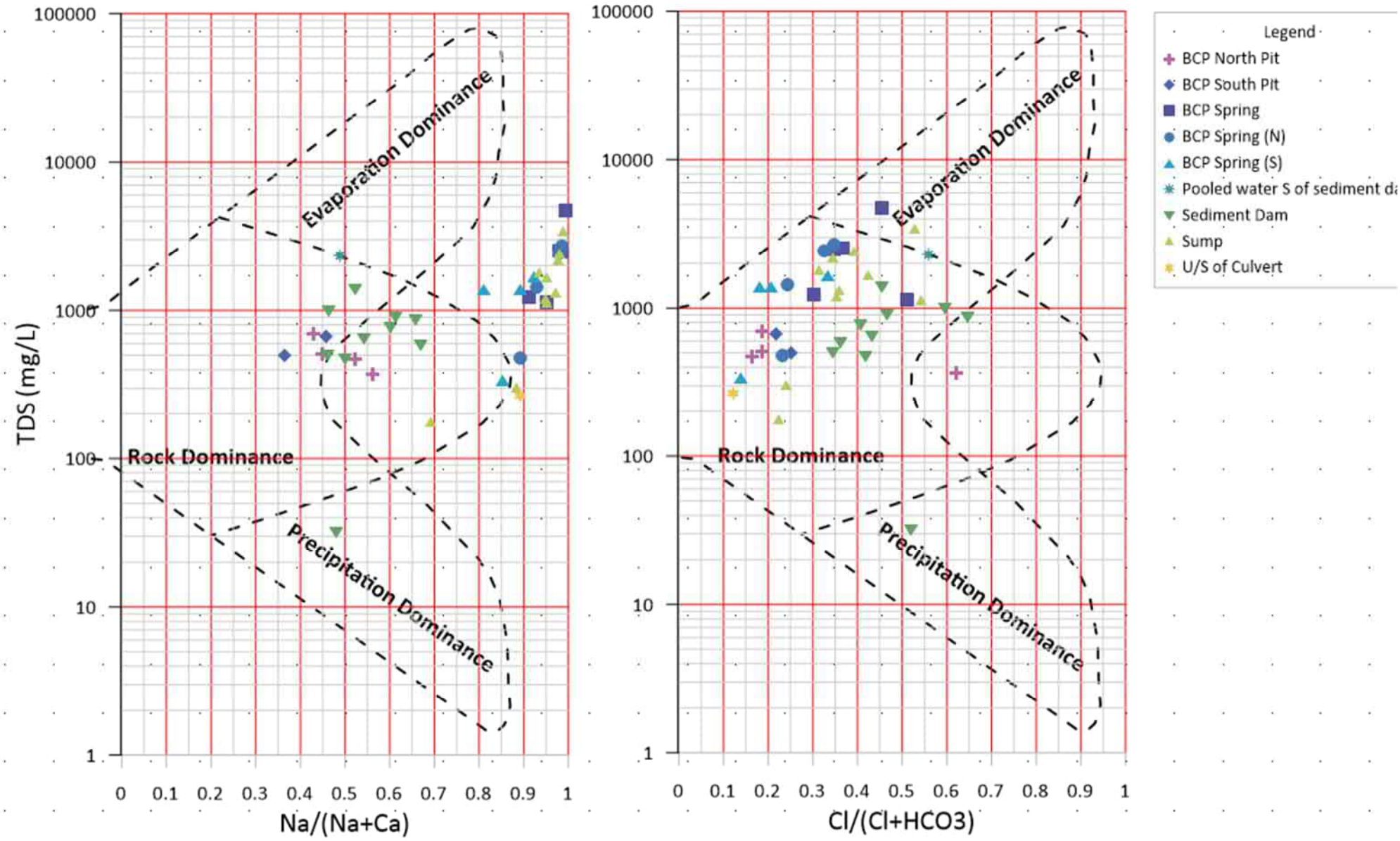
pH (lab)

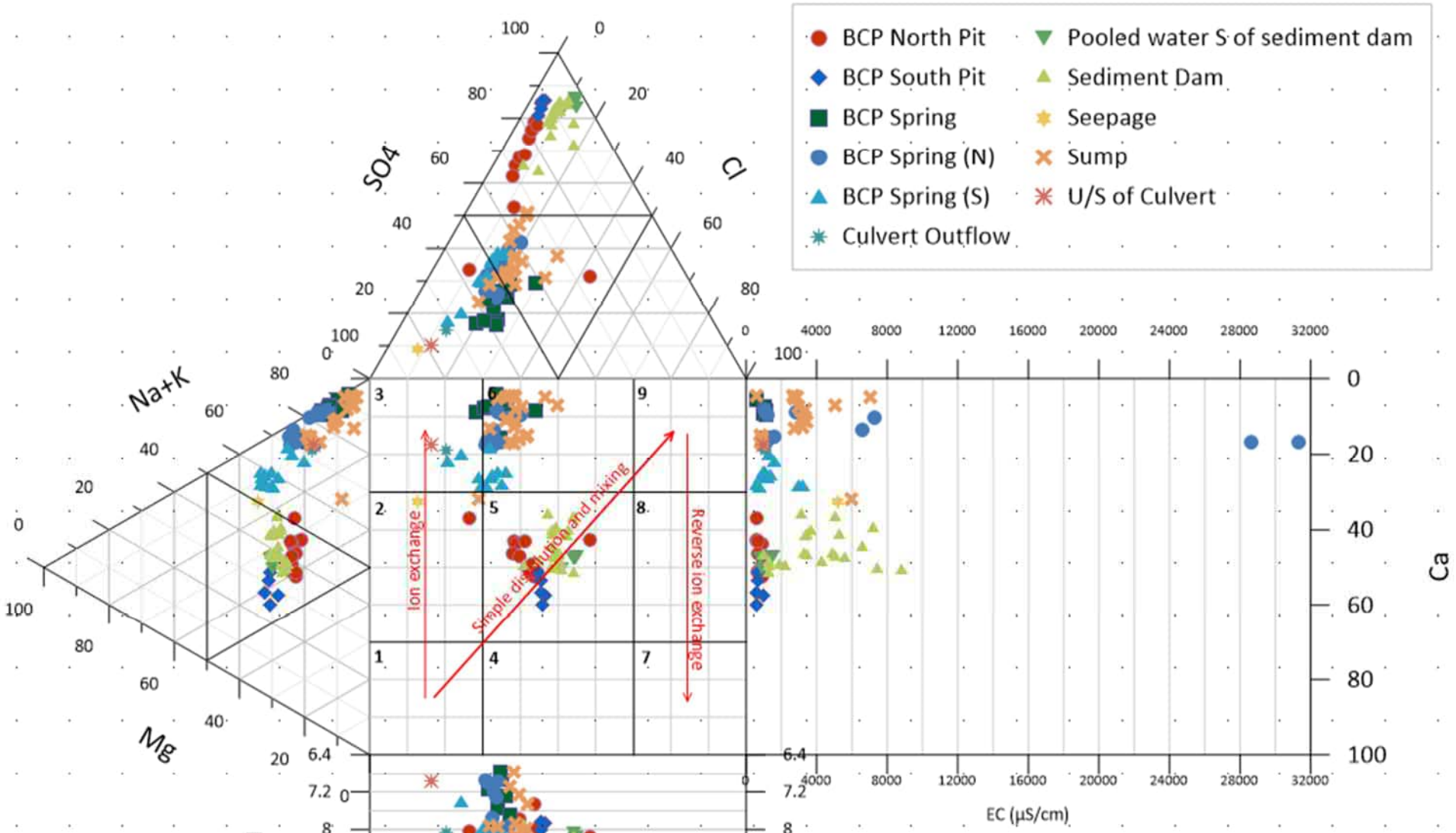

Sediment Dam
Sump
BCP Spring (S)
BCP Spring (N)
BCP Spring
BCP North Pit
BCP South Pit
Seepage
Value/reading
9.4
9.2
9.0
8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0

F.4 Hydrogeochemistry plots

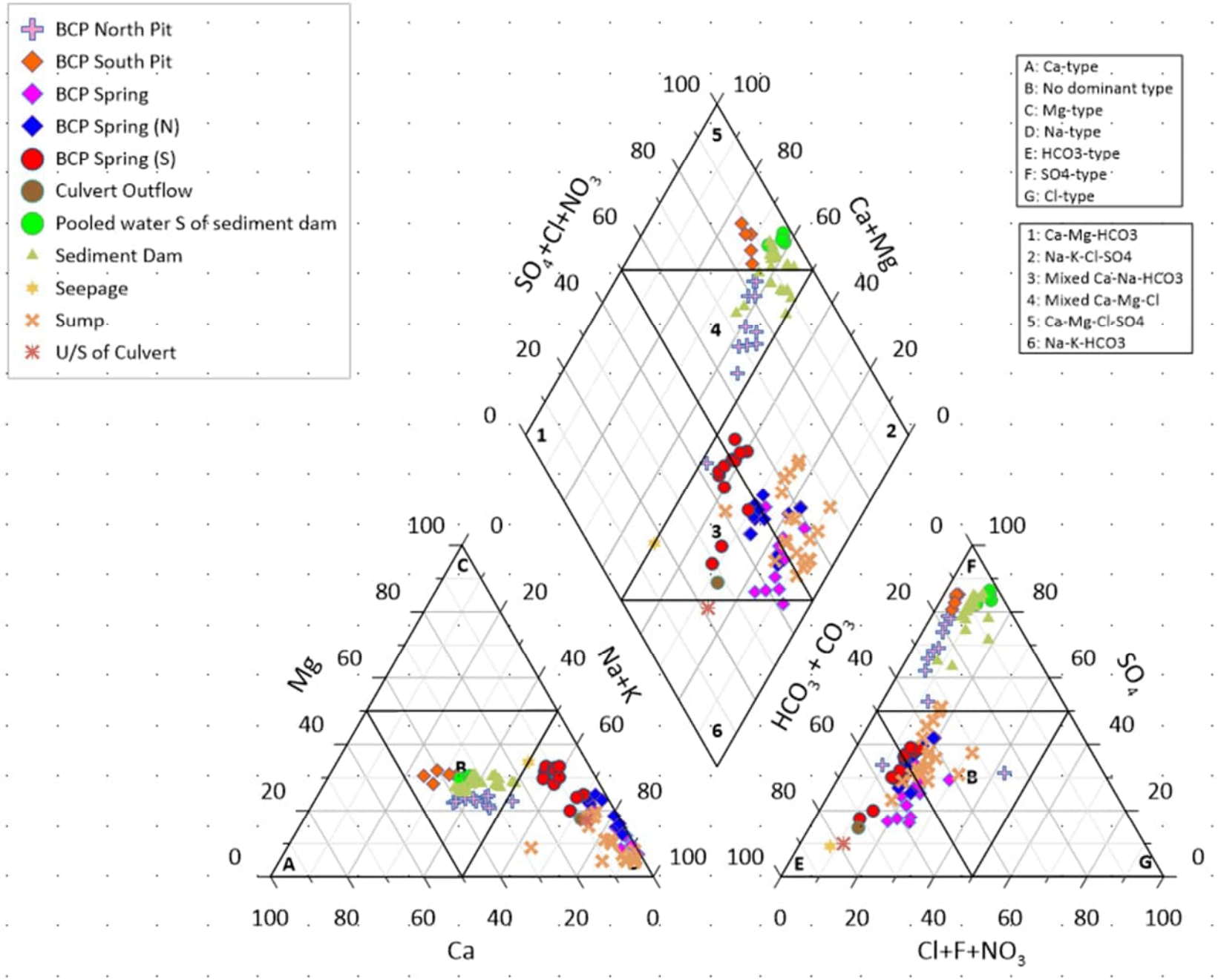

Chadha Diagram
(HCO3+CO3)-(Cl+SO4) (% meq/L)
(Ca+Mg)-(Na+K) (% meq/L)
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
1
2
5
6
BCP North Pit
BCP South Pit
BCP Spring
BCP Spring (N)
BCP Spring (S)
Culvert Outflow
Pooled water S of sediment dam
Sediment Dam
Seepage
Sump
U/S of Culvert
1: Ca-Mg-HCO3
2: Na-K-Cl-SO4
3: Mixed Ca-Na-HCO3
4: Mixed Ca-Mg-Cl
5: Ca-Mg-Cl-SO4
6: Na-K-HCO3

Gibbs Diagram





1: HCO3 and Ca dominant; frequently indicates recharging waters in limestone, sandstone and many other aquifers.
2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant. If Na is significant, an important ion exchange is presumed.
3: HCO3 and Na are dominant, indicates ion exchange water.
4: Ca and SO4 are dominant. Frequently indicates recharge water in lava, and otherwise mixed water or water exhibiting simple dissolution.
5: No dominant anion or cation, indicates water exhibiting dissolution or mixing.
6: SO4 and Na are dominant. Water type is not frequently encountered and indicates probable mixing, or uncommon dissolution influences.
7: Cl and Na dominant. Frequently encountered unless cement pollution is present. Otherwise, the water may result from reverse ion exchange of Na-Cl waters.
8: Cl and Na dominant, indicating the water is related to reverse ion exchange of Na-Cl waters.
9: Cl and Na dominant. Frequently indicates end-point waters through dissolution.


BCP North Pit
BCP South Pit
BCP Spring
BCP Spring (N)
BCP Spring (S)
Culvert Outflow
Pooled water S of sediment dam
Sediment Dam
Seepage
Sump
U/S of Culvert
A: Ca-type
B: No dominant type
C: Mg-type
D: Na-type
E: HCO3-type
F: SO4-type
G: Cl-type
1: Ca-Mg-HCO3
2: Na-K-Cl-SO4
3: Mixed Ca-Na-HCO3
4: Mixed Ca-Mg-Cl
5: Ca-Mg-Cl-SO4
6: Na-K-HCO3
SO4+Cl+NO3
Ca+Mg
Mg
Na+K
Ca
HCO3+CO3
SO4
Cl+F+NO3

Appendix G Groundwater monitoring data

G.1 Groundwater data tables

Table G.1 Groundwater monitoring events

Year	Month	BARC071	BAWB01	BAWB02	BAWB03	BAWB04	BAWB05	BAWB07	BAWBR01	BAWBR02	BAWBR03	Bore E
2014												
	8		✓	✓		✓		✓				
	9		✓	✓		✓	✓	✓				
	10	✓	✓	✓		✓	✓	✓				
	11	✓	✓	✓		✓	✓	✓				
2015												
	2		✓				✓					
	4		✓	✓		✓	✓	✓				
	11		✓	✓		✓	✓					
2016												
	9		✓	✓		✓	✓				✓	
	11		✓	✓		✓	✓					
2017												
	1		✓	✓	✓	✓	✓					
	4		✓	✓		✓	✓					
	11		✓	✓			✓					
2018												
	1		✓	✓	✓	✓	✓					
	3		✓	✓	✓	✓	✓			✓		
	6		✓	✓	✓	✓	✓	✓	✓	✓		✓
	7		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	8		✓	✓	✓	✓	✓	✓	✓	✓		✓
	9		✓	✓	✓	✓	✓	✓				✓
	11		✓	✓	✓	✓	✓	✓				✓
2019												
	1		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Year	Month	BARC071	BAWB01	BAWB02	BAWB03	BAWB04	BAWB05	BAWB07	BAWBR01	BAWBR02	BAWBR03	Bore E
	2			✓				✓				
	3		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	4		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	5		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	6		✓	✓	✓	✓	✓		✓	✓	✓	✓
	7		✓	✓	✓	✓	✓		✓		✓	✓
	8		✓	✓	✓	✓	✓			✓	✓	✓
	9		✓	✓	✓		✓		✓	✓	✓	✓
	10		✓	✓	✓	✓	✓		✓	✓	✓	✓
	11		✓	✓	✓	✓	✓		✓	✓	✓	✓
2020												
	2		✓	✓	✓	✓	✓		✓	✓	✓	✓
	4		✓	✓	✓	✓	✓		✓	✓	✓	✓
	5		✓	✓	✓	✓	✓		✓	✓	✓	✓
	6		✓	✓	✓	✓	✓		✓	✓	✓	✓
	7		✓	✓	✓	✓	✓		✓	✓	✓	✓
	8		✓		✓		✓		✓	✓	✓	✓
	9		✓	✓	✓	✓	✓		✓	✓	✓	✓
	11		✓	✓	✓	✓	✓		✓	✓	✓	✓
	12		✓	✓	✓	✓	✓		✓	✓	✓	✓
2021												
	1		✓	✓	✓	✓	✓		✓	✓	✓	✓
	2		✓	✓	✓	✓	✓		✓	✓	✓	✓
	3		✓	✓	✓	✓	✓		✓	✓	✓	✓
	4		✓	✓	✓	✓	✓		✓	✓	✓	✓
	5		✓	✓	✓	✓	✓		✓	✓	✓	✓
	6		✓	✓	✓	✓	✓		✓	✓	✓	✓
	7		✓	✓	✓	✓	✓		✓	✓	✓	✓

Year	Month	BARC071	BAWB01	BAWB02	BAWB03	BAWB04	BAWB05	BAWB07	BAWBR01	BAWBR02	BAWBR03	Bore E
	8		✓	✓	✓	✓	✓		✓	✓	✓	✓
	9		✓	✓	✓	✓	✓		✓	✓	✓	✓
	10		✓	✓	✓	✓	✓		✓	✓	✓	✓
	11		✓	✓	✓	✓	✓		✓	✓		✓
	12		✓	✓	✓	✓	✓		✓	✓	✓	✓
2022												
	1						✓		✓	✓	✓	✓
	2		✓	✓	✓	✓	✓		✓	✓	✓	✓
	3		✓	✓	✓	✓	✓		✓	✓	✓	✓
	4		✓	✓	✓	✓	✓		✓	✓	✓	✓
	5		✓	✓	✓	✓	✓		✓	✓	✓	✓
	6		✓	✓	✓	✓	✓		✓	✓	✓	✓
	7		✓	✓	✓	✓	✓		✓	✓	✓	✓
	8		✓	✓	✓	✓	✓		✓	✓	✓	✓
	9		✓	✓	✓	✓	✓		✓	✓	✓	✓
	10		✓	✓	✓	✓	✓		✓	✓	✓	✓
	11		✓	✓	✓	✓	✓		✓	✓	✓	✓
	12		✓	✓	✓	✓	✓		✓	✓	✓	✓
2023												
	1		✓	✓	✓	✓	✓		✓	✓	✓	✓
	2		✓	✓	✓	✓	✓		✓	✓	✓	✓
	3		✓	✓	✓	✓	✓		✓	✓	✓	✓
	4		✓	✓	✓	✓	✓		✓	✓	✓	✓
	5				✓	✓						✓
	7		✓	✓	✓	✓	✓				✓	✓
	10		✓	✓	✓	✓	✓					✓

Table G.2 Descriptive statistics: groundwater monitoring results (all sites)

	NumObs	No. > LOR	No. < LOR	% < LOR	No. distinct values (>LOR)	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	10%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	80%ile	90%ile (> LOR)	95%ile (>LOR)	99%ile (>LOR)
Alkalinity																				
Bicarbonate Alkalinity as CaCO3 (mg/L)	320	320			193	66	465.2281	218.1886	2220	2154	249.95	290	385.8	410.75	453	486	515.6	581.2	643.1	1859.89
Carbonate Alkalinity as CaCO3 (mg/L)	320	6	314	98.1	6	4	17.0000	8.2057	28	24	6.25	8.5	13	13	15.5	24	26	27	27.5	27.9
Hydroxide Alkalinity as CaCO3 (mg/L)	320		320	100.0	1															
Temperature (field) (°C)	320	320			193	66	465.5594	217.9721	2220	2154	249.95	290	386	410.75	453	486	515.6	581.2	643.1	1859.89
Field Measurements																				
Electrical Conductivity (field) (µS/cm)	225	225			192	11.17	1026.1606	519.0249	7385	7373.83	628.6	665	831.8	860	991	1204	1225.2	1274.2	1386.8	1780.88
ORP (field) (mV)	178	178			168	-300.9	-40.9590	91.6788	302.4	603.3	-172.72	-156.8	-113.86	-104.25	-50.35	25.725	38.54	68.52	111.03	211.269
pH (field)	224	224			129	5.91	7.3445	0.5086	8.99	3.08	6.636	6.799	6.96	7	7.305	7.64	7.724	8.01	8.2385	8.6708
Salinity (field) (PSU)	210	210			55	0.06	0.6762	1.6770	17.79	17.73	0.31	0.329	0.4	0.42	0.48	0.6	0.61	0.64	0.7055	3.827
TDS (field) (ppm)	210	210			175	21.99	30.4813	2.0480	35.42	13.43	27.0495	27.825	29.216	29.6275	30.685	31.6775	32.004	32.713	33.4755	34.4703
Total Dissolved Solids (field) (ppm)	178	178			144	14.19	527.2230	277.9189	3692	3677.81	318.85	332	416	431.25	500	605	615.6	658.3	713.6	1004.06
Turbidity (field) (FNU)	128	128			52	0	2.9469	5.5738	35.1	35.1	0	0	0	0	1.15	3.05	3.76	6.4	13.58	29.701
Hardness																				
Total Hardness (mg CaCO3/L)	286	286			160	43	284.6538	134.4622	1300	1257	168.5	185.5	222	233	263	320	334	395	413	1140
Ion Balance																				
Ionic Balance (%)	318	318			247	-3.3	3.1369	4.3282	65.4	68.7	0.21	0.387	0.908	1.175	2.655	4.095	4.418	5.599	8.6415	13.796
Total Anions (meq/L)	320	320			161	1.73	13.8481	27.6105	352	350.27	6.638	7.497	9.244	9.425	11	13.2	13.5	14.42	15.72	84.62
Total Cations (meq/L)	320	320			155	1.66	14.2483	30.7640	397	395.34	6.95	7.567	9.246	9.6175	11.1	13.5	13.8	14.71	15.83	81.507
Major Ions																				
Calcium (mg/L)	491	491			71	9	52.6314	17.2303	184	175	32	36	41	43.5	51	60	62	67	71	125.5
Chloride (mg/L)	321	321			60	5	70.4330	432.8077	5490	5485	12	13	17	19	28	39	41	45	58	776
Fluoride (mg/L)	254	253	1	0.4	20	0.2	0.8830	0.4678	2.4	2.2	0.3	0.4	0.5	0.5	0.8	1.3	1.4	1.6	1.7	1.896
Magnesium (mg/L)	491	491			76	5	38.7637	29.4048	277	272	17	19	23	24	30	47	52	68	72	191.8
Potassium (mg/L)	491	491			33	1	10.5483	4.9726	37	36	5	6	7	7	10	12	13	18	20	22.3
Sodium (mg/L)	491	491			166	16	206.0835	733.9214	8580	8564	66	70	89	95	112	157.5	181	205	220	1543
Sulfate (as SO4)	321	315	6	1.9	120	1	125.4200	585.3403	7360	7359	6	8	37.8	40.5	56	75	93	157	180.6	1212.58
Metals (dissolved)																				
Aluminium - dissolved (mg/L)	11	6	5	45.5	6	0.012	0.0208	0.0085	0.034	0.022	0.012	0.012	0.012	0.01325	0.0185	0.0275	0.03	0.032	0.033	0.0338
Arsenic - dissolved (mg/L)	321	166	155	48.3	12	0.001	0.0023	0.0030	0.018	0.017	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.003	0.006	0.018
Barium - dissolved (mg/L)	317	317			184	0.003	0.1726	0.1115	0.493	0.49	0.0558	0.067	0.0902	0.098	0.145	0.191	0.2316	0.3704	0.4304	0.48684
Beryllium - dissolved (mg/L)	49		49	100.0	1															
Bismuth - dissolved (mg/L)	268	1	267	99.6	2	0.00006	0.0001	0.0000	0.00006	0	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006
Boron - dissolved (mg/L)	51	44	7	13.7	27	0.034	0.1373	0.1048	0.35	0.316	0.03915	0.0486	0.0596	0.06	0.0805	0.2625	0.284	0.307	0.32	0.3414
Cadmium - dissolved (mg/L)	55	3	52	94.5	4	0.0001	0.0003	0.0002	0.0005	0.0004	0.00011	0.00012	0.00014	0.00015	0.0002	0.00035	0.00038	0.00044	0.00047	0.000494

	NumObs	No. > LOR	No. < LOR	% < LOR	No. distinct values (>LOR)	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	10%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	80%ile	90%ile (> LOR)	95%ile (>LOR)	99%ile (>LOR)
Chromium - dissolved (mg/L)	321	16	305	95.0	7	0.001	0.0025	0.0018	0.007	0.006	0.001	0.001	0.001	0.001	0.002	0.003	0.003	0.005	0.00625	0.00685
Cobalt - dissolved (mg/L)	321	86	235	73.2	8	0.001	0.0019	0.0020	0.015	0.014	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.004	0.0133
Copper - dissolved (mg/L)	321	139	182	56.7	18	0.001	0.0054	0.0210	0.247	0.246	0.001	0.001	0.001	0.001	0.002	0.004	0.005	0.008	0.012	0.0302
Iron - dissolved (mg/L)	5		5	100.0	1															
Lead - dissolved (mg/L)	55	7	48	87.3	4	0.001	0.0026	0.0017	0.006	0.005	0.001	0.001	0.001	0.001	0.003	0.003	0.003	0.0042	0.0051	0.00582
Manganese - dissolved (mg/L)	55	54	1	1.8	51	0.007	1.2328	1.1681	4.06	4.053	0.0688	0.0825	0.2952	0.34175	0.9915	1.375	1.94	3.269	3.735	4.0494
Mercury - dissolved (mg/L)	53		53	100.0	1															
Molybdenum - dissolved (mg/L)	268	262	6	2.2	31	0.001	0.0071	0.0189	0.212	0.211	0.002	0.002	0.002	0.002	0.003	0.004	0.005	0.018	0.022	0.03039
Nickel - dissolved (mg/L)	321	73	248	77.3	10	0.001	0.0030	0.0034	0.025	0.024	0.001	0.001	0.001	0.001	0.002	0.004	0.004	0.005	0.006	0.01852
Selenium - dissolved (mg/L)	317	1	316	99.7	2	0.003	0.0030	0.0000	0.003	0	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Silicon - dissolved (mg/L)	5	5			4	13	17.4000	5.6071	28	15	13	13	13	13	15	18	20	24	26	27.6
Uranium - dissolved (mg/L)	268	265	3	1.1	16	0.001	0.0086	0.0423	0.496	0.495	0.002	0.002	0.002	0.002	0.004	0.005	0.006	0.006	0.007	0.11292
Vanadium - dissolved (mg/L)	49	6	43	87.8	6	0.002	0.0058	0.0032	0.01	0.008	0.00225	0.0025	0.003	0.003	0.0055	0.00875	0.009	0.0095	0.00975	0.00995
Zinc - dissolved (mg/L)	55	37	18	32.7	21	0.005	0.0146	0.0108	0.06	0.055	0.005	0.0066	0.0072	0.008	0.012	0.017	0.0178	0.0234	0.03	0.05496
Metals (total)																				
Aluminium - total (mg/L)	11	11			9	0.02	0.0562	0.0485	0.19	0.17	0.0205	0.021	0.024	0.027	0.039	0.067	0.09	0.09	0.14	0.18
Arsenic - total (mg/L)	321	188	133	41.4	13	0.001	0.0024	0.0028	0.019	0.018	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.003	0.006	0.018
Barium - total (mg/L)	317	317			193	0.027	0.1830	0.1173	0.529	0.502	0.0618	0.069	0.0932	0.103	0.152	0.206	0.2526	0.3876	0.4576	0.50884
Beryllium - total (mg/L)	49		49	100.0	1															
Bismuth - total (mg/L)	268	2	266	99.3	3	0.00009	0.0001	0.0001	0.0002	0.00011	0.000095	0.00010	0.00012	0.000115	0.00014	0.000175	0.00018	0.00019	0.000195	0.000199
Boron - total (mg/L)	51	42	9	17.6	26	0.03	0.1384	0.1059	0.35	0.32	0.04005	0.0491	0.06	0.0625	0.0805	0.24	0.286	0.309	0.3395	0.3459
Cadmium - total (mg/L)	55	8	47	85.5	6	0.0001	0.0003	0.0001	0.0005	0.0004	0.0001	0.0001	0.00014	0.000175	0.00025	0.000325	0.00036	0.00043	0.000465	0.000493
Chromium - total (mg/L)	321	58	263	81.9	11	0.001	0.0034	0.0029	0.013	0.012	0.001	0.001	0.001	0.001	0.002	0.004	0.005	0.006	0.01115	0.01243
Cobalt - total (mg/L)	321	107	214	66.7	9	0.001	0.0022	0.0022	0.014	0.013	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.003	0.004	0.01394
Copper - total (mg/L)	321	270	51	15.9	27	0.001	0.0111	0.0609	0.89	0.889	0.001	0.001	0.002	0.002	0.003	0.006	0.0062	0.011	0.019	0.20896
Iron - total (mg/L)	5	5			5	0.071	0.4982	0.5053	1.4	1.329	0.0848	0.0986	0.1262	0.14	0.17	0.71	0.848	1.124	1.262	1.3724
Lead - total (mg/L)	55	22	33	60.0	7	0.001	0.0030	0.0039	0.019	0.018	0.001	0.001	0.001	0.001	0.002	0.002	0.0028	0.0057	0.0079	0.01669
Manganese - total (mg/L)	55	55			48	0.006	1.2809	1.2290	4.35	4.344	0.074	0.0824	0.2752	0.38	1	1.4	1.702	3.604	3.805	4.2906
Mercury - total (mg/L)	53		53	100.0	1															
Molybdenum - total (mg/L)	268	267	1	0.4	28	0.001	0.0076	0.0186	0.216	0.215	0.002	0.002	0.002	0.003	0.004	0.004	0.005	0.0212	0.025	0.03234
Nickel - total (mg/L)	321	88	233	72.6	12	0.001	0.0033	0.0040	0.033	0.032	0.001	0.001	0.001	0.002	0.002	0.004	0.004	0.0063	0.00865	0.01647
Selenium - total (mg/L)	317	1	316	99.7	2	0.003	0.0030	0.0000	0.003	0	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Silicon - total (mg/L)	5	5			5	13	17.8000	5.8447	29	16	13.2	13.4	13.8	14	15	18	20.2	24.6	26.8	28.56
Uranium - total (mg/L)	268	266	2	0.7	17	0.001	0.0093	0.0409	0.459	0.458	0.002	0.002	0.002	0.003	0.005	0.006	0.006	0.007	0.007	0.1365
Vanadium - total (mg/L)	49	7	42	85.7	6	0.001	0.0059	0.0042	0.011	0.01	0.0013	0.0016	0.0022	0.0025	0.003	0.0105	0.0108	0.011	0.011	0.011
Zinc - total (mg/L)	55	47	8	14.5	22	0.006	0.0176	0.0130	0.074	0.068	0.006	0.006	0.008	0.01	0.016	0.021	0.022	0.0262	0.0371	0.06802
Nutrients																				

	NumObs	No. > LOR	No. < LOR	% < LOR	No. distinct values (>LOR)	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	10%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	80%ile	90%ile (> LOR)	95%ile (>LOR)	99%ile (>LOR)
Nitrite + Nitrate as N (mg/L)	17	14	3	17.6	13	0.02	0.5164	0.8398	2.56	2.54	0.02	0.023	0.036	0.04	0.13	0.3625	0.59	1.975	2.482	2.5444
Total Kjeldahl Nitrogen as N (mg/L)	17	16	1	5.9	8	0.1	0.8313	1.2578	3.7	3.6	0.1	0.1	0.1	0.1	0.3	0.4	0.4	3.3	3.475	3.655
Total Nitrogen as N (mg/L)	17	17			11	0.1	1.2000	1.3430	3.7	3.6	0.1	0.16	0.22	0.3	0.4	2.8	2.96	3.32	3.54	3.668
Total Phosphorus as P (mg/L)	17	17			9	0.01	0.0788	0.0859	0.26	0.25	0.018	0.02	0.022	0.03	0.04	0.07	0.078	0.26	0.26	0.26
Physico-Chemical Parameters																				
Electrical Conductivity (µS/cm)	267	267			156	164	1259.8801	2567.1192	31300	31136	620.3	658.8	811.4	845.5	977	1180	1210	1274	1378	6824.6
pH (lab)	285	285			111	6.98	7.7323	0.3086	8.66	1.68	7.24	7.32	7.43	7.49	7.74	7.97	8.03	8.13	8.2	8.3916
Total Dissolved Solids (mg/L)	5	5			5	470	640.0000	127.5931	820	350	488	506	542	560	600	750	764	792	806	817.2
Turbidity (NTU)	267	267			109	0.1	6.6228	9.5877	61.4	61.3	0.4	0.6	0.82	1	2.4	8.1	11.16	18.02	24.27	48.786

Table G.3 Descriptive statistics: groundwater monitoring results (by location)

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
BAWB01												
Alkalinity												
Bicarbonate Alkalinity as CaCO3 (mg/L)	53	53		163	568.1132	86.7916	695	436.8	534	570	622	671.4
Carbonate Alkalinity as CaCO3 (mg/L)	53		53									
Hydroxide Alkalinity as CaCO3 (mg/L)	53		53									
Field Measurements												
Dissolved Oxygen (field) (% sat))	29	29		0	28.3103	34.7277	131.5	0	5.8	12.6	40.9	97.38
Electrical Conductivity (field) (µS/cm)	32	32		14.63	1203.0509	239.9184	1529	1130.5	1157.25	1197.5	1287.25	1468.4
ORP (field) (mV)	24	24		-104.5	-0.1125	71.2899	184.8	-84.665	-53.15	-18.25	37.2	124.12
pH (field)	32	32		5.91	6.9794	0.3958	7.98	6.409	6.76	6.945	7.23	7.655
Salinity (field) (PSU)	29	29		0.06	0.5948	0.1163	0.76	0.55	0.57	0.59	0.66	0.726
TDS (field) (ppm)	29	29		27	30.8693	1.9516	35.42	27.498	29.75	30.69	32.02	33.904
Total Dissolved Solids (field) (ppm)	24	24		563	629.5000	59.3317	765	567.9	580	605.5	681	736.1
Temperature (field) (°C)	53	53		163	568.1132	86.7916	695	436.8	534	570	622	671.4
Turbidity (field) (FNU)	18	18		0	4.0167	6.9898	27	0	0	0.65	5.225	17.48
Hardness												
Total Hardness (mg CaCO3/L)	45	45		112	375.1333	56.7719	440	278	369	391	405	424
Ion Balance												
Ionic Balance (%)	53	53		-3.3	2.6019	2.1902	8.64	0.142	1.1	2.59	3.9	6.006
Total Anions (meq/L)	53	53		3.81	13.6434	2.1383	17	10.388	12.7	13.7	14.9	16.4
Total Cations (meq/L)	53	53		3.76	13.8438	2.2025	17.5	9.792	13.1	14	14.8	17.08
Major Ions												
Calcium (mg/L)	79	79		22	44.1139	5.9086	55	33.8	40.5	45	48	51
Chloride (mg/L)	53	53		7	34.9434	9.3676	65	22.2	30	34	38	50.6
Fluoride (mg/L)	38	38		0.3	1.4553	0.3201	1.8	0.7	1.4	1.6	1.675	1.715
Magnesium (mg/L)	79	79		9	64.6456	11.9895	80	44	63	68	71	75

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Potassium (mg/L)	79	79		4	7.2278	1.2180	9.6	4.9	7	7	8	9
Sodium (mg/L)	79	79		32	137.6076	41.4055	242	77.5	117	128	157	221
Sulfate (as SO4)	53	53		17	63.0189	14.4764	104	42	57	62	68	86.4
Metals (dissolved)												
Aluminium - dissolved (mg/L)	2	1	1	0.012	0.0120	0.0000	0.012	0.012	0.012	0.012	0.012	0.012
Arsenic - dissolved (mg/L)	53	45	8	0.001	0.0016	0.0006	0.003	0.001	0.001	0.002	0.002	0.002
Barium - dissolved (mg/L)	52	52		0.03	0.1060	0.0479	0.216	0.0452	0.06475	0.0985	0.14725	0.17645
Beryllium - dissolved (mg/L)	11		11									
Bismuth - dissolved (mg/L)	41		41									
Boron - dissolved (mg/L)	11	11		0.034	0.0773	0.0621	0.26	0.0355	0.0445	0.06	0.07	0.19
Cadmium - dissolved (mg/L)	12		12									
Chromium - dissolved (mg/L)	53	2	51	0.001	0.0015	0.0005	0.002	0.00105	0.00125	0.0015	0.00175	0.00195
Cobalt - dissolved (mg/L)	53	42	11	0.001	0.0017	0.0008	0.005	0.001	0.001	0.002	0.002	0.00295
Copper - dissolved (mg/L)	53	24	29	0.001	0.0030	0.0033	0.018	0.001	0.00175	0.002	0.003	0.005
Iron - dissolved (mg/L)	1		1									
Lead - dissolved (mg/L)	12	2	10	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001
Manganese - dissolved (mg/L)	12	12		0.098	0.8108	0.4485	1.5	0.1486	0.3425	0.9445	1.13	1.3845
Mercury - dissolved (mg/L)	12		12									
Molybdenum - dissolved (mg/L)	41	40	1	0.002	0.0036	0.0012	0.009	0.002	0.003	0.0035	0.004	0.00505
Nickel - dissolved (mg/L)	53	6	47	0.001	0.0022	0.0007	0.003	0.00125	0.002	0.002	0.00275	0.003
Selenium - dissolved (mg/L)	52		52									
Silicon - dissolved (mg/L)	1	1		28	28.0000	0.0000	28	28	28	28	28	28
Uranium - dissolved (mg/L)	41	41		0.001	0.0050	0.0012	0.007	0.003	0.004	0.005	0.006	0.006
Vanadium - dissolved (mg/L)	11	3	8	0.008	0.0090	0.0008	0.01	0.0081	0.0085	0.009	0.0095	0.0099
Zinc - dissolved (mg/L)	12	10	2	0.007	0.0136	0.0041	0.02	0.00745	0.0105	0.014	0.01675	0.0191
Metals (total)												
Aluminium - total (mg/L)	2	2		0.021	0.0255	0.0045	0.03	0.02145	0.02325	0.0255	0.02775	0.02955

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Arsenic - total (mg/L)	53	46	7	0.001	0.0017	0.0005	0.003	0.001	0.001	0.002	0.002	0.002
Barium - total (mg/L)	52	52		0.027	0.1085	0.0481	0.253	0.04785	0.066	0.106	0.14075	0.17695
Beryllium - total (mg/L)	11		11									
Bismuth - total (mg/L)	41		41									
Boron - total (mg/L)	11	9	2	0.03	0.0741	0.0425	0.18	0.0324	0.041	0.07	0.08	0.144
Cadmium - total (mg/L)	12	2	10	0.0001	0.0002	0.0001	0.0002	0.000105	0.000125	0.00015	0.000175	0.000195
Chromium - total (mg/L)	53	5	48	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001
Cobalt - total (mg/L)	53	44	9	0.001	0.0020	0.0010	0.007	0.001	0.001	0.002	0.002	0.003
Copper - total (mg/L)	53	48	5	0.001	0.0041	0.0047	0.034	0.001	0.002	0.003	0.004	0.00765
Iron - total (mg/L)	1	1		0.14	0.1400	0.0000	0.14	0.14	0.14	0.14	0.14	0.14
Lead - total (mg/L)	12	4	8	0.001	0.0020	0.0007	0.003	0.00115	0.00175	0.002	0.00225	0.00285
Manganese - total (mg/L)	12	12		0.12	0.8431	0.4706	1.49	0.164	0.3275	0.9775	1.195	1.4295
Mercury - total (mg/L)	12		12									
Molybdenum - total (mg/L)	41	41		0.001	0.0040	0.0010	0.006	0.002	0.004	0.004	0.004	0.006
Nickel - total (mg/L)	53	5	48	0.001	0.0022	0.0007	0.003	0.0012	0.002	0.002	0.003	0.003
Selenium - total (mg/L)	52		52									
Silicon - total (mg/L)	1	1		29	29.0000	0.0000	29	29	29	29	29	29
Uranium - total (mg/L)	41	41		0.002	0.0056	0.0012	0.007	0.004	0.005	0.006	0.007	0.007
Vanadium - total (mg/L)	11	3	8	0.01	0.0107	0.0005	0.011	0.0101	0.0105	0.011	0.011	0.011
Zinc - total (mg/L)	12	11	1	0.006	0.0142	0.0065	0.024	0.006	0.009	0.013	0.0215	0.023
Nutrients												
Nitrite + Nitrate as N (mg/L)	3	3		0.03	0.1167	0.0634	0.18	0.041	0.085	0.14	0.16	0.176
Total Kjeldahl Nitrogen as N (mg/L)	3	3		0.1	0.1000	#NUM!	0.1	0.1	0.1	0.1	0.1	0.1
Total Nitrogen as N (mg/L)	3	3		0.1	0.2000	0.0816	0.3	0.11	0.15	0.2	0.25	0.29
Total Phosphorus as P (mg/L)	3	3		0.02	0.0400	0.0163	0.06	0.022	0.03	0.04	0.05	0.058
Physico-Chemical Parameters												
Electrical Conductivity (µS/cm)	41	41		389	1187.3415	194.2453	1560	929	1140	1190	1260	1450

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
pH (lab)	45	45		6.98	7.4791	0.2601	8.06	7.134	7.25	7.5	7.7	7.848
Total Dissolved Solids (mg/L)	1	1		750	750.0000	0.0000	750	750	750	750	750	750
Turbidity (NTU)	41	41		0.1	5.5439	6.6446	32.9	0.2	0.9	2.5	8	17
BAWB02												
Alkalinity												
Bicarbonate Alkalinity as CaCO3 (mg/L)	51	51		124	439.5686	61.4058	510	336	440.5	456	468.5	484.5
Carbonate Alkalinity as CaCO3 (mg/L)	51	2	49	13	15.5000	2.5000	18	13.25	14.25	15.5	16.75	17.75
Carbonate Alkalinity as CO3 (mg/L)	1		1									
Hydroxide Alkalinity as CaCO3 (mg/L)	51		51									
Temperature (field) (°C)	51	51		137	440.1765	59.5956	510	341	440.5	456	468.5	484.5
Field Measurements												
Appearance or Colour	23											
Depth of Bore (mbgl)	54	54		104	104.0000	0.0000	104	104	104	104	104	104
Depth to Water (mbRL)	55	55		3.28	6.7382	1.3416	9	3.92	6.135	7.01	7.685	8.278
Depth to Water (mbGL)	19	19		3.28	6.1984	1.4908	8.32	3.343	5.415	6.59	7.21	8.059
Dissolved Oxygen (field) (% sat))	30	30		0	31.8100	80.8807	450.6	0	2.125	9.05	19.85	73.115
Electrical Conductivity (field) (µS/cm)	33	33		13.9	1208.4818	233.7828	1416	1022.4	1218	1251	1270	1372.2
Groundwater Level (mAHD)	53	53		303.21	330.2138	14.2328	370.68	317.288	322.77	325.572	331.25	358.6266
GWL Depth Reference Elevation	54	54		311.33	336.7573	14.2120	378.09	323.92	330.01	332.402	337.569	363.64115
Odour	26											
ORP (field) (mV)	26	26		-200.4	-101.7462	103.8320	302.4	-198	-166.725	-128.05	-69.35	45.525
pH (field)	32	32		6.39	7.5369	0.4188	8.6	6.928	7.29	7.485	7.7925	8.0695
Salinity (field) (PSU)	30	30		0.36	0.6140	0.0536	0.7	0.5945	0.6025	0.62	0.6275	0.681
TDS (field) (ppm)	30	30		24.52	30.5217	2.3072	33.61	25.407	29.8175	30.625	32.105	33.3275
Total Dissolved Solids (field) (ppm)	26	26		378	623.3077	56.5466	713	602.25	610.5	627	641.25	695
Turbidity (field) (FNU)	18	18		0	2.1222	2.9047	11.5	0	0.1	1.5	2.5	8.015
Hardness												

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Total Hardness (mg CaCO3/L)	45	45		77	242.8889	43.2616	320	171.8	240	250	263	278.8
Ion Balance												
Ionic Balance (%)	51	51		-3	3.6888	8.9820	65.4	0.11	0.865	2.58	3.91	6.375
Total Anions (meq/L)	51	51		3.96	13.1755	1.7458	16.2	10.89	13	13.5	13.8	14.5
Total Cations (meq/L)	51	51		2.85	13.3018	2.3596	16.5	9.38	13.25	13.7	14.35	15.15
Major Ions												
Calcium (mg/L)	78	78		16	52.4744	8.9768	75	36.7	50	53	58	65.3
Chloride (mg/L)	52	52		11	40.7885	9.0412	82	28.55	38.75	41	44	48.45
Fluoride (mg/L)	37	37		0.3	0.7243	0.1303	0.9	0.46	0.7	0.8	0.8	0.8
Magnesium (mg/L)	78	78		6	28.3462	4.9790	41	18.7	28	29	30	32
Potassium (mg/L)	78	78		1	10.6795	2.3777	16	6	10	11	12	14
Sodium (mg/L)	78	78		26	187.7179	34.3656	229	113.65	185.5	194	204	216.15
Sulfate (as SO4)	52	52		44	155.4827	27.3018	220	125.8	144.75	153.5	170.25	195
Metals (dissolved)												
Aluminium - dissolved (mg/L)	3	1	2	0.017	0.0170	0.0000	0.017	0.017	0.017	0.017	0.017	0.017
Arsenic - dissolved (mg/L)	52	3	49	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001
Barium - dissolved (mg/L)	51	51		0.083	0.1408	0.0231	0.179	0.1015	0.1255	0.143	0.159	0.175
Beryllium - dissolved (mg/L)	10		10									
Bismuth - dissolved (mg/L)	41		41									
Boron - dissolved (mg/L)	11	11		0.27	0.3064	0.0219	0.35	0.275	0.295	0.3	0.32	0.34
Cadmium - dissolved (mg/L)	12	1	11	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Chromium - dissolved (mg/L)	52	2	50	0.001	0.0025	0.0015	0.004	0.00115	0.00175	0.0025	0.00325	0.00385
Cobalt - dissolved (mg/L)	52	2	50	0.001	0.0015	0.0005	0.002	0.00105	0.00125	0.0015	0.00175	0.00195
Copper - dissolved (mg/L)	52	22	30	0.001	0.0025	0.0023	0.01	0.001	0.001	0.002	0.003	0.00785
Iron - dissolved (mg/L)	1		1									
Lead - dissolved (mg/L)	12	1	11	0.003	0.0030	0.0000	0.003	0.003	0.003	0.003	0.003	0.003
Manganese - dissolved (mg/L)	12	12		0.288	1.0280	0.2666	1.4	0.5685	1.0125	1.065	1.1175	1.345

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Mercury - dissolved (mg/L)	11		11									
Molybdenum - dissolved (mg/L)	41	40	1	0.001	0.0032	0.0011	0.007	0.002	0.00275	0.003	0.004	0.005
Nickel - dissolved (mg/L)	52	8	44	0.001	0.0046	0.0045	0.016	0.00135	0.002	0.003	0.005	0.01215
Selenium - dissolved (mg/L)	51		51									
Silicon - dissolved (mg/L)	1	1		13	13.0000	0.0000	13	13	13	13	13	13
Uranium - dissolved (mg/L)	41	41		0.002	0.0047	0.0010	0.008	0.003	0.004	0.005	0.005	0.006
Vanadium - dissolved (mg/L)	10		10									
Zinc - dissolved (mg/L)	12	6	6	0.005	0.0137	0.0078	0.026	0.005	0.00625	0.013	0.019	0.0245
Metals (total)												
Aluminium - total (mg/L)	3	3		0.024	0.0513	0.0281	0.09	0.0256	0.032	0.04	0.065	0.085
Arsenic - total (mg/L)	52	11	41	0.001	0.0012	0.0004	0.002	0.001	0.001	0.001	0.001	0.002
Barium - total (mg/L)	51	51		0.083	0.1526	0.0250	0.197	0.1155	0.139	0.152	0.1735	0.187
Beryllium - total (mg/L)	10		10									
Bismuth - total (mg/L)	41		41									
Boron - total (mg/L)	11	11		0.26	0.3082	0.0279	0.35	0.265	0.295	0.3	0.335	0.345
Cadmium - total (mg/L)	12	1	11	0.0005	0.0005	0.0000	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Chromium - total (mg/L)	52	5	47	0.002	0.0042	0.0034	0.011	0.002	0.002	0.003	0.003	0.0094
Cobalt - total (mg/L)	52	5	47	0.001	0.0040	0.0050	0.014	0.001	0.001	0.002	0.002	0.0116
Copper - total (mg/L)	52	42	10	0.001	0.0050	0.0084	0.051	0.001	0.002	0.002	0.004	0.016
Iron - total (mg/L)	1	1		0.17	0.1700	0.0000	0.17	0.17	0.17	0.17	0.17	0.17
Lead - total (mg/L)	12	6	6	0.001	0.0028	0.0023	0.008	0.00125	0.002	0.002	0.002	0.0065
Manganese - total (mg/L)	12	12		0.294	1.0882	0.2863	1.4	0.602	1.015	1.125	1.285	1.4
Mercury - total (mg/L)	11		11									
Molybdenum - total (mg/L)	41	41		0.001	0.0034	0.0009	0.005	0.002	0.003	0.004	0.004	0.004
Nickel - total (mg/L)	52	10	42	0.001	0.0031	0.0038	0.014	0.001	0.001	0.002	0.00275	0.0095
Selenium - total (mg/L)	51		51									
Silicon - total (mg/L)	1	1		13	13.0000	0.0000	13	13	13	13	13	13

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Uranium - total (mg/L)	41	41		0.003	0.0050	0.0007	0.006	0.004	0.005	0.005	0.005	0.006
Vanadium - total (mg/L)	10		10									
Zinc - total (mg/L)	12	9	3	0.006	0.0188	0.0077	0.035	0.0084	0.016	0.018	0.022	0.031
Nutrients												
Nitrite + Nitrate as N (mg/L)	3	2	1	0.02	0.0500	0.0300	0.08	0.023	0.035	0.05	0.065	0.077
Total Kjeldahl Nitrogen as N (mg/L)	3	3		3.2	3.4333	0.2055	3.7	3.22	3.3	3.4	3.55	3.67
Total Nitrogen as N (mg/L)	3	3		3.2	3.4667	0.2055	3.7	3.23	3.35	3.5	3.6	3.68
Total Phosphorus as P (mg/L)	3	3		0.26	0.2600	0.0000	0.26	0.26	0.26	0.26	0.26	0.26
Physico-Chemical Parameters												
Electrical Conductivity (µS/cm)	40	40		331	1194.8500	171.9393	1340	897.95	1200	1240	1252.5	1310.5
pH (lab)	44	44		7.56	7.9064	0.2262	8.66	7.603	7.7175	7.9	8.04	8.1895
Total Dissolved Solids (mg/L)	1	1		820	820.0000	0.0000	820	820	820	820	820	820
Turbidity (NTU)	40	40		0.2	3.4250	7.4574	47.8	0.395	0.775	1.55	2.725	8.08
BAWB03												
Alkalinity												
Bicarbonate Alkalinity as CaCO3 (mg/L)	39	39		108	400.4359	83.5819	546	266.9	350	431	457	480.1
Carbonate Alkalinity as CaCO3 (mg/L)	39		39									
Carbonate Alkalinity as CO3 (mg/L)	1		1									
Hydroxide Alkalinity as CaCO3 (mg/L)	39		39									
Temperature (field) (°C)	39	39		108	400.4359	83.5819	546	266.9	350	431	457	480.1
Field Measurements												
Appearance or Colour	19											
Depth of Bore (mbgl)	54	54		104	104.0000	0.0000	104	104	104	104	104	104
Depth to Water (mbRL)	54	54		0.75	10.4609	2.9349	13.81	4.561	9.67	10.855	12.9125	13.621
Depth to Water (mbGL)	20	20		0.75	8.6405	3.0427	12.97	2.2415	7.665	9.27	10.7475	11.925
Dissolved Oxygen (field) (% sat))	30	30		0	36.8333	65.7100	296.3	0	3.1	7	30.4	162.565
Electrical Conductivity (field) (µS/cm)	30	30		665	913.8667	138.1151	1221	688.6	788.75	945.5	1001.5	1125.35

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Groundwater Level (mAHD)	54	54		297.74	328.9926	14.4226	367.98	315.7655	321.3025	323.8495	341.49575	356.73765
GWL Depth Reference Elevation	54	54		311.33	339.4536	14.5363	378.09	325.766	332.092	332.939	353.32	363.64115
Odour	20											
ORP (field) (mV)	25	25		-154.9	-43.3040	71.2425	208.9	-108.22	-88.9	-67.4	-32.9	57.64
pH (field)	30	30		6.12	7.1973	0.3926	8.11	6.67	6.99	7.205	7.3925	7.827
Salinity (field) (PSU)	30	30		0.32	0.4423	0.0708	0.6	0.329	0.38	0.46	0.4875	0.551
TDS (field) (ppm)	30	30		27.11	30.3893	1.7558	33.53	27.207	29.5775	30.4	31.64	32.894
Total Dissolved Solids (field) (ppm)	25	25		352	473.3200	61.6303	610	372.8	457	484	503	567.2
Turbidity (field) (FNU)	21	21		0	1.2190	1.2831	3.8	0	0	0.7	2.6	3.6
Hardness												
Total Hardness (mg CaCO3/L)	39	39		63	226.0769	43.7067	295	167.1	216	233	248	279
Ion Balance												
Ionic Balance (%)	38	38		0.06	3.6474	3.2027	14	0.645	1.495	2.675	4.685	9.6975
Total Anions (meq/L)	39	39		2.65	9.3964	1.8585	12.4	6.67	8.265	10.1	10.8	11.17
Total Cations (meq/L)	39	39		2.62	9.6215	1.8569	12.2	7.056	8.38	10.2	10.9	11.61
Major Ions												
Calcium (mg/L)	63	63		15	60.6032	10.5748	77	45.5	57.5	62	66	73.8
Chloride (mg/L)	39	39		7	15.4103	3.3106	23	11	13	15	17	22.1
Fluoride (mg/L)	36	36		0.3	0.7000	0.3536	2.4	0.3	0.5	0.7	0.8	0.9
Magnesium (mg/L)	63	63		5	19.3016	3.0532	26	16.1	18	19	20	24
Potassium (mg/L)	63	63		4	10.9794	1.9176	14	8	10	11	12	14
Sodium (mg/L)	63	63		29	113.6190	25.5600	150	70.5	96	117	136	145
Sulfate (as SO4)	39	39		14	46.0769	7.3288	56	36	43	48	51	55
Metals (dissolved)												
Aluminium - dissolved (mg/L)	1	1		0.03	0.0300	0.0000	0.03	0.03	0.03	0.03	0.03	0.03
Arsenic - dissolved (mg/L)	39	4	35	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001
Barium - dissolved (mg/L)	39	39		0.057	0.1065	0.0237	0.169	0.0679	0.091	0.108	0.1225	0.1368

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Beryllium - dissolved (mg/L)	1		1									
Bismuth - dissolved (mg/L)	38		38									
Boron - dissolved (mg/L)	1	1		0.15	0.1500	0.0000	0.15	0.15	0.15	0.15	0.15	0.15
Cadmium - dissolved (mg/L)	1		1									
Chromium - dissolved (mg/L)	39		39									
Cobalt - dissolved (mg/L)	39	5	34	0.001	0.0014	0.0005	0.002	0.001	0.001	0.001	0.002	0.002
Copper - dissolved (mg/L)	39	11	28	0.001	0.0032	0.0029	0.012	0.0015	0.002	0.002	0.003	0.008
Iron - dissolved (mg/L)	1		1									
Lead - dissolved (mg/L)	1		1									
Manganese - dissolved (mg/L)	1		1									
Mercury - dissolved (mg/L)	1		1									
Molybdenum - dissolved (mg/L)	38	38		0.001	0.0022	0.0007	0.005	0.00185	0.002	0.002	0.002	0.00315
Nickel - dissolved (mg/L)	39	7	32	0.001	0.0024	0.0012	0.004	0.001	0.0015	0.002	0.0035	0.004
Selenium - dissolved (mg/L)	39		39									
Silicon - dissolved (mg/L)	1	1		15	15.0000	0.0000	15	15	15	15	15	15
Uranium - dissolved (mg/L)	38	38		0.002	0.0053	0.0011	0.008	0.00385	0.005	0.005	0.006	0.007
Vanadium - dissolved (mg/L)	1	1		0.003	0.0030	0.0000	0.003	0.003	0.003	0.003	0.003	0.003
Zinc - dissolved (mg/L)	1	1		0.06	0.0600	0.0000	0.06	0.06	0.06	0.06	0.06	0.06
Metals (total)												
Aluminium - total (mg/L)	1	1		0.09	0.0900	0.0000	0.09	0.09	0.09	0.09	0.09	0.09
Arsenic - total (mg/L)	39	3	36	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001
Barium - total (mg/L)	39	39		0.058	0.1070	0.0280	0.183	0.0627	0.0915	0.104	0.1245	0.144
Beryllium - total (mg/L)	1		1									
Bismuth - total (mg/L)	38		38									
Boron - total (mg/L)	1	1		0.15	0.1500	0.0000	0.15	0.15	0.15	0.15	0.15	0.15
Cadmium - total (mg/L)	1		1									
Chromium - total (mg/L)	39	1	38	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Cobalt - total (mg/L)	39	8	31	0.001	0.0011	0.0003	0.002	0.001	0.001	0.001	0.001	0.00165
Copper - total (mg/L)	39	30	9	0.001	0.0032	0.0023	0.012	0.001	0.002	0.0025	0.00375	0.00765
Iron - total (mg/L)	1	1		0.071	0.0710	0.0000	0.071	0.071	0.071	0.071	0.071	0.071
Lead - total (mg/L)	1		1									
Manganese - total (mg/L)	1	1		0.007	0.0070	0.0000	0.007	0.007	0.007	0.007	0.007	0.007
Mercury - total (mg/L)	1		1									
Molybdenum - total (mg/L)	38	38		0.001	0.0023	0.0006	0.004	0.00185	0.002	0.002	0.003	0.003
Nickel - total (mg/L)	39	3	36	0.001	0.0023	0.0012	0.004	0.0011	0.0015	0.002	0.003	0.0038
Selenium - total (mg/L)	39		39									
Silicon - total (mg/L)	1	1		15	15.0000	0.0000	15	15	15	15	15	15
Uranium - total (mg/L)	38	38		0.003	0.0057	0.0010	0.007	0.004	0.005	0.006	0.006	0.007
Vanadium - total (mg/L)	1	1		0.003	0.0030	0.0000	0.003	0.003	0.003	0.003	0.003	0.003
Zinc - total (mg/L)	1	1		0.074	0.0740	0.0000	0.074	0.074	0.074	0.074	0.074	0.074
Nutrients												
Nitrite + Nitrate as N (mg/L)	3	3		0.89	1.9633	0.7605	2.56	1.045	1.665	2.44	2.5	2.548
Total Kjeldahl Nitrogen as N (mg/L)	3	3		0.1	0.3000	0.1414	0.4	0.13	0.25	0.4	0.4	0.4
Total Nitrogen as N (mg/L)	3	3		1	2.2667	0.8994	3	1.18	1.9	2.8	2.9	2.98
Total Phosphorus as P (mg/L)	3	3		0.02	0.0233	0.0047	0.03	0.02	0.02	0.02	0.025	0.029
Physico-Chemical Parameters												
Electrical Conductivity (µS/cm)	38	38		246	862.2895	168.8863	1130	640.4	740.25	911	993.25	1043
pH (lab)	39	39		7.24	7.6751	0.2665	8.2	7.268	7.415	7.69	7.865	8.101
Total Dissolved Solids (mg/L)	1	1		470	470.0000	0.0000	470	470	470	470	470	470
Turbidity (NTU)	38	38		0.3	2.4368	6.4626	41.4	0.485	0.725	1.15	1.975	3.31
BAWB04												
Alkalinity												
Bicarbonate Alkalinity as CaCO3 (mg/L)	54	54		166	434.6296	67.2743	601	320.95	421	437	463	538.3
Carbonate Alkalinity as CaCO3 (mg/L)	54	1	53	4	4.0000	0.0000	4	4	4	4	4	4

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Carbonate Alkalinity as CO3 (mg/L)	1		1									
Hydroxide Alkalinity as CaCO3 (mg/L)	54		54									
Temperature (field) (°C)	54	54		170	434.7037	66.9800	601	320.95	421	437	463	538.3
Field Measurements												
Appearance or Colour	23											
Depth of Bore (mbgl)	54	54		100	100.2963	1.0476	104	100	100	100	100	104
Depth to Water (mbRL)	55	55		8.04	13.1813	2.0067	15.64	9.32	12.32	14.03	14.515	14.994
Depth to Water (mbGL)	17	17		8.2	11.8818	1.7246	14.03	9.168	10.46	12.44	13.45	13.79
Dissolved Oxygen (field) (% sat))	34	34		0	36.1118	74.3109	422.6	0	3.05	8.3	44.475	107.175
Electrical Conductivity (field) (µS/cm)	37	37		82	845.7568	181.8187	1269	454.6	838	876	903	987
Groundwater Level (mAHD)	53	53		296.47	322.8486	13.7595	363.58	296.746	317	321.74	324.68	343.913
GWL Depth Reference Elevation	54	54		311.33	335.9609	13.6744	378.09	311.33	330.22	332.939	337.486	355.861
Odour	25											
ORP (field) (mV)	29	29		-156.8	-52.1345	72.8763	187.9	-119.14	-90.9	-74.9	-35.6	91.98
pH (field)	37	37		6.17	7.2530	0.3520	8.12	6.786	7.05	7.23	7.49	7.754
Salinity (field) (PSU)	34	34		0.19	0.4132	0.0652	0.63	0.3175	0.41	0.42	0.43	0.4435
TDS (field) (ppm)	34	34		23.25	30.4112	2.4010	35.33	26.591	29.7925	30.705	31.415	34.2855
Total Dissolved Solids (field) (ppm)	29	29		200	426.1724	69.4049	635	302.8	418	438	447	460.8
Turbidity (field) (FNU)	20	20		0	2.1300	2.0691	6.4	0	0.35	1.65	3.25	5.83
Hardness												
Total Hardness (mg CaCO3/L)	47	47		69	246.1064	36.9803	288	182	237.5	254	266.5	283.4
Ion Balance												
Ionic Balance (%)	54	54		-2.6	2.5576	2.1075	9.33	0.3255	1.3625	2.075	3.4	7.148
Total Anions (meq/L)	54	54		3.66	9.4644	1.4230	13	6.948	9.255	9.445	9.9525	11.645
Total Cations (meq/L)	54	54		3.03	9.4957	1.3774	11.4	7.194	9.0725	9.72	10.1	11.3
Major Ions												
Calcium (mg/L)	83	83		11	61.0000	9.4167	79	44.3	57	63	66.5	71

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Chloride (mg/L)	54	54		7	22.0741	7.4133	67	15	19	21	24	28
Fluoride (mg/L)	41	41		0.2	0.4317	0.0839	0.6	0.3	0.4	0.4	0.5	0.6
Magnesium (mg/L)	83	83		10	23.2289	3.1482	31	17	22	24	25	26
Potassium (mg/L)	83	83		2	6.4398	1.4390	11	4	6	6	7	9
Sodium (mg/L)	83	83		37	99.8675	17.1442	168	67.1	95	101	105.5	117.8
Sulfate (as SO4)	54	48	6	1	8.4792	6.7453	39	2	4.75	7	10.25	20.3
Metals (dissolved)												
Aluminium - dissolved (mg/L)	3	1	2	0.012	0.0120	0.0000	0.012	0.012	0.012	0.012	0.012	0.012
Arsenic - dissolved (mg/L)	54	27	27	0.001	0.0013	0.0008	0.004	0.001	0.001	0.001	0.001	0.003
Barium - dissolved (mg/L)	53	53		0.06	0.3703	0.0970	0.493	0.2046	0.315	0.394	0.433	0.487
Beryllium - dissolved (mg/L)	10		10									
Bismuth - dissolved (mg/L)	43		43									
Boron - dissolved (mg/L)	11	11		0.06	0.0895	0.0205	0.13	0.065	0.075	0.084	0.1	0.125
Cadmium - dissolved (mg/L)	12	1	11	0.0002	0.0002	0.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Chromium - dissolved (mg/L)	54	2	52	0.001	0.0015	0.0005	0.002	0.00105	0.00125	0.0015	0.00175	0.00195
Cobalt - dissolved (mg/L)	54	3	51	0.001	0.0023	0.0012	0.004	0.0011	0.0015	0.002	0.003	0.0038
Copper - dissolved (mg/L)	54	26	28	0.001	0.0034	0.0038	0.02	0.001	0.002	0.002	0.003	0.00775
Iron - dissolved (mg/L)	1		1									
Lead - dissolved (mg/L)	12	2	10	0.003	0.0030	0.0000	0.003	0.003	0.003	0.003	0.003	0.003
Manganese - dissolved (mg/L)	12	12		0.684	3.1303	0.8798	4.06	1.7378	2.8625	3.255	3.725	4.049
Mercury - dissolved (mg/L)	11		11									
Molybdenum - dissolved (mg/L)	43	43		0.002	0.0027	0.0007	0.005	0.002	0.002	0.003	0.003	0.0039
Nickel - dissolved (mg/L)	54	9	45	0.001	0.0023	0.0011	0.004	0.001	0.002	0.002	0.003	0.004
Selenium - dissolved (mg/L)	53	1	52	0.003	0.0030	0.0000	0.003	0.003	0.003	0.003	0.003	0.003
Silicon - dissolved (mg/L)	1	1		18	18.0000	0.0000	18	18	18	18	18	18
Uranium - dissolved (mg/L)	43	40	3	0.001	0.0020	0.0004	0.003	0.001	0.002	0.002	0.002	0.003
Vanadium - dissolved (mg/L)	10		10									

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Zinc - dissolved (mg/L)	12	9	3	0.007	0.0144	0.0056	0.024	0.0078	0.011	0.014	0.017	0.0236
Metals (total)												
Aluminium - total (mg/L)	3	3		0.02	0.0297	0.0078	0.039	0.021	0.025	0.03	0.0345	0.0381
Arsenic - total (mg/L)	54	30	24	0.001	0.0017	0.0008	0.004	0.001	0.001	0.0015	0.002	0.00355
Barium - total (mg/L)	53	53		0.068	0.3921	0.0997	0.529	0.2384	0.34	0.413	0.468	0.5094
Beryllium - total (mg/L)	10		10									
Bismuth - total (mg/L)	43		43									
Boron - total (mg/L)	11	10	1	0.06	0.0858	0.0215	0.13	0.0645	0.07	0.0805	0.08925	0.1255
Cadmium - total (mg/L)	12	1	11	0.0003	0.0003	0.0000	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Chromium - total (mg/L)	54	3	51	0.002	0.0037	0.0017	0.006	0.0021	0.0025	0.003	0.0045	0.0057
Cobalt - total (mg/L)	54	4	50	0.002	0.0025	0.0009	0.004	0.002	0.002	0.002	0.0025	0.0037
Copper - total (mg/L)	54	47	7	0.001	0.0170	0.0594	0.369	0.001	0.002	0.004	0.007	0.0175
Iron - total (mg/L)	1	1		1.4	1.4000	0.0000	1.4	1.4	1.4	1.4	1.4	1.4
Lead - total (mg/L)	12	4	8	0.001	0.0018	0.0008	0.003	0.001	0.001	0.0015	0.00225	0.00285
Manganese - total (mg/L)	12	12		0.696	3.2955	0.9454	4.35	1.7157	2.895	3.59	3.7875	4.2895
Mercury - total (mg/L)	11		11									
Molybdenum - total (mg/L)	43	42	1	0.002	0.0030	0.0007	0.005	0.002	0.003	0.003	0.003	0.004
Nickel - total (mg/L)	54	9	45	0.001	0.0021	0.0010	0.004	0.001	0.001	0.002	0.003	0.0036
Selenium - total (mg/L)	53	1	52	0.003	0.0030	0.0000	0.003	0.003	0.003	0.003	0.003	0.003
Silicon - total (mg/L)	1	1		18	18.0000	0.0000	18	18	18	18	18	18
Uranium - total (mg/L)	43	41	2	0.001	0.0020	0.0004	0.003	0.001	0.002	0.002	0.002	0.003
Vanadium - total (mg/L)	10		10									
Zinc - total (mg/L)	12	11	1	0.007	0.0169	0.0086	0.038	0.007	0.0105	0.017	0.0185	0.0315
Nutrients												
Nitrite + Nitrate as N (mg/L)	3	1	2	0.28	0.2800	0.0000	0.28	0.28	0.28	0.28	0.28	0.28
Total Kjeldahl Nitrogen as N (mg/L)	3	3		0.2	0.2333	0.0471	0.3	0.2	0.2	0.2	0.25	0.29
Total Nitrogen as N (mg/L)	3	3		0.2	0.3333	0.1247	0.5	0.21	0.25	0.3	0.4	0.48

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Total Phosphorus as P (mg/L)	3	3		0.03	0.0600	0.0216	0.08	0.034	0.05	0.07	0.075	0.079
Physico-Chemical Parameters												
Electrical Conductivity (µS/cm)	43	43		233	814.8372	117.6562	950	596	813.5	848	868	890.9
pH (lab)	47	47		7.25	7.6762	0.2477	8.33	7.323	7.48	7.68	7.88	8.079
Total Dissolved Solids (mg/L)	1	1		560	560.0000	0.0000	560	560	560	560	560	560
Turbidity (NTU)	43	43		0.4	15.0465	10.4173	50.7	1.83	5.3	16.5	22.75	28.19
BAWB05												
Alkalinity												
Bicarbonate Alkalinity as CaCO3 (mg/L)	50	50		66	342.5800	100.6598	501	230.35	250.5	349	442	470.65
Carbonate Alkalinity as CaCO3 (mg/L)	50	2	48	13	19.5000	6.5000	26	13.65	16.25	19.5	22.75	25.35
Carbonate Alkalinity as CO3 (mg/L)	1		1									
Hydroxide Alkalinity as CaCO3 (mg/L)	50		50									
Temperature (field) (°C)	50	50		66	343.4400	100.7659	501	230.35	250.5	355	442	470.65
Field Measurements												
Appearance or Colour	19											
Depth of Bore (mbgl)	55	55		102	102.0000	0.0000	102	102	102	102	102	102
Depth to Water (mbRL)	56	56		12.86	22.2573	3.3583	25.96	14.8875	21.7075	23.785	24.3375	24.9525
Depth to Water (mbGL)	19	19		12.86	19.6247	3.7342	25.14	13.607	15.99	20.24	22.49	24.915
Dissolved Oxygen (field) (% sat))	30	30		0	20.1000	28.0009	116.1	0	3.1	7.95	23.95	78.615
Electrical Conductivity (field) (µS/cm)	34	34		11.17	749.8579	190.6070	1142	601.2	650.75	713.5	874.25	973.8
Groundwater Level (mAHD)	54	54		287.43	315.3653	13.8797	353.73	299.3225	307.477	310.9645	319.5145	341.10965
GWL Depth Reference Elevation	55	55		311.33	337.4472	14.1016	378.09	323.92	330.22	332.939	335.23	362.5297
Odour	21											
ORP (field) (mV)	26	26		-190.1	-97.1692	76.1229	158.4	-177.925	-154.475	-108.05	-69.4	33.775
pH (field)	34	34		6.99	7.7491	0.4076	8.68	7.1525	7.435	7.655	8.0025	8.51
Salinity (field) (PSU)	31	31		0.3	0.3771	0.0723	0.56	0.3	0.31	0.35	0.43	0.48
TDS (field) (ppm)	31	31		21.99	30.6306	1.9696	33.47	28.615	29.93	31.05	31.515	32.775

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Total Dissolved Solids (field) (ppm)	26	26		312	377.5000	68.5286	571	315	327.25	345.5	428.5	489
Turbidity (field) (FNU)	20	20		0	1.9350	2.1178	8.7	0	0	1.8	2.5	4.9
Hardness												
Total Hardness (mg CaCO3/L)	43	43		43	228.3721	59.5268	327	170.1	184	214	279	319.6
Ion Balance												
Ionic Balance (%)	49	49		-2	3.3308	2.7853	14.3	0.278	1.42	2.96	4.46	9.172
Total Anions (meq/L)	50	50		1.73	8.5838	2.0640	11.6	6.238	6.84	9.02	10.45	11.11
Total Cations (meq/L)	50	50		1.66	8.6134	1.9111	11.8	6.647	7.0925	8.93	9.9425	11.31
Major Ions												
Calcium (mg/L)	74	74		9	38.6081	7.0420	58	31	34	37	43	49.35
Chloride (mg/L)	50	50		5	17.0800	5.3994	28	11.45	12	17	21.75	26
Fluoride (mg/L)	36	35	1	0.2	0.5343	0.1194	0.8	0.27	0.5	0.6	0.6	0.63
Magnesium (mg/L)	74	74		5	32.1486	9.4378	53	23	24	28.5	40.75	47
Potassium (mg/L)	74	74		4	18.5270	2.5797	25	16	18	19	20	22
Sodium (mg/L)	74	74		16	77.5405	15.6552	118	62.65	68	72	89	102.75
Sulfate (as SO4)	50	50		13	59.6840	14.7785	84	36.15	49.5	63.6	69.75	77.65
Metals (dissolved)												
Aluminium - dissolved (mg/L)	2	2		0.02	0.0270	0.0070	0.034	0.0207	0.0235	0.027	0.0305	0.0333
Arsenic - dissolved (mg/L)	50	25	25	0.001	0.0014	0.0005	0.002	0.001	0.001	0.001	0.002	0.002
Barium - dissolved (mg/L)	49	49		0.071	0.1777	0.0669	0.374	0.0984	0.141	0.159	0.205	0.3144
Beryllium - dissolved (mg/L)	10		10									
Bismuth - dissolved (mg/L)	39		39									
Boron - dissolved (mg/L)	10	5	5	0.04	0.0594	0.0144	0.08	0.0416	0.048	0.059	0.07	0.078
Cadmium - dissolved (mg/L)	11	1	10	0.0005	0.0005	0.0000	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Chromium - dissolved (mg/L)	50	1	49	0.002	0.0020	0.0000	0.002	0.002	0.002	0.002	0.002	0.002
Cobalt - dissolved (mg/L)	50		50									
Copper - dissolved (mg/L)	50	18	32	0.001	0.0041	0.0053	0.024	0.001	0.002	0.002	0.00375	0.0104

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Iron - dissolved (mg/L)	1		1									
Lead - dissolved (mg/L)	11		11									
Manganese - dissolved (mg/L)	11	11		0.3	0.5906	0.3265	1.4	0.312	0.3695	0.461	0.6305	1.225
Mercury - dissolved (mg/L)	11		11									
Molybdenum - dissolved (mg/L)	39	39		0.005	0.0191	0.0057	0.031	0.0098	0.015	0.02	0.023	0.0273
Nickel - dissolved (mg/L)	50	9	41	0.001	0.0018	0.0012	0.005	0.001	0.001	0.001	0.002	0.0038
Selenium - dissolved (mg/L)	49		49									
Silicon - dissolved (mg/L)	1	1		13	13.0000	0.0000	13	13	13	13	13	13
Uranium - dissolved (mg/L)	39	39		0.001	0.0025	0.0012	0.006	0.001	0.002	0.002	0.003	0.005
Vanadium - dissolved (mg/L)	10	1	9	0.002	0.0020	0.0000	0.002	0.002	0.002	0.002	0.002	0.002
Zinc - dissolved (mg/L)	11	5	6	0.007	0.0108	0.0030	0.015	0.0072	0.008	0.011	0.013	0.0146
Metals (total)												
Aluminium - total (mg/L)	2	2		0.044	0.1170	0.0730	0.19	0.0513	0.0805	0.117	0.1535	0.1827
Arsenic - total (mg/L)	50	33	17	0.001	0.0017	0.0009	0.005	0.001	0.001	0.002	0.002	0.003
Barium - total (mg/L)	49	49		0.088	0.1952	0.0812	0.399	0.1016	0.153	0.167	0.247	0.3662
Beryllium - total (mg/L)	10		10									
Bismuth - total (mg/L)	39		39									
Boron - total (mg/L)	10	6	4	0.04	0.0563	0.0095	0.07	0.04225	0.0515	0.0595	0.06	0.0675
Cadmium - total (mg/L)	11	2	9	0.0003	0.0004	0.0001	0.0004	0.000305	0.000325	0.00035	0.000375	0.000395
Chromium - total (mg/L)	50	6	44	0.001	0.0018	0.0011	0.004	0.001	0.001	0.0015	0.002	0.0035
Cobalt - total (mg/L)	50	4	46	0.001	0.0015	0.0005	0.002	0.001	0.001	0.0015	0.002	0.002
Copper - total (mg/L)	50	48	2	0.001	0.0047	0.0032	0.019	0.00135	0.003	0.004	0.006	0.00965
Iron - total (mg/L)	1	1		0.71	0.7100	0.0000	0.71	0.71	0.71	0.71	0.71	0.71
Lead - total (mg/L)	11	5	6	0.001	0.0024	0.0019	0.006	0.001	0.001	0.002	0.002	0.0052
Manganese - total (mg/L)	11	11		0.346	0.6552	0.3198	1.4	0.368	0.4175	0.54	0.747	1.265
Mercury - total (mg/L)	11		11									
Molybdenum - total (mg/L)	39	39		0.007	0.0217	0.0062	0.033	0.0128	0.0155	0.024	0.026	0.0311

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Nickel - total (mg/L)	50	13	37	0.001	0.0029	0.0033	0.014	0.001	0.002	0.002	0.002	0.0086
Selenium - total (mg/L)	49		49									
Silicon - total (mg/L)	1	1		14	14.0000	0.0000	14	14	14	14	14	14
Uranium - total (mg/L)	39	39		0.002	0.0028	0.0012	0.006	0.002	0.002	0.002	0.003	0.006
Vanadium - total (mg/L)	10	2	8	0.001	0.0015	0.0005	0.002	0.00105	0.00125	0.0015	0.00175	0.00195
Zinc - total (mg/L)	11	10	1	0.006	0.0101	0.0041	0.02	0.006	0.00625	0.0105	0.011	0.01685
Nutrients												
Nitrite + Nitrate as N (mg/L)	3	3		0.02	0.0333	0.0094	0.04	0.022	0.03	0.04	0.04	0.04
Total Kjeldahl Nitrogen as N (mg/L)	3	3		0.3	0.3333	0.0471	0.4	0.3	0.3	0.3	0.35	0.39
Total Nitrogen as N (mg/L)	3	3		0.3	0.3333	0.0471	0.4	0.3	0.3	0.3	0.35	0.39
Total Phosphorus as P (mg/L)	3	3		0.03	0.0467	0.0125	0.06	0.032	0.04	0.05	0.055	0.059
Physico-Chemical Parameters												
Electrical Conductivity (µS/cm)	39	39		164	738.7436	170.8824	996	604.2	621.5	662	895.5	978.9
pH (lab)	43	43		7.1	7.9895	0.2410	8.4	7.649	7.83	8.05	8.17	8.289
Total Dissolved Solids (mg/L)	1	1		600	600.0000	0.0000	600	600	600	600	600	600
Turbidity (NTU)	39	39		0.3	4.6564	4.8768	18.5	0.49	1.8	2.6	5.65	17.6
BAWB07												
Alkalinity												
Bicarbonate Alkalinity as CaCO3 (mg/L)	17	17		419	485.5294	36.3401	554	443	462	476	497	548.4
Carbonate Alkalinity as CaCO3 (mg/L)	17		17									
Hydroxide Alkalinity as CaCO3 (mg/L)	17		17									
Temperature (field) (°C)	17	17		419	485.5294	36.3401	554	443	462	476	497	548.4
Field Measurements												
Appearance or Colour	1											
Depth of Bore (mbgl)	8	8		146	146.0000	0.0000	146	146	146	146	146	146
Depth to Water (mbRL)	9	9		10.04	14.3811	2.2769	16.93	10.404	13.59	14.96	15.96	16.71
Depth to Water (mbGL)	5	5		10.04	13.2080	2.2937	15.74	10.222	10.95	14.12	15.19	15.63

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Depth to Water Comments	1											
Dissolved Oxygen (field) (% sat))	7	7		2.4	9.5714	7.2691	25.2	3.06	5.1	5.6	11.8	21.78
Electrical Conductivity (field) (µS/cm)	10	10		998	1100.7000	72.5811	1264	1006.55	1070	1087	1115.75	1225.75
Groundwater Level (mAHD)	7	7		307.96	317.5799	4.4072	322.052	310.4776	317.052	317.832	320.5555	322.0331
GWL Depth Reference Elevation	8	8		323.92	331.3934	2.8452	332.939	326.7368	332.061	332.402	332.712	332.85955
Odour	1											
ORP (field) (mV)	3	3		-77.3	1.6333	55.8611	43.9	-65.74	-19.5	38.3	41.1	43.34
pH (field)	10	10		6.62	7.0330	0.3803	8.01	6.6245	6.82	6.965	7.0975	7.686
Salinity (field) (PSU)	7	7		0.5	0.5386	0.0236	0.58	0.506	0.525	0.54	0.55	0.571
TDS (field) (ppm)	7	7		24.79	29.4014	2.1045	31.68	26.005	28.975	29.75	30.82	31.425
Total Dissolved Solids (field) (ppm)	3	3		541	561.6667	20.7257	590	542.3	547.5	554	572	586.4
Turbidity (field) (FNU)	7	7		0	2.8714	6.4322	18.6	0	0	0	0.75	13.35
Hardness												
Total Hardness (mg CaCO3/L)	11	11		236	265.6364	19.1751	307	236	258.5	264	272	296
Ion Balance												
Ionic Balance (%)	17	17		0.38	2.9853	2.2451	8.8	0.588	1.38	2.42	3.64	7.744
Total Anions (meq/L)	17	17		11	12.0941	0.5936	13.1	11.32	11.6	12	12.6	13.1
Total Cations (meq/L)	17	17		9.55	12.1676	0.9002	13.7	10.79	12	12.2	12.6	13.14
Major Ions												
Calcium (mg/L)	17	17		44	52.8824	4.4043	62	44	50	53	55	58.8
Chloride (mg/L)	17	17		36	41.7647	3.9931	49	36	39	42	44	47.4
Fluoride (mg/L)	11	11		0.8	1.4545	0.3173	1.7	0.8	1.5	1.6	1.65	1.7
Magnesium (mg/L)	17	17		26	32.4706	3.1271	37	26.8	32	33	34	37
Potassium (mg/L)	17	17		5	7.4118	1.0878	10	5.8	7	8	8	8.4
Sodium (mg/L)	17	17		117	153.4118	12.9254	173	134.6	150	153	161	170.6
Sulfate (as SO4)	17	17		39	58.2353	10.9627	75	42.2	47	61	66	71
Metals (dissolved)												

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Arsenic - dissolved (mg/L)	17	17		0.002	0.0079	0.0063	0.018	0.002	0.003	0.004	0.015	0.018
Barium - dissolved (mg/L)	17	17		0.054	0.0884	0.0242	0.152	0.0548	0.073	0.084	0.1	0.128
Beryllium - dissolved (mg/L)	6		6									
Bismuth - dissolved (mg/L)	11		11									
Boron - dissolved (mg/L)	6	4	2	0.05	0.0675	0.0109	0.08	0.053	0.065	0.07	0.0725	0.0785
Cadmium - dissolved (mg/L)	6		6									
Chromium - dissolved (mg/L)	17	2	15	0.001	0.0015	0.0005	0.002	0.00105	0.00125	0.0015	0.00175	0.00195
Cobalt - dissolved (mg/L)	17	1	16	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001
Copper - dissolved (mg/L)	17	11	6	0.001	0.0043	0.0049	0.015	0.001	0.001	0.002	0.0055	0.0135
Lead - dissolved (mg/L)	6	2	4	0.001	0.0035	0.0025	0.006	0.00125	0.00225	0.0035	0.00475	0.00575
Manganese - dissolved (mg/L)	6	6		0.058	0.0733	0.0105	0.086	0.05875	0.064	0.077	0.081	0.08475
Mercury - dissolved (mg/L)	6		6									
Molybdenum - dissolved (mg/L)	11	11		0.003	0.0039	0.0007	0.005	0.003	0.0035	0.004	0.004	0.005
Nickel - dissolved (mg/L)	17	4	13	0.001	0.0025	0.0015	0.004	0.001	0.001	0.0025	0.004	0.004
Selenium - dissolved (mg/L)	17		17									
Uranium - dissolved (mg/L)	11	11		0.004	0.0042	0.0004	0.005	0.004	0.004	0.004	0.004	0.005
Vanadium - dissolved (mg/L)	6		6									
Zinc - dissolved (mg/L)	6	5	1	0.005	0.0068	0.0012	0.008	0.0052	0.006	0.007	0.008	0.008
Metals (total)												
Arsenic - total (mg/L)	17	17		0.002	0.0081	0.0063	0.019	0.002	0.003	0.005	0.014	0.0182
Barium - total (mg/L)	17	17		0.066	0.0885	0.0111	0.105	0.074	0.08	0.086	0.098	0.1042
Beryllium - total (mg/L)	6		6									
Bismuth - total (mg/L)	11		11									
Boron - total (mg/L)	6	4	2	0.05	0.0725	0.0148	0.09	0.053	0.065	0.075	0.0825	0.0885
Cadmium - total (mg/L)	6	1	5	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Chromium - total (mg/L)	17	3	14	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001
Cobalt - total (mg/L)	17		17									

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Copper - total (mg/L)	17	15	2	0.002	0.0093	0.0082	0.029	0.0027	0.0035	0.006	0.0125	0.0241
Lead - total (mg/L)	6	3	3	0.001	0.0073	0.0083	0.019	0.0011	0.0015	0.002	0.0105	0.0173
Manganese - total (mg/L)	6	6		0.074	0.0850	0.0145	0.116	0.074	0.0755	0.08	0.0845	0.1085
Mercury - total (mg/L)	6		6									
Molybdenum - total (mg/L)	11	11		0.003	0.0040	0.0006	0.005	0.003	0.004	0.004	0.004	0.005
Nickel - total (mg/L)	17	7	10	0.001	0.0014	0.0005	0.002	0.001	0.001	0.001	0.002	0.002
Selenium - total (mg/L)	17		17									
Uranium - total (mg/L)	11	11		0.003	0.0039	0.0005	0.005	0.003	0.004	0.004	0.004	0.0045
Vanadium - total (mg/L)	6		6									
Zinc - total (mg/L)	6	4	2	0.011	0.0203	0.0061	0.028	0.0125	0.0185	0.021	0.02275	0.02695
Nutrients												
Nitrite + Nitrate as N (mg/L)	1	1		0.39	0.3900	0.0000	0.39	0.39	0.39	0.39	0.39	0.39
Total Kjeldahl Nitrogen as N (mg/L)	1	1		0.1	0.1000	0.0000	0.1	0.1	0.1	0.1	0.1	0.1
Total Nitrogen as N (mg/L)	1	1		0.5	0.5000	0.0000	0.5	0.5	0.5	0.5	0.5	0.5
Total Phosphorus as P (mg/L)	1	1		0.04	0.0400	0.0000	0.04	0.04	0.04	0.04	0.04	0.04
Physico-Chemical Parameters												
Electrical Conductivity (µS/cm)	11	11		951	1077.3636	51.8429	1130	995.5	1050	1100	1120	1130
pH (lab)	11	11		7.31	7.4382	0.1372	7.71	7.31	7.33	7.43	7.45	7.705
Turbidity (NTU)	11	11		0.3	5.0182	5.6307	16.2	0.55	1.05	1.7	6	16.2
BAWBR01												
Alkalinity												
Bicarbonate Alkalinity as CaCO3 (mg/L)	2	2		2120	2170.0000	50.0000	2220	2125	2145	2170	2195	2215
Carbonate Alkalinity as CaCO3 (mg/L)	2		2									
Hydroxide Alkalinity as CaCO3 (mg/L)	2		2									
Temperature (field) (°C)	2	2		2120	2170.0000	50.0000	2220	2125	2145	2170	2195	2215
Field Measurements												
Appearance or Colour	2											

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Depth of Bore (mbgl)	51	51		3.5	5.9627	0.3581	6.6	6	6	6	6	6
Depth to Water (mbRL)	24	24		1.22	5.0142	1.7549	6.9	1.533	3.37	5.795	6.1075	6.77
Depth to Water (mbGL)	12	12		3.34	5.5517	1.0583	6.9	3.362	5.6975	5.775	5.87	6.845
Depth to Water Comments	39											
Dissolved Oxygen (field) (% sat))	3	3		6	79.2333	84.9327	198.3	8.74	19.7	33.4	115.85	181.81
Dry?	39											
Electrical Conductivity (field) (µS/cm)	3	3		28.4	240.8100	299.9477	665	28.463	28.715	29.03	347.015	601.403
Groundwater Level (mAHD)	24	24		318.16	329.8427	9.1451	349.971	318.653	325.3355	326.6705	331.93425	349.56885
GWL Depth Reference Elevation	51	51		323.92	338.2382	13.2926	378.09	325.34	331.094	332.939	337.237	366.9755
Odour	2											
ORP (field) (mV)	3	3		-118.7	-40.0667	59.9494	26.7	-109.65	-73.45	-28.2	-0.75	21.21
pH (field)	3	3		7.67	8.1200	0.3195	8.38	7.734	7.99	8.31	8.345	8.373
Salinity (field) (PSU)	3	3		0.32	11.7967	8.1179	17.79	2.016	8.8	17.28	17.535	17.739
TDS (field) (ppm)	3	3		30.6	31.7333	1.2532	33.48	30.652	30.86	31.12	32.3	33.244
Total Dissolved Solids (field) (ppm)	3	3		14.19	120.2333	149.7417	332	14.222	14.35	14.51	173.255	300.251
Turbidity (field) (FNU)	1	1		4.6	4.6000	0.0000	4.6	4.6	4.6	4.6	4.6	4.6
Hardness												
Total Hardness (mg CaCO3/L)	2	2		1140	1140.0000	0.0000	1140	1140	1140	1140	1140	1140
Ion Balance												
Ionic Balance (%)	2	2		4.44	5.6800	1.2400	6.92	4.564	5.06	5.68	6.3	6.796
Total Anions (meq/L)	2	2		346	349.0000	3.0000	352	346.3	347.5	349	350.5	351.7
Total Cations (meq/L)	2	2		385	391.0000	6.0000	397	385.6	388	391	394	396.4
Major Ions												
Calcium (mg/L)	4	4		125	132.7500	6.2199	142	125.75	128.75	132	136	140.8
Chloride (mg/L)	2	2		5420	5455.0000	35.0000	5490	5423.5	5437.5	5455	5472.5	5486.5
Fluoride (mg/L)	2	2		2	2.2000	0.2000	2.4	2.02	2.1	2.2	2.3	2.38
Magnesium (mg/L)	4	4		173	187.0000	9.4868	199	174.8	182	188	193	197.8

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Potassium (mg/L)	4	4		35	35.7500	0.8292	37	35	35	35.5	36.25	36.85
Sodium (mg/L)	4	4		7790	8150.0000	313.4486	8580	7809.5	7887.5	8115	8377.5	8539.5
Sulfate (as SO4)	2	2		7220	7290.0000	70.0000	7360	7227	7255	7290	7325	7353
Metals (dissolved)												
Arsenic - dissolved (mg/L)	2	2		0.006	0.0060	0.0000	0.006	0.006	0.006	0.006	0.006	0.006
Barium - dissolved (mg/L)	2	2		0.091	0.0935	0.0025	0.096	0.09125	0.09225	0.0935	0.09475	0.09575
Bismuth - dissolved (mg/L)	2		2									
Chromium - dissolved (mg/L)	2		2									
Cobalt - dissolved (mg/L)	2	2		0.013	0.0140	0.0010	0.015	0.0131	0.0135	0.014	0.0145	0.0149
Copper - dissolved (mg/L)	2	1	1	0.007	0.0070	0.0000	0.007	0.007	0.007	0.007	0.007	0.007
Molybdenum - dissolved (mg/L)	2	2		0.209	0.2105	0.0015	0.212	0.20915	0.20975	0.2105	0.21125	0.21185
Nickel - dissolved (mg/L)	2		2									
Selenium - dissolved (mg/L)	2		2									
Uranium - dissolved (mg/L)	2	2		0.461	0.4785	0.0175	0.496	0.46275	0.46975	0.4785	0.48725	0.49425
Metals (total)												
Arsenic - total (mg/L)	2	2		0.006	0.0065	0.0005	0.007	0.00605	0.00625	0.0065	0.00675	0.00695
Barium - total (mg/L)	2	2		0.076	0.0860	0.0100	0.096	0.077	0.081	0.086	0.091	0.095
Bismuth - total (mg/L)	2		2									
Chromium - total (mg/L)	2		2									
Cobalt - total (mg/L)	2	2		0.013	0.0135	0.0005	0.014	0.01305	0.01325	0.0135	0.01375	0.01395
Copper - total (mg/L)	2	1	1	0.009	0.0090	0.0000	0.009	0.009	0.009	0.009	0.009	0.009
Molybdenum - total (mg/L)	2	2		0.195	0.2055	0.0105	0.216	0.19605	0.20025	0.2055	0.21075	0.21495
Nickel - total (mg/L)	2		2									
Selenium - total (mg/L)	2		2									
Uranium - total (mg/L)	2	2		0.448	0.4535	0.0055	0.459	0.44855	0.45075	0.4535	0.45625	0.45845
Physico-Chemical Parameters												
Electrical Conductivity (µS/cm)	2	2		28600	29950.0000	1350.0000	31300	28735	29275	29950	30625	31165

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
pH (lab)	2	2		8.07	8.0800	0.0100	8.09	8.071	8.075	8.08	8.085	8.089
Turbidity (NTU)	2	2		9.6	13.1000	3.5000	16.6	9.95	11.35	13.1	14.85	16.25
BAWBR02												
Alkalinity												
Bicarbonate Alkalinity as CaCO3 (mg/L)	6	6		290	1033.6667	816.5747	2200	305.5	381.25	610	1792.75	2185
Carbonate Alkalinity as CaCO3 (mg/L)	6		6									
Hydroxide Alkalinity as CaCO3 (mg/L)	6		6									
Temperature (field) (°C)	6	6		290	1033.6667	816.5747	2200	305.5	381.25	610	1792.75	2185
Field Measurements												
Appearance or Colour	5											
Depth of Bore (mbgl)	53	53		3	3.0336	0.1176	3.45	3	3	3	3	3.44
Depth to Water (mbRL)	35	35		0.98	2.5114	0.7307	3.4	1.094	2.23	2.5	3.34	3.39
Depth to Water (mbGL)	13	13		1.35	2.9692	0.5944	3.39	2.028	2.5	3.36	3.37	3.384
Depth to Water Comments	30											
Dissolved Oxygen (field) (% sat))	7	7		0	45.5000	68.9561	208.5	0.9	6.9	14.9	40.65	163.56
Dry?	30											
Electrical Conductivity (field) (µS/cm)	7	7		557	2274.5714	2186.7162	7385	662	916.5	1676	2235.5	5966.6
Groundwater Level (mAHD)	35	35		309.11	330.9629	10.3460	354.551	320.55	327.36	328.588	330.81	353.714
GWL Depth Reference Elevation	53	53		311.33	335.9972	14.6118	378.09	318.884	329.94	332.092	337.237	364.7526
Odour	5											
ORP (field) (mV)	7	7		-300.9	-24.9857	128.5353	104.9	-232.89	-62.4	4.9	70.5	99.05
pH (field)	7	7		7.05	7.9329	0.6247	8.99	7.092	7.475	7.98	8.28	8.798
Salinity (field) (PSU)	7	7		0.26	1.1929	1.2245	4.07	0.314	0.445	0.85	1.14	3.26
TDS (field) (ppm)	7	7		23.81	29.6229	2.7849	31.97	24.974	28.495	31.32	31.635	31.958
Total Dissolved Solids (field) (ppm)	7	7		279	1138.2857	1092.9212	3692	331.2	458	845	1118	2983.1
Turbidity (field) (FNU)	2	2		0.6	1.0500	0.4500	1.5	0.645	0.825	1.05	1.275	1.455
Hardness												

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Total Hardness (mg CaCO3/L)	6	6		80	529.0000	540.2481	1300	89.75	128.5	197.5	1019.5	1295
Ion Balance												
Ionic Balance (%)	6	6		0.45	2.7367	2.3514	7.32	0.6	1.085	1.8	3.6025	6.49
Total Anions (meq/L)	6	6		9.1	43.4500	37.9807	96.4	9.95	13.525	23.15	79.725	96.4
Total Cations (meq/L)	6	6		9.85	42.3083	36.5460	94.4	10.0875	12.35	23.45	76.4	93.775
Major Ions												
Calcium (mg/L)	12	12		17	63.9167	54.9643	184	18.65	23.75	41.5	78	176.85
Chloride (mg/L)	6	6		58	396.8333	381.0680	950	65.75	98.75	188	743	939.5
Fluoride (mg/L)	6	6		0.3	0.6333	0.2625	1	0.3	0.375	0.7	0.8	0.95
Magnesium (mg/L)	12	12		9	96.5833	112.7818	277	9	14.75	23.5	224	273.7
Potassium (mg/L)	12	12		2	8.0000	6.0690	20	2.55	4	5	12.25	19.45
Sodium (mg/L)	12	12		170	703.0000	570.8289	1570	172.75	208	431.5	1355	1553.5
Sulfate (as SO4)	6	6		80	557.8333	525.1001	1290	95.75	151.25	272	1059.5	1290
Metals (dissolved)												
Arsenic - dissolved (mg/L)	6	5	1	0.001	0.0034	0.0034	0.01	0.001	0.001	0.002	0.003	0.0086
Barium - dissolved (mg/L)	6	6		0.003	0.0670	0.0510	0.162	0.00975	0.036	0.0555	0.08625	0.1455
Bismuth - dissolved (mg/L)	6	1	5	0.00006	0.0001	0.0000	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006
Chromium - dissolved (mg/L)	6	2	4	0.001	0.0040	0.0030	0.007	0.0013	0.0025	0.004	0.0055	0.0067
Cobalt - dissolved (mg/L)	6	2	4	0.002	0.0035	0.0015	0.005	0.00215	0.00275	0.0035	0.00425	0.00485
Copper - dissolved (mg/L)	6	5	1	0.005	0.0600	0.0941	0.247	0.0052	0.006	0.008	0.034	0.2044
Molybdenum - dissolved (mg/L)	6	4	2	0.002	0.0068	0.0065	0.018	0.00215	0.00275	0.0035	0.0075	0.0159
Nickel - dissolved (mg/L)	6	4	2	0.002	0.0088	0.0095	0.025	0.002	0.002	0.004	0.01075	0.02215
Selenium - dissolved (mg/L)	6		6									
Uranium - dissolved (mg/L)	6	6		0.003	0.0317	0.0502	0.143	0.003	0.00425	0.01	0.01875	0.1125
Metals (total)												
Arsenic - total (mg/L)	6	6		0.001	0.0042	0.0034	0.011	0.00125	0.002	0.0025	0.00525	0.00975
Barium - total (mg/L)	6	6		0.067	0.1112	0.0395	0.182	0.0675	0.077	0.1075	0.129	0.17

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Bismuth - total (mg/L)	6	2	4	0.00009	0.0001	0.0001	0.0002	0.0000955	0.0001175	0.000145	0.0001725	0.0001945
Chromium - total (mg/L)	6	4	2	0.001	0.0043	0.0051	0.013	0.001	0.001	0.0015	0.00475	0.01135
Cobalt - total (mg/L)	6	4	2	0.001	0.0038	0.0031	0.009	0.00115	0.00175	0.0025	0.0045	0.0081
Copper - total (mg/L)	6	6		0.009	0.1965	0.3190	0.89	0.0095	0.012	0.0245	0.1735	0.7225
Molybdenum - total (mg/L)	6	6		0.001	0.0077	0.0063	0.017	0.00175	0.004	0.004	0.013	0.01675
Nickel - total (mg/L)	6	6		0.001	0.0092	0.0109	0.033	0.00125	0.0025	0.0055	0.00775	0.02675
Selenium - total (mg/L)	6		6									
Uranium - total (mg/L)	6	6		0.004	0.0563	0.0611	0.156	0.00475	0.0085	0.0225	0.1025	0.1485
Physico-Chemical Parameters												
Electrical Conductivity (µS/cm)	6	6		883	3393.8333	2582.8299	7280	959.75	1292.5	2210	5647.5	7107.5
pH (lab)	6	6		7.46	7.9350	0.2375	8.24	7.575	7.9275	7.96	8.045	8.1975
Turbidity (NTU)	6	6		1.9	6.9500	6.1592	20	2.2	3.225	4.25	7.375	17.05
BAWBR03												
Alkalinity												
Bicarbonate Alkalinity as CaCO3 (mg/L)	6	6		255	486.3333	152.0523	662	271.25	369.75	519	612	657.25
Carbonate Alkalinity as CaCO3 (mg/L)	6		6									
Hydroxide Alkalinity as CaCO3 (mg/L)	6		6									
Temperature (field) (°C)	6	6		255	486.3333	152.0523	662	271.25	369.75	519	612	657.25
Field Measurements												
Appearance or Colour	2											
Depth of Bore (mbgl)	49	49		3.61	3.9982	0.0703	4.3	4	4	4	4	4
Depth to Water (mbRL)	16	16		1.72	3.3306	0.6833	4.3	1.735	3.335	3.62	3.6325	3.805
Depth to Water (mbGL)	14	14		2.61	3.5064	0.2708	3.64	3.052	3.5725	3.62	3.63	3.64
Depth to Water Comments	43											
Dissolved Oxygen (field) (% sat))	4	4		0	20.3750	29.8818	72	0.525	2.625	4.75	22.5	62.1
Dry?	43											
Electrical Conductivity (field) (µS/cm)	4	4		665	1251.0000	358.6698	1621	758	1130	1359	1480	1592.8

	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Groundwater Level (mAHD)	16	16		308.04	328.0186	5.5376	333.617	320.79	328.3985	328.54	329.35975	333.52175
GWL Depth Reference Elevation	49	49		311.33	337.9139	15.3164	378.09	317.502	331.968	332.939	337.237	378.09
Odour	3											
ORP (field) (mV)	4	4		-156.8	-71.0000	76.0383	43.6	-151.085	-128.225	-85.4	-28.175	29.245
pH (field)	4	4		7.4	8.0400	0.5601	8.86	7.4405	7.6025	7.95	8.3875	8.7655
Salinity (field) (PSU)	4	4		0.32	0.6175	0.1832	0.81	0.3665	0.5525	0.67	0.735	0.795
TDS (field) (ppm)	4	4		28.84	30.3875	1.3851	32.28	28.9105	29.1925	30.215	31.41	32.106
Total Dissolved Solids (field) (ppm)	4	4		332	625.5000	179.4861	810	378.65	565.25	680	740.25	796.05
Turbidity (field) (FNU)	2	2		4.6	12.1500	7.5500	19.7	5.355	8.375	12.15	15.925	18.945
Hardness												
Total Hardness (mg CaCO3/L)	6	6		114	300.6667	160.9986	517	114	138	313	428.75	496
Ion Balance												
Ionic Balance (%)	6	6		-2.3	1.5717	2.2585	4.29	-1.59	0.54	1.52	3.52	4.1825
Total Anions (meq/L)	6	6		7.93	19.3883	9.6909	34.4	9.3225	13.5	14.9	27.1	33.475
Total Cations (meq/L)	6	6		7.57	20.2617	10.7520	37.2	9.0275	13.4	15.55	28.65	35.975
Major Ions												
Calcium (mg/L)	9	9		26	83.2222	35.8043	118	26	54	97	112	118
Chloride (mg/L)	6	6		16	95.5000	79.2817	220	22.75	43	51.5	158.25	212.75
Fluoride (mg/L)	5	5		0.2	0.5600	0.3666	1	0.2	0.2	0.4	1	1
Magnesium (mg/L)	9	9		12	35.7778	16.2739	54	12	17	44	47	53.6
Potassium (mg/L)	9	9		5	7.4444	2.1140	12	5	6	8	8	10.8
Sodium (mg/L)	9	9		72	367.7778	194.6226	627	125.2	228	252	546	621
Sulfate (as SO4)	6	6		47	334.3333	269.7497	737	58.5	93	274	549.5	698
Metals (dissolved)												
Arsenic - dissolved (mg/L)	6	5	1	0.002	0.0022	0.0004	0.003	0.002	0.002	0.002	0.002	0.0028
Barium - dissolved (mg/L)	6	6		0.031	0.0468	0.0111	0.068	0.034	0.043	0.045	0.0485	0.06325
Beryllium - dissolved (mg/L)	1		1									

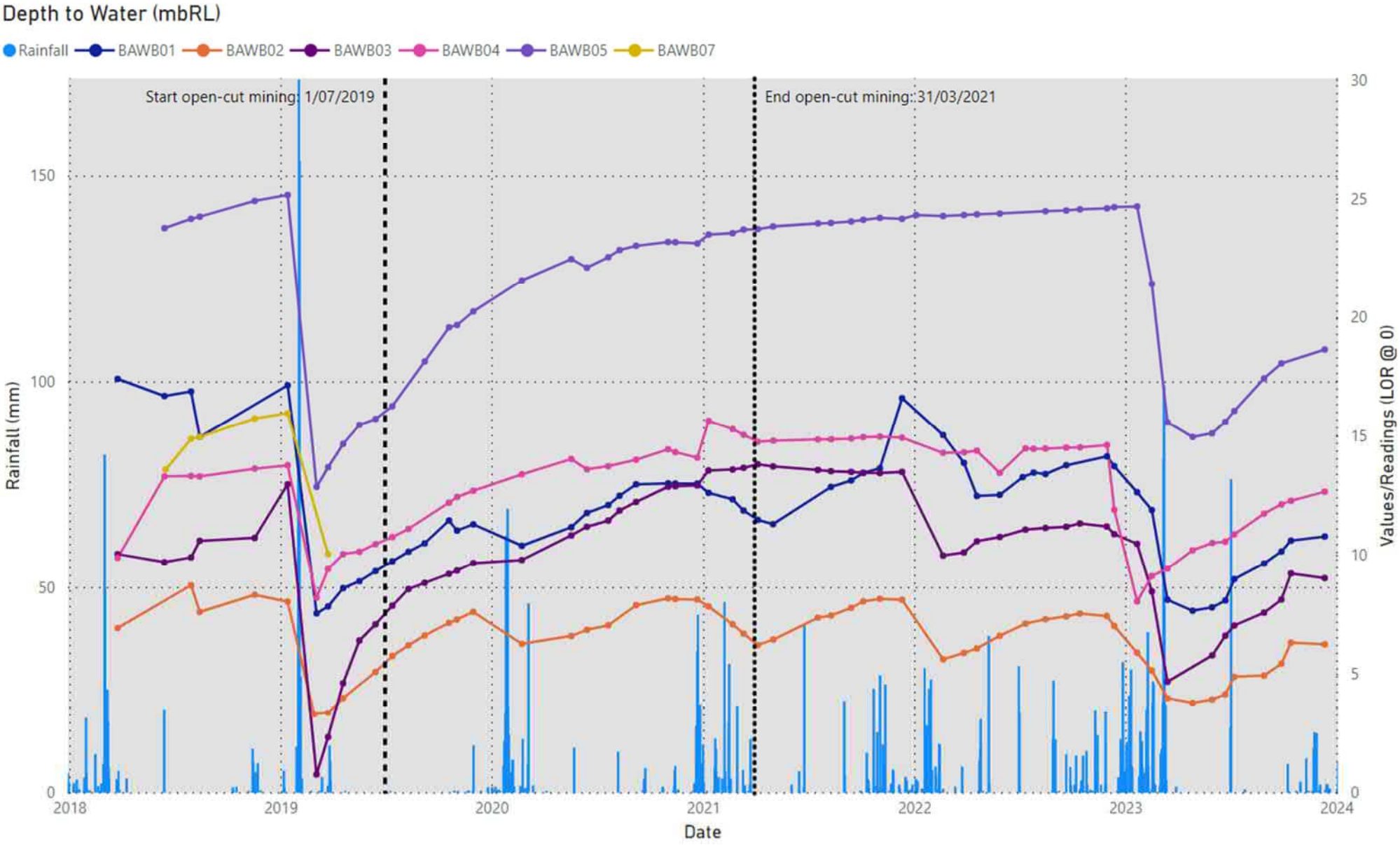
	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Bismuth - dissolved (mg/L)	5		5									
Boron - dissolved (mg/L)	1	1		0.12	0.1200	0.0000	0.12	0.12	0.12	0.12	0.12	0.12
Cadmium - dissolved (mg/L)	1		1									
Chromium - dissolved (mg/L)	6	5	1	0.001	0.0032	0.0016	0.006	0.0014	0.003	0.003	0.003	0.0054
Cobalt - dissolved (mg/L)	6	2	4	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001
Copper - dissolved (mg/L)	6	6		0.002	0.0055	0.0021	0.008	0.0025	0.00425	0.006	0.007	0.00775
Lead - dissolved (mg/L)	1		1									
Manganese - dissolved (mg/L)	1	1		0.007	0.0070	0.0000	0.007	0.007	0.007	0.007	0.007	0.007
Mercury - dissolved (mg/L)	1		1									
Molybdenum - dissolved (mg/L)	5	5		0.003	0.0066	0.0026	0.011	0.0036	0.006	0.006	0.007	0.0102
Nickel - dissolved (mg/L)	6		6									
Selenium - dissolved (mg/L)	6		6									
Uranium - dissolved (mg/L)	5	5		0.002	0.0244	0.0363	0.096	0.002	0.002	0.004	0.018	0.0804
Vanadium - dissolved (mg/L)	1	1		0.003	0.0030	0.0000	0.003	0.003	0.003	0.003	0.003	0.003
Zinc - dissolved (mg/L)	1	1		0.046	0.0460	0.0000	0.046	0.046	0.046	0.046	0.046	0.046
Metals (total)												
Arsenic - total (mg/L)	6	5	1	0.002	0.0022	0.0004	0.003	0.002	0.002	0.002	0.002	0.0028
Barium - total (mg/L)	6	6		0.031	0.0553	0.0140	0.068	0.035	0.04775	0.059	0.068	0.068
Beryllium - total (mg/L)	1		1									
Bismuth - total (mg/L)	5		5									
Boron - total (mg/L)	1	1		0.12	0.1200	0.0000	0.12	0.12	0.12	0.12	0.12	0.12
Cadmium - total (mg/L)	1	1		0.0002	0.0002	0.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Chromium - total (mg/L)	6	5	1	0.002	0.0044	0.0016	0.006	0.0022	0.003	0.005	0.006	0.006
Cobalt - total (mg/L)	6	4	2	0.002	0.0020	0.0000	0.002	0.002	0.002	0.002	0.002	0.002
Copper - total (mg/L)	6	6		0.004	0.0123	0.0072	0.022	0.0045	0.00675	0.01	0.01925	0.022
Lead - total (mg/L)	1		1									
Manganese - total (mg/L)	1	1		0.006	0.0060	0.0000	0.006	0.006	0.006	0.006	0.006	0.006

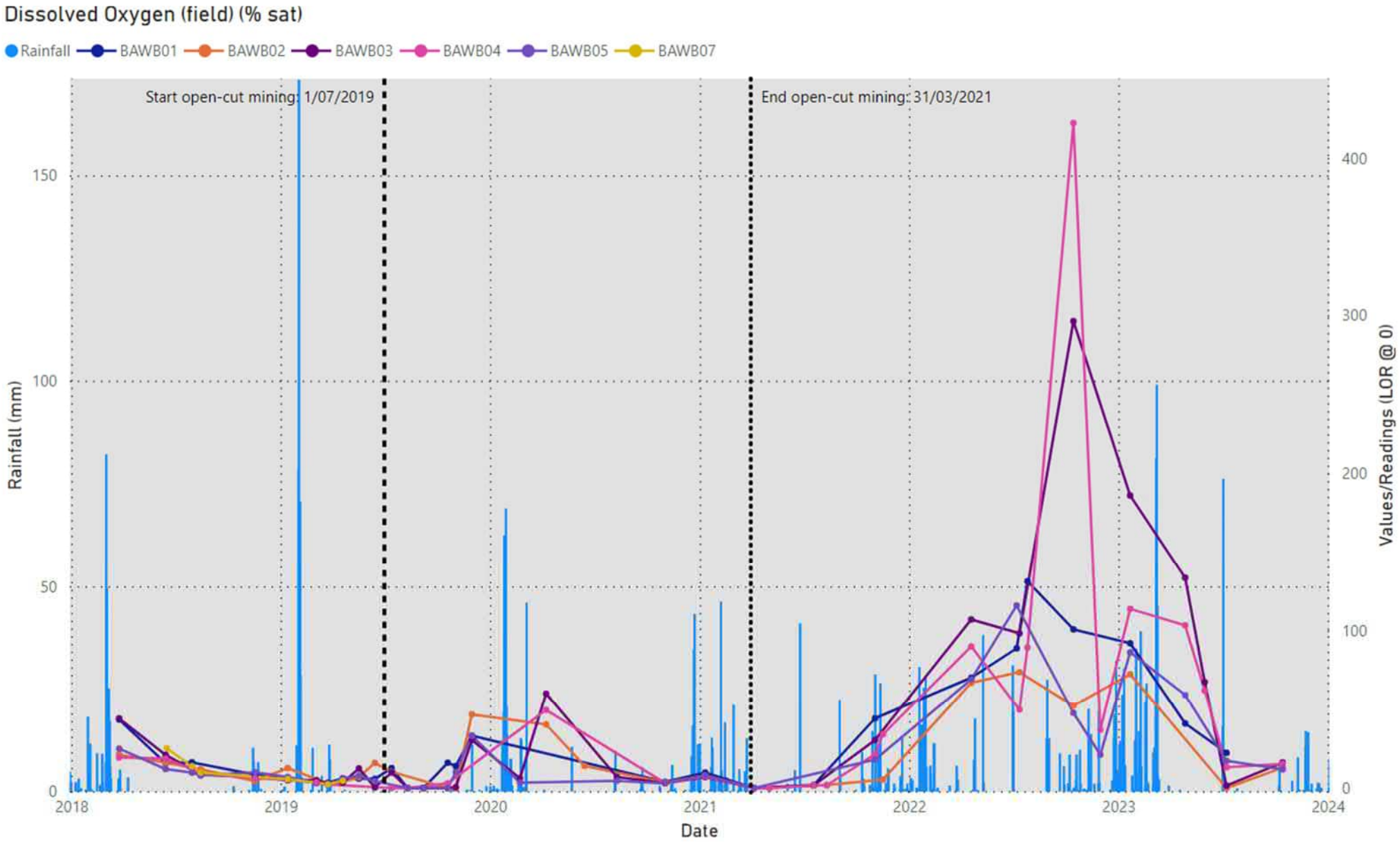
	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Mercury - total (mg/L)	1		1									
Molybdenum - total (mg/L)	5	5		0.004	0.0066	0.0026	0.011	0.004	0.004	0.007	0.007	0.0102
Nickel - total (mg/L)	6	3	3	0.001	0.0017	0.0005	0.002	0.0011	0.0015	0.002	0.002	0.002
Selenium - total (mg/L)	6		6									
Uranium - total (mg/L)	5	5		0.003	0.0260	0.0375	0.1	0.003	0.003	0.005	0.019	0.0838
Vanadium - total (mg/L)	1	1		0.003	0.0030	0.0000	0.003	0.003	0.003	0.003	0.003	0.003
Zinc - total (mg/L)	1	1		0.061	0.0610	0.0000	0.061	0.061	0.061	0.061	0.061	0.061
Physico-Chemical Parameters												
Electrical Conductivity (µS/cm)	5	5		1250	2062.0000	856.3037	3190	1250	1250	1620	3000	3152
pH (lab)	6	6		7.71	7.9383	0.1781	8.2	7.71	7.775	7.975	8.04	8.165
Turbidity (NTU)	5	5		0.6	7.2400	7.2456	16.1	0.8	1.6	1.8	16.1	16.1
Bore E												
Alkalinity												
Bicarbonate Alkalinity as CaCO3 (mg/L)	42	42		261	438.4524	48.8014	515	351.15	420.5	447.5	468	495.6
Carbonate Alkalinity as CaCO3 (mg/L)	42	1	41	28	28.0000	0.0000	28	28	28	28	28	28
Hydroxide Alkalinity as CaCO3 (mg/L)	42		42									
Temperature (field) (°C)	42	42		261	439.1190	47.7828	515	355.25	420.5	447.5	468	495.6
Field Measurements												
Appearance or Colour	25											
Depth of Bore (mbgl)	56	56		83	83.0000	0.0000	83	83	83	83	83	83
Depth to Water (mbRL)	54	54		5.97	10.0202	1.2795	12.21	7.3025	9.89	10.32	10.81	11.31
Depth to Water (mbGL)	20	20		0	8.8615	2.5872	12.21	5.6715	7.9225	9.63	10.2425	12.1245
Depth to Water Comments	1											
Dissolved Oxygen (field) (% sat))	34	34		0	28.6912	48.5231	171.1	0	2.45	8.8	22.05	152.965
Dry?	1											
Electrical Conductivity (field) (µS/cm)	35	35		844	1018.5429	97.1518	1226	864.8	951	1018	1095	1190.5
Groundwater Level (mAHD)	54	54		300.52	324.5317	14.7531	367.62	301.1855	319.3825	323.7395	326.754	353.50865

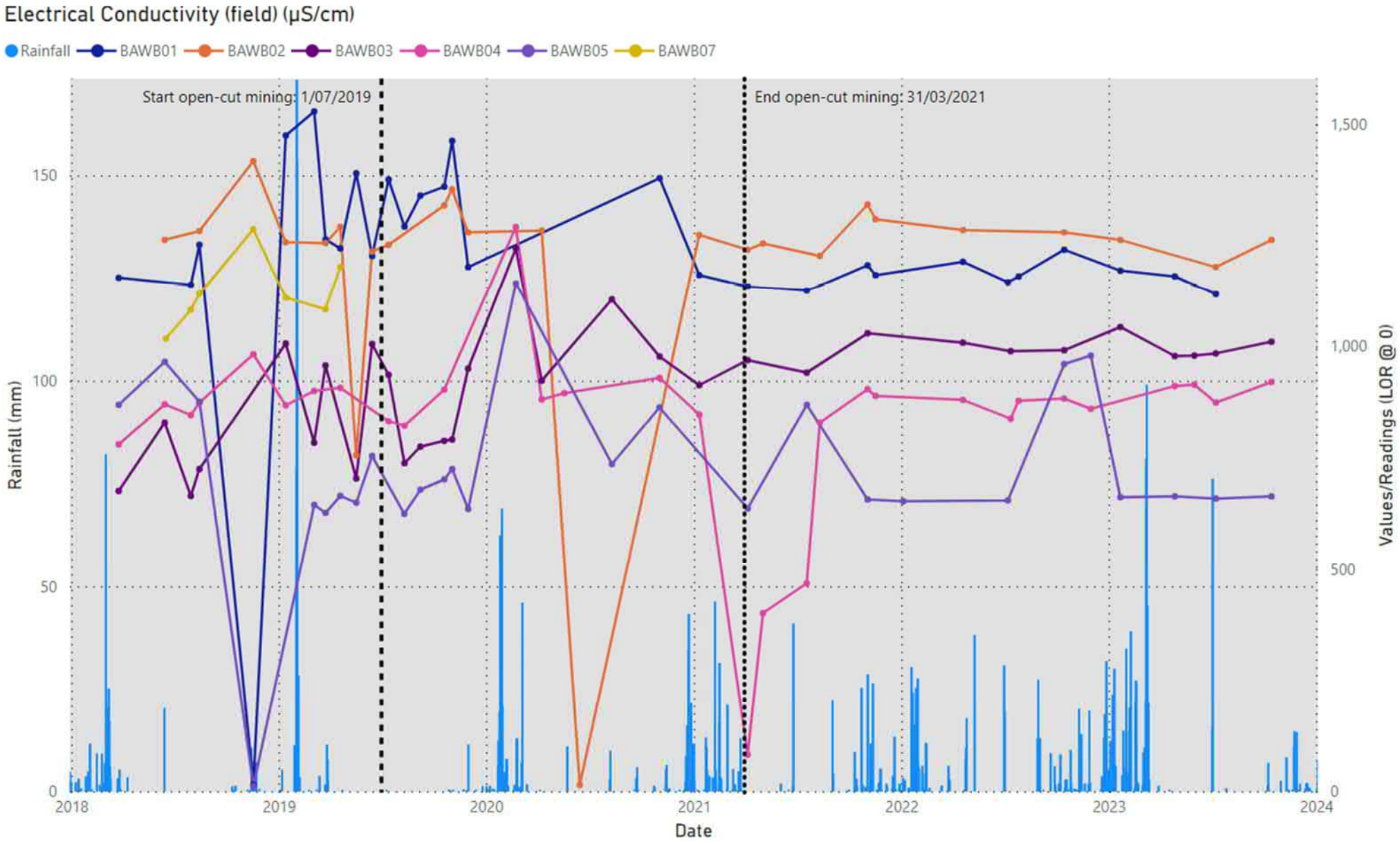
	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
GWL Depth Reference Elevation	56	56		311.33	334.5120	14.5995	378.09	311.33	329.94	332.712	337.237	361.41825
Odour	23											
ORP (field) (mV)	31	31		-71.1	33.9516	55.7929	219.2	-38.55	-7.9	28.4	64	117.95
pH (field)	35	35		6.09	7.1574	0.4269	8.51	6.573	6.985	7.17	7.345	7.691
Salinity (field) (PSU)	35	35		0.41	0.4957	0.0513	0.6	0.42	0.455	0.5	0.54	0.586
TDS (field) (ppm)	35	35		27.47	30.4311	1.5170	33.55	27.795	29.445	30.41	31.32	33.13
Total Dissolved Solids (field) (ppm)	31	31		431	516.4194	46.2042	613	448.5	483	512	550.5	600
Turbidity (field) (FNU)	19	19		0	5.7211	9.9379	35.1	0	0	1.5	4.3	31.14
Hardness												
Total Hardness (mg CaCO3/L)	42	42		194	314.6667	45.8152	405	248.4	280	322	342.75	380.9
Ion Balance												
Ionic Balance (%)	42	42		0.23	3.4200	2.8166	14	0.468	1.465	3	4.29	9.229
Total Anions (meq/L)	42	42		6.56	10.6902	1.2195	13.4	9.1135	10.325	10.75	11.3	12.2
Total Cations (meq/L)	42	42		7.08	11.0569	1.3736	14.3	9.17	10.1	11.25	11.8	13.195
Major Ions												
Calcium (mg/L)	72	72		30	49.7222	7.4893	63	36.55	45.75	51	55	59.45
Chloride (mg/L)	42	42		22	33.6905	11.0507	77	23	28	31	35.75	51.6
Fluoride (mg/L)	42	42		0.5	1.2548	0.2352	1.6	1	1.1	1.3	1.4	1.595
Magnesium (mg/L)	72	72		24	47.3750	8.3988	76	36	42	47	52	61
Potassium (mg/L)	72	72		6	10.3611	2.0770	14	7	9	11	12	13
Sodium (mg/L)	72	72		70	104.6528	11.9979	137	82.2	99	104	111.25	123.45
Sulfate (as SO4)	42	42		28	46.9286	11.3838	74	28.15	38	47.5	52	69.75
Metals (dissolved)												
Arsenic - dissolved (mg/L)	42	33	9	0.001	0.0017	0.0006	0.003	0.001	0.001	0.002	0.002	0.0024
Barium - dissolved (mg/L)	42	42		0.06	0.1707	0.0705	0.474	0.064	0.12925	0.1755	0.199	0.25065
Bismuth - dissolved (mg/L)	42		42									
Chromium - dissolved (mg/L)	42		42									

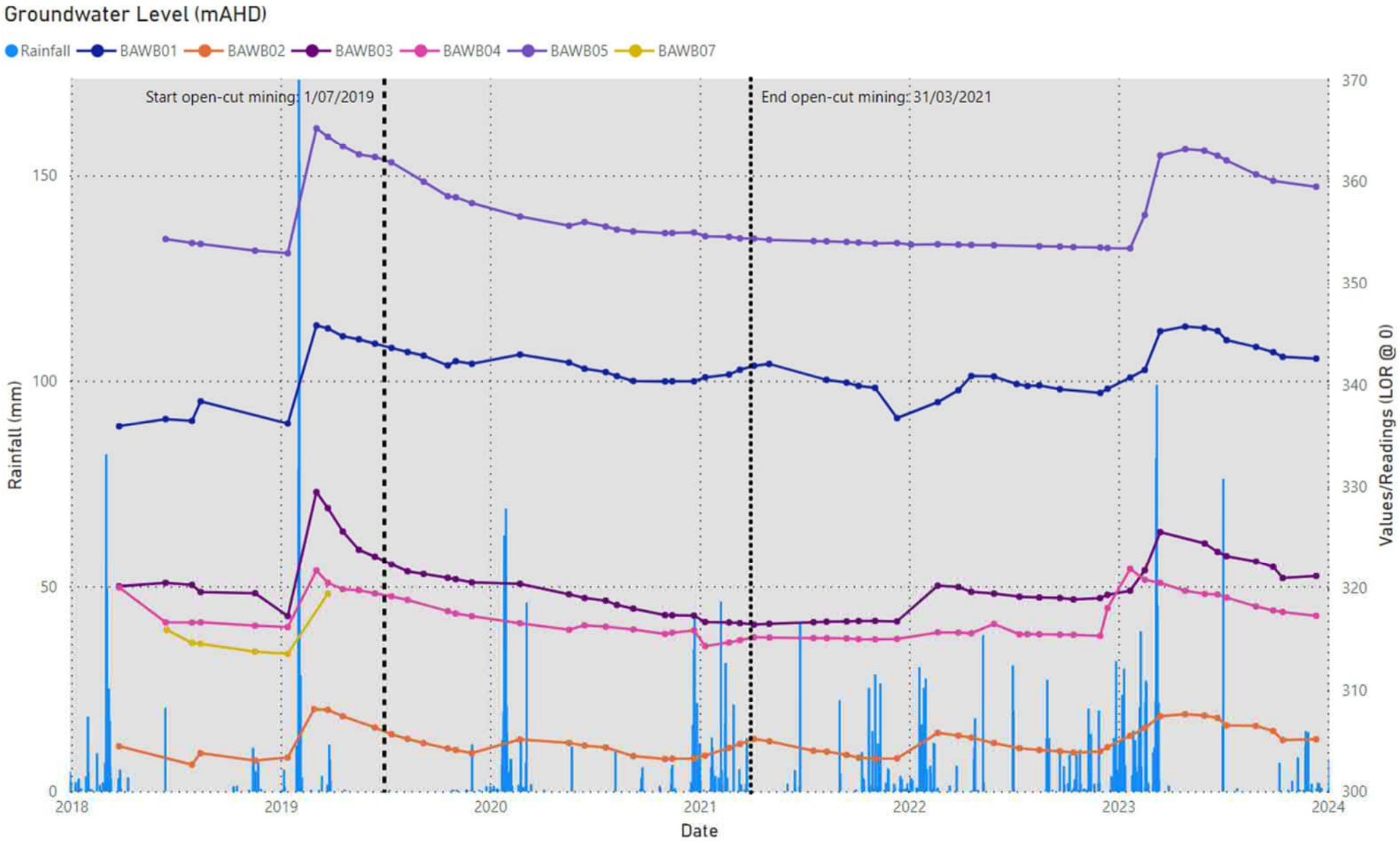
	NumObs	No. > LOR	No. < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Cobalt - dissolved (mg/L)	42	27	15	0.001	0.0014	0.0005	0.002	0.001	0.001	0.001	0.002	0.002
Copper - dissolved (mg/L)	42	15	27	0.001	0.0023	0.0017	0.008	0.001	0.001	0.002	0.002	0.0052
Molybdenum - dissolved (mg/L)	42	40	2	0.001	0.0030	0.0013	0.008	0.002	0.002	0.003	0.003	0.0051
Nickel - dissolved (mg/L)	42	26	16	0.001	0.0027	0.0017	0.007	0.001	0.00125	0.002	0.00375	0.006
Selenium - dissolved (mg/L)	42		42									
Uranium - dissolved (mg/L)	42	42		0.001	0.0043	0.0015	0.007	0.002	0.003	0.005	0.005	0.006
Metals (total)												
Arsenic - total (mg/L)	42	35	7	0.001	0.0017	0.0007	0.004	0.001	0.001	0.002	0.002	0.003
Barium - total (mg/L)	42	42		0.06	0.1757	0.0554	0.258	0.06125	0.153	0.1815	0.21775	0.251
Bismuth - total (mg/L)	42		42									
Chromium - total (mg/L)	42	26	16	0.001	0.0040	0.0027	0.012	0.00125	0.002	0.0035	0.005	0.01075
Cobalt - total (mg/L)	42	32	10	0.001	0.0018	0.0004	0.002	0.001	0.00175	0.002	0.002	0.002
Copper - total (mg/L)	42	27	15	0.001	0.0021	0.0009	0.005	0.001	0.002	0.002	0.002	0.003
Molybdenum - total (mg/L)	42	42		0.002	0.0032	0.0013	0.008	0.002	0.002	0.003	0.003	0.00595
Nickel - total (mg/L)	42	32	10	0.001	0.0037	0.0021	0.009	0.00155	0.002	0.003	0.004	0.00845
Selenium - total (mg/L)	42		42									
Uranium - total (mg/L)	42	42		0.002	0.0049	0.0015	0.008	0.002	0.004	0.005	0.006	0.007
Nutrients												
Nitrite + Nitrate as N (mg/L)	1	1		0.12	0.1200	0.0000	0.12	0.12	0.12	0.12	0.12	0.12
Total Kjeldahl Nitrogen as N (mg/L)	1		1									
Total Nitrogen as N (mg/L)	1	1		0.1	0.1000	0.0000	0.1	0.1	0.1	0.1	0.1	0.1
Total Phosphorus as P (mg/L)	1	1		0.01	0.0100	0.0000	0.01	0.01	0.01	0.01	0.01	0.01
Physico-Chemical Parameters												
Electrical Conductivity (µS/cm)	42	42		653	973.1667	113.1575	1280	835.75	879	992	1040	1119.5
pH (lab)	42	42		7.01	7.6757	0.3007	8.39	7.2425	7.425	7.695	7.92	8.155
Turbidity (NTU)	42	42		0.2	7.7024	13.7808	61.4	0.305	1	2.2	6.275	29.1

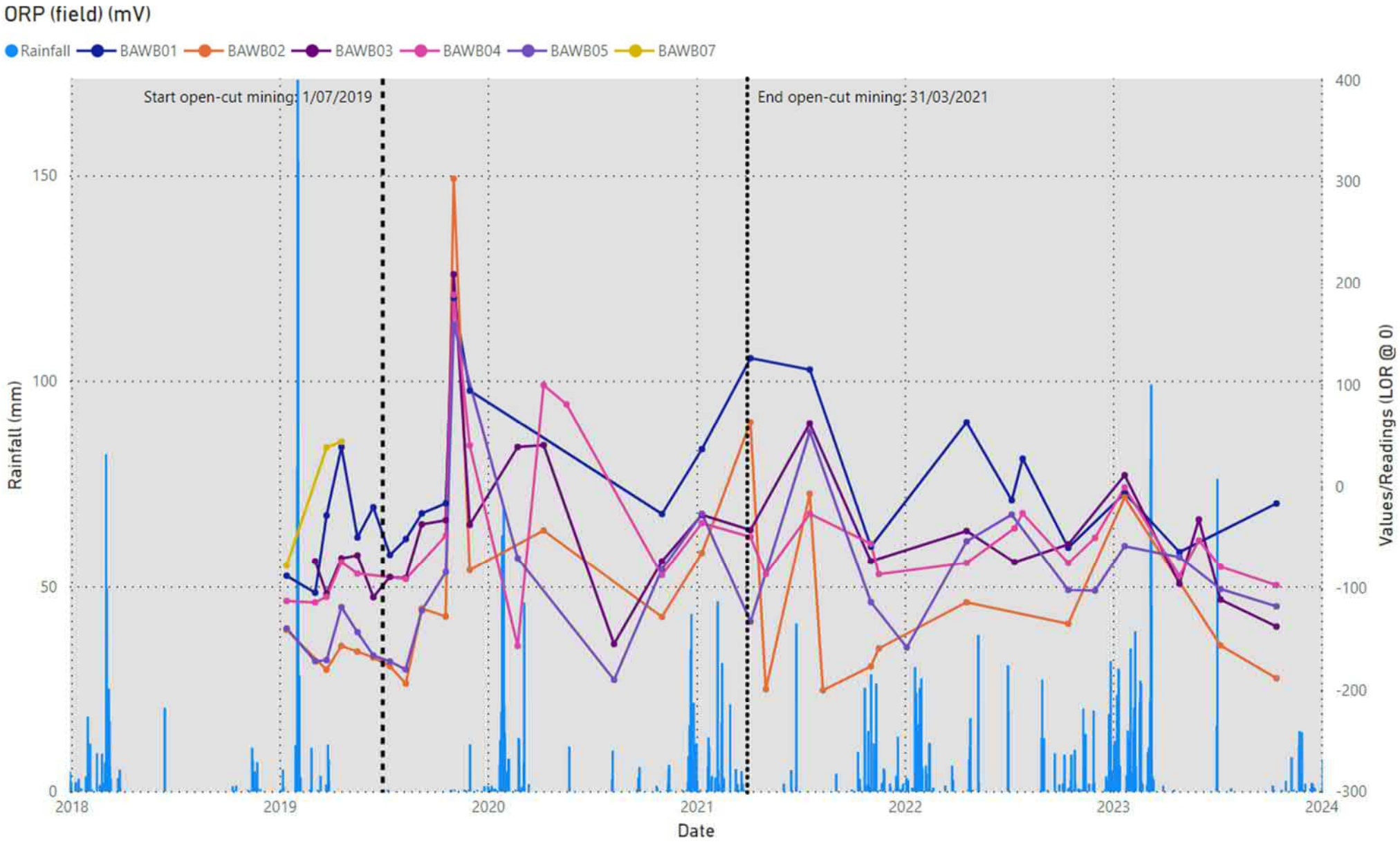
G.2 Water quality time series

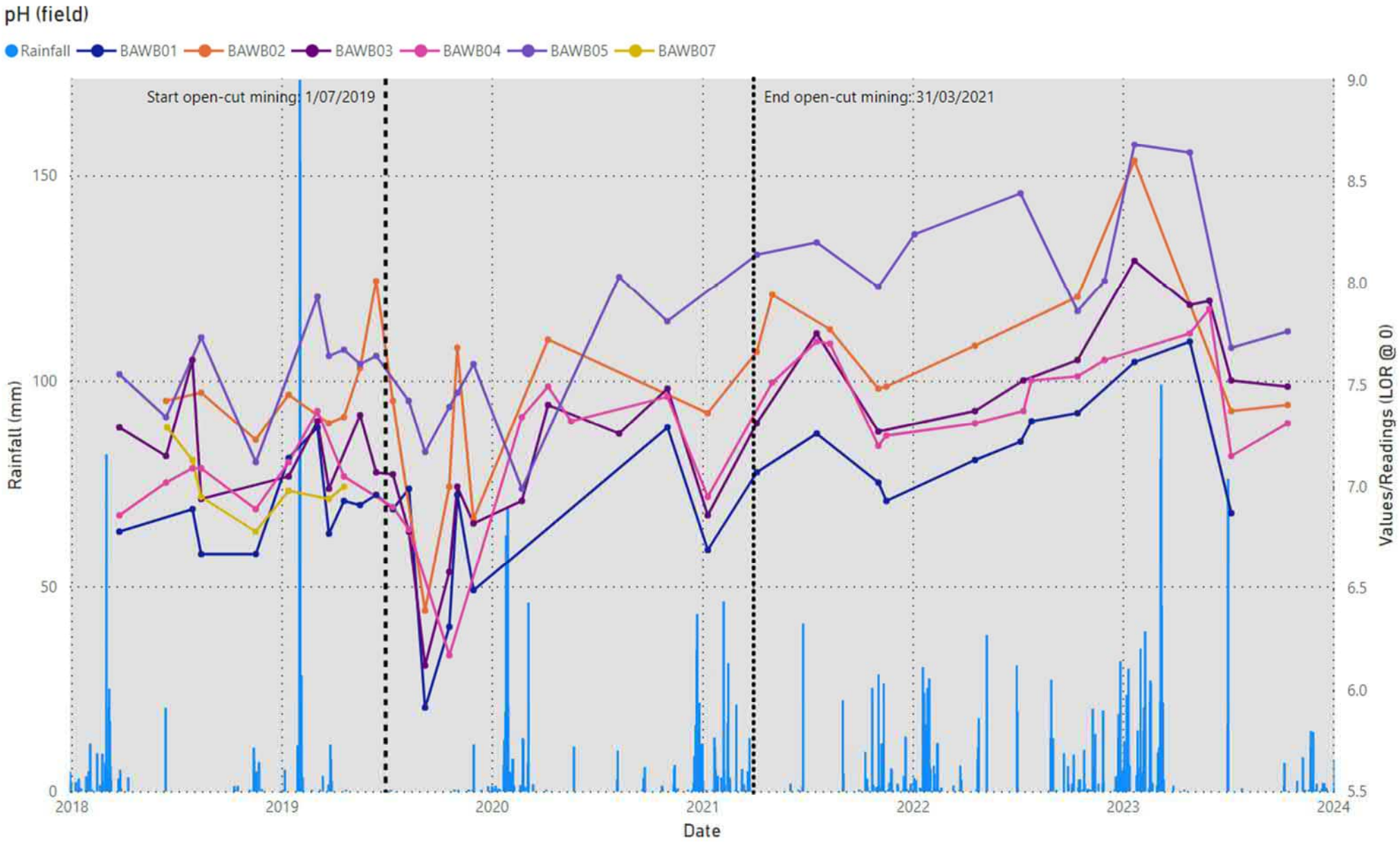

Depth to Water (mbRL)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining::31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
5
10
15
20
25
30
2018
2019
2020
2021
2022
2023
2024

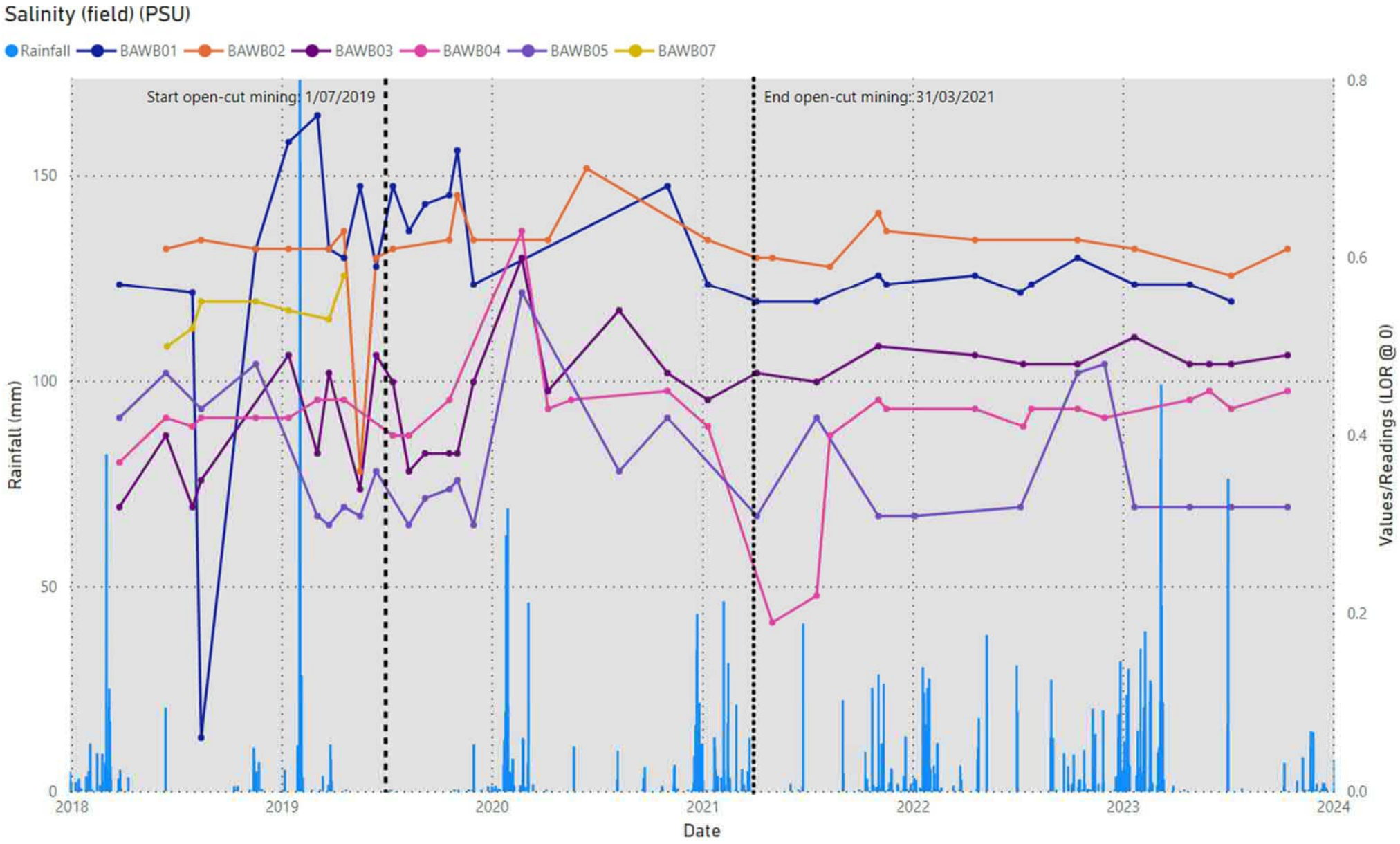

Dissolved Oxygen (field) (% sat)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
100
200
300
400
2018
2019
2020
2021
2022
2023
2024

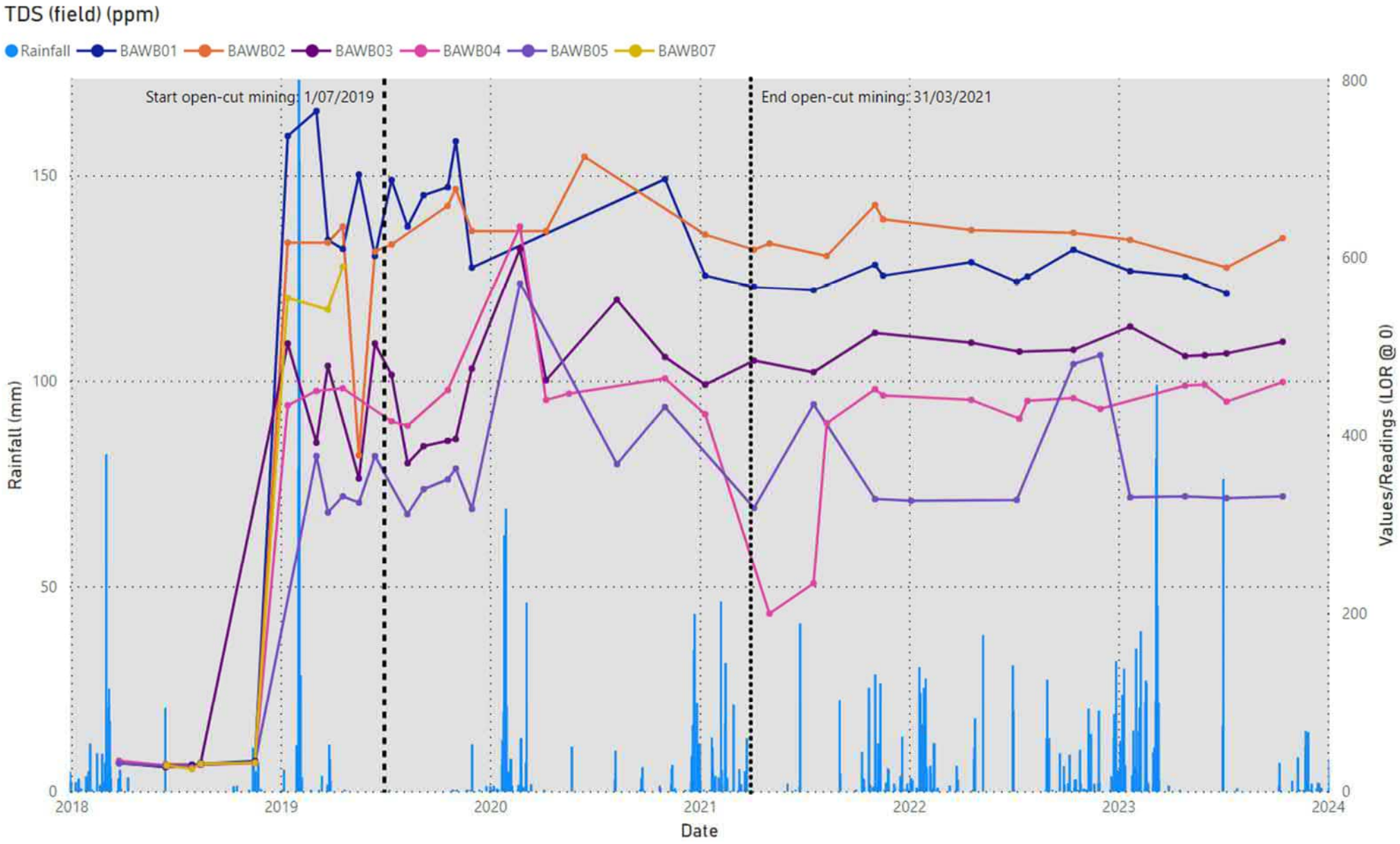

Electrical Conductivity (field) (µS/cm)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
500
1,000
1,500
2018
2019
2020
2021
2022
2023
2024

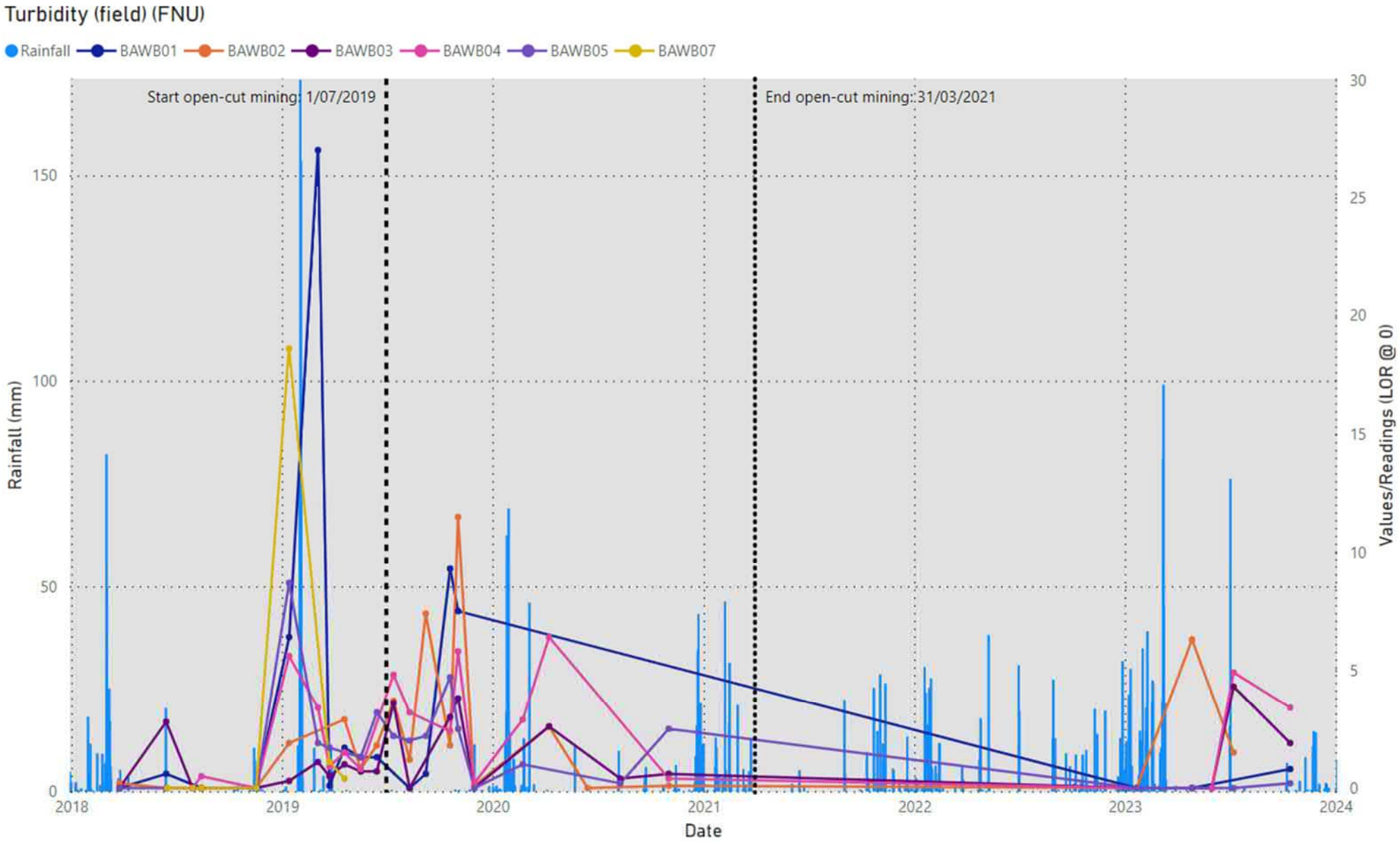

Groundwater Level (mAHD)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
300
310
320
330
340
350
360
370
2018
2019
2020
2021
2022
2023
2024

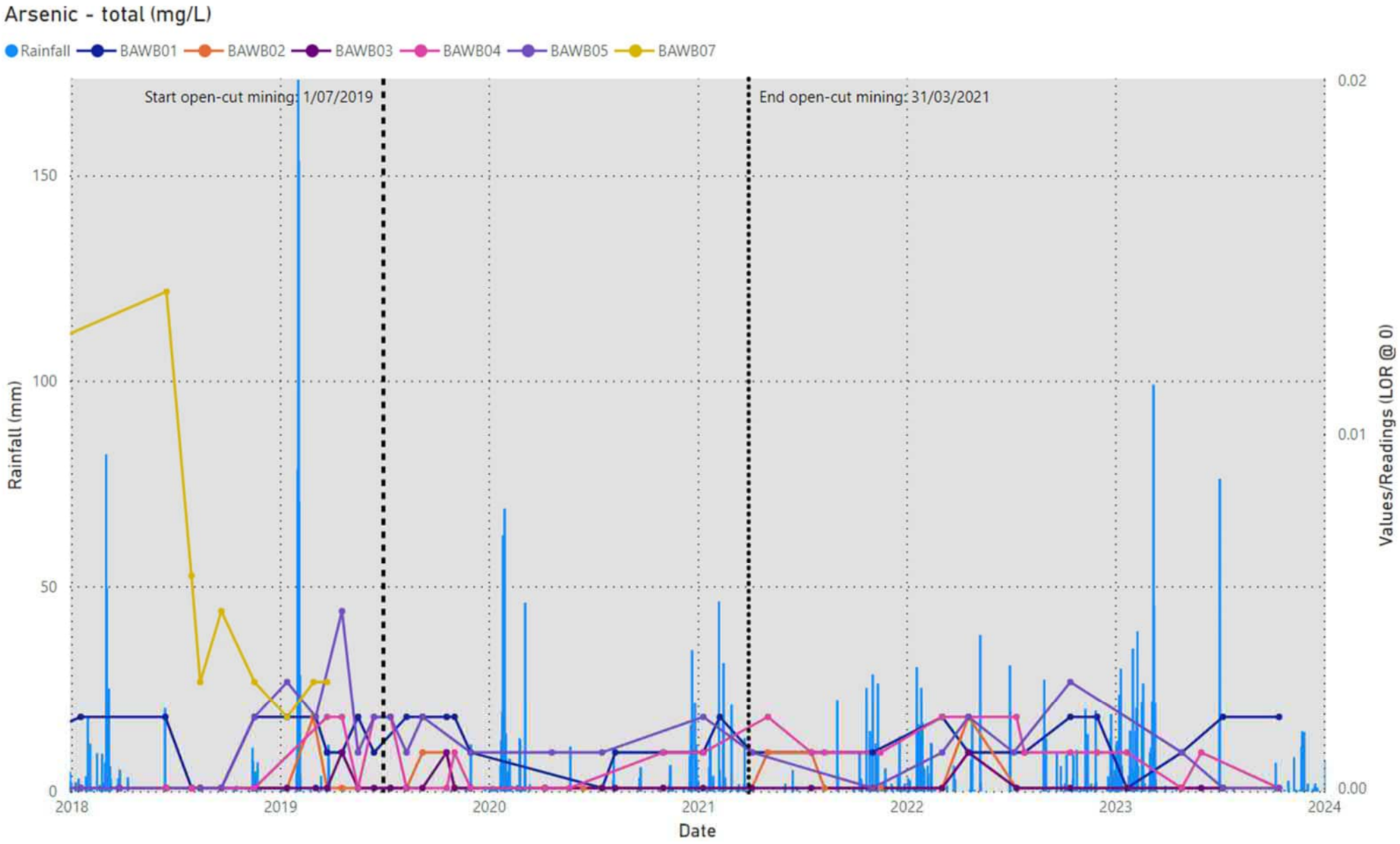

ORP (field) (mV)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
-300
-200
-100
0
100
200
300
400
2018
2019
2020
2021
2022
2023
2024

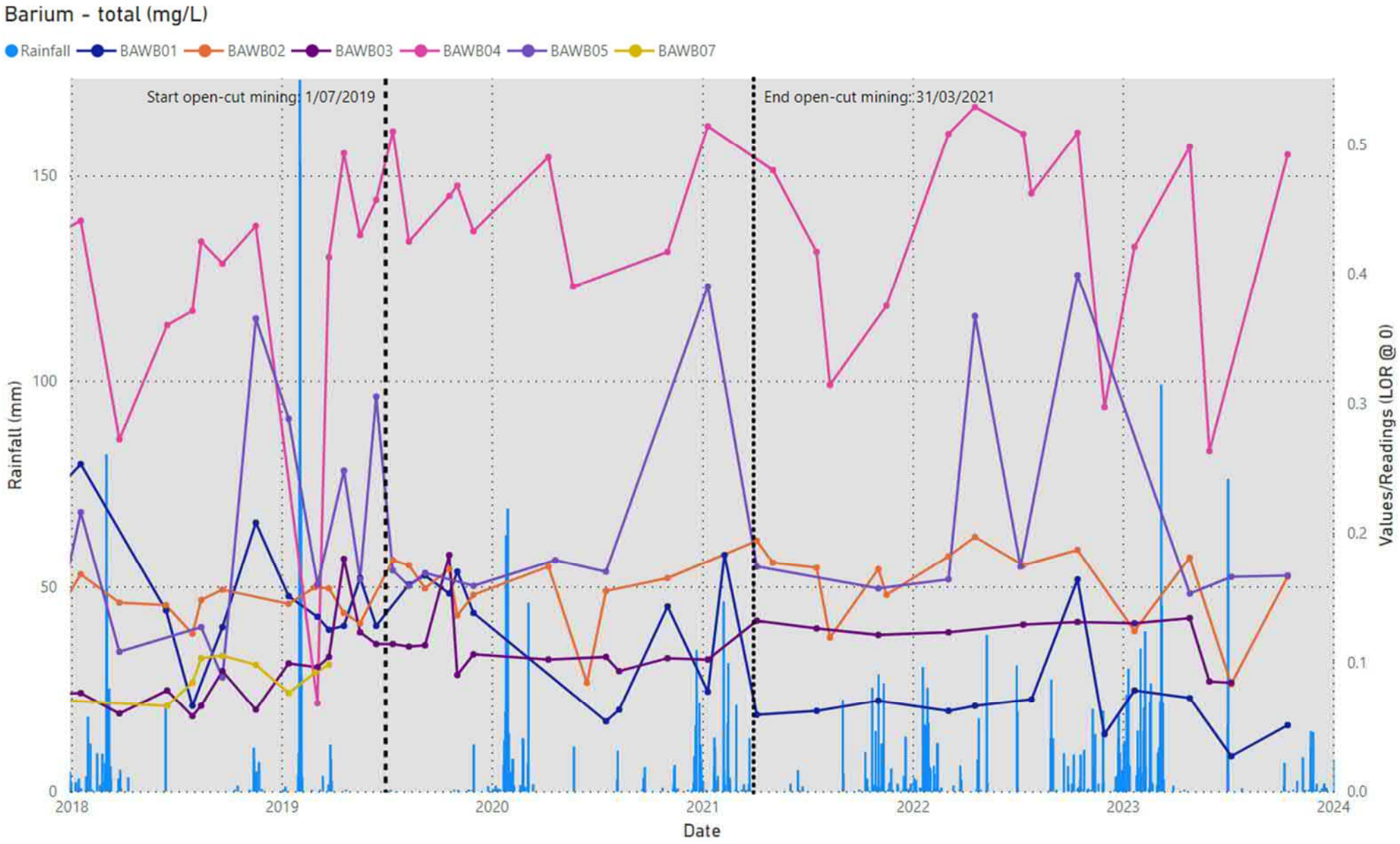

pH (field)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
2018
2019
2020
2021
2022
2023
2024

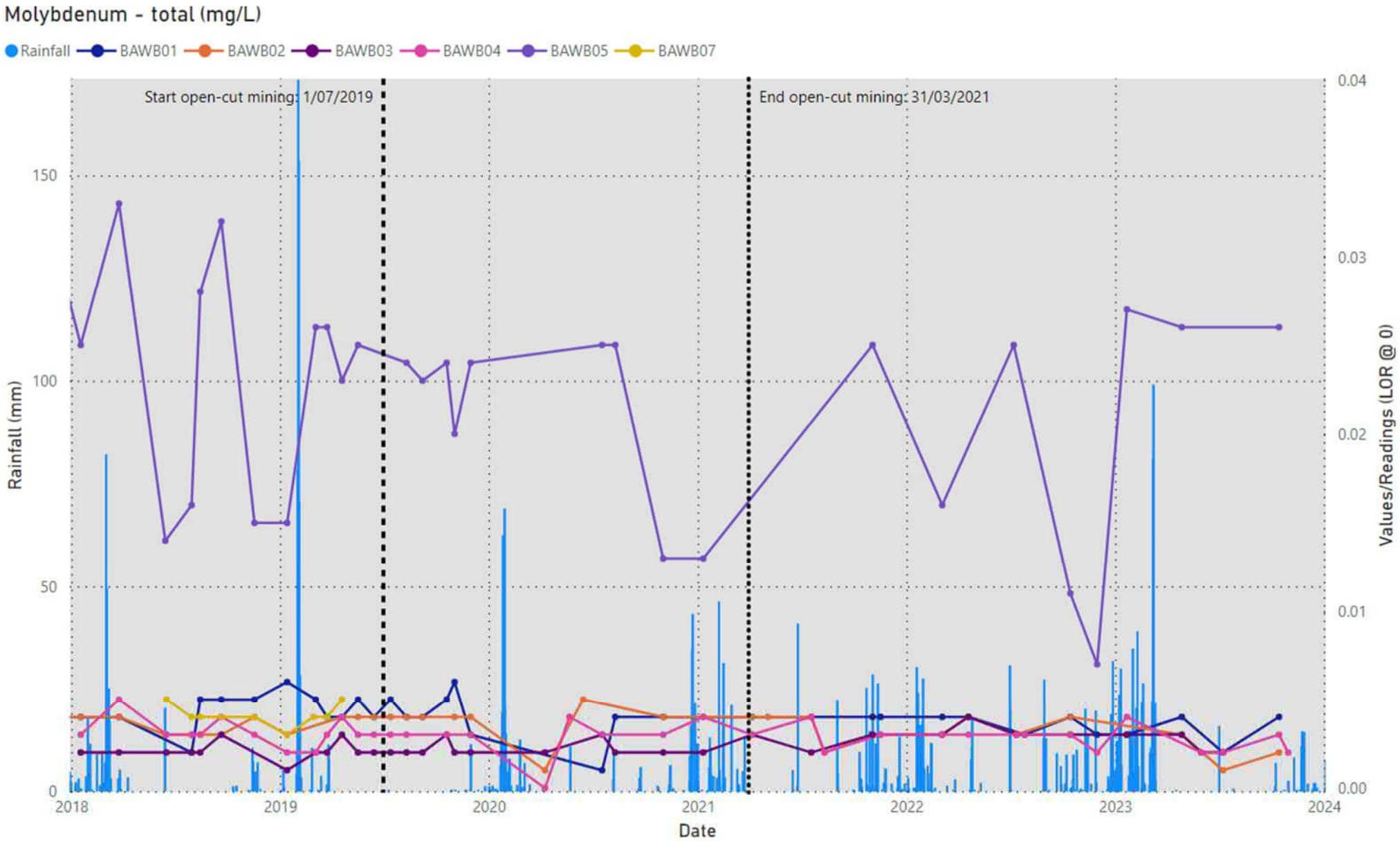

Salinity (field) (PSU)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.0
0.2
0.4
0.6
0.8
2018
2019
2020
2021
2022
2023
2024

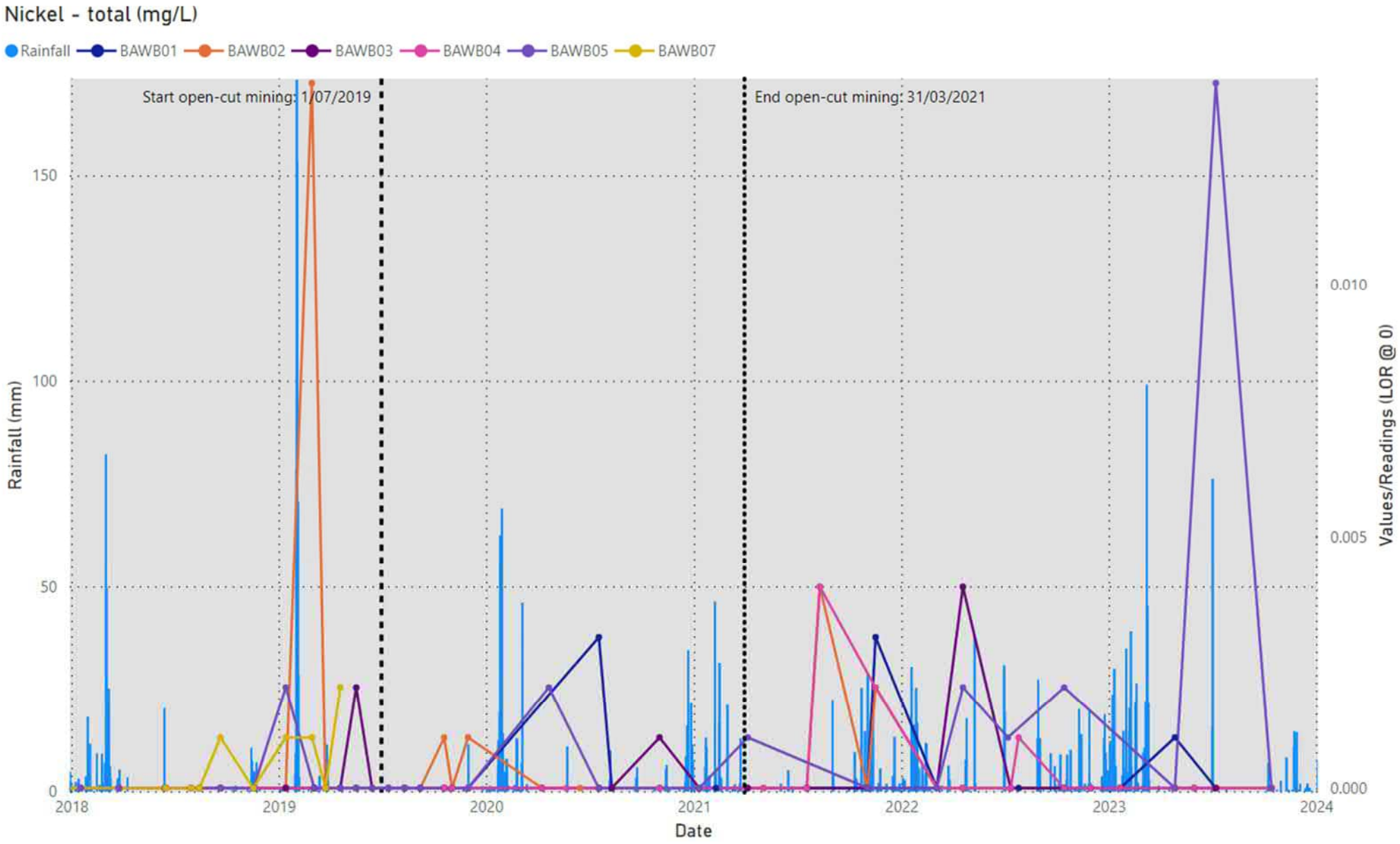

TDS (field) (ppm)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
200
400
600
800
2018
2019
2020
2021
2022
2023
2024

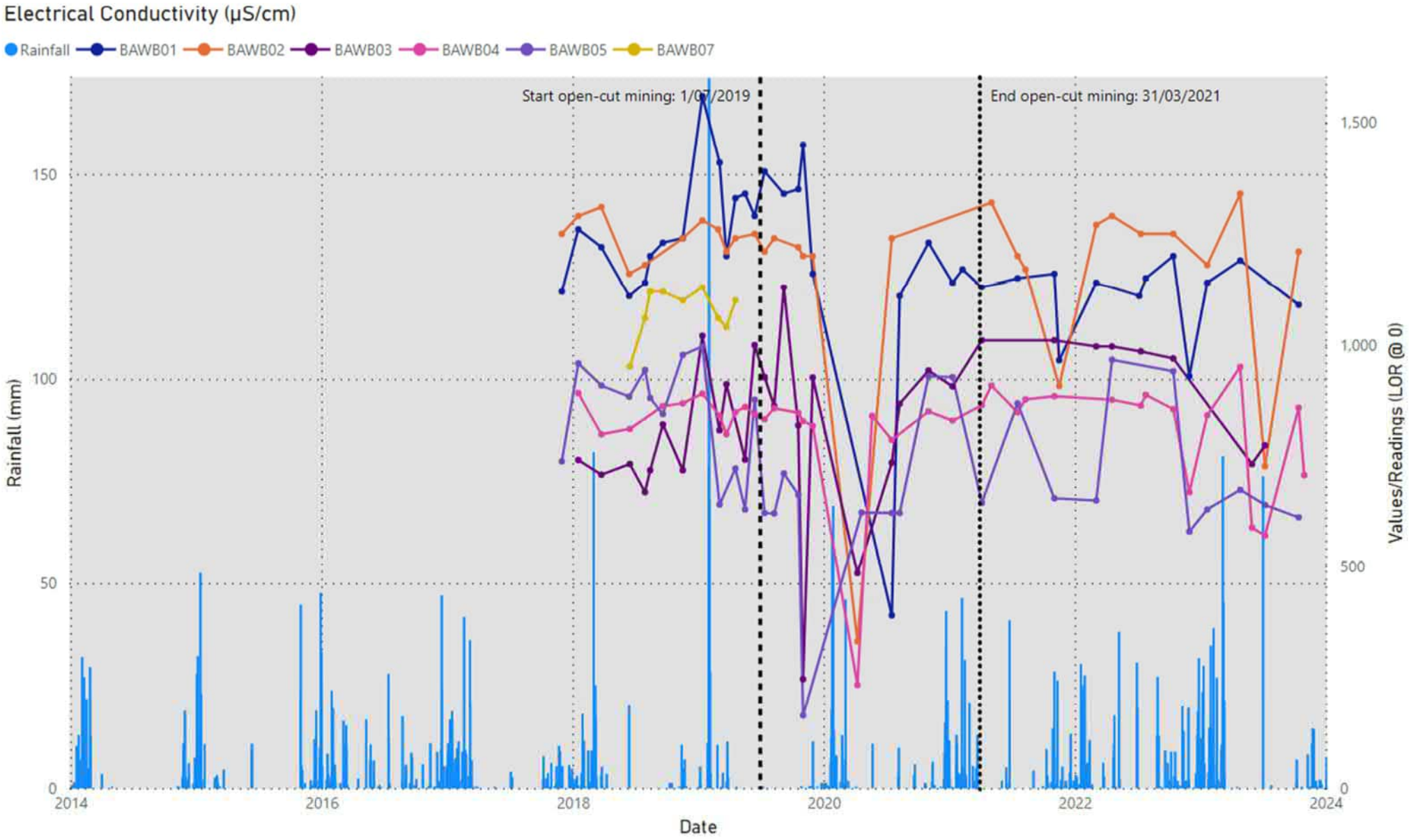

Turbidity (field) (FNU)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
5
10
15
20
25
30
2018
2019
2020
2021
2022
2023
2024

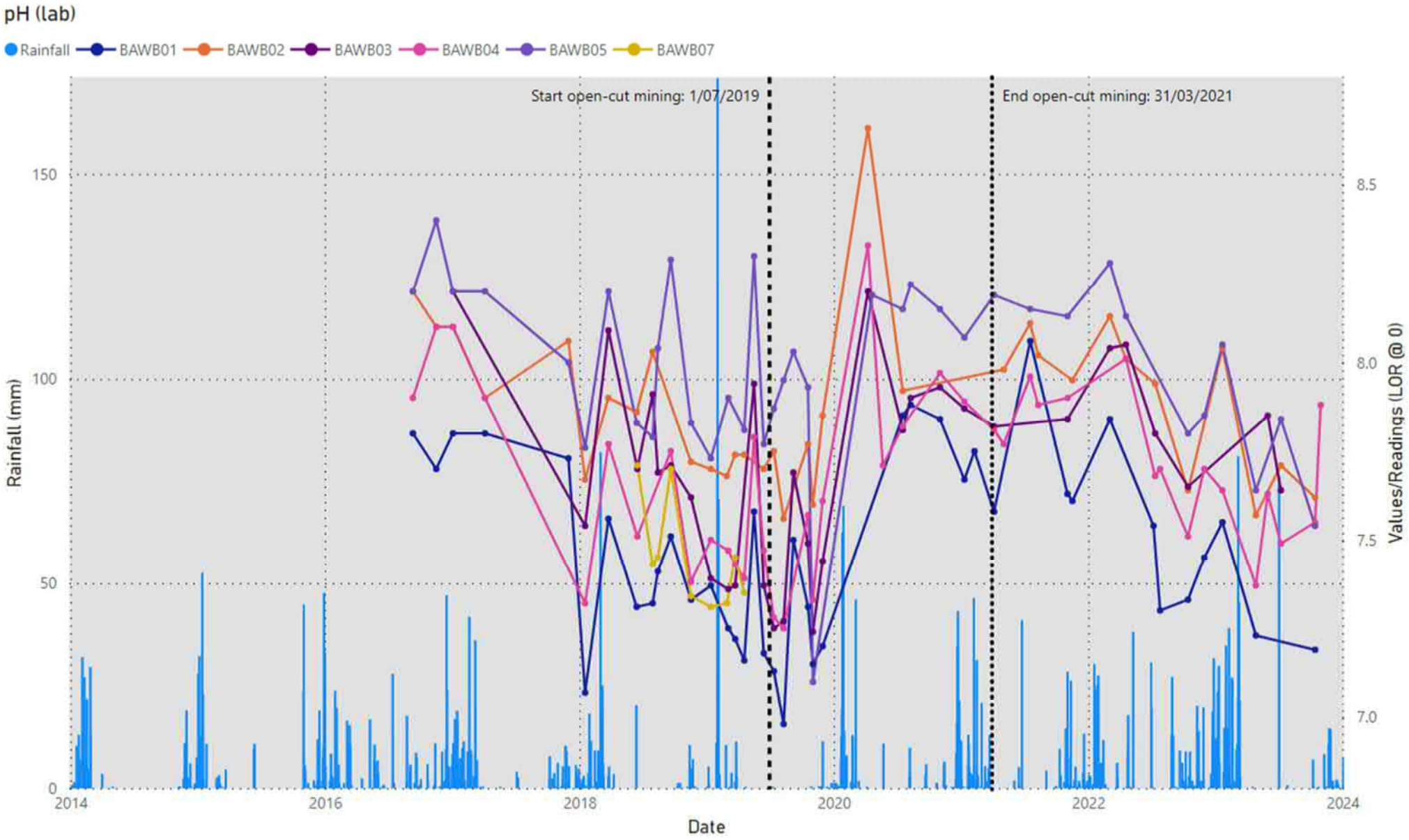

Arsenic - total (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.01
0.02
2018
2019
2020
2021
2022
2023
2024

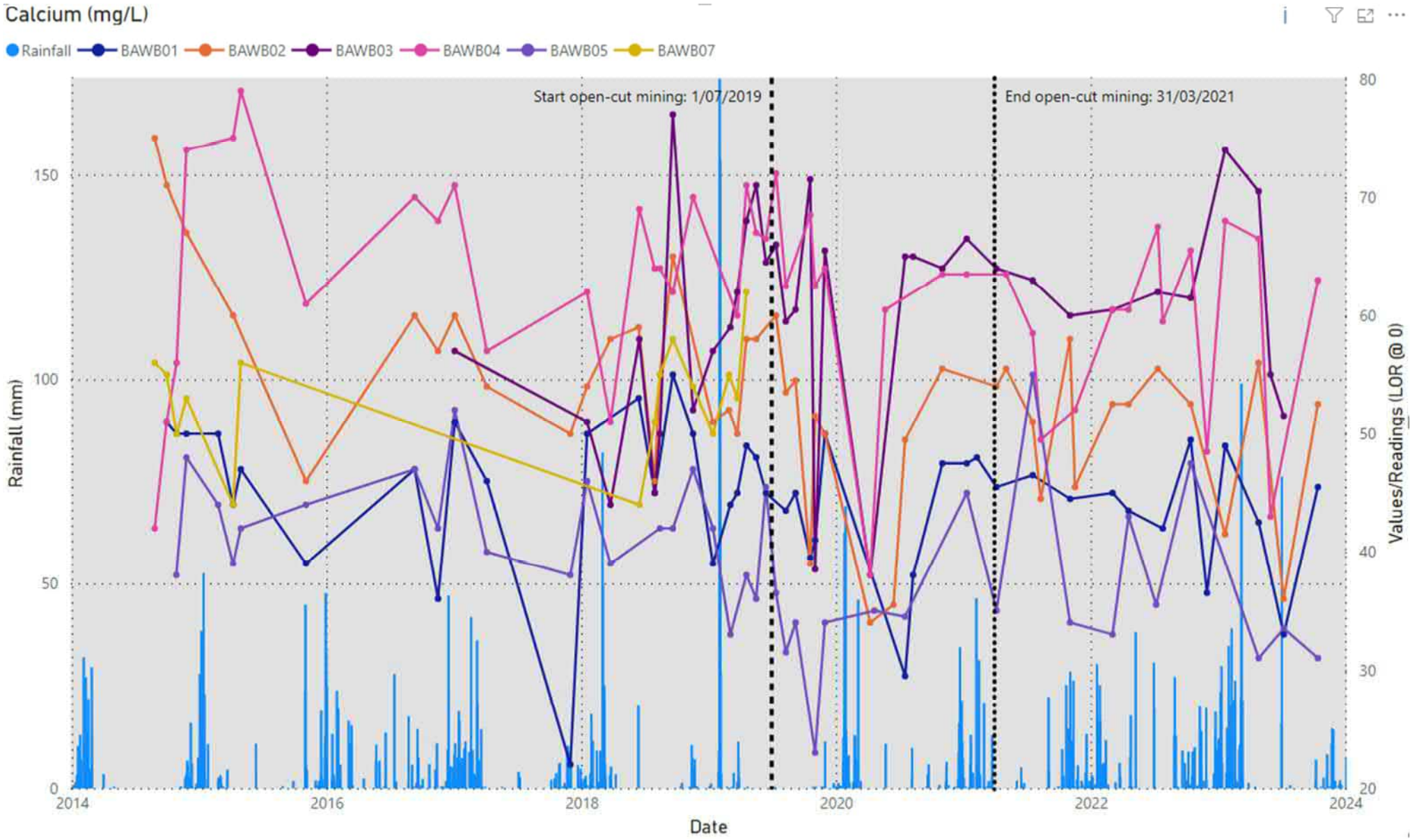

Barium - total (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.0
0.1
0.2
0.3
0.4
0.5
2018
2019
2020
2021
2022
2023
2024

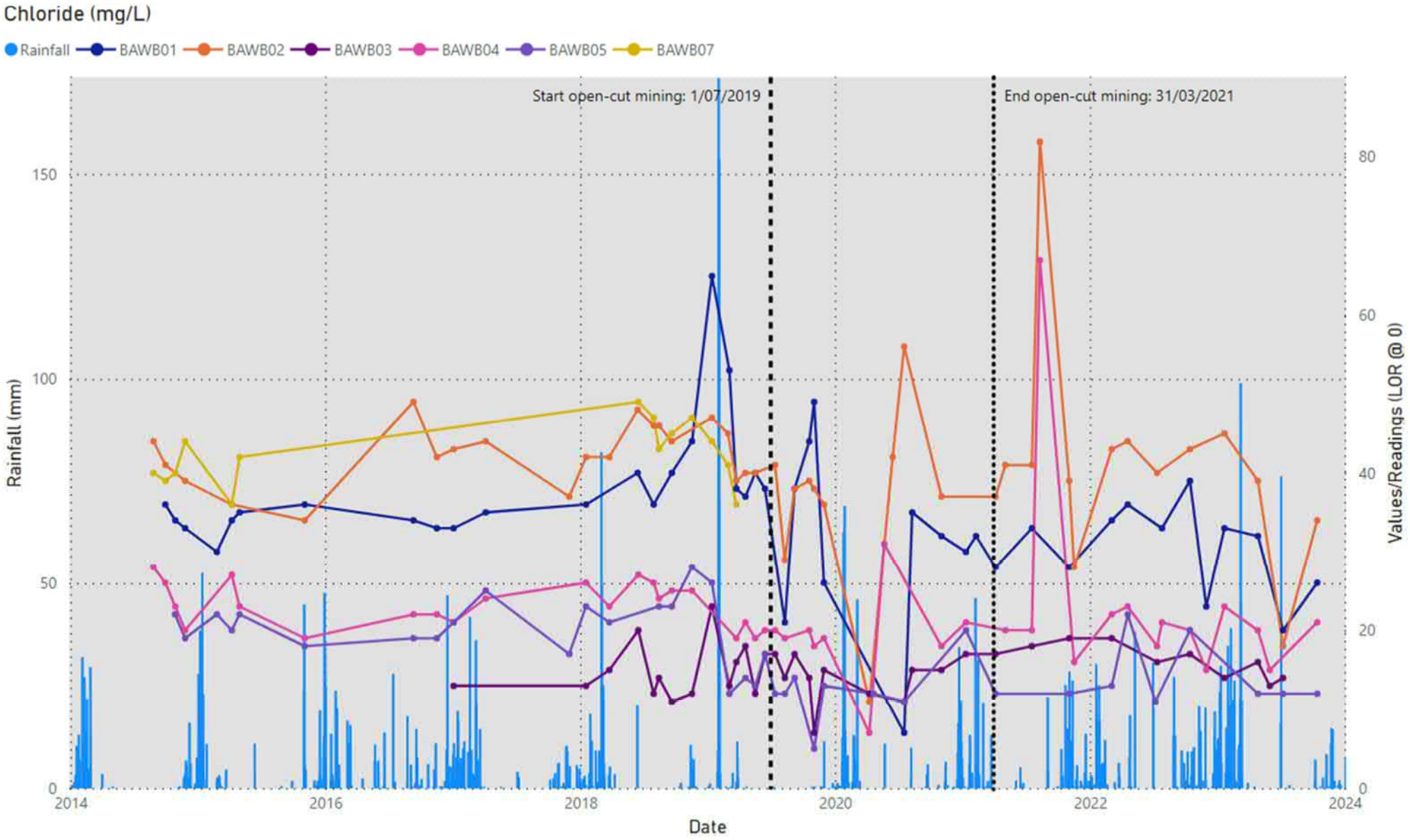

Molybdenum - total (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.01
0.02
0.03
0.04
2018
2019
2020
2021
2022
2023
2024

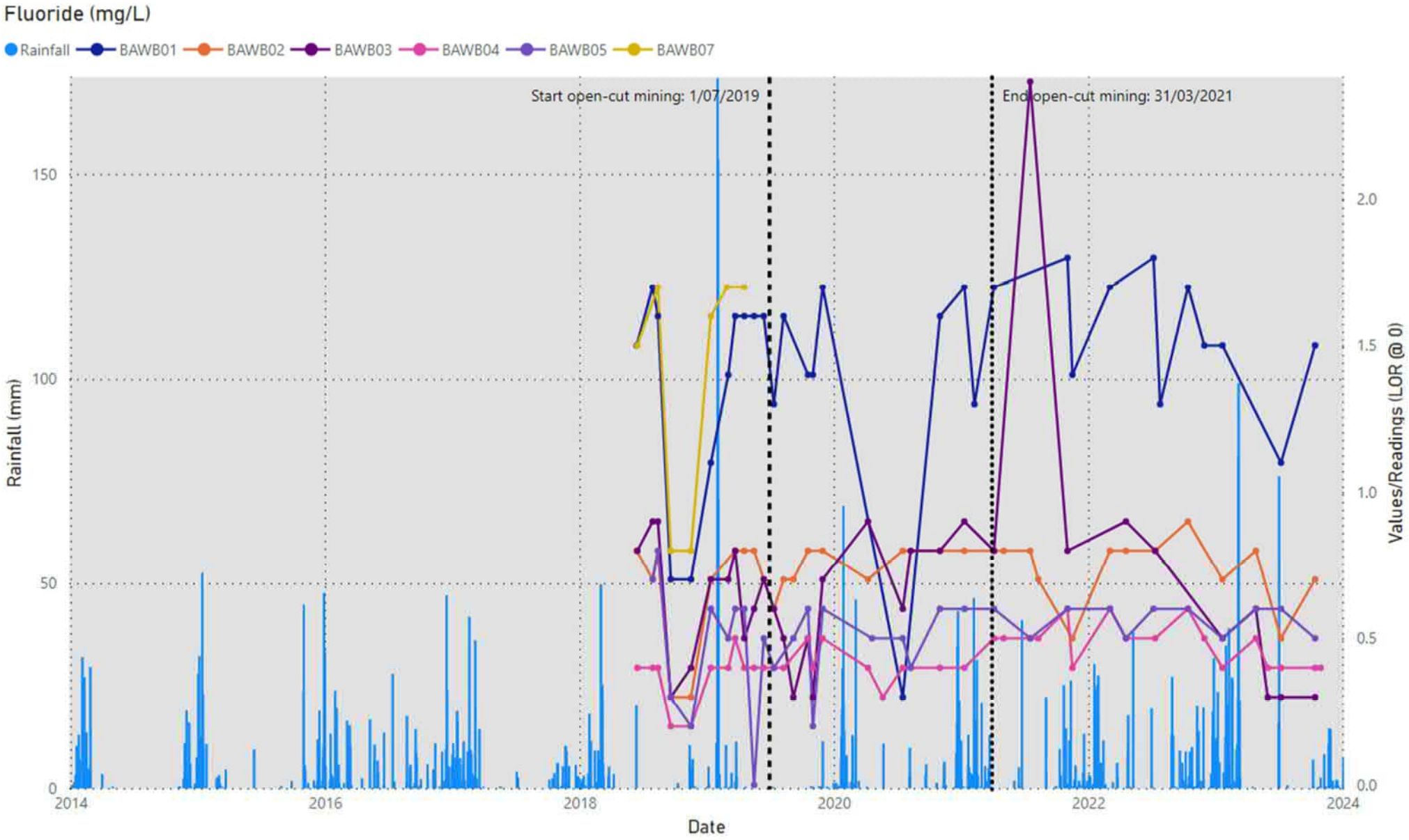

Nickel - total (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.000
0.005
0.010
2018
2019
2020
2021
2022
2023
2024

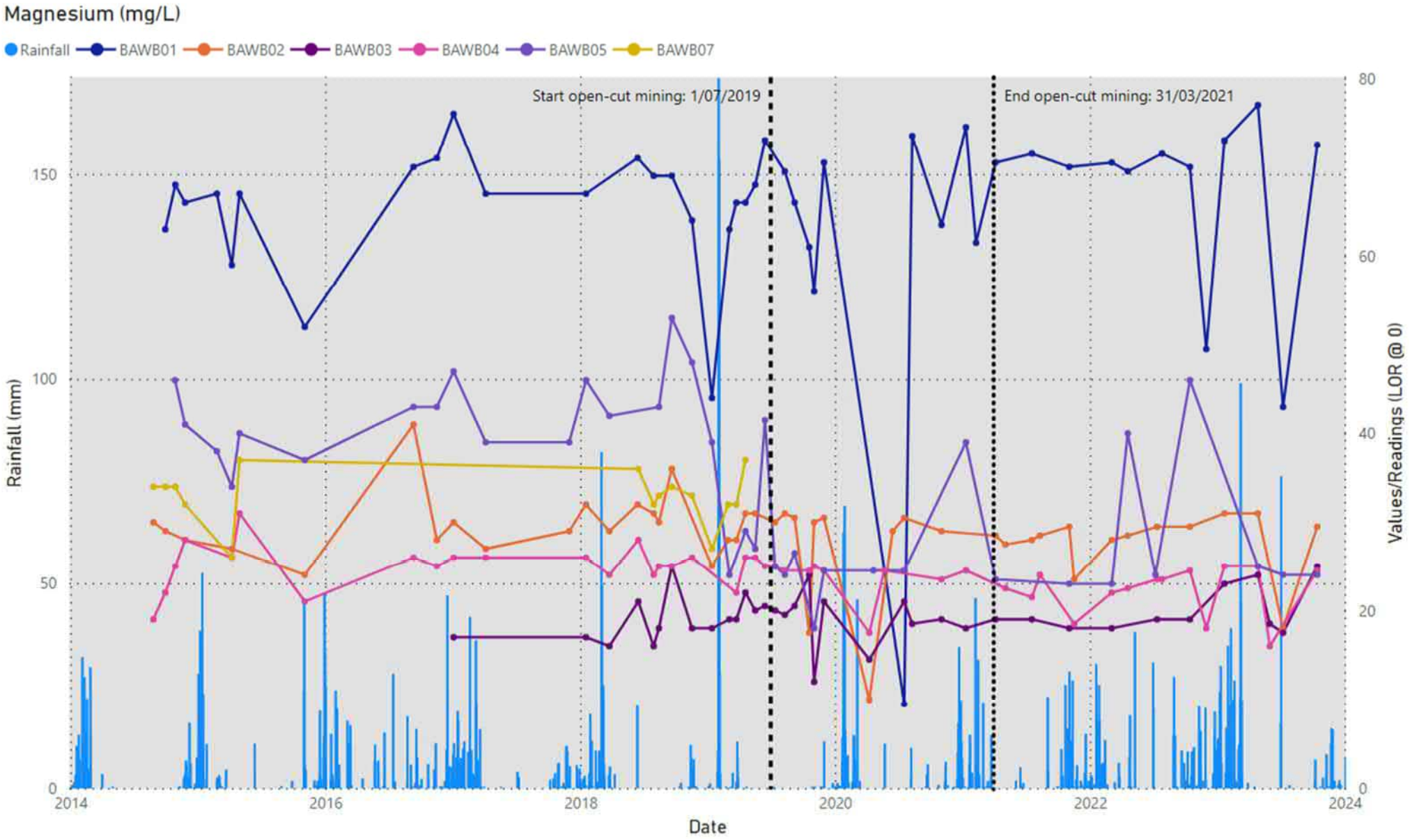

Electrical Conductivity (µS/cm)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
500
1,000
1,500
2014
2016
2018
2020
2022
2024

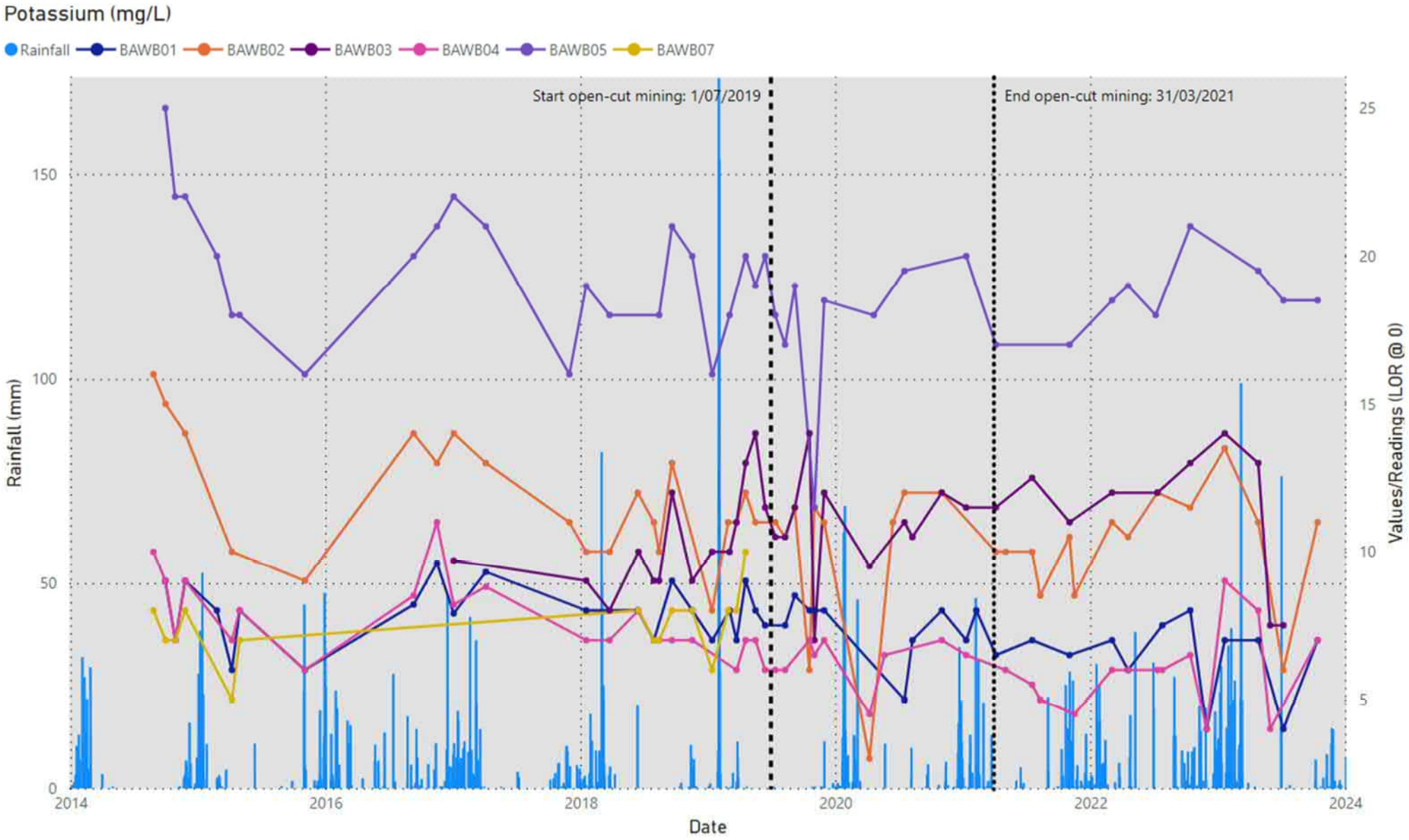

pH (lab)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
7.0
7.5
8.0
8.5
2014
2016
2018
2020
2022
2024

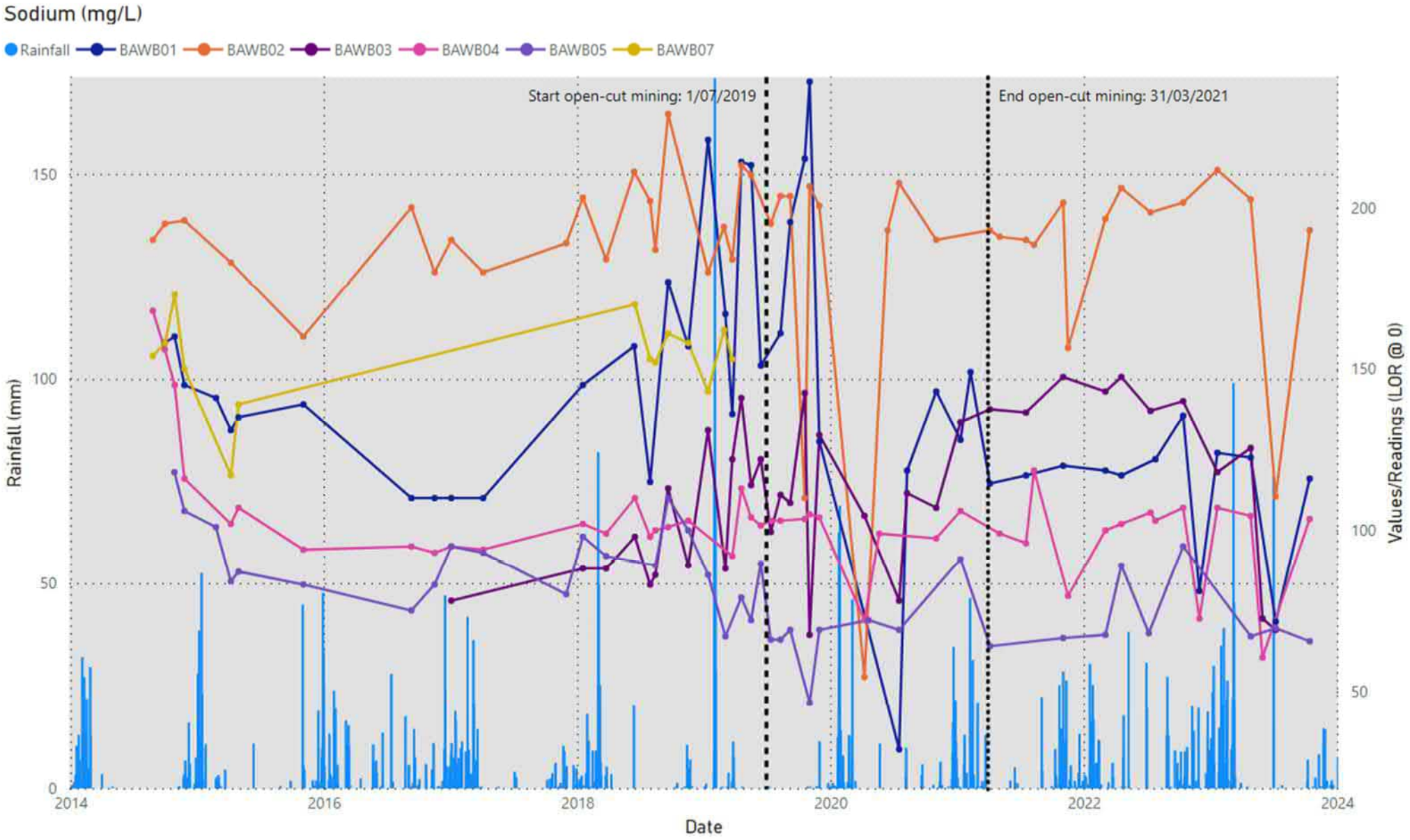

Calcium (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
20
30
40
50
60
70
80
2014
2016
2018
2020
2022
2024

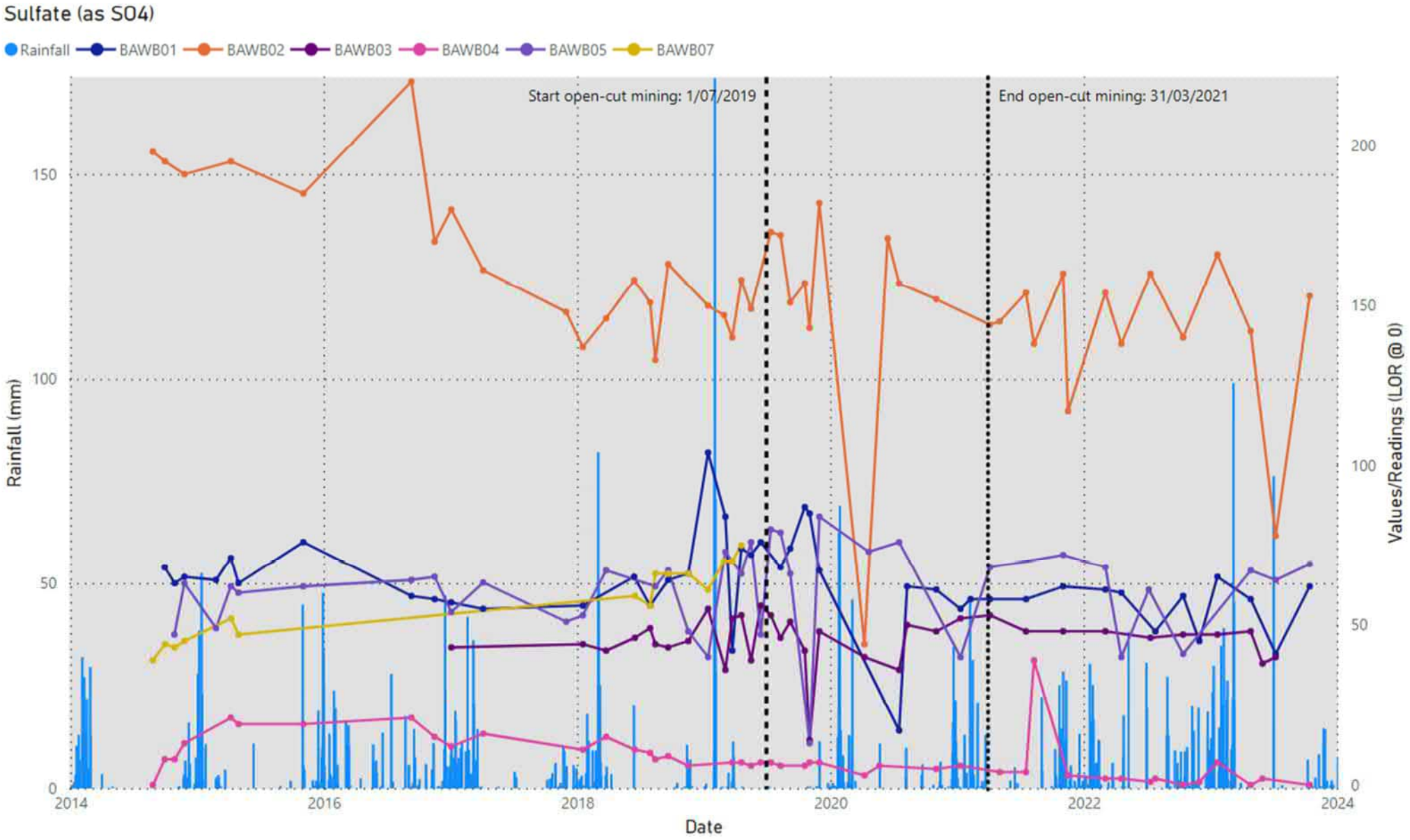

Chloride (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
20
40
60
80
2014
2016
2018
2020
2022
2024

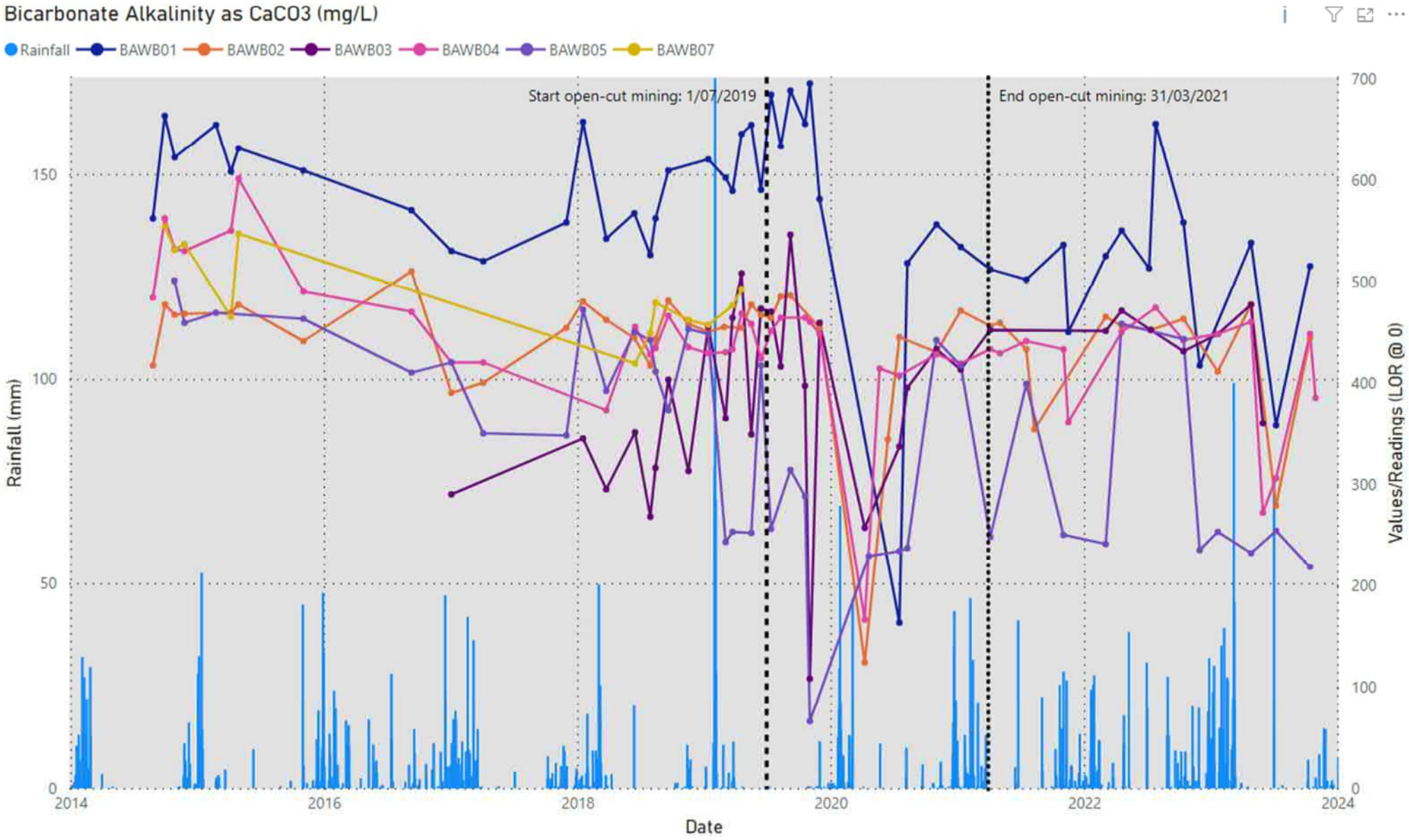

Fluoride (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.0
0.5
1.0
1.5
2.0
2014
2016
2018
2020
2022
2024

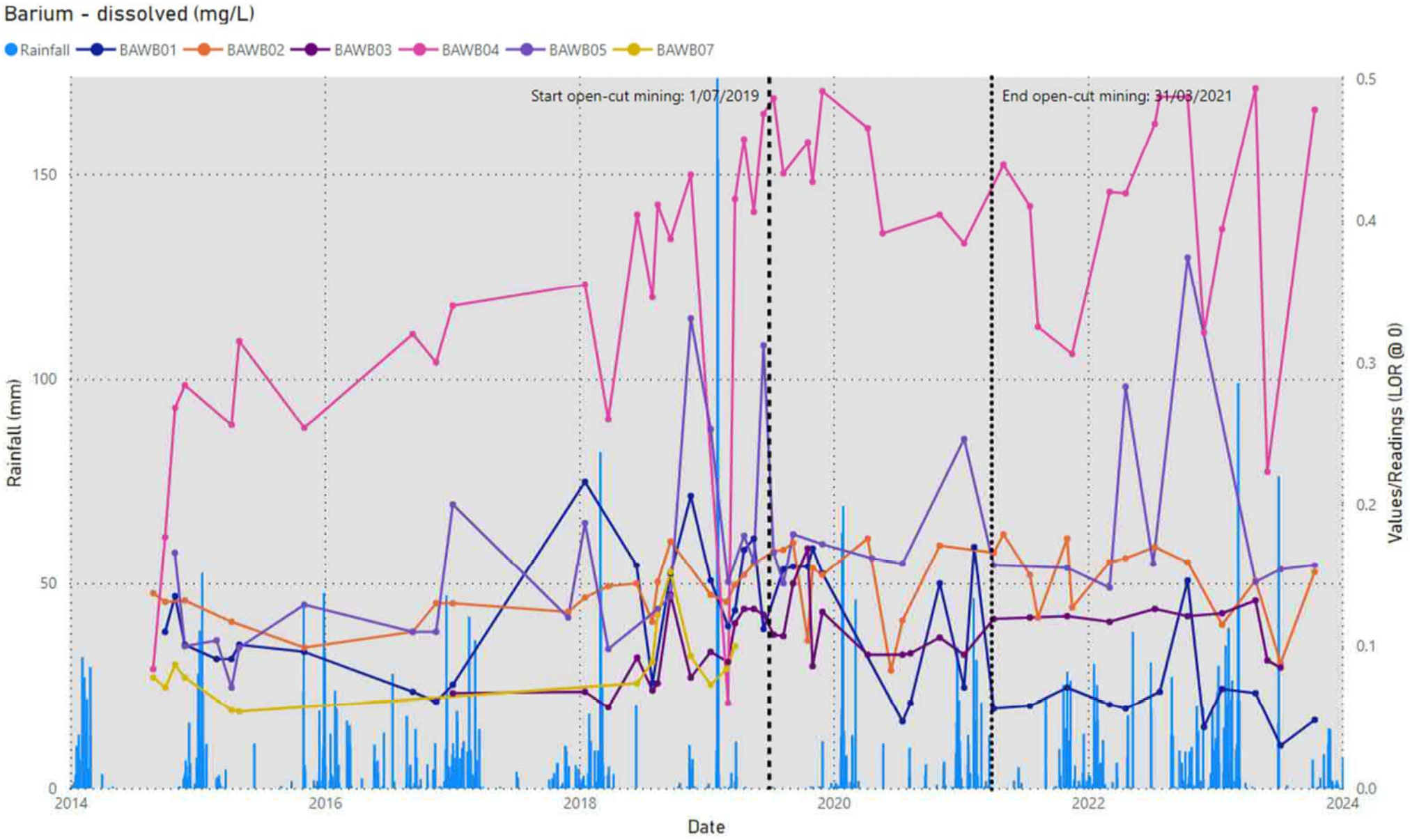

Magnesium (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
20
40
60
80
2014
2016
2018
2020
2022
2024

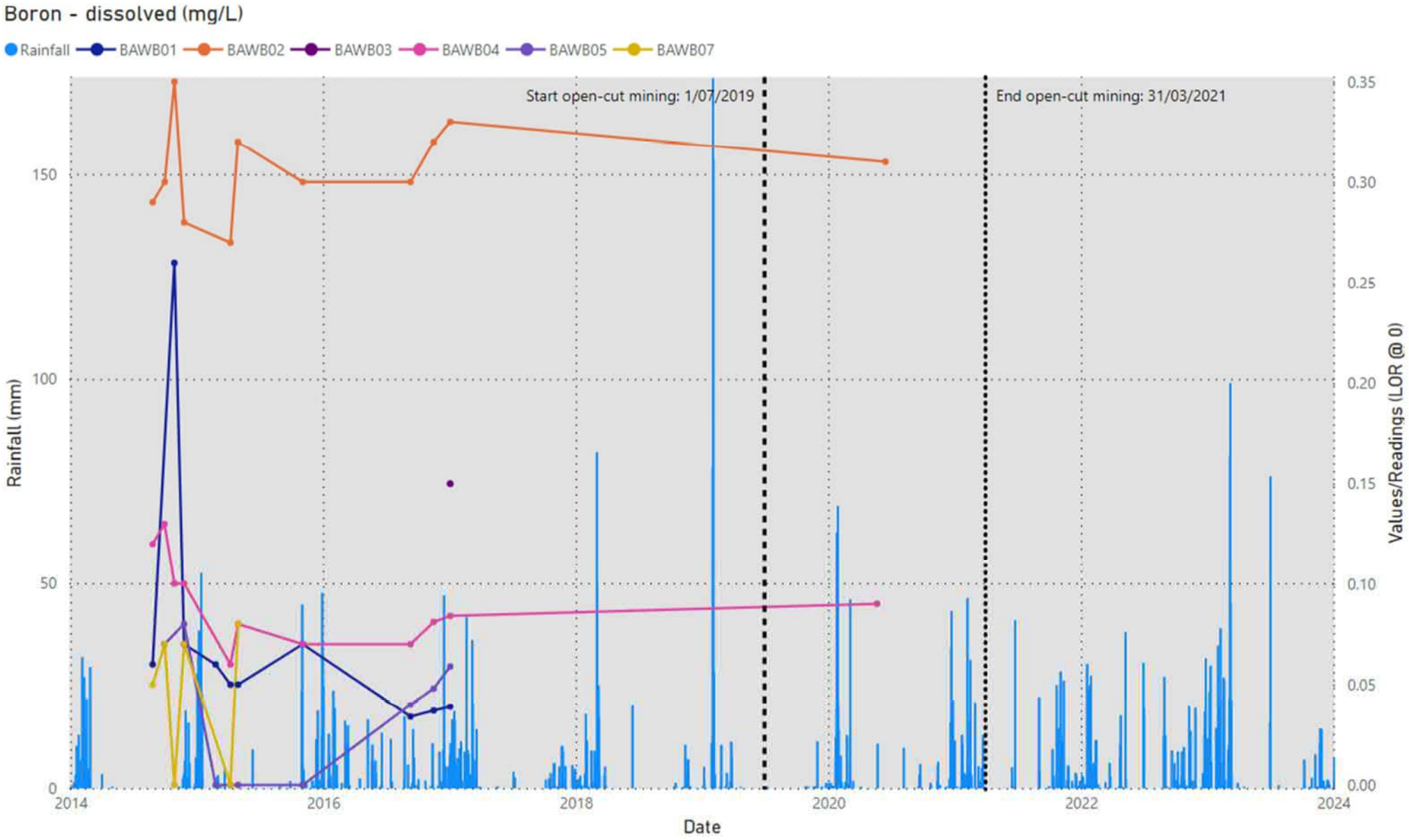

Potassium (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
5
10
15
20
25
2014
2016
2018
2020
2022
2024

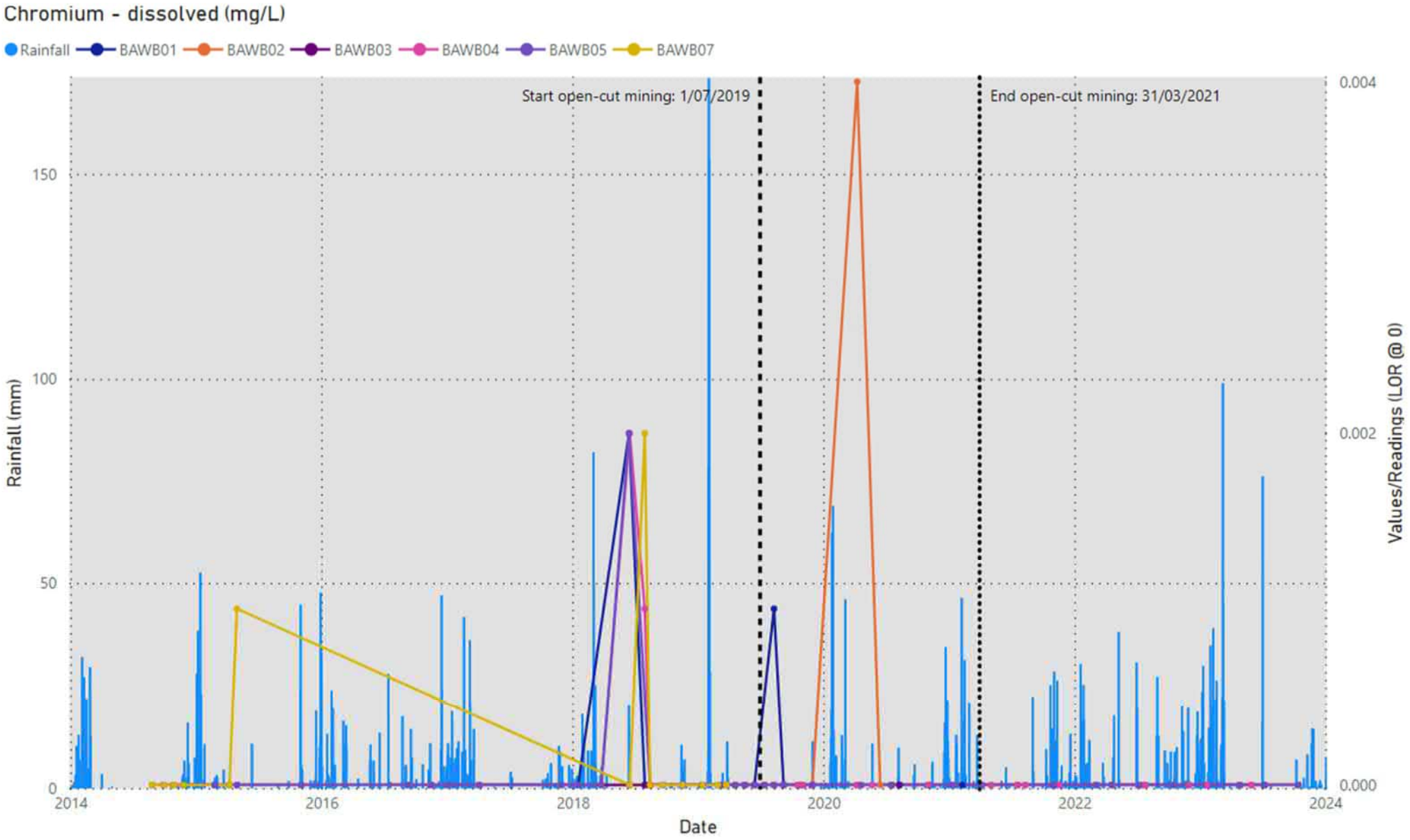

Sodium (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
200
2014
2016
2018
2020
2022
2024

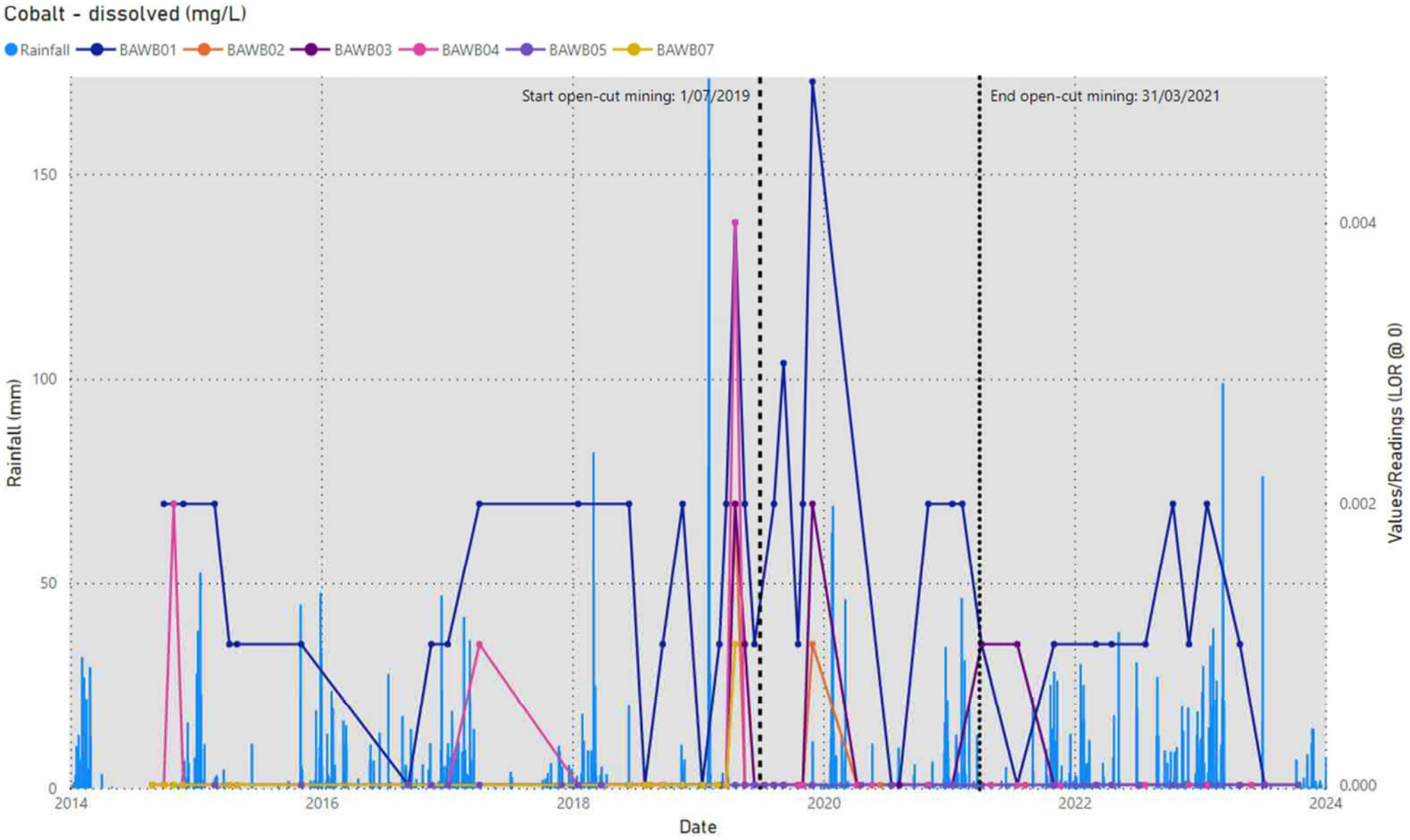

Sulfate (as SO4)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
200
2014
2016
2018
2020
2022
2024

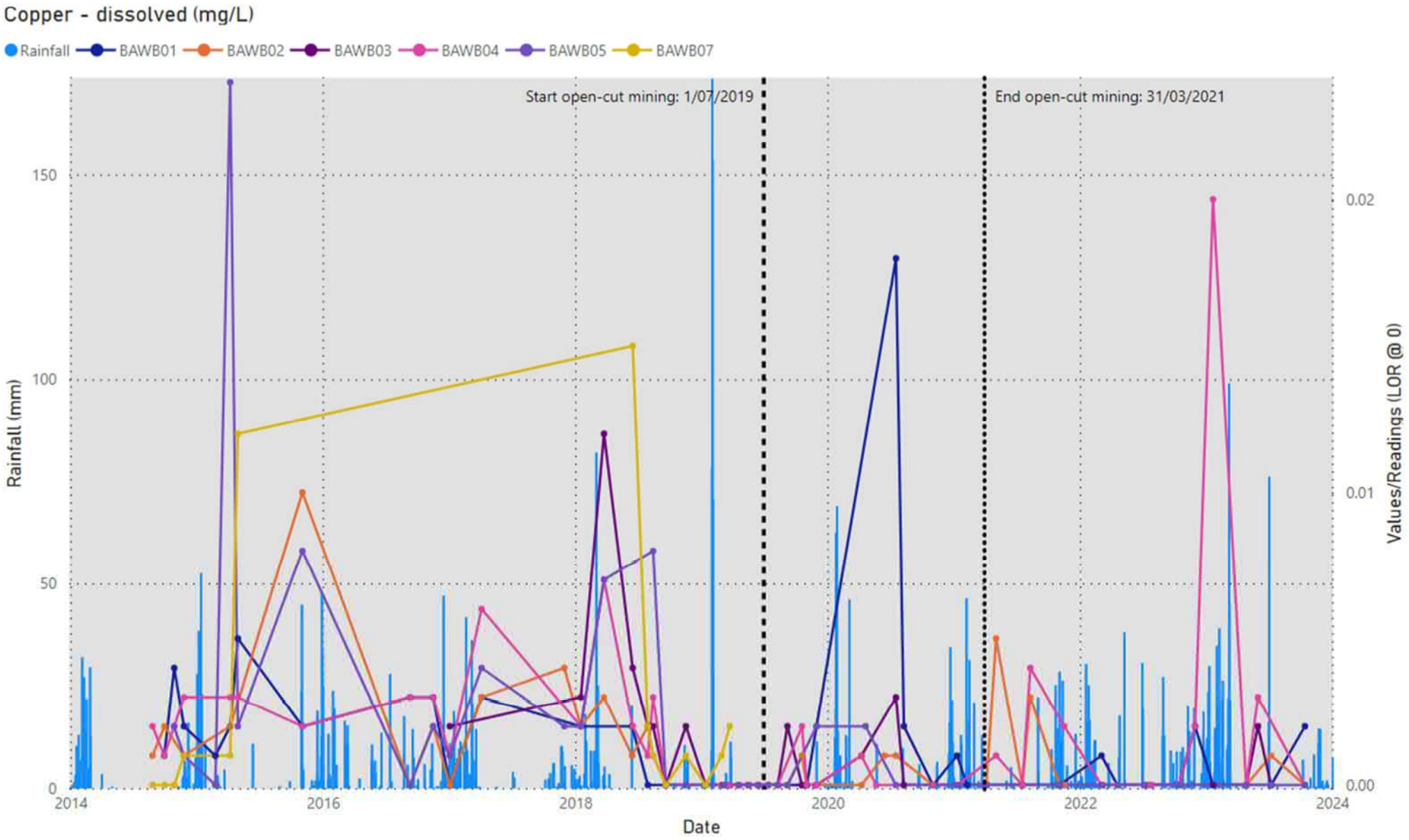

Bicarbonate Alkalinity as CaCO3 (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
100
200
300
400
500
600
700
2014
2016
2018
2020
2022
2024

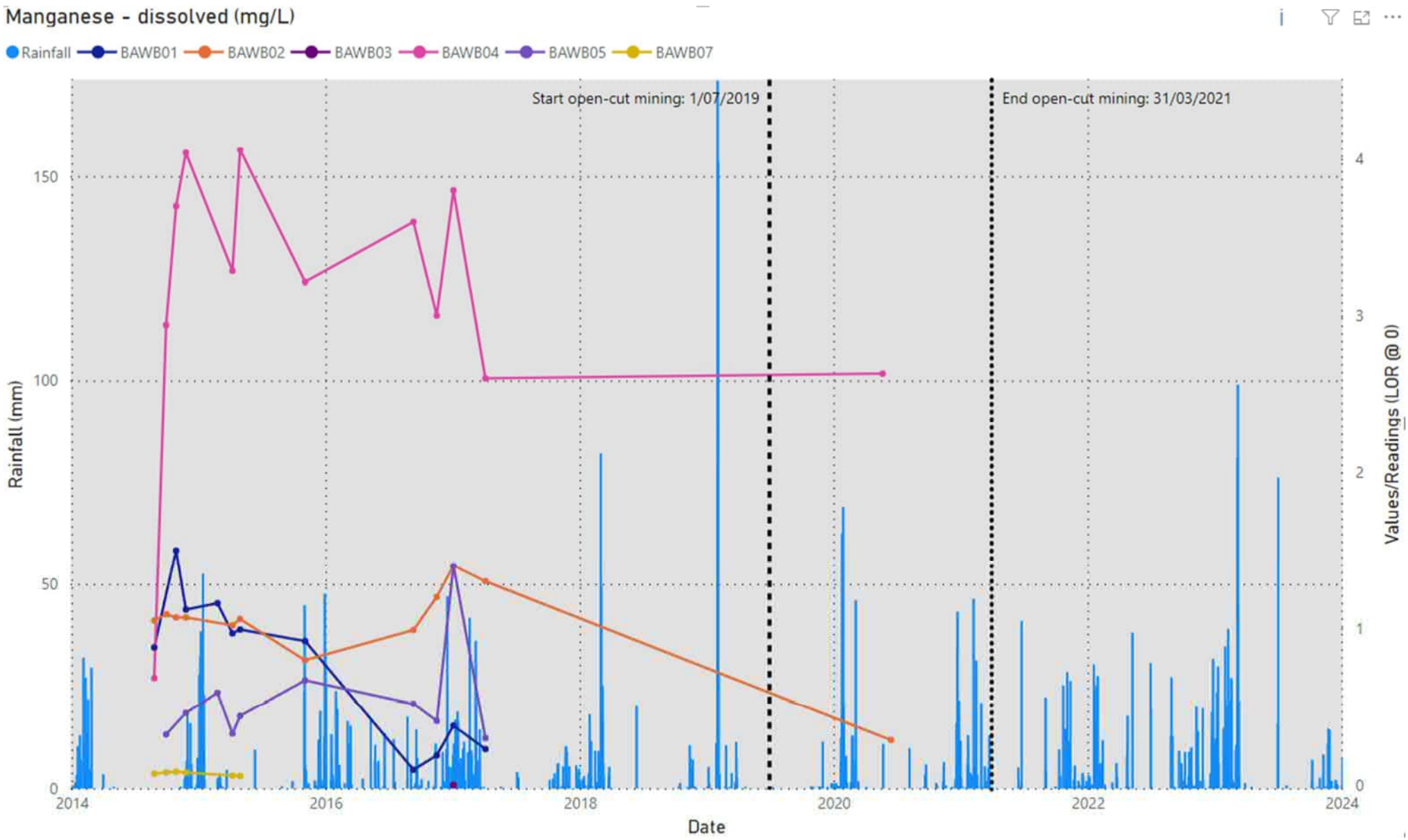

Barium - dissolved (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.0
0.1
0.2
0.3
0.4
0.5
2014
2016
2018
2020
2022
2024

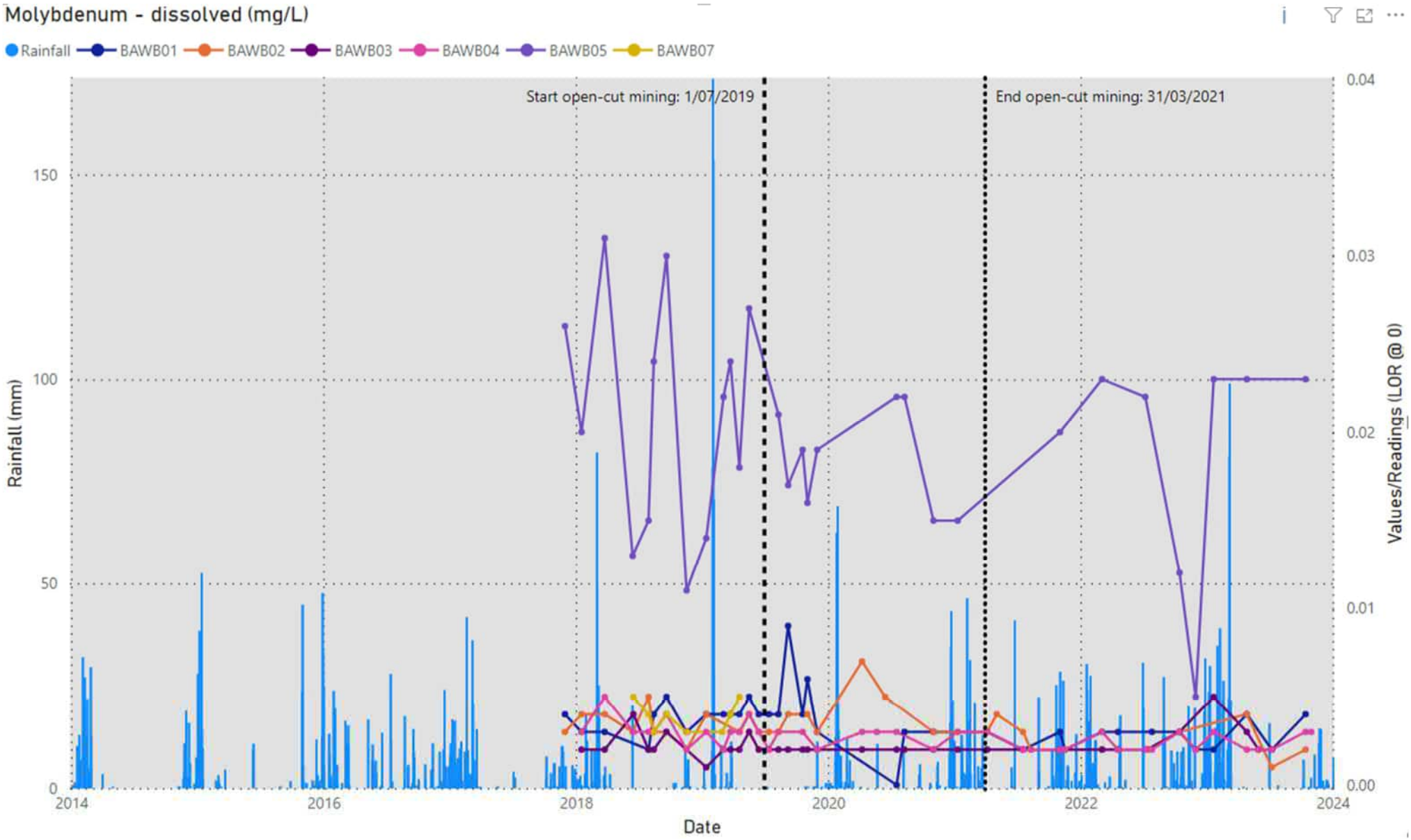

Boron - dissolved (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
2014
2016
2018
2020
2022
2024

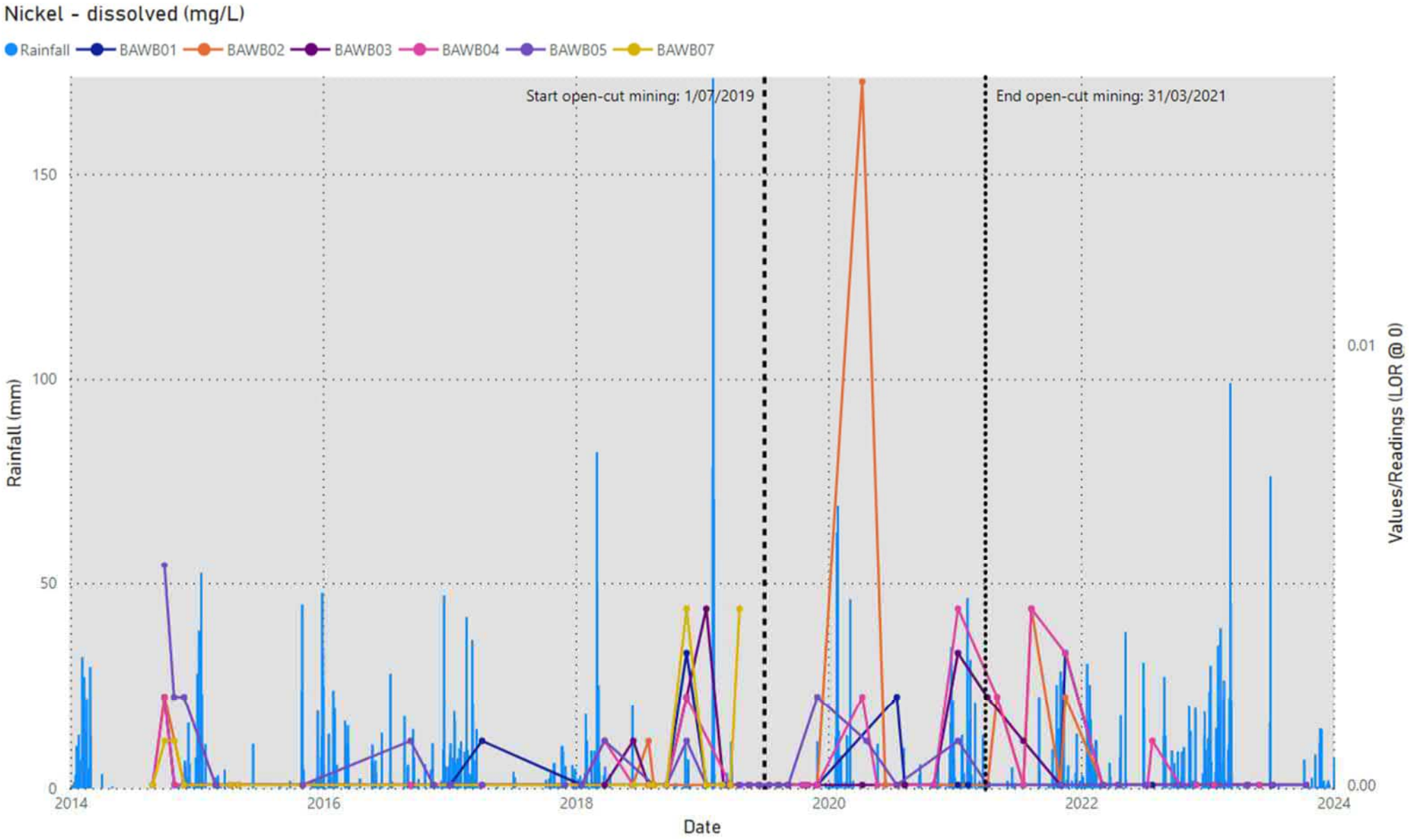

Chromium - dissolved (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.000
0.002
0.004
2014
2016
2018
2020
2022
2024

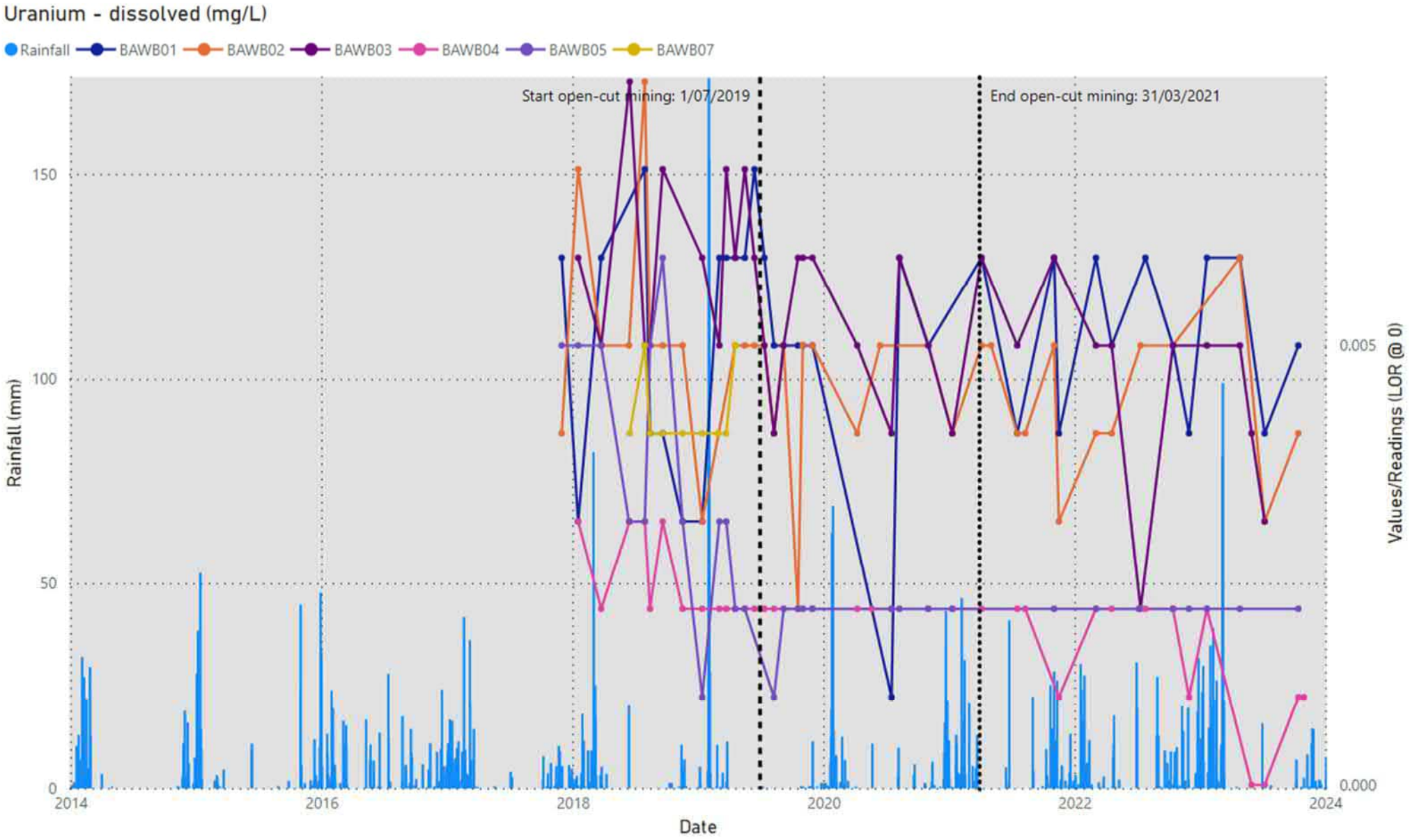

Cobalt - dissolved (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.000
0.002
0.004
2014
2016
2018
2020
2022
2024

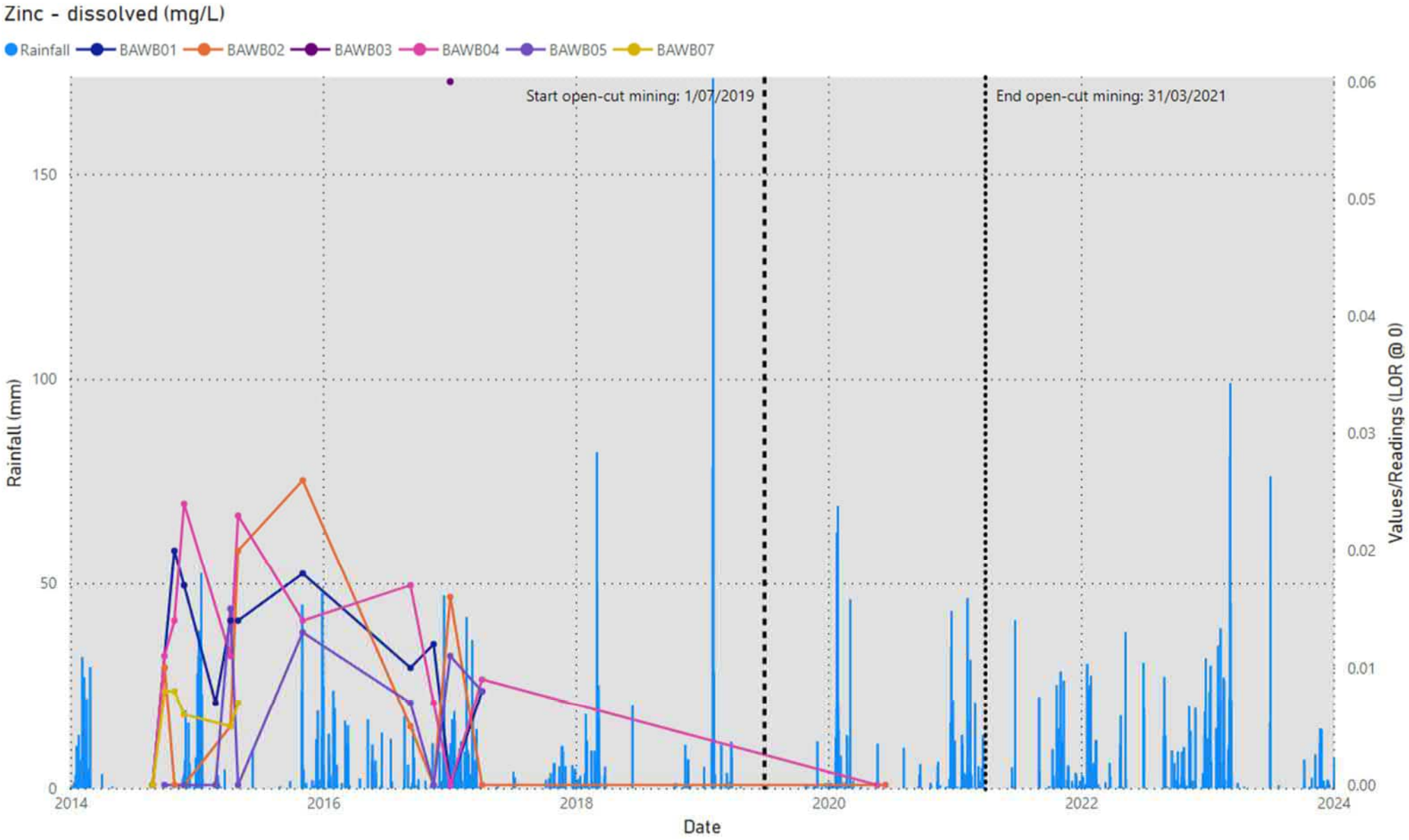

Copper - dissolved (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.01
0.02
2014
2016
2018
2020
2022
2024

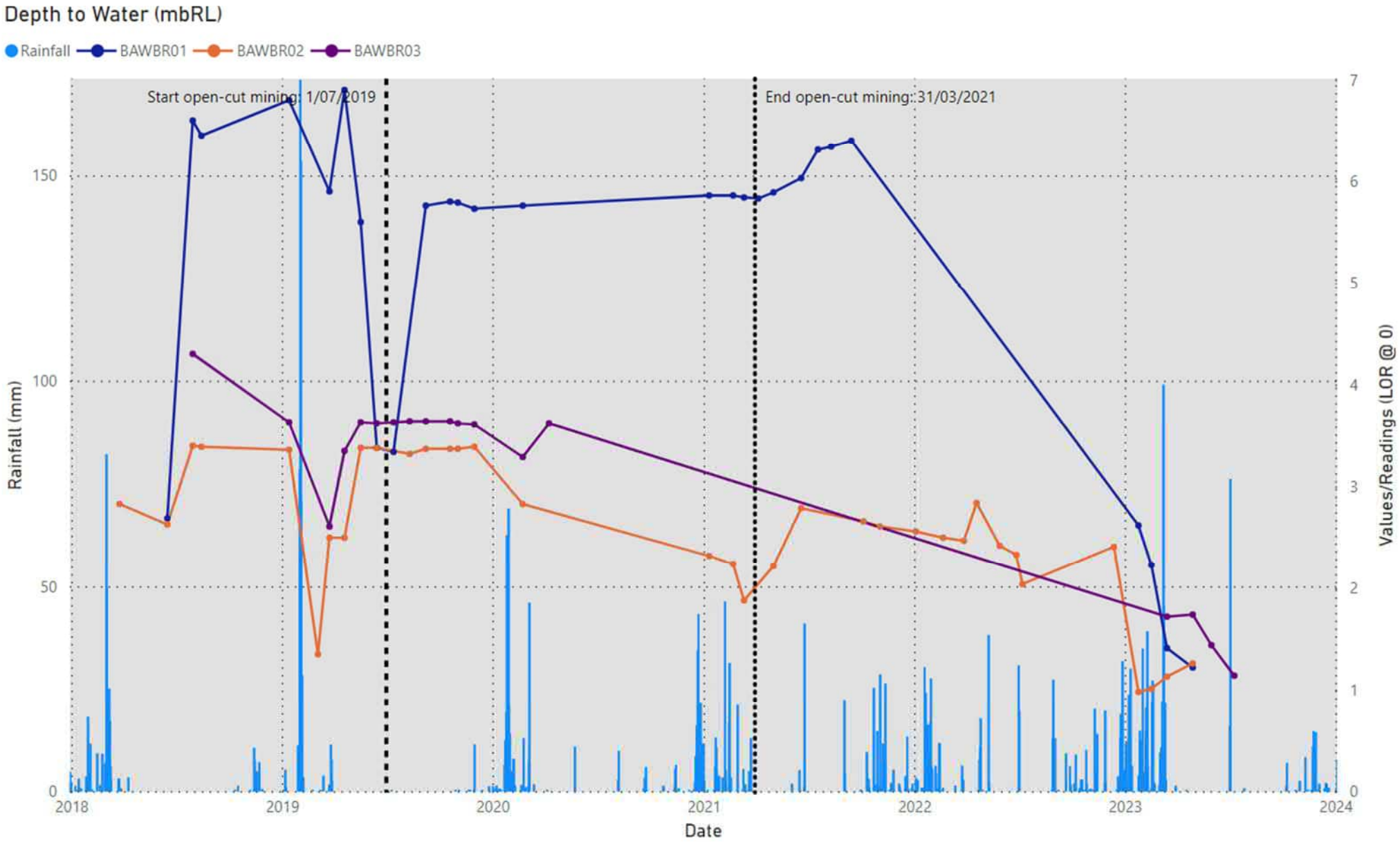

Manganese - dissolved (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
1
2
3
4
2014
2016
2018
2020
2022
2024

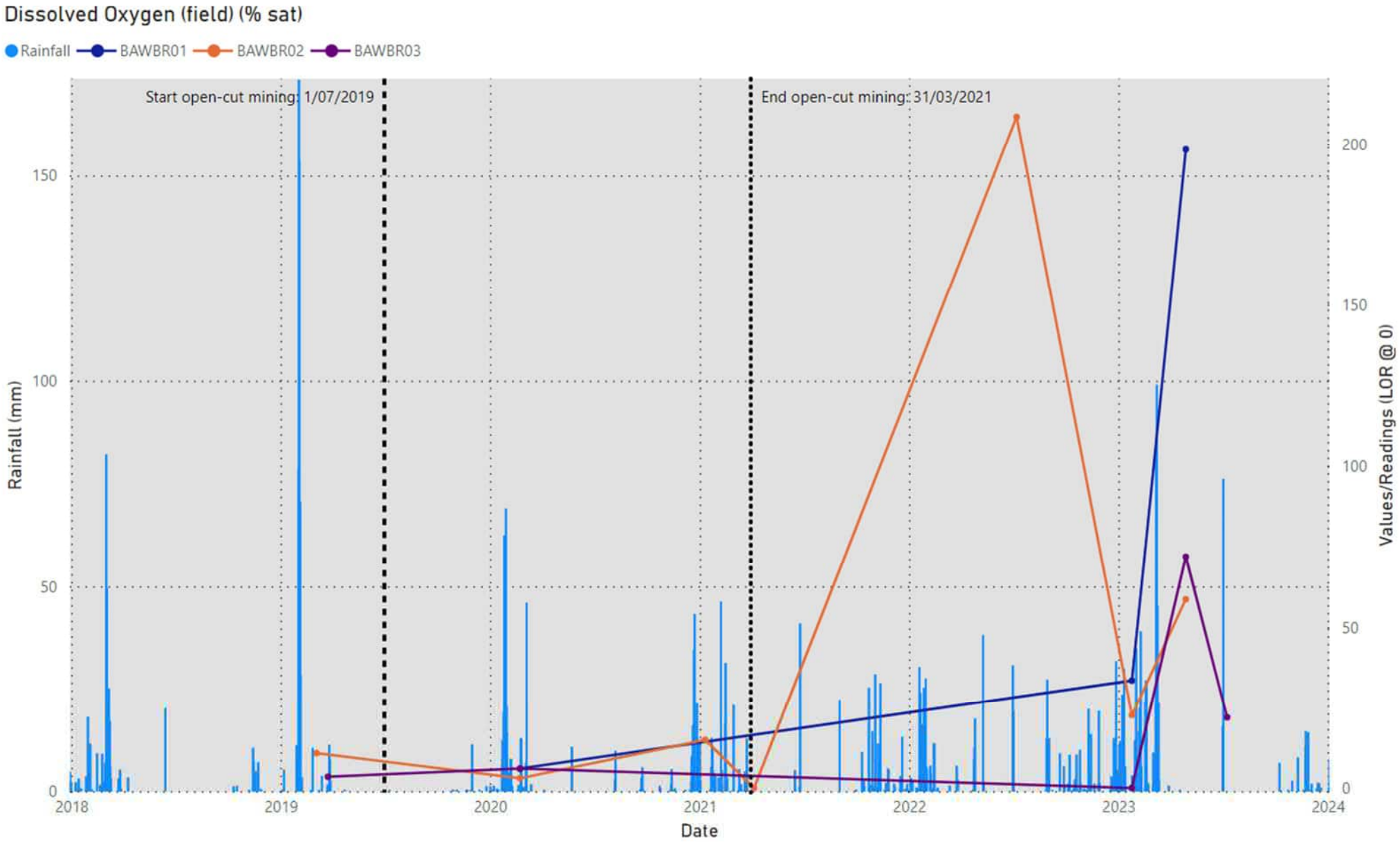

Molybdenum - dissolved (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.01
0.02
0.03
0.04
2014
2016
2018
2020
2022
2024

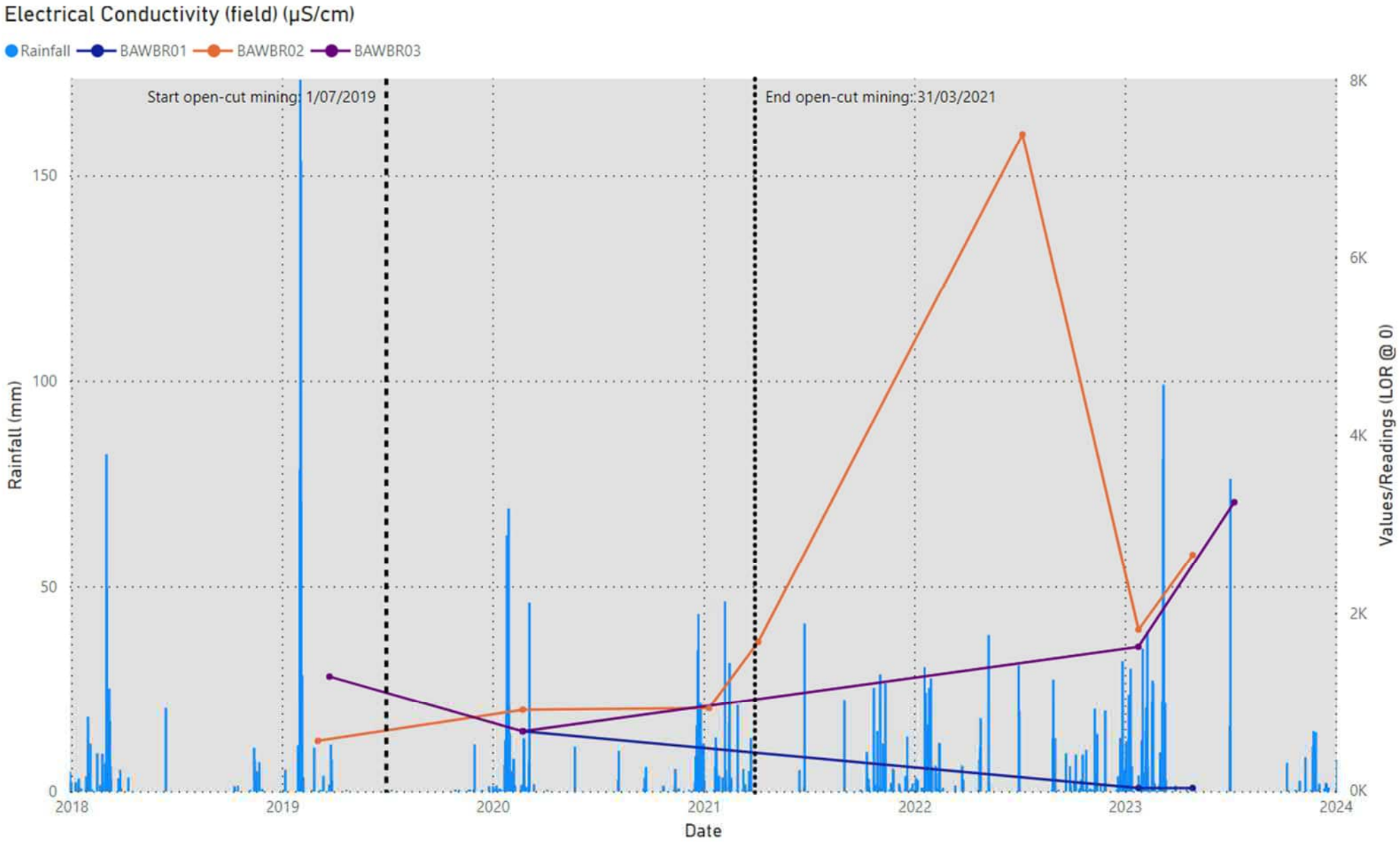

Nickel - dissolved (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
0
50
100
150
0.00
0.01
2014
2016
2018
2020
2022
2024
Date

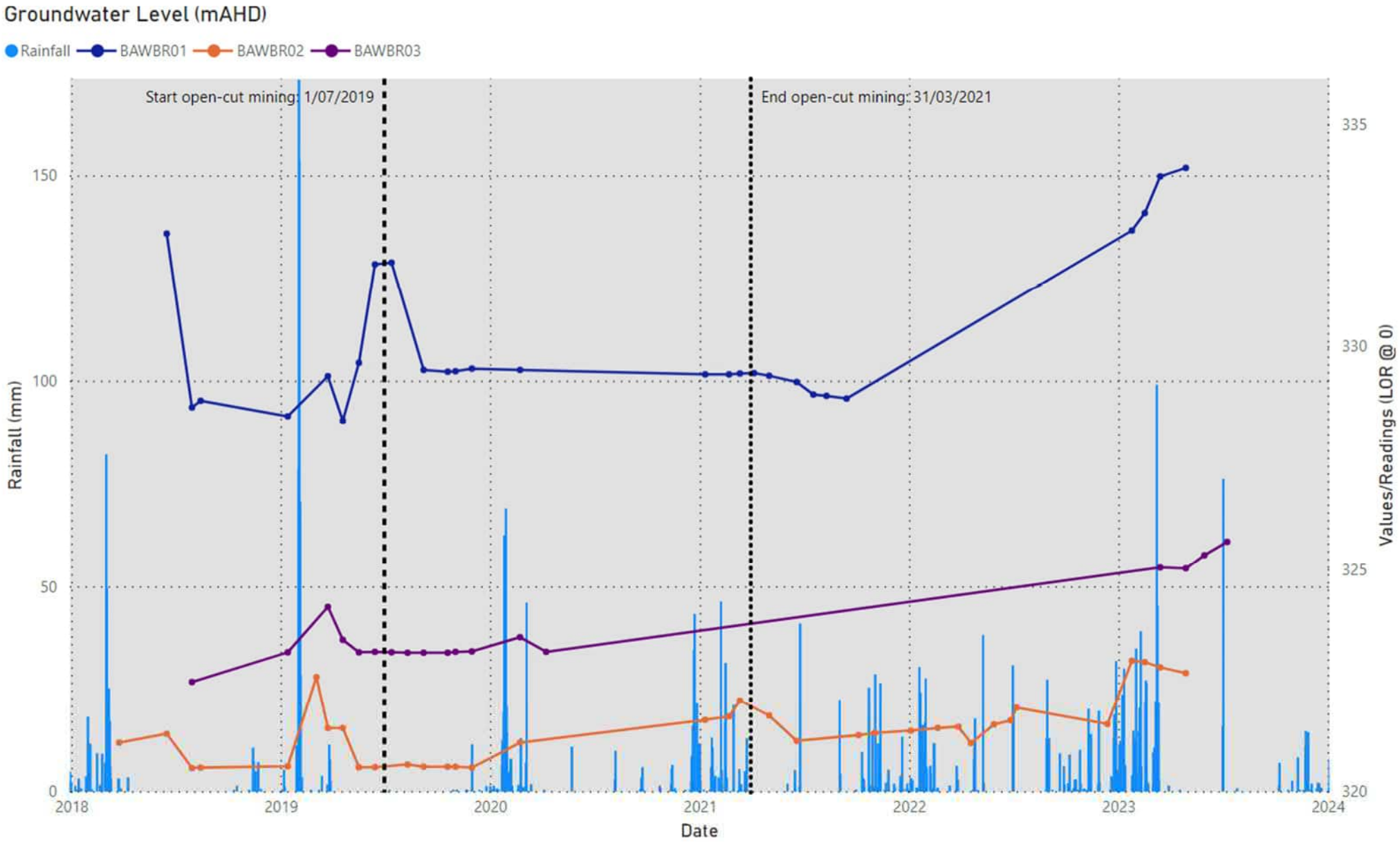

Uranium - dissolved (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
Values/Readings (LOR @ 0)
0.005
0.000
2014
2016
2018
2020
2022
2024
Date

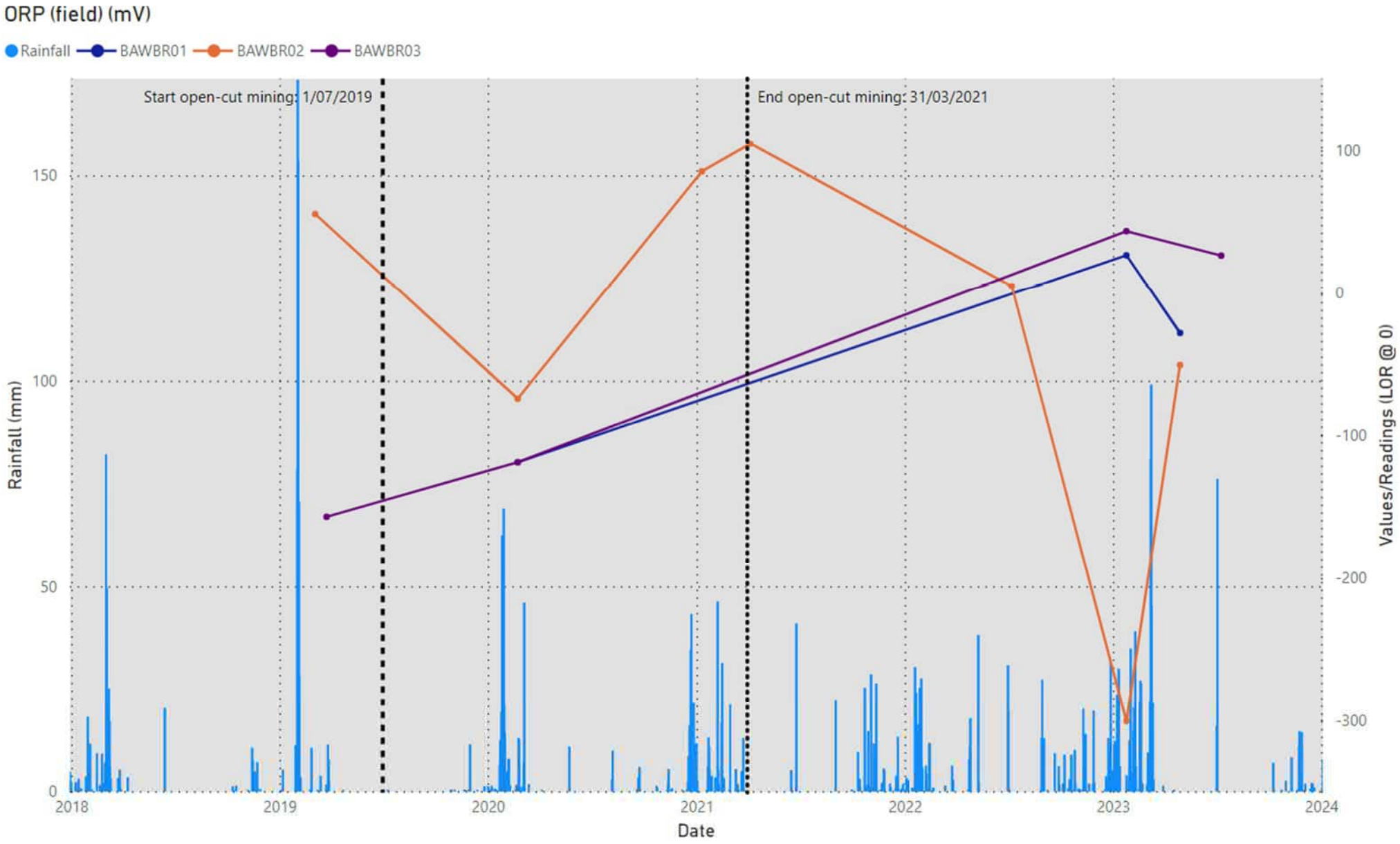

Zinc - dissolved (mg/L)
Rainfall
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.01
0.02
0.03
0.04
0.05
0.06
2014
2016
2018
2020
2022
2024

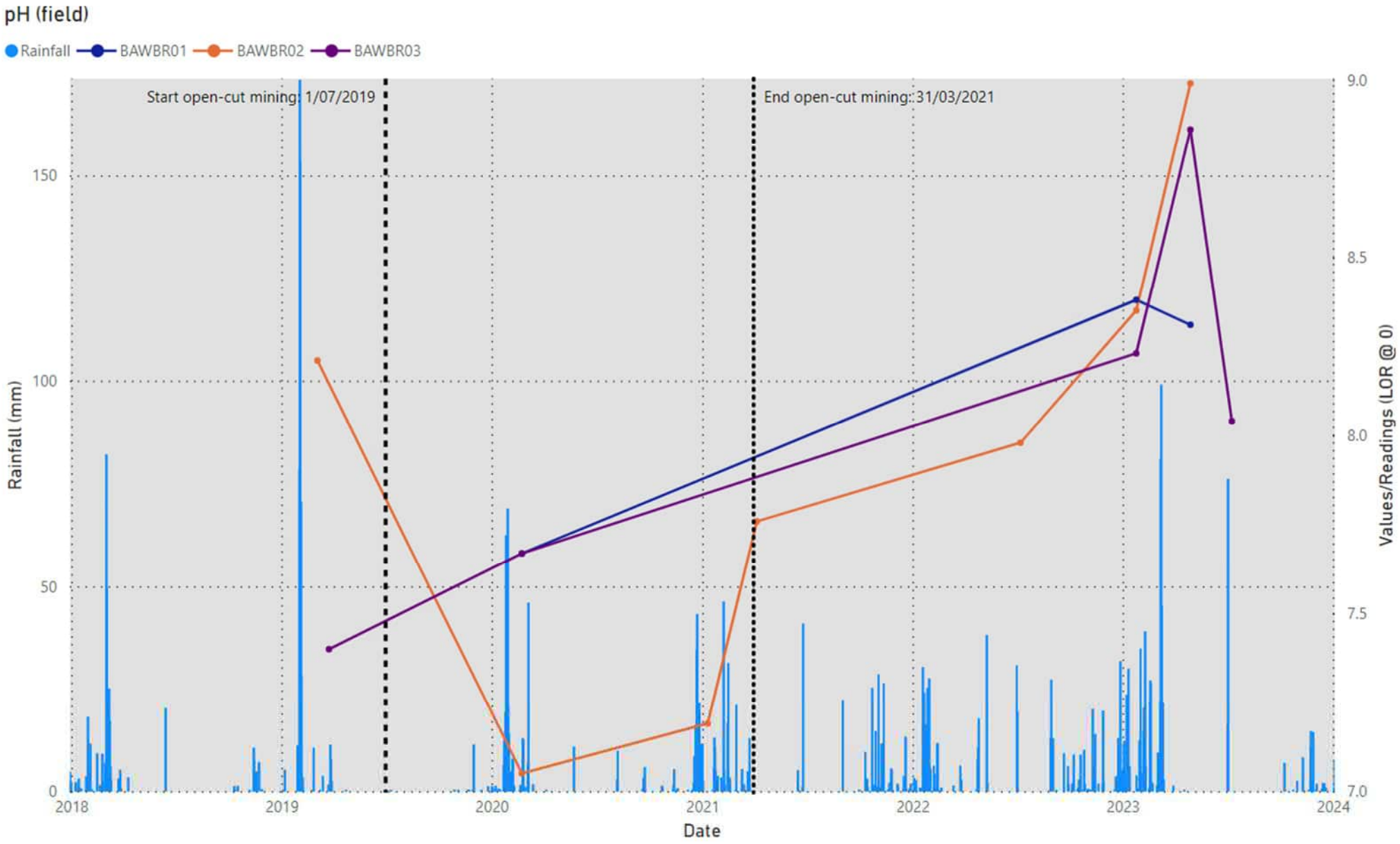

Depth to Water (mbRL)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
1
2
3
4
5
6
7
2018
2019
2020
2021
2022
2023
2024

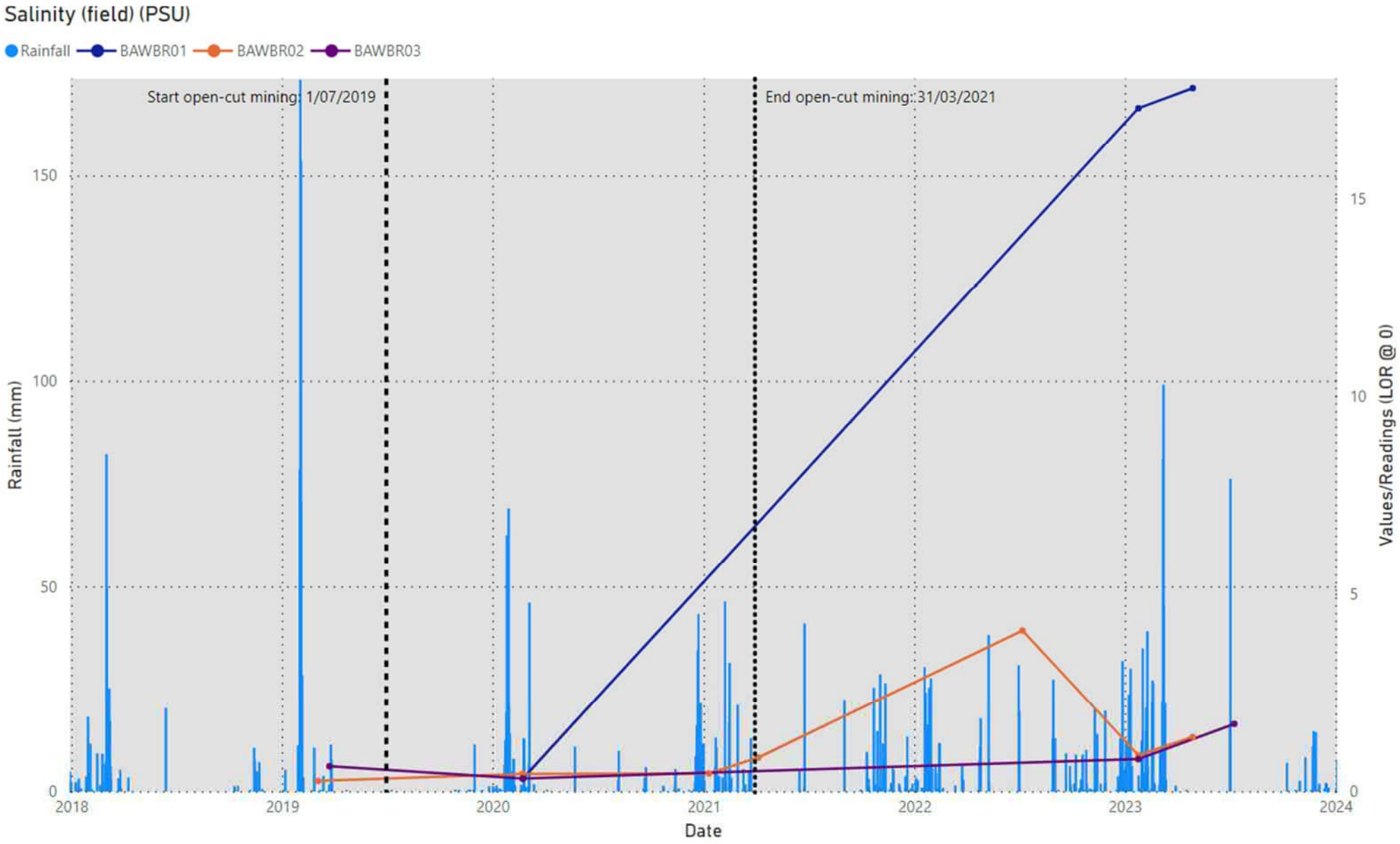

Dissolved Oxygen (field) (% sat)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
200
2018
2019
2020
2021
2022
2023
2024

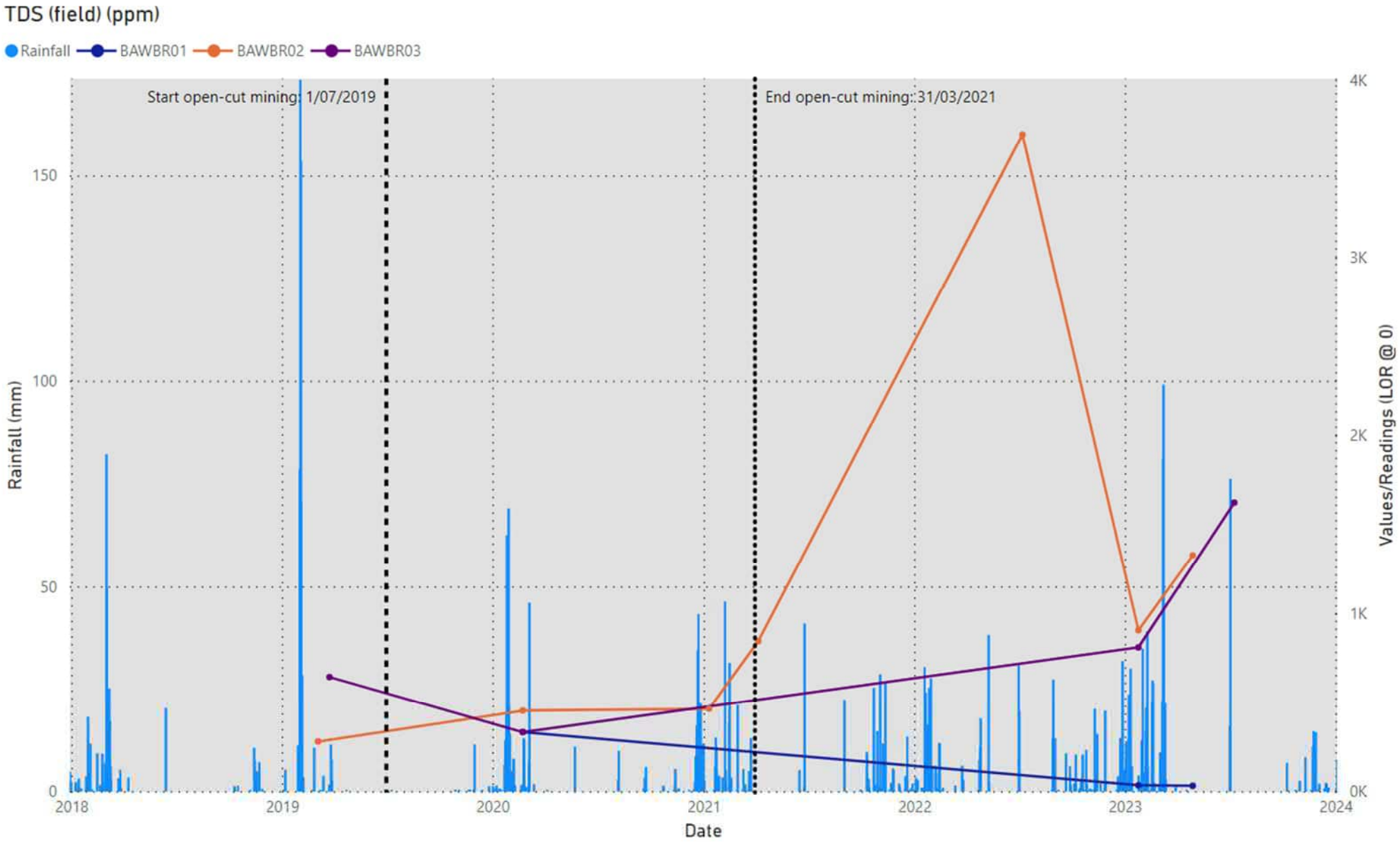

Electrical Conductivity (field) (µS/cm)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0K
2K
4K
6K
8K
2018
2019
2020
2021
2022
2023
2024
Date

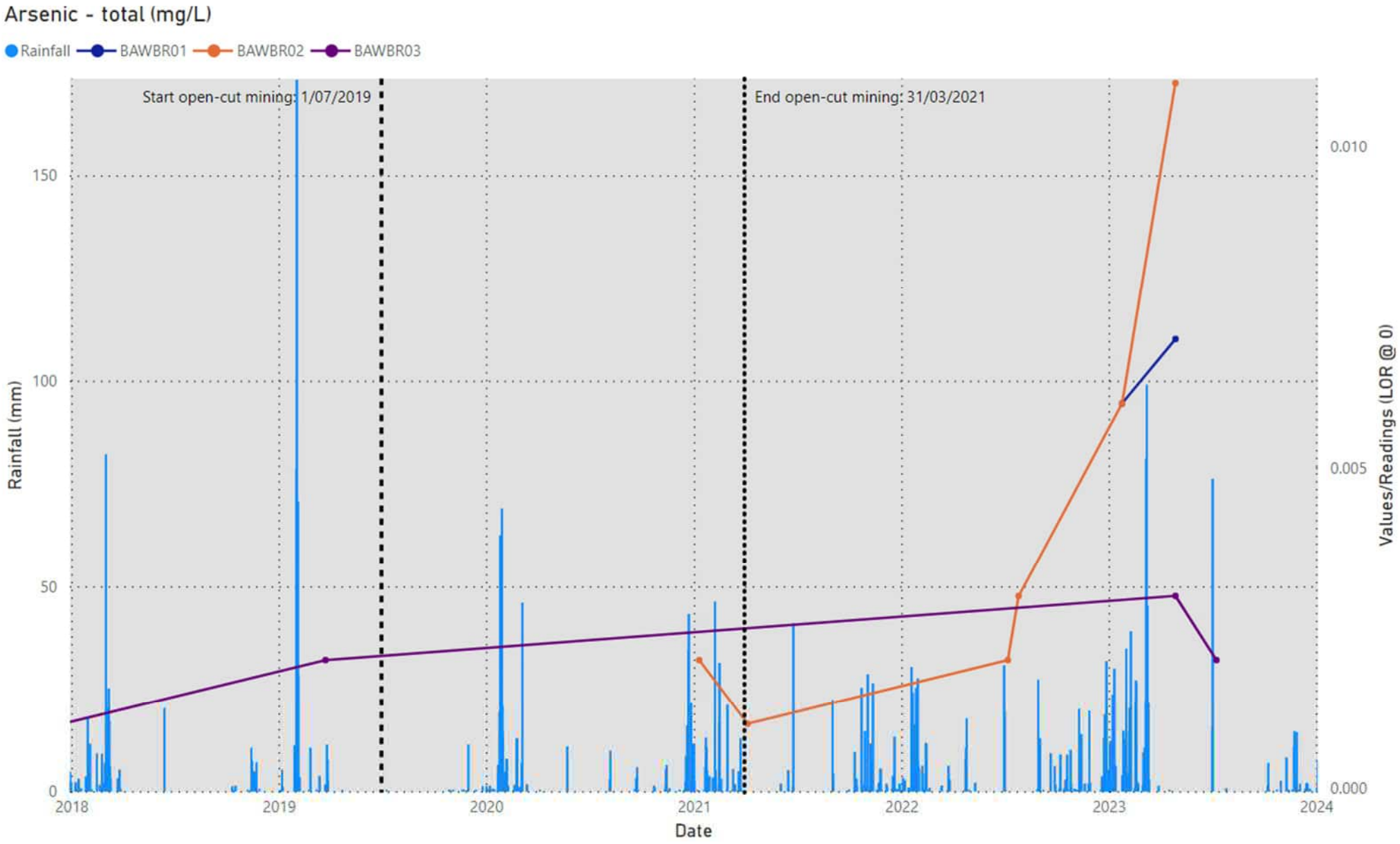

Groundwater Level (mAHD)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
320
325
330
335
2018
2019
2020
2021
2022
2023
2024

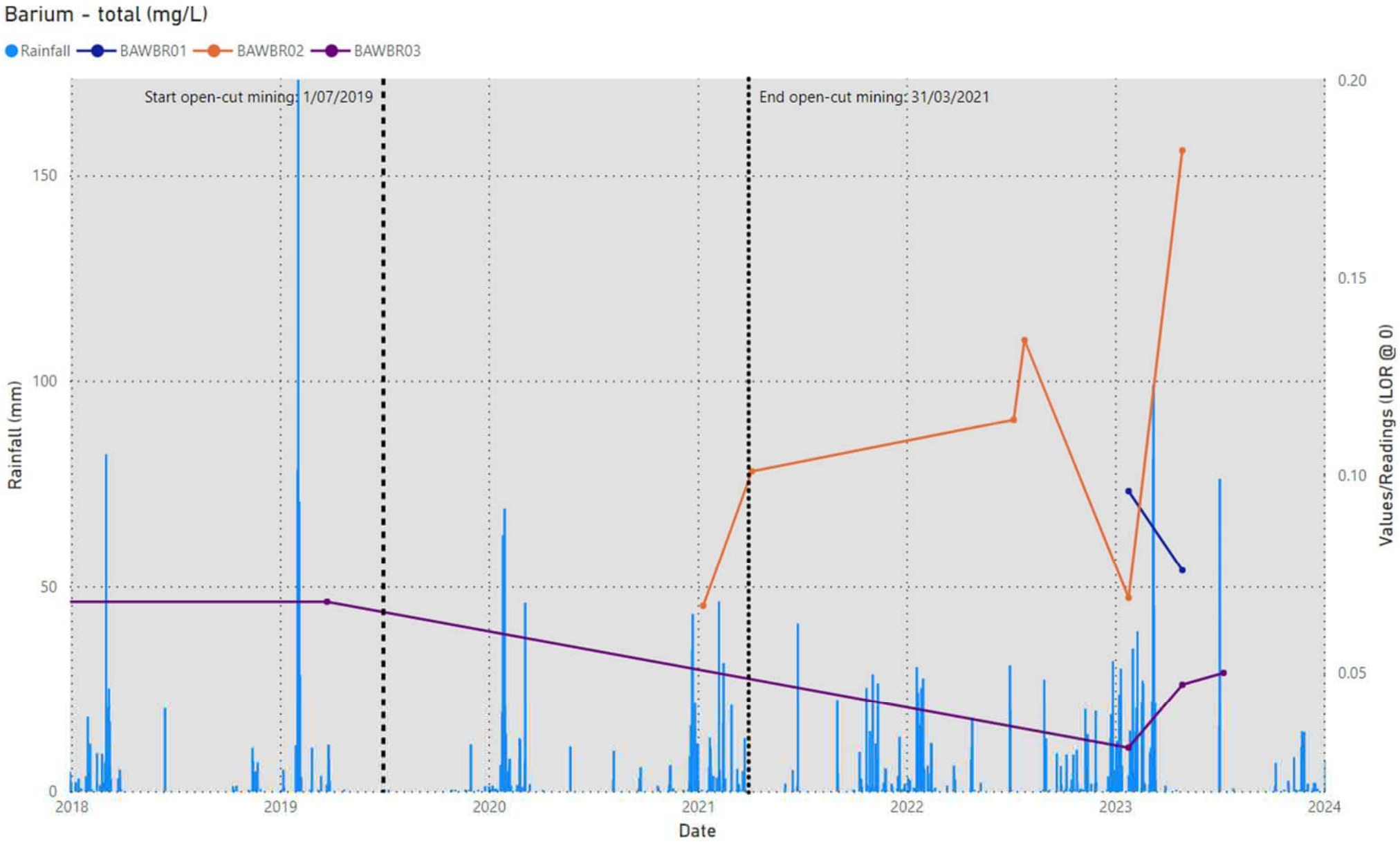

ORP (field) (mV)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
100
0
-100
-200
-300
2018
2019
2020
2021
2022
2023
2024

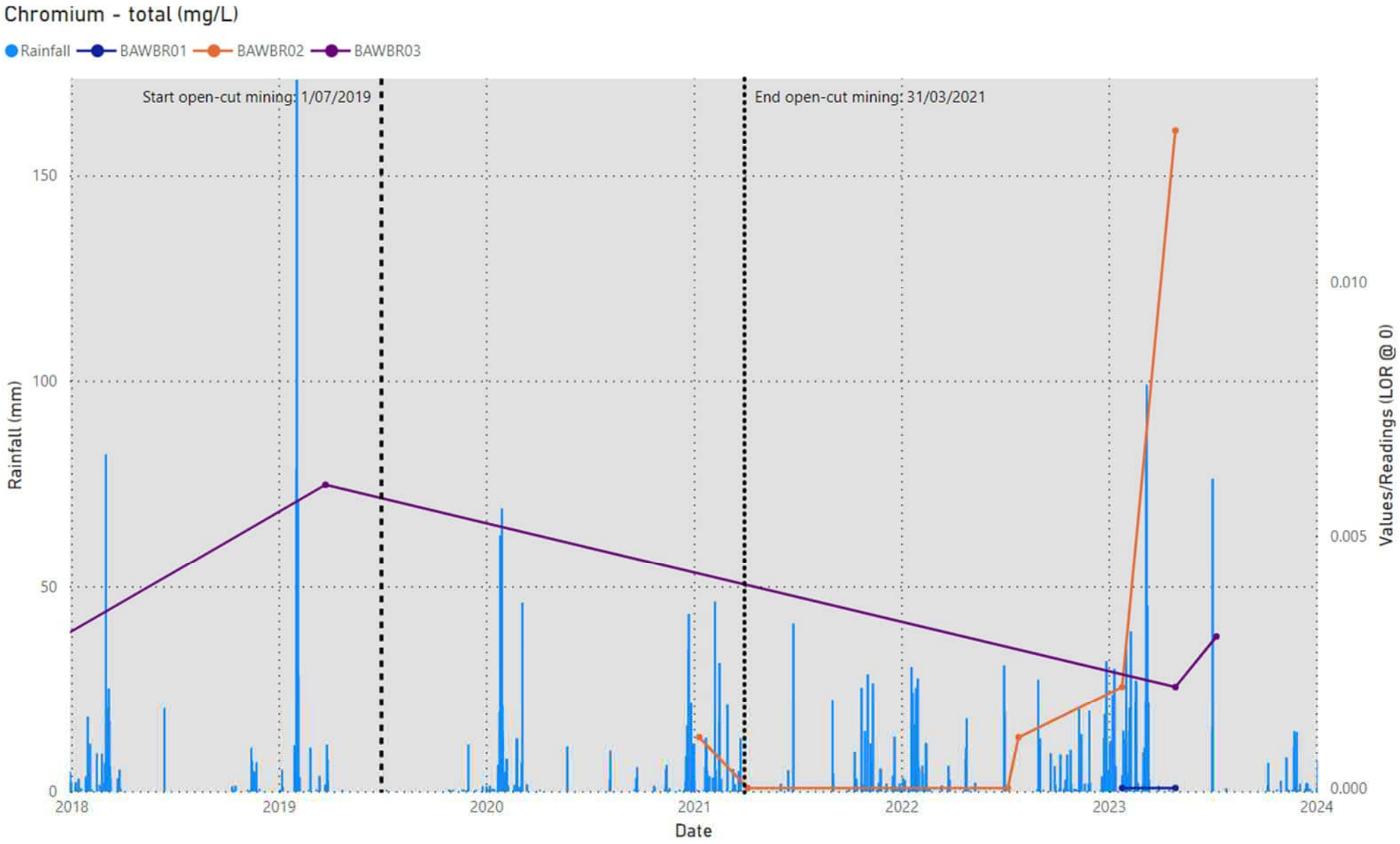

pH (field)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
7.0
7.5
8.0
8.5
9.0
2018
2019
2020
2021
2022
2023
2024

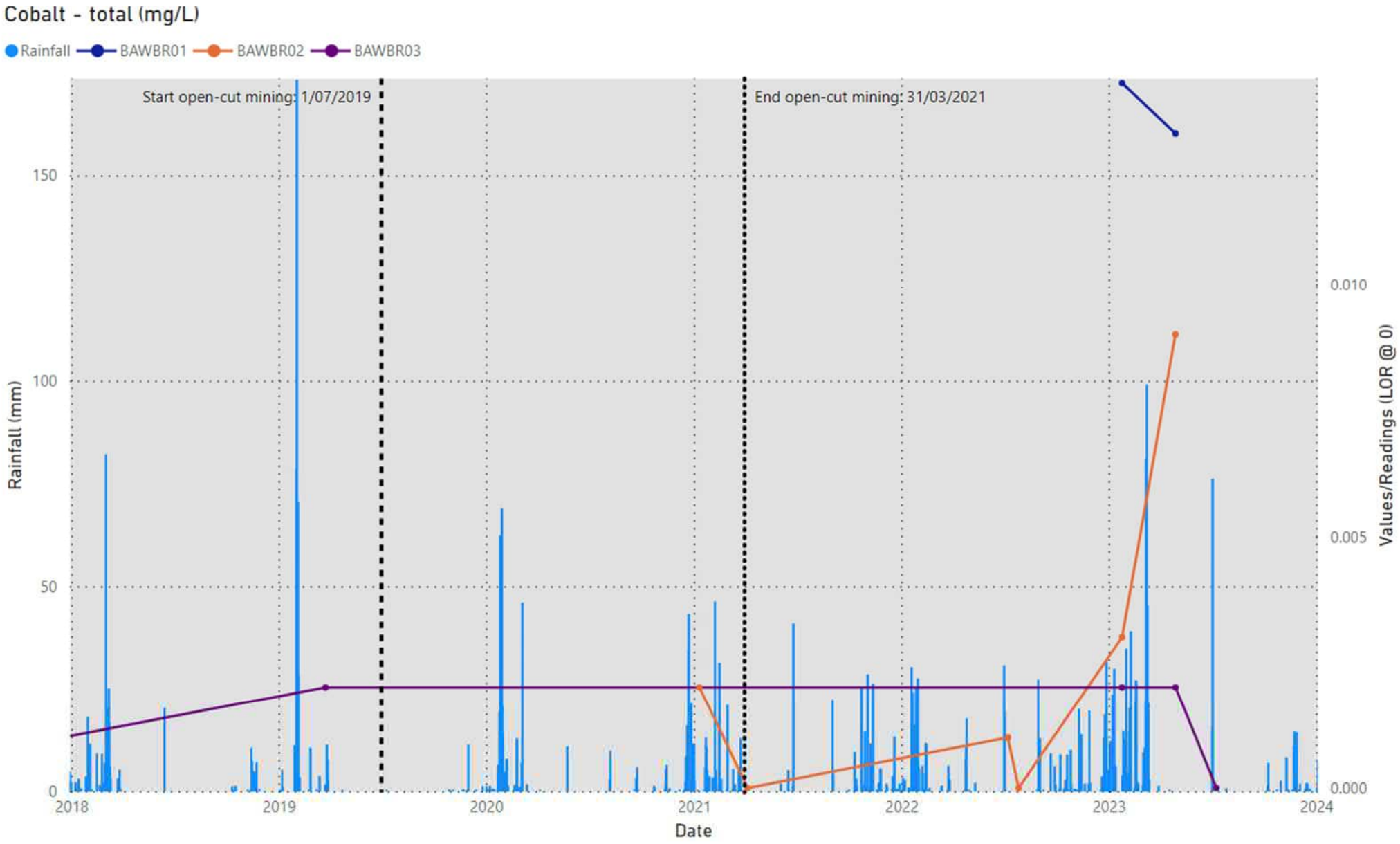

Salinity (field) (PSU)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
5
10
15
2018
2019
2020
2021
2022
2023
2024

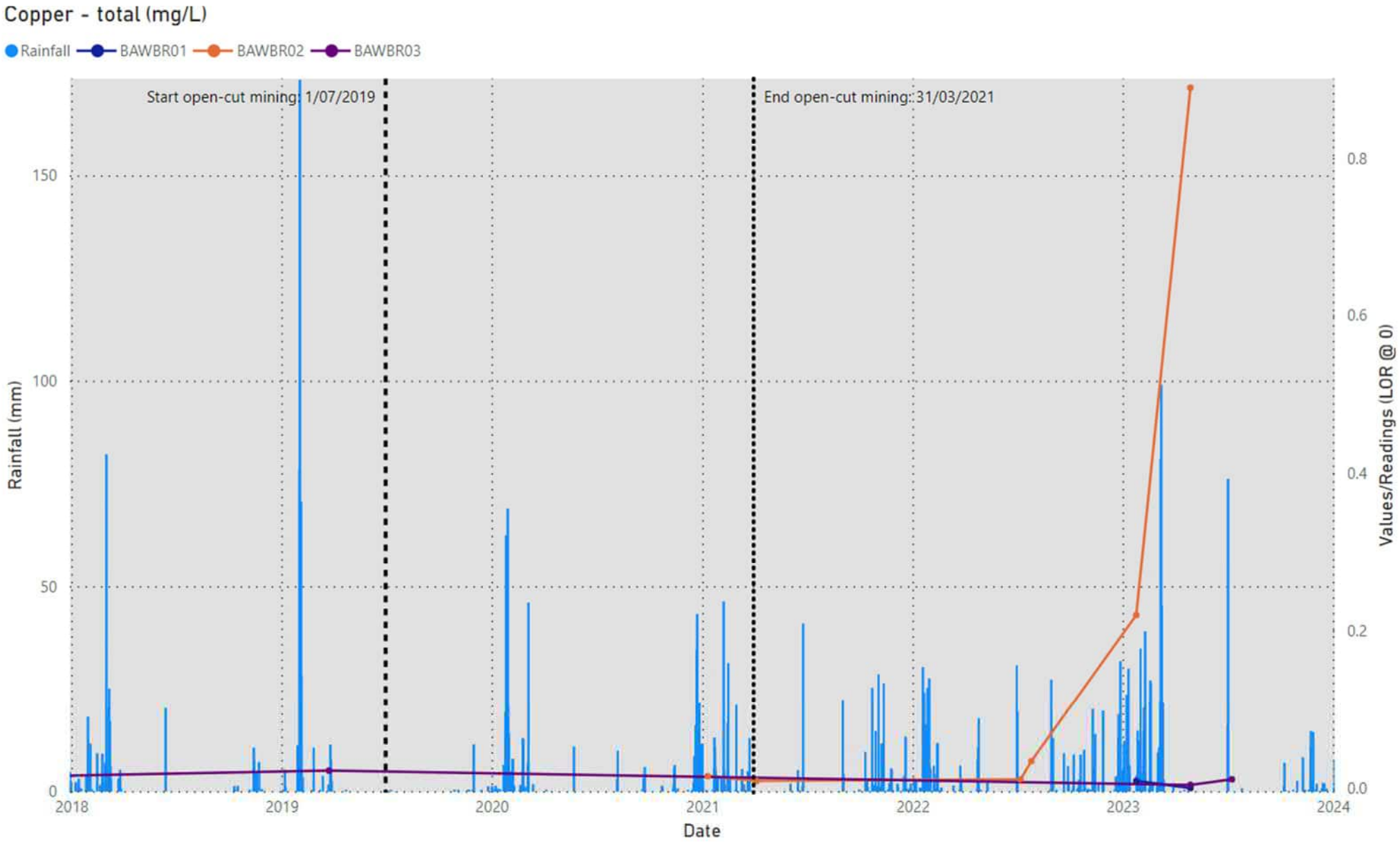

TDS (field) (ppm)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0K
1K
2K
3K
4K
2018
2019
2020
2021
2022
2023
2024

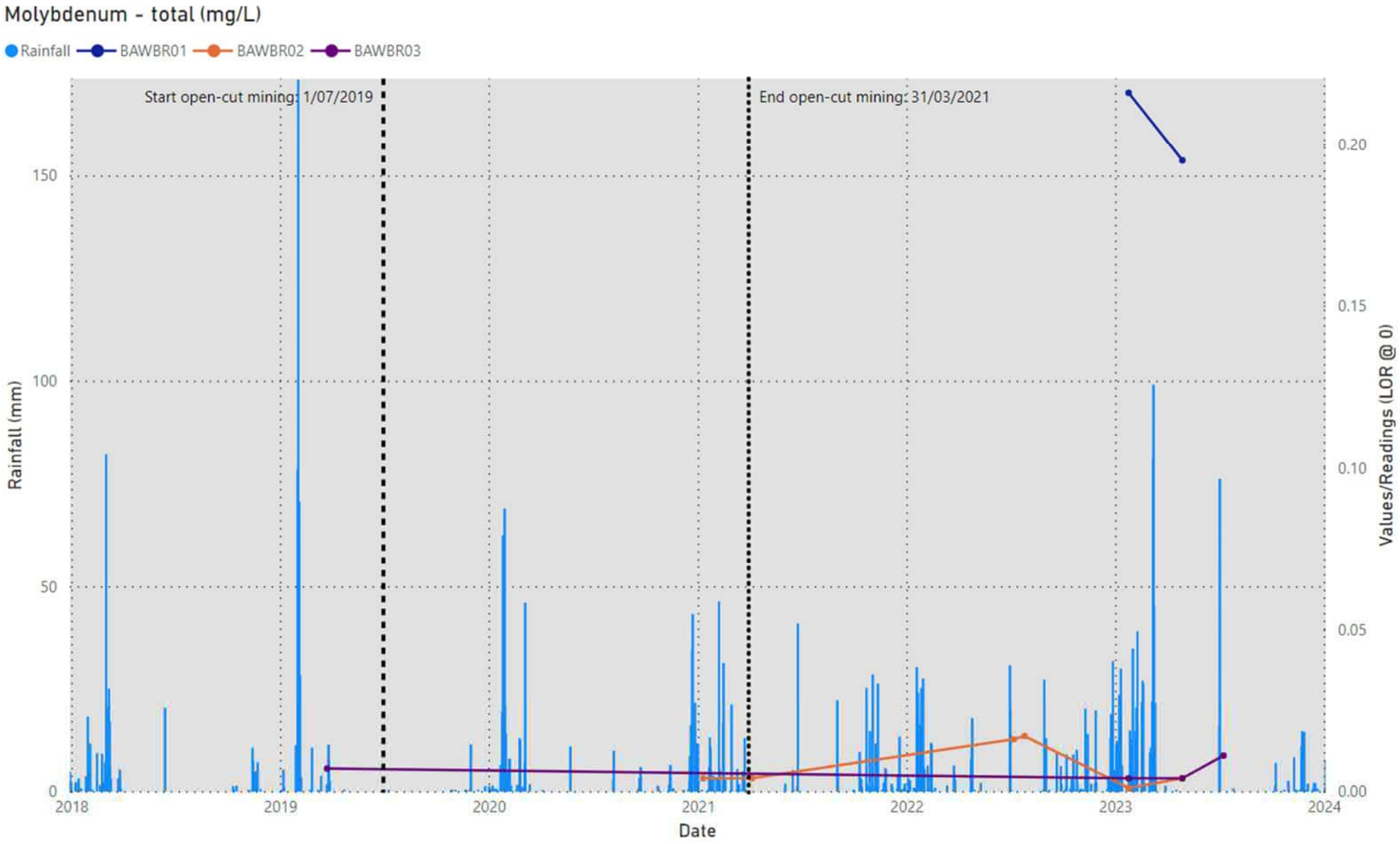

Arsenic - total (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
0.010
0.005
0.000
Values/Readings (LOR @ 0)
2018
2019
2020
2021
2022
2023
2024
Date

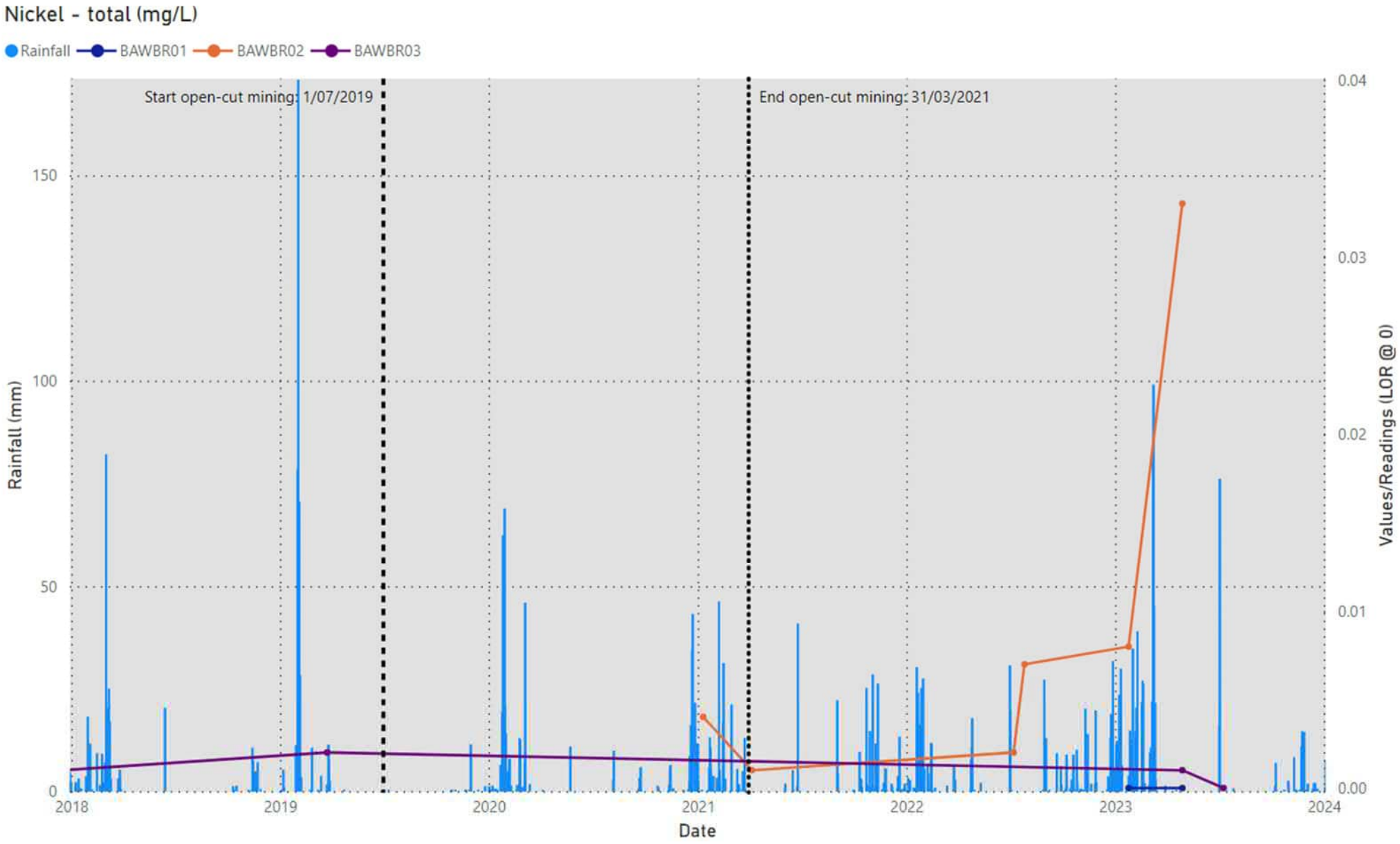

Barium - total (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.05
0.10
0.15
0.20
2018
2019
2020
2021
2022
2023
2024

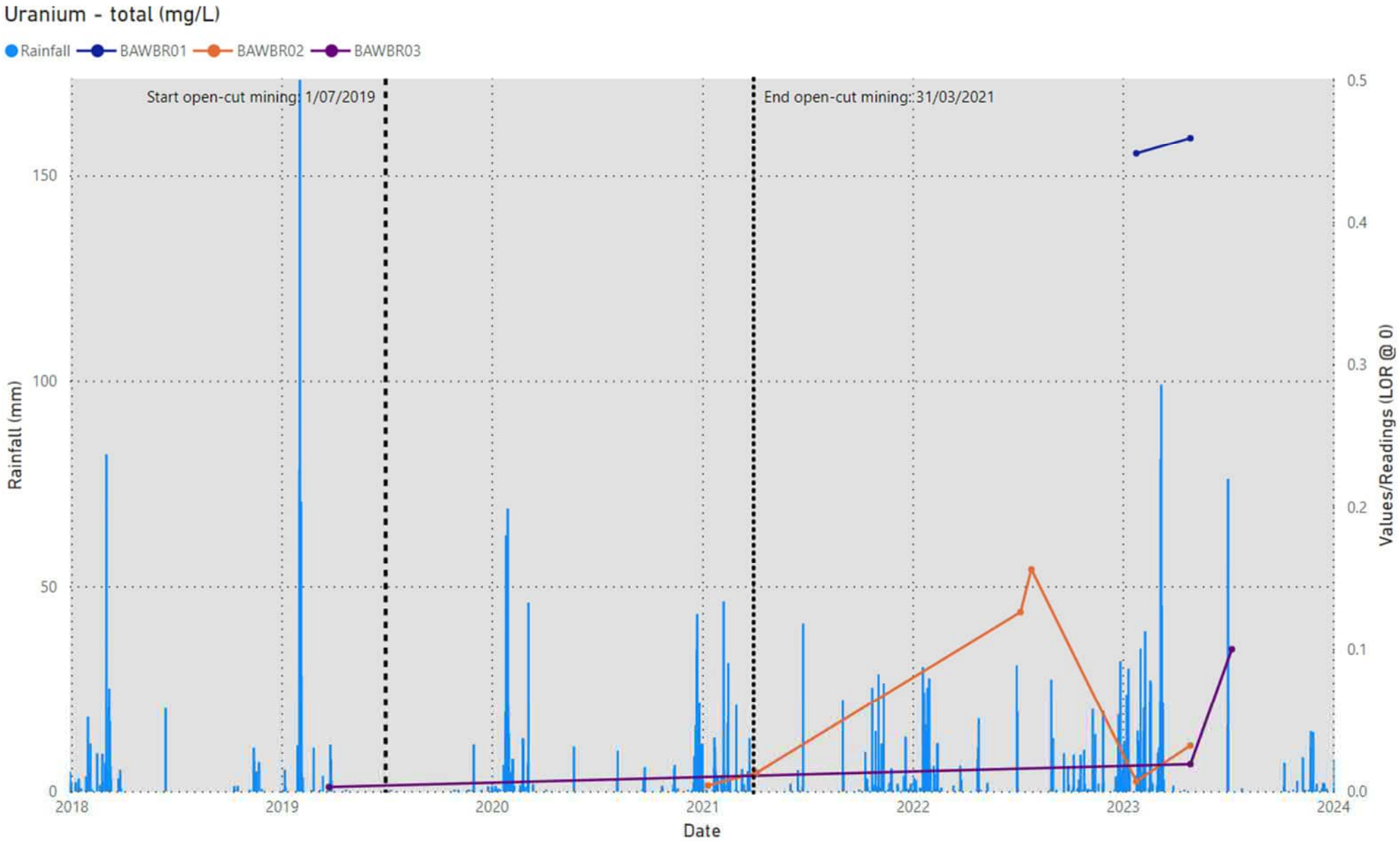

Chromium - total (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.000
0.005
0.010
2018
2019
2020
2021
2022
2023
2024

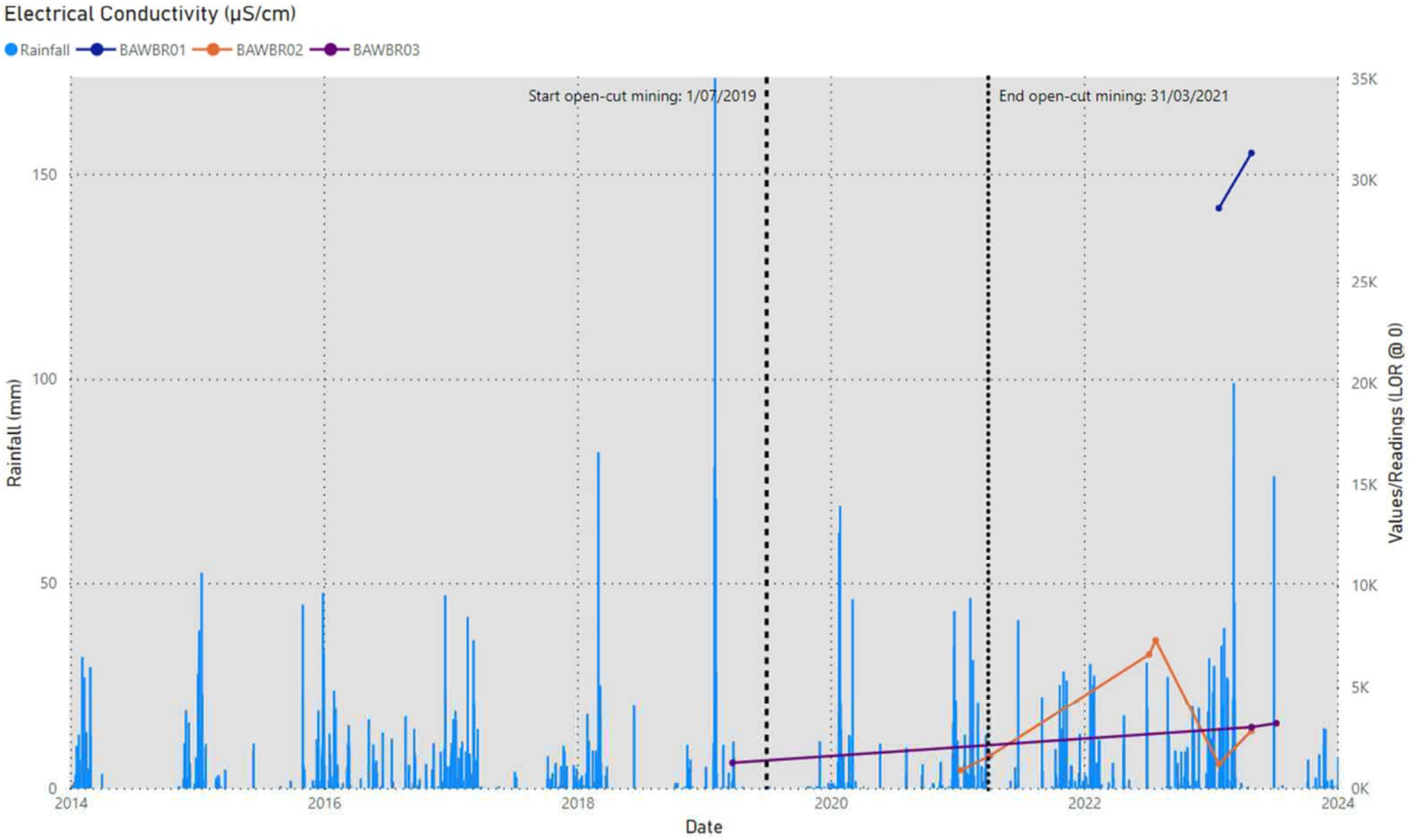

Cobalt - total (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
0.010
0.005
0.000
Values/Readings (LOR @ 0)
2018
2019
2020
2021
2022
2023
2024
Date

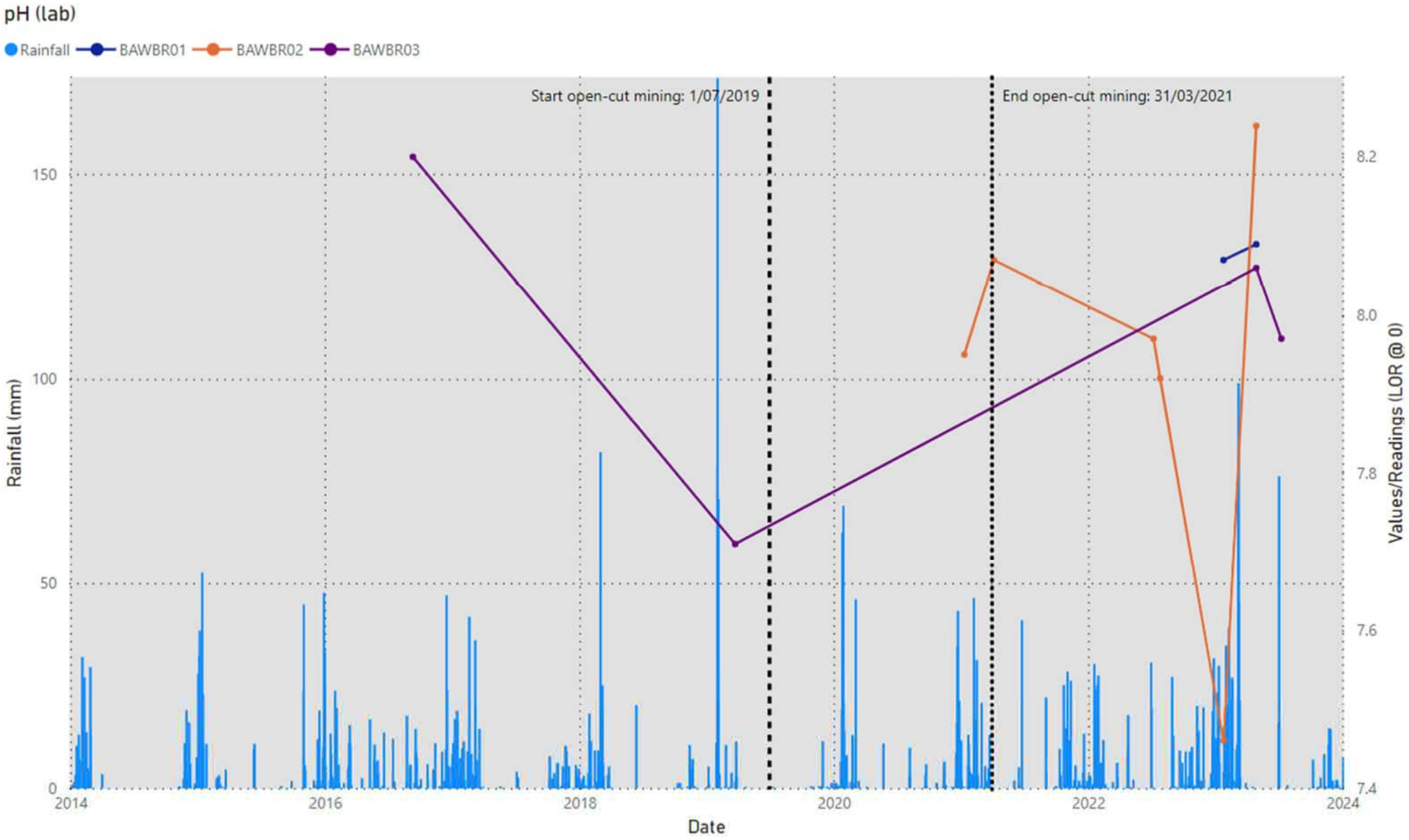

Copper - total (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.0
0.2
0.4
0.6
0.8
2018
2019
2020
2021
2022
2023
2024

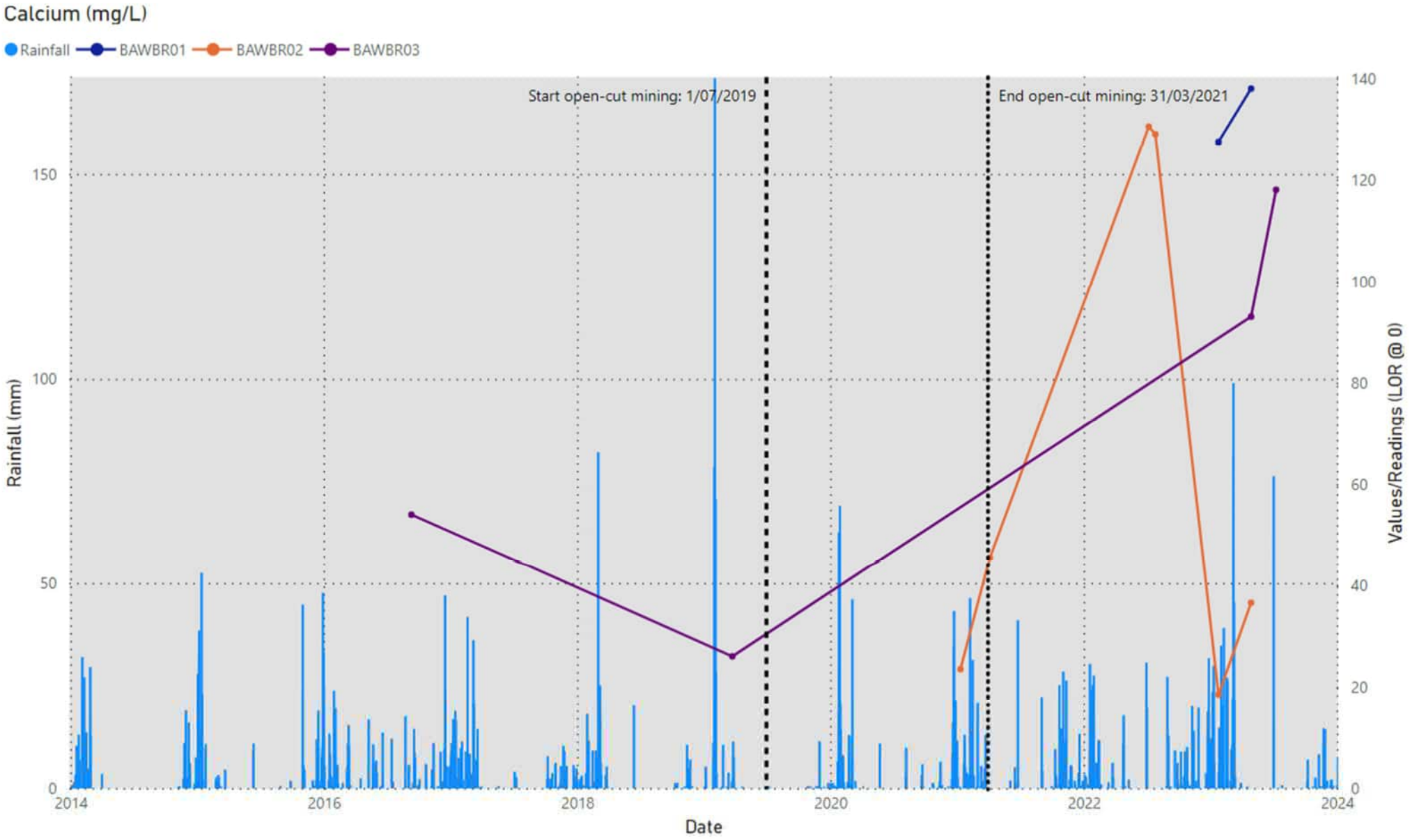

Molybdenum - total (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.05
0.10
0.15
0.20
2018
2019
2020
2021
2022
2023
2024

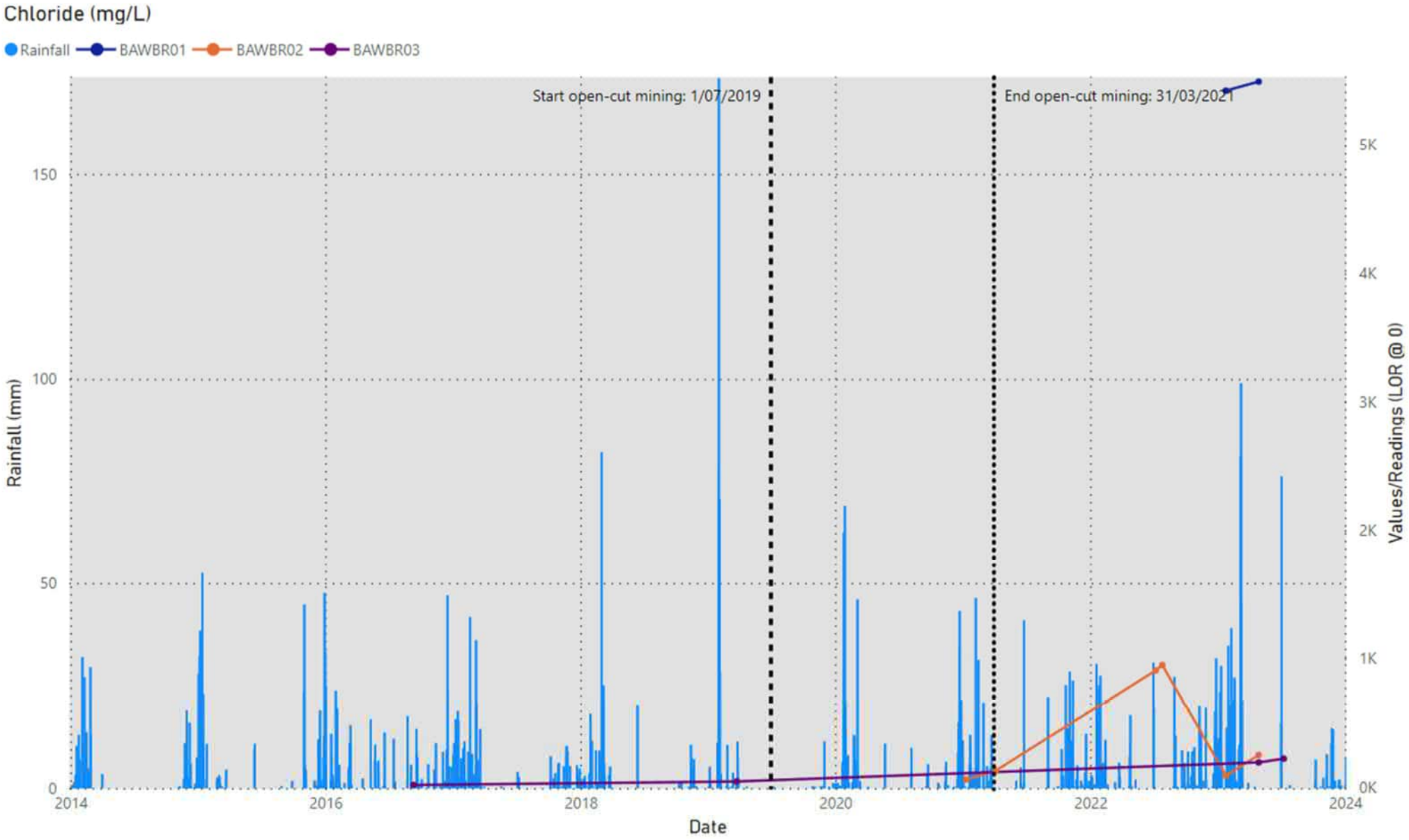

Nickel - total (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.01
0.02
0.03
0.04
2018
2019
2020
2021
2022
2023
2024

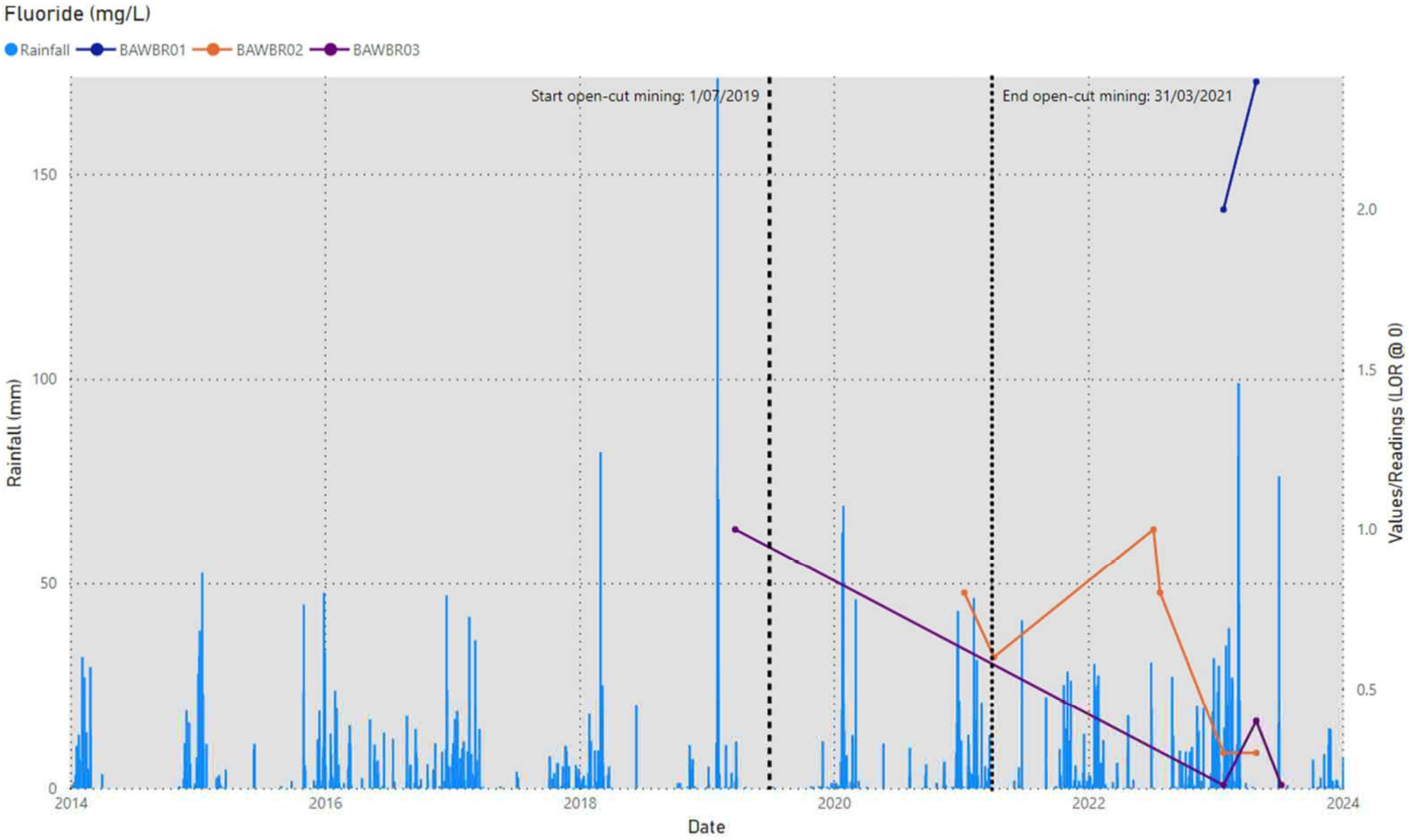

Uranium - total (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.0
0.1
0.2
0.3
0.4
0.5
2018
2019
2020
2021
2022
2023
2024

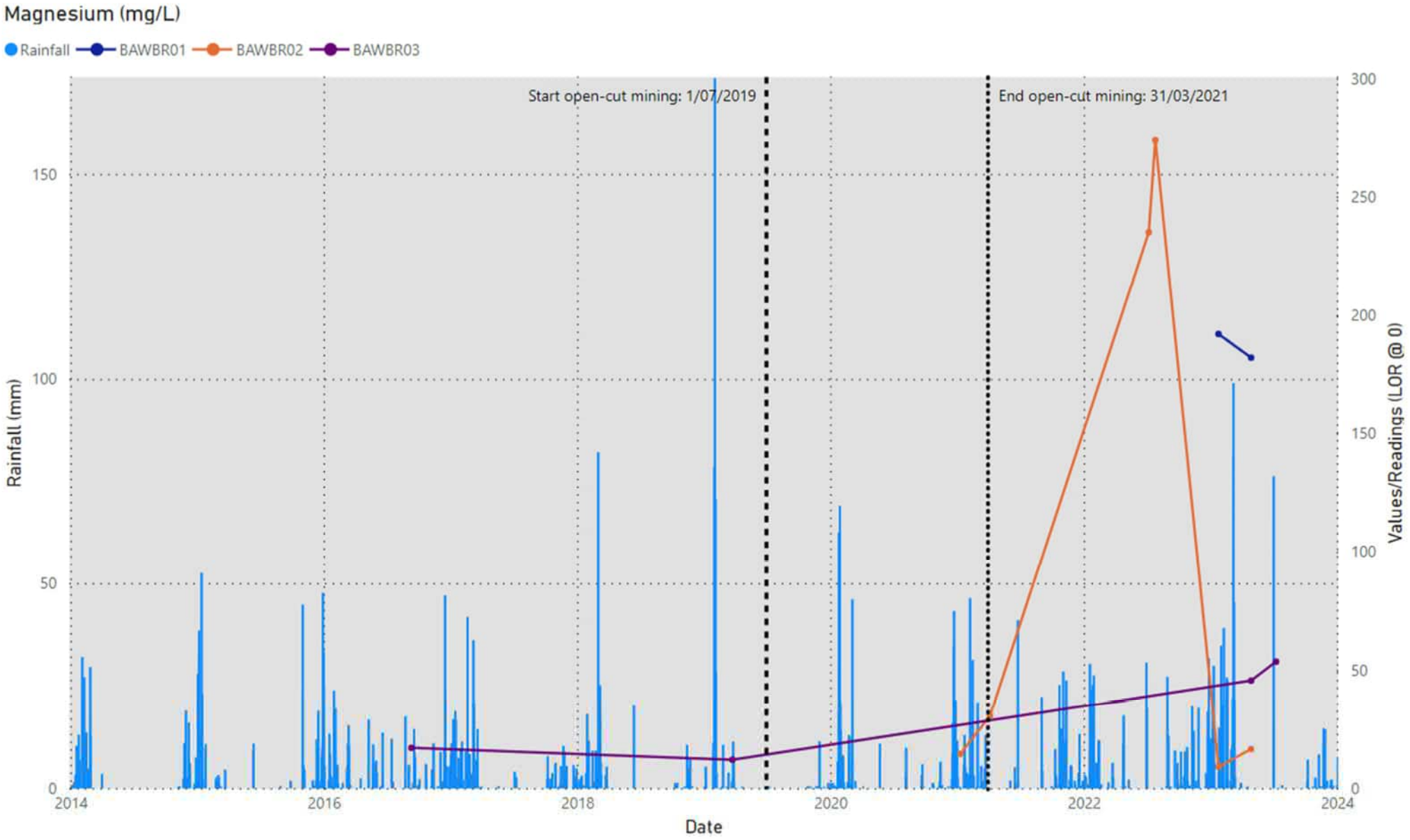

Electrical Conductivity (µS/cm)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0K
5K
10K
15K
20K
25K
30K
35K
2014
2016
2018
2020
2022
2024

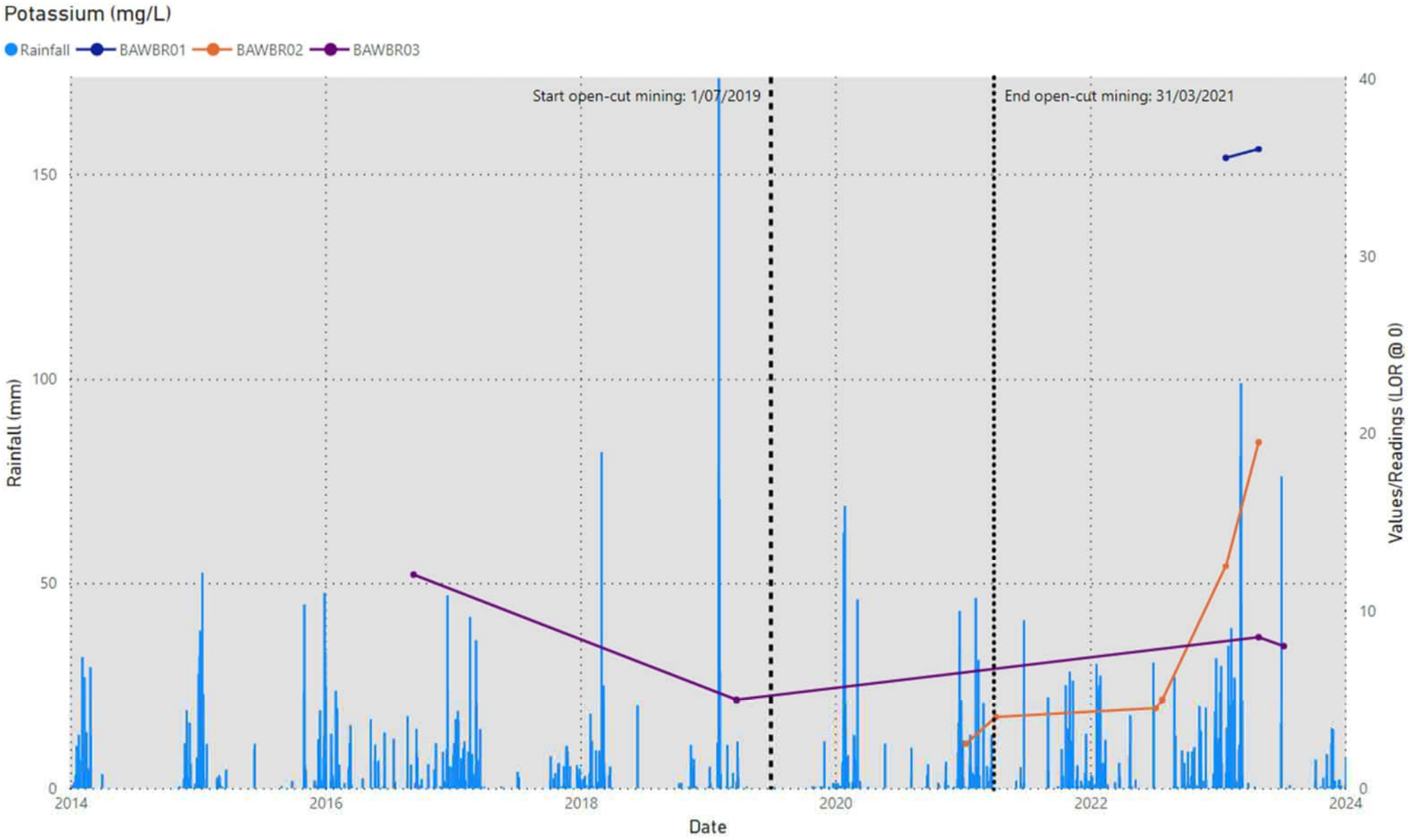

pH (lab)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
7.4
7.6
7.8
8.0
8.2
2014
2016
2018
2020
2022
2024

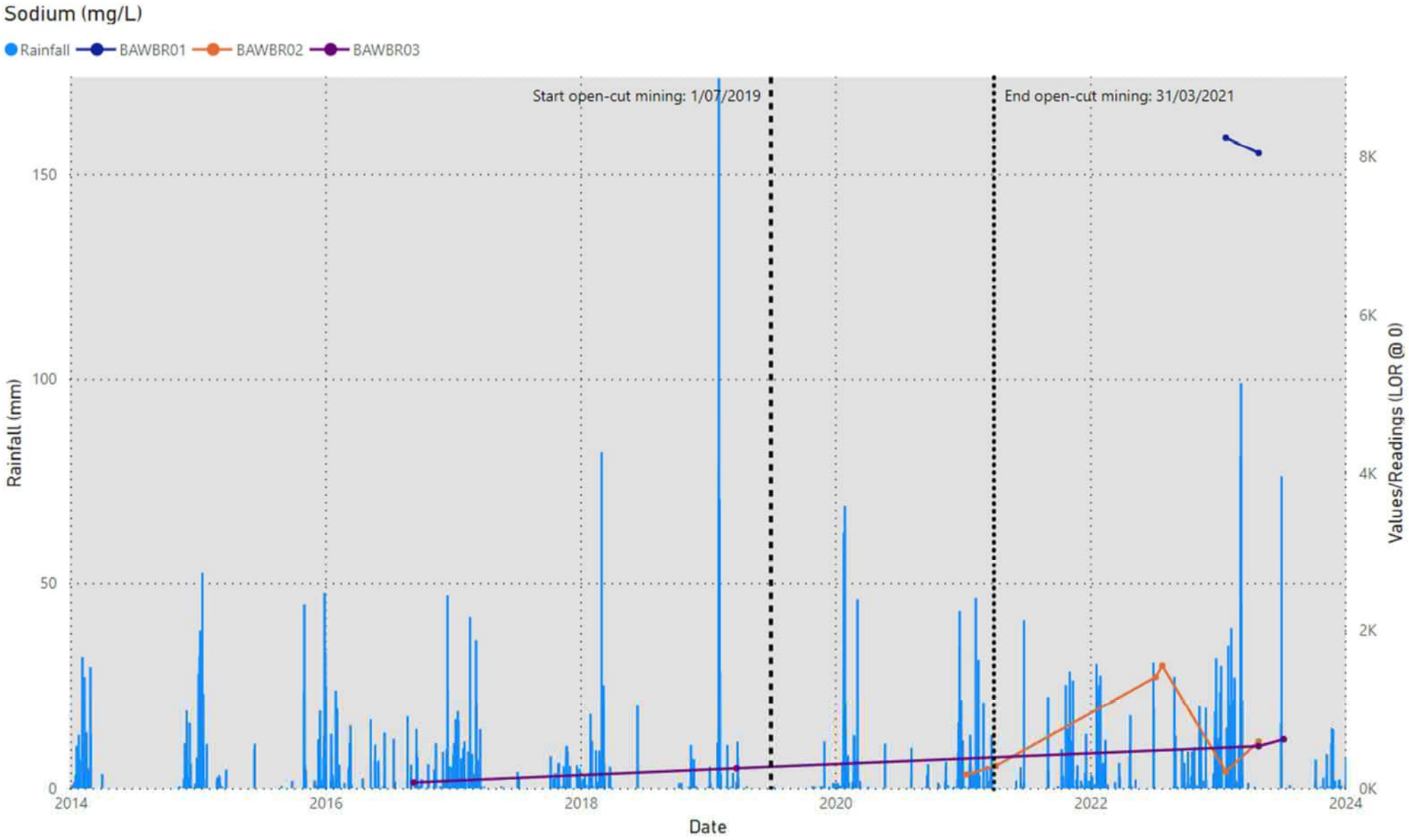

Calcium (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
20
40
60
80
100
120
140
2014
2016
2018
2020
2022
2024

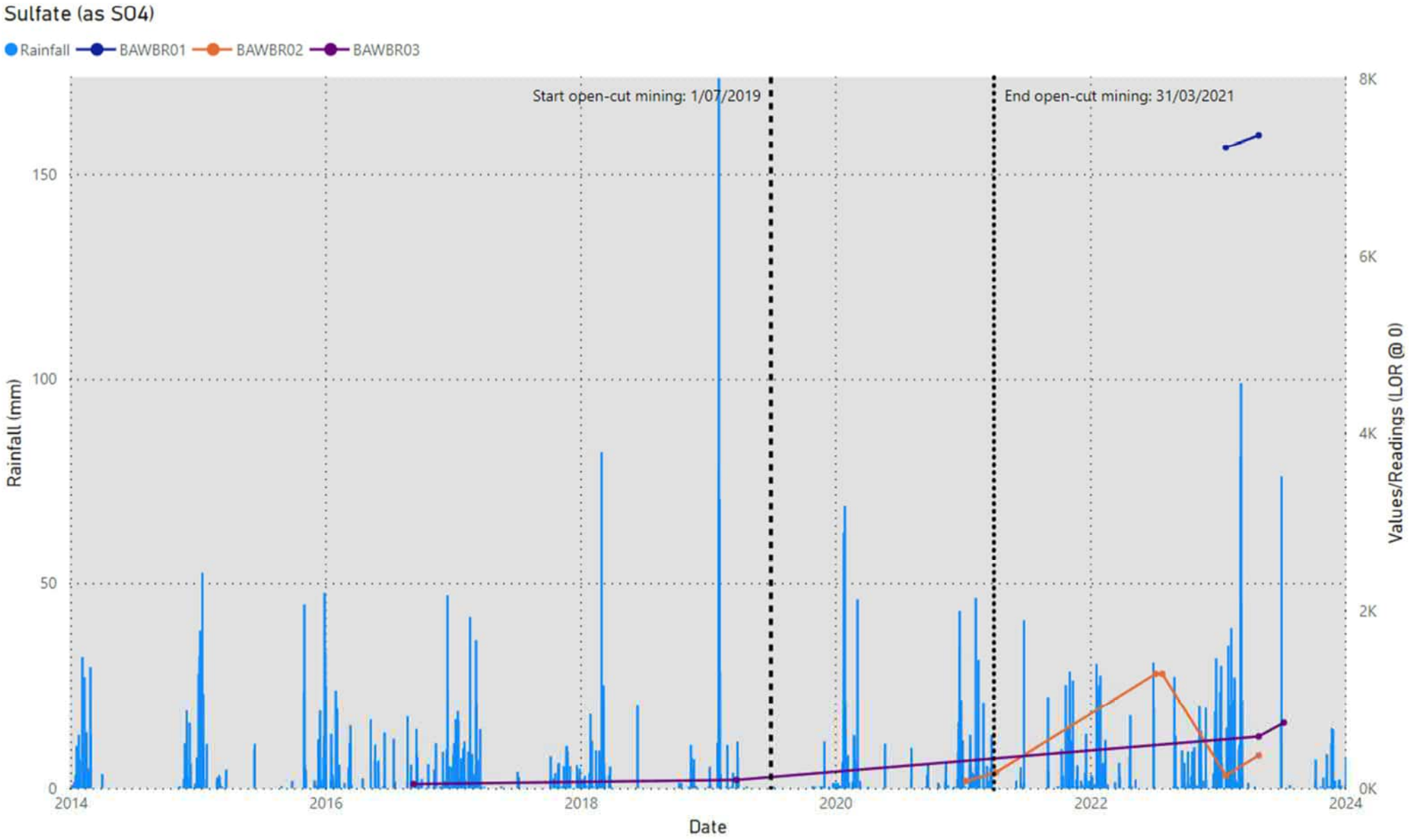

Chloride (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
Values/Readings (LOR @ 0)
5K
4K
3K
2K
1K
0K
2014
2016
2018
2020
2022
2024
Date

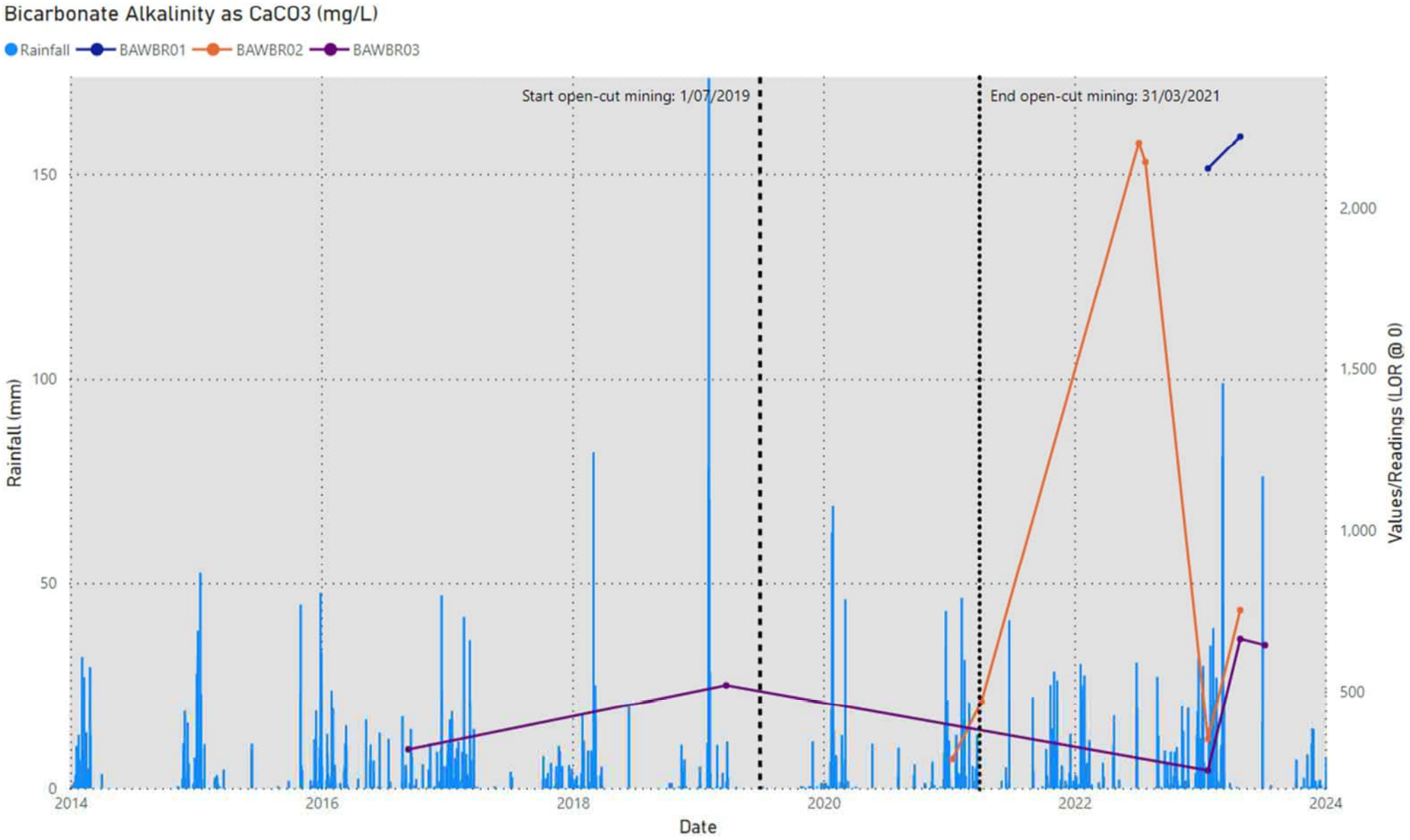

Fluoride (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.5
1.0
1.5
2.0
2014
2016
2018
2020
2022
2024

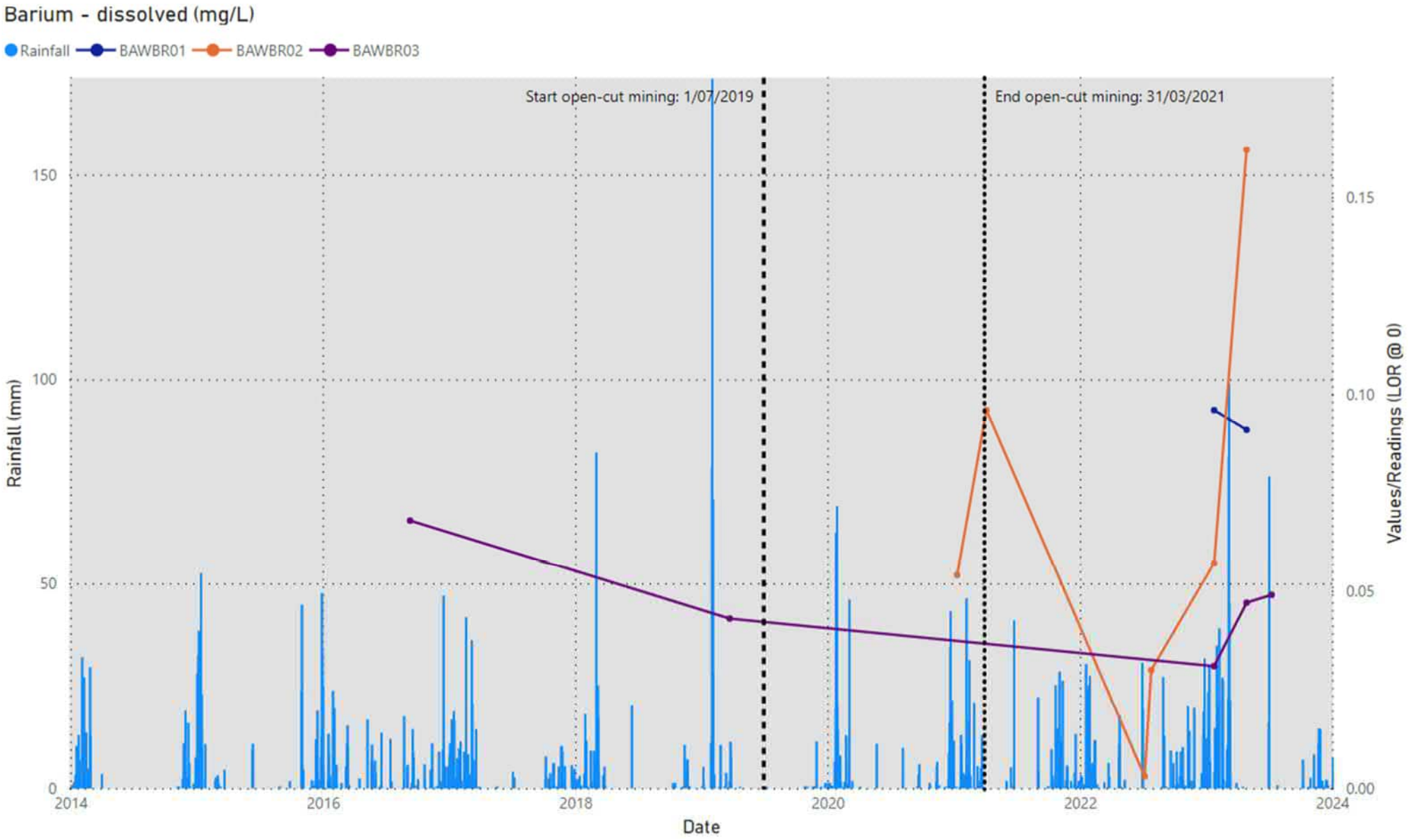

Magnesium (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
50
100
150
200
250
300
2014
2016
2018
2020
2022
2024

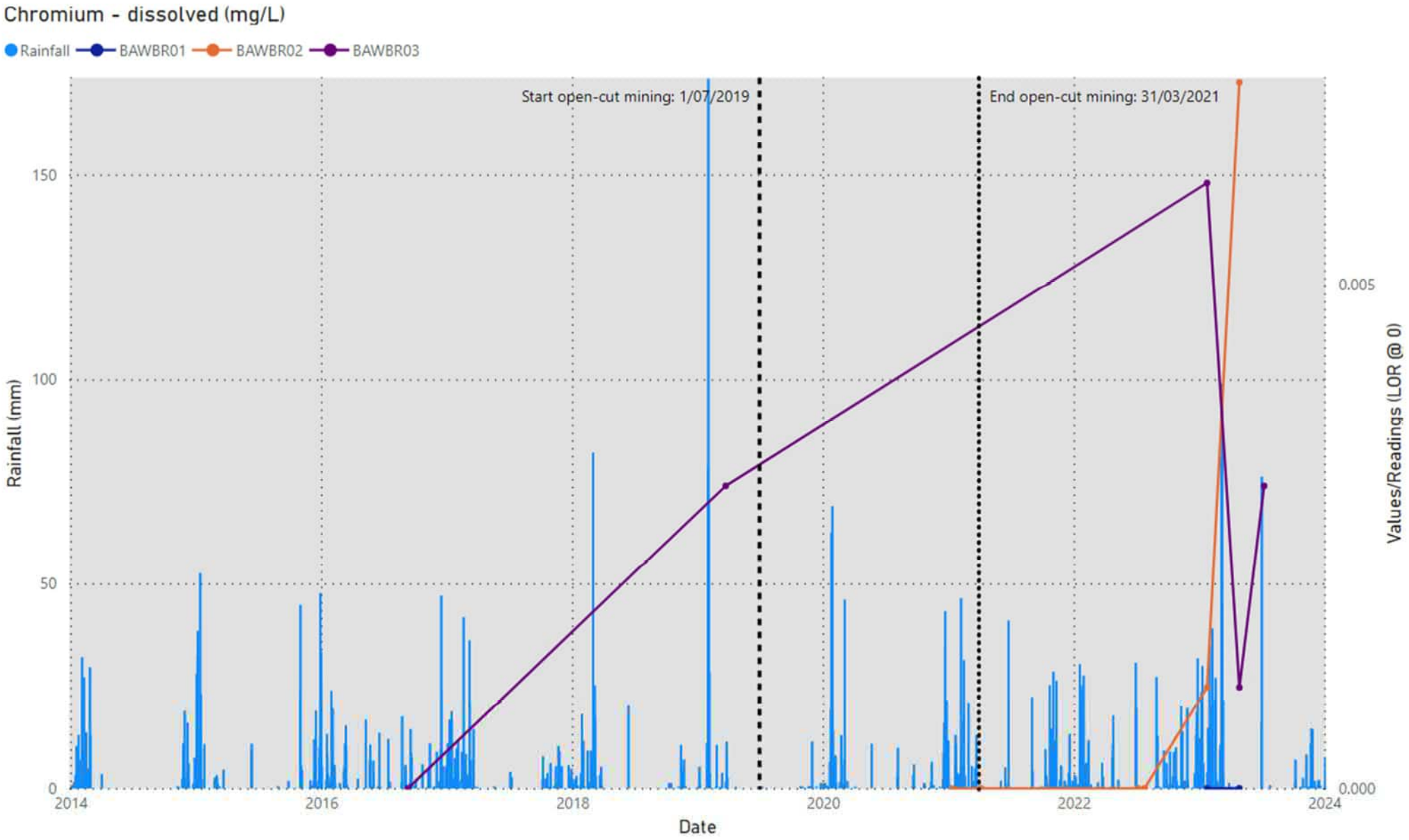

Potassium (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
10
20
30
40
2014
2016
2018
2020
2022
2024

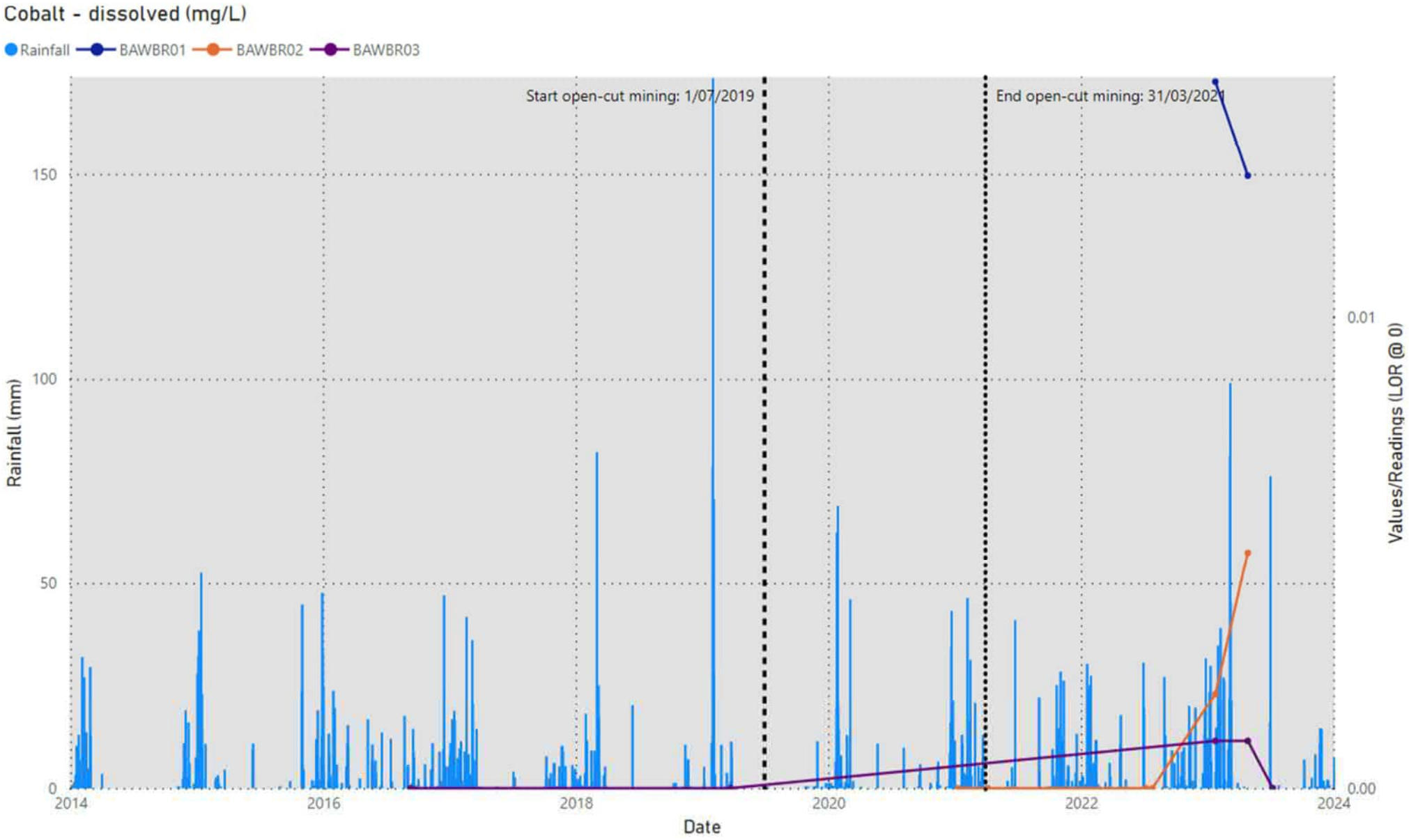

Sodium (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0K
2K
4K
6K
8K
2014
2016
2018
2020
2022
2024

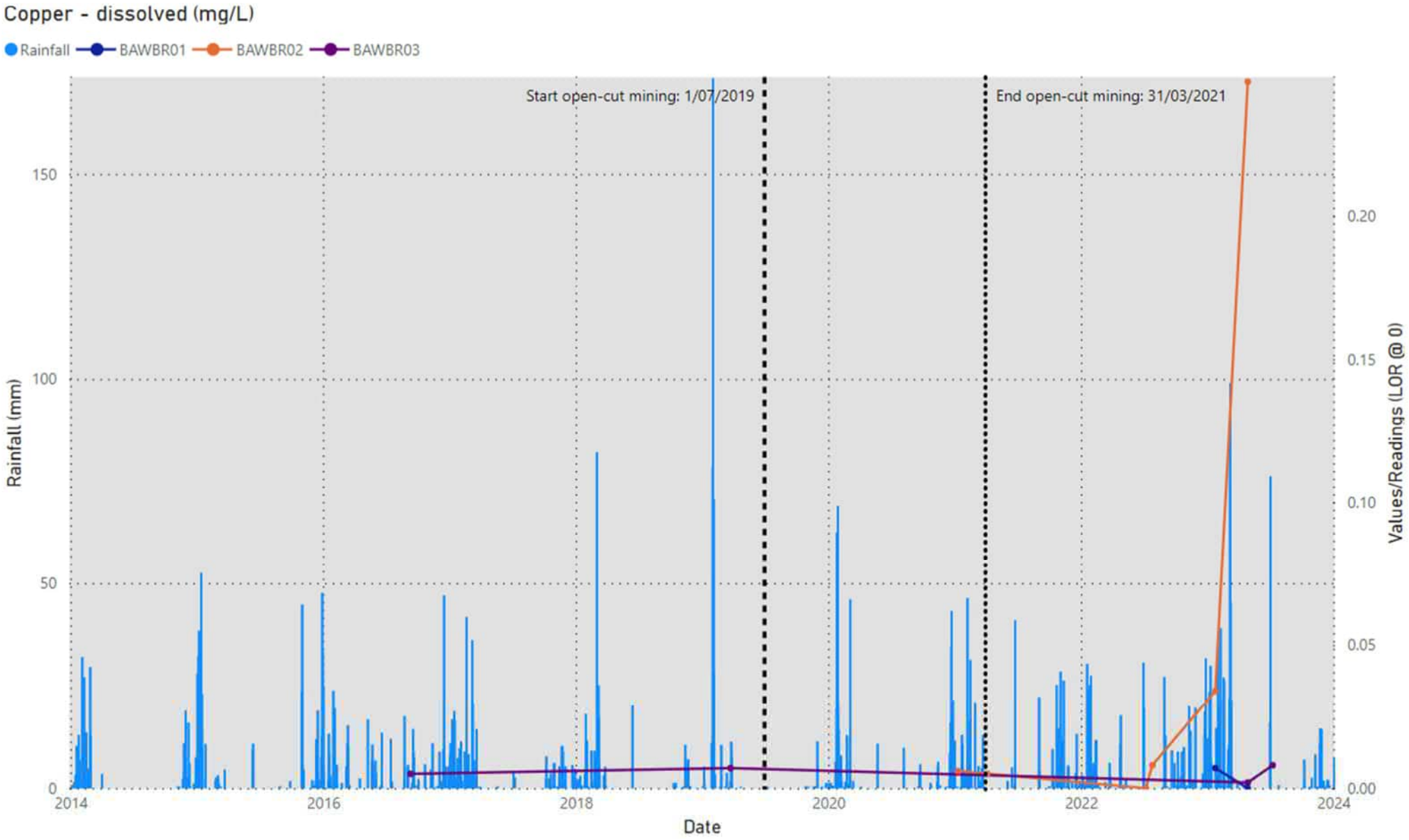

Sulfate (as SO4)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0K
2K
4K
6K
8K
2014
2016
2018
2020
2022
2024

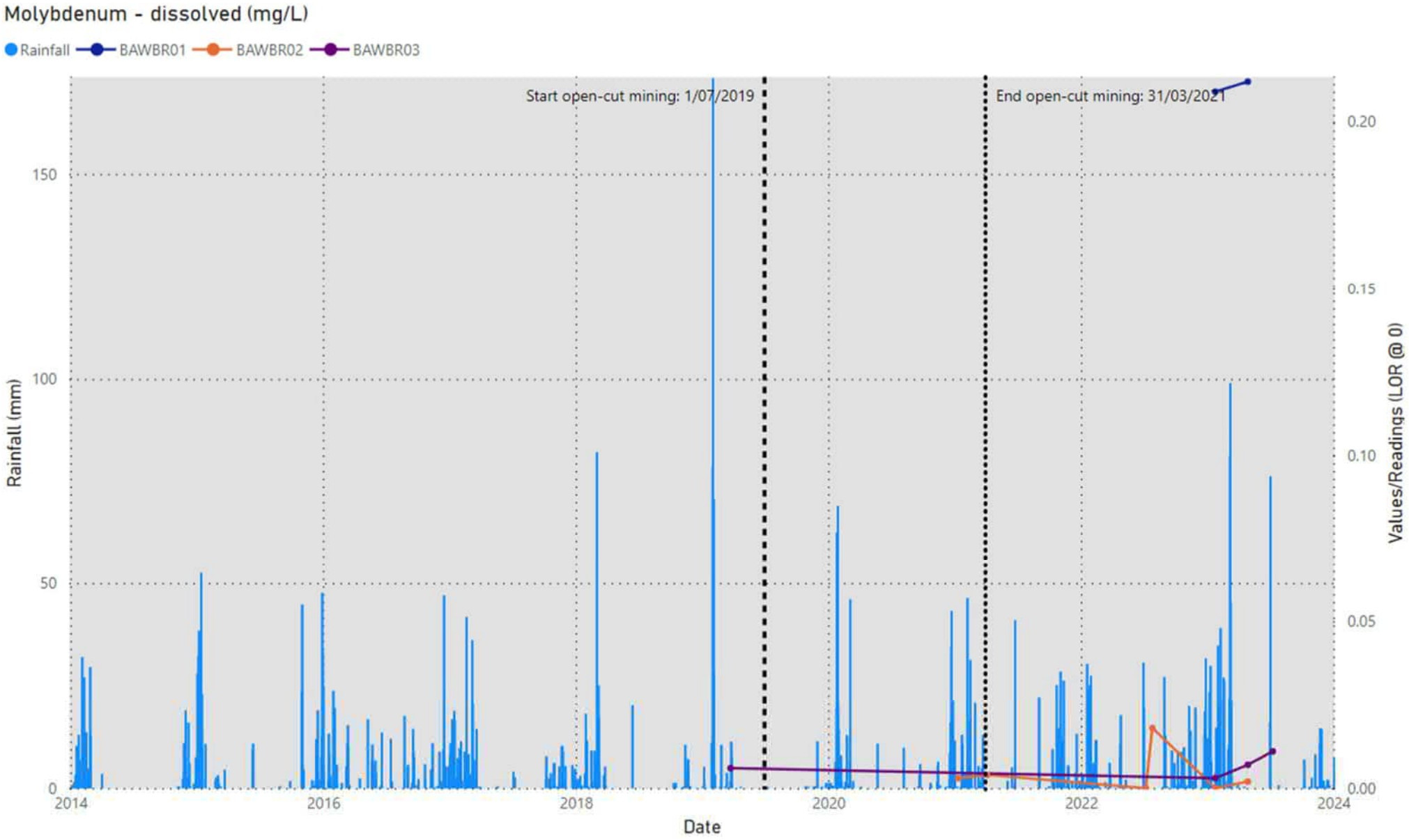

Bicarbonate Alkalinity as CaCO3 (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
500
1,000
1,500
2,000
2014
2016
2018
2020
2022
2024

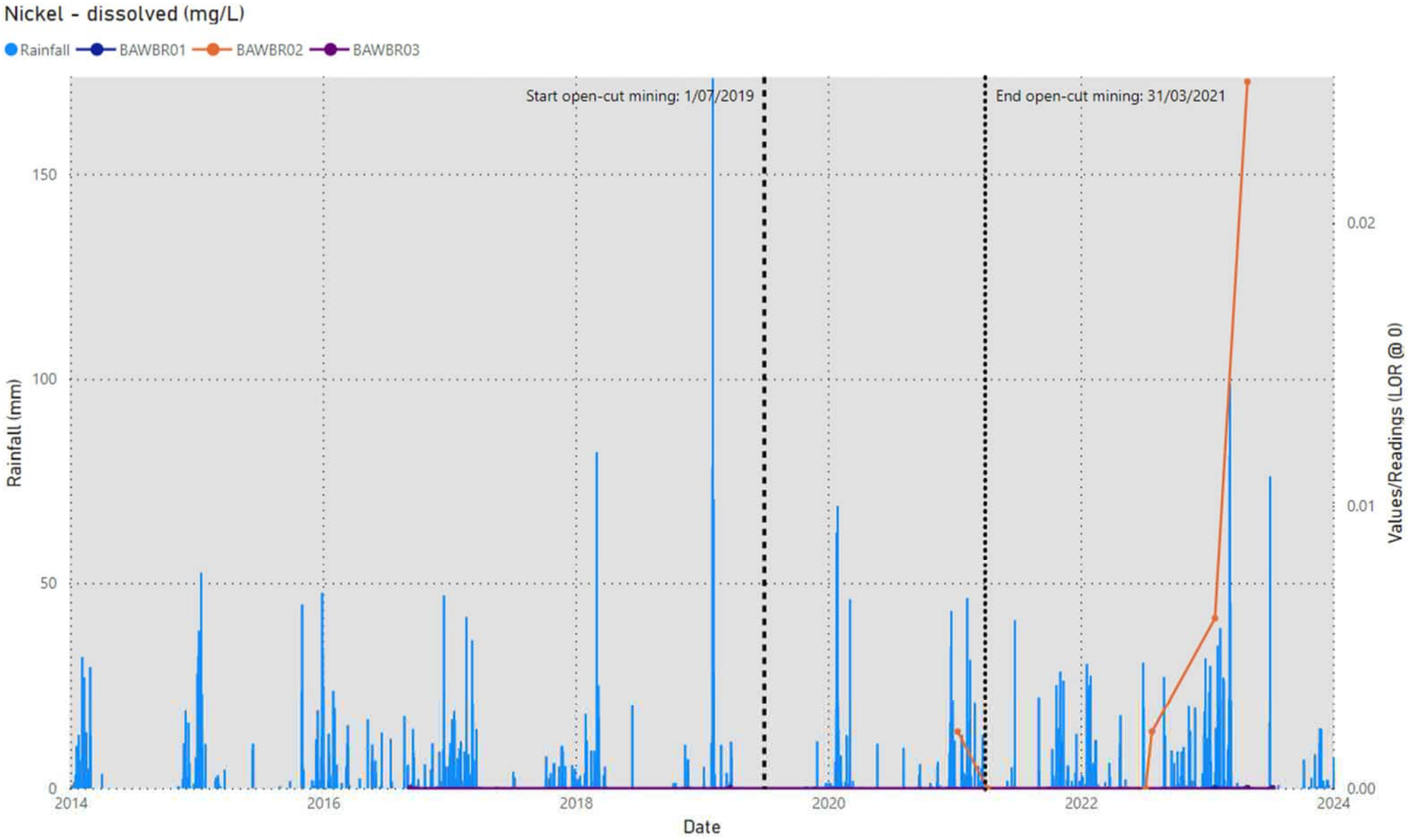

Barium - dissolved (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.05
0.10
0.15
2014
2016
2018
2020
2022
2024

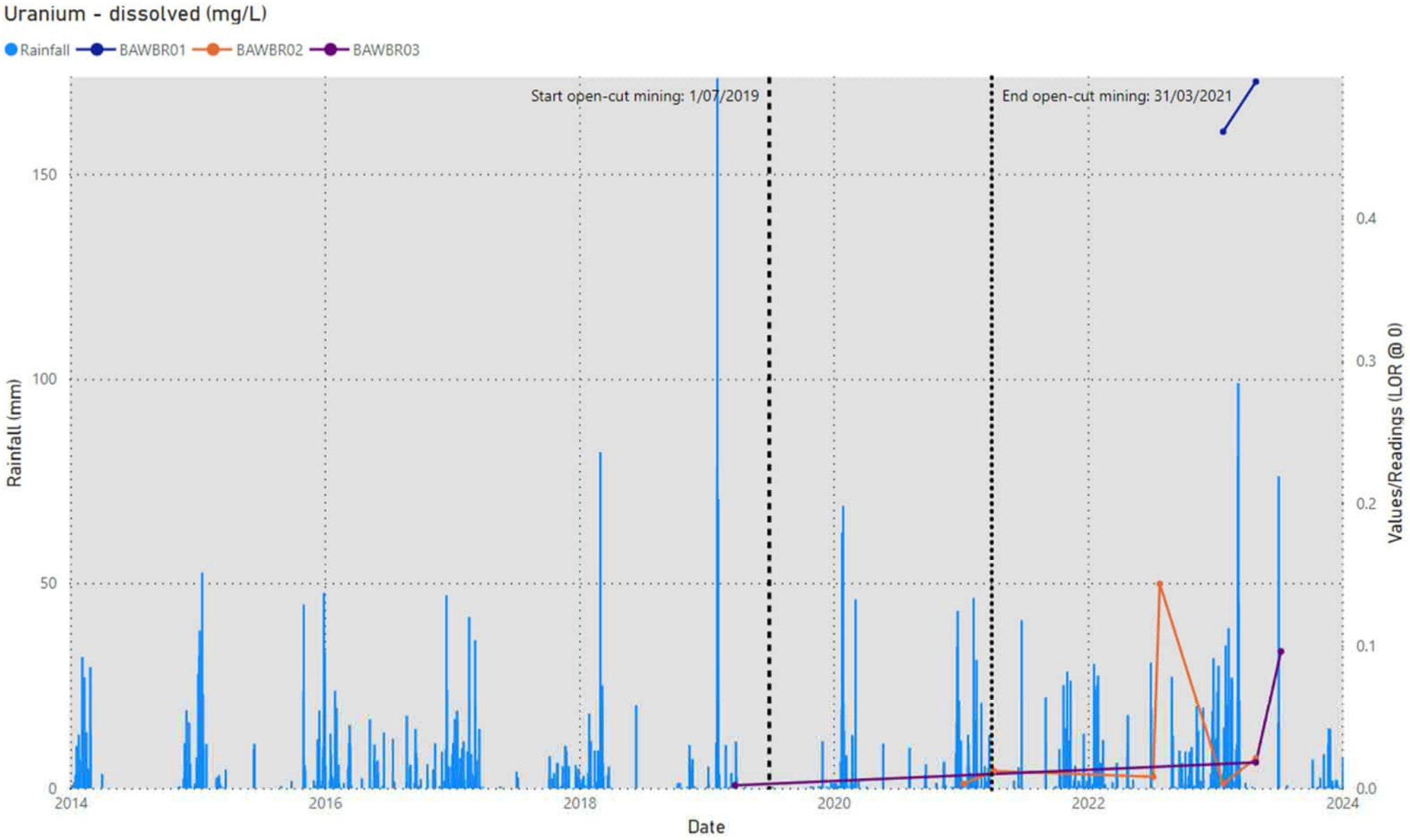

Chromium - dissolved (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.000
0.005
2014
2016
2018
2020
2022
2024

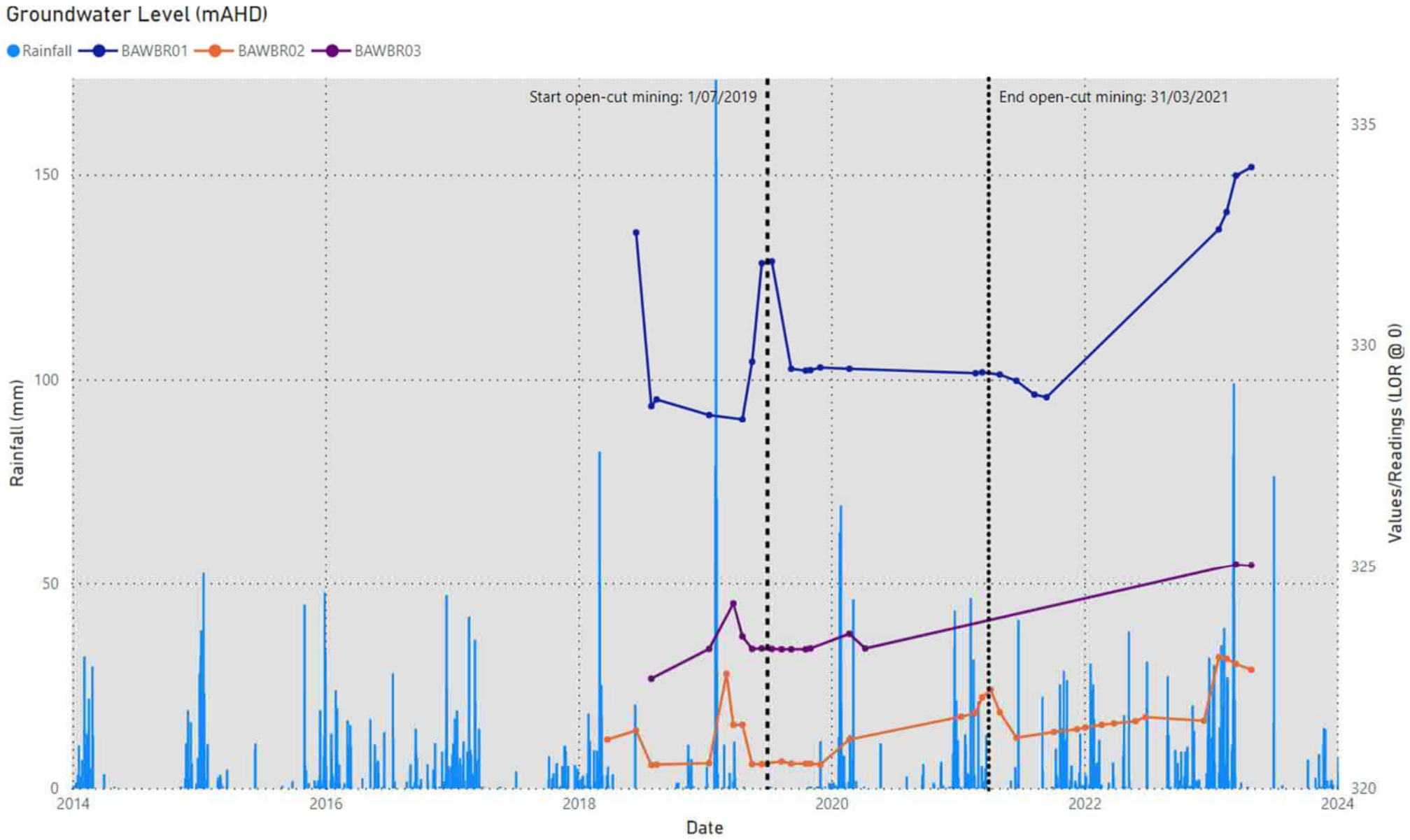

Cobalt - dissolved (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
0.01
0.00
Values/Readings (LOR @ 0)
2014
2016
2018
2020
2022
2024
Date


Copper - dissolved (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.05
0.10
0.15
0.20
2014
2016
2018
2020
2022
2024


Molybdenum - dissolved (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.05
0.10
0.15
0.20
2014
2016
2018
2020
2022
2024

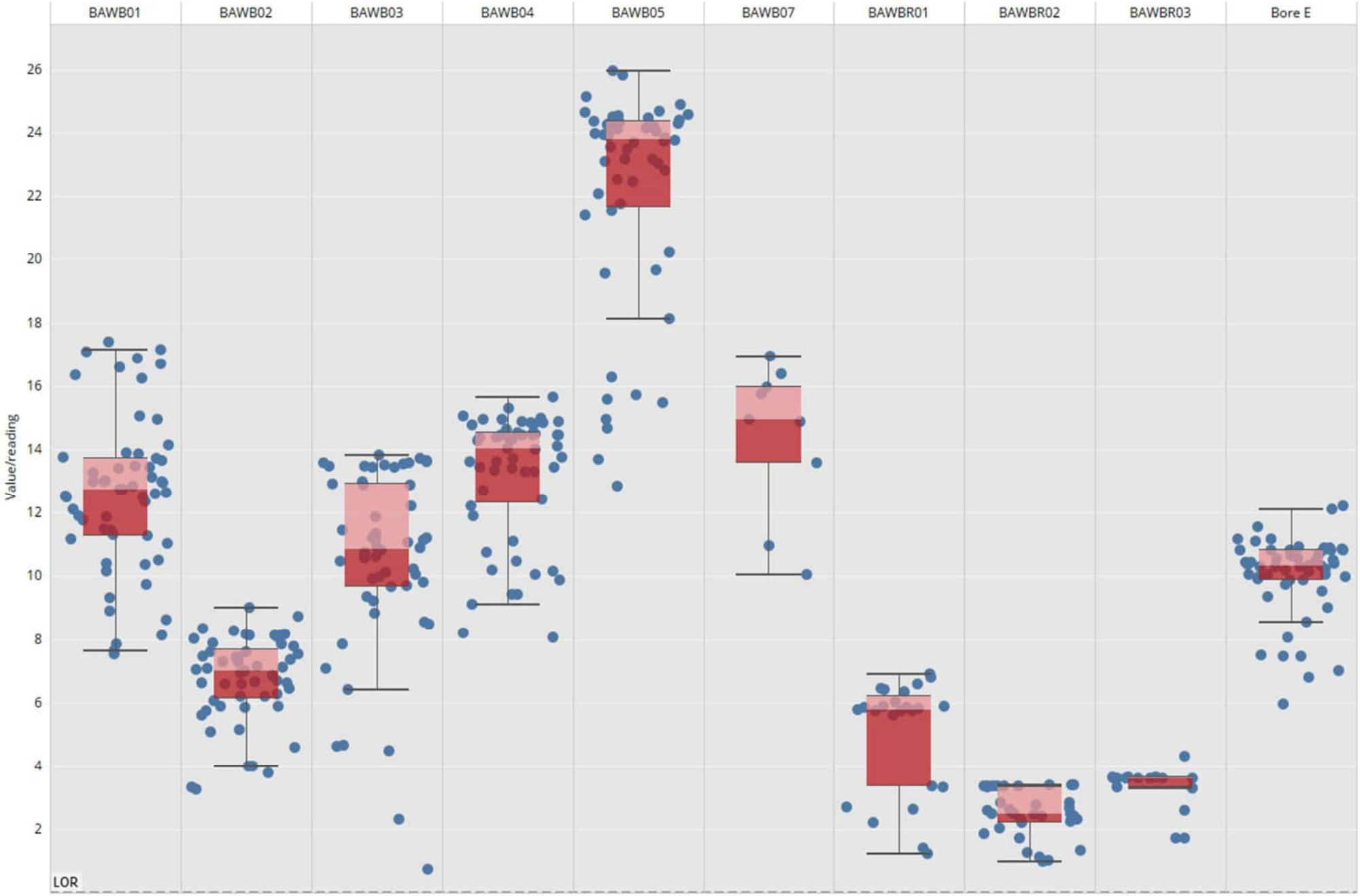

Nickel - dissolved (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.01
0.02
2014
2016
2018
2020
2022
2024


Uranium - dissolved (mg/L)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.0
0.1
0.2
0.3
0.4
2014
2016
2018
2020
2022
2024

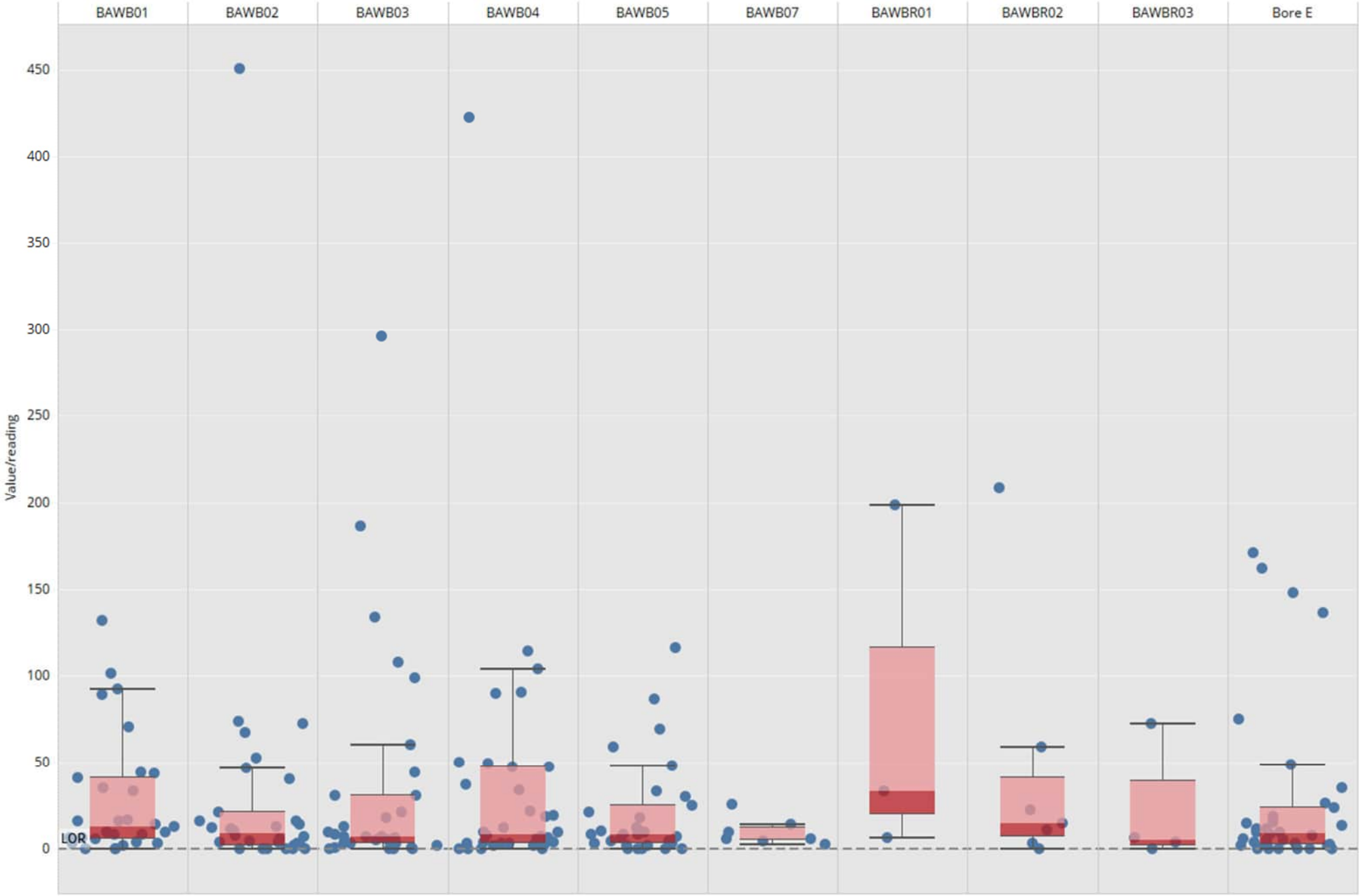

Groundwater Level (mAHD)
Rainfall
BAWBR01
BAWBR02
BAWBR03
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
320
325
330
335
2014
2016
2018
2020
2022
2024

G.3 Water quality box & whisker plots

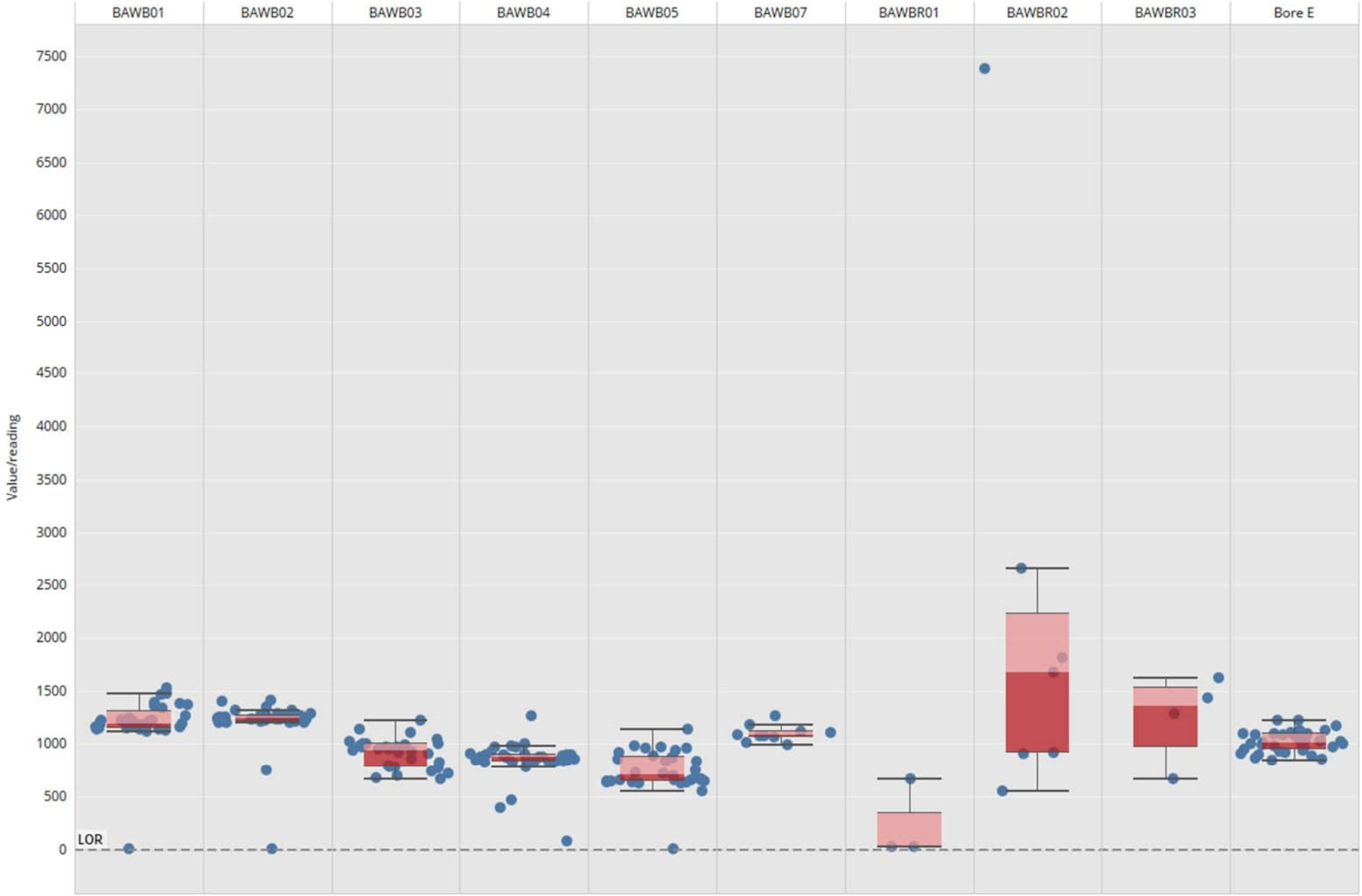
Depth to Water (mbRL)



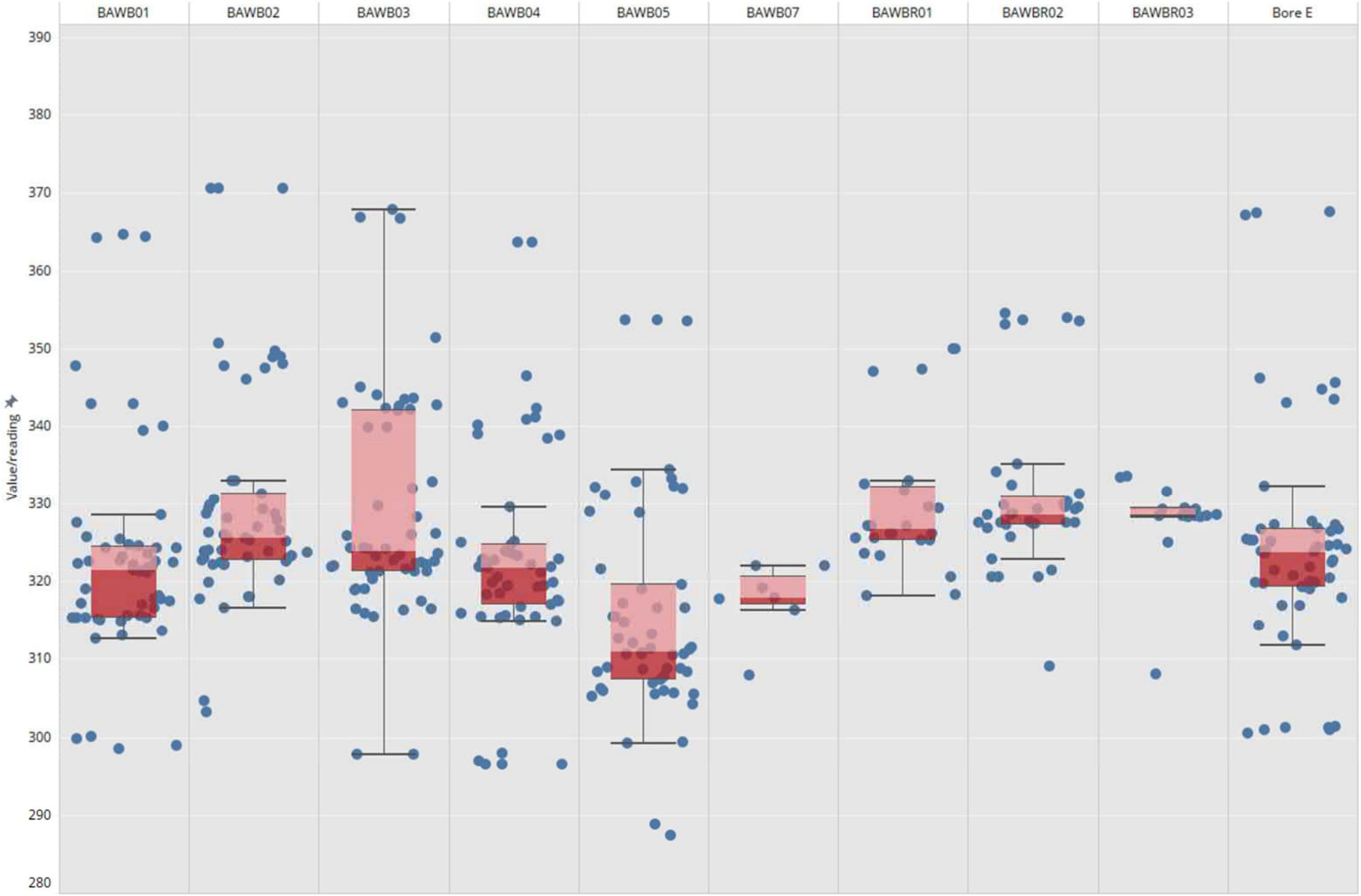
Dissolved Oxygen (field) (% sat)



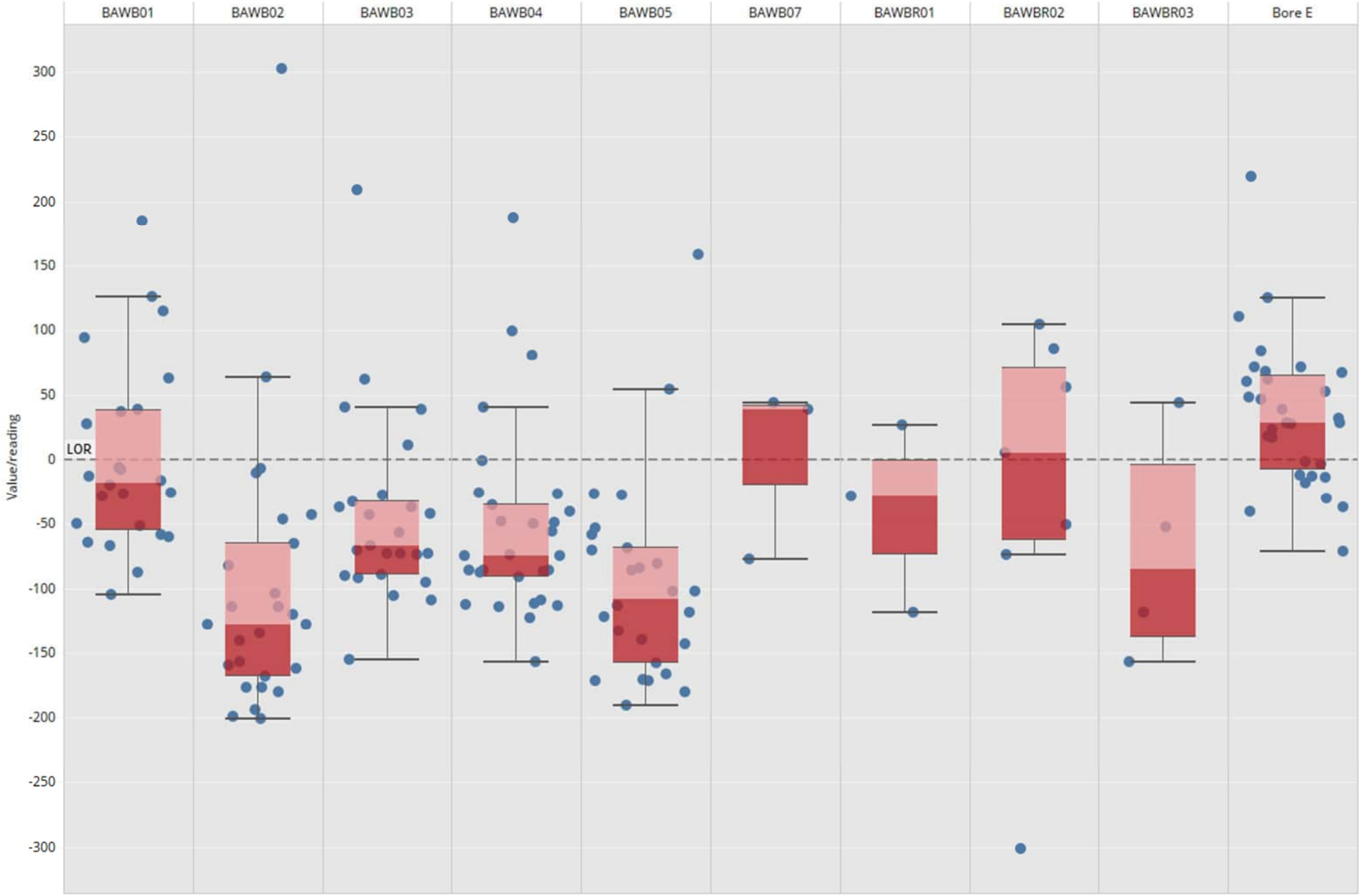
Electrical Conductivity (field) (µS/cm)



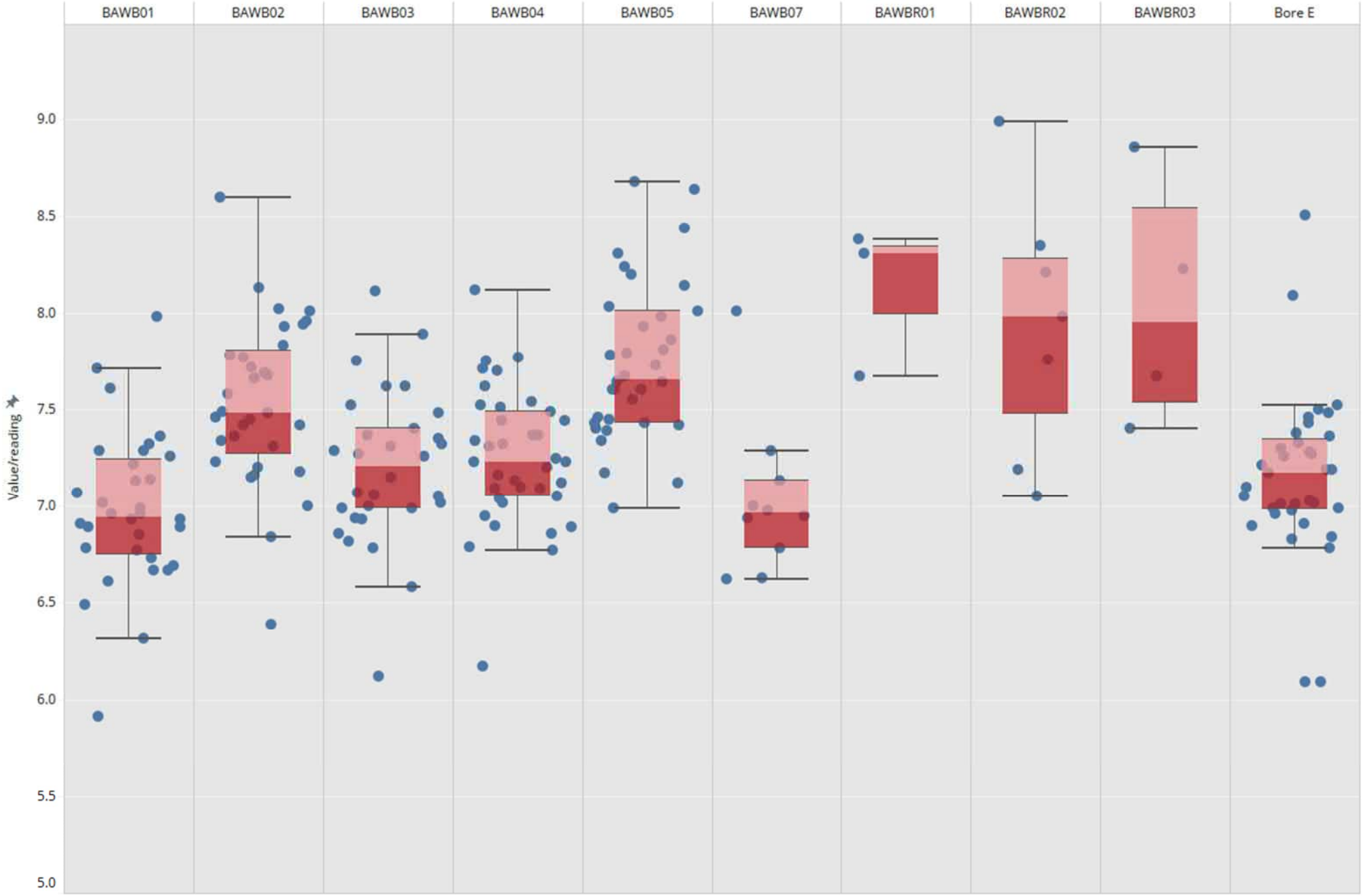
Groundwater Level (mAHD)



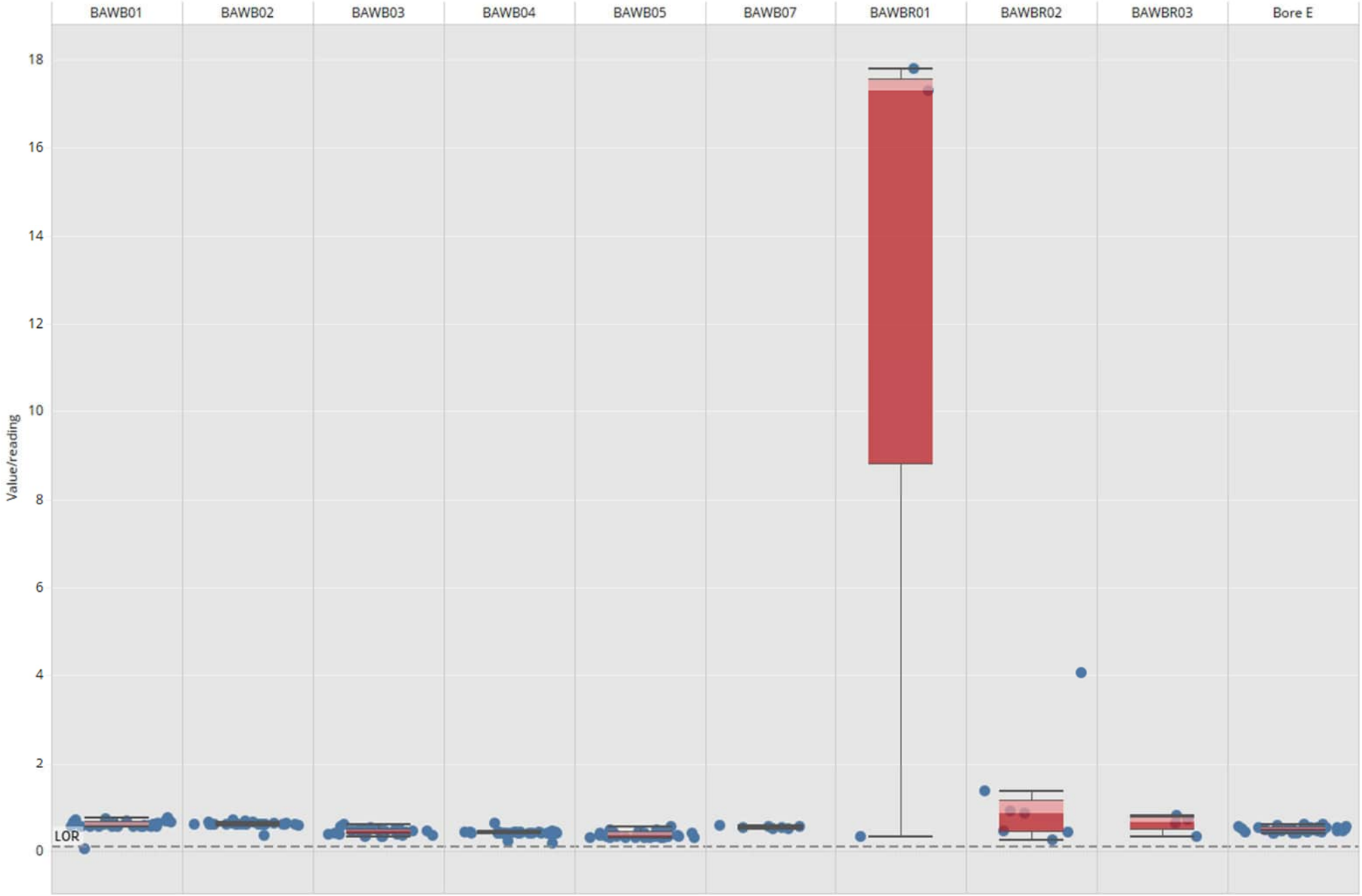
ORP (field) (mV)


BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
BAWBR01
BAWBR02
BAWBR03
Bore E
Value/reading
LOR
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300

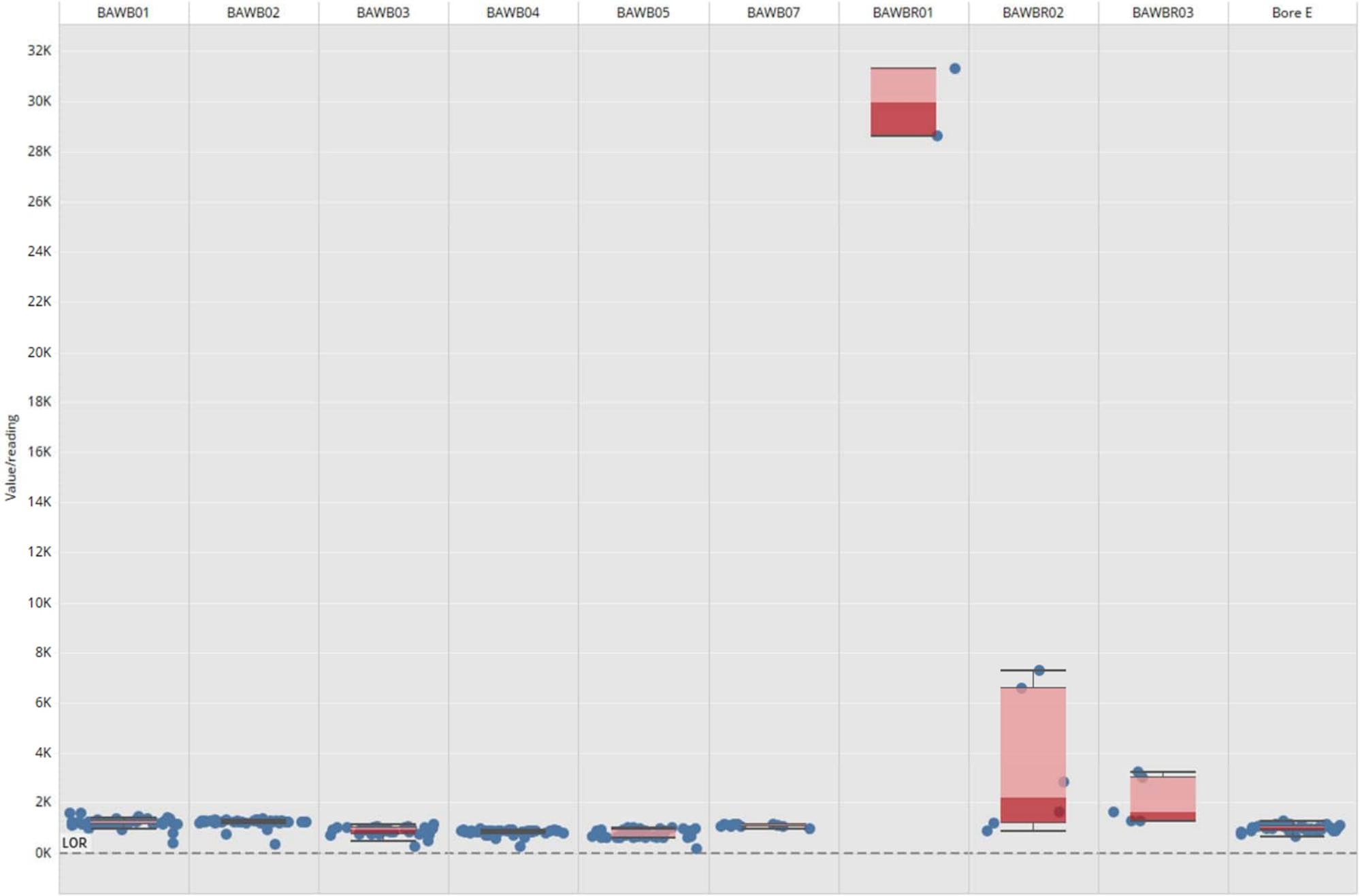
pH (field)


BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
BAWBR01
BAWBR02
BAWBR03
Bore E
Value/reading
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0

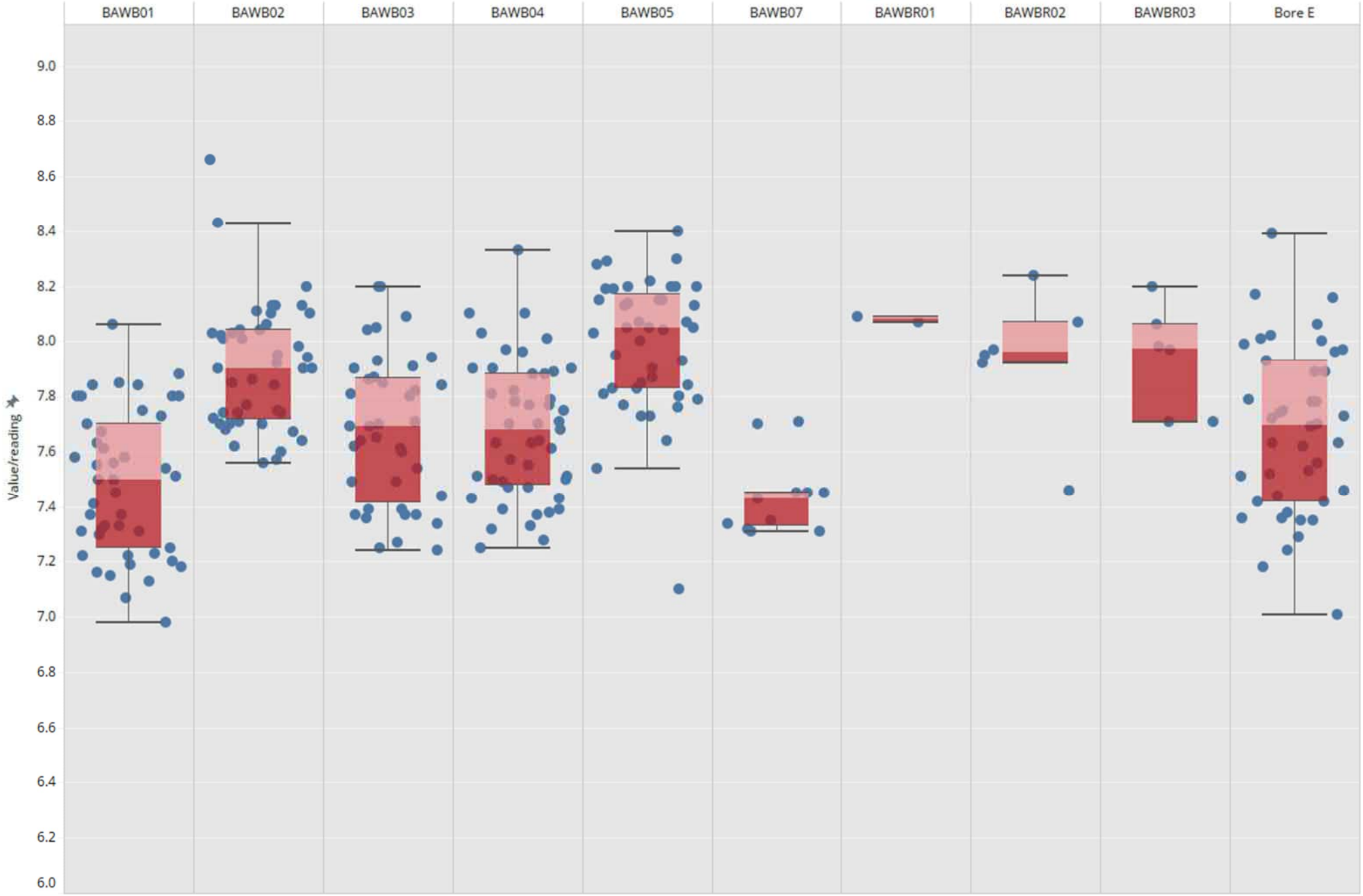
Salinity (field) (PSU)



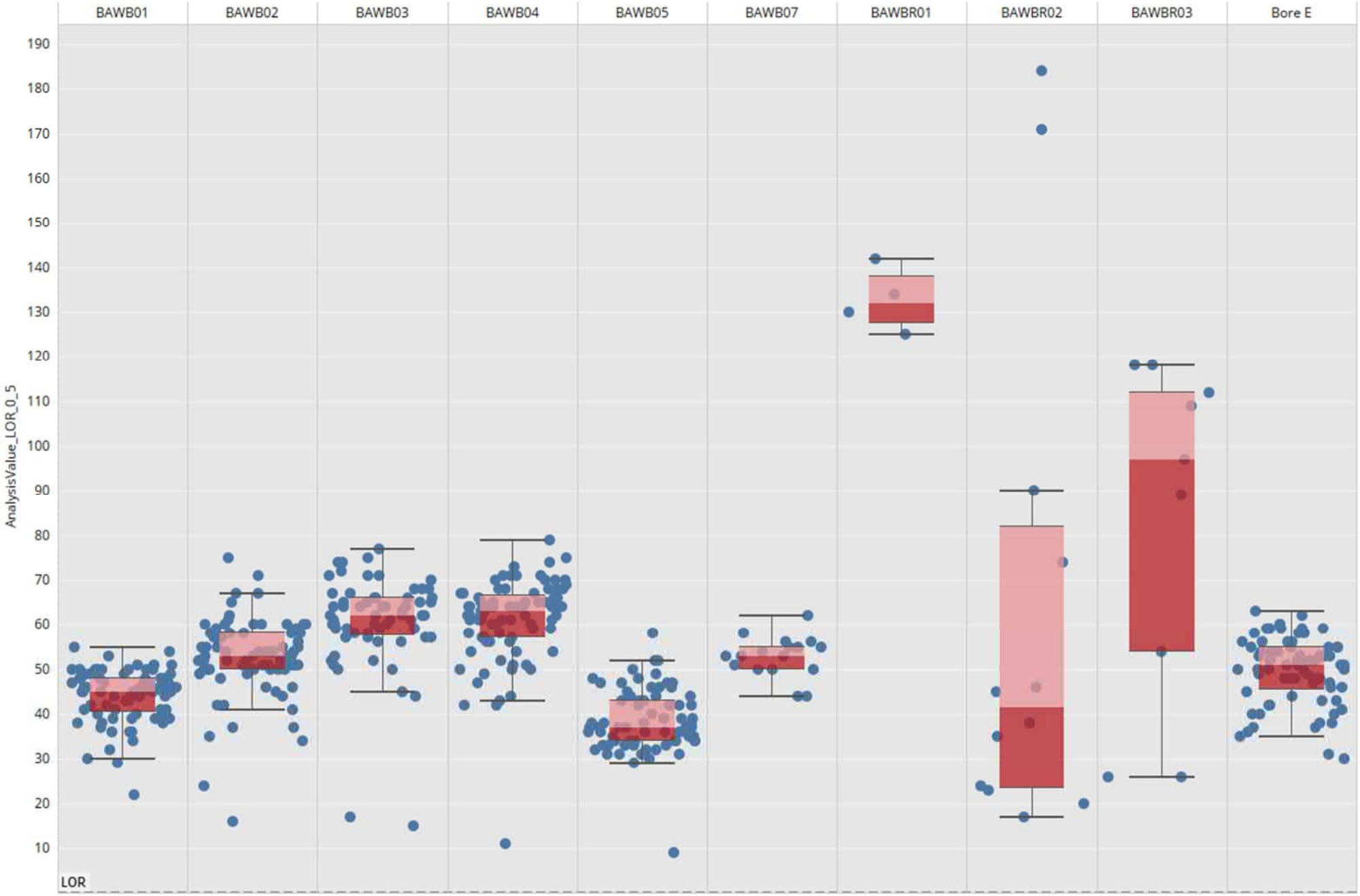
Electrical Conductivity (µS/cm)



pH (lab)

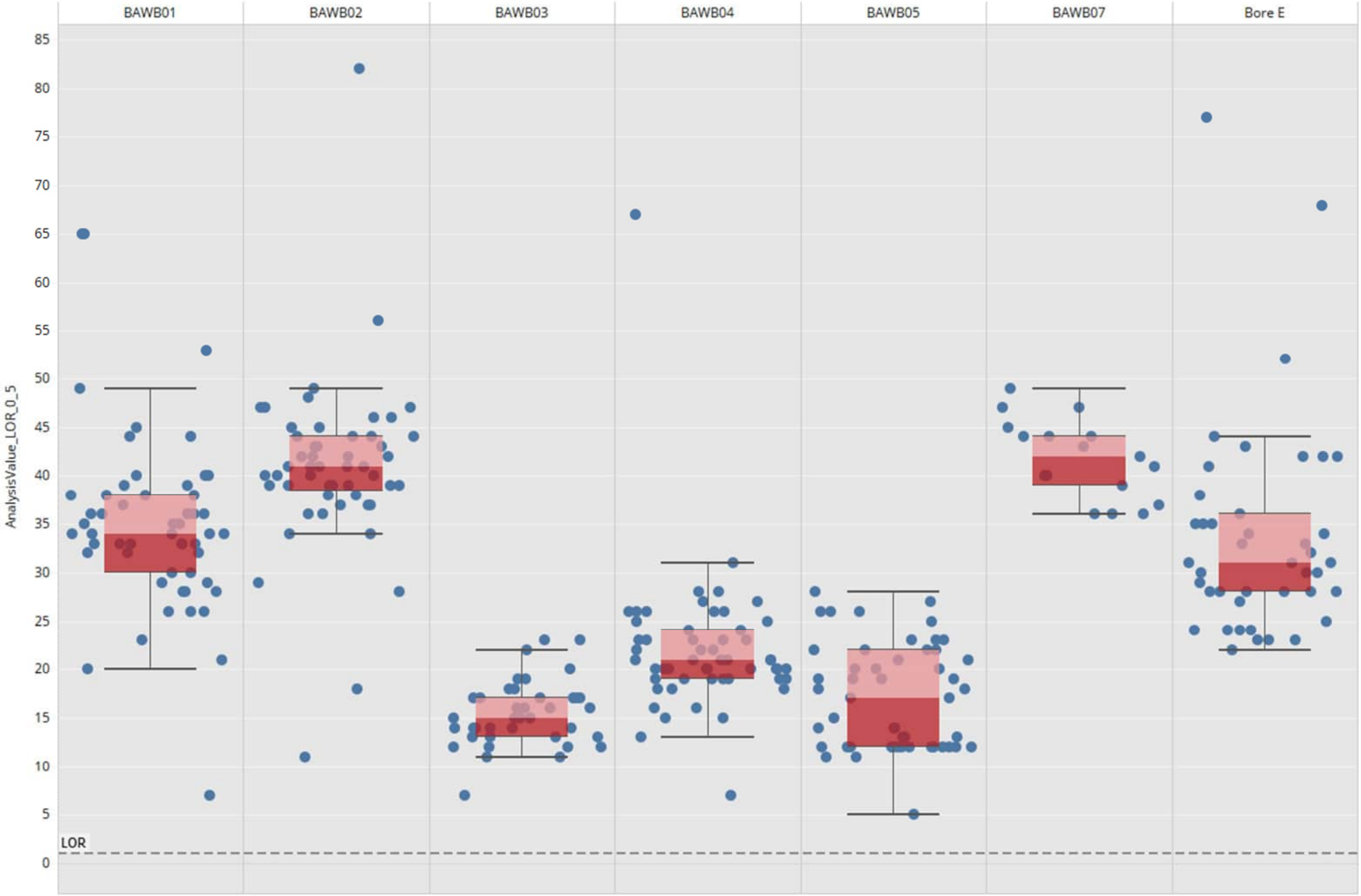

BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
BAWBR01
BAWBR02
BAWBR03
Bore E
Value/reading
9.0
8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
6.2
6.0

Calcium (mg/L)

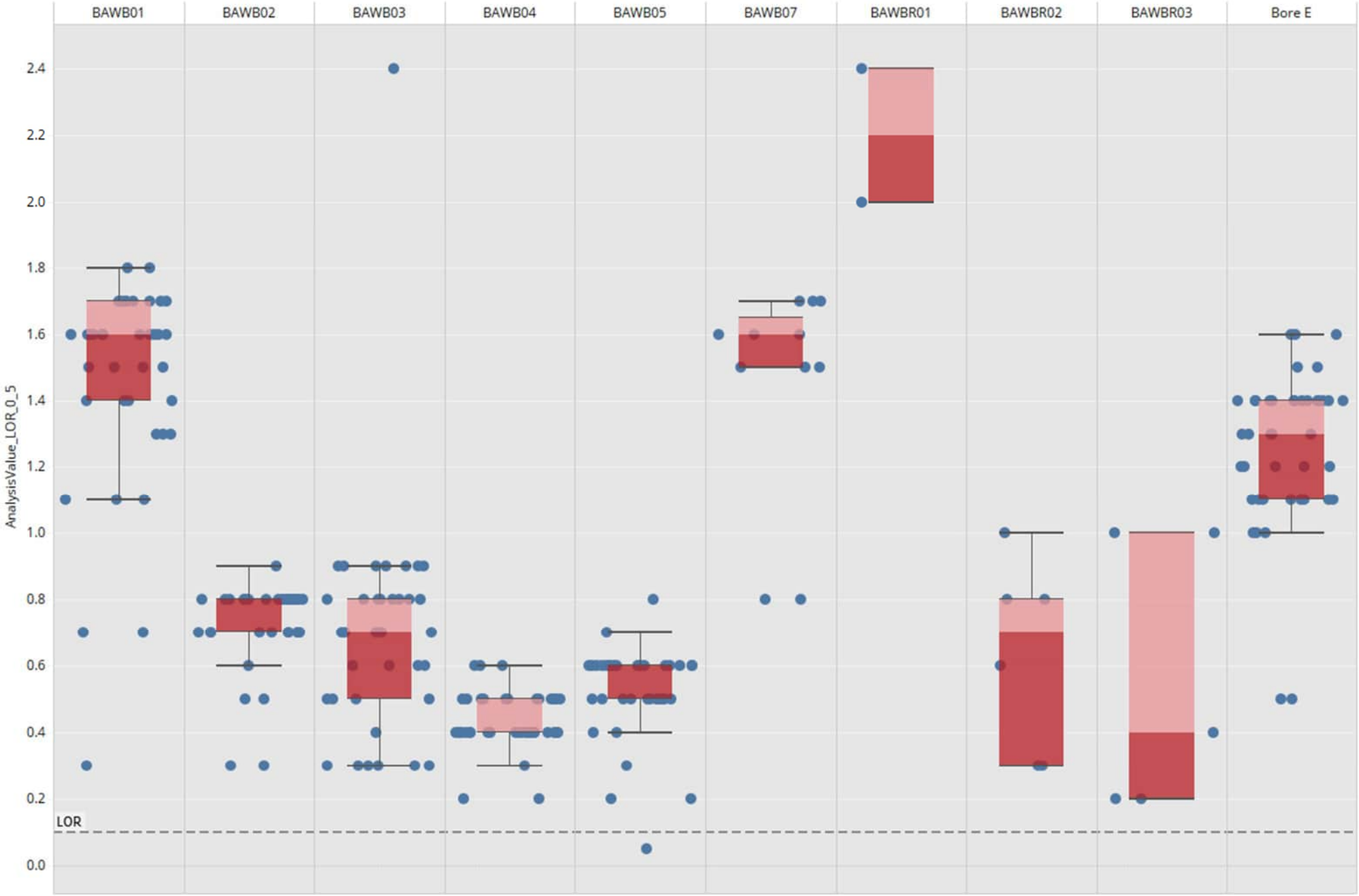

BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
BAWBR01
BAWBR02
BAWBR03
Bore E
AnalysisValue_LOR_0_5
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
LOR

Chloride (mg/L)

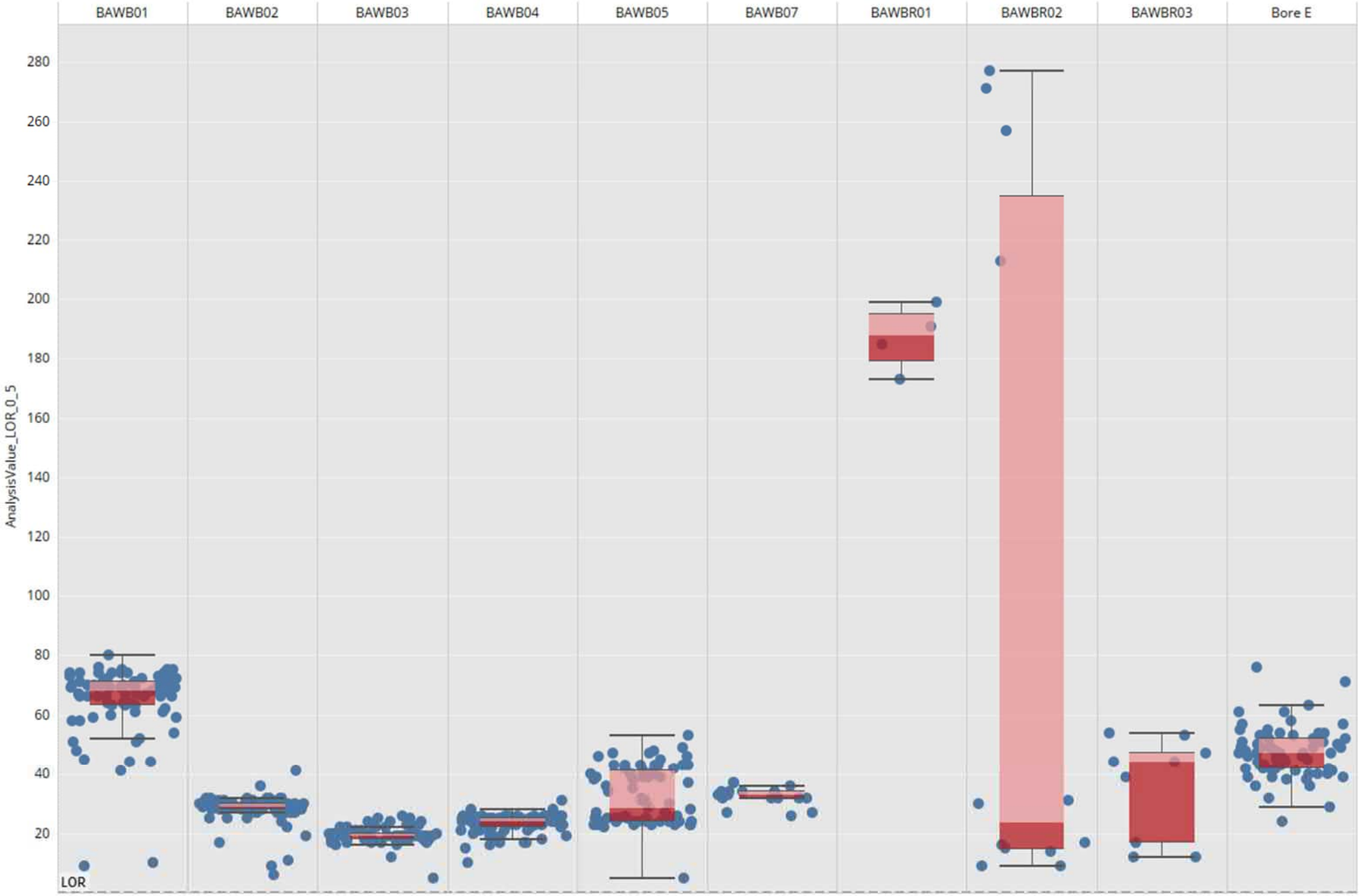
Chloride (mg/L)



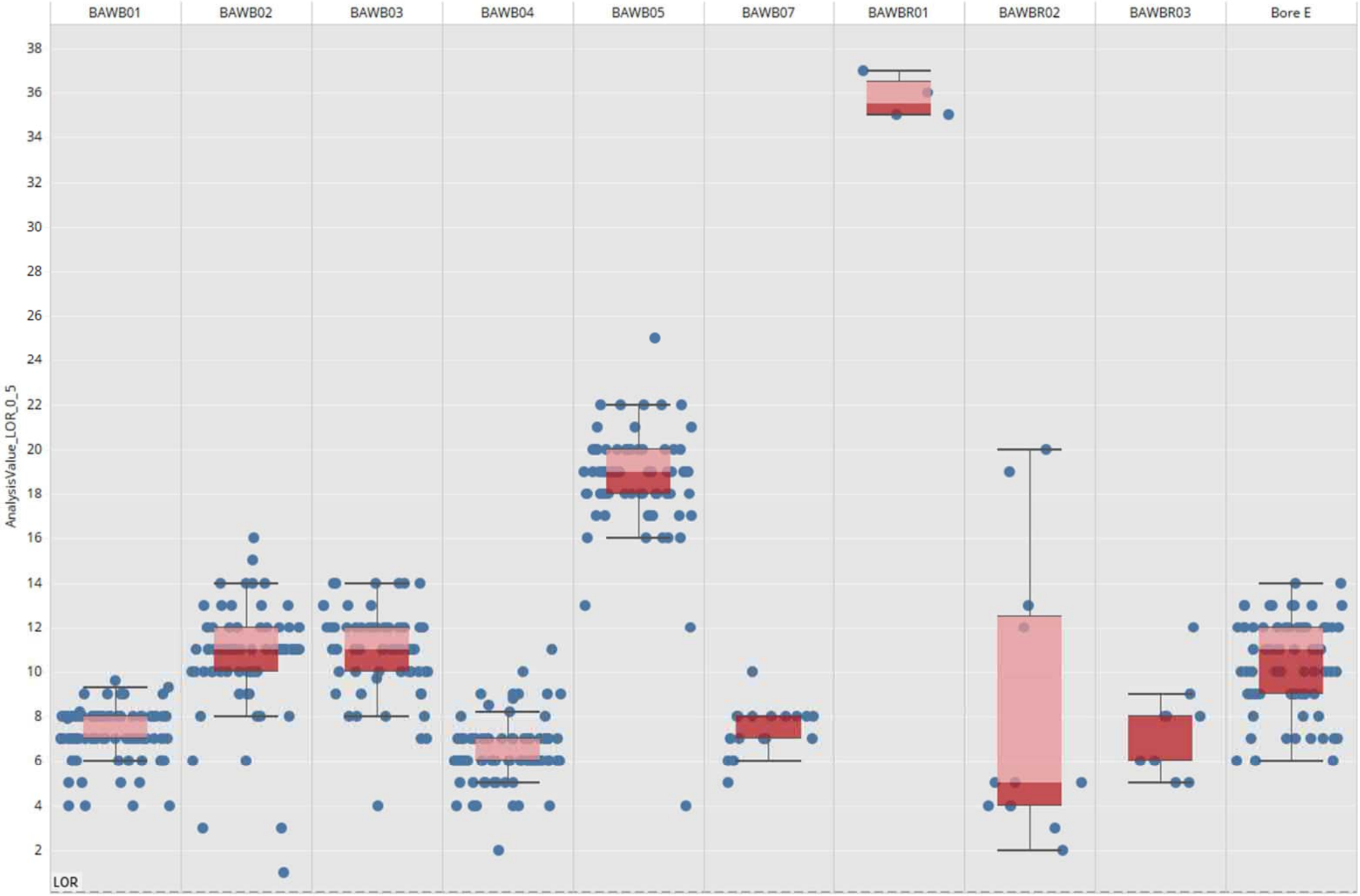
Fluoride (mg/L)



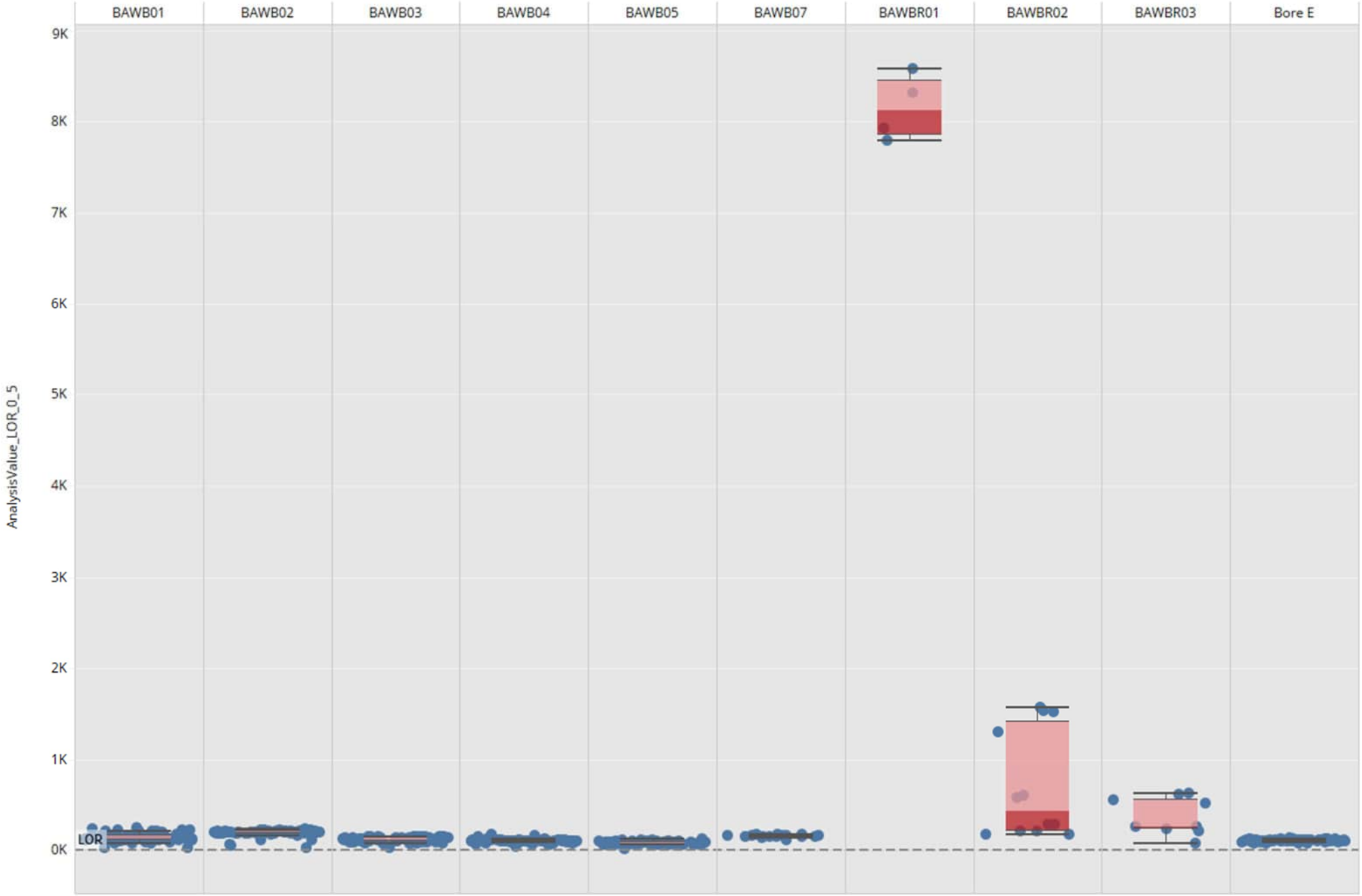
Magnesium (mg/L)



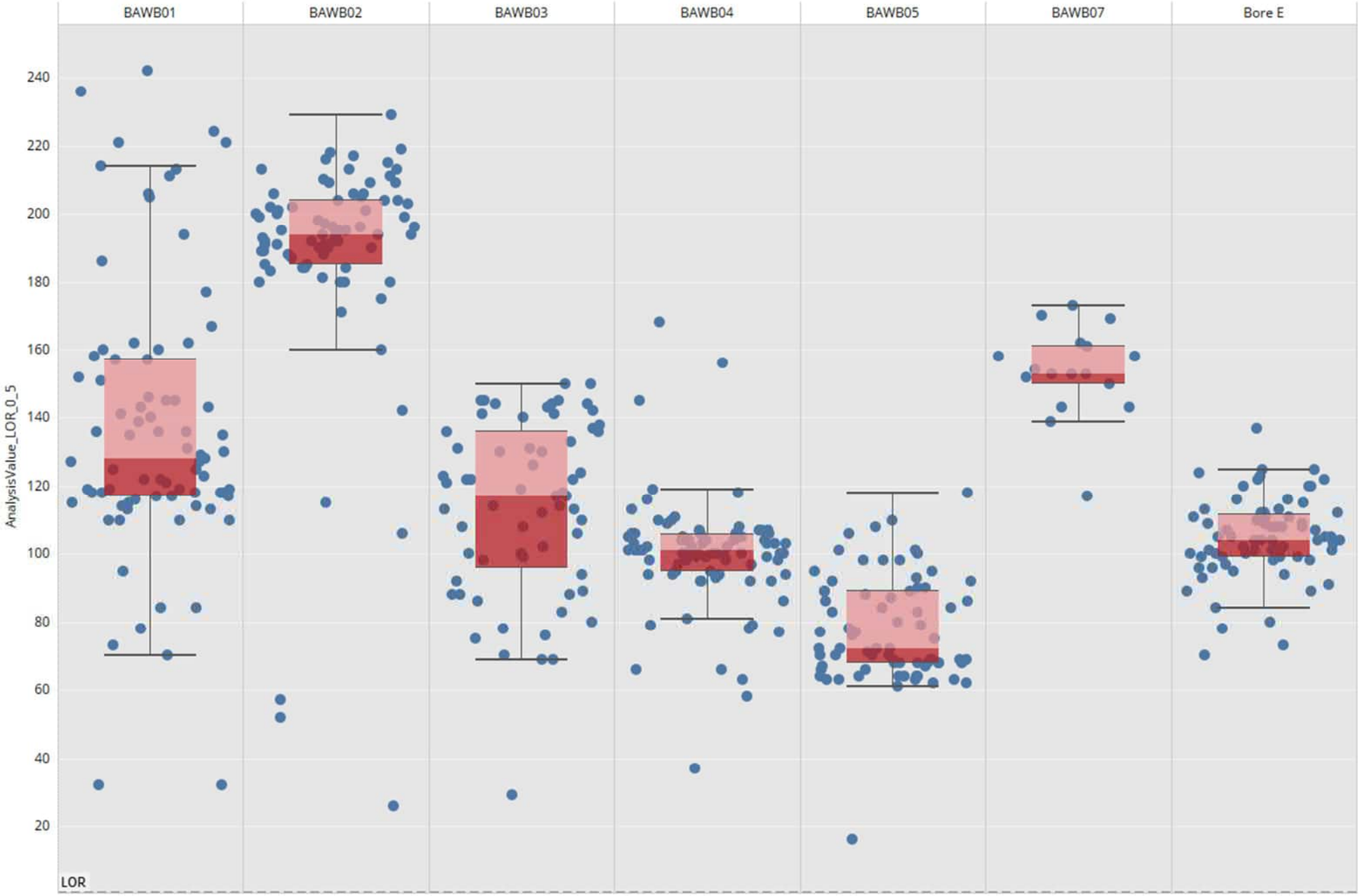
Potassium (mg/L)



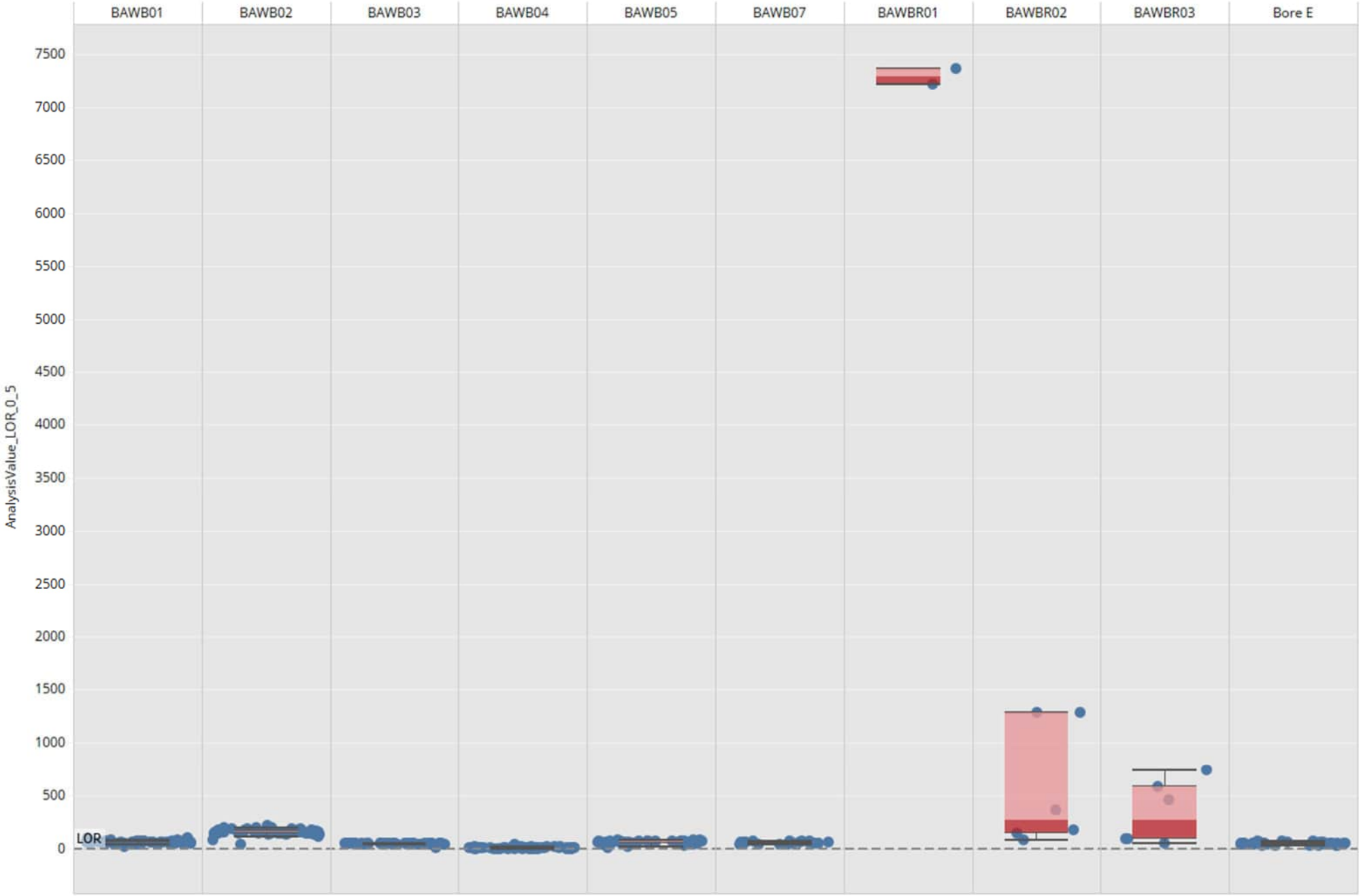
Sodium (mg/L)


BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
BAWBR01
BAWBR02
BAWBR03
Bore E
9K
8K
7K
6K
5K
4K
3K
2K
1K
0K
AnalysisValue_LOR_0_5
LOR

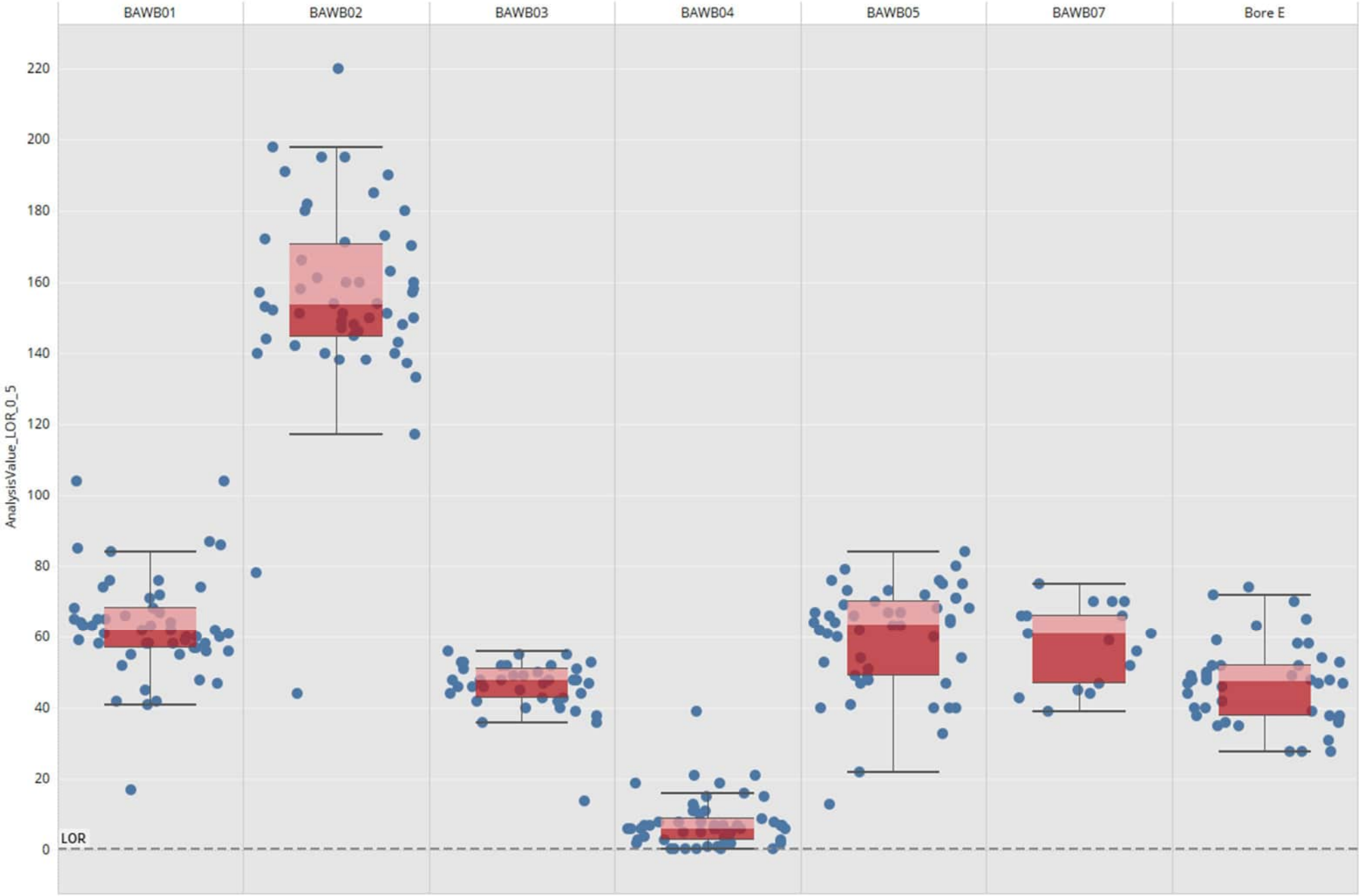
Sodium (mg/L)


BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
Bore E
AnalysisValue_LOR_0_5
240
220
200
180
160
140
120
100
80
60
40
20
LOR

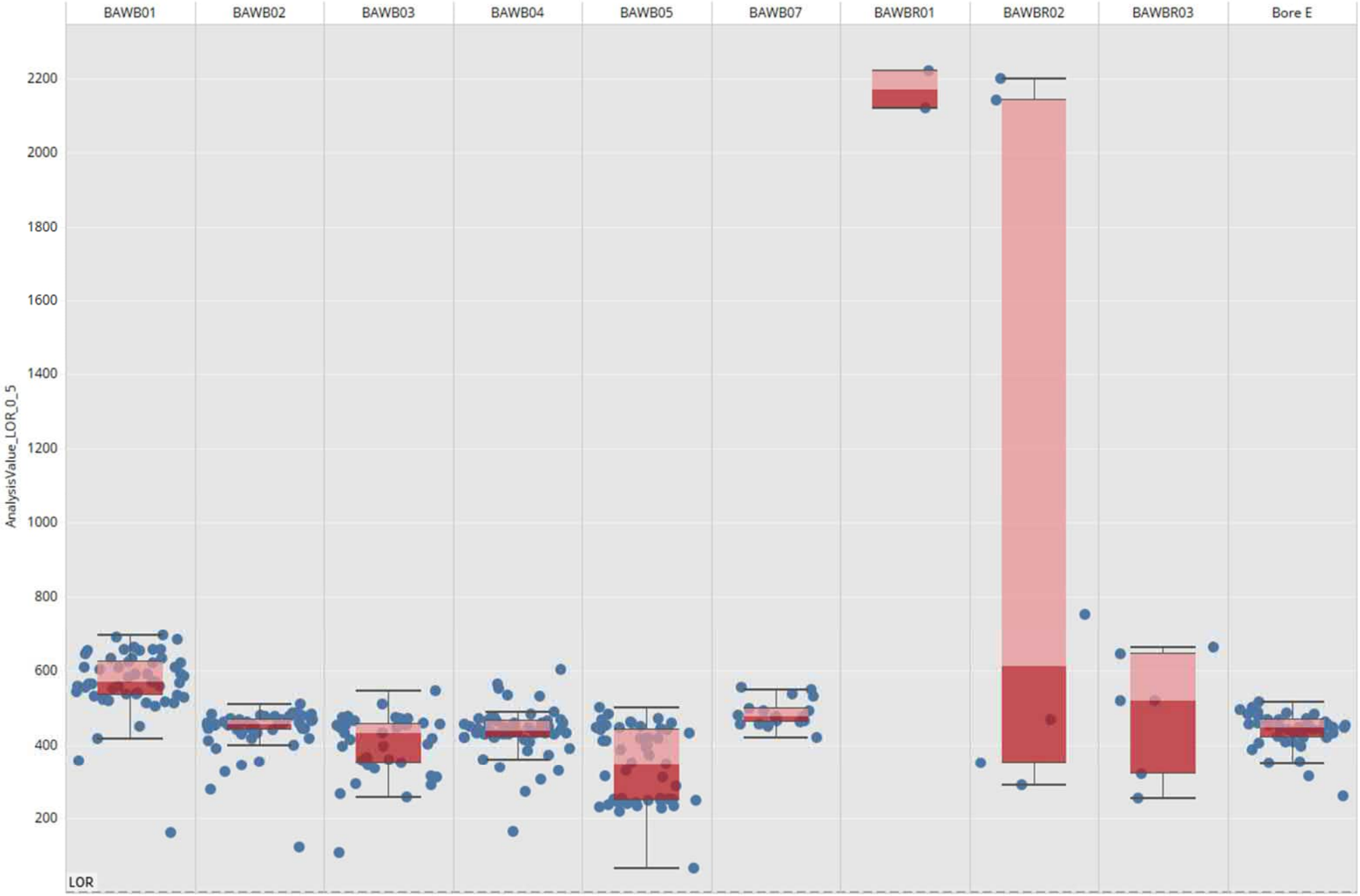
Sulfate (as SO4)



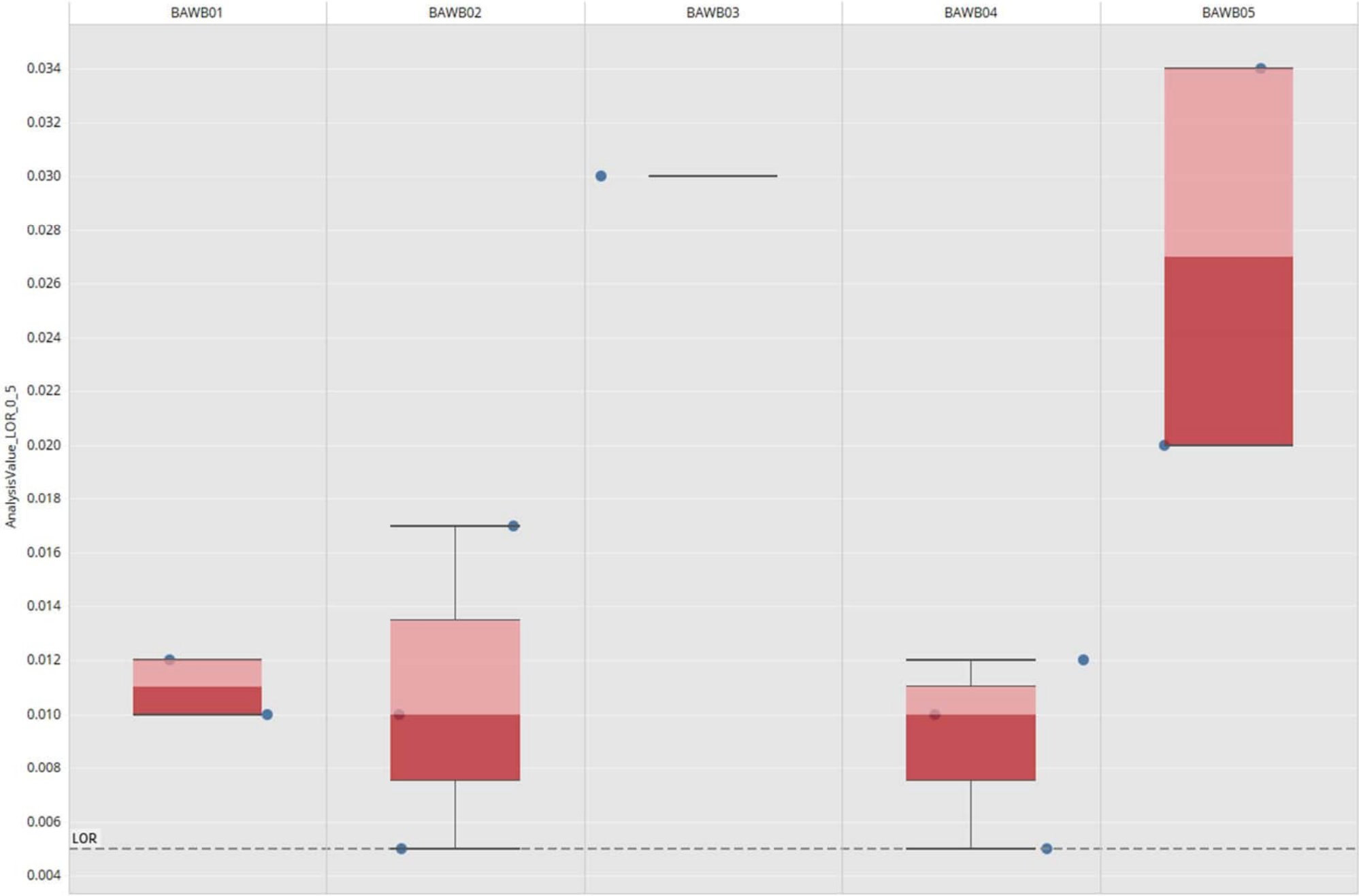
Sulfate (as SO4)



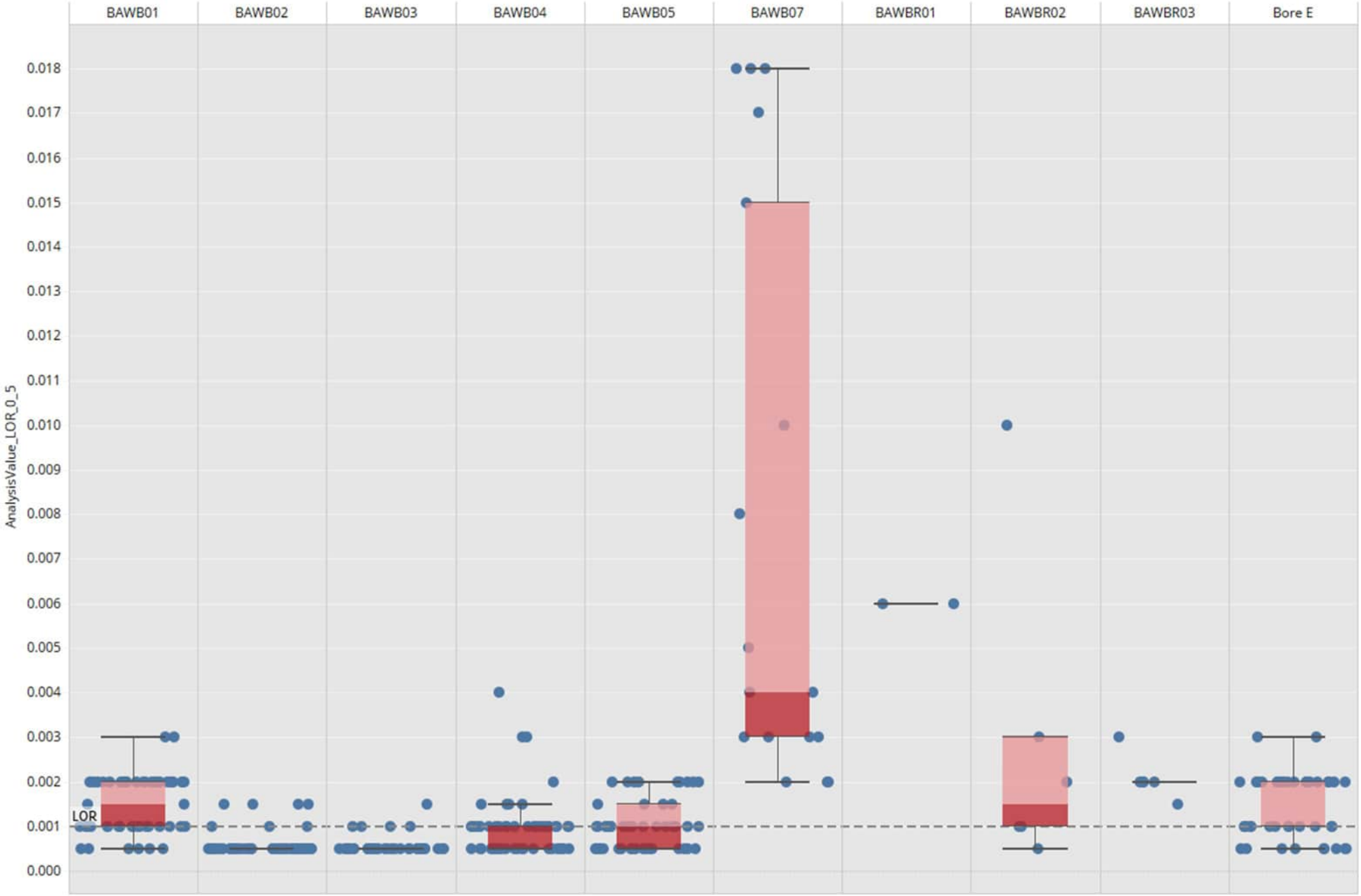
Bicarbonate Alkalinity as CaCO3 (mg/L)



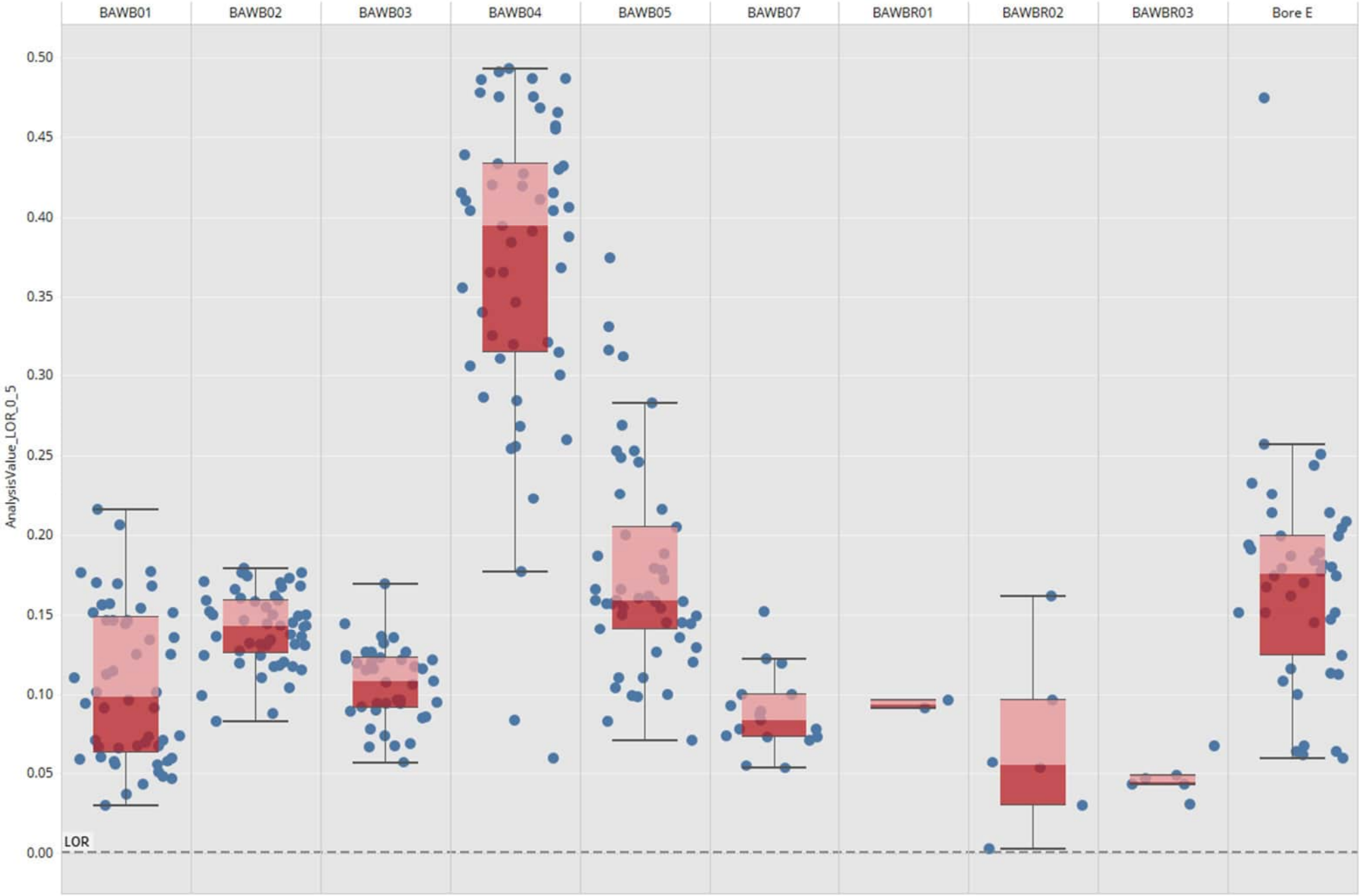
Aluminium - dissolved (mg/L)



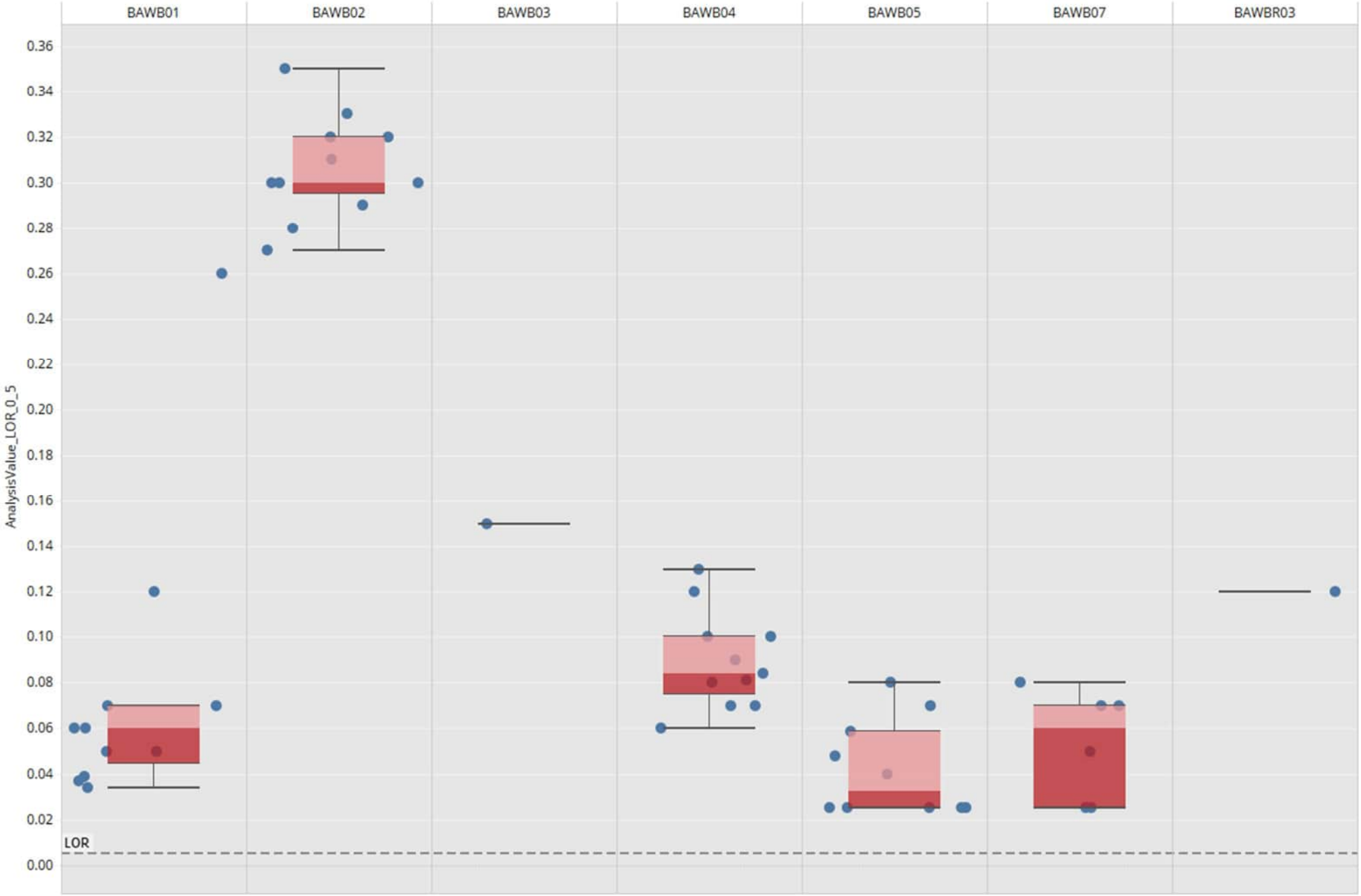
Arsenic - dissolved (mg/L)



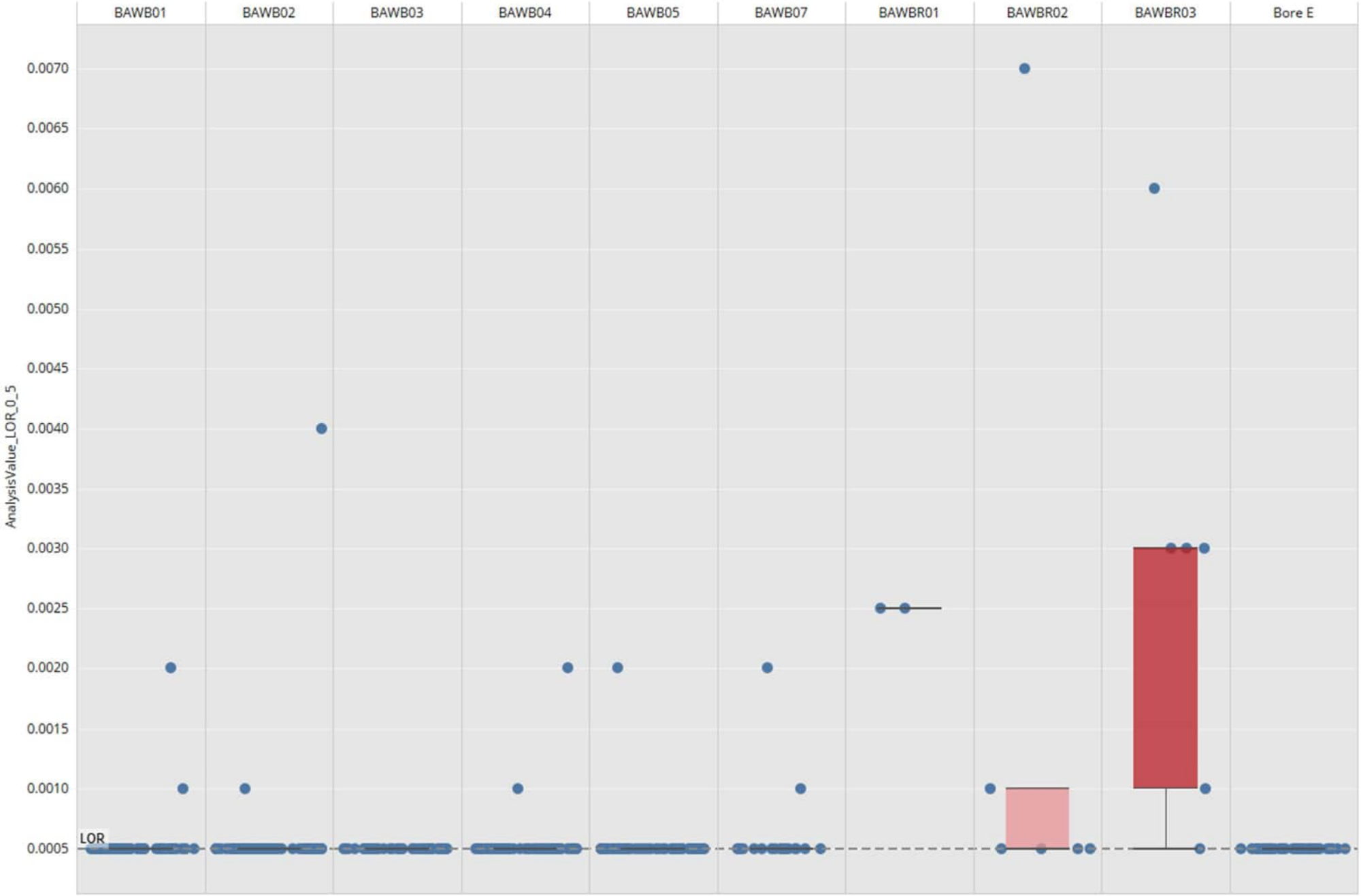
Barium - dissolved (mg/L)



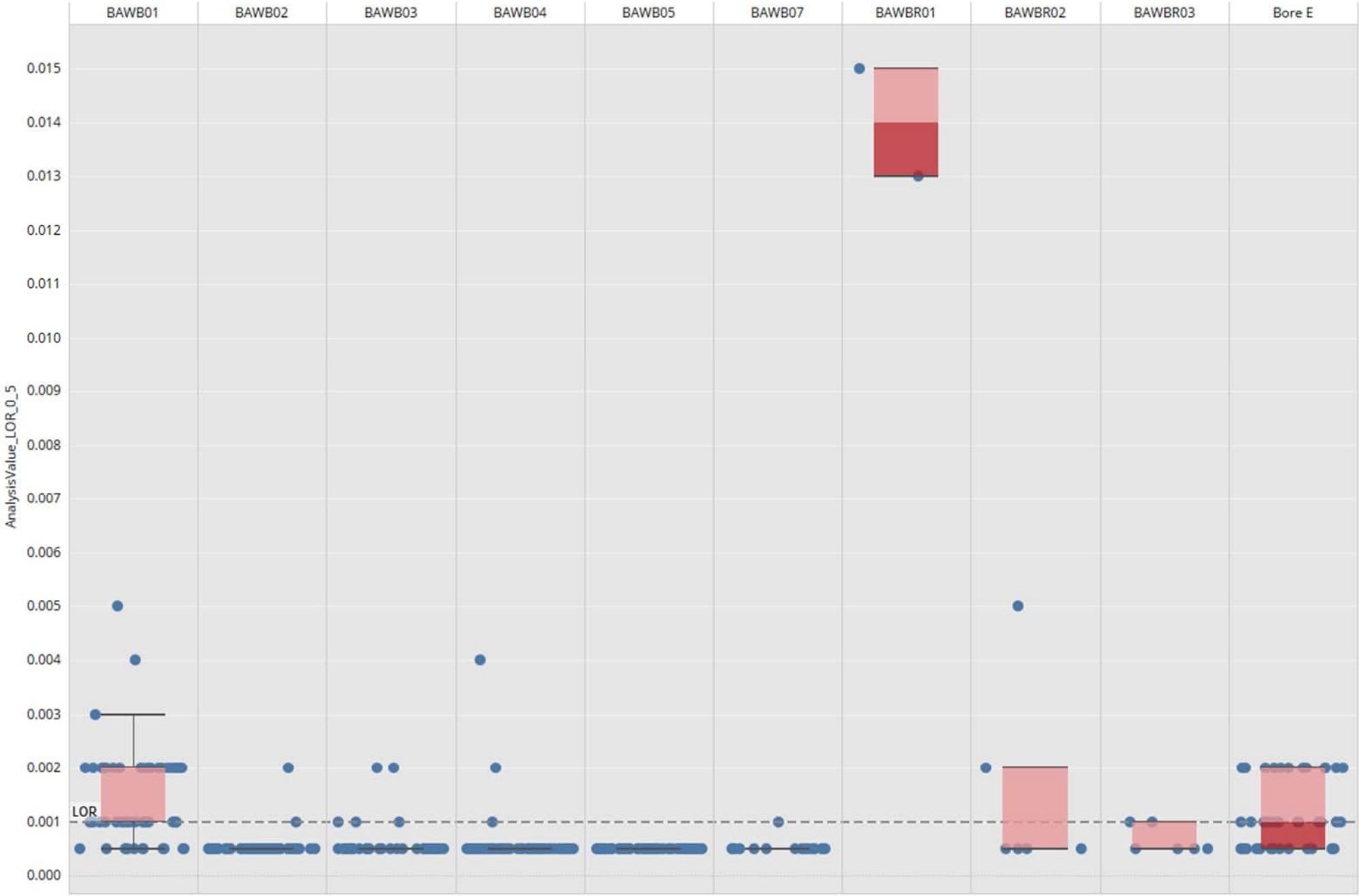
Boron - dissolved (mg/L)



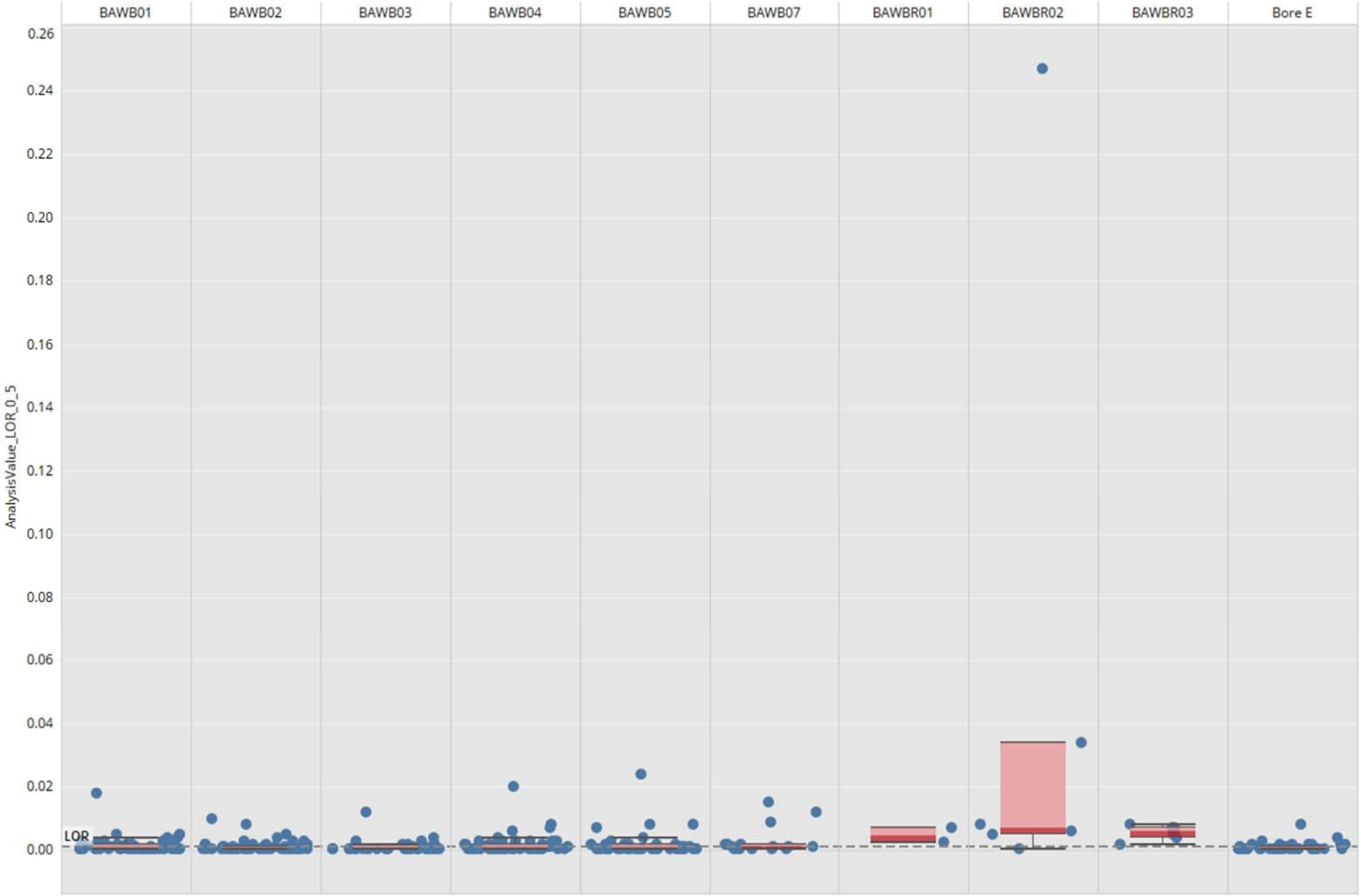
Chromium - dissolved (mg/L)



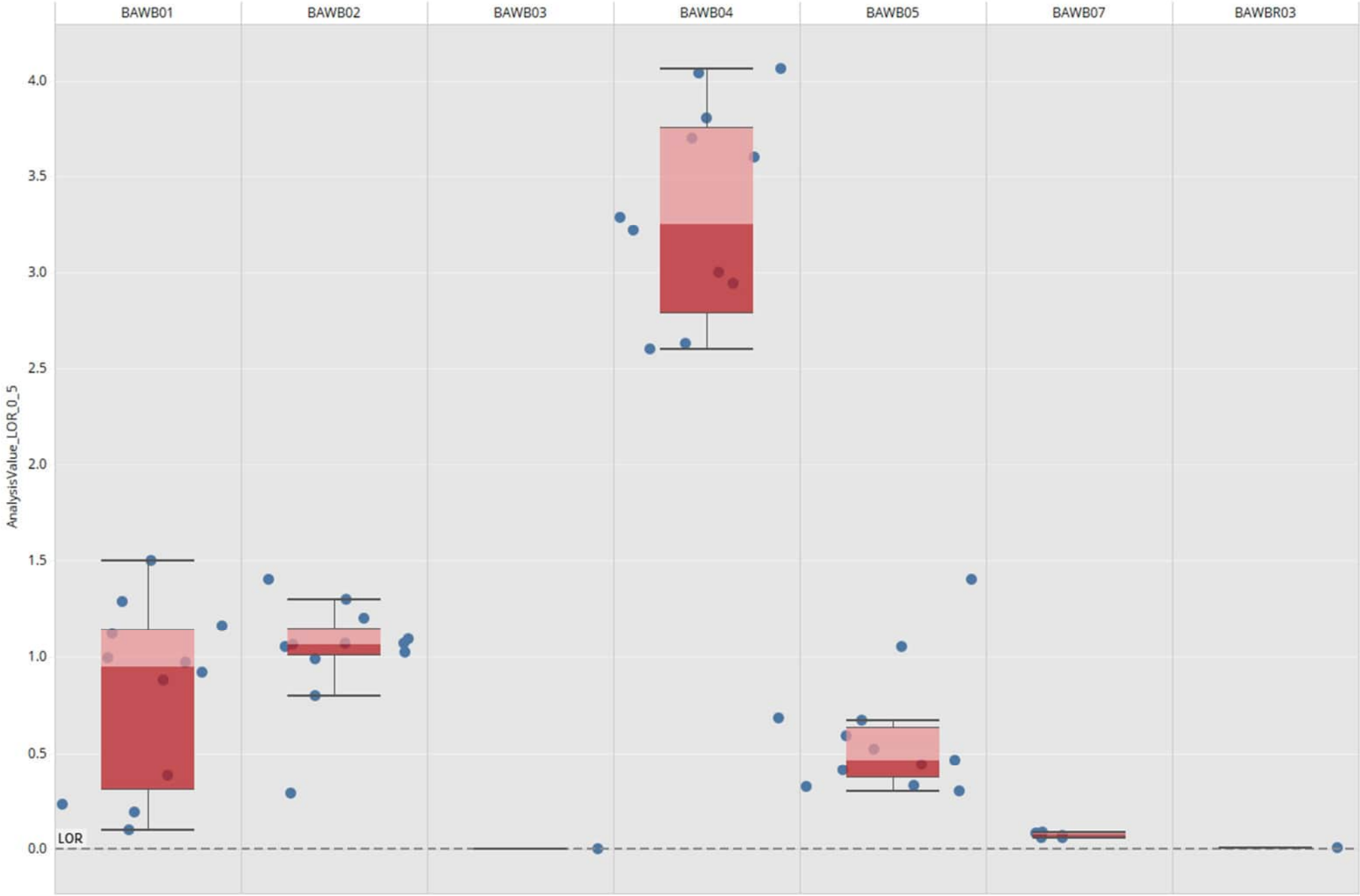
Cobalt - dissolved (mg/L)



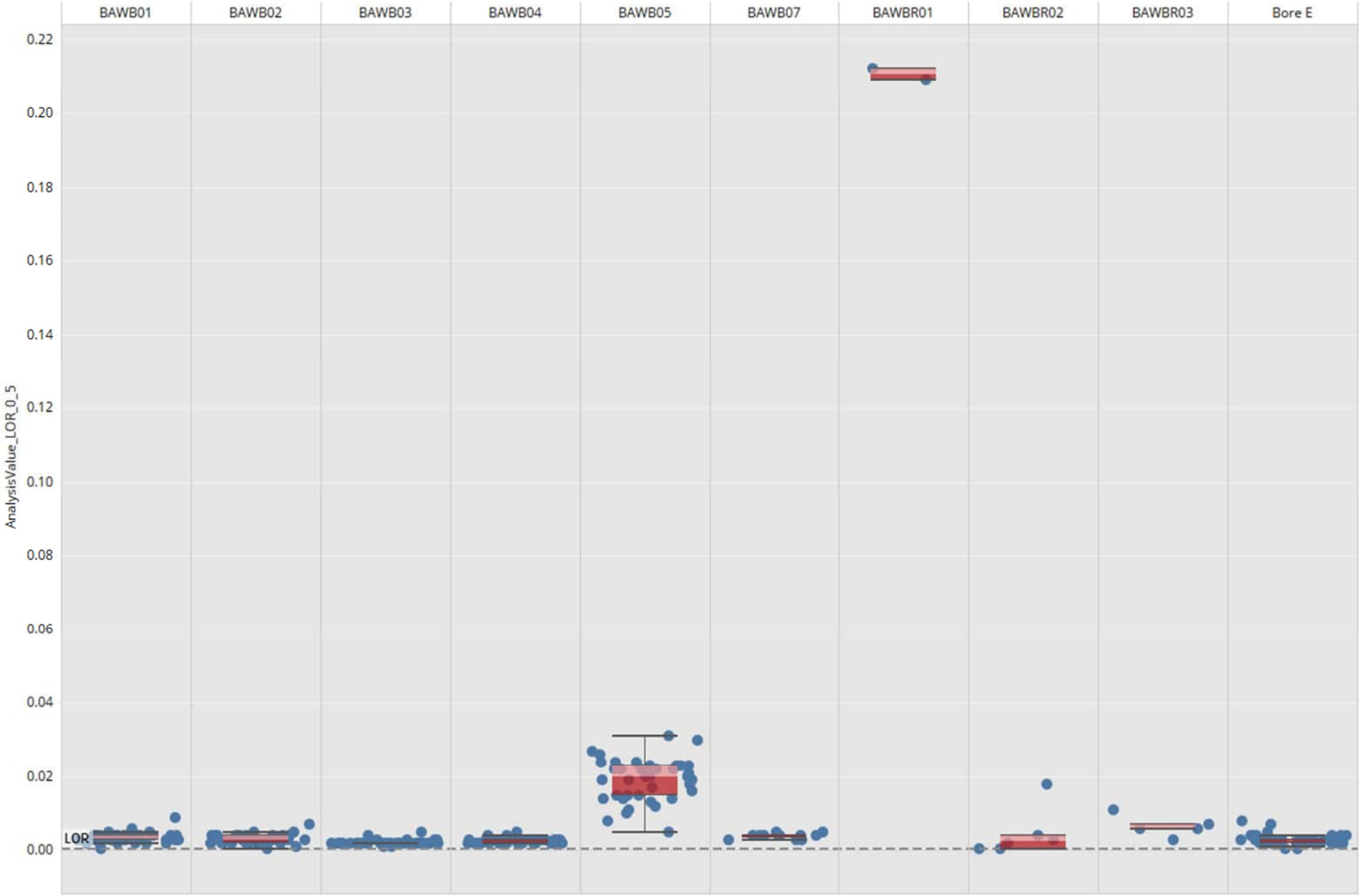
Copper - dissolved (mg/L)



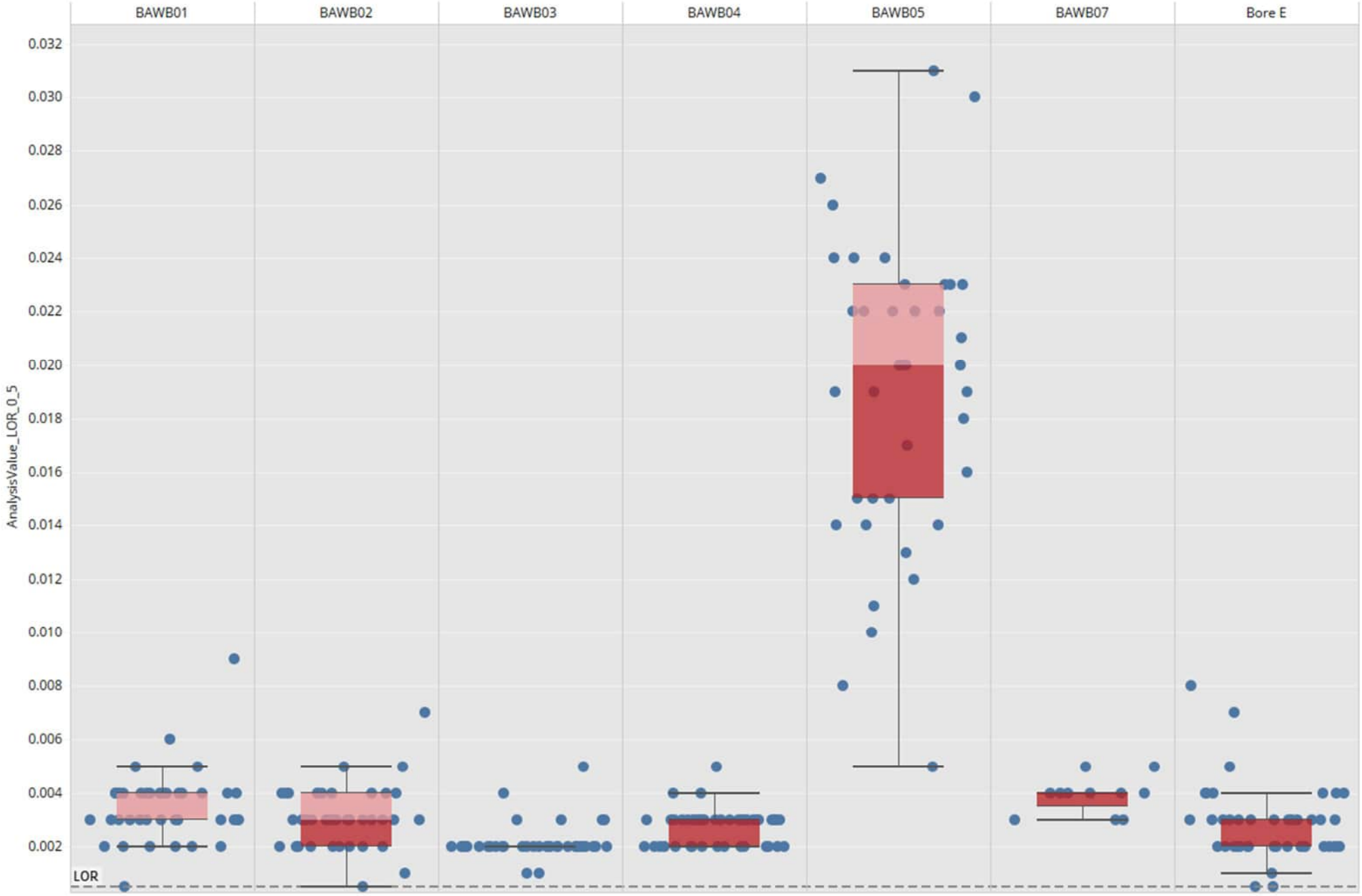
Manganese - dissolved (mg/L)



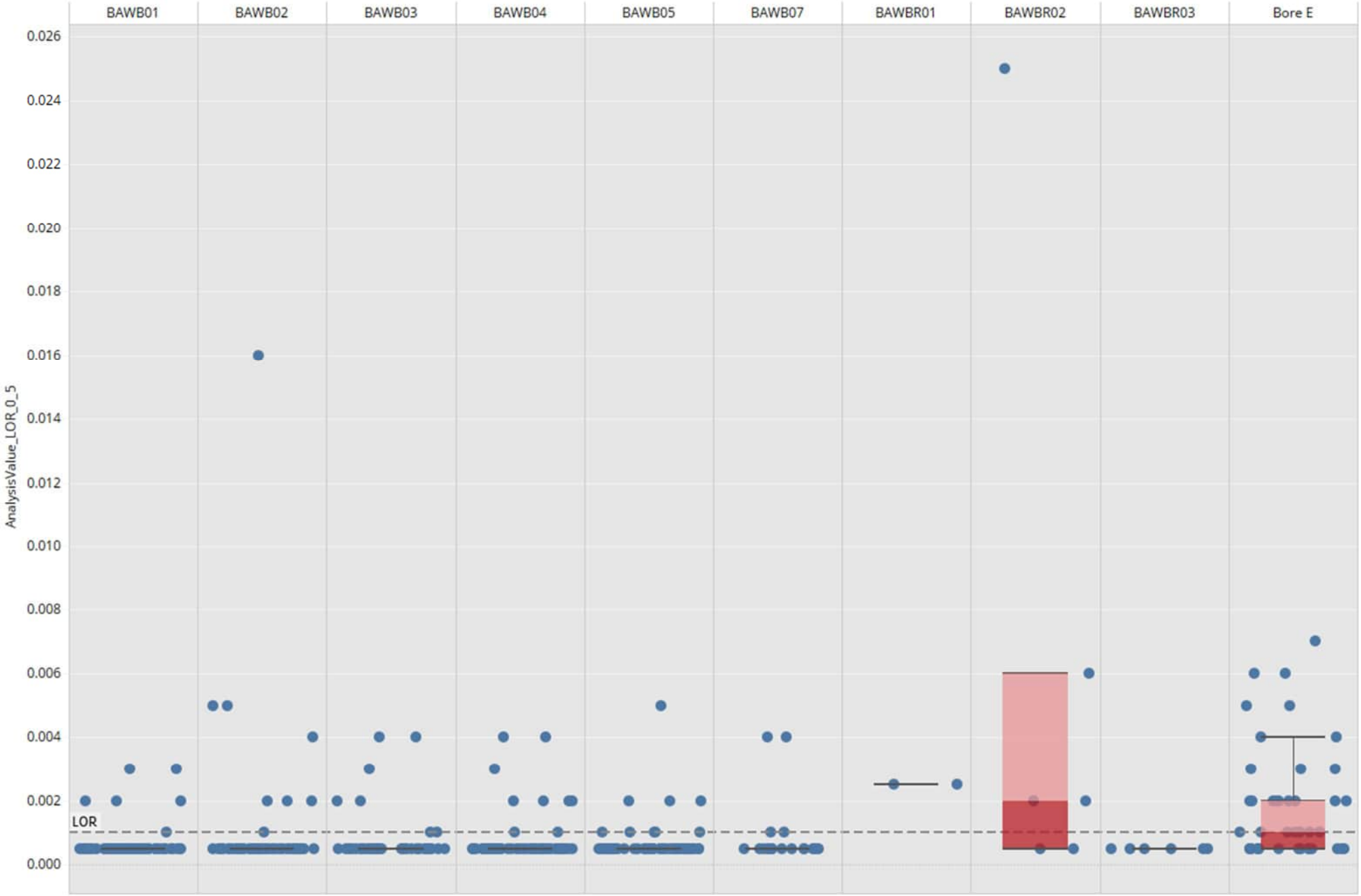
Molybdenum - dissolved (mg/L)



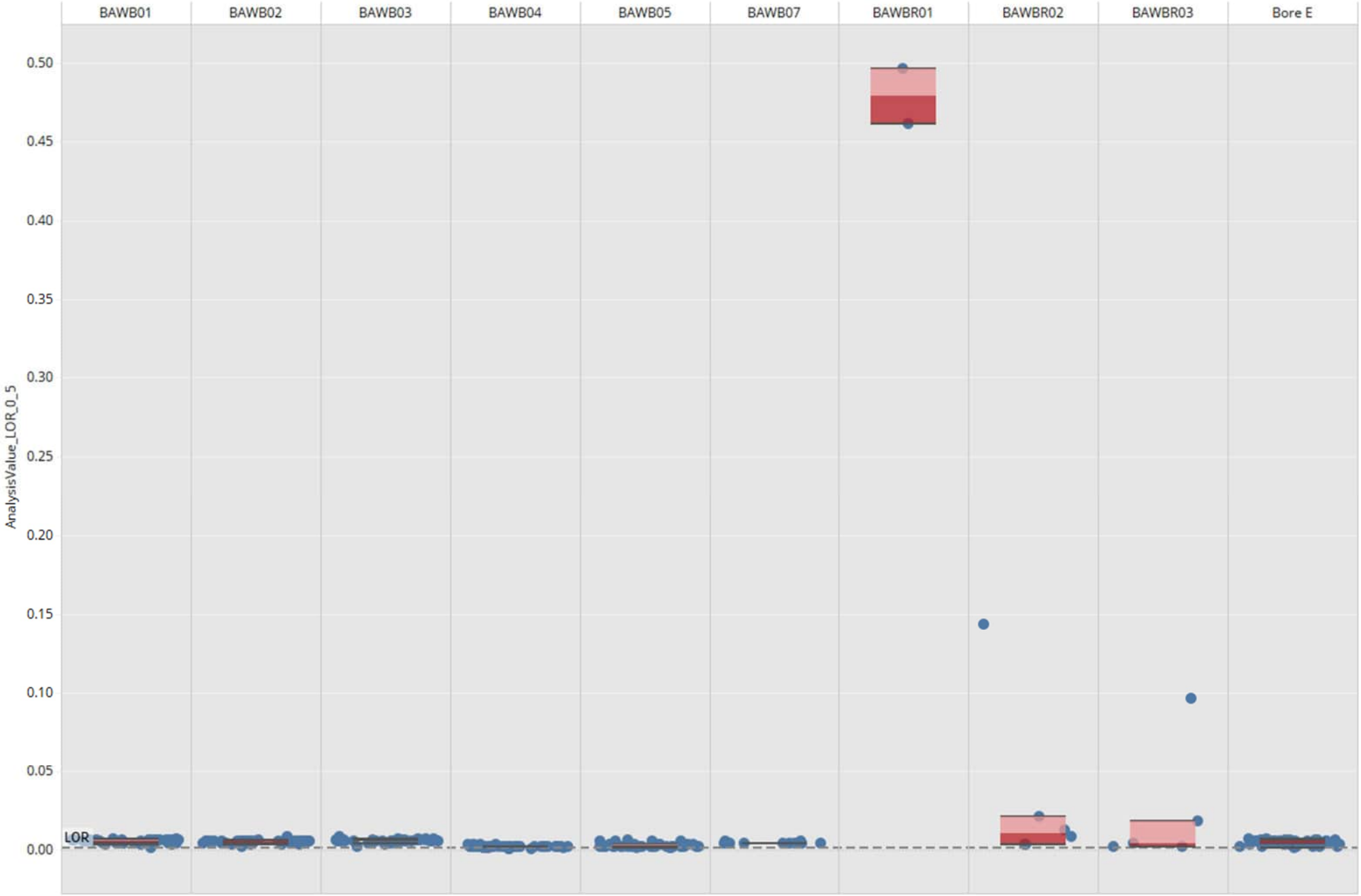
Molybdenum - dissolved (mg/L)



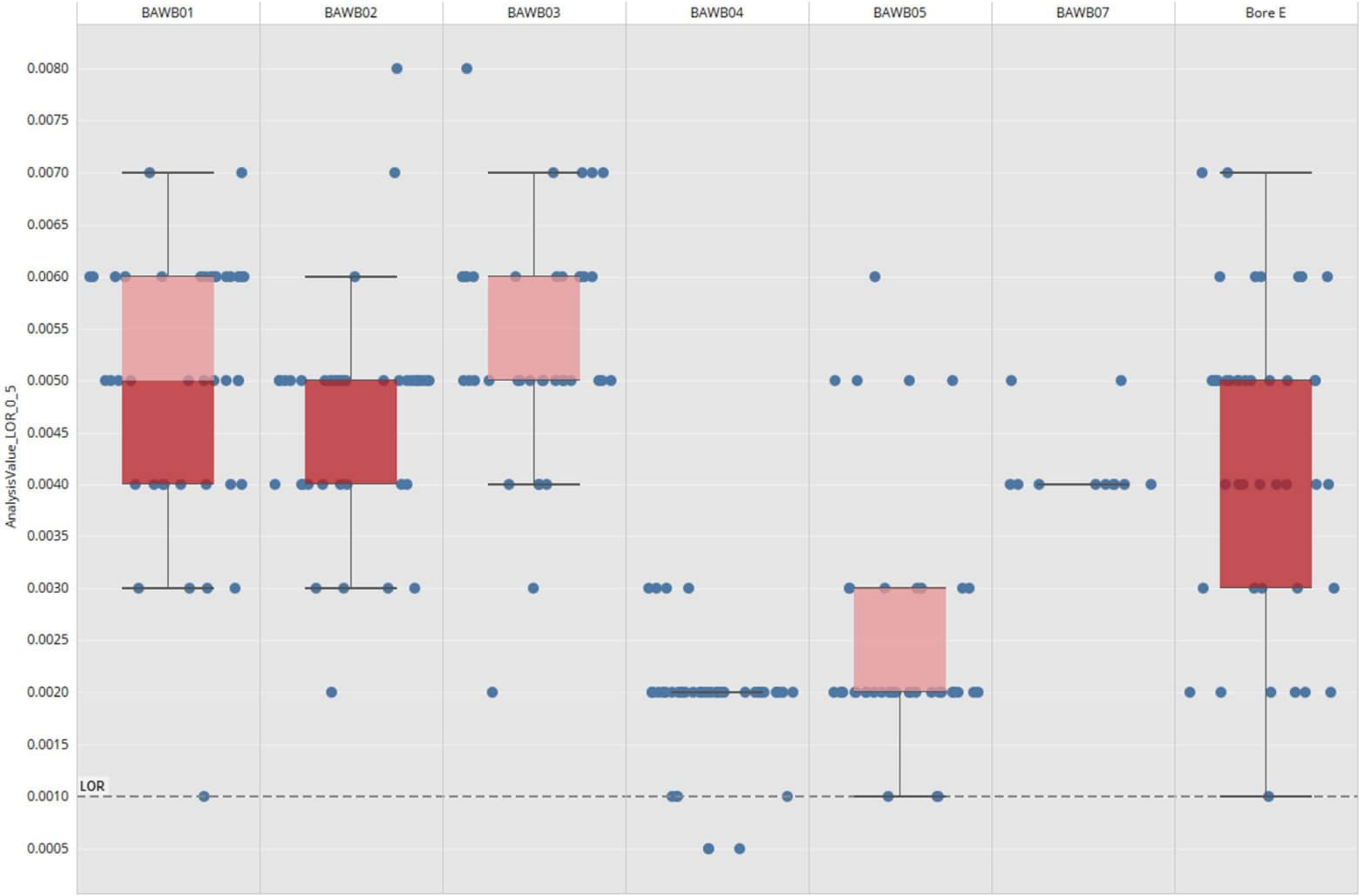
Nickel - dissolved (mg/L)



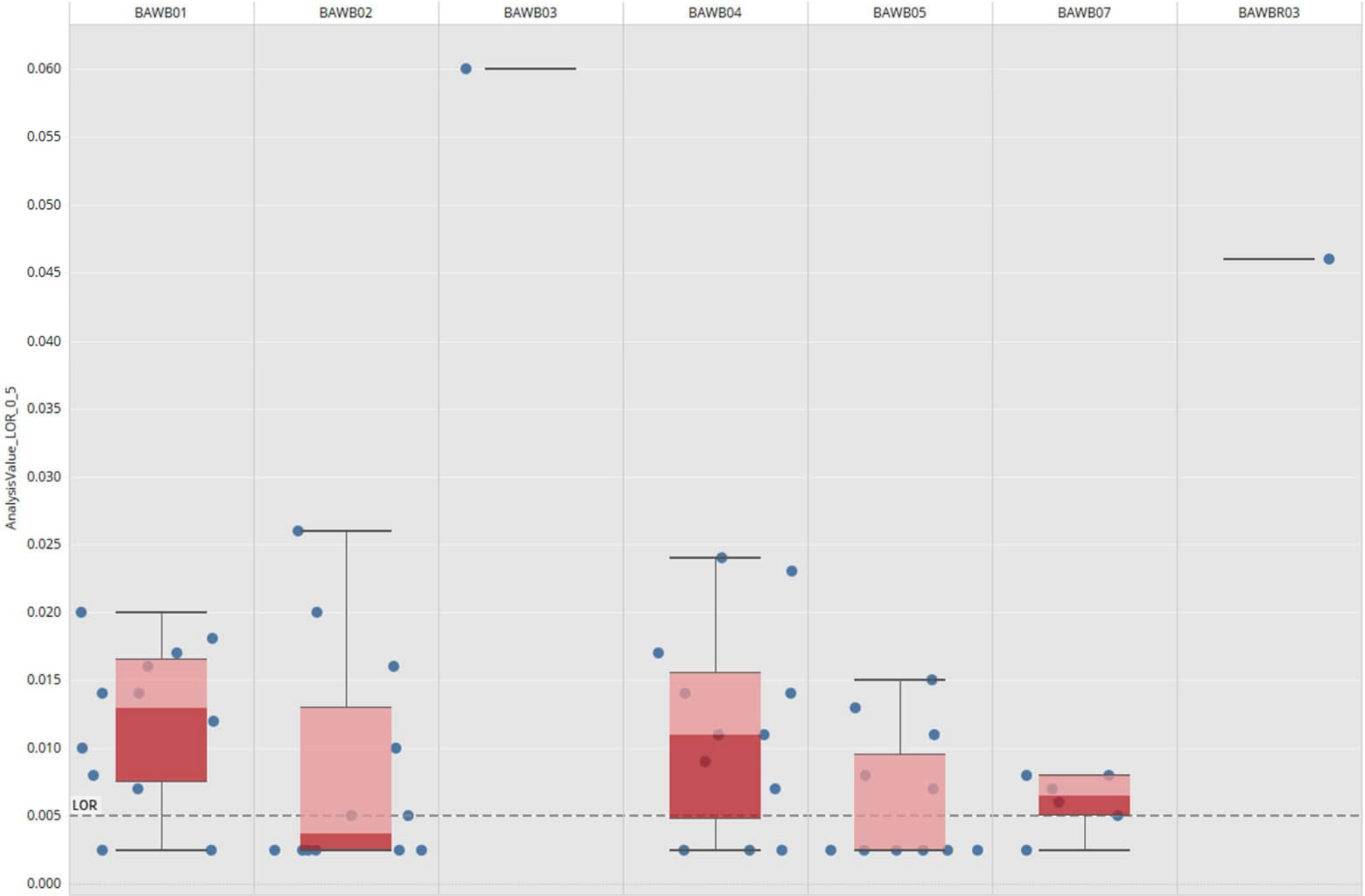
Uranium - dissolved (mg/L)



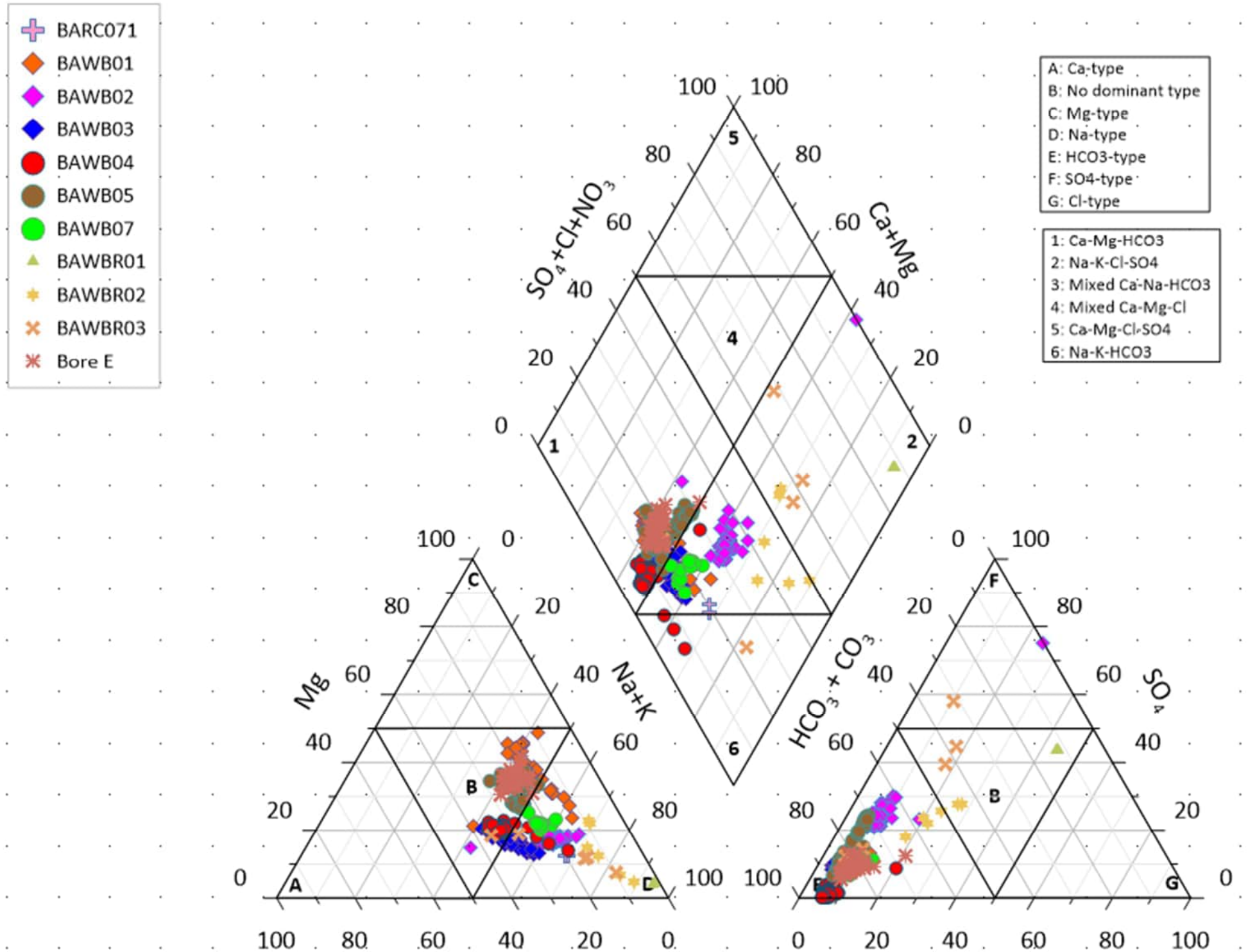
Uranium - dissolved (mg/L)

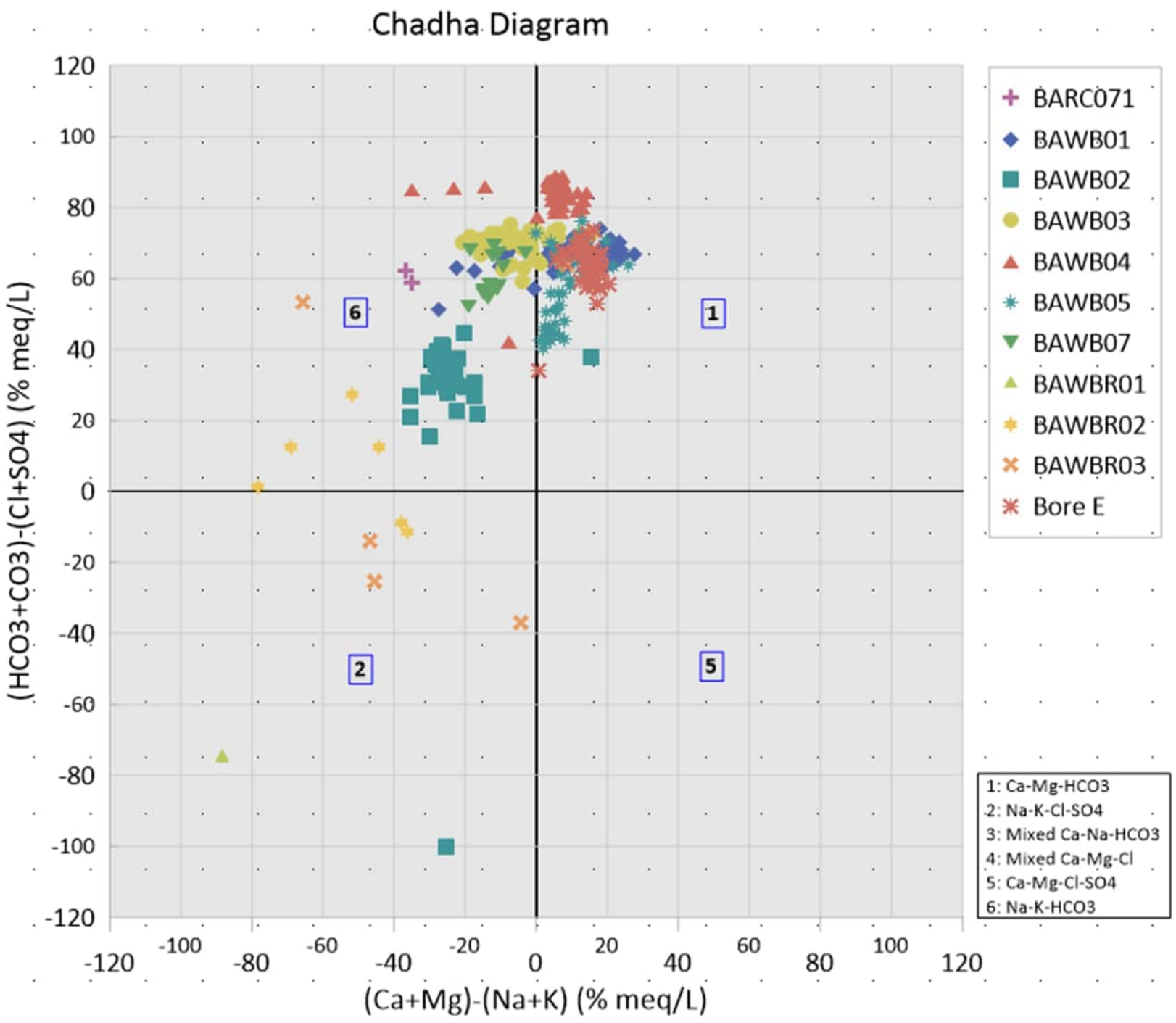


Zinc - dissolved (mg/L)

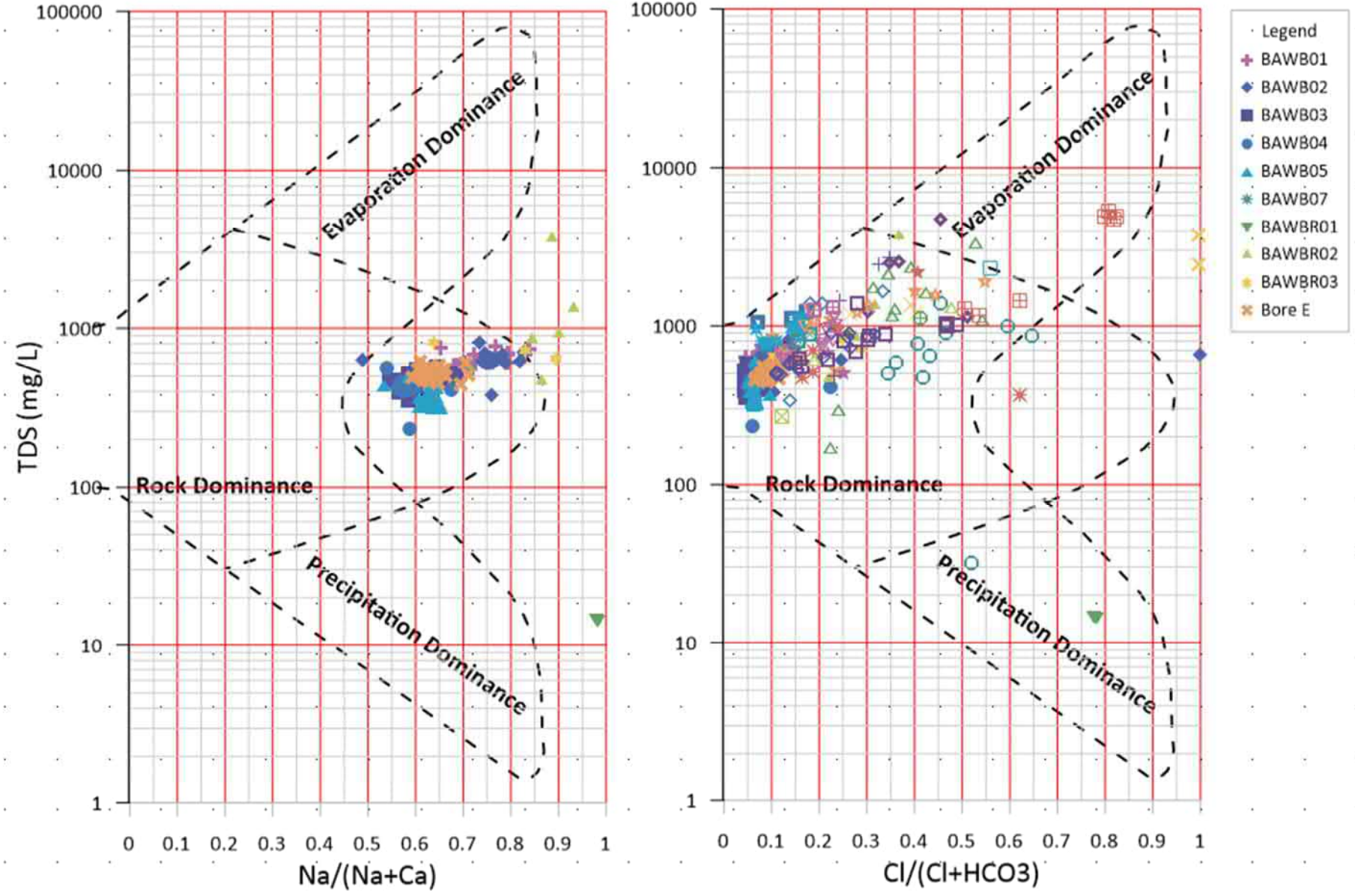


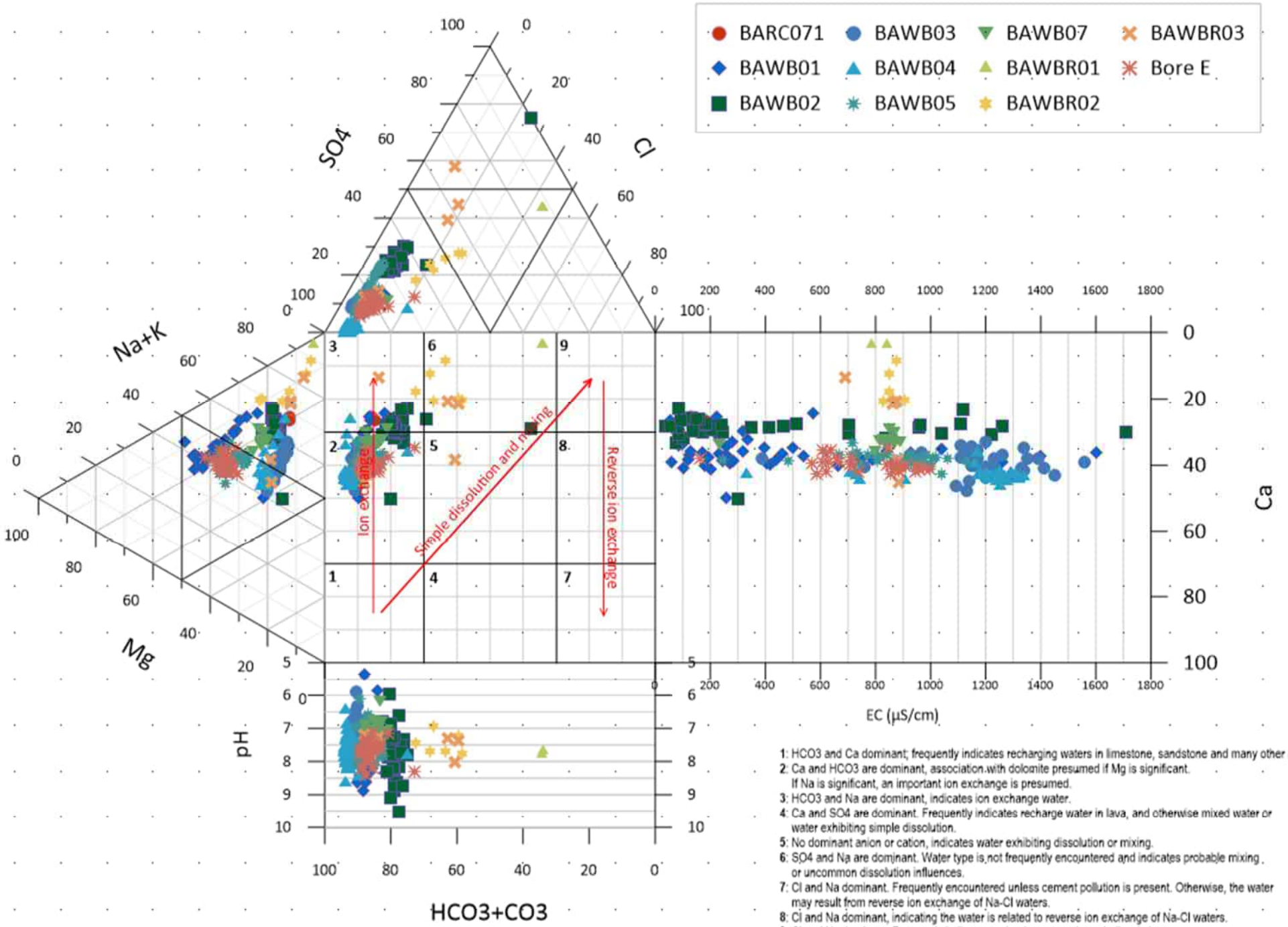
G.4 Hydrogeochemistry plots


BARC071
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
BAWBR01
BAWBR02
BAWBR03
Bore E
A: Ca-type
B: No dominant type
C: Mg-type
D: Na-type
E: HCO3-type
F: SO4-type
G: Cl-type
1: Ca-Mg-HCO3
2: Na-K-Cl-SO4
3: Mixed Ca-Na-HCO3
4: Mixed Ca-Mg-Cl
5: Ca-Mg-Cl-SO4
6: Na-K-HCO3
SO4+Cl+NO3
Ca+Mg
Mg
Na+K
HCO3 + CO3
SO4


Chadha Diagram
(HCO3+CO3)-(Cl+SO4) (% meq/L)
(Ca+Mg)-(Na+K) (% meq/L)
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
1
2
5
6
BARC071
BAWB01
BAWB02
BAWB03
BAWB04
BAWB05
BAWB07
BAWBR01
BAWBR02
BAWBR03
Bore E
1: Ca-Mg-HCO3
2: Na-K-Cl-SO4
3: Mixed Ca-Na-HCO3
4: Mixed Ca-Mg-Cl
5: Ca-Mg-Cl-SO4
6: Na-K-HCO3

Gibbs Diagram





1: HCO3 and Ca dominant; frequently indicates recharging waters in limestone, sandstone and many other aquifers.
2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant.
If Na is significant, an important ion exchange is presumed.
3: HCO3 and Na are dominant, indicates ion exchange water.
4: Ca and SO4 are dominant. Frequently indicates recharge water in lava, and otherwise mixed water or water exhibiting simple dissolution.
5: No dominant anion or cation, indicates water exhibiting dissolution or mixing.
6: SO4 and Na are dominant. Water type is not frequently encountered and indicates probable mixing, or uncommon dissolution influences.
7: Cl and Na dominant. Frequently encountered unless cement pollution is present. Otherwise, the water may result from reverse ion exchange of Na-Cl waters.
8: Cl and Na dominant, indicating the water is related to reverse ion exchange of Na-Cl waters.
9: Cl and Na dominant. Frequently indicates end-point waters through dissolution.

Appendix H Seepage monitoring bore results

H.1 Seepage monitoring bores data tables

Table H.1 Seepage monitoring bore sampling events

Year/ Moth	Seepage Bore 1a	Seepage Bore 1b	Seepage Bore 2a	Seepage Bore 2b	Seepage Bore 3a	Seepage Bore 3b	Seepage Bore 4a	Seepage Bore 4b	Seepage Bore 5a	Seepage Bore 5b	Seepage Bore 6a	Seepage Bore 6b	Seepage Bore 7a	Seepage Bore 8a	Seepage Bore 9a
2019															
9	✓	✓	✓	✓	✓	✓	✓	✓							
10	✓	✓	✓	✓	✓	✓	✓	✓							
11	✓	✓	✓	✓	✓	✓	✓	✓							
2020															
2	✓	✓	✓	✓	✓	✓	✓	✓							
4	✓	✓	✓	✓	✓	✓	✓	✓							
5	✓	✓	✓	✓	✓	✓	✓	✓							
6	✓	✓	✓	✓	✓	✓	✓	✓							
7	✓	✓	✓	✓	✓	✓	✓	✓							
8	✓	✓	✓	✓	✓	✓		✓							
9	✓	✓	✓	✓	✓	✓	✓	✓							
11	✓	✓	✓	✓	✓	✓	✓	✓							
12	✓	✓	✓	✓	✓	✓	✓	✓							
2021															
1	✓	✓	✓	✓	✓	✓	✓	✓							
2	✓	✓	✓	✓	✓	✓	✓	✓							
3	✓	✓	✓	✓	✓	✓	✓	✓							
4	✓	✓	✓	✓	✓	✓	✓	✓							
5	✓	✓	✓	✓	✓	✓	✓	✓							
6	✓	✓	✓	✓	✓	✓	✓	✓							
7	✓	✓	✓	✓	✓	✓	✓	✓							

Year/ Moth	Seepage Bore 1a	Seepage Bore 1b	Seepage Bore 2a	Seepage Bore 2b	Seepage Bore 3a	Seepage Bore 3b	Seepage Bore 4a	Seepage Bore 4b	Seepage Bore 5a	Seepage Bore 5b	Seepage Bore 6a	Seepage Bore 6b	Seepage Bore 7a	Seepage Bore 8a	Seepage Bore 9a
8	✓	✓	✓	✓	✓	✓	✓	✓							
9	✓	✓	✓	✓	✓	✓	✓	✓							
10	✓	✓	✓	✓	✓	✓	✓	✓							
11	✓	✓	✓	✓	✓	✓	✓	✓							
12	✓	✓	✓	✓	✓	✓	✓	✓							
2022															
1	✓	✓	✓	✓	✓	✓	✓	✓							
2	✓	✓	✓	✓	✓	✓	✓	✓							
3	✓	✓	✓	✓	✓	✓	✓	✓							
4	✓	✓	✓	✓	✓	✓	✓	✓							
5	✓	✓	✓	✓	✓	✓	✓	✓							
6	✓	✓	✓	✓	✓	✓	✓	✓							
7	✓	✓	✓	✓	✓	✓	✓	✓							
8	✓	✓	✓	✓	✓	✓	✓	✓							
9	✓	✓	✓	✓	✓	✓	✓	✓							
10	✓	✓	✓	✓	✓	✓	✓	✓							
11	✓	✓	✓	✓	✓	✓	✓	✓							
12	✓	✓	✓	✓	✓	✓	✓	✓							
2023															
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	✓	✓	✓	✓	✓	✓	✓	✓							
3	✓	✓	✓	✓	✓	✓	✓	✓							
4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Year/ Moth	Seepage Bore 1a	Seepage Bore 1b	Seepage Bore 2a	Seepage Bore 2b	Seepage Bore 3a	Seepage Bore 3b	Seepage Bore 4a	Seepage Bore 4b	Seepage Bore 5a	Seepage Bore 5b	Seepage Bore 6a	Seepage Bore 6b	Seepage Bore 7a	Seepage Bore 8a	Seepage Bore 9a
5									✓	✓	✓	✓	✓	✓	✓
6									✓	✓	✓	✓	✓	✓	✓
7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
8					✓				✓	✓	✓	✓	✓	✓	✓
9									✓	✓	✓	✓	✓	✓	✓
10	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
11									✓	✓	✓	✓	✓	✓	✓
12									✓	✓	✓	✓	✓	✓	✓

Table H.2 Descriptive statistics: seepage monitoring results (all sites)

R	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	10%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	80%ile	90%ile (> LOR)	95%ile (>LOR)	99%ile (>LOR)
Alkalinity																			
Bicarbonate Alkalinity as CaCO3 (mg/L)	193	183	10	5.2%	38	542.7760	249.5573	1200	1162	127.1	143.4	340	429	538	709.5	800.4	848.8	936.3	1104.4
Carbonate Alkalinity as CaCO3 (mg/L)	193	16	177	91.7%	8	198.0625	170.6764	659	651	8	8	13	29.5	190	239.25	282	391.5	473.75	621.95
Hydroxide Alkalinity as CaCO3 (mg/L)	193	10	183	94.8%	371	551.7000	124.5536	819	448	389.45	407.9	437.6	453.5	567	608.75	617.2	659.7	739.35	803.07
Field Measurements																			
Dissolved Oxygen (field) (% sat))	108	108			0	52.4278	76.2069	468	468	0	0	1.84	2	24	76.3	88.18	134	192.945	337.64
Electrical Conductivity (field) (µS/cm)	108	108			10.58	2128.1535	1552.4815	9912	9901.42	1027.3	1197.3	1345.4	1453	1775	2227.75	2400.2	2734.8	4124.4	9872.54
ORP (field) (mV)	108	108			-162.8	48.9500	82.4488	231.4	394.2	-63.985	-58.62	-26.06	-20.375	51.6	101	113.48	148.54	210.575	230.517
pH (field)	108	108			5.95	7.4281	1.0170	12.8	6.85	6.128	6.283	6.778	6.925	7.27	7.7925	8.014	8.272	8.8815	12.4013
Salinity (field) (PSU)	108	108			0.47	2.0795	9.7098	102	101.53	0.517	0.59	0.668	0.72	0.895	1.1525	1.236	1.513	3.5685	5.9227
TDS (field) (ppm)	108	108			24.67	30.6013	2.4089	36.26	11.59	26.527	27.438	28.494	29.0625	30.635	32.05	32.768	33.509	34.755	35.679
Temperature (field) (°C)	193	193			50	559.6632	255.7568	1480	1430	127.6	150.6	393.2	432	543	754	803	848.8	941	1172.4
Total Dissolved Solids (field) (ppm)	108	108			486	1111.6204	869.1024	5293	4807	533.35	603.7	679.6	729	893	1123.25	1199.8	1393.1	2335.6	4955.72
Turbidity (field) (FNU)	37	37			0	5.8514	6.9829	33.7	33.7	0.24	0.7	1.24	1.7	3.1	7.7	9.3	15.92	18.76	28.696
Hardness																			
Total Hardness (mg CaCO3/L)	193	193			40	591.1192	385.8419	2500	2460	308	320.4	363.8	378	514	631	677.2	888.2	1364	2348
Ion Balance																			
Ionic Balance (%)	191	191			0.06	4.7971	4.6460	24	23.94	0.45	0.75	1.28	1.665	3.46	6.19	7.83	10.9	15.85	19.95
Total Anions (meq/L)	193	193			1.36	26.5007	17.5837	109	107.64	11	13.1	16.44	18.1	22.5	28.6	29.82	38.12	47	104
Total Cations (meq/L)	193	193			1.27	28.8345	19.7506	119	117.73	11.8	13.8	17.54	18.8	24.2	30.4	31.98	44.68	64.8	110.32
Major Ions																			
Calcium (mg/L)	386	386			4	129.6865	95.6918	483	479	32	54	64	72	106	146	161	244.5	369.75	470
Chloride (mg/L)	193	193			6	203.0363	374.0589	2170	2164	36.8	48.8	64	69	116	161	181	276	408.8	2031.6
Fluoride (mg/L)	193	193			0.2	1.6119	1.1312	5.8	5.6	0.2	0.52	1	1	1.4	1.9	2.06	2.6	4.34	5.432
Magnesium (mg/L)	386	367	19	4.9%	3	71.6076	47.9622	316	313	27.3	32	42	46	58	86	92	113.2	161.5	296.34
Potassium (mg/L)	386	383	3	0.8%	1	9.7363	15.1308	120	119	2	2	4	4	6	8	9	15.8	45.1	79.08
Sodium (mg/L)	386	386			11	389.5181	411.2366	2500	2489	118.25	146.5	186	196	302.5	421	437	510.5	765.75	2337.5
Sulfate (as SO4)	193	193			9	460.9482	437.1279	1910	1901	48.6	67.2	91	110	311	650	701.4	1118	1568	1732.8
Metals (dissolved)																			
Arsenic - dissolved (mg/L)	194	119	75	38.7%	0.001	0.0027	0.0016	0.008	0.007	0.001	0.001	0.001	0.002	0.002	0.003	0.004	0.005	0.006	0.007
Barium - dissolved (mg/L)	194	194			0.042	0.1382	0.0587	0.329	0.287	0.06265	0.0773	0.089	0.09225	0.1245	0.17875	0.192	0.2187	0.24285	0.29821
Bismuth - dissolved (mg/L)	194		194	100.0%															
Chromium - dissolved (mg/L)	194	15	179	92.3%	0.001	0.0150	0.0122	0.05	0.049	0.0017	0.002	0.0028	0.004	0.015	0.021	0.022	0.0226	0.0311	0.04622
Cobalt - dissolved (mg/L)	194	119	75	38.7%	0.001	0.0022	0.0014	0.009	0.008	0.001	0.001	0.001	0.001	0.002	0.003	0.003	0.004	0.005	0.006
Copper - dissolved (mg/L)	194	117	77	39.7%	0.001	0.0062	0.0088	0.04	0.039	0.001	0.001	0.001	0.001	0.002	0.007	0.0088	0.0124	0.0302	0.03484
Molybdenum - dissolved (mg/L)	194	188	6	3.1%	0.001	0.0279	0.0705	0.612	0.611	0.002	0.002	0.003	0.003	0.005	0.01525	0.0186	0.0663	0.1871	0.28234
Nickel - dissolved (mg/L)	194	87	107	55.2%	0.001	0.0041	0.0046	0.015	0.014	0.001	0.001	0.001	0.001	0.002	0.004	0.004	0.014	0.015	0.015
Selenium - dissolved (mg/L)	194	55	139	71.6%	0.01	0.0584	0.0668	0.3	0.29	0.02	0.02	0.02	0.02	0.03	0.06	0.07	0.12	0.243	0.2946
Uranium - dissolved (mg/L)	194	179	15	7.7%	0.001	0.0263	0.0558	0.328	0.327	0.003	0.004	0.006	0.008	0.013	0.018	0.0204	0.0264	0.1829	0.29328

R	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	Range (>LOR)	5%ile (>LOR)	10%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	80%ile	90%ile (> LOR)	95%ile (>LOR)	99%ile (>LOR)
Metals (total)																			
Arsenic - total (mg/L)	194	127	67	34.5%	0.001	0.0030	0.0019	0.01	0.009	0.001	0.001	0.001	0.002	0.002	0.004	0.004	0.006	0.008	0.00874
Barium - total (mg/L)	194	194			0.048	0.1479	0.0628	0.362	0.314	0.06495	0.0863	0.0958	0.101	0.13	0.19375	0.202	0.233	0.2667	0.31017
Bismuth - total (mg/L)	194	1	193	99.5%	0.00014	0.0001	0.0000	0.00014	0	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014
Chromium - total (mg/L)	194	27	167	86.1%	0.001	0.0133	0.0247	0.132	0.131	0.001	0.001	0.002	0.002	0.003	0.018	0.0206	0.023	0.0237	0.10392
Cobalt - total (mg/L)	194	155	39	20.1%	0.001	0.0027	0.0018	0.016	0.015	0.001	0.001	0.001	0.002	0.002	0.003	0.004	0.005	0.006	0.00838
Copper - total (mg/L)	194	177	17	8.8%	0.001	0.0079	0.0102	0.073	0.072	0.001	0.002	0.002	0.003	0.004	0.009	0.01	0.0148	0.032	0.04644
Molybdenum - total (mg/L)	194	190	4	2.1%	0.001	0.0303	0.0757	0.66	0.659	0.002	0.003	0.003	0.004	0.006	0.01775	0.02	0.0744	0.17595	0.32288
Nickel - total (mg/L)	194	101	93	47.9%	0.001	0.0056	0.0143	0.142	0.141	0.001	0.001	0.001	0.002	0.002	0.004	0.004	0.014	0.016	0.016
Selenium - total (mg/L)	194	55	139	71.6%	0.01	0.0607	0.0663	0.29	0.28	0.02	0.02	0.02	0.02	0.03	0.06	0.09	0.126	0.239	0.2846
Uranium - total (mg/L)	194	180	14	7.2%	0.001	0.0280	0.0567	0.325	0.324	0.004	0.005	0.007	0.008	0.014	0.02	0.0222	0.0291	0.1909	0.29352
Physico-Chemical Parameters																			
Electrical Conductivity (µS/cm)	193	193			109	2637.8756	1868.4069	11200	11091	1020	1198	1544	1650	2090	2750	3128	4550	5462	10200
pH (lab)	193	193			6.65	7.9548	0.9851	12.1	5.45	7.2	7.32	7.504	7.56	7.78	7.99	8.056	8.22	9.972	12
Turbidity (NTU)	193	192	1	0.5%	0.1	8.6417	35.7670	477	476.9	0.3	0.5	0.6	0.8	2.4	5.65	6.6	14.51	38.7	62.424

Table H.3 Descriptive statistics: seepage monitoring results (by location)

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Seepage Bore 1a														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	10	10			446	508.0000	37.9368	578	456.35	473	477	510.5	535.75	562.25
Carbonate Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Hydroxide Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Temperature (field) (°C)	10	10			446	508.0000	37.9368	578	456.35	473	477	510.5	535.75	562.25
Field Measurements														
Appearance or Colour	6													
Depth of Bore (mbgl)	42	42			6	6.0000	0.0000	6	6	6	6	6	6	6
Depth to Water (mbRL)	34	34			3.17	4.9118	0.8504	6.43	3.766	4.412	4.4475	4.72	5.145	6.417
Depth to Water (mbGL)	3	3			6.17	6.2833	0.0865	6.38	6.183	6.222	6.235	6.3	6.34	6.372
Depth to Water Comments	11													
Dissolved Oxygen (field) (% sat))	6	6			0	64.4000	52.4729	136.1	0.5	2	13.575	65.9	108.25	131.2
Dry?	11													
Electrical Conductivity (field) (µS/cm)	6	6			1241	2196.6667	538.6259	2730	1364	1733	1894.25	2387	2625.5	2723
Groundwater Level (mAHD)	34	34			306.61	332.5229	17.3126	373.54	306.9665	320.22	321.0875	329.67	344.45675	373.4085
GWL Depth Reference Elevation	42	42			311.33	338.7630	16.2100	378.09	311.9595	326.76	327.555	335.23	353.32	376.97855
Odour	6													

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
ORP (field) (mV)	6	6			-63.4	20.2167	59.1466	100.8	-53.6	-24.2	-23.2	19.8	66.325	92.725
pH (field)	6	6			7.1	7.5417	0.3051	7.9	7.115	7.16	7.275	7.645	7.7675	7.875
Salinity (field) (PSU)	6	6			0.61	1.1150	0.2868	1.39	0.6725	0.86	0.9475	1.22	1.35	1.39
TDS (field) (ppm)	6	6			26.91	30.2550	1.9055	32.68	27.42	28.95	29.2325	30.655	31.5675	32.43
Total Dissolved Solids (field) (ppm)	6	6			620	1097.0000	270.7520	1365	679.5	858	941	1194	1312.75	1361.5
Hardness														
Total Hardness (mg CaCO3/L)	10	10			616	875.6000	153.3905	1180	654.25	769.8	801.75	869.5	929.75	1121.5
Ion Balance														
Ionic Balance (%)	10	10			0.11	3.2520	1.6259	5.53	0.722	1.862	2.13	3.74	4	5.476
Total Anions (meq/L)	10	10			14.4	27.0600	5.9126	34.2	16.02	24.32	26.3	29	30.425	33.345
Total Cations (meq/L)	10	10			14.4	27.0800	6.2483	34.2	15.39	24.68	26.775	28.7	31.3	33.435
Major Ions														
Calcium (mg/L)	20	20			207	284.3500	59.8576	415	213.65	242.4	243.75	264	308.25	404.55
Chloride (mg/L)	10	10			65	192.6000	63.0955	301	101	148.2	153.5	192	235.75	278.05
Fluoride (mg/L)	10	10			0.2	0.4500	0.2500	0.9	0.2	0.2	0.225	0.35	0.65	0.855
Magnesium (mg/L)	20	20			24	44.8000	19.0594	89	24	30.8	31.75	36.5	58.25	83.3
Potassium (mg/L)	20	20			1	2.5000	1.1180	4	1	1.8	2	2	4	4
Sodium (mg/L)	20	20			46	220.2000	97.9043	353	46.95	155.2	180.25	229.5	300.25	347.3
Sulfate (as SO4)	10	10			116	551.7000	199.5059	747	170.9	496.4	562	603	685	738.45
Metals (dissolved)														
Arsenic - dissolved (mg/L)	10		10	100.0										
Barium - dissolved (mg/L)	10	10			0.084	0.1407	0.0846	0.329	0.084	0.084	0.08575	0.103	0.13125	0.30785

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Bismuth - dissolved (mg/L)	10		10	100.0										
Chromium - dissolved (mg/L)	10		10	100.0										
Cobalt - dissolved (mg/L)	10	8	2	20.0	0.001	0.0028	0.0025	0.009	0.001	0.001	0.001	0.002	0.0025	0.00725
Copper - dissolved (mg/L)	10	4	6	60.0	0.001	0.0020	0.0007	0.003	0.00115	0.0016	0.00175	0.002	0.00225	0.00285
Molybdenum - dissolved (mg/L)	10	9	1	10.0	0.001	0.0019	0.0009	0.003	0.001	0.001	0.001	0.002	0.003	0.003
Nickel - dissolved (mg/L)	10	4	6	60.0	0.001	0.0018	0.0004	0.002	0.00115	0.0016	0.00175	0.002	0.002	0.002
Selenium - dissolved (mg/L)	10	1	9	90.0	0.02	0.0200	0.0000	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Uranium - dissolved (mg/L)	10	10			0.012	0.0139	0.0015	0.016	0.012	0.0128	0.013	0.0135	0.0155	0.016
Metals (total)														
Arsenic - total (mg/L)	10	1	9	90.0	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Barium - total (mg/L)	10	10			0.086	0.1558	0.0989	0.362	0.0878	0.0956	0.09725	0.109	0.14	0.35165
Bismuth - total (mg/L)	10		10	100.0										
Chromium - total (mg/L)	10		10	100.0										
Cobalt - total (mg/L)	10	9	1	10.0	0.001	0.0037	0.0024	0.01	0.0014	0.0026	0.003	0.003	0.003	0.008
Copper - total (mg/L)	10	10			0.001	0.0042	0.0026	0.01	0.00145	0.002	0.00225	0.0035	0.005	0.00865
Molybdenum - total (mg/L)	10	9	1	10.0	0.001	0.0021	0.0006	0.003	0.0014	0.002	0.002	0.002	0.002	0.003
Nickel - total (mg/L)	10	5	5	50.0	0.001	0.0020	0.0006	0.003	0.0012	0.0018	0.002	0.002	0.002	0.0028
Selenium - total (mg/L)	10	1	9	90.0	0.02	0.0200	0.0000	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Uranium - total (mg/L)	10	10			0.012	0.0150	0.0018	0.019	0.0129	0.014	0.014	0.0145	0.01575	0.0181
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	10	10			1320	2357.0000	518.2866	2880	1414.5	2050	2205	2540	2742.5	2857.5

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
pH (lab)	10	10			7.27	7.6160	0.2141	7.9	7.3105	7.368	7.4175	7.635	7.7875	7.882
Turbidity (NTU)	10	10			0.4	3.1200	2.6095	8.9	0.445	0.9	1.1	2.05	4.95	7.19
Seepage Bore 1b														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	18	18			135	527.3889	110.9140	697	401.05	494.4	506.5	540.5	568.25	639.2
Carbonate Alkalinity as CaCO3 (mg/L)	18	1	17	94.4	8	8.0000	0.0000	8	8	8	8	8	8	8
Hydroxide Alkalinity as CaCO3 (mg/L)	18		18	100.0										
Temperature (field) (°C)	18	18			143	527.8333	109.3457	697	402.25	494.4	506.5	540.5	568.25	639.2
Field Measurements														
Appearance or Colour	12													
Depth of Bore (mbgl)	42	42			16	16.0000	0.0000	16	16	16	16	16	16	16
Depth to Water (mbRL)	42	42			3.09	5.6521	1.4948	9.17	4.0065	4.512	4.5525	5.045	6.965	8.3105
Depth to Water (mbGL)	6	6			6.27	6.8533	0.3318	7.22	6.3525	6.6	6.665	6.93	7.1275	7.2075
Dissolved Oxygen (field) (% sat))	15	15			0	46.6333	59.7785	193.4	0	1.52	2.4	15.2	68.6	169.88

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Electrical Conductivity (field) (µS/cm)	15	15			1232	2114.1333	759.7664	3789	1308.3	1436.8	1458	1908	2533	3425.7
Groundwater Level (mAHD)	42	42			306.41	334.3304	15.3054	373.38	316.8895	324.3588	324.84825	329.6285	348.23825	372.20455
GWL Depth Reference Elevation	42	42			311.33	339.9825	14.9648	378.09	324.062	329.94	330.22	335.23	353.32	376.97855
Odour	12													
ORP (field) (mV)	15	15			-64.3	60.0000	89.1381	231	-64.3	-15.7	-2.15	77	114.7	207.06
pH (field)	15	15			6.1	7.1253	0.5840	8.03	6.1	6.542	6.795	7.27	7.55	7.904
Salinity (field) (PSU)	15	15			0.6	1.0720	0.4078	1.98	0.642	0.708	0.72	0.96	1.29	1.777
TDS (field) (ppm)	15	15			25.11	31.1307	2.6510	35.7	25.971	29.754	30.02	31.64	33.09	34.181
Total Dissolved Solids (field) (ppm)	15	15			616	1057.1333	379.8327	1894	654.5	718.4	729	954	1266	1712.7
Turbidity (field) (FNU)	8	8			0.7	8.4375	7.3043	18.5	0.7	1.1	1.45	6.6	15.275	18.5
Hardness														
Total Hardness (mg CaCO3/L)	18	18			90	609.1667	289.8753	1340	300.8	380.8	417.5	558	724.75	1076.5
Ion Balance														
Ionic Balance (%)	18	18			0.68	4.0339	2.9762	10.9	0.714	1.292	1.38	3.245	5.9	9.1235
Total Anions (meq/L)	18	18			3.81	23.4283	9.5342	44.6	12.1315	15.94	16.5	23.7	26.8	39.16
Total Cations (meq/L)	18	18			3.2	24.8667	10.1932	46.7	12.72	16.3	17.075	24.9	30.5	40.41
Major Ions														
Calcium (mg/L)	36	36			18	123.8611	55.1040	280	69	85	87.5	109.5	139.5	226.25
Chloride (mg/L)	18	18			11	136.8889	95.4969	410	49.25	68.4	71	108.5	159.5	296.1
Fluoride (mg/L)	18	18			1	1.5056	0.2818	2	1	1.34	1.4	1.5	1.6	1.915
Magnesium (mg/L)	36	36			11	76.7222	35.1699	166	32.75	48	50	70.5	92.25	139.75

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Potassium (mg/L)	36	35	1	2.8	4	5.9429	0.9840	8	5	5	5	6	6	8
Sodium (mg/L)	36	36			32	293.1111	97.7269	453	167.75	197	201.25	319.5	365.25	432.5
Sulfate (as SO4)	18	18			31	433.3333	325.0398	1130	53.95	81.2	104.75	463	614.5	950.65
Metals (dissolved)														
Arsenic - dissolved (mg/L)	19	19			0.001	0.0029	0.0009	0.004	0.0019	0.002	0.002	0.003	0.0035	0.004
Barium - dissolved (mg/L)	19	19			0.06	0.1119	0.0568	0.274	0.0618	0.0642	0.0725	0.096	0.1195	0.2182
Bismuth - dissolved (mg/L)	19		19	100.0										
Chromium - dissolved (mg/L)	19		19	100.0										
Cobalt - dissolved (mg/L)	19	15	4	21.1	0.001	0.0020	0.0013	0.006	0.001	0.001	0.001	0.002	0.002	0.0039
Copper - dissolved (mg/L)	19	15	4	21.1	0.001	0.0014	0.0006	0.003	0.001	0.001	0.001	0.001	0.002	0.0023
Molybdenum - dissolved (mg/L)	19	19			0.003	0.0039	0.0011	0.007	0.003	0.003	0.003	0.004	0.004	0.0061
Nickel - dissolved (mg/L)	19	1	18	94.7	0.003	0.0030	0.0000	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Selenium - dissolved (mg/L)	19	2	17	89.5	0.02	0.0250	0.0050	0.03	0.0205	0.022	0.0225	0.025	0.0275	0.0295
Uranium - dissolved (mg/L)	19	19			0.005	0.0128	0.0056	0.026	0.005	0.0076	0.0085	0.014	0.015	0.0224
Metals (total)														
Arsenic - total (mg/L)	19	18	1	5.3	0.002	0.0031	0.0008	0.004	0.002	0.002	0.00225	0.003	0.004	0.004
Barium - total (mg/L)	19	19			0.063	0.1178	0.0552	0.27	0.063	0.081	0.087	0.102	0.124	0.225
Bismuth - total (mg/L)	19		19	100.0										
Chromium - total (mg/L)	19		19	100.0										
Cobalt - total (mg/L)	19	14	5	26.3	0.001	0.0026	0.0013	0.007	0.00165	0.002	0.002	0.002	0.003	0.0044
Copper - total (mg/L)	19	19			0.001	0.0038	0.0024	0.01	0.001	0.002	0.002	0.003	0.005	0.0091

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Molybdenum - total (mg/L)	19	19			0.003	0.0045	0.0011	0.008	0.003	0.004	0.004	0.004	0.005	0.0062
Nickel - total (mg/L)	19	4	15	78.9	0.001	0.0013	0.0004	0.002	0.001	0.001	0.001	0.001	0.00125	0.00185
Selenium - total (mg/L)	19	2	17	89.5	0.02	0.0250	0.0050	0.03	0.0205	0.022	0.0225	0.025	0.0275	0.0295
Uranium - total (mg/L)	19	19			0.005	0.0146	0.0055	0.026	0.0059	0.0106	0.0115	0.015	0.016	0.0251
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	18	18			267	2115.9444	847.3263	3910	1043.05	1400	1460	2100	2707.5	3315
pH (lab)	18	18			7.16	7.7428	0.2876	8.42	7.3045	7.548	7.59	7.73	7.8875	8.114
Turbidity (NTU)	18	18			0.2	7.0500	13.6646	48.4	0.2	0.74	0.85	1.15	4.225	42.62
Seepage Bore 2a														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	13	13			286	511.3846	149.6244	690	292	342.8	353	582	649	684.6
Carbonate Alkalinity as CaCO3 (mg/L)	13		13	100.0										
Hydroxide Alkalinity as CaCO3 (mg/L)	13		13	100.0										
Temperature (field) (°C)	13	13			286	511.3846	149.6244	690	292	342.8	353	582	649	684.6
Field Measurements														
Appearance or Colour	7													
Depth of Bore (mbgl)	42	42			6	6.0333	0.1491	6.7	6	6	6	6	6	6
Depth to Water (mbRL)	41	41			0.67	4.1100	2.0912	7.12	0.85	1.67	1.86	5.13	5.58	6.8
Depth to Water (mbGL)	6	6			5.43	5.5883	0.1336	5.82	5.445	5.49	5.495	5.545	5.67	5.79
Depth to Water Comments	4													
Dissolved Oxygen (field) (% sat))	7	7			2	69.5143	42.4591	110.6	2.69	21.38	47	90.7	94.65	105.95

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Dry?	4													
Electrical Conductivity (field) (µS/cm)	7	7			10.58	5298.6543	3973.8157	9912	695.906	2350.8	2434.5	2879	9710	9908.1
Groundwater Level (mAHD)	41	41			306.2	336.2881	18.0595	377.3	306.6	323.1	324.97	331.867	350.351	376.23
GWL Depth Reference Elevation	42	42			311.33	339.7060	17.7596	378.09	311.33	327.396	330.01	335.005	355.18825	376.97855
Odour	7													
ORP (field) (mV)	7	7			-78.5	45.3714	78.7164	199.5	-58.52	-2.78	10.9	45.9	64.45	161.4
pH (field)	7	7			7.75	8.3186	0.3979	8.92	7.822	8.004	8.025	8.3	8.605	8.887
Salinity (field) (PSU)	7	7			1.17	3.7557	2.1186	5.95	1.212	1.344	1.395	5.29	5.545	5.833
TDS (field) (ppm)	7	7			26.52	29.7500	1.7122	31.86	27.072	28.55	28.835	30.24	30.98	31.701
Total Dissolved Solids (field) (ppm)	7	7			1148	3405.2857	1837.8282	5293	1189.7	1317.6	1363.5	4761	4954	5191.9
Turbidity (field) (FNU)	1	1			19.8	19.8000	0.0000	19.8	19.8	19.8	19.8	19.8	19.8	19.8
Hardness														
Total Hardness (mg CaCO3/L)	13	13			329	466.1538	78.3845	578	339.2	383.2	436	483	520	563
Ion Balance														
Ionic Balance (%)	13	13			0.28	2.5208	2.2004	6.68	0.304	0.396	0.48	2.08	2.99	6.578
Total Anions (meq/L)	13	13			26	72.2846	35.6054	109	26.24	26.94	27.3	96	100	106
Total Cations (meq/L)	13	13			25.5	76.4385	39.4531	119	25.62	26.98	27.4	101	110	116
Major Ions														
Calcium (mg/L)	26	26			86	111.5000	17.8525	150	86.75	96	97.5	113.5	124.75	144.25
Chloride (mg/L)	13	13			276	1329.9231	800.4024	2170	284.4	318.6	342	1860	1950	2098
Fluoride (mg/L)	13	13			1	3.7077	2.0660	5.8	1.06	1.14	1.2	5.1	5.4	5.8

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Magnesium (mg/L)	26	26			23	46.8077	16.1508	64	23.25	25	29.25	55.5	60	63.75
Potassium (mg/L)	26	26			9	13.6923	2.3496	16	10	10	13	14.5	16	16
Sodium (mg/L)	26	26			414	1537.5385	881.9129	2500	421.5	427	436	2085	2247.5	2427.5
Sulfate (as SO4)	13	13			515	1180.9231	490.4217	1630	522.2	555.6	564	1490	1600	1624
Metals (dissolved)														
Arsenic - dissolved (mg/L)	13	13			0.001	0.0025	0.0012	0.004	0.001	0.001	0.001	0.003	0.003	0.004
Barium - dissolved (mg/L)	13	13			0.06	0.0853	0.0166	0.121	0.0618	0.0696	0.075	0.085	0.091	0.112
Bismuth - dissolved (mg/L)	13		13	100.0										
Chromium - dissolved (mg/L)	13		13	100.0										
Cobalt - dissolved (mg/L)	13	8	5	38.5	0.001	0.0011	0.0003	0.002	0.001	0.001	0.001	0.001	0.001	0.00165
Copper - dissolved (mg/L)	13	13			0.002	0.0069	0.0028	0.01	0.0026	0.0034	0.004	0.008	0.009	0.01
Molybdenum - dissolved (mg/L)	13	13			0.014	0.0307	0.0130	0.05	0.014	0.0154	0.016	0.032	0.038	0.0494
Nickel - dissolved (mg/L)	13	12	1	7.7	0.001	0.0018	0.0009	0.004	0.001	0.001	0.001	0.002	0.002	0.00345
Selenium - dissolved (mg/L)	13	8	5	38.5	0.05	0.0538	0.0048	0.06	0.05	0.05	0.05	0.05	0.06	0.06
Uranium - dissolved (mg/L)	13	13			0.014	0.1653	0.1212	0.328	0.0152	0.0196	0.022	0.204	0.254	0.3184
Metals (total)														
Arsenic - total (mg/L)	13	13			0.001	0.0029	0.0014	0.005	0.001	0.0014	0.002	0.003	0.004	0.005
Barium - total (mg/L)	13	13			0.063	0.0911	0.0200	0.131	0.0666	0.0734	0.074	0.09	0.1	0.1274
Bismuth - total (mg/L)	13		13	100.0										
Chromium - total (mg/L)	13	2	11	84.6	0.002	0.0020	0.0000	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cobalt - total (mg/L)	13	9	4	30.8	0.001	0.0022	0.0010	0.005	0.0014	0.002	0.002	0.002	0.002	0.0038

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Copper - total (mg/L)	13	13			0.003	0.0106	0.0046	0.02	0.0048	0.007	0.007	0.01	0.012	0.0194
Molybdenum - total (mg/L)	13	13			0.018	0.0358	0.0130	0.054	0.018	0.0206	0.023	0.038	0.044	0.0528
Nickel - total (mg/L)	13	13			0.001	0.0032	0.0023	0.01	0.001	0.0014	0.002	0.002	0.004	0.007
Selenium - total (mg/L)	13	8	5	38.5	0.05	0.0563	0.0048	0.06	0.05	0.05	0.05	0.06	0.06	0.06
Uranium - total (mg/L)	13	13			0.014	0.1705	0.1220	0.325	0.0164	0.0212	0.023	0.23	0.261	0.3118
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	13	13			2340	7036.1538	3601.7806	11200	2418	2550	2640	9230	10100	10600
pH (lab)	13	13			7.99	8.1323	0.0782	8.25	8.002	8.074	8.08	8.15	8.2	8.232
Turbidity (NTU)	13	13			0.4	2.8462	2.6590	9.4	0.58	0.7	0.7	1.8	3.9	8.08
Seepage Bore 2b														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	19	19			160	574.8421	115.3682	694	468.7	528.8	537	603	660	681.4
Carbonate Alkalinity as CaCO3 (mg/L)	19	1	18	94.7	8	8.0000	0.0000	8	8	8	8	8	8	8
Hydroxide Alkalinity as CaCO3 (mg/L)	19		19	100.0										
Temperature (field) (°C)	19	19			168	575.2632	113.8581	694	469.5	528.8	537	603	660	681.4
Field Measurements														
Appearance or Colour	11													
Depth of Bore (mbgl)	42	42			16	16.0000	0.0000	16	16	16	16	16	16	16
Depth to Water (mbRL)	42	42			0.05	1.5783	0.9540	3.63	0.2735	0.932	0.9825	1.18	2.465	3.4155
Depth to Water (mbGL)	5	5			2.17	2.3720	0.1197	2.49	2.2	2.29	2.32	2.39	2.49	2.49
Dissolved Oxygen (field) (% sat))	15	15			0	52.8067	79.1845	252.5	0	0	0.95	9.1	62.85	210.22

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Electrical Conductivity (field) (µS/cm)	15	15			1206	1611.8000	368.9174	2554	1209.5	1229	1306.5	1546	1887.5	2172.5
Groundwater Level (mAHD)	42	42			308.59	337.6785	18.4241	377.11	310.2955	328.488	328.704	332.609	352.24	377.087
GWL Depth Reference Elevation	42	42			311.33	339.2569	18.2684	378.09	311.33	329.94	330.22	333.746	353.32	378.09
Odour	10													
ORP (field) (mV)	15	15			-43.4	93.1133	66.3781	216.7	1.05	48.04	52.3	100.8	118.5	212.78
pH (field)	15	15			6.02	7.0687	0.6131	8.1	6.02	6.62	6.775	7.18	7.525	7.883
Salinity (field) (PSU)	15	15			0.59	0.7940	0.1708	1.15	0.59	0.6	0.645	0.77	0.95	1.052
TDS (field) (ppm)	15	15			27.83	31.1840	2.4788	36.26	27.935	28.014	29.22	31.28	32.25	35.49
Total Dissolved Solids (field) (ppm)	15	15			603	795.8667	161.1975	1127	605.1	614	653	774	943.5	1040.9
Turbidity (field) (FNU)	7	7			1.1	7.7000	10.6796	33.7	1.7	3.1	3.1	3.4	4.75	25.18
Hardness														
Total Hardness (mg CaCO3/L)	19	19			81	457.3684	143.0735	702	285.3	354.2	363.5	440	530.5	682.2
Ion Balance														
Ionic Balance (%)	19	19			0.24	2.6937	2.4545	10.7	0.528	0.984	1.145	1.89	2.755	6.56
Total Anions (meq/L)	19	19			3.99	17.6626	4.7968	23.4	12.189	13.76	14.55	17.1	21.35	23.04
Total Cations (meq/L)	19	19			3.21	18.1058	5.2559	26	12.021	14.16	15.2	17.5	21.5	25.19
Major Ions														
Calcium (mg/L)	38	38			16	104.2632	28.5571	160	72.4	79.4	81.25	106.5	122	152.3
Chloride (mg/L)	19	19			12	102.4737	40.5805	154	48.9	59.2	61	106	142	145
Fluoride (mg/L)	19	19			1	1.2842	0.1843	1.6	1	1.1	1.15	1.3	1.4	1.6
Magnesium (mg/L)	38	38			10	50.7632	14.8225	79	32.7	36	38	49	59	74.45
Potassium (mg/L)	38	38			1	6.6579	1.1760	8	5	6	6	7	7	8
Sodium (mg/L)	38	38			36	205.8158	48.6220	272	148.75	169.4	172.25	200	245	266.75
Sulfate (as SO4)	19	19			14	157.2632	90.6693	361	55.4	68.2	73.5	138	201	314.2

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Metals (dissolved)														
Arsenic - dissolved (mg/L)	19	4	15	78.9	0.001	0.0013	0.0004	0.002	0.001	0.001	0.001	0.001	0.00125	0.00185
Barium - dissolved (mg/L)	19	19			0.106	0.2053	0.0276	0.239	0.1816	0.1936	0.1945	0.208	0.222	0.2309
Bismuth - dissolved (mg/L)	19		19	100.0										
Chromium - dissolved (mg/L)	19		19	100.0										
Cobalt - dissolved (mg/L)	19	2	17	89.5	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Copper - dissolved (mg/L)	19	11	8	42.1	0.001	0.0017	0.0009	0.004	0.001	0.001	0.001	0.002	0.002	0.003
Molybdenum - dissolved (mg/L)	19	19			0.003	0.0041	0.0010	0.006	0.003	0.003	0.003	0.004	0.005	0.006
Nickel - dissolved (mg/L)	19	7	12	63.2	0.001	0.0011	0.0003	0.002	0.001	0.001	0.001	0.001	0.001	0.0017
Selenium - dissolved (mg/L)	19		19	100.0										
Uranium - dissolved (mg/L)	19	19			0.005	0.0142	0.0056	0.021	0.0059	0.008	0.008	0.016	0.0195	0.021
Metals (total)														
Arsenic - total (mg/L)	19	6	13	68.4	0.001	0.0013	0.0005	0.002	0.001	0.001	0.001	0.001	0.00175	0.002
Barium - total (mg/L)	19	19			0.111	0.2178	0.0323	0.266	0.174	0.2012	0.2055	0.224	0.2345	0.2534
Bismuth - total (mg/L)	19	1	18	94.7	0.00014	0.0001	0.0000	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014
Chromium - total (mg/L)	19	2	17	89.5	0.001	0.0020	0.0010	0.003	0.0011	0.0014	0.0015	0.002	0.0025	0.0029
Cobalt - total (mg/L)	19	12	7	36.8	0.001	0.0019	0.0011	0.005	0.001	0.001	0.001	0.002	0.002	0.0039
Copper - total (mg/L)	19	19			0.002	0.0083	0.0149	0.07	0.002	0.003	0.003	0.003	0.007	0.0178
Molybdenum - total (mg/L)	19	19			0.003	0.0046	0.0011	0.007	0.003	0.004	0.004	0.004	0.0055	0.0061
Nickel - total (mg/L)	19	9	10	52.6	0.001	0.0019	0.0010	0.004	0.001	0.001	0.001	0.002	0.002	0.0036
Selenium - total (mg/L)	19		19	100.0										

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Uranium - total (mg/L)	19	19			0.006	0.0157	0.0060	0.024	0.0069	0.008	0.0085	0.018	0.0205	0.0231
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	19	19			248	1561.4737	450.8181	2210	1068.8	1190	1245	1550	1865	2147
pH (lab)	19	19			7.28	7.7558	0.2684	8.45	7.361	7.516	7.595	7.76	7.915	8.09
Turbidity (NTU)	19	19			0.2	9.5579	18.1888	74.8	0.47	1.08	1.35	3.1	5.7	45.91
Seepage Bore 3a														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	20	20			38	510.6500	212.0121	1060	400.9	429.6	430.75	454	494.5	965
Carbonate Alkalinity as CaCO3 (mg/L)	20	1	19	95.0	13	13.0000	0.0000	13	13	13	13	13	13	13
Hydroxide Alkalinity as CaCO3 (mg/L)	20		20	100.0										
Temperature (field) (°C)	20	20			50	511.2500	210.6865	1060	401.5	429.6	430.75	454	494.5	965
Field Measurements														
Appearance or Colour	12													
Depth of Bore (mbgl)	42	42			6	6.0000	0.0000	6	6	6	6	6	6	6
Depth to Water (mbRL)	42	42			1.34	2.3983	0.5270	3.6	1.567	2.094	2.135	2.245	2.77	3.488
Depth to Water (mbGL)	6	6			2.58	2.7300	0.0879	2.83	2.5975	2.65	2.6725	2.76	2.795	2.8225
Dissolved Oxygen (field) (% sat))	16	16			0	42.8563	81.7536	343.1	0	0	1.35	7.7	47.125	142.775
Electrical Conductivity (field) (µS/cm)	16	16			1093	1714.5625	423.5285	2746	1156	1229	1335.5	1720	2034	2230.75
Groundwater Level (mAHD)	42	42			308.53	335.6640	17.9143	375.89	309.331	324.228	325.375	330.649	351.1375	375.798
GWL Depth Reference Elevation	42	42			311.33	338.0624	17.8890	378.09	311.33	326.76	326.76	333.436	353.32	378.09
Odour	11													

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
ORP (field) (mV)	16	16			-63.3	71.1875	73.6103	223.9	-36.3	30.8	34.775	64.5	102.575	213.175
pH (field)	16	16			6.33	6.9913	0.3921	7.75	6.33	6.63	6.7275	7.075	7.2375	7.525
Salinity (field) (PSU)	16	16			0.53	7.1694	24.4861	102	0.5675	0.61	0.6625	0.86	1.03	26.5575
TDS (field) (ppm)	16	16			25.84	30.8113	2.8376	35.19	25.9825	28.45	28.9675	30.515	33.59	34.5225
Total Dissolved Solids (field) (ppm)	16	16			547	857.3125	211.7583	1373	577.75	615	667.5	860	1017	1114.25
Turbidity (field) (FNU)	7	7			0	5.1143	3.6795	9.9	0.66	2.36	2.6	3.2	8.75	9.9
Hardness														
Total Hardness (mg CaCO3/L)	20	20			40	482.8500	172.5599	787	278.45	315	331	506	559.25	744.25
Ion Balance														
Ionic Balance (%)	19	19			0.22	3.3884	2.6865	12.3	0.553	1.46	1.77	3.06	4.07	7.404
Total Anions (meq/L)	20	20			1.36	18.8880	7.3967	33.6	10.613	12.4	14.475	18.9	22.125	32.365
Total Cations (meq/L)	20	20			1.27	19.3735	7.7406	36.6	11.2735	12.62	13.15	19.05	23.5	32.04
Major Ions														
Calcium (mg/L)	40	40			11	114.3000	35.7402	170	71.2	75.8	77	117.5	143.5	160.1
Chloride (mg/L)	20	20			6	157.3500	82.0386	294	49.7	78.4	107	155	208.25	276.9
Fluoride (mg/L)	20	20			0.5	1.1950	0.2765	1.6	0.69	1	1	1.3	1.4	1.505
Magnesium (mg/L)	40	40			3	49.7250	19.8834	92	26.3	32.4	35.75	46.5	58.25	82.3
Potassium (mg/L)	40	39	1	2.5	3	6.4359	1.9585	10	4	5	5	6	6.5	10
Sodium (mg/L)	40	40			11	222.5500	102.9424	498	121.1	146.8	149.5	189.5	275	389.5
Sulfate (as SO4)	20	20			9	203.6000	104.9030	376	50.8	84.8	121.25	222	278.25	342.75
Metals (dissolved)														
Arsenic - dissolved (mg/L)	20	5	15	75.0	0.001	0.0014	0.0005	0.002	0.001	0.001	0.001	0.001	0.002	0.002
Barium - dissolved (mg/L)	20	20			0.123	0.1699	0.0362	0.25	0.1249	0.1362	0.143	0.1675	0.195	0.23195
Bismuth - dissolved (mg/L)	20		20	100.0										

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Chromium - dissolved (mg/L)	20	1	19	95.0	0.002	0.0020	0.0000	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cobalt - dissolved (mg/L)	20	8	12	60.0	0.001	0.0029	0.0019	0.005	0.001	0.001	0.001	0.0025	0.005	0.005
Copper - dissolved (mg/L)	20	8	12	60.0	0.001	0.0021	0.0020	0.007	0.001	0.001	0.001	0.001	0.00225	0.0056
Molybdenum - dissolved (mg/L)	20	20			0.002	0.0061	0.0039	0.014	0.002	0.0038	0.004	0.0045	0.006	0.01305
Nickel - dissolved (mg/L)	20	8	12	60.0	0.001	0.0039	0.0036	0.013	0.001	0.0014	0.00175	0.003	0.004	0.00985
Selenium - dissolved (mg/L)	20		20	100.0										
Uranium - dissolved (mg/L)	20	20			0.003	0.0341	0.0630	0.244	0.0049	0.007	0.00775	0.011	0.012	0.18415
Metals (total)														
Arsenic - total (mg/L)	20	6	14	70.0	0.001	0.0017	0.0005	0.002	0.001	0.001	0.00125	0.002	0.002	0.002
Barium - total (mg/L)	20	20			0.13	0.1850	0.0360	0.258	0.1357	0.1524	0.15625	0.1825	0.204	0.2466
Bismuth - total (mg/L)	20		20	100.0										
Chromium - total (mg/L)	20	1	19	95.0	0.003	0.0030	0.0000	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Cobalt - total (mg/L)	20	17	3	15.0	0.001	0.0029	0.0017	0.006	0.001	0.0012	0.002	0.002	0.005	0.0052
Copper - total (mg/L)	20	13	7	35.0	0.001	0.0035	0.0033	0.013	0.001	0.002	0.002	0.002	0.003	0.0106
Molybdenum - total (mg/L)	20	20			0.003	0.0066	0.0045	0.016	0.003	0.004	0.004	0.0045	0.006	0.016
Nickel - total (mg/L)	20	11	9	45.0	0.001	0.0025	0.0013	0.004	0.001	0.001	0.001	0.002	0.004	0.004
Selenium - total (mg/L)	20		20	100.0										
Uranium - total (mg/L)	20	20			0.005	0.0360	0.0647	0.247	0.00595	0.008	0.008	0.0115	0.013	0.1919
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	20	20			109	1710.4500	649.1339	2940	993.45	1198	1327.5	1685	2025	2902
pH (lab)	20	20			7.14	7.7310	0.3760	8.82	7.216	7.4	7.4725	7.655	7.9225	8.174

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Turbidity (NTU)	20	20			0.2	3.7000	7.7545	36.2	0.295	0.54	0.6	0.95	3.825	8.65
Seepage Bore 3b														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	19	19			99	450.9474	91.8858	543	381.6	428	432	462	498	538.5
Carbonate Alkalinity as CaCO3 (mg/L)	19	1	18	94.7	8	8.0000	0.0000	8	8	8	8	8	8	8
Hydroxide Alkalinity as CaCO3 (mg/L)	19		19	100.0										
Temperature (field) (°C)	19	19			107	451.3684	90.2763	543	382.4	428	432	462	498	538.5
Field Measurements														
Appearance or Colour	11													
Depth of Bore (mbgl)	42	42			16	16.0000	0.0000	16	16	16	16	16	16	16
Depth to Water (mbRL)	42	42			0.05	1.2914	1.0368	3.23	0.1	0.45	0.515	0.805	2.4125	3.195
Depth to Water (mbGL)	6	6			2.06	2.3567	0.1350	2.45	2.14	2.38	2.3825	2.405	2.435	2.4475
Dissolved Oxygen (field) (% sat))	16	16			0	48.0188	110.3114	468	0	2.8	5.725	13.45	41.775	172.275
Electrical Conductivity (field) (µS/cm)	16	16			974	1349.6875	340.4487	1804	975.5	1014	1014	1199	1731	1798.75
Groundwater Level (mAHD)	42	42			308.74	337.4589	15.8527	377.48	311.32	329.008	329.327	334.7335	348.39675	376.25855
GWL Depth Reference Elevation	42	42			311.33	338.7503	15.5816	378.09	311.9595	329.94	329.94	335.23	349.38225	376.97605
Odour	10													
ORP (field) (mV)	16	16			-59.9	90.1375	70.6897	231.4	-8.3	51.8	55.325	86.65	122.9	225.925
pH (field)	16	16			5.95	6.8869	0.4636	7.66	6.145	6.62	6.6425	6.98	7.165	7.63
Salinity (field) (PSU)	16	16			0.47	0.6700	0.1784	0.91	0.47	0.5	0.5	0.59	0.875	0.9025

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
TDS (field) (ppm)	16	16			24.67	30.9531	2.7324	35.4	26.5	29.7	29.8125	30.7	32.8625	35.1
Total Dissolved Solids (field) (ppm)	16	16			486	674.8750	170.3467	902	487.5	507	507	599.5	865.75	899.75
Turbidity (field) (FNU)	7	7			0	1.2571	0.8398	2.2	0.09	0.42	0.6	1.2	2.1	2.17
Hardness														
Total Hardness (mg CaCO3/L)	19	19			86	450.1579	169.7764	817	259.7	314	316.5	490	570	654.1
Ion Balance														
Ionic Balance (%)	18	18			1.1	3.8300	2.4736	10.2	1.355	1.796	1.9825	3.045	4.6225	8.8315
Total Anions (meq/L)	19	19			2.57	14.6826	4.8537	22.2	9.707	10.86	10.95	15.8	18.85	20.4
Total Cations (meq/L)	19	19			3.07	15.7405	5.4791	27.2	9.847	11.56	11.6	16.6	19.8	22.7
Major Ions														
Calcium (mg/L)	38	38			18	104.4211	36.1333	182	64.85	72.4	73	114	132.25	151.4
Chloride (mg/L)	19	19			8	84.1053	46.7692	162	35	40.8	44	77	125	151.2
Fluoride (mg/L)	19	19			0.9	1.1579	0.0990	1.3	0.99	1.1	1.1	1.2	1.2	1.3
Magnesium (mg/L)	38	38			10	47.8684	17.1636	88	29	32	33	51	60	69.3
Potassium (mg/L)	38	37	1	2.6	4	5.3784	0.6304	7	4.8	5	5	5	6	6
Sodium (mg/L)	38	38			31	154.2632	43.0781	246	111.85	117.4	119.25	153.5	184.5	221.35
Sulfate (as SO4)	19	19			10	158.2632	116.9336	441	39.7	47.2	48	157	246.5	324
Metals (dissolved)														
Arsenic - dissolved (mg/L)	19	4	15	78.9	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Barium - dissolved (mg/L)	19	19			0.089	0.1516	0.0460	0.274	0.0971	0.1054	0.1105	0.154	0.1795	0.2155
Bismuth - dissolved (mg/L)	19		19	100.0										
Chromium - dissolved (mg/L)	19		19	100.0										
Cobalt - dissolved (mg/L)	19	5	14	73.7	0.001	0.0012	0.0004	0.002	0.001	0.001	0.001	0.001	0.001	0.0018

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Copper - dissolved (mg/L)	19	1	18	94.7	0.002	0.0020	0.0000	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Molybdenum - dissolved (mg/L)	19	19			0.001	0.0025	0.0009	0.005	0.0019	0.002	0.002	0.002	0.003	0.0041
Nickel - dissolved (mg/L)	19		19	100.0										
Selenium - dissolved (mg/L)	19	1	18	94.7	0.02	0.0200	0.0000	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Uranium - dissolved (mg/L)	19	19			0.003	0.0090	0.0048	0.018	0.0039	0.0046	0.005	0.008	0.012	0.0171
Metals (total)														
Arsenic - total (mg/L)	19	5	14	73.7	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Barium - total (mg/L)	19	19			0.101	0.1608	0.0484	0.288	0.1046	0.112	0.116	0.163	0.1945	0.2205
Bismuth - total (mg/L)	19		19	100.0										
Chromium - total (mg/L)	19	1	18	94.7	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cobalt - total (mg/L)	19	13	6	31.6	0.001	0.0016	0.0008	0.003	0.001	0.001	0.001	0.001	0.002	0.003
Copper - total (mg/L)	19	11	8	42.1	0.001	0.0048	0.0072	0.027	0.001	0.002	0.002	0.002	0.003	0.017
Molybdenum - total (mg/L)	19	19			0.002	0.0030	0.0010	0.005	0.002	0.002	0.002	0.003	0.003	0.005
Nickel - total (mg/L)	19	1	18	94.7	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Selenium - total (mg/L)	19	1	18	94.7	0.02	0.0200	0.0000	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Uranium - total (mg/L)	19	19			0.005	0.0100	0.0049	0.02	0.005	0.0056	0.006	0.008	0.0125	0.0182
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	19	19			192	1360.8421	478.4407	2200	869.7	968.2	989.5	1430	1750	1939
pH (lab)	19	19			7.13	7.6184	0.3095	8.47	7.166	7.352	7.4	7.62	7.785	7.993
Turbidity (NTU)	19	18	1	5.3	0.1	4.7611	11.7446	51.2	0.27	0.3	0.35	1.25	1.6	20.515
Seepage Bore 4a														
Alkalinity														

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Bicarbonate Alkalinity as CaCO3 (mg/L)	7	7			346	941.0000	267.6229	1200	503.2	885.4	908.5	964	1130	1191
Carbonate Alkalinity as CaCO3 (mg/L)	7	1	6	85.7	412	412.0000	0.0000	412	412	412	412	412	412	412
Hydroxide Alkalinity as CaCO3 (mg/L)	7		7	100.0										
Temperature (field) (°C)	7	7			758	999.8571	149.5559	1200	791.6	885.4	908.5	964	1130	1191
Field Measurements														
Appearance or Colour	4													
Depth of Bore (mbgl)	41	41			6	6.0000	0.0000	6	6	6	6	6	6	6
Depth to Water (mbRL)	20	20			3.91	5.2365	0.8929	6.49	4.0715	4.402	4.5075	4.955	5.935	6.49
Depth to Water (mbGL)	2	2			4.25	4.6400	0.3900	5.03	4.289	4.406	4.445	4.64	4.835	4.991
Depth to Water Comments	24													
Dissolved Oxygen (field) (% sat))	4	4			0	24.7000	26.5333	68.3	1.095	4.38	5.475	15.25	34.475	61.535
Dry?	24													
Electrical Conductivity (field) (µS/cm)	4	4			1508	2062.7500	342.9208	2436	1596.05	1860.2	1948.25	2153.5	2268	2402.4
Groundwater Level (mAHD)	20	20			305.32	328.2914	13.5573	351.301	305.4435	321.318	322.4425	326.222	331.67975	351.168
GWL Depth Reference Elevation	41	41			311.33	338.4755	16.5203	378.09	311.33	329.94	330.22	334.78	337.569	378.09
Odour	4													
ORP (field) (mV)	4	4			-81.1	-43.3500	24.2828	-20.9	-76.165	-61.36	-56.425	-35.7	-22.625	-21.245
pH (field)	4	4			7.16	7.7650	0.3806	8.1	7.244	7.496	7.58	7.9	8.085	8.097
Salinity (field) (PSU)	4	4			0.75	1.0425	0.1809	1.24	0.7965	0.936	0.9825	1.09	1.15	1.222
TDS (field) (ppm)	4	4			29.36	31.1150	1.3197	33.08	29.6015	30.326	30.5675	31.01	31.5575	32.7755

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Total Dissolved Solids (field) (ppm)	4	4			754	1031.0000	171.1768	1217	797.95	929.8	973.75	1076.5	1133.75	1200.35
Hardness														
Total Hardness (mg CaCO3/L)	7	7			340	436.0000	63.6014	526	345.4	371.8	392.5	431	485	514.3
Ion Balance														
Ionic Balance (%)	7	7			0.06	2.4657	2.0532	6.13	0.168	0.514	0.655	2.51	3.625	5.584
Total Anions (meq/L)	7	7			19.2	24.2286	3.2358	28.1	19.62	21.04	21.7	24.5	27.2	27.89
Total Cations (meq/L)	7	7			19.4	24.5714	3.2261	28.4	19.85	21.56	22.55	24.2	27.45	28.34
Major Ions														
Calcium (mg/L)	14	14			4	18.7857	20.3862	70	4.65	6	6	6	24.25	63.5
Chloride (mg/L)	7	7			62	89.7143	33.5632	161	62.6	65.2	67	70	100.5	146.9
Fluoride (mg/L)	7	7			1.4	1.8571	0.2195	2.1	1.49	1.74	1.8	1.9	2	2.07
Magnesium (mg/L)	14	14			74	97.5714	14.5784	122	77.25	82.8	84.75	100.5	108	118.75
Potassium (mg/L)	14	14			6	8.5714	1.1157	10	6.65	8	8	9	9	10
Sodium (mg/L)	14	14			220	363.2143	69.1894	440	220.65	315	326.25	397	412.75	429.6
Sulfate (as SO4)	7	7			69	83.0000	9.2428	99	71.7	78	78	79	89	96.6
Metals (dissolved)														
Arsenic - dissolved (mg/L)	7	7			0.002	0.0056	0.0017	0.008	0.0029	0.0052	0.0055	0.006	0.006	0.0074
Barium - dissolved (mg/L)	7	7			0.085	0.1503	0.0382	0.202	0.0961	0.1256	0.131	0.14	0.1815	0.1996
Bismuth - dissolved (mg/L)	7		7	100.0										
Chromium - dissolved (mg/L)	7	1	6	85.7	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cobalt - dissolved (mg/L)	7	5	2	28.6	0.001	0.0014	0.0005	0.002	0.001	0.001	0.001	0.001	0.002	0.002
Copper - dissolved (mg/L)	7	2	5	71.4	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Molybdenum - dissolved (mg/L)	7	7			0.011	0.0140	0.0027	0.019	0.0113	0.012	0.012	0.013	0.0155	0.0184

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Nickel - dissolved (mg/L)	7	2	5	71.4	0.002	0.0045	0.0025	0.007	0.00225	0.003	0.00325	0.0045	0.00575	0.00675
Selenium - dissolved (mg/L)	7		7	100.0										
Uranium - dissolved (mg/L)	7	7			0.009	0.0124	0.0028	0.016	0.009	0.0092	0.0095	0.013	0.015	0.0157
Metals (total)														
Arsenic - total (mg/L)	7	7			0.003	0.0057	0.0016	0.008	0.0033	0.0044	0.005	0.006	0.0065	0.0077
Barium - total (mg/L)	7	7			0.109	0.1656	0.0366	0.22	0.1129	0.1296	0.141	0.168	0.19	0.2128
Bismuth - total (mg/L)	7		7	100.0										
Chromium - total (mg/L)	7	2	5	71.4	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cobalt - total (mg/L)	7	6	1	14.3	0.001	0.0023	0.0014	0.005	0.001	0.001	0.00125	0.002	0.00275	0.0045
Copper - total (mg/L)	7	5	2	28.6	0.001	0.0044	0.0031	0.01	0.0012	0.0018	0.002	0.004	0.005	0.009
Molybdenum - total (mg/L)	7	7			0.013	0.0163	0.0025	0.021	0.0133	0.0142	0.0145	0.016	0.0175	0.0201
Nickel - total (mg/L)	7	3	4	57.1	0.001	0.0013	0.0005	0.002	0.001	0.001	0.001	0.001	0.0015	0.0019
Selenium - total (mg/L)	7		7	100.0										
Uranium - total (mg/L)	7	7			0.01	0.0146	0.0032	0.019	0.0106	0.0122	0.0125	0.014	0.017	0.019
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	7	7			1690	2067.1429	268.4726	2550	1723	1836	1890	2070	2190	2472
pH (lab)	7	7			7.81	8.0500	0.1918	8.34	7.825	7.862	7.865	8.11	8.18	8.313
Turbidity (NTU)	7	7			0.4	3.7000	2.0633	6.9	0.85	2	2.15	4.4	4.95	6.39
Seepage Bore 4b														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	17	17			645	822.0000	77.9796	1020	706.6	780.4	798	821	859	928.8

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Carbonate Alkalinity as CaCO3 (mg/L)	17	1	16	94.1	35	35.0000	0.0000	35	35	35	35	35	35	35
Hydroxide Alkalinity as CaCO3 (mg/L)	17		17	100.0										
Temperature (field) (°C)	17	17			680	824.0588	73.6194	1020	713.6	780.4	798	821	859	928.8
Field Measurements														
Appearance or Colour	11													
Depth of Bore (mbgl)	42	42			16	16.0000	0.0000	16	16	16	16	16	16	16
Depth to Water (mbRL)	41	41			3.98	5.6566	0.9769	7.56	4.14	4.66	4.88	5.89	6.4	7.1
Depth to Water (mbGL)	4	4			4.28	4.7050	0.3841	5.21	4.2965	4.346	4.3625	4.665	5.0075	5.1695
Depth to Water Comments	1													
Dissolved Oxygen (field) (% sat))	16	16			0	29.5250	41.1348	133.1	0	0	0.375	7.1	40.45	114.8
Dry?	1													
Electrical Conductivity (field) (µS/cm)	16	16			1514	1802.6875	227.9141	2286	1555.25	1582	1592.5	1787.5	1916	2238.75
Groundwater Level (mAHD)	41	41			305.05	330.9974	16.8173	372.82	306.67	319.94	322.38	325.152	346.22	370.99
GWL Depth Reference Elevation	42	42			311.33	336.6679	16.7673	378.09	311.33	324.488	327.445	331.968	349.38225	376.97605
Odour	11													
ORP (field) (mV)	16	16			-66.8	33.8875	66.0963	193.9	-54.65	-24.1	-23.275	39.55	66.2	132.775
pH (field)	16	16			6.18	7.1688	0.5650	8.03	6.18	6.79	6.895	7.315	7.5225	7.955
Salinity (field) (PSU)	16	16			0.75	0.9025	0.1217	1.16	0.7725	0.78	0.7875	0.895	0.96	1.1375
TDS (field) (ppm)	16	16			26.92	30.7931	1.7998	34	28.15	29.1	29.4225	30.935	32.05	33.295
Total Dissolved Solids (field) (ppm)	16	16			757	901.3750	113.8787	1143	778	790	796	894	957.5	1119.75
Turbidity (field) (FNU)	7	7			1.4	4.3857	2.4098	7.7	1.61	2.24	2.45	3.5	6.6	7.7

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Hardness														
Total Hardness (mg CaCO3/L)	17	17			315	479.5294	87.7115	632	319	416.4	434	496	538	615.2
Ion Balance														
Ionic Balance (%)	17	17			1.05	2.9118	2.1468	9.67	1.106	1.3	1.38	2.16	3.68	6.91
Total Anions (meq/L)	17	17			16.2	20.5824	2.0495	23.4	16.44	19.06	19.3	20.8	22.3	22.84
Total Cations (meq/L)	17	17			17.4	21.0235	2.2399	24.4	17.64	18.56	18.8	21.5	23	23.6
Major Ions														
Calcium (mg/L)	34	34			31	56.7647	13.7863	85	32	48	49.25	56.5	65	77.35
Chloride (mg/L)	17	17			44	84.0000	25.3168	122	50.4	54.2	59	89	108	115.6
Fluoride (mg/L)	17	17			1.9	2.3176	0.4656	4	1.98	2.02	2.1	2.2	2.3	2.88
Magnesium (mg/L)	34	34			56	83.8824	13.4093	108	58.3	73.4	76	87	92	103.45
Potassium (mg/L)	34	34			5	6.2647	0.5588	7	5.65	6	6	6	7	7
Sodium (mg/L)	34	34			212	262.7353	29.1520	312	216.95	234.6	244	259.5	286.5	310.35
Sulfate (as SO4)	17	17			42	84.0000	17.4996	110	50.8	71.6	74	89	95	106
Metals (dissolved)														
Arsenic - dissolved (mg/L)	17	17			0.002	0.0031	0.0010	0.005	0.002	0.002	0.002	0.003	0.004	0.0042
Barium - dissolved (mg/L)	17	17			0.068	0.1062	0.0188	0.131	0.076	0.0862	0.091	0.115	0.119	0.1294
Bismuth - dissolved (mg/L)	17		17	100.0										
Chromium - dissolved (mg/L)	17		17	100.0										
Cobalt - dissolved (mg/L)	17	8	9	52.9	0.001	0.0015	0.0007	0.003	0.001	0.001	0.001	0.001	0.002	0.00265
Copper - dissolved (mg/L)	17	12	5	29.4	0.001	0.0018	0.0006	0.003	0.001	0.0012	0.00175	0.002	0.002	0.00245
Molybdenum - dissolved (mg/L)	17	17			0.009	0.0132	0.0021	0.017	0.009	0.012	0.012	0.013	0.015	0.0162

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Nickel - dissolved (mg/L)	17		17	100.0										
Selenium - dissolved (mg/L)	17		17	100.0										
Uranium - dissolved (mg/L)	17	17			0.006	0.0115	0.0026	0.017	0.0084	0.0092	0.01	0.011	0.013	0.0154
Metals (total)														
Arsenic - total (mg/L)	17	17			0.002	0.0033	0.0008	0.005	0.002	0.003	0.003	0.003	0.004	0.0042
Barium - total (mg/L)	17	17			0.07	0.1136	0.0170	0.138	0.0844	0.1024	0.108	0.116	0.126	0.1316
Bismuth - total (mg/L)	17		17	100.0										
Chromium - total (mg/L)	17		17	100.0										
Cobalt - total (mg/L)	17	12	5	29.4	0.001	0.0018	0.0008	0.004	0.001	0.001	0.001	0.002	0.002	0.0029
Copper - total (mg/L)	17	17			0.001	0.0038	0.0020	0.008	0.001	0.002	0.002	0.004	0.005	0.0064
Molybdenum - total (mg/L)	17	17			0.012	0.0161	0.0019	0.021	0.0136	0.015	0.015	0.016	0.017	0.0186
Nickel - total (mg/L)	17	1	16	94.1	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Selenium - total (mg/L)	17		17	100.0										
Uranium - total (mg/L)	17	17			0.007	0.0136	0.0024	0.017	0.0102	0.012	0.012	0.014	0.015	0.017
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	17	17			1440	1771.1765	170.9793	2080	1512	1602	1610	1820	1870	1992
pH (lab)	17	17			7.41	7.8147	0.2771	8.36	7.426	7.526	7.59	7.78	8.01	8.192
Turbidity (NTU)	17	17			0.4	3.1353	2.7585	8.6	0.4	0.62	0.7	2.4	6.1	7.64
Seepage Bore 5a														
Alkalinity														

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Bicarbonate Alkalinity as CaCO3 (mg/L)	10	10			176	223.8000	37.2177	301	183.65	197	199.25	213	236.75	290.65
Carbonate Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Hydroxide Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Temperature (field) (°C)	10	10			176	223.8000	37.2177	301	183.65	197	199.25	213	236.75	290.65
Field Measurements														
Appearance or Colour	2													
Depth to Water (mbRL)	2	2			3.13	3.1800	0.0500	3.23	3.135	3.15	3.155	3.18	3.205	3.225
Dissolved Oxygen (field) (% sat))	2	2			28.7	37.9000	9.2000	47.1	29.62	32.38	33.3	37.9	42.5	46.18
Electrical Conductivity (field) (µS/cm)	2	2			1595	1686.0000	91.0000	1777	1604.1	1631.4	1640.5	1686	1731.5	1767.9
Groundwater Level (mAHD)	2	2			323.53	323.5800	0.0500	323.63	323.535	323.55	323.555	323.58	323.605	323.625
GWL Depth Reference Elevation	2	2			326.76	326.7600	0.0000	326.76	326.76	326.76	326.76	326.76	326.76	326.76
Odour	2													
ORP (field) (mV)	2	2			-54.4	-49.3500	5.0500	-44.3	-53.895	-52.38	-51.875	-49.35	-46.825	-44.805
pH (field)	2	2			9.08	9.1550	0.0750	9.23	9.0875	9.11	9.1175	9.155	9.1925	9.2225
Salinity (field) (PSU)	2	2			0.8	0.8450	0.0450	0.89	0.8045	0.818	0.8225	0.845	0.8675	0.8855
TDS (field) (ppm)	2	2			28.08	28.7900	0.7100	29.5	28.151	28.364	28.435	28.79	29.145	29.429
Total Dissolved Solids (field) (ppm)	2	2			797	843.0000	46.0000	889	801.6	815.4	820	843	866	884.4
Hardness														
Total Hardness (mg CaCO3/L)	10	10			448	1291.8000	615.4362	2060	467.35	511	622.75	1410	1892.5	2028.5
Ion Balance														
Ionic Balance (%)	10	10			3.8	14.4150	4.9748	20.4	6.2525	10.73	11.675	15.35	18.35	20.175

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Total Anions (meq/L)	10	10			12.9	30.0800	10.9523	43	13.935	15.68	19.275	33	39.05	42.91
Total Cations (meq/L)	10	10			17.1	41.3100	17.4151	62.9	17.91	18.98	22.275	44.65	58.35	62.045
Major Ions														
Calcium (mg/L)	20	20			110	312.4500	141.3448	483	110	125.6	130.25	350.5	445.5	470.65
Chloride (mg/L)	10	10			23	109.0000	52.9415	171	26.6	43.8	62.75	124.5	155.25	166.95
Fluoride (mg/L)	10	10			0.5	0.7100	0.1972	1	0.5	0.58	0.6	0.6	0.925	1
Magnesium (mg/L)	20	20			41	135.8500	65.4884	211	41.95	49.8	50.75	149	204	209.1
Potassium (mg/L)	20	20			7	13.5000	3.9937	19	7	8.8	9	15.5	17	18.05
Sodium (mg/L)	20	20			183	355.8000	117.4915	494	183.95	199.2	203.75	383.5	462.5	490.2
Sulfate (as SO4)	10	10			418	1082.5000	434.1404	1660	453.1	500	643.25	1195	1397.5	1615
Metals (dissolved)														
Arsenic - dissolved (mg/L)	10	3	7	70.0	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Barium - dissolved (mg/L)	10	10			0.083	0.0982	0.0112	0.125	0.08615	0.0908	0.0915	0.095	0.1025	0.11735
Bismuth - dissolved (mg/L)	10		10	100.0										
Chromium - dissolved (mg/L)	10		10	100.0										
Cobalt - dissolved (mg/L)	10	8	2	20.0	0.001	0.0030	0.0011	0.004	0.00135	0.002	0.002	0.0035	0.004	0.004
Copper - dissolved (mg/L)	10	10			0.002	0.0097	0.0071	0.029	0.0029	0.004	0.005	0.009	0.01	0.02135
Molybdenum - dissolved (mg/L)	10	10			0.007	0.0141	0.0042	0.02	0.00835	0.0108	0.01125	0.013	0.018	0.01955
Nickel - dissolved (mg/L)	10	6	4	40.0	0.001	0.0015	0.0008	0.003	0.001	0.001	0.001	0.001	0.00175	0.00275
Selenium - dissolved (mg/L)	10	10			0.02	0.0810	0.0448	0.14	0.02	0.02	0.03	0.095	0.12	0.131
Uranium - dissolved (mg/L)	10	10			0.009	0.0166	0.0074	0.032	0.00945	0.01	0.0105	0.015	0.01825	0.0302
Metals (total)														

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Arsenic - total (mg/L)	10	4	6	60.0	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Barium - total (mg/L)	10	10			0.08	0.1045	0.0116	0.126	0.0881	0.098	0.0985	0.104	0.11225	0.1206
Bismuth - total (mg/L)	10		10	100.0										
Chromium - total (mg/L)	10	2	8	80.0	0.003	0.0040	0.0010	0.005	0.0031	0.0034	0.0035	0.004	0.0045	0.0049
Cobalt - total (mg/L)	10	9	1	10.0	0.001	0.0037	0.0018	0.006	0.001	0.0022	0.003	0.004	0.005	0.006
Copper - total (mg/L)	10	10			0.003	0.0098	0.0046	0.02	0.00345	0.0056	0.007	0.01	0.01175	0.0164
Molybdenum - total (mg/L)	10	10			0.009	0.0148	0.0044	0.021	0.009	0.0114	0.012	0.014	0.019	0.021
Nickel - total (mg/L)	10	6	4	40.0	0.001	0.0022	0.0011	0.004	0.001	0.001	0.00125	0.002	0.00275	0.00375
Selenium - total (mg/L)	10	10			0.02	0.0850	0.0457	0.15	0.02	0.02	0.0375	0.095	0.12	0.1365
Uranium - total (mg/L)	10	10			0.009	0.0180	0.0069	0.032	0.0099	0.011	0.012	0.017	0.0215	0.0293
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	10	10			1570	3794.0000	1449.3944	5510	1646.5	1860	2387.5	4050	5007.5	5442.5
pH (lab)	10	10			7.5	7.7330	0.1736	8.09	7.509	7.576	7.6075	7.705	7.8375	8
Turbidity (NTU)	10	10			0.3	4.1400	7.6216	25.8	0.345	0.56	0.625	0.8	1.725	18.195
Seepage Bore 5b														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	10	10			124	136.6000	9.9418	158	125.35	127.8	129.25	134.5	140.5	153.95
Carbonate Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Hydroxide Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Temperature (field) (°C)	10	10			124	136.6000	9.9418	158	125.35	127.8	129.25	134.5	140.5	153.95
Field Measurements														

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Appearance or Colour	1													
Depth to Water (mbRL)	2	2			3.09	3.1600	0.0700	3.23	3.097	3.118	3.125	3.16	3.195	3.223
Dissolved Oxygen (field) (% sat))	1	1			56.9	56.9000	0.0000	56.9	56.9	56.9	56.9	56.9	56.9	56.9
Electrical Conductivity (field) (µS/cm)	1	1			2242	2242.0000	0.0000	2242	2242	2242	2242	2242	2242	2242
Groundwater Level (mAHD)	2	2			323.67	338.1255	14.4555	352.581	325.11555	329.4522	330.89775	338.1255	345.35325	351.13545
GWL Depth Reference Elevation	2	2			326.76	341.2855	14.5255	355.811	328.21255	332.5702	334.02275	341.2855	348.54825	354.35845
Odour	1													
ORP (field) (mV)	1	1			-59.1	-59.1000	0.0000	-59.1	-59.1	-59.1	-59.1	-59.1	-59.1	-59.1
pH (field)	1	1			9.06	9.0600	0.0000	9.06	9.06	9.06	9.06	9.06	9.06	9.06
Salinity (field) (PSU)	1	1			1.14	1.1400	0.0000	1.14	1.14	1.14	1.14	1.14	1.14	1.14
TDS (field) (ppm)	1	1			28.67	28.6700	0.0000	28.67	28.67	28.67	28.67	28.67	28.67	28.67
Total Dissolved Solids (field) (ppm)	1	1			1122	1122.0000	0.0000	1122	1122	1122	1122	1122	1122	1122
Hardness														
Total Hardness (mg CaCO3/L)	10	10			405	550.8000	76.9919	632	419.85	490.8	509	577	617.75	632
Ion Balance														
Ionic Balance (%)	10	10			4.66	8.6050	2.3265	13	5.335	6.928	7.125	8.915	9.515	12.235
Total Anions (meq/L)	10	10			17.3	20.9000	1.5710	23.6	18.29	20.06	20.375	21.3	21.65	22.745
Total Cations (meq/L)	10	10			20.6	24.8700	2.2181	27.7	21.41	23.12	23.325	25.5	26.625	27.475
Major Ions														
Calcium (mg/L)	20	20			91	128.6000	19.9685	161	92.9	111.6	115.25	132.5	142.75	154.35
Chloride (mg/L)	10	10			52	66.5000	7.1589	82	56.5	63.6	64.25	66.5	67.75	77.5

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Fluoride (mg/L)	10	10			1.2	1.3700	0.1269	1.5	1.2	1.2	1.225	1.4	1.5	1.5
Magnesium (mg/L)	20	20			39	57.3000	7.7143	71	41.85	53.4	54.75	58	64	65.3
Potassium (mg/L)	20	20			2	3.8000	0.5099	4	2.95	4	4	4	4	4
Sodium (mg/L)	20	20			287	320.5500	18.1590	353	288.9	309.4	312.5	320.5	333.25	348.25
Sulfate (as SO4)	10	10			626	783.0000	65.4034	879	672.35	756.2	763.5	804.5	812.75	858.75
Metals (dissolved)														
Arsenic - dissolved (mg/L)	10	10			0.001	0.0017	0.0005	0.002	0.001	0.001	0.00125	0.002	0.002	0.002
Barium - dissolved (mg/L)	10	10			0.098	0.1244	0.0140	0.15	0.10205	0.1158	0.1195	0.126	0.12825	0.1455
Bismuth - dissolved (mg/L)	10		10	100.0										
Chromium - dissolved (mg/L)	10	1	9	90.0	0.005	0.0050	0.0000	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Cobalt - dissolved (mg/L)	10	10			0.002	0.0026	0.0007	0.004	0.002	0.002	0.002	0.0025	0.003	0.00355
Copper - dissolved (mg/L)	10	10			0.003	0.0074	0.0030	0.013	0.0039	0.005	0.00525	0.007	0.0085	0.01255
Molybdenum - dissolved (mg/L)	10	10			0.066	0.0787	0.0102	0.1	0.06645	0.0686	0.06975	0.078	0.0855	0.09415
Nickel - dissolved (mg/L)	10	10			0.004	0.0042	0.0006	0.006	0.004	0.004	0.004	0.004	0.004	0.0051
Selenium - dissolved (mg/L)	10	10			0.01	0.0230	0.0064	0.03	0.0145	0.02	0.02	0.02	0.03	0.03
Uranium - dissolved (mg/L)	10	10			0.002	0.0029	0.0007	0.004	0.002	0.002	0.00225	0.003	0.003	0.004
Metals (total)														
Arsenic - total (mg/L)	10	10			0.002	0.0020	#NUM!	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Barium - total (mg/L)	10	10			0.094	0.1302	0.0137	0.148	0.1066	0.1268	0.12925	0.133	0.13575	0.1444
Bismuth - total (mg/L)	10		10	100.0										
Chromium - total (mg/L)	10	1	9	90.0	0.006	0.0060	0.0000	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Cobalt - total (mg/L)	10	10			0.002	0.0029	0.0009	0.004	0.002	0.002	0.002	0.0025	0.004	0.004
Copper - total (mg/L)	10	10			0.006	0.0093	0.0023	0.014	0.00645	0.0078	0.008	0.009	0.0105	0.0131

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Molybdenum - total (mg/L)	10	10			0.074	0.0876	0.0095	0.105	0.0758	0.0812	0.08225	0.085	0.0925	0.10365
Nickel - total (mg/L)	10	10			0.004	0.0042	0.0004	0.005	0.004	0.004	0.004	0.004	0.004	0.005
Selenium - total (mg/L)	10	10			0.01	0.0250	0.0081	0.04	0.0145	0.02	0.02	0.025	0.03	0.0355
Uranium - total (mg/L)	10	10			0.003	0.0037	0.0006	0.005	0.003	0.003	0.003	0.004	0.004	0.00455
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	10	10			1770	2291.0000	218.8812	2600	1900.5	2180	2245	2350	2390	2528
pH (lab)	10	10			7.55	7.8140	0.1472	8.05	7.5905	7.68	7.7175	7.825	7.895	8.0275
Turbidity (NTU)	10	10			0.5	1.3300	1.2442	4.2	0.5	0.5	0.525	0.6	1.4	3.75
Seepage Bore 6a														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	10	10			78	125.8000	25.0152	172	91.95	112.2	113.5	122	138	165.25
Carbonate Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Hydroxide Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Temperature (field) (°C)	10	10			78	125.8000	25.0152	172	91.95	112.2	113.5	122	138	165.25
Field Measurements														
Appearance or Colour	2													
Depth to Water (mbRL)	2	2			2.15	2.9200	0.7700	3.69	2.227	2.458	2.535	2.92	3.305	3.613
Dissolved Oxygen (field) (% sat))	2	2			68.5	80.5500	12.0500	92.6	69.705	73.32	74.525	80.55	86.575	91.395
Electrical Conductivity (field) (µS/cm)	2	2			1208	1894.5000	686.5000	2581	1276.65	1482.6	1551.25	1894.5	2237.75	2512.35
Groundwater Level (mAHD)	2	2			331.54	332.3100	0.7700	333.08	331.617	331.848	331.925	332.31	332.695	333.003
GWL Depth Reference Elevation	2	2			335.23	335.2300	0.0000	335.23	335.23	335.23	335.23	335.23	335.23	335.23

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Odour	2													
ORP (field) (mV)	2	2			-56.1	-20.6000	35.5000	14.9	-52.55	-41.9	-38.35	-20.6	-2.85	11.35
pH (field)	2	2			7.52	7.8900	0.3700	8.26	7.557	7.668	7.705	7.89	8.075	8.223
Salinity (field) (PSU)	2	2			0.6	0.9650	0.3650	1.33	0.6365	0.746	0.7825	0.965	1.1475	1.2935
TDS (field) (ppm)	2	2			27.2	27.3700	0.1700	27.54	27.217	27.268	27.285	27.37	27.455	27.523
Total Dissolved Solids (field) (ppm)	2	2			604	947.5000	343.5000	1291	638.35	741.4	775.75	947.5	1119.25	1256.65
Hardness														
Total Hardness (mg CaCO3/L)	10	10			448	1328.5000	841.4824	2500	454.3	506.8	575	885.5	2270	2473
Ion Balance														
Ionic Balance (%)	10	10			3.53	13.9550	6.0042	24	4.0655	9.584	11.25	14.95	18.025	21.525
Total Anions (meq/L)	10	10			10.1	27.3200	13.8388	46.2	11.27	12.86	13.925	24.2	41.475	45.57
Total Cations (meq/L)	10	10			13	37.3900	22.3248	69.1	13.36	15.4	17.5	26.5	61.625	68.11
Major Ions														
Calcium (mg/L)	20	20			102	272.7500	149.3629	481	104.85	122.2	125.5	189.5	439.5	479.1
Chloride (mg/L)	10	10			13	63.6000	41.8645	118	14.35	16	20.75	56.5	108.25	114.4
Fluoride (mg/L)	10	10			0.2	0.2100	0.0300	0.3	0.2	0.2	0.2	0.2	0.2	0.255
Magnesium (mg/L)	20	20			35	163.1000	110.1794	316	36.9	55.6	56.75	108	278	316
Potassium (mg/L)	20	20			4	8.1000	3.6729	16	4	4.8	5	8	9	15.05
Sodium (mg/L)	20	20			83	248.2000	125.2692	442	83.95	123.8	127.75	196	372	435.35
Sulfate (as SO4)	10	10			392	1105.3000	589.7756	1910	429.8	476.8	522.75	979	1685	1896.5
Metals (dissolved)														
Arsenic - dissolved (mg/L)	10		10	100.0										

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Barium - dissolved (mg/L)	10	10			0.046	0.0672	0.0228	0.102	0.0469	0.0488	0.049	0.0555	0.0915	0.10155
Bismuth - dissolved (mg/L)	10		10	100.0										
Chromium - dissolved (mg/L)	10		10	100.0										
Cobalt - dissolved (mg/L)	10	10			0.001	0.0034	0.0016	0.006	0.00145	0.002	0.002	0.003	0.005	0.00555
Copper - dissolved (mg/L)	10	9	1	10.0	0.002	0.0031	0.0010	0.005	0.002	0.002	0.002	0.003	0.004	0.0046
Molybdenum - dissolved (mg/L)	10	6	4	40.0	0.001	0.0027	0.0012	0.004	0.001	0.001	0.0015	0.003	0.00375	0.004
Nickel - dissolved (mg/L)	10	9	1	10.0	0.001	0.0067	0.0059	0.015	0.001	0.001	0.001	0.003	0.012	0.015
Selenium - dissolved (mg/L)	10	9	1	10.0	0.02	0.1456	0.1136	0.3	0.024	0.036	0.04	0.07	0.25	0.296
Uranium - dissolved (mg/L)	10	5	5	50.0	0.001	0.0028	0.0017	0.006	0.0012	0.0018	0.002	0.002	0.003	0.0054
Metals (total)														
Arsenic - total (mg/L)	10		10	100.0										
Barium - total (mg/L)	10	10			0.048	0.0676	0.0211	0.107	0.04845	0.0506	0.051	0.058	0.08275	0.1034
Bismuth - total (mg/L)	10		10	100.0										
Chromium - total (mg/L)	10		10	100.0										
Cobalt - total (mg/L)	10	10			0.001	0.0039	0.0019	0.006	0.001	0.0026	0.003	0.004	0.00575	0.006
Copper - total (mg/L)	10	10			0.002	0.0048	0.0019	0.009	0.00245	0.003	0.00325	0.005	0.00575	0.00765
Molybdenum - total (mg/L)	10	7	3	30.0	0.001	0.0026	0.0013	0.005	0.001	0.0012	0.0015	0.003	0.003	0.0044
Nickel - total (mg/L)	10	7	3	30.0	0.002	0.0273	0.0471	0.142	0.0023	0.0034	0.004	0.011	0.014	0.1042
Selenium - total (mg/L)	10	9	1	10.0	0.03	0.1511	0.1068	0.29	0.03	0.036	0.04	0.13	0.26	0.286
Uranium - total (mg/L)	10	5	5	50.0	0.001	0.0030	0.0018	0.006	0.0012	0.0018	0.002	0.002	0.004	0.0056
Physico-Chemical Parameters														

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Electrical Conductivity (µS/cm)	10	10			1170	3297.0000	1753.2544	5430	1219.5	1312	1500	3120	5082.5	5389.5
pH (lab)	10	10			6.65	7.1110	0.2777	7.68	6.722	6.922	6.965	7.07	7.2675	7.527
Turbidity (NTU)	10	10			0.5	2.2100	2.3132	7.3	0.5	0.5	0.5	0.9	2.9	6.535
Seepage Bore 6b														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Carbonate Alkalinity as CaCO3 (mg/L)	10	10			175	268.5000	141.9488	659	179.05	188.8	190	204.5	267.75	529.4
Hydroxide Alkalinity as CaCO3 (mg/L)	10	10			371	551.7000	124.5536	819	389.45	437.6	453.5	567	608.75	739.35
Temperature (field) (°C)	10	10			601	820.4000	229.6159	1480	630.7	714.2	730	773	814.25	1182.55
Field Measurements														
Appearance or Colour	2													
Depth to Water (mbRL)	2	2			4.24	4.5750	0.3350	4.91	4.2735	4.374	4.4075	4.575	4.7425	4.8765
Dissolved Oxygen (field) (% sat))	2	2			26.2	28.5000	2.3000	30.8	26.43	27.12	27.35	28.5	29.65	30.57
Electrical Conductivity (field) (µS/cm)	2	2			4872	6165.5000	1293.5000	7459	5001.35	5389.4	5518.75	6165.5	6812.25	7329.65
Groundwater Level (mAHD)	2	2			319.01	320.7650	1.7550	322.52	319.1855	319.712	319.8875	320.765	321.6425	322.3445
GWL Depth Reference Elevation	2	2			323.92	325.3400	1.4200	326.76	324.062	324.488	324.63	325.34	326.05	326.618
Odour	2													
ORP (field) (mV)	2	2			-162.8	-12.0500	150.7500	138.7	-147.725	-102.5	-87.425	-12.05	63.325	123.625
pH (field)	2	2			12.64	12.7200	0.0800	12.8	12.648	12.672	12.68	12.72	12.76	12.792
Salinity (field) (PSU)	2	2			2.6	3.3450	0.7450	4.09	2.6745	2.898	2.9725	3.345	3.7175	4.0155
TDS (field) (ppm)	2	2			26.54	27.3050	0.7650	28.07	26.6165	26.846	26.9225	27.305	27.6875	27.9935

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Total Dissolved Solids (field) (ppm)	2	2			2435	3082.5000	647.5000	3730	2499.75	2694	2758.75	3082.5	3406.25	3665.25
Hardness														
Total Hardness (mg CaCO3/L)	10	10			372	470.0000	88.2100	692	385.5	403.6	406.5	443	505.25	617.75
Ion Balance														
Ionic Balance (%)	10	10			2.25	8.1850	3.3690	15.8	3.1185	7.1	7.8375	7.99	9.3475	12.938
Total Anions (meq/L)	10	10			21.8	27.2800	7.1634	48.2	22.025	24.14	24.7	25.55	26.375	38.795
Total Cations (meq/L)	10	10			26.7	31.8400	6.3380	50.4	27.42	29.42	29.725	30.1	30.8	42.165
Major Ions														
Calcium (mg/L)	20	20			149	196.0000	41.5307	316	152.8	161.8	165	188	210.25	278.95
Chloride (mg/L)	10	10			76	87.9000	9.8939	116	79.6	84	84.25	86	87	103.4
Fluoride (mg/L)	10	10			1.4	1.5500	0.2335	2.2	1.4	1.4	1.4	1.45	1.6	1.93
Magnesium (mg/L)	20	1	19	95.0	13	13.0000	0.0000	13	13	13	13	13	13	13
Potassium (mg/L)	20	20			48	69.5000	19.2964	120	53.7	55.8	56	61.5	75.75	119.05
Sodium (mg/L)	20	20			382	480.6500	106.1448	794	401.95	420.6	423.25	446	486.5	772.15
Sulfate (as SO4)	10	10			327	404.1000	115.0447	738	334.2	344.6	347.25	358.5	406.25	595.8
Metals (dissolved)														
Arsenic - dissolved (mg/L)	10	10			0.001	0.0022	0.0006	0.003	0.00145	0.002	0.002	0.002	0.00275	0.003
Barium - dissolved (mg/L)	10	10			0.178	0.2423	0.0481	0.301	0.18205	0.1878	0.19425	0.238	0.2925	0.29965
Bismuth - dissolved (mg/L)	10		10	100.0										
Chromium - dissolved (mg/L)	10	10			0.012	0.0212	0.0103	0.05	0.01245	0.0146	0.01525	0.0195	0.022	0.03785
Cobalt - dissolved (mg/L)	10	10			0.002	0.0020	#NUM!	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Copper - dissolved (mg/L)	10	10			0.027	0.0321	0.0034	0.04	0.02835	0.03	0.03	0.031	0.03375	0.03775
Molybdenum - dissolved (mg/L)	10	10			0.234	0.2960	0.1071	0.612	0.2367	0.2416	0.2425	0.2675	0.27875	0.4707

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Nickel - dissolved (mg/L)	10	10			0.012	0.0142	0.0010	0.015	0.01245	0.0138	0.014	0.0145	0.015	0.015
Selenium - dissolved (mg/L)	10	10			0.02	0.0270	0.0078	0.04	0.02	0.02	0.02	0.025	0.03	0.04
Uranium - dissolved (mg/L)	10		10	100.0										
Metals (total)														
Arsenic - total (mg/L)	10	10			0.002	0.0028	0.0006	0.004	0.002	0.002	0.00225	0.003	0.003	0.00355
Barium - total (mg/L)	10	10			0.178	0.2537	0.0486	0.308	0.1888	0.2044	0.2065	0.266	0.29925	0.3071
Bismuth - total (mg/L)	10		10	100.0										
Chromium - total (mg/L)	10	10			0.012	0.0298	0.0343	0.132	0.01245	0.0146	0.0155	0.02	0.02275	0.0834
Cobalt - total (mg/L)	10	10			0.002	0.0023	0.0009	0.005	0.002	0.002	0.002	0.002	0.002	0.00365
Copper - total (mg/L)	10	10			0.031	0.0380	0.0120	0.073	0.03145	0.032	0.032	0.0335	0.0375	0.0577
Molybdenum - total (mg/L)	10	10			0.234	0.3184	0.1173	0.66	0.2439	0.256	0.2585	0.2815	0.31575	0.5115
Nickel - total (mg/L)	10	10			0.014	0.0153	0.0008	0.016	0.014	0.0148	0.015	0.0155	0.016	0.016
Selenium - total (mg/L)	10	10			0.02	0.0270	0.0064	0.04	0.02	0.02	0.02	0.03	0.03	0.0355
Uranium - total (mg/L)	10	1	9	90.0	0.002	0.0020	0.0000	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	10	10			3660	4553.0000	1127.4578	7640	3669	3712	3792.5	4230	4580	6542
pH (lab)	10	10			11.7	11.9400	0.1114	12.1	11.745	11.88	11.9	12	12	12.055
Turbidity (NTU)	10	10			3.1	8.9800	11.3287	42.6	3.235	3.56	3.725	5.65	6.55	27.345
Seepage Bore 7a														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	10	10			670	832.4000	75.4854	951	720.85	787	795.5	829	870.5	941.55

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Carbonate Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Hydroxide Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Temperature (field) (°C)	10	10			670	832.4000	75.4854	951	720.85	787	795.5	829	870.5	941.55
Field Measurements														
Appearance or Colour	2													
Depth to Water (mbRL)	2	2			2.44	2.6900	0.2500	2.94	2.465	2.54	2.565	2.69	2.815	2.915
Dissolved Oxygen (field) (% sat))	2	2			118.2	191.6500	73.4500	265.1	125.545	147.58	154.925	191.65	228.375	257.755
Electrical Conductivity (field) (µS/cm)	2	2			1979	2245.5000	266.5000	2512	2005.65	2085.6	2112.25	2245.5	2378.75	2485.35
Groundwater Level (mAHD)	2	2			324.32	338.5955	14.2755	352.871	325.74755	330.0302	331.45775	338.5955	345.73325	351.44345
GWL Depth Reference Elevation	2	2			326.76	341.2855	14.5255	355.811	328.21255	332.5702	334.02275	341.2855	348.54825	354.35845
Odour	2													
ORP (field) (mV)	2	2			-58.5	-32.0000	26.5000	-5.5	-55.85	-47.9	-45.25	-32	-18.75	-8.15
pH (field)	2	2			8.21	8.2650	0.0550	8.32	8.2155	8.232	8.2375	8.265	8.2925	8.3145
Salinity (field) (PSU)	2	2			1	1.1400	0.1400	1.28	1.014	1.056	1.07	1.14	1.21	1.266
TDS (field) (ppm)	2	2			30.01	30.3100	0.3000	30.61	30.04	30.13	30.16	30.31	30.46	30.58
Total Dissolved Solids (field) (ppm)	2	2			990	1123.0000	133.0000	1256	1003.3	1043.2	1056.5	1123	1189.5	1242.7
Hardness														
Total Hardness (mg CaCO3/L)	10	10			227	353.3000	43.1603	380	281	355.8	359.25	365.5	374.75	379.1
Ion Balance														
Ionic Balance (%)	10	10			0.72	2.1850	1.1675	3.83	0.792	0.92	0.9475	2.43	3.2225	3.7625

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Total Anions (meq/L)	10	10			21	26.0300	1.9804	28.6	22.845	25.18	25.35	26.4	26.95	28.33
Total Cations (meq/L)	10	10			22.7	26.8200	2.1917	30.6	23.285	25.76	26.225	26.6	28.4	29.79
Major Ions														
Calcium (mg/L)	20	20			35	56.3000	7.7466	66	35	55.6	56	58	60	64.1
Chloride (mg/L)	10	10			97	141.4000	15.5512	155	116.35	140	140.25	145.5	149.75	153.2
Fluoride (mg/L)	10	10			3.3	3.9400	0.5748	5.2	3.345	3.48	3.5	3.8	4.275	4.84
Magnesium (mg/L)	20	20			34	53.2500	6.8401	59	34	52.8	53	56	56.25	58.05
Potassium (mg/L)	20	20			2	4.1500	0.8529	5	2	4	4	4	5	5
Sodium (mg/L)	20	20			390	458.0500	33.4835	526	414.7	432.4	435.25	456	479	518.4
Sulfate (as SO4)	10	10			235	260.0000	12.6412	286	241.75	250.8	252.5	262	265.75	277
Metals (dissolved)														
Arsenic - dissolved (mg/L)	10	10			0.003	0.0052	0.0015	0.007	0.003	0.0038	0.004	0.0055	0.00675	0.007
Barium - dissolved (mg/L)	10	10			0.075	0.0855	0.0062	0.093	0.0759	0.0794	0.081	0.0865	0.091	0.093
Bismuth - dissolved (mg/L)	10		10	100.0										
Chromium - dissolved (mg/L)	10	1	9	90.0	0.002	0.0020	0.0000	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cobalt - dissolved (mg/L)	10	8	2	20.0	0.001	0.0014	0.0005	0.002	0.001	0.001	0.001	0.001	0.002	0.002
Copper - dissolved (mg/L)	10	4	6	60.0	0.001	0.0023	0.0011	0.004	0.00115	0.0016	0.00175	0.002	0.0025	0.0037
Molybdenum - dissolved (mg/L)	10	10			0.015	0.0198	0.0037	0.027	0.0159	0.017	0.01725	0.019	0.0205	0.02655
Nickel - dissolved (mg/L)	10	9	1	10.0	0.001	0.0018	0.0006	0.003	0.001	0.001	0.001	0.002	0.002	0.0026
Selenium - dissolved (mg/L)	10		10	100.0										
Uranium - dissolved (mg/L)	10	10			0.018	0.0250	0.0035	0.03	0.01935	0.0226	0.023	0.026	0.0275	0.02955
Metals (total)														
Arsenic - total (mg/L)	10	10			0.003	0.0074	0.0019	0.01	0.00435	0.006	0.0065	0.008	0.008	0.00955

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Barium - total (mg/L)	10	10			0.087	0.0969	0.0067	0.107	0.0879	0.0906	0.09125	0.0975	0.10175	0.1061
Bismuth - total (mg/L)	10		10	100.0										
Chromium - total (mg/L)	10	3	7	70.0	0.002	0.0020	0.0000	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cobalt - total (mg/L)	10	10			0.001	0.0022	0.0009	0.004	0.001	0.0018	0.002	0.002	0.00275	0.00355
Copper - total (mg/L)	10	10			0.002	0.0083	0.0053	0.019	0.00245	0.0038	0.00425	0.007	0.01	0.01765
Molybdenum - total (mg/L)	10	10			0.016	0.0199	0.0027	0.026	0.01645	0.017	0.01775	0.02	0.02075	0.0242
Nickel - total (mg/L)	10	9	1	10.0	0.002	0.0031	0.0007	0.004	0.002	0.0026	0.003	0.003	0.004	0.004
Selenium - total (mg/L)	10		10	100.0										
Uranium - total (mg/L)	10	10			0.017	0.0272	0.0047	0.034	0.0197	0.0238	0.02425	0.0285	0.03	0.0331
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	10	10			1960	2331.0000	223.4032	2660	2005	2108	2137.5	2375	2517.5	2606
pH (lab)	10	10			7.59	7.8510	0.1723	8.23	7.6305	7.696	7.7225	7.85	7.94	8.1175
Turbidity (NTU)	10	10			4.7	28.1000	16.8588	61.2	7.67	14.02	15.75	22.75	39.9	54.765
Seepage Bore 8a														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	10	10			570	799.4000	87.8353	937	655.95	794.6	803.25	808.5	828	896.95
Carbonate Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Hydroxide Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Temperature (field) (°C)	10	10			570	799.4000	87.8353	937	655.95	794.6	803.25	808.5	828	896.95
Field Measurements														

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Appearance or Colour	2													
Depth to Water (mbRL)	2	2			1.47	1.5550	0.0850	1.64	1.4785	1.504	1.5125	1.555	1.5975	1.6315
Dissolved Oxygen (field) (% sat))	2	2			77.2	161.9500	84.7500	246.7	85.675	111.1	119.575	161.95	204.325	238.225
Electrical Conductivity (field) (µS/cm)	2	2			1905	3105.0000	1200.0000	4305	2025	2385	2505	3105	3705	4185
Groundwater Level (mAHD)	2	2			325.12	339.7305	14.6105	354.341	326.58105	330.9642	332.42525	339.7305	347.03575	352.87995
GWL Depth Reference Elevation	2	2			326.76	341.2855	14.5255	355.811	328.21255	332.5702	334.02275	341.2855	348.54825	354.35845
Odour	2													
ORP (field) (mV)	2	2			-49.6	-29.3000	20.3000	-9	-47.57	-41.48	-39.45	-29.3	-19.15	-11.03
pH (field)	2	2			8.18	8.3700	0.1900	8.56	8.199	8.256	8.275	8.37	8.465	8.541
Salinity (field) (PSU)	2	2			0.96	1.6150	0.6550	2.27	1.0255	1.222	1.2875	1.615	1.9425	2.2045
TDS (field) (ppm)	2	2			28.8	29.2650	0.4650	29.73	28.8465	28.986	29.0325	29.265	29.4975	29.6835
Total Dissolved Solids (field) (ppm)	2	2			952	1551.5000	599.5000	2151	1011.95	1191.8	1251.75	1551.5	1851.25	2091.05
Hardness														
Total Hardness (mg CaCO3/L)	10	10			118	353.4000	100.0822	529	208	321.2	324.75	353.5	381.25	494.35
Ion Balance														
Ionic Balance (%)	10	10			0.15	1.7840	1.3363	3.96	0.258	0.462	0.525	1.625	2.9625	3.744
Total Anions (meq/L)	10	10			20	36.7500	6.8993	50.1	27.11	36.12	36.275	36.8	37.575	45.825
Total Cations (meq/L)	10	10			20.5	36.4400	6.7216	49.7	26.71	34.78	35.175	36.55	38.575	44.795
Major Ions														
Calcium (mg/L)	20	20			21	57.9000	17.7874	94	22.9	50.4	51.75	56.5	62	90.2
Chloride (mg/L)	10	10			127	261.0000	81.9902	453	166.6	215	215.5	243	285.75	395.85

	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Fluoride (mg/L)	10	10			0.8	0.9900	0.2071	1.4	0.8	0.8	0.8	0.9	1.175	1.31
Magnesium (mg/L)	20	20			16	52.9500	17.0190	100	17.9	47.6	49.5	51.5	56	75.3
Potassium (mg/L)	20	20			2	2.9000	1.9468	11	2	2	2	2	3	4.35
Sodium (mg/L)	20	20			394	681.5500	116.2624	916	414.9	651.4	668	681	717.5	898.9
Sulfate (as SO4)	10	10			243	644.8000	158.1150	895	376.2	627	650.75	669	703.5	819.85
Metals (dissolved)														
Arsenic - dissolved (mg/L)	10	7	3	30.0	0.001	0.0011	0.0003	0.002	0.001	0.001	0.001	0.001	0.001	0.0017
Barium - dissolved (mg/L)	10	10			0.042	0.1300	0.0354	0.178	0.0726	0.114	0.118	0.135	0.14975	0.17125
Bismuth - dissolved (mg/L)	10		10	100.0										
Chromium - dissolved (mg/L)	10	1	9	90.0	0.003	0.0030	0.0000	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Cobalt - dissolved (mg/L)	10	4	6	60.0	0.001	0.0013	0.0004	0.002	0.001	0.001	0.001	0.001	0.00125	0.00185
Copper - dissolved (mg/L)	10	4	6	60.0	0.001	0.0020	0.0012	0.004	0.001	0.001	0.001	0.0015	0.0025	0.0037
Molybdenum - dissolved (mg/L)	10	9	1	10.0	0.003	0.0048	0.0017	0.008	0.003	0.003	0.003	0.004	0.006	0.0076
Nickel - dissolved (mg/L)	10	3	7	70.0	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Selenium - dissolved (mg/L)	10		10	100.0										
Uranium - dissolved (mg/L)	10	10			0.008	0.0222	0.0072	0.038	0.0125	0.0188	0.0195	0.022	0.023	0.0335
Metals (total)														
Arsenic - total (mg/L)	10	10			0.001	0.0014	0.0009	0.004	0.001	0.001	0.001	0.001	0.001	0.0031
Barium - total (mg/L)	10	10			0.049	0.1459	0.0534	0.268	0.08095	0.1224	0.1235	0.1355	0.157	0.23335
Bismuth - total (mg/L)	10		10	100.0										
Chromium - total (mg/L)	10	1	9	90.0	0.023	0.0230	0.0000	0.023	0.023	0.023	0.023	0.023	0.023	0.023
Cobalt - total (mg/L)	10	4	6	60.0	0.001	0.0050	0.0064	0.016	0.001	0.001	0.001	0.0015	0.0055	0.0139

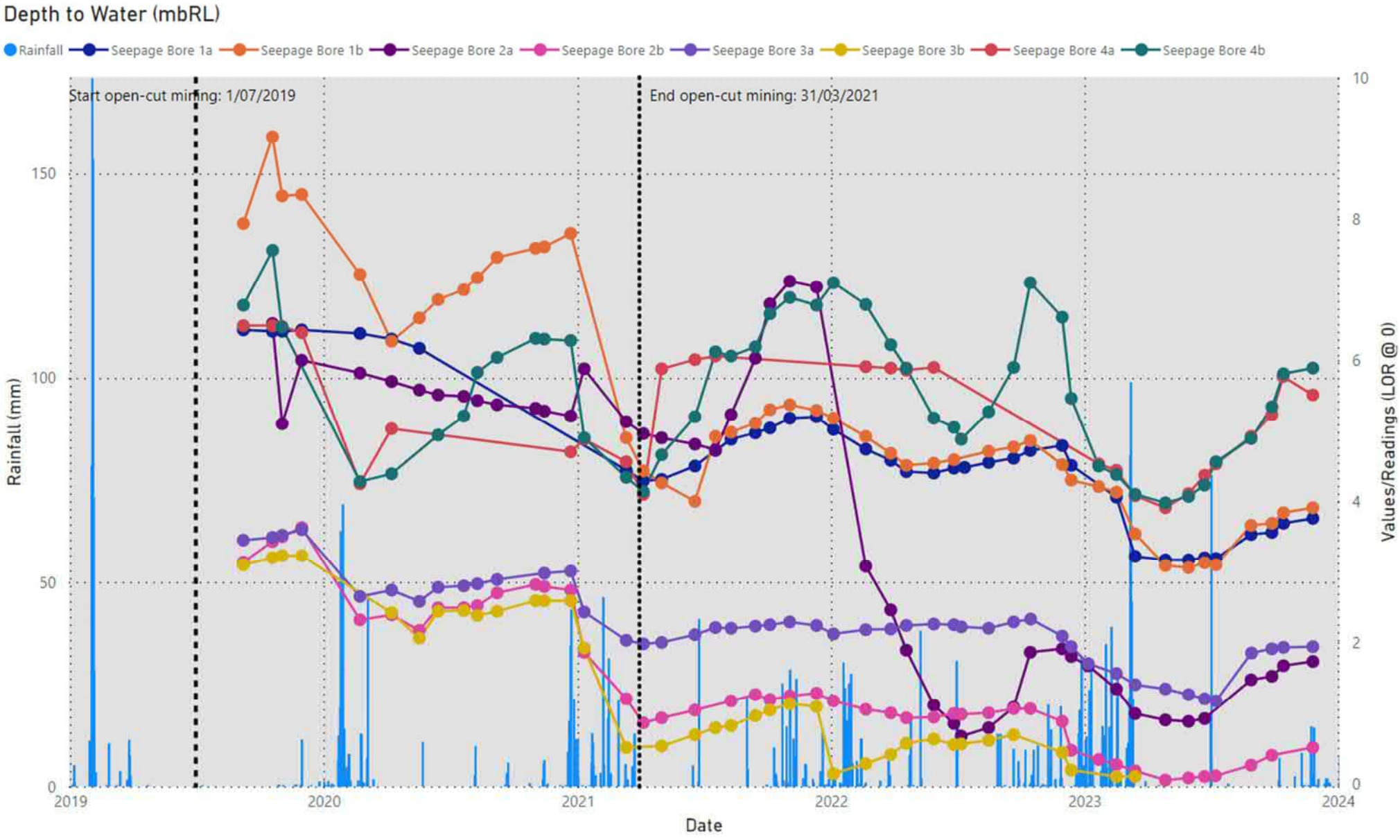
	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Copper - total (mg/L)	10	10			0.001	0.0038	0.0038	0.014	0.001	0.0018	0.002	0.0025	0.003	0.01085
Molybdenum - total (mg/L)	10	10			0.003	0.0048	0.0021	0.01	0.003	0.003	0.00325	0.004	0.005	0.00865
Nickel - total (mg/L)	10	4	6	60.0	0.001	0.0035	0.0038	0.01	0.001	0.001	0.001	0.0015	0.004	0.0088
Selenium - total (mg/L)	10		10	100.0										
Uranium - total (mg/L)	10	10			0.01	0.0244	0.0087	0.046	0.01405	0.0206	0.02125	0.023	0.0255	0.0388
Physico-Chemical Parameters														
Electrical Conductivity (µS/cm)	10	10			2040	3279.0000	570.9720	4430	2494.5	3098	3117.5	3260	3377.5	4151
pH (lab)	10	10			7.31	7.6220	0.2697	8.2	7.3145	7.336	7.395	7.625	7.6375	8.0965
Turbidity (NTU)	10	10			1	52.8600	141.4153	477	1.36	2.36	3.175	6.4	9.4	267.345
Seepage Bore 9a														
Alkalinity														
Bicarbonate Alkalinity as CaCO3 (mg/L)	10	10			550	666.3000	87.7315	846	558.55	584.2	597.25	650.5	726.5	803.7
Carbonate Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Hydroxide Alkalinity as CaCO3 (mg/L)	10		10	100.0										
Temperature (field) (°C)	10	10			550	666.3000	87.7315	846	558.55	584.2	597.25	650.5	726.5	803.7
Field Measurements														
Appearance or Colour	2													
Depth to Water (mbRL)	2	2			0.49	1.2500	0.7600	2.01	0.566	0.794	0.87	1.25	1.63	1.934
Dissolved Oxygen (field) (% sat))	2	2			58.8	107.2000	48.4000	155.6	63.64	78.16	83	107.2	131.4	150.76
Electrical Conductivity (field) (µS/cm)	2	2			2525	2562.0000	37.0000	2599	2528.7	2539.8	2543.5	2562	2580.5	2595.3

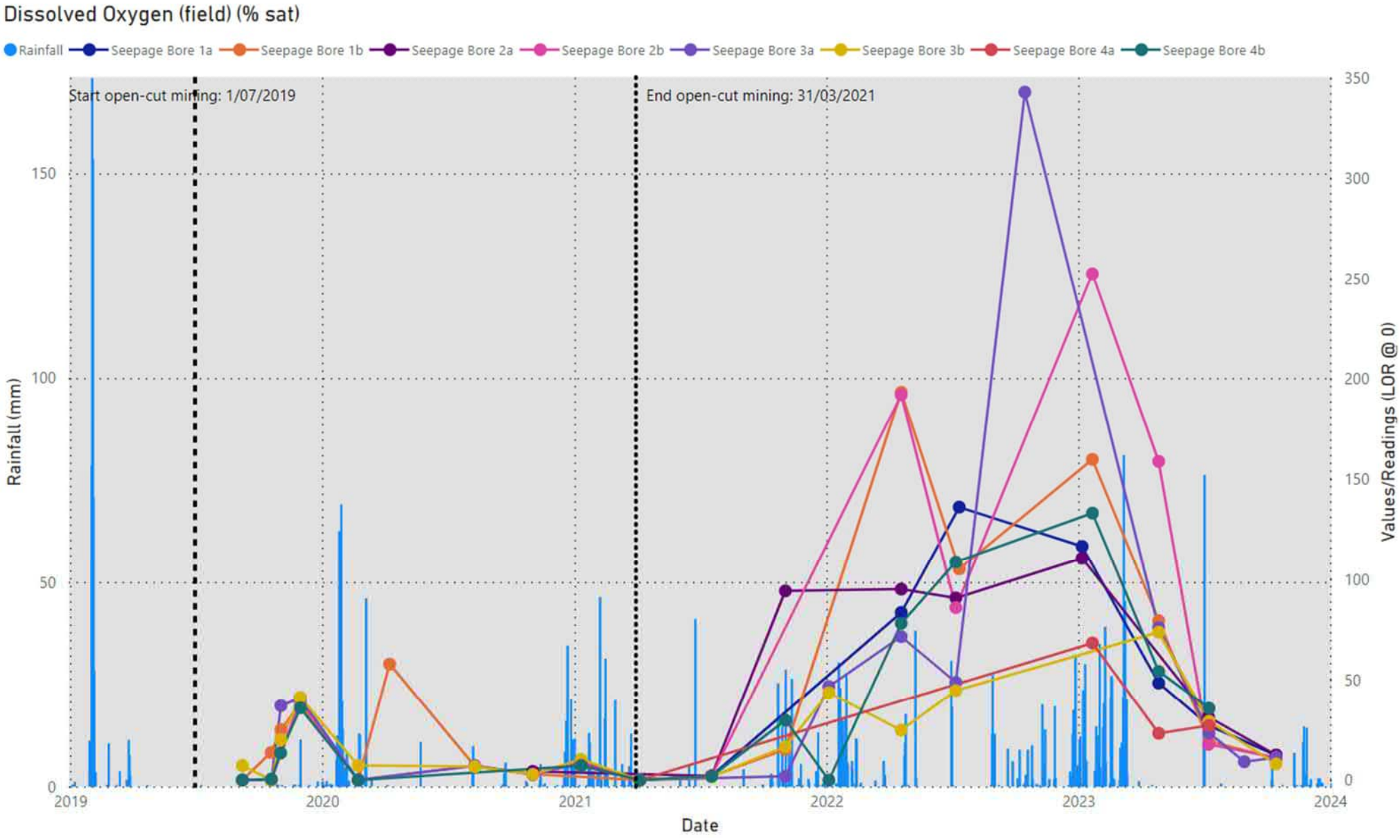
	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Groundwater Level (mAHD)	2	2			323.43	324.0900	0.6600	324.75	323.496	323.694	323.76	324.09	324.42	324.684
GWL Depth Reference Elevation	2	2			323.92	325.3400	1.4200	326.76	324.062	324.488	324.63	325.34	326.05	326.618
Odour	2													
ORP (field) (mV)	2	2			-54.7	-26.6500	28.0500	1.4	-51.895	-43.48	-40.675	-26.65	-12.625	-1.405
pH (field)	2	2			8.03	8.0850	0.0550	8.14	8.0355	8.052	8.0575	8.085	8.1125	8.1345
Salinity (field) (PSU)	2	2			1.29	1.3100	0.0200	1.33	1.292	1.298	1.3	1.31	1.32	1.328
TDS (field) (ppm)	2	2			29.71	30.1550	0.4450	30.6	29.7545	29.888	29.9325	30.155	30.3775	30.5555
Total Dissolved Solids (field) (ppm)	2	2			1263	1281.5000	18.5000	1300	1264.85	1270.4	1272.25	1281.5	1290.75	1298.15
Hardness														
Total Hardness (mg CaCO3/L)	10	10			577	672.3000	57.2853	765	600.85	630.8	634.75	653.5	716.75	760.95
Ion Balance														
Ionic Balance (%)	10	10			0.85	3.5790	2.4715	7.81	0.904	1.25	1.4975	2.8	5.515	7.531
Total Anions (meq/L)	10	10			27.5	28.7200	0.8518	30.2	27.635	27.88	28	28.7	29.25	30.065
Total Cations (meq/L)	10	10			29.4	30.6300	1.0734	32.6	29.445	29.5	29.525	30.8	31	32.375
Major Ions														
Calcium (mg/L)	20	20			74	91.9500	8.5234	106	75.9	84	87.75	93	99.25	102.2
Chloride (mg/L)	10	10			129	146.5000	15.1542	185	129.9	136.6	138.25	144	149.75	171.95
Fluoride (mg/L)	10	10			1.7	2.0900	0.1758	2.4	1.835	2	2	2.1	2.2	2.31
Magnesium (mg/L)	20	20			88	109.4000	10.0717	125	93.7	101.4	102.75	109	116.5	124.05
Potassium (mg/L)	20	20			2	2.0000	0.0000	2	2	2	2	2	2	2
Sodium (mg/L)	20	20			368	396.1500	23.3865	447	368.95	377.8	378	388.5	402.25	445.1
Sulfate (as SO4)	10	10			382	542.1000	77.6382	650	416.2	488.4	503	547	597.5	640.55
Metals (dissolved)														
Arsenic - dissolved (mg/L)	10	10			0.002	0.0021	0.0003	0.003	0.002	0.002	0.002	0.002	0.002	0.00255

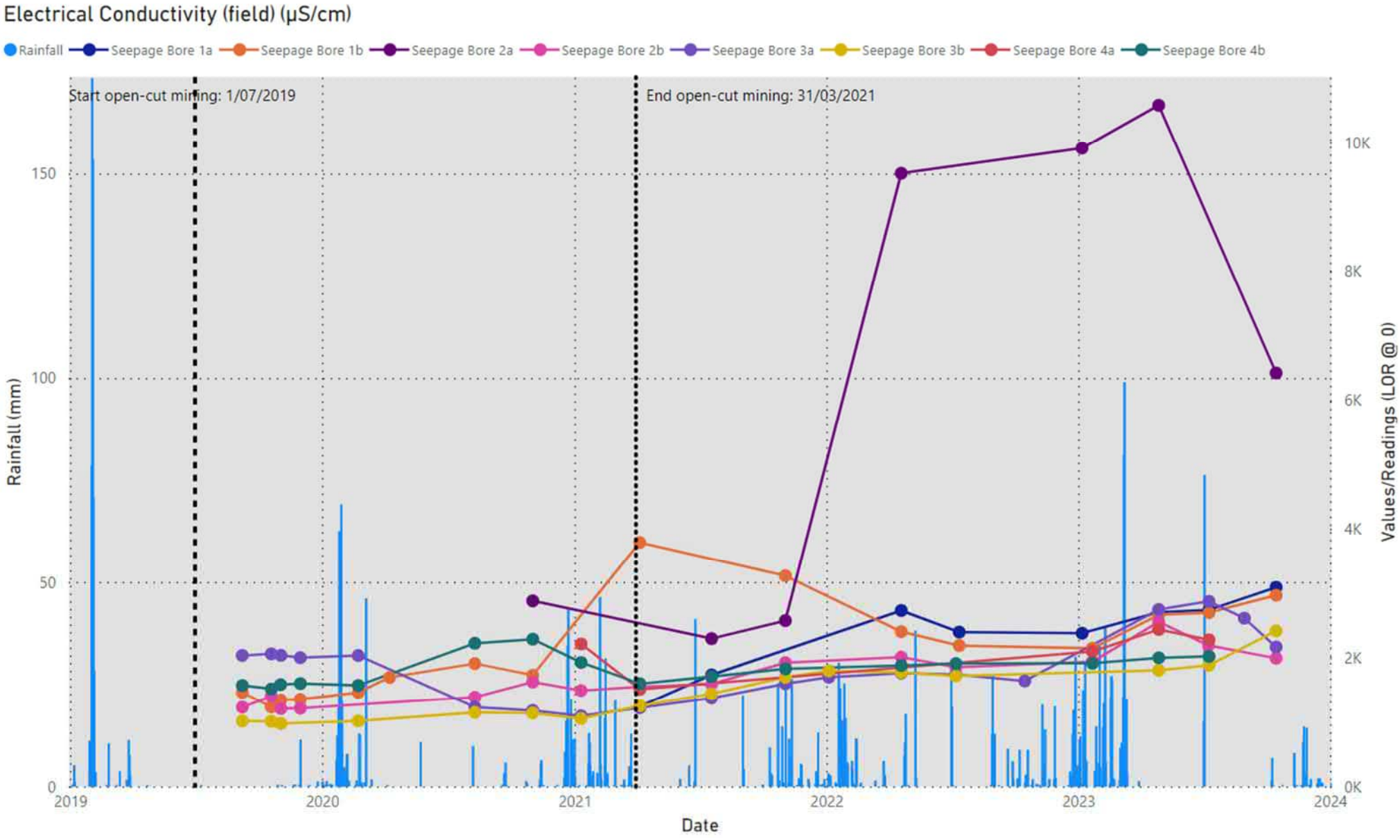
	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Barium - dissolved (mg/L)	10	10			0.146	0.1651	0.0138	0.192	0.1469	0.1504	0.15325	0.1665	0.172	0.18615
Bismuth - dissolved (mg/L)	10		10	100.0										
Chromium - dissolved (mg/L)	10		10	100.0										
Cobalt - dissolved (mg/L)	10	10			0.002	0.0027	0.0005	0.003	0.002	0.002	0.00225	0.003	0.003	0.003
Copper - dissolved (mg/L)	10	4	6	60.0	0.001	0.0013	0.0004	0.002	0.001	0.001	0.001	0.001	0.00125	0.00185
Molybdenum - dissolved (mg/L)	10	10			0.003	0.0050	0.0010	0.006	0.00345	0.004	0.00425	0.005	0.006	0.006
Nickel - dissolved (mg/L)	10	6	4	40.0	0.001	0.0010	0.0000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Selenium - dissolved (mg/L)	10	4	6	60.0	0.01	0.0175	0.0043	0.02	0.0115	0.016	0.0175	0.02	0.02	0.02
Uranium - dissolved (mg/L)	10	10			0.006	0.0097	0.0038	0.016	0.006	0.006	0.006	0.0085	0.013	0.0151
Metals (total)														
Arsenic - total (mg/L)	10	10			0.002	0.0022	0.0004	0.003	0.002	0.002	0.002	0.002	0.002	0.003
Barium - total (mg/L)	10	10			0.148	0.1735	0.0153	0.196	0.1498	0.1552	0.16	0.1785	0.184	0.1915
Bismuth - total (mg/L)	10		10	100.0										
Chromium - total (mg/L)	10	2	8	80.0	0.002	0.0020	0.0000	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cobalt - total (mg/L)	10	10			0.003	0.0033	0.0005	0.004	0.003	0.003	0.003	0.003	0.00375	0.004
Copper - total (mg/L)	10	10			0.003	0.0056	0.0040	0.016	0.003	0.003	0.00325	0.004	0.00475	0.0133
Molybdenum - total (mg/L)	10	10			0.004	0.0056	0.0008	0.007	0.00445	0.005	0.005	0.006	0.006	0.00655
Nickel - total (mg/L)	10	8	2	20.0	0.001	0.0018	0.0004	0.002	0.001	0.0014	0.00175	0.002	0.002	0.002
Selenium - total (mg/L)	10	4	6	60.0	0.01	0.0175	0.0043	0.02	0.0115	0.016	0.0175	0.02	0.02	0.02
Uranium - total (mg/L)	10	10			0.006	0.0109	0.0049	0.022	0.00645	0.007	0.007	0.0095	0.0135	0.01885
Physico-Chemical Parameters														

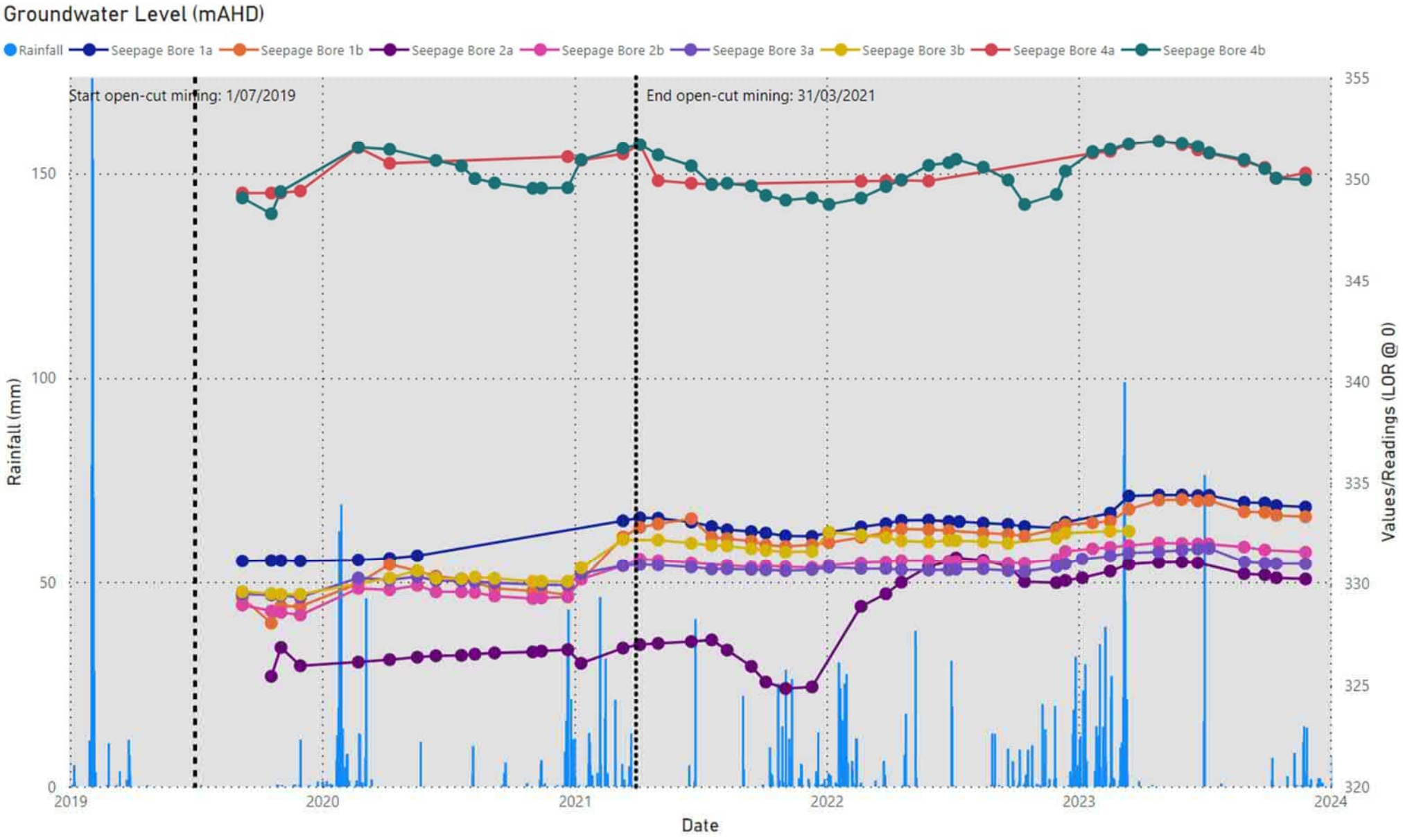
	NumObs	No. > LOR	No. < LOR	% < LOR	Min > LOR	Average > LOR	STDev > LOR	Max >LOR	5%ile (>LOR)	20%ile (>LOR)	25%ile (Q1) (> LOR)	50%ile (Q2) (> LOR)	75%ile (Q3) (> LOR)	95%ile (>LOR)
Electrical Conductivity (µS/cm)	10	10			2520	2622.0000	93.2523	2840	2520	2552	2565	2605	2635	2790.5
pH (lab)	10	10			7.49	7.7390	0.1685	8.09	7.508	7.618	7.6425	7.73	7.8425	7.9955
Turbidity (NTU)	10	10			1.5	6.7400	6.6000	24.5	1.995	3.08	3.275	4.3	5.425	19.235

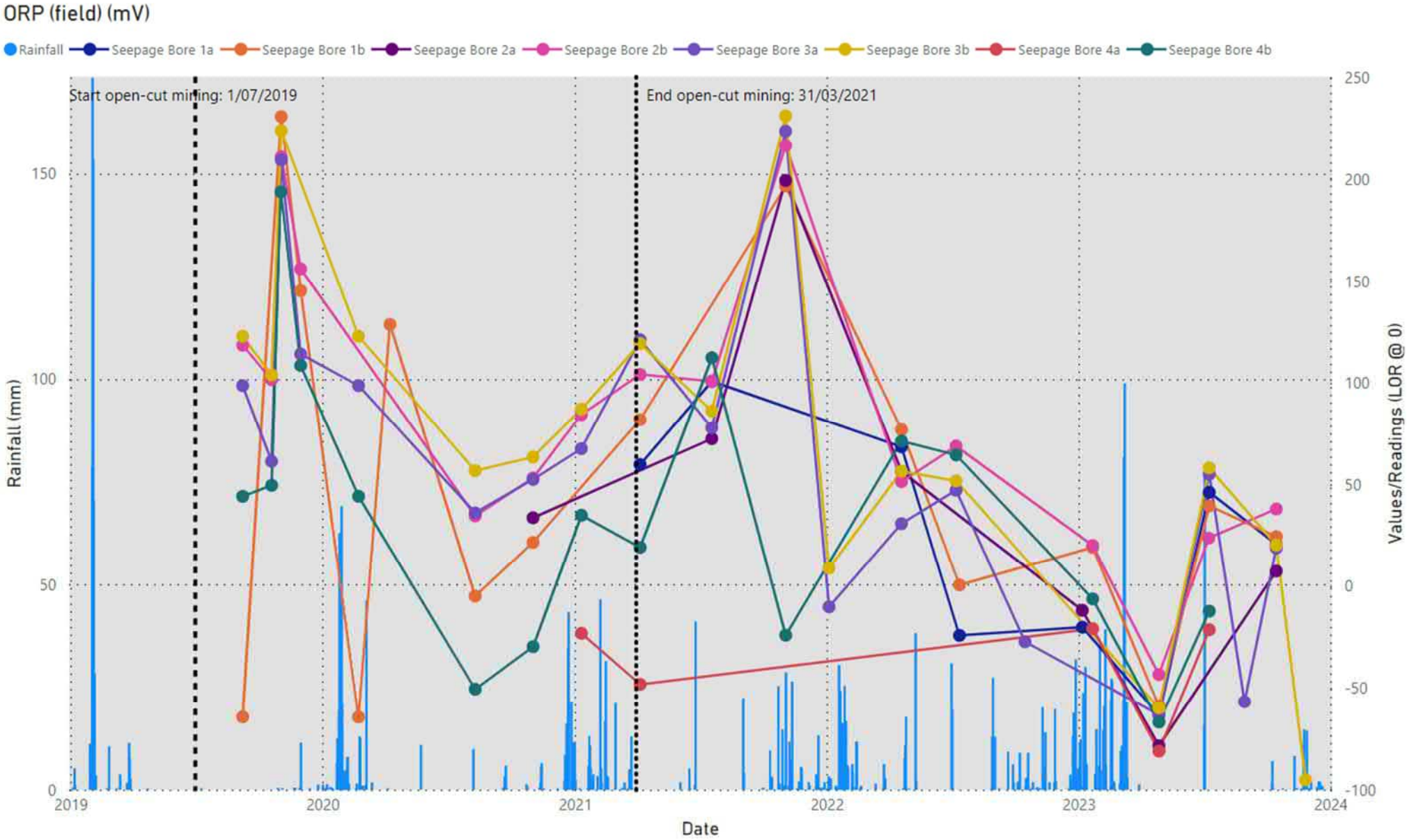
H.2 Water quality time series

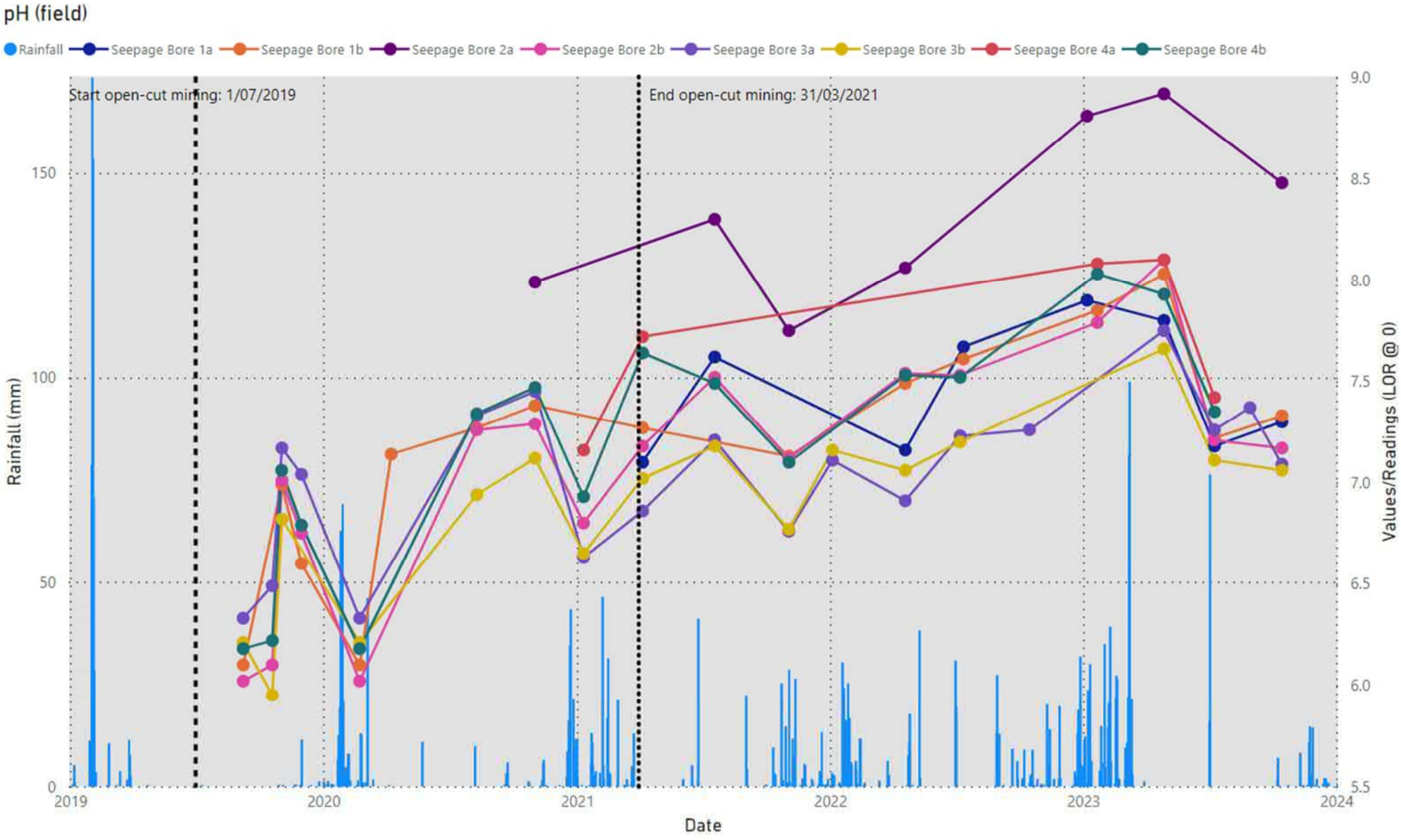

Depth to Water (mbRL)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
2
4
6
8
10
2019
2020
2021
2022
2023
2024

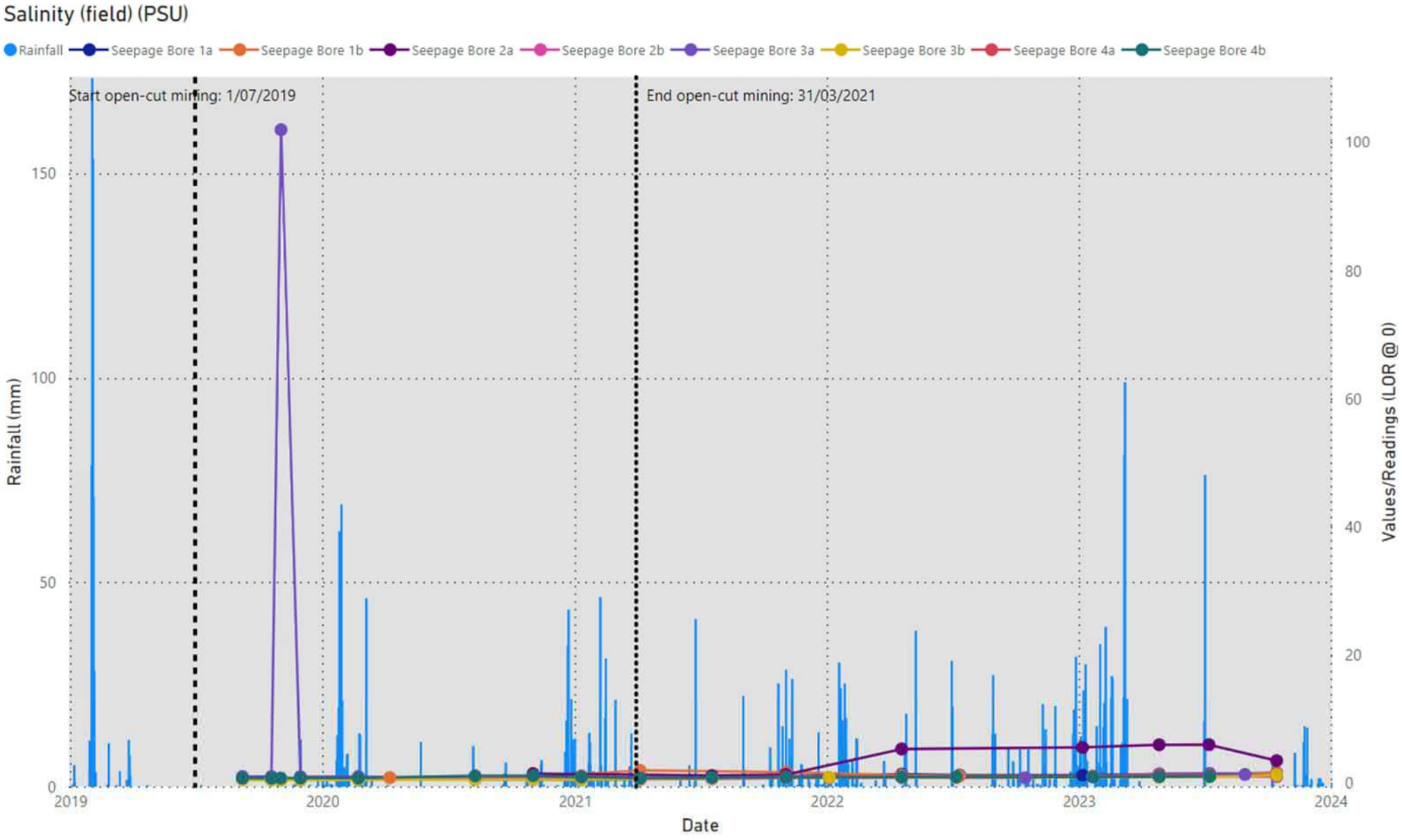

Dissolved Oxygen (field) (% sat)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
50
100
150
200
250
300
350
2019
2020
2021
2022
2023
2024

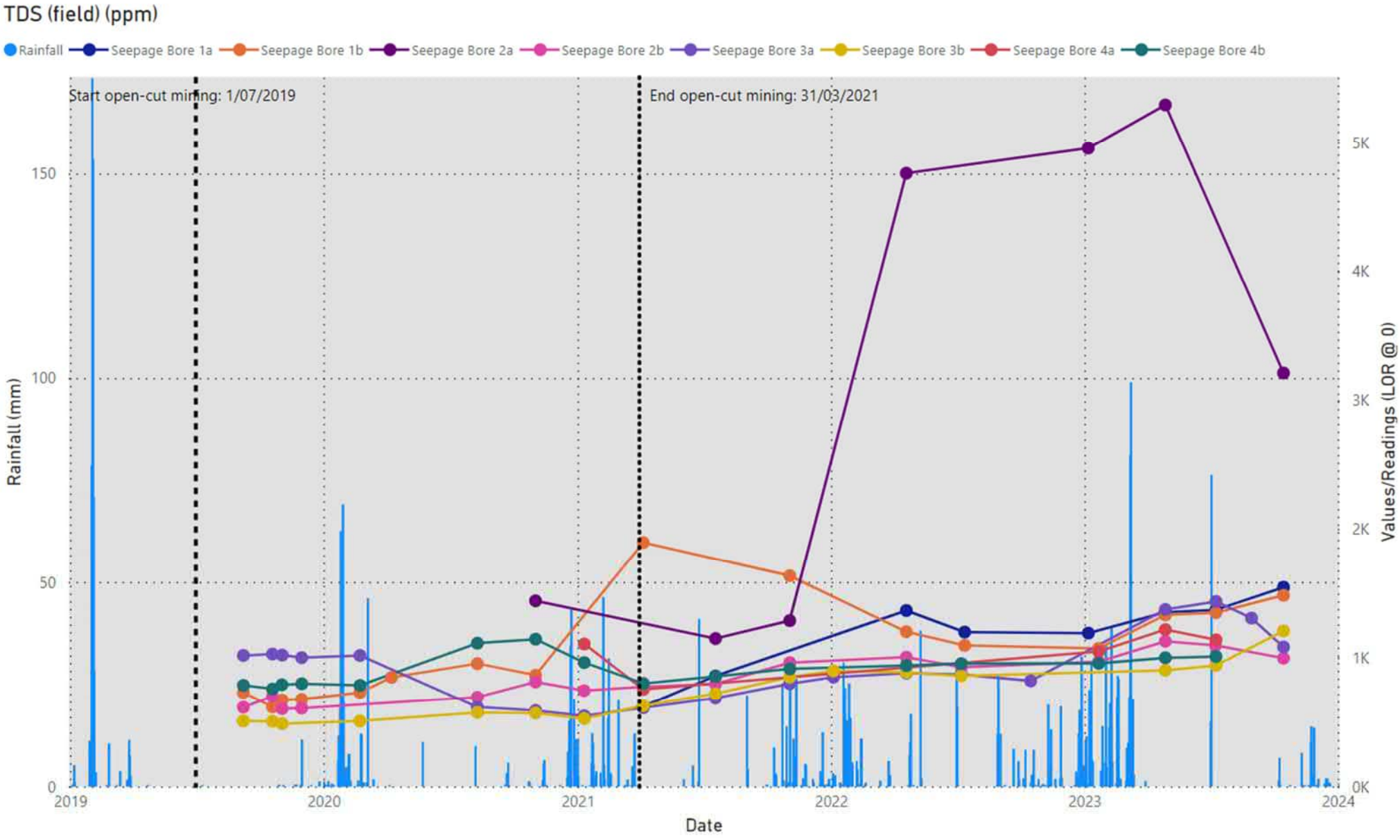

Electrical Conductivity (field) (µS/cm)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0K
2K
4K
6K
8K
10K
2019
2020
2021
2022
2023
2024
Date

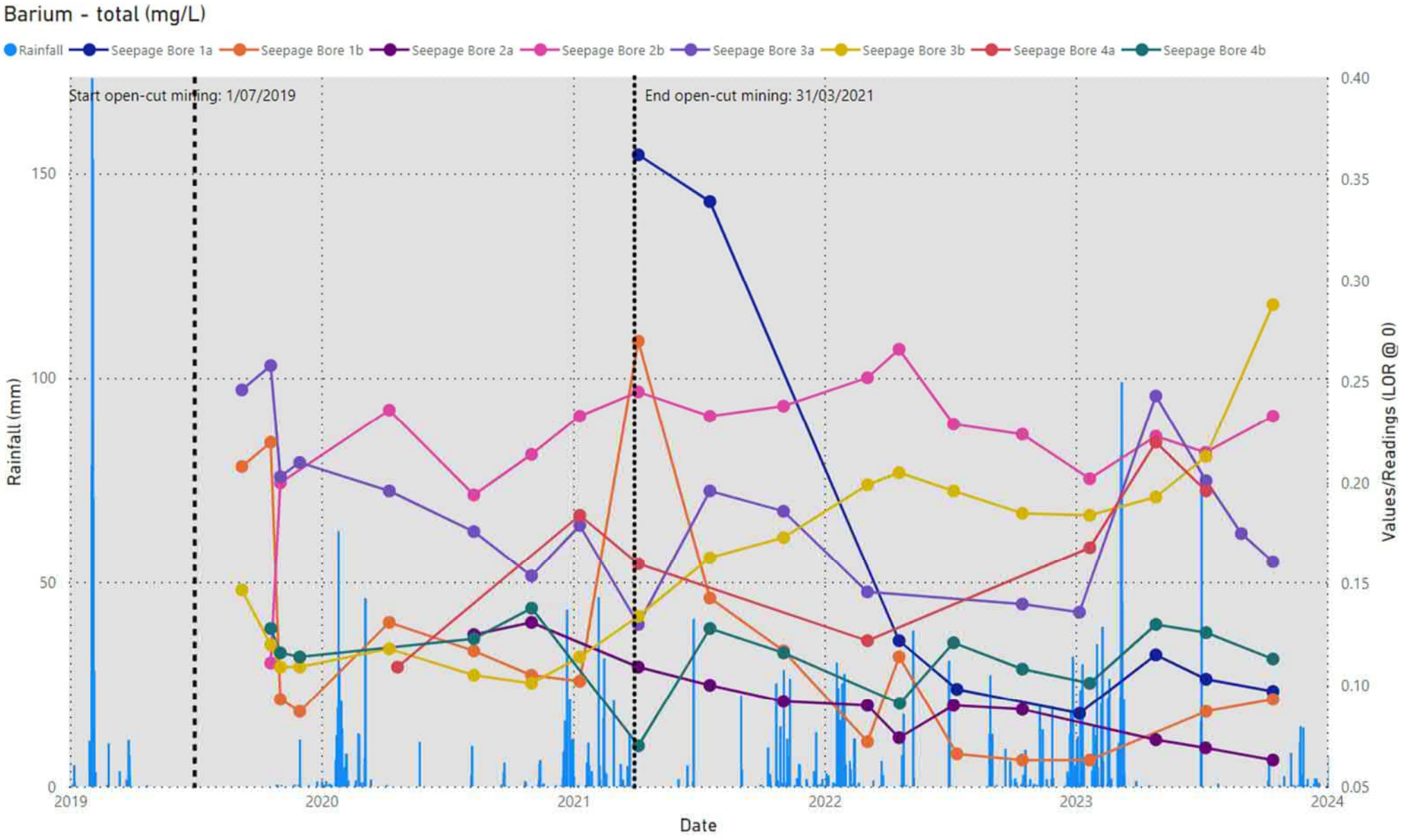

Groundwater Level (mAHD)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
320
325
330
335
340
345
350
355
2019
2020
2021
2022
2023
2024

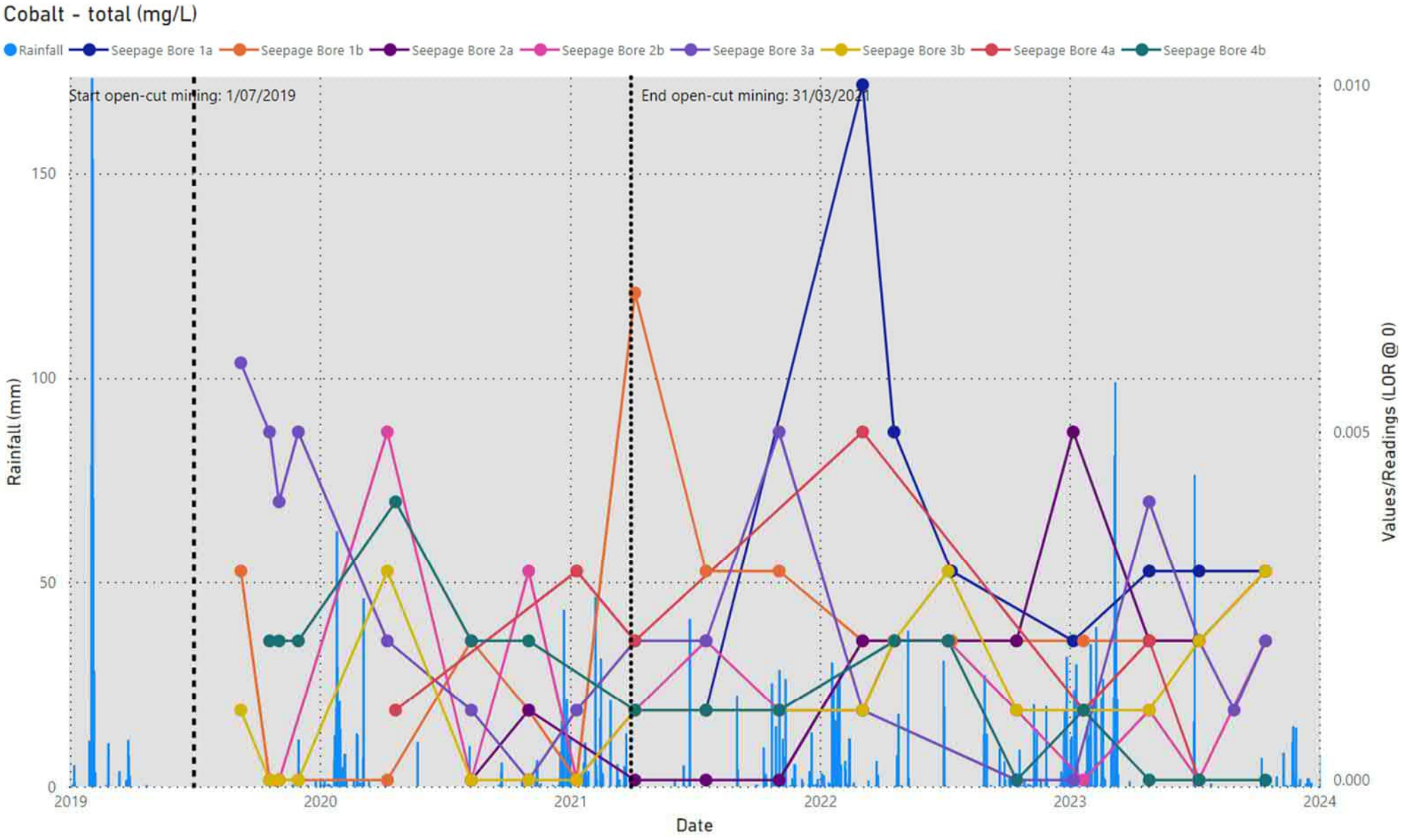

ORP (field) (mV)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
-100
-50
0
50
100
150
200
250
2019
2020
2021
2022
2023
2024

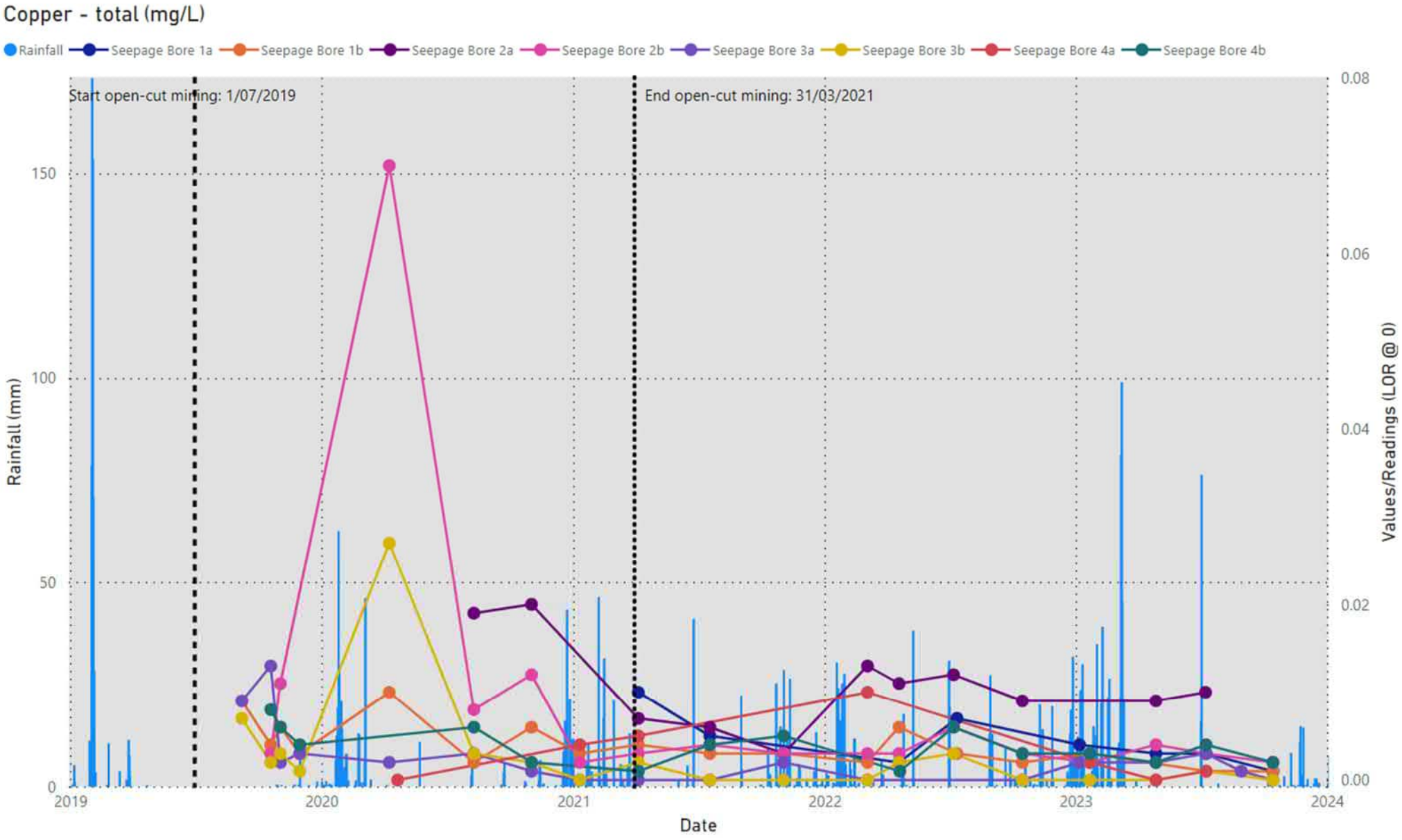

pH (field)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
2019
2020
2021
2022
2023
2024

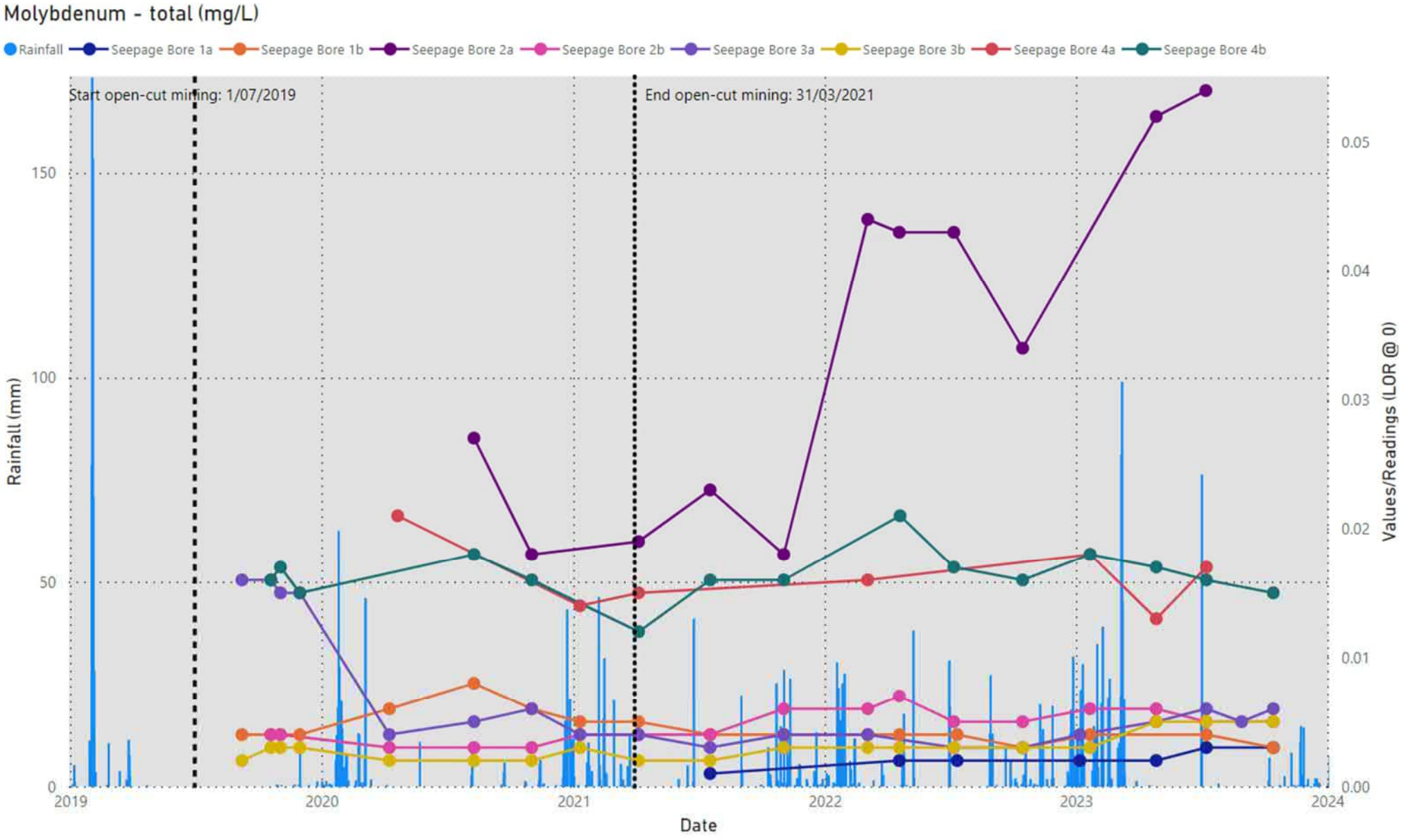

Salinity (field) (PSU)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
20
40
60
80
100
2019
2020
2021
2022
2023
2024

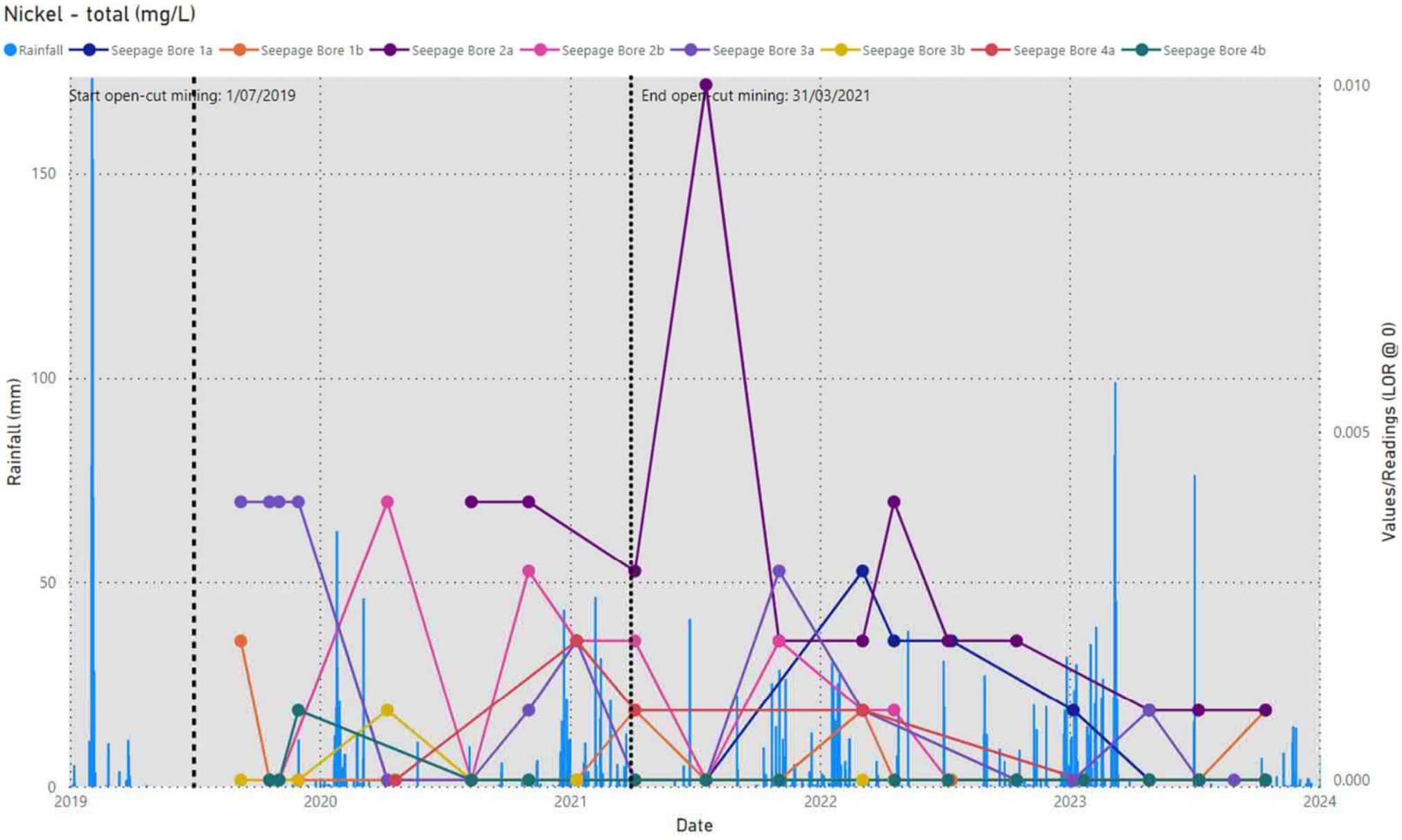

TDS (field) (ppm)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0K
1K
2K
3K
4K
5K
2019
2020
2021
2022
2023
2024
Date

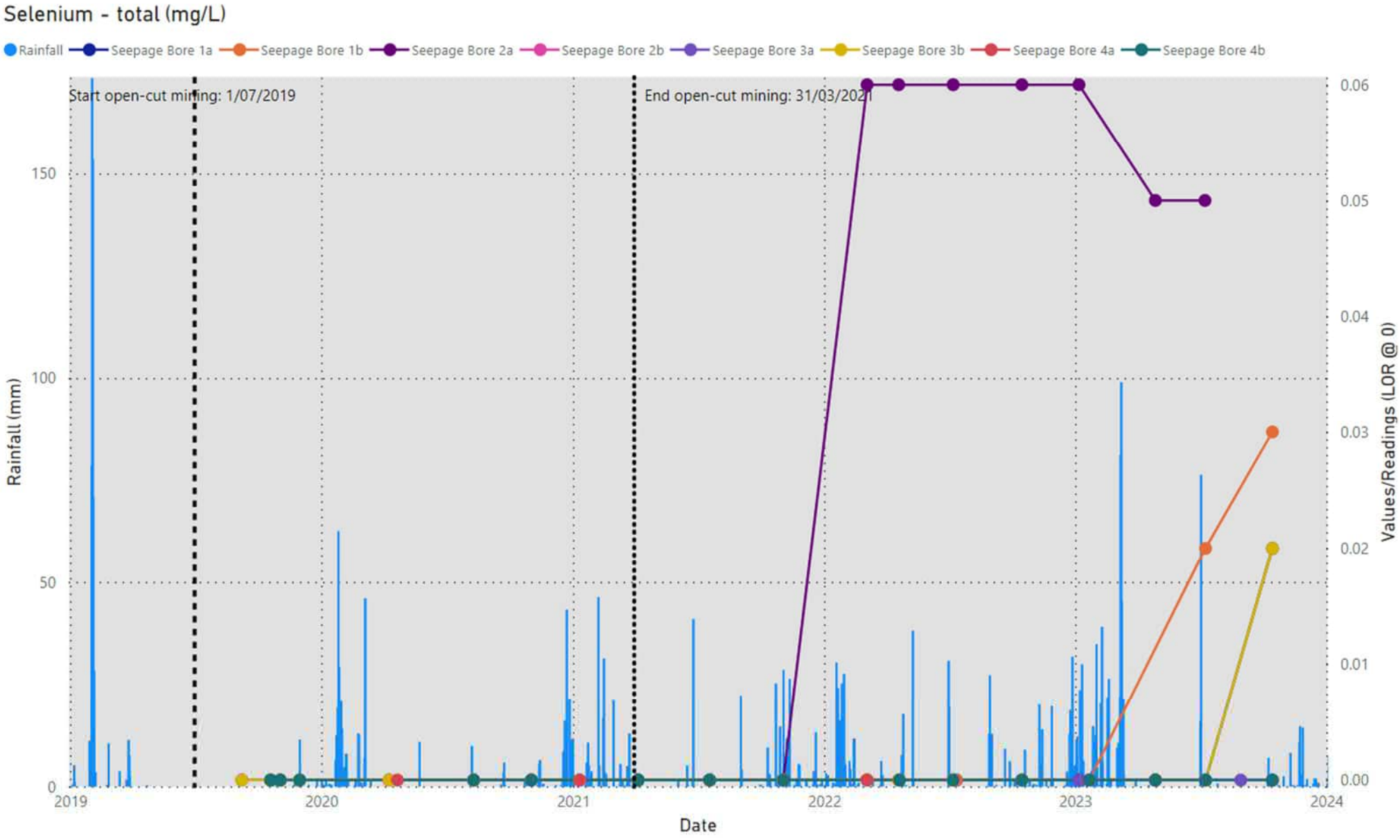

Barium - total (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
2019
2020
2021
2022
2023
2024

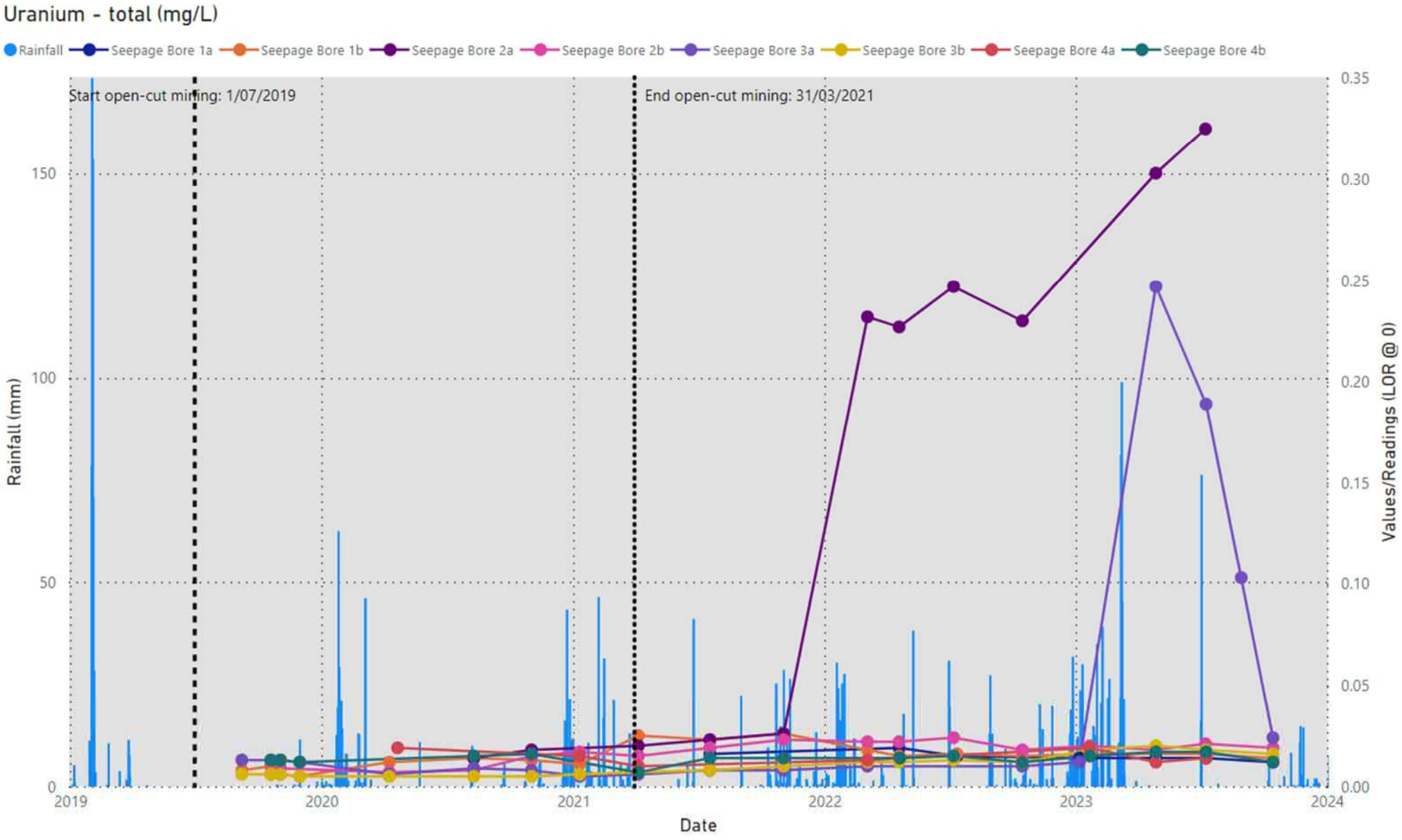

Cobalt - total (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
Values/Readings (LOR @ 0)
0.010
0.005
0.000
2019
2020
2021
2022
2023
2024
Date

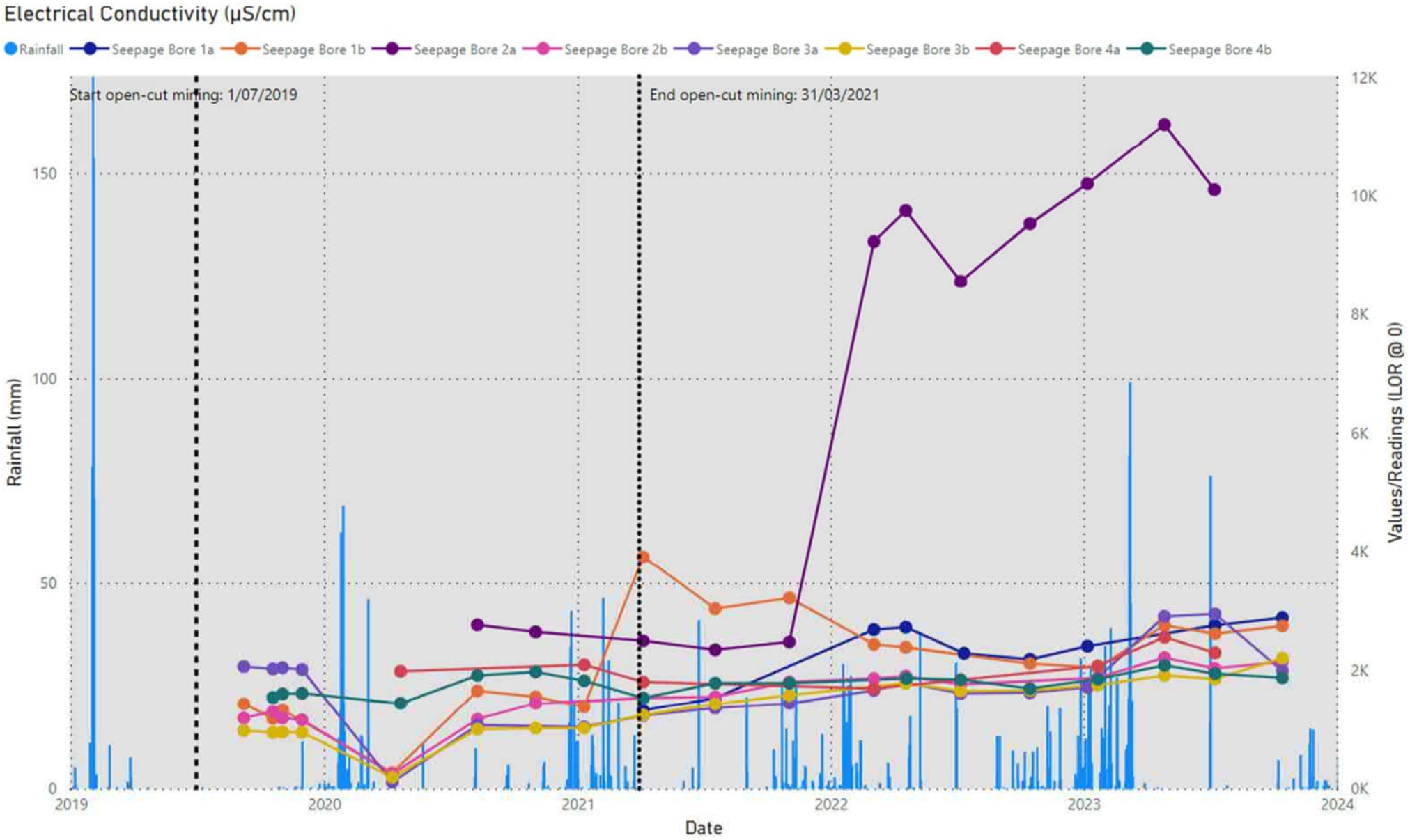

Copper - total (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.02
0.04
0.06
0.08
2019
2020
2021
2022
2023
2024

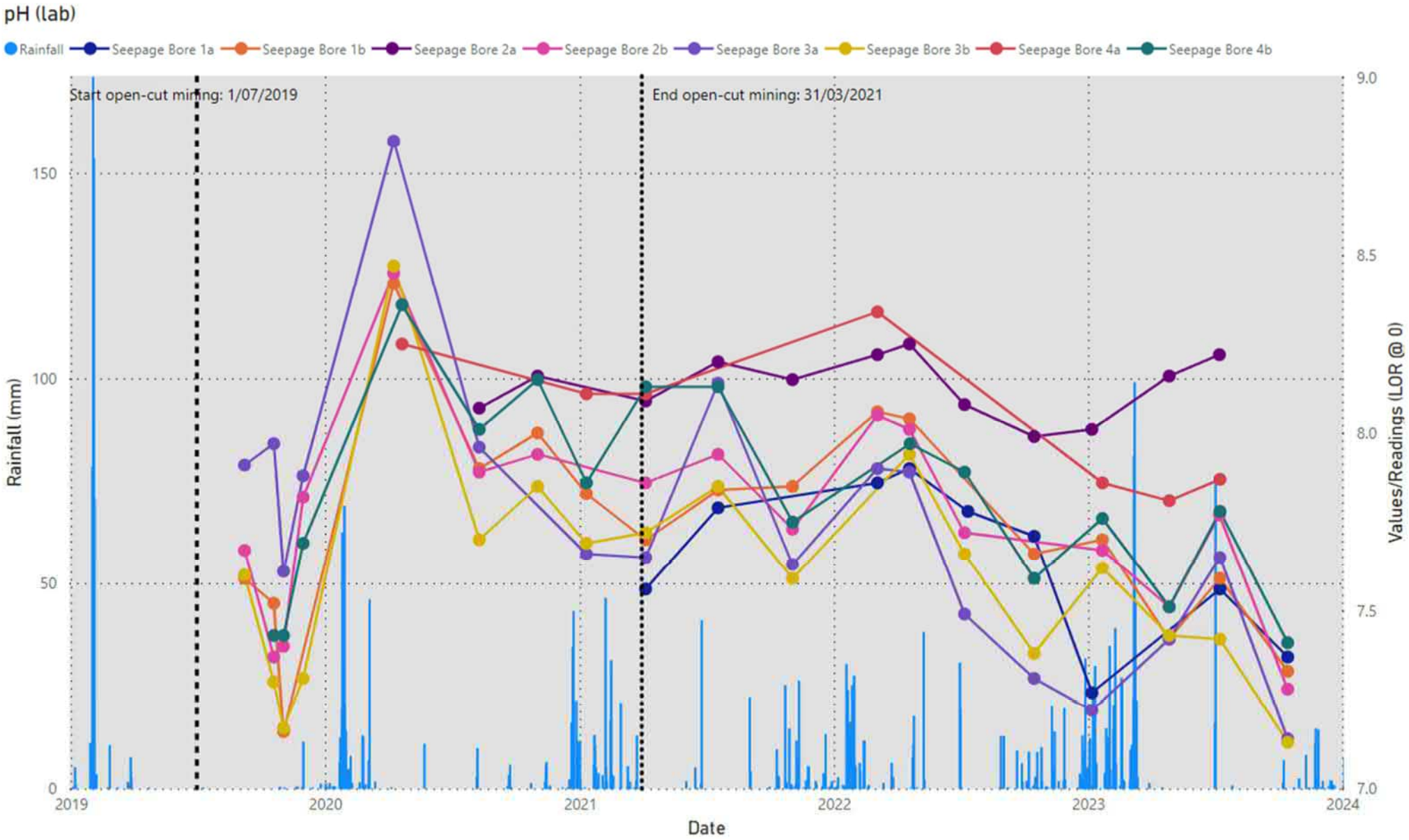

Molybdenum - total (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.01
0.02
0.03
0.04
0.05
2019
2020
2021
2022
2023
2024

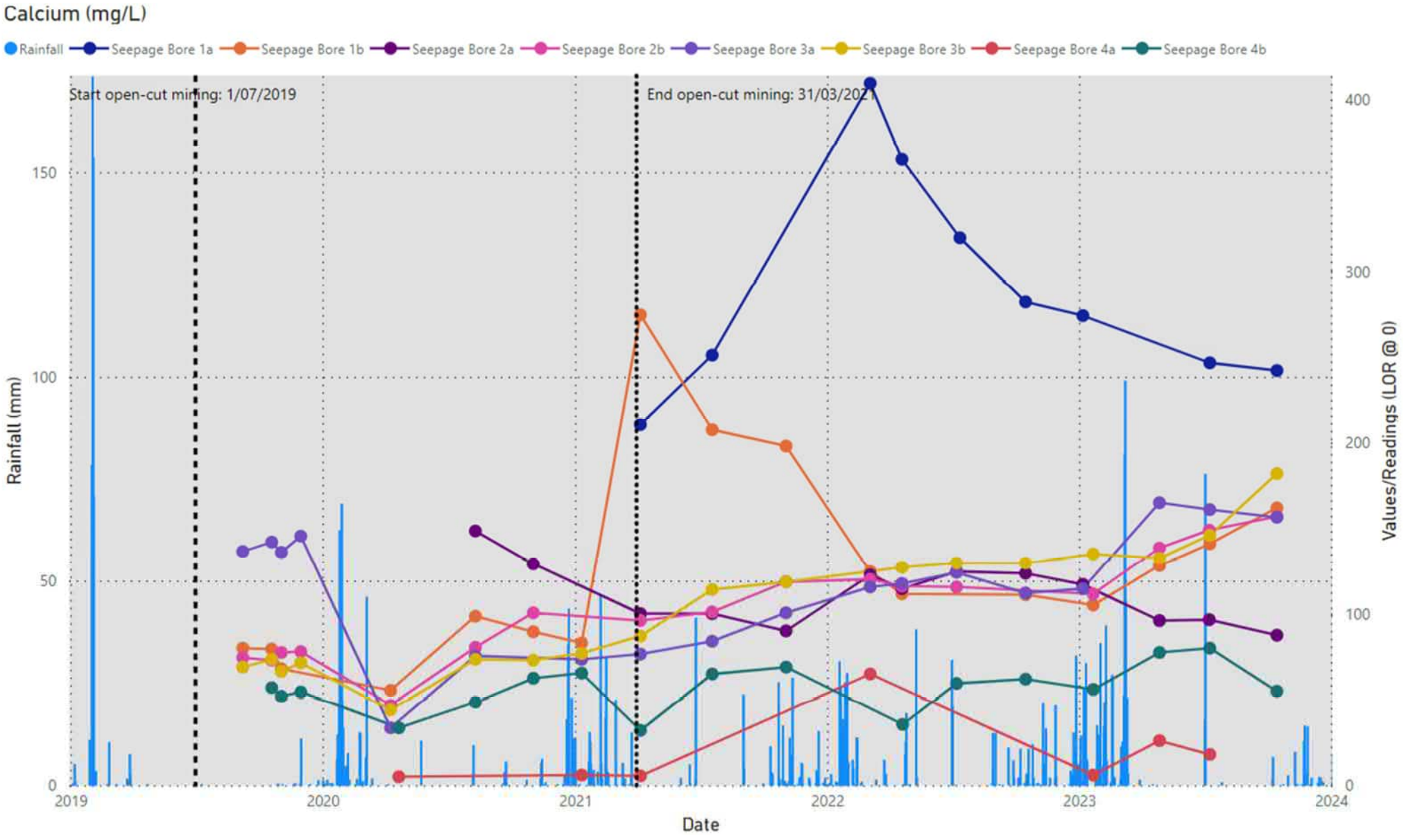

Nickel - total (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.000
0.005
0.010
2019
2020
2021
2022
2023
2024

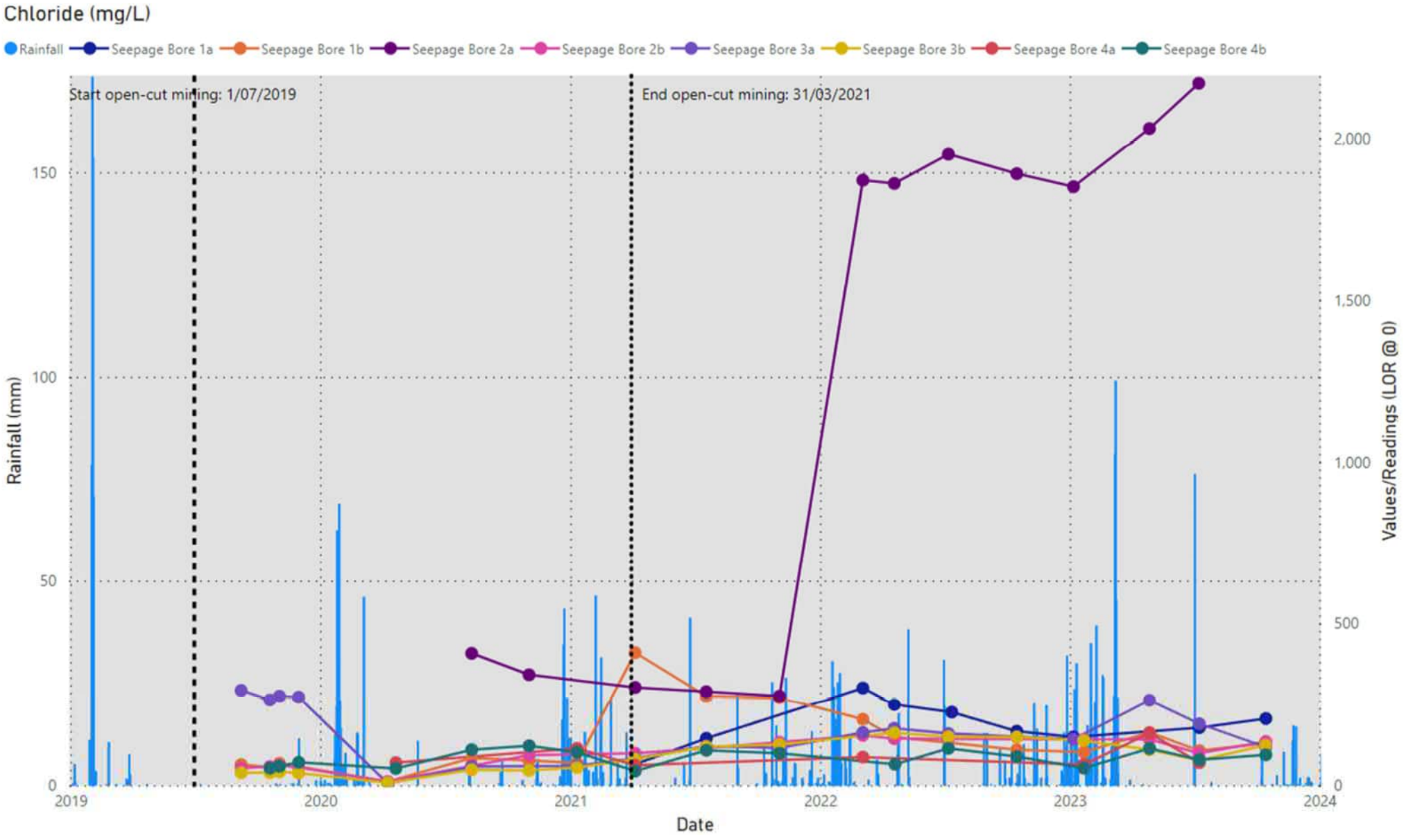

Selenium - total (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.01
0.02
0.03
0.04
0.05
0.06
2019
2020
2021
2022
2023
2024

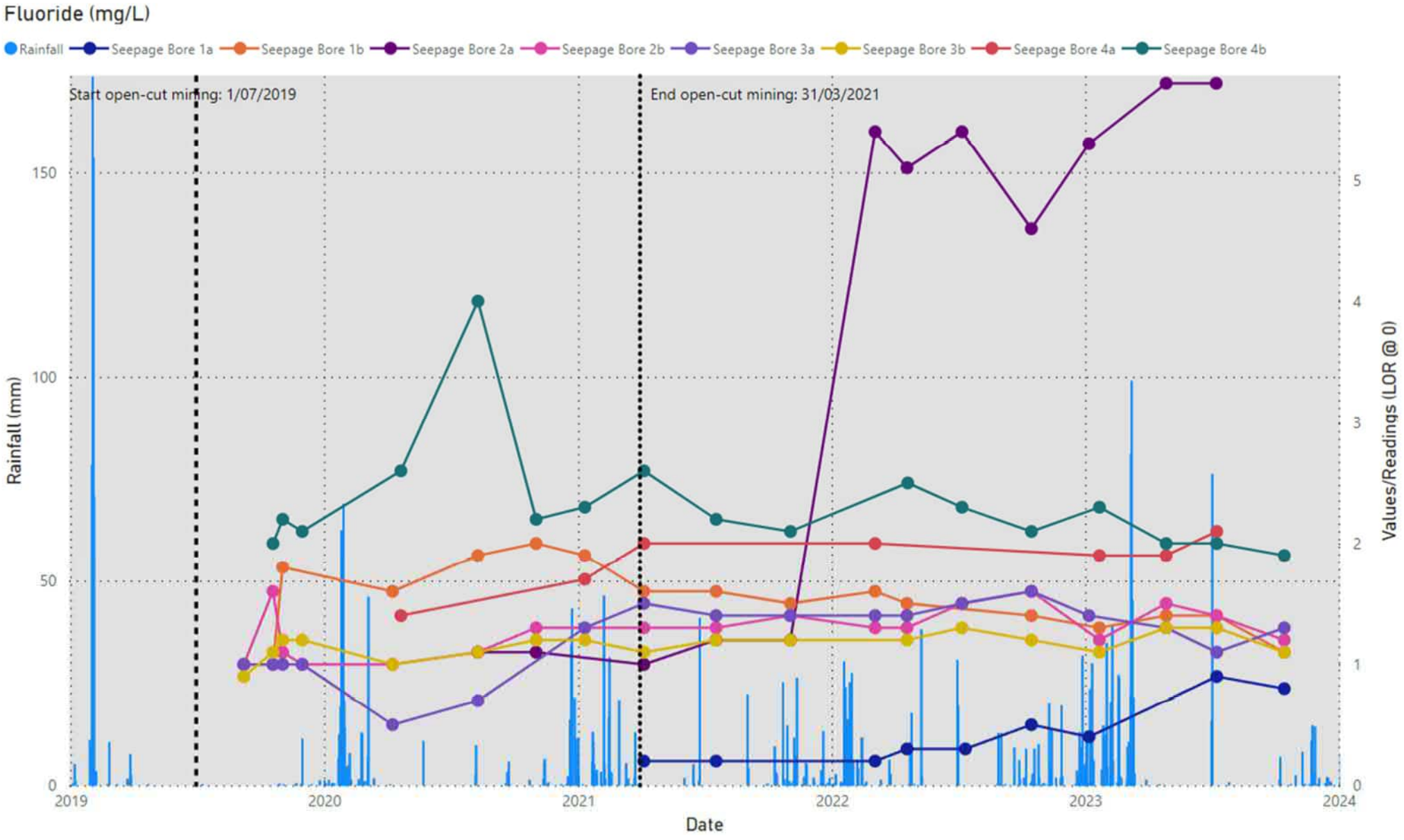

Uranium - total (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
2019
2020
2021
2022
2023
2024

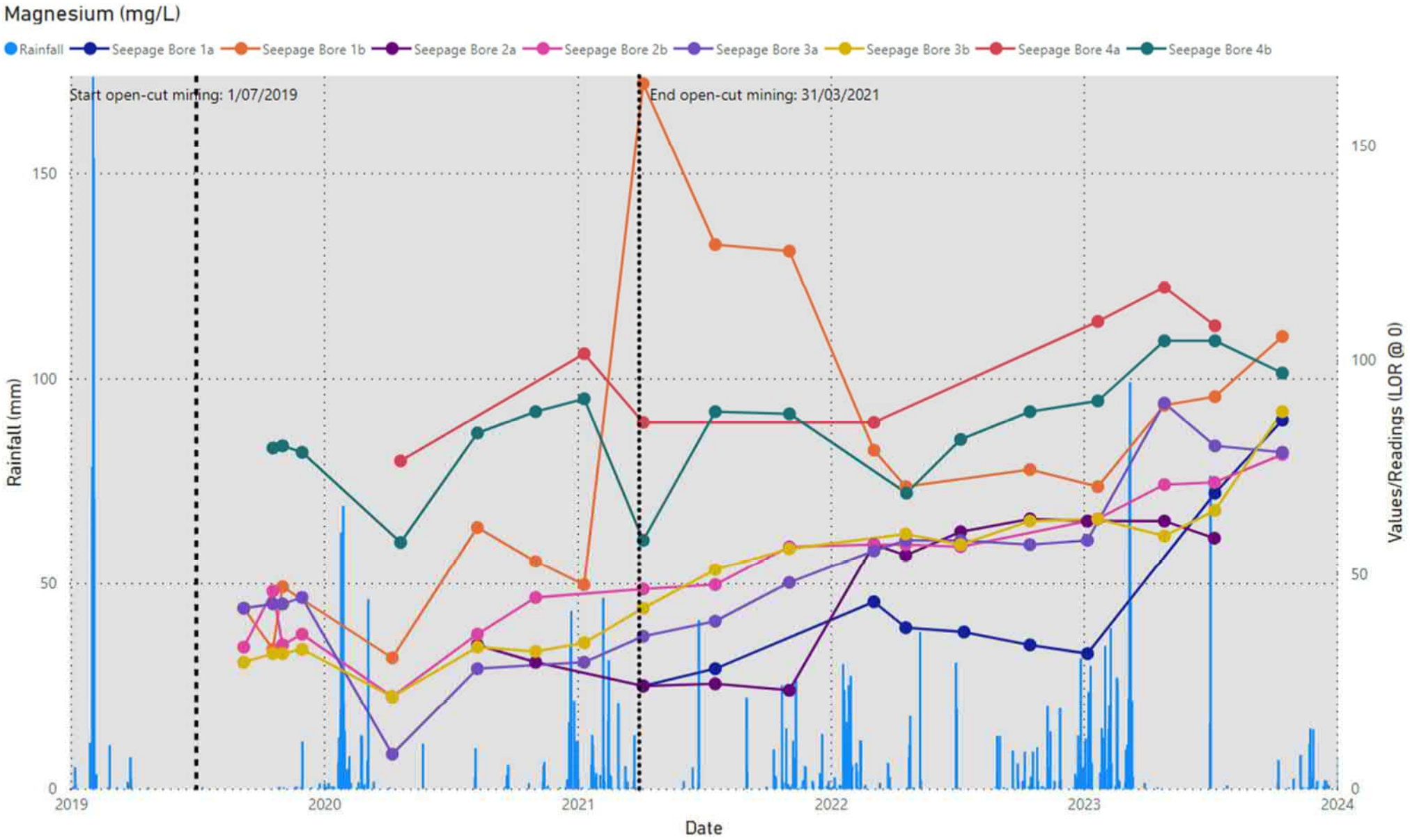

Electrical Conductivity (µS/cm)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0K
2K
4K
6K
8K
10K
12K
2019
2020
2021
2022
2023
2024
Date

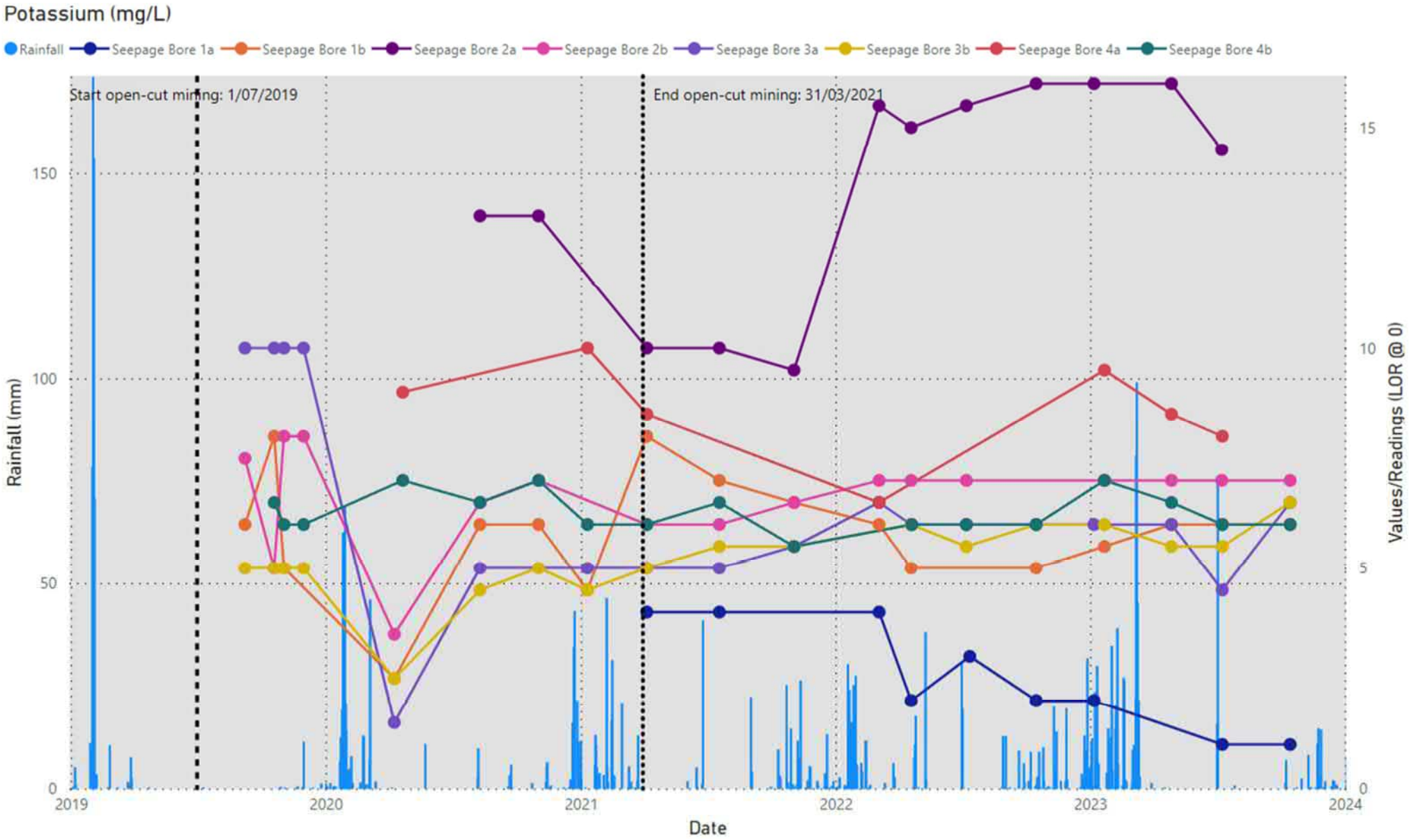

pH (lab)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
7.0
7.5
8.0
8.5
9.0
2019
2020
2021
2022
2023
2024

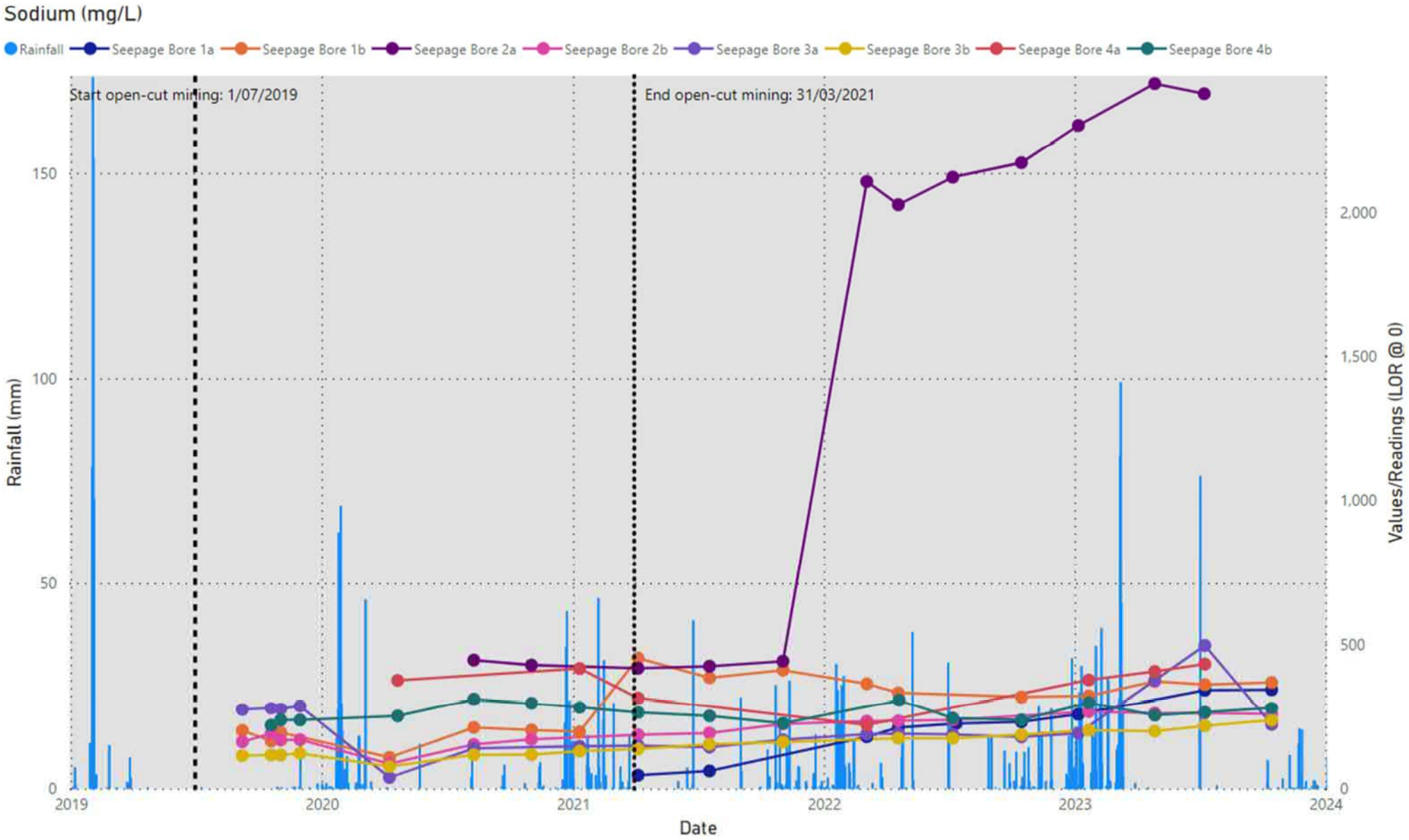

Calcium (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
100
200
300
400
2019
2020
2021
2022
2023
2024

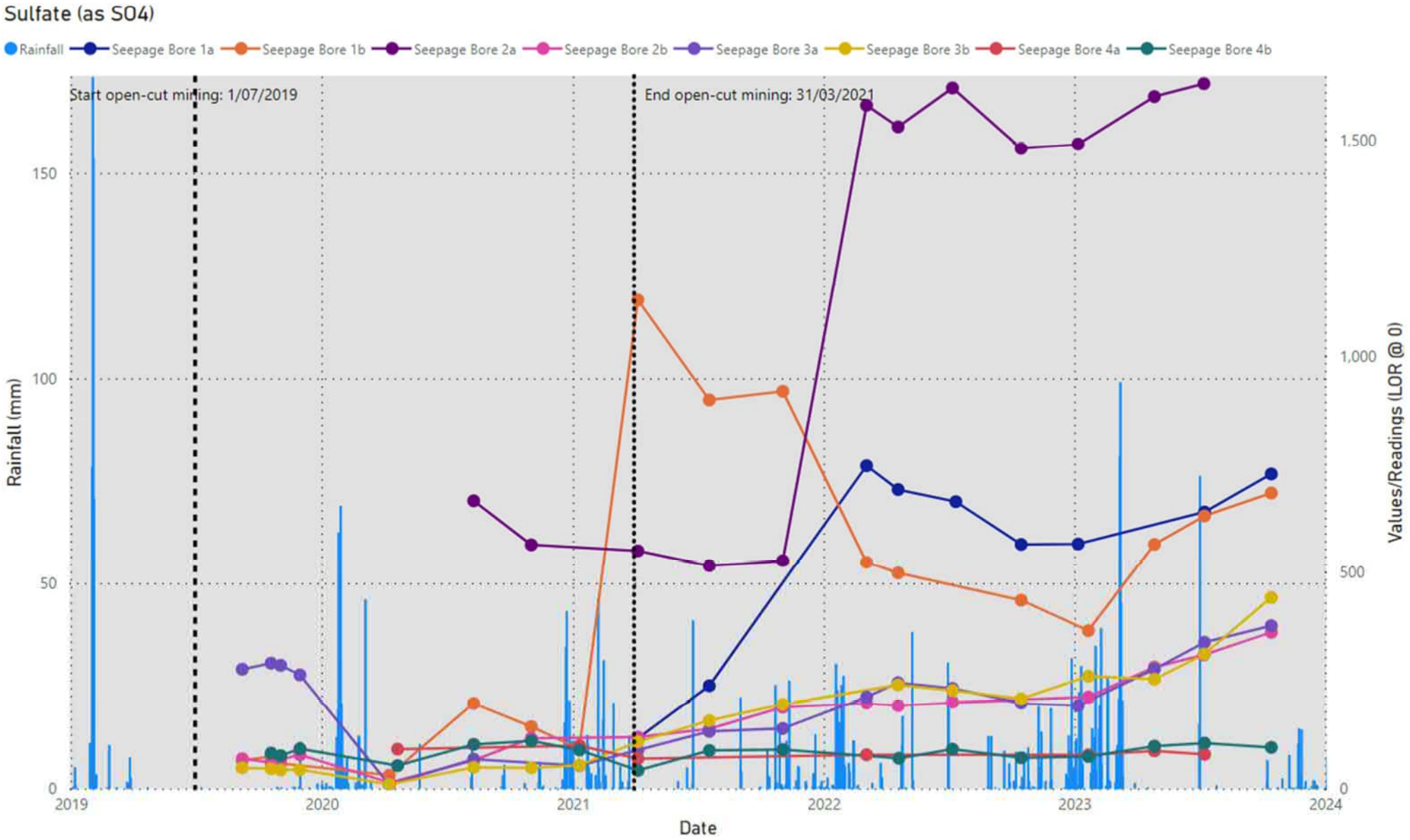

Chloride (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
500
1,000
1,500
2,000
2019
2020
2021
2022
2023
2024

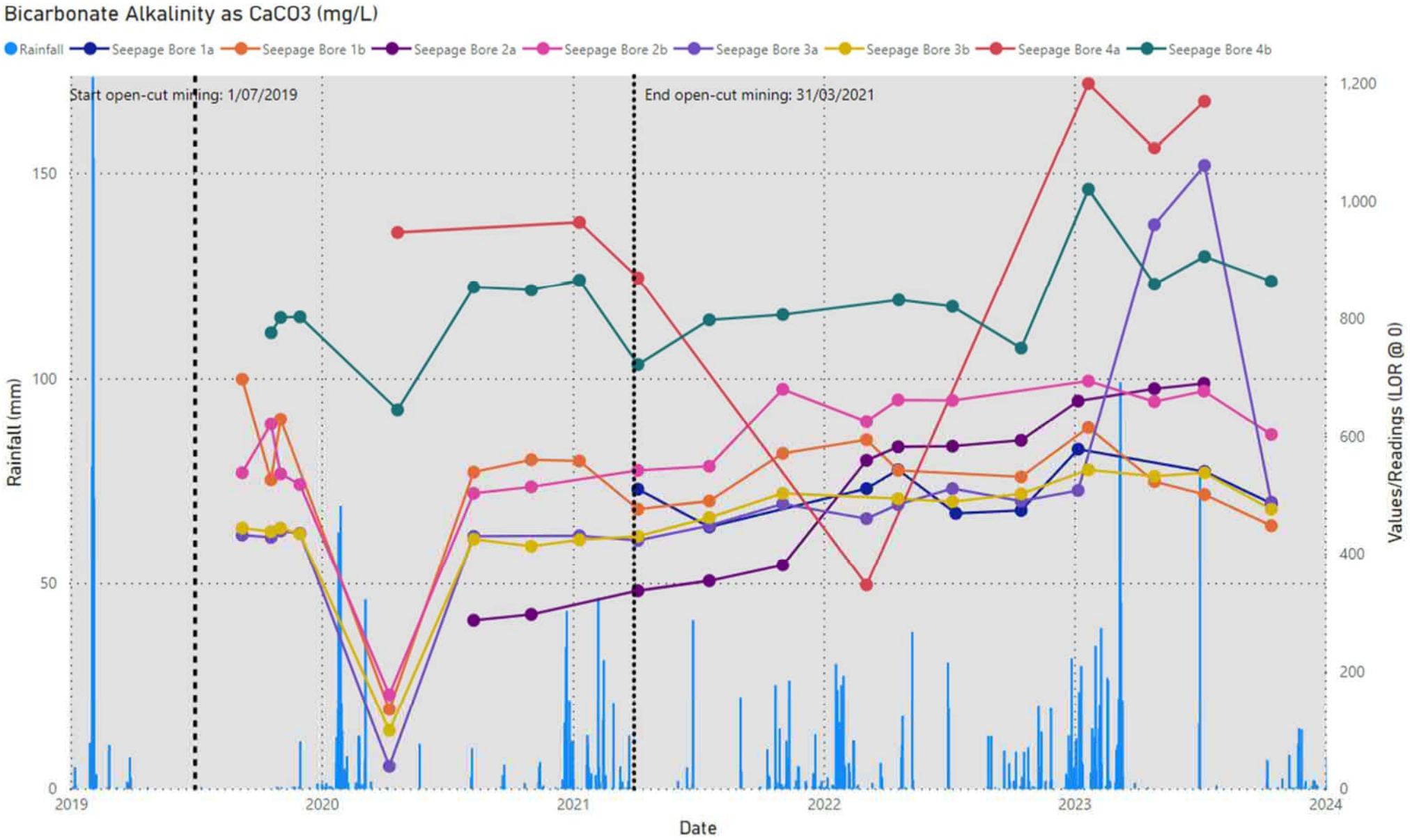

Fluoride (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
1
2
3
4
5
2019
2020
2021
2022
2023
2024

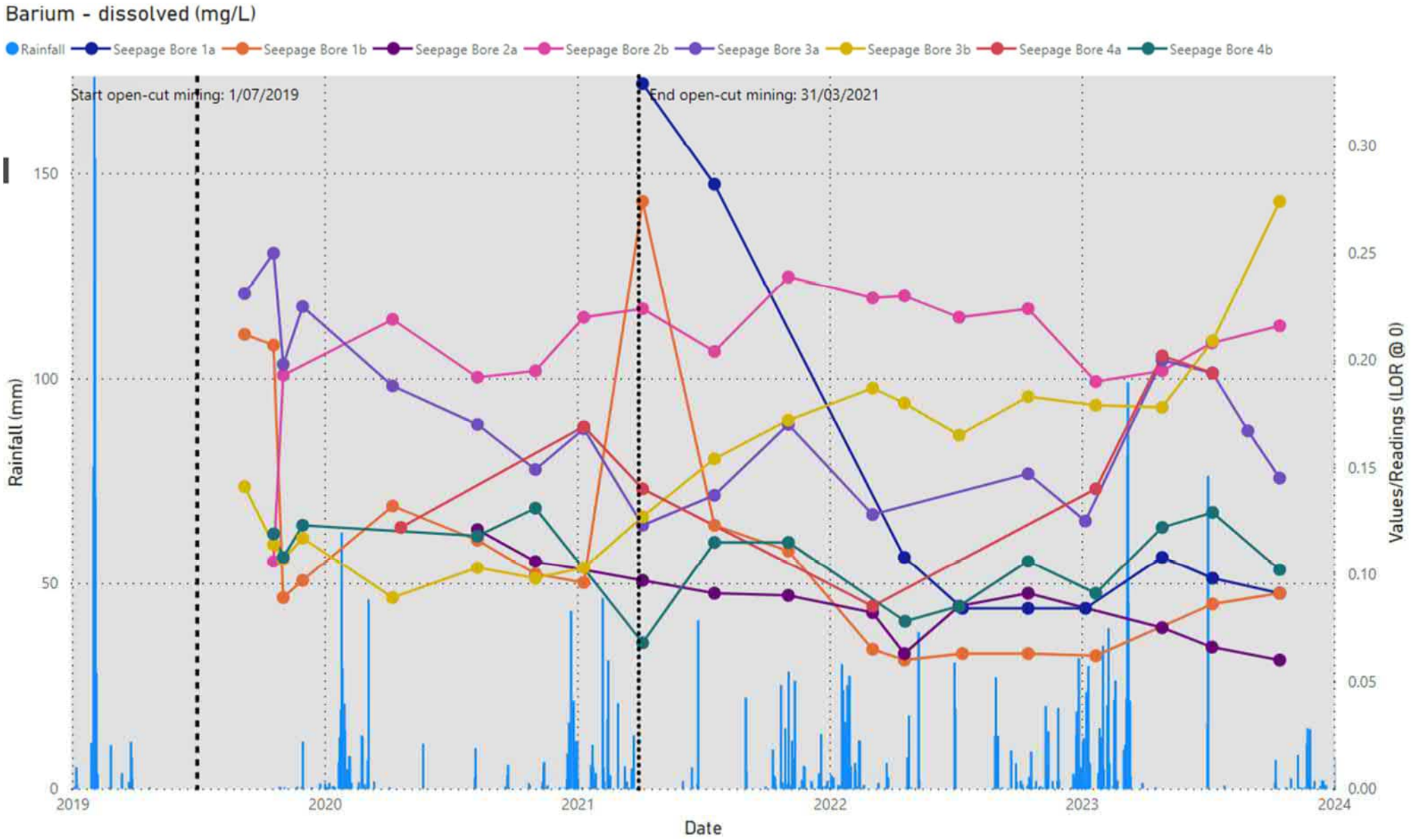

Magnesium (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
2019
2020
2021
2022
2023
2024

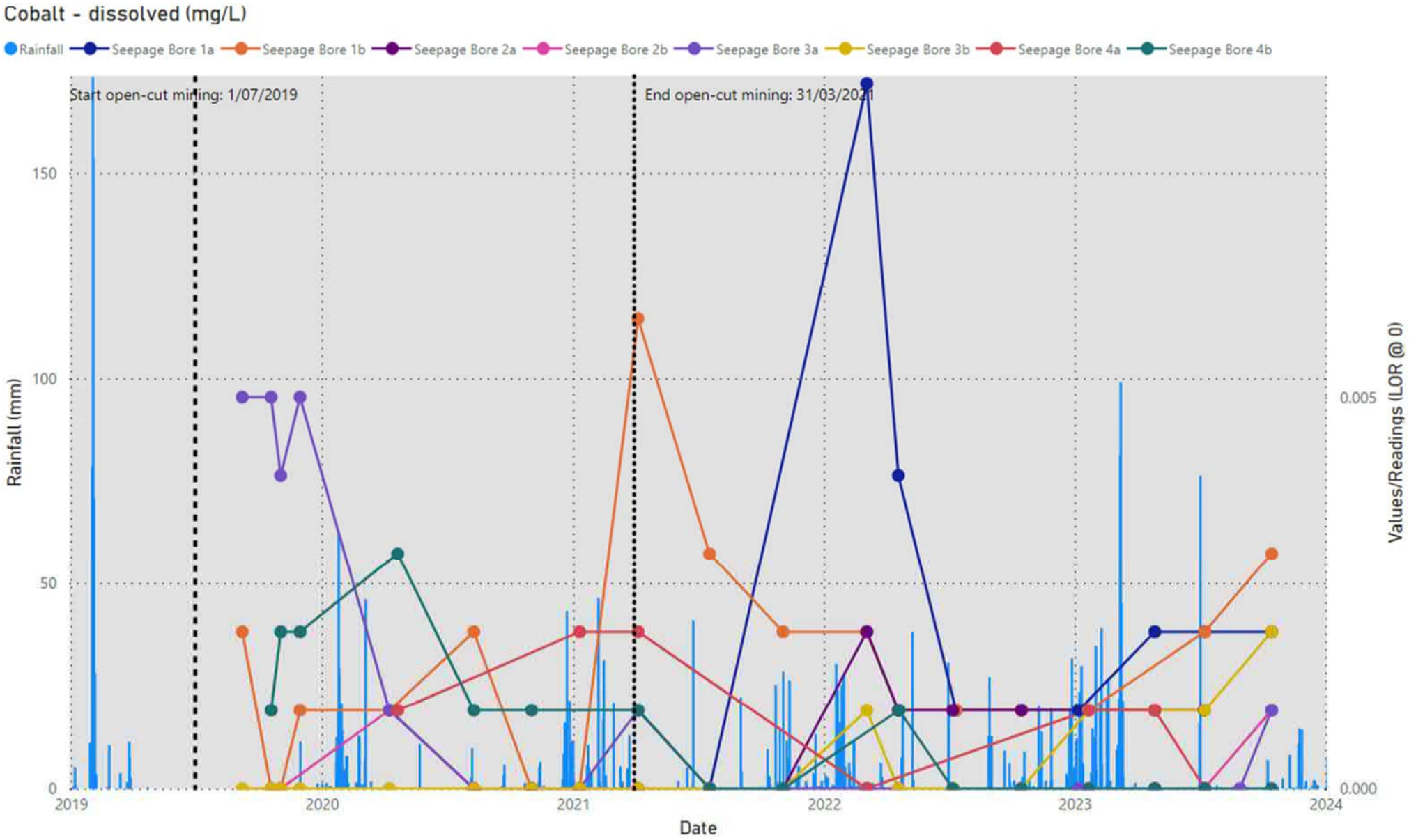

Potassium (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
5
10
15
2019
2020
2021
2022
2023
2024

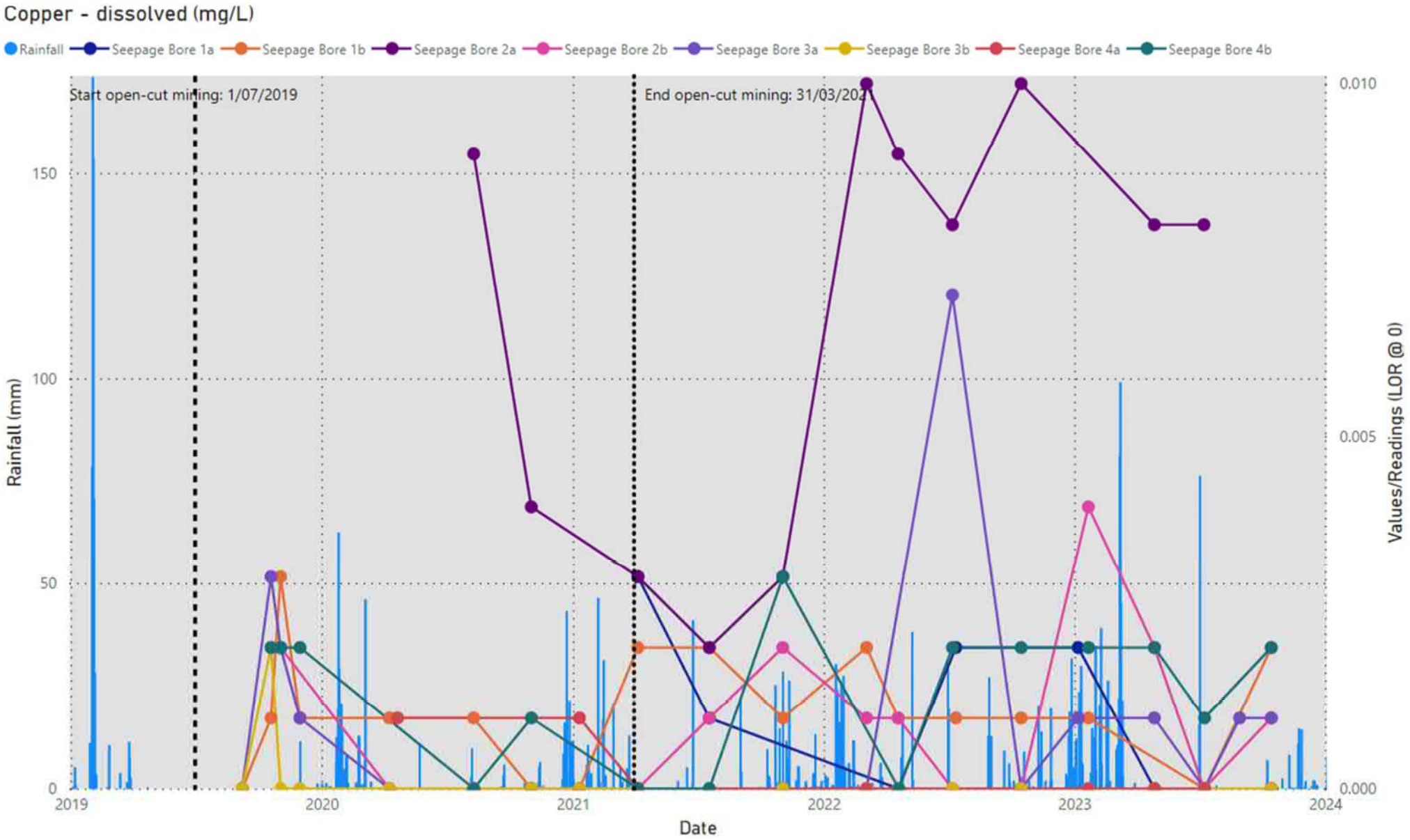

Sodium (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
500
1,000
1,500
2,000
2019
2020
2021
2022
2023
2024

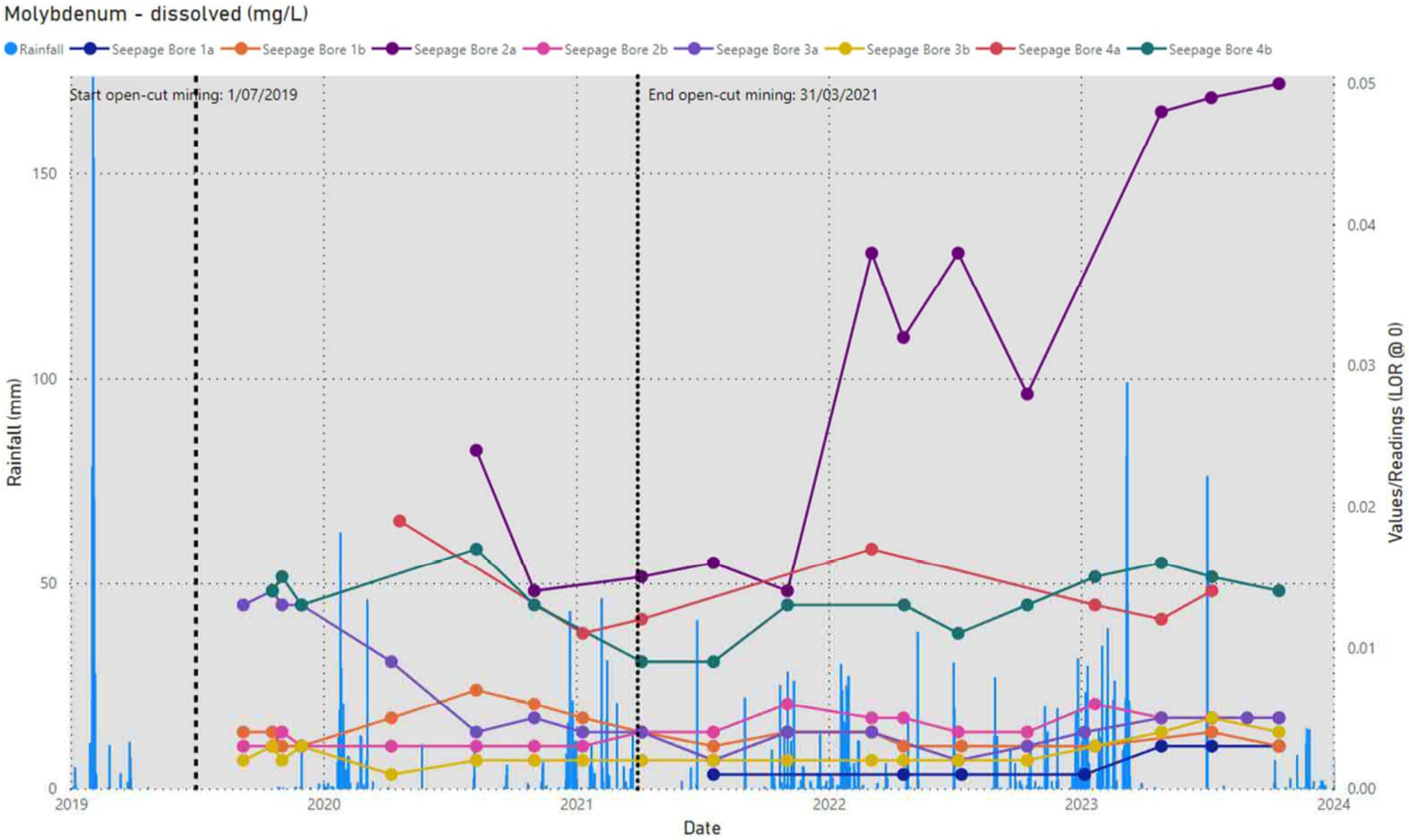

Sulfate (as SO4)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
500
1,000
1,500
2019
2020
2021
2022
2023
2024

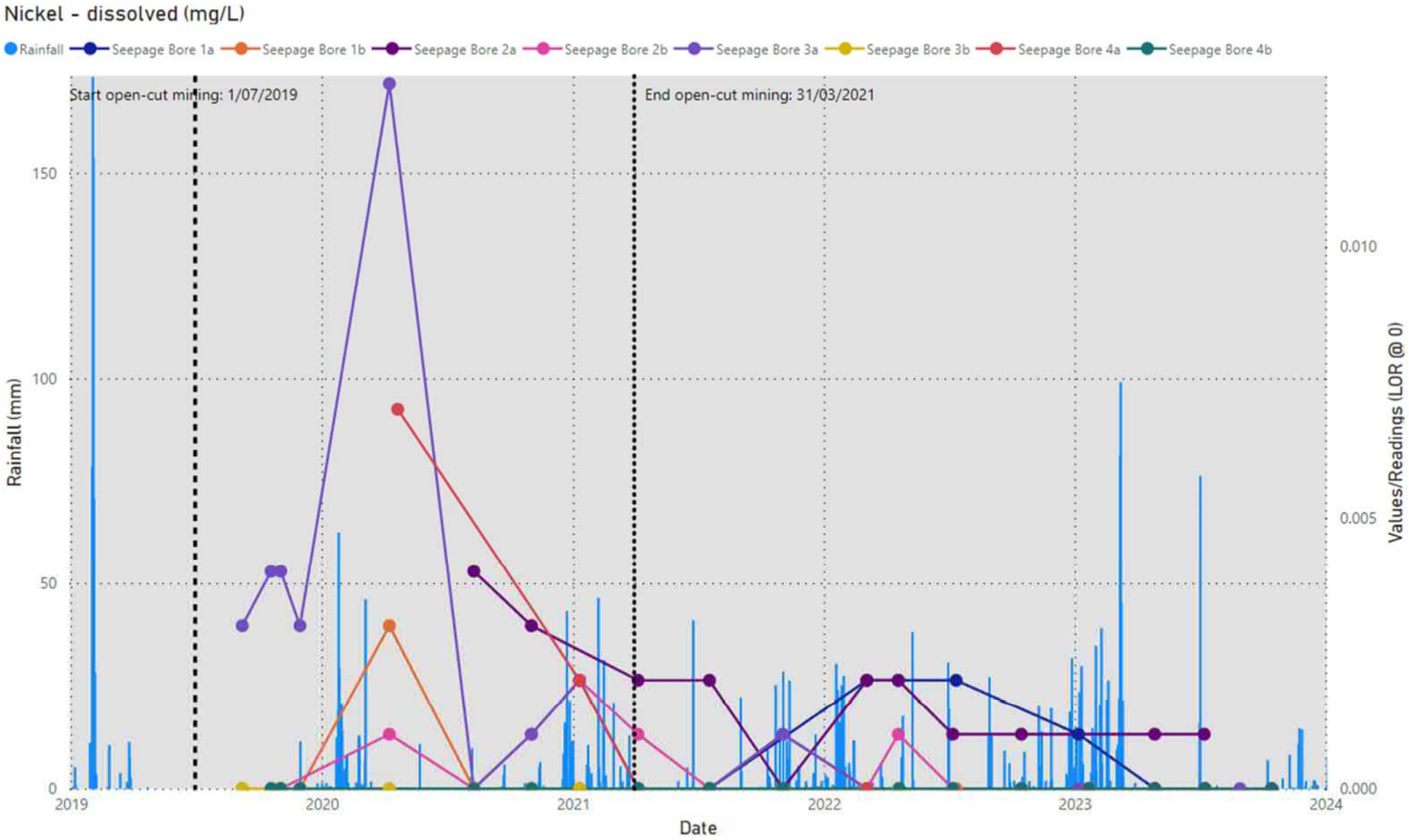

Bicarbonate Alkalinity as CaCO3 (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
200
400
600
800
1,000
1,200
2019
2020
2021
2022
2023
2024

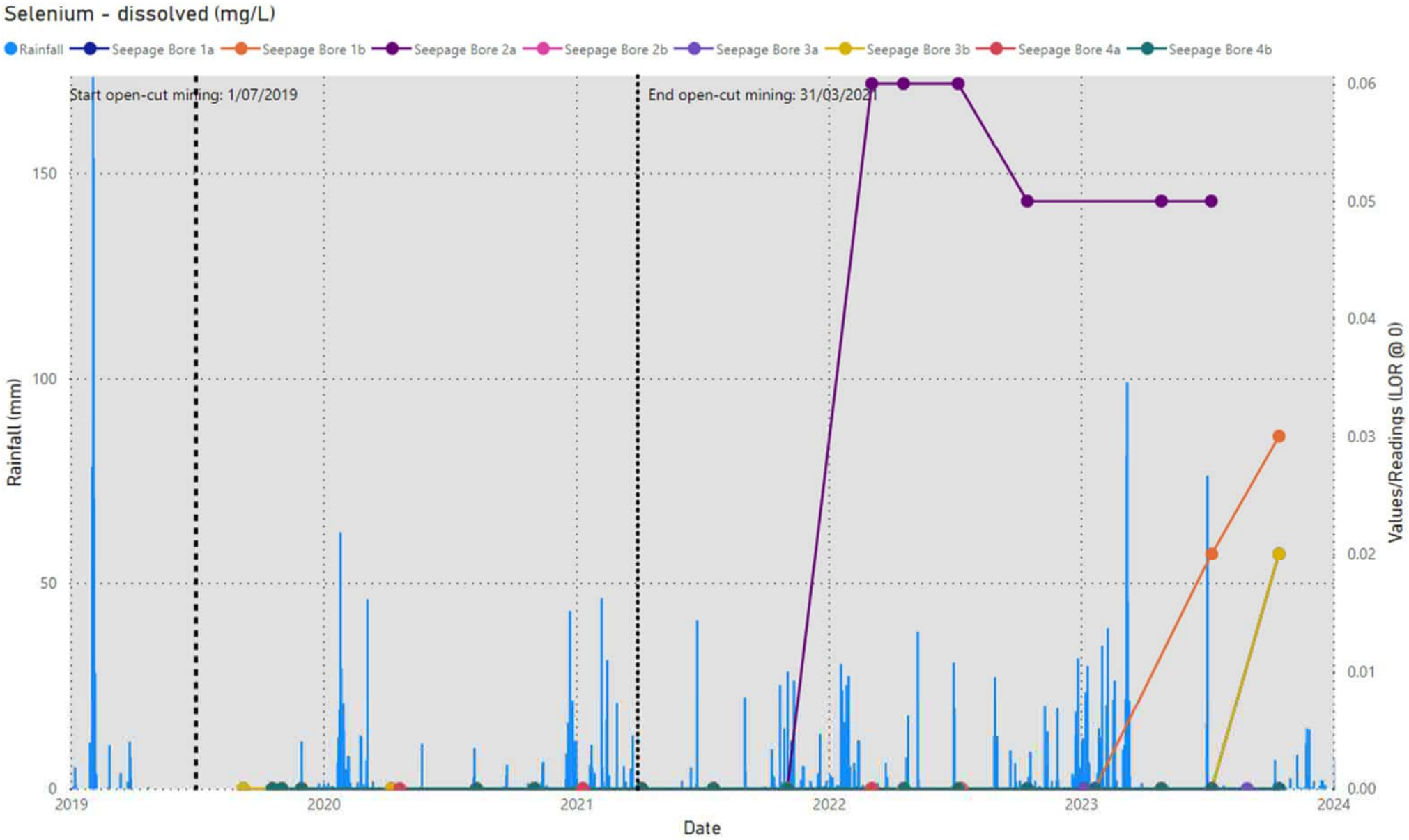

Barium - dissolved (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.05
0.10
0.15
0.20
0.25
0.30
2019
2020
2021
2022
2023
2024

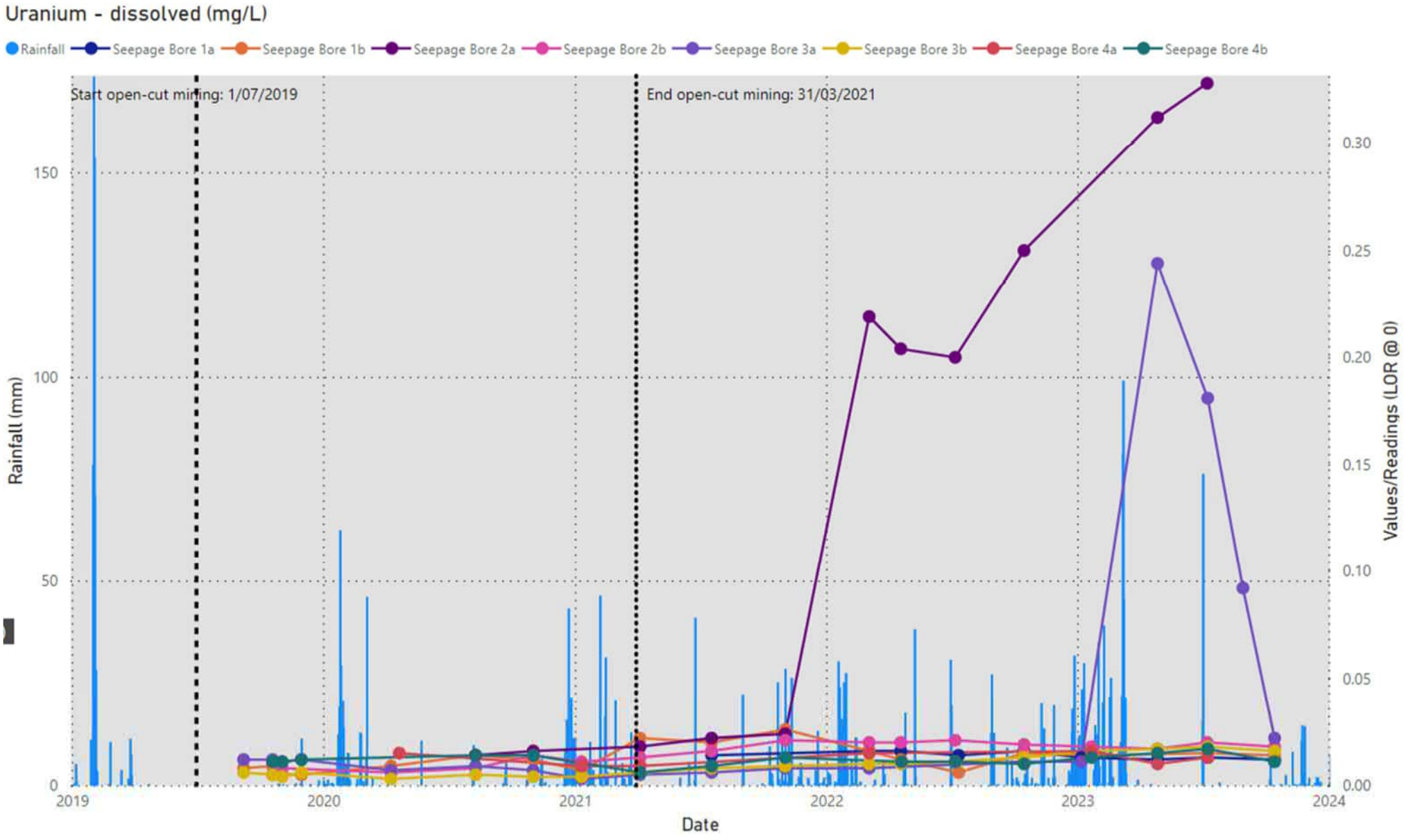

Cobalt - dissolved (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
Values/Readings (LOR @ 0)
0.005
0.000
2019
2020
2021
2022
2023
2024
Date

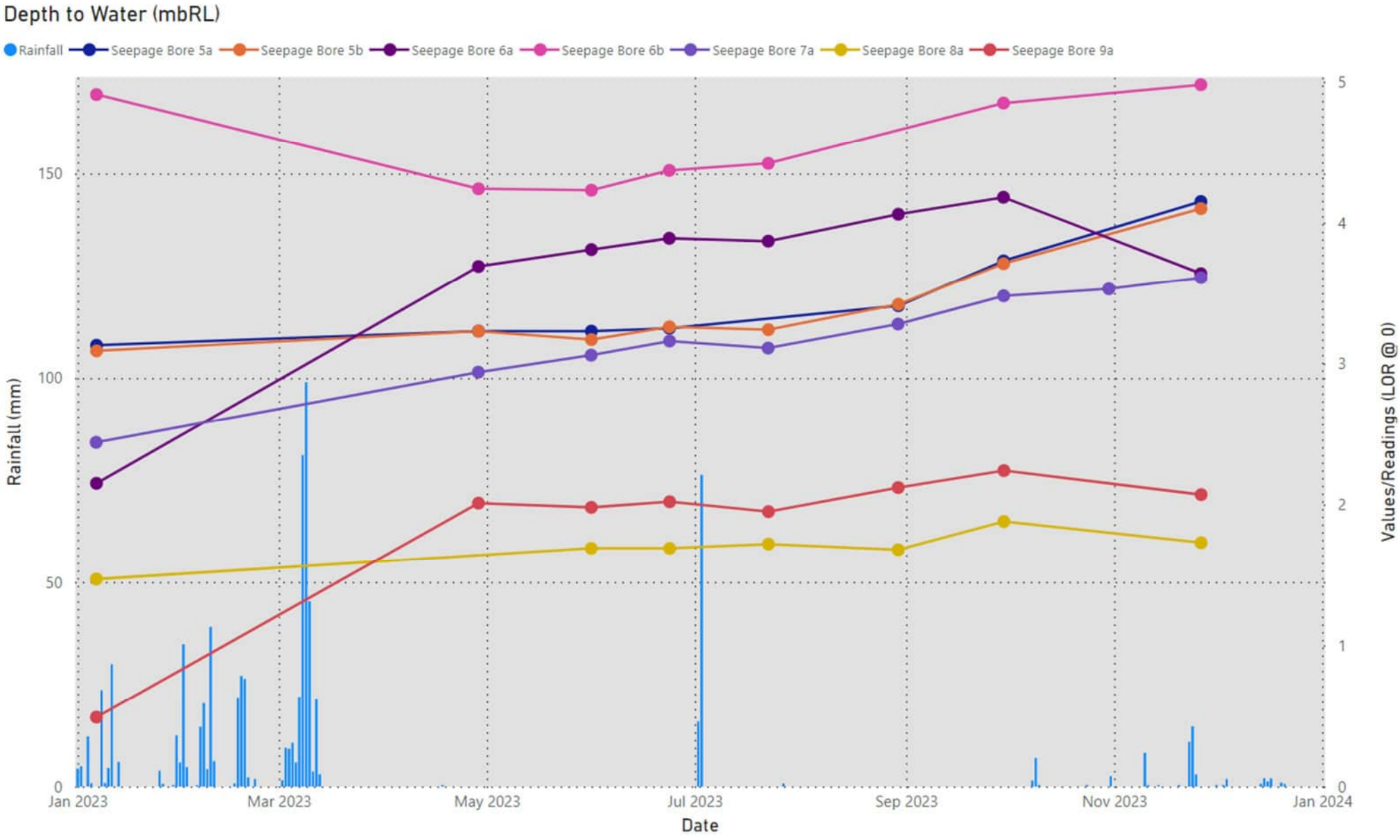

Copper - dissolved (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.000
0.005
0.010
2019
2020
2021
2022
2023
2024

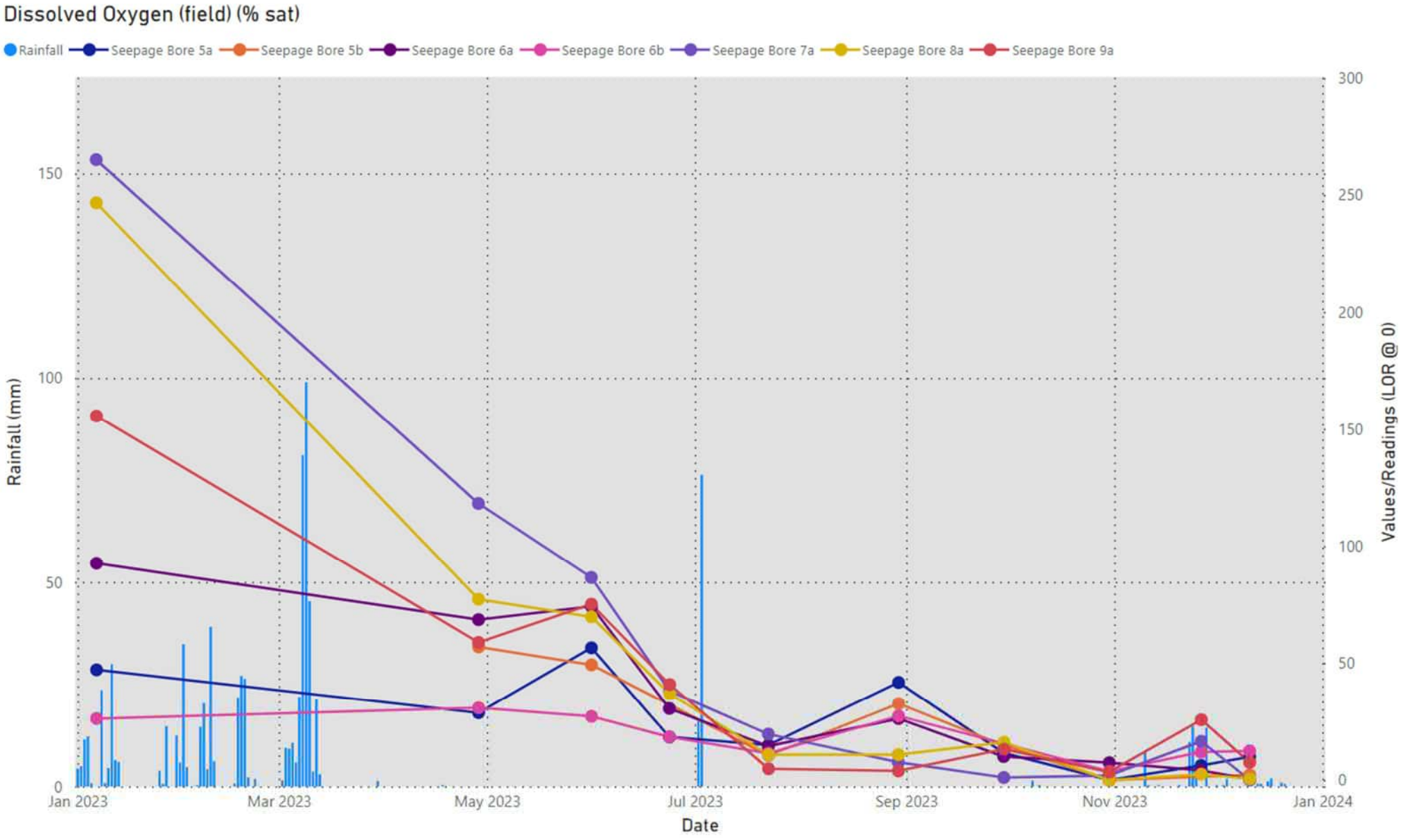

Molybdenum - dissolved (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.01
0.02
0.03
0.04
0.05
2019
2020
2021
2022
2023
2024

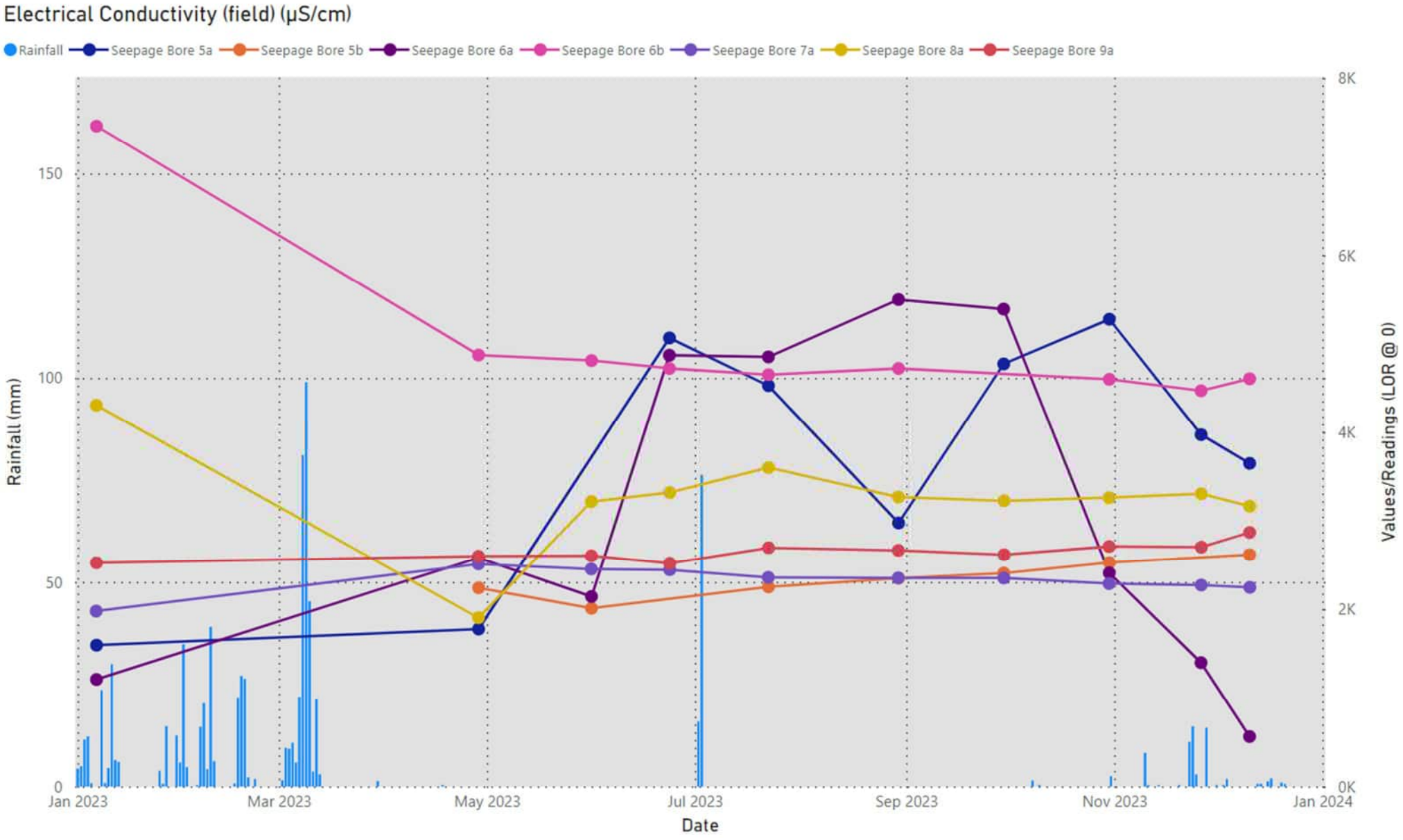

Nickel - dissolved (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
150
100
50
0
0.010
0.005
0.000
Values/Readings (LOR @ 0)
2019
2020
2021
2022
2023
2024
Date

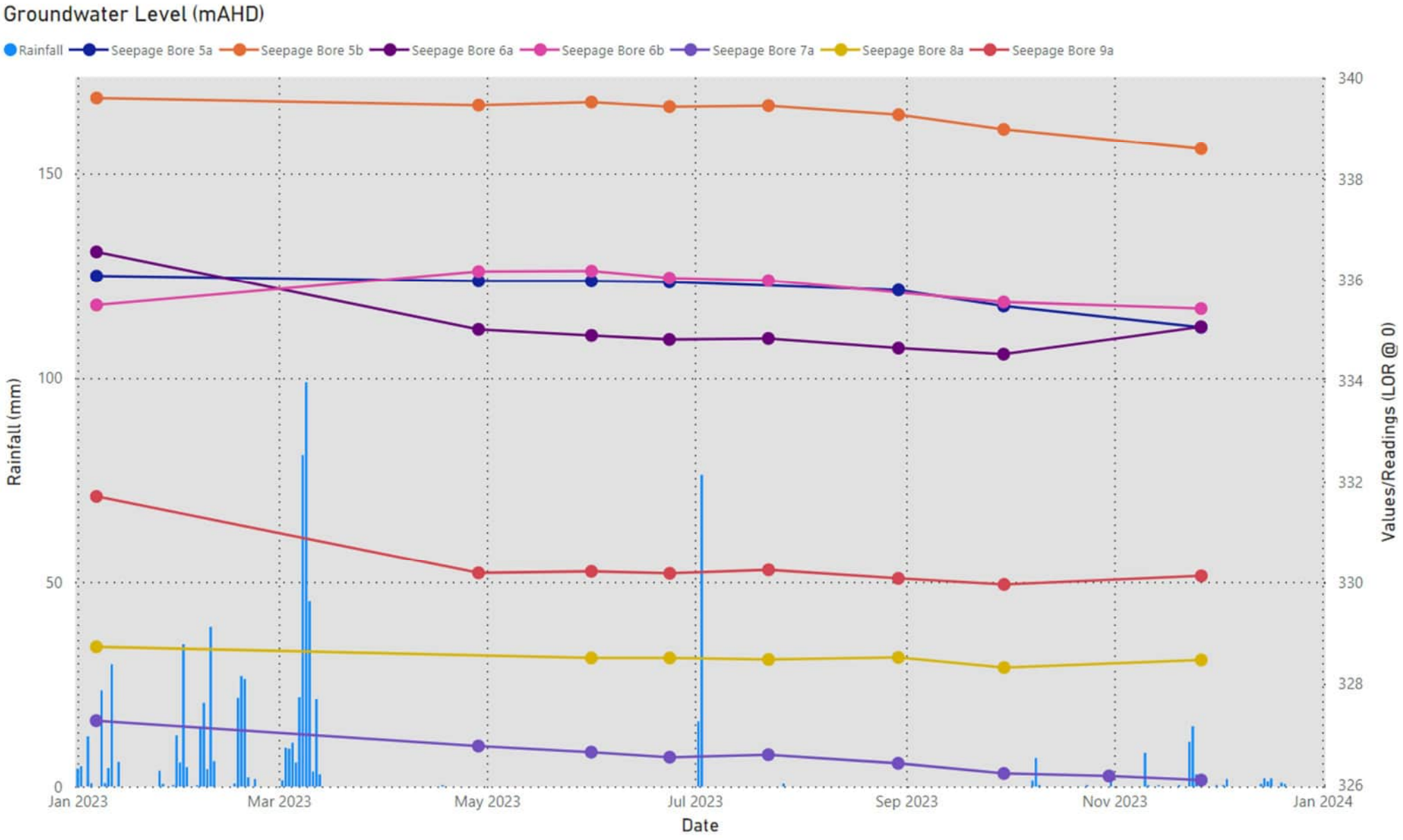

Selenium - dissolved (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.01
0.02
0.03
0.04
0.05
0.06
2019
2020
2021
2022
2023
2024

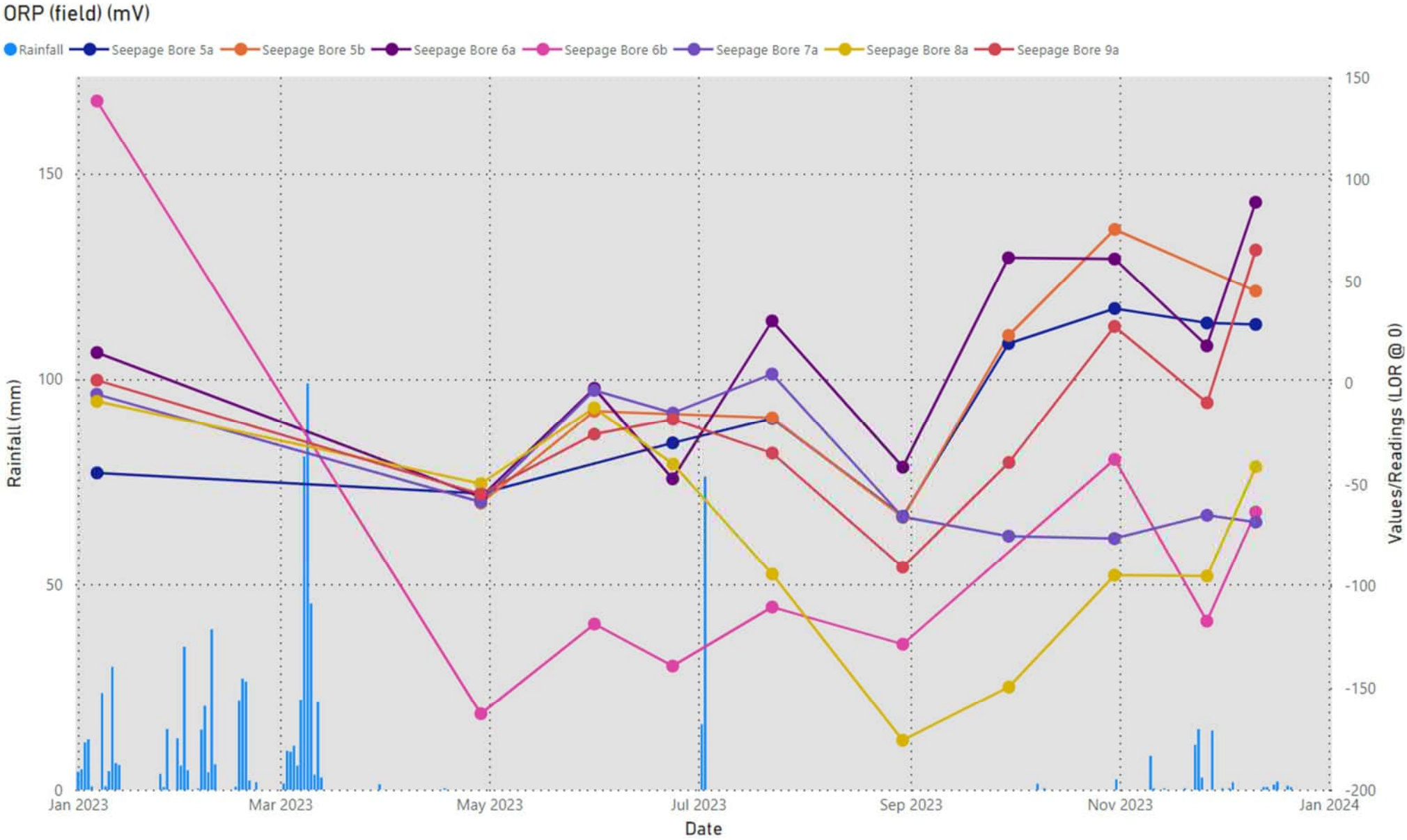

Uranium - dissolved (mg/L)
Rainfall
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Start open-cut mining: 1/07/2019
End open-cut mining: 31/03/2021
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.05
0.10
0.15
0.20
0.25
0.30
2019
2020
2021
2022
2023
2024

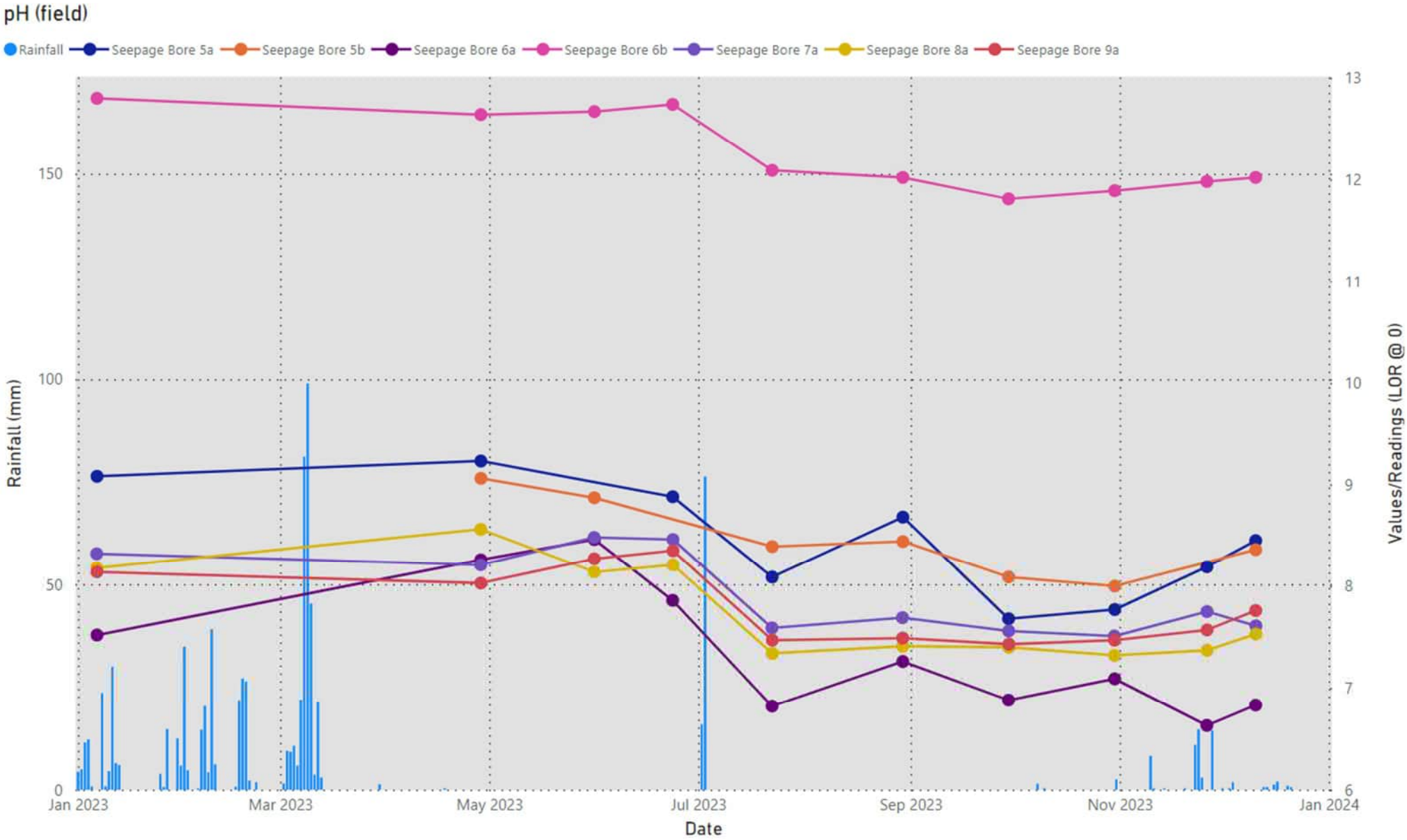

Depth to Water (mbRL)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
Values/Readings (LOR @ 0)
0
50
100
150
0
1
2
3
4
5
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

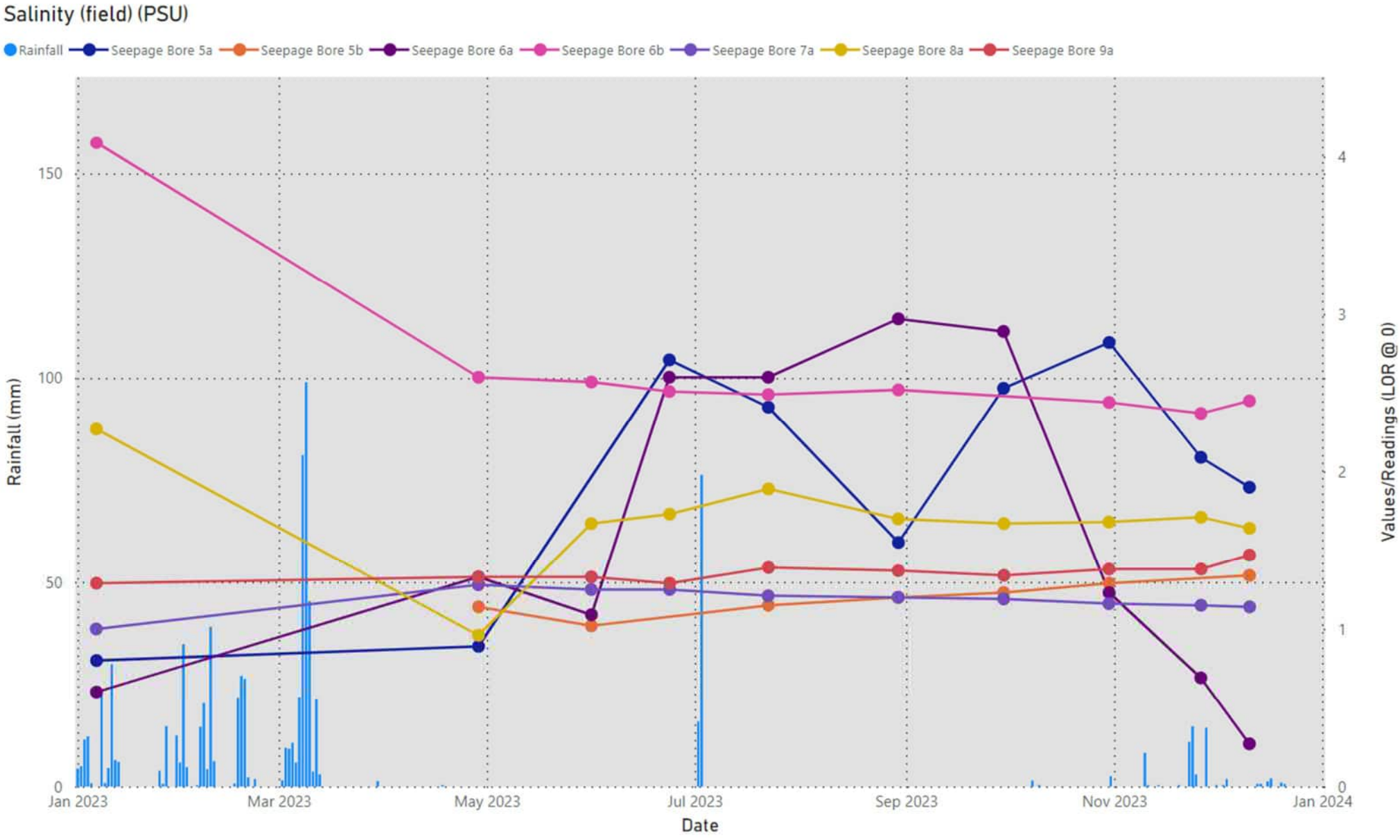

Dissolved Oxygen (field) (% sat)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0
50
100
150
200
250
300
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

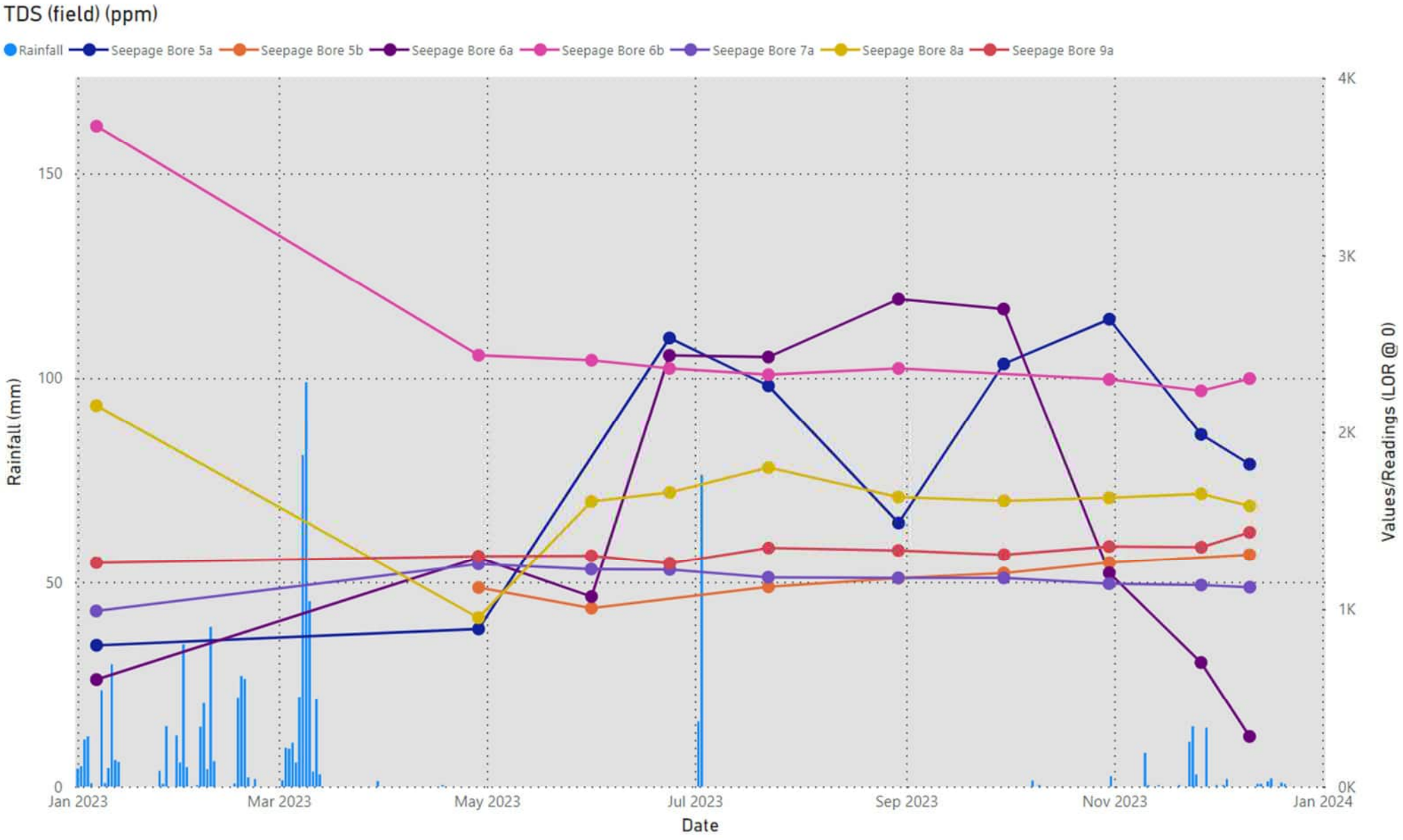

Electrical Conductivity (field) (µS/cm)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0K
2K
4K
6K
8K
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

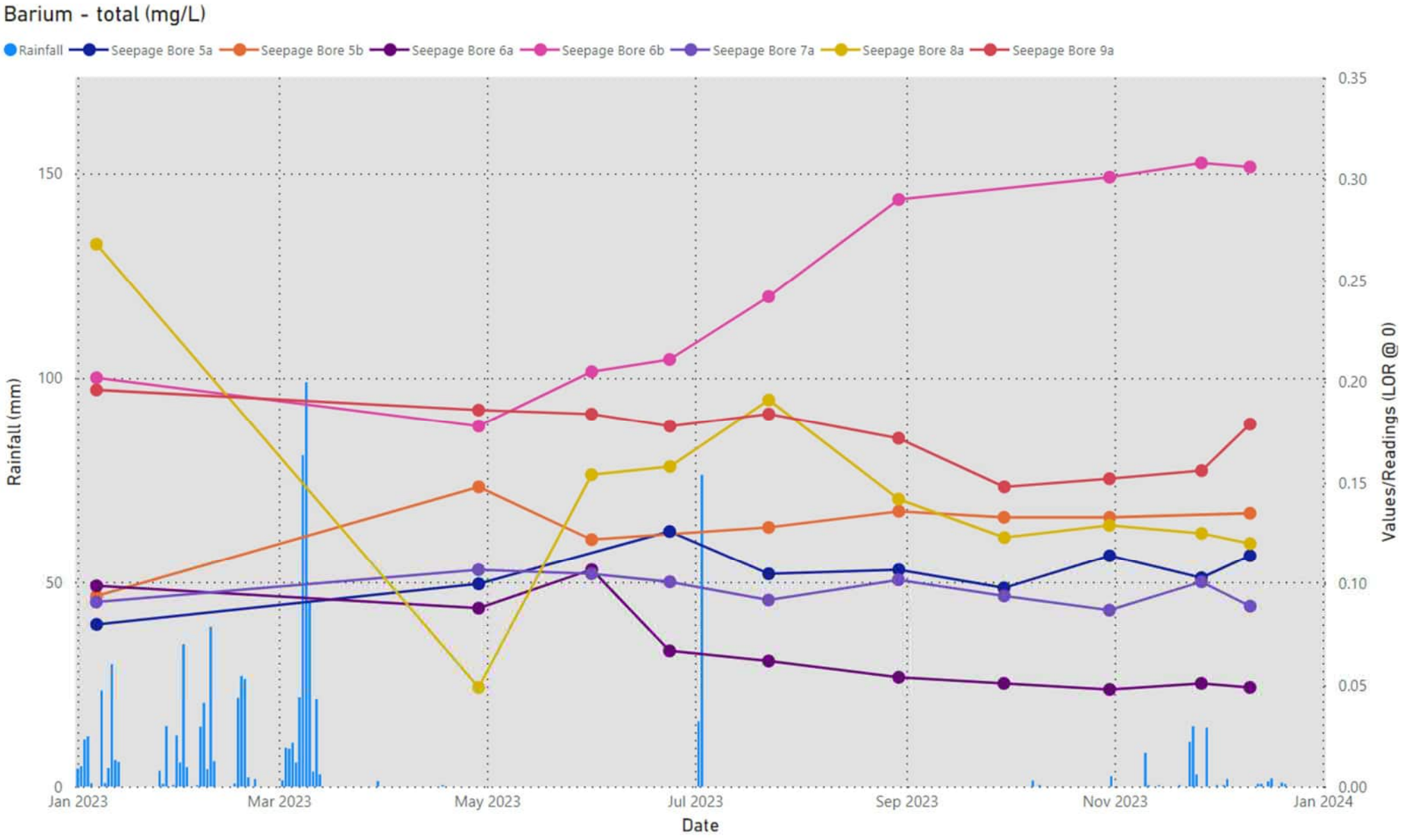

Groundwater Level (mAHD)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
326
328
330
332
334
336
338
340
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

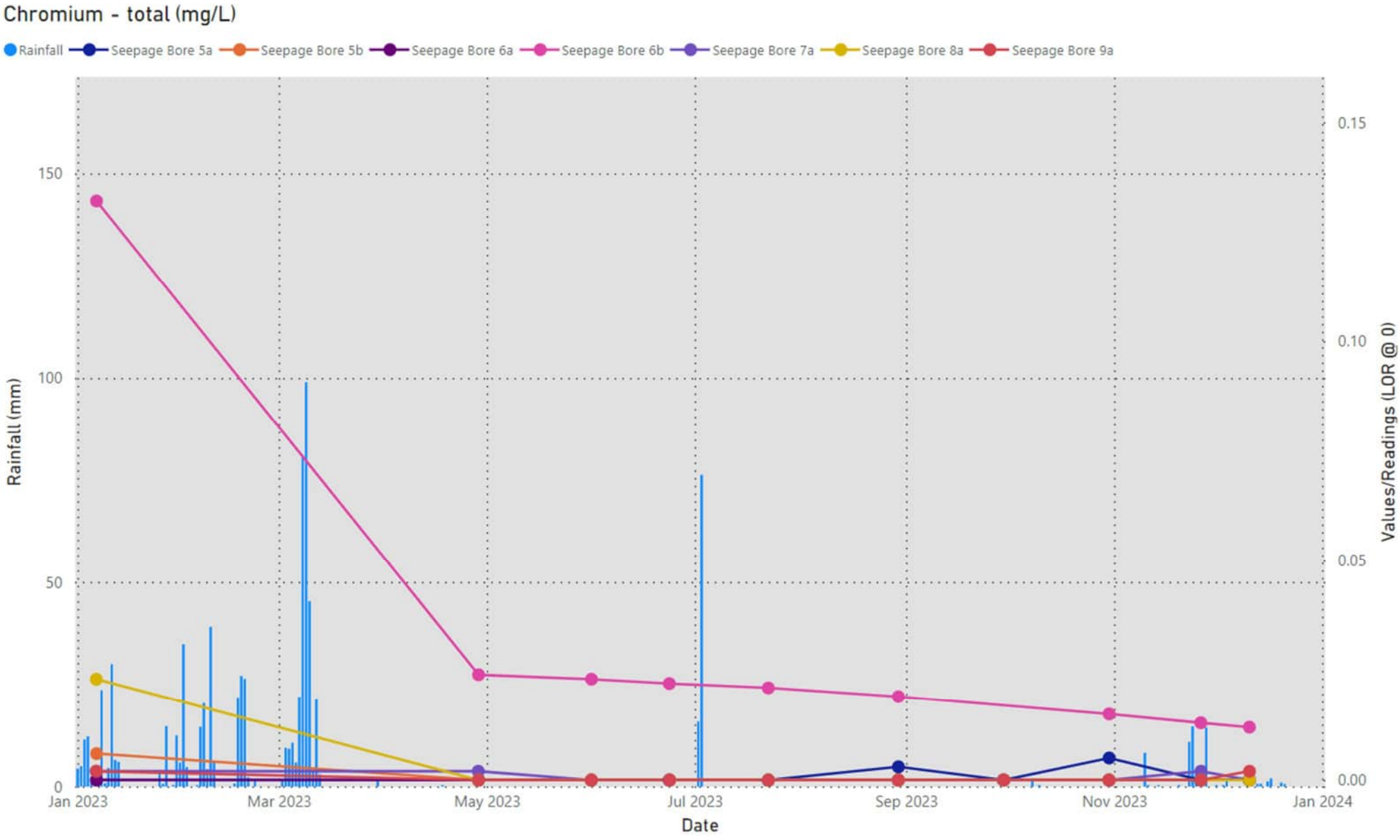

ORP (field) (mV)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
150
100
50
0
150
100
50
0
-50
-100
-150
-200

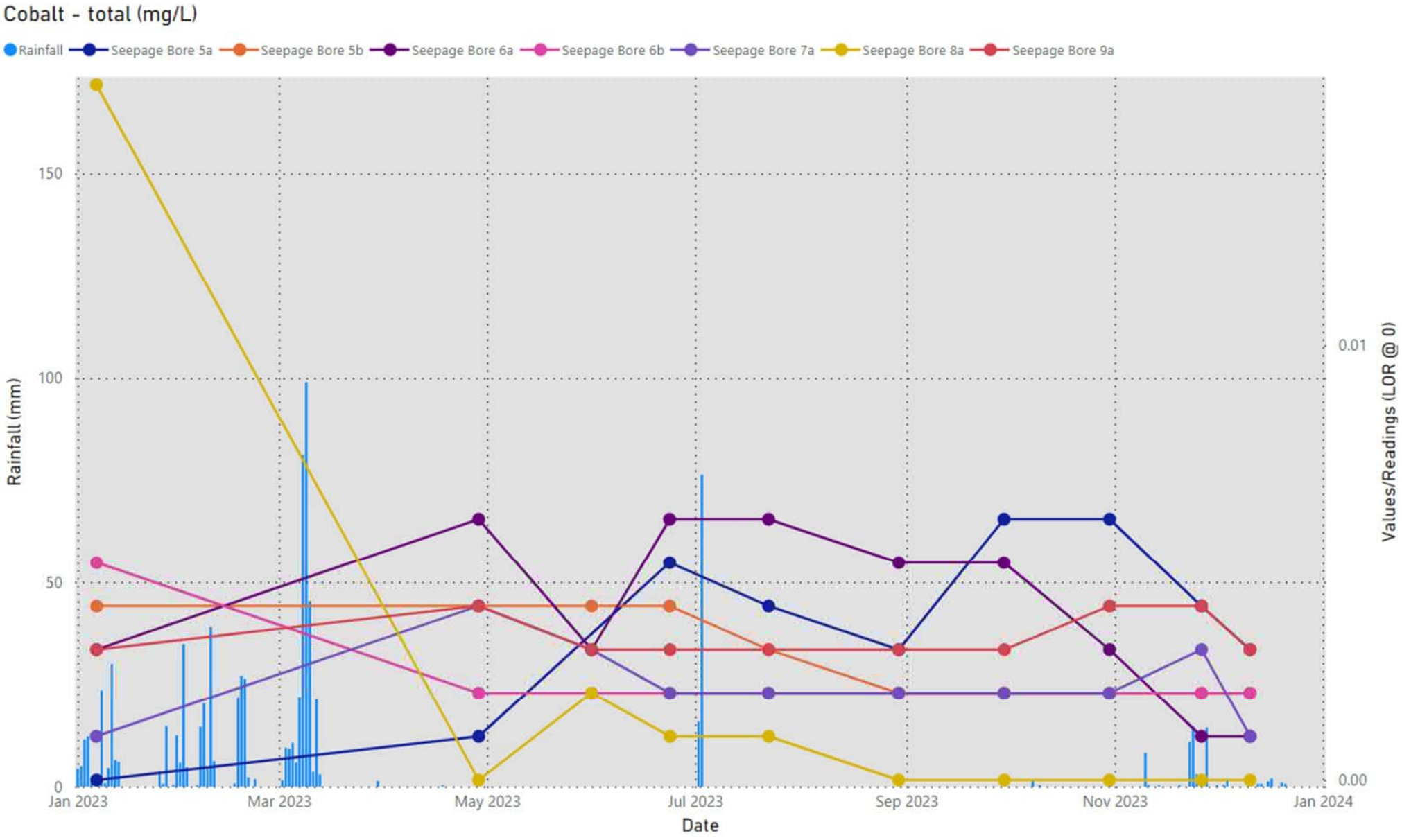

pH (field)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
6
7
8
9
10
11
12
13
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

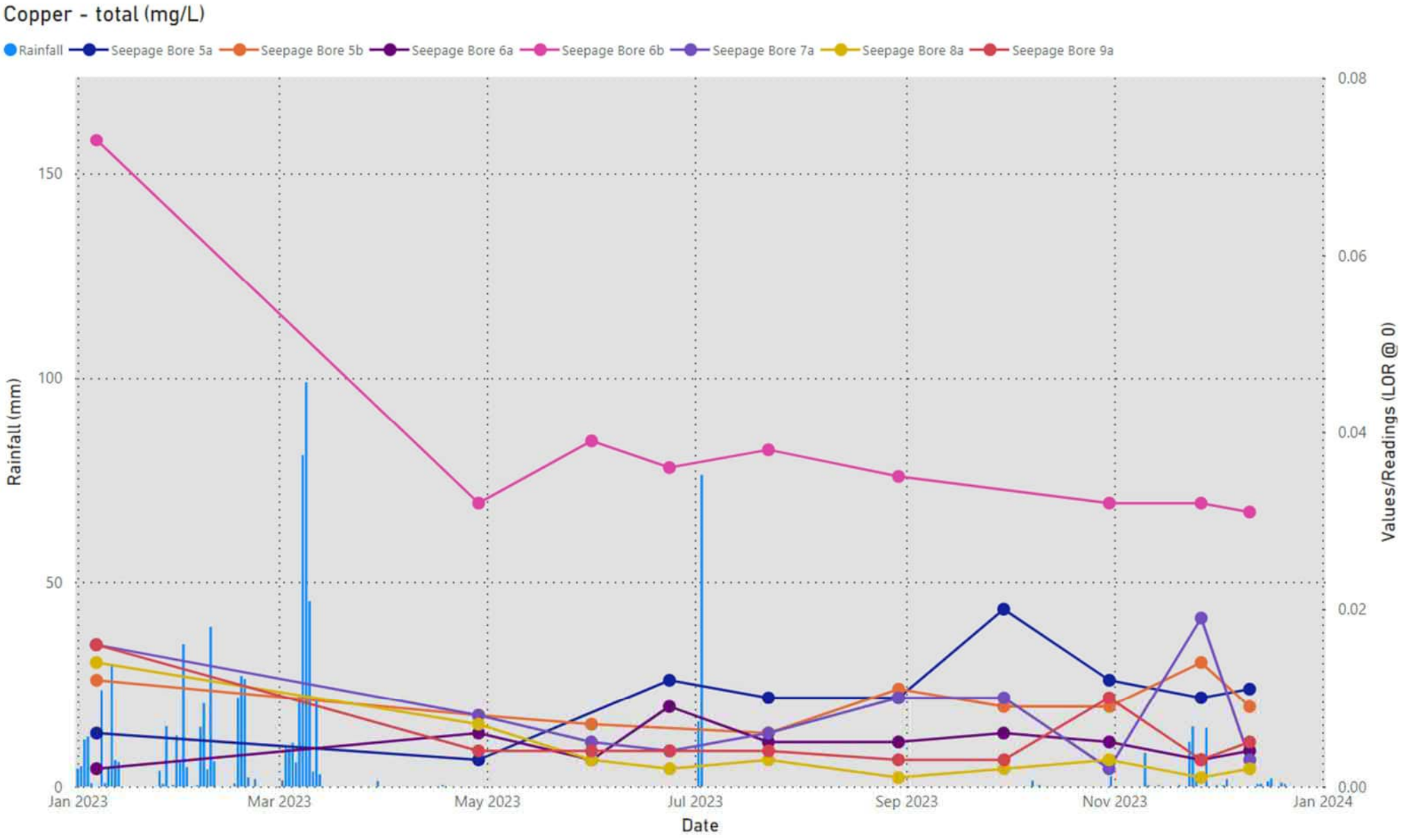

Salinity (field) (PSU)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
1
2
3
4
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024

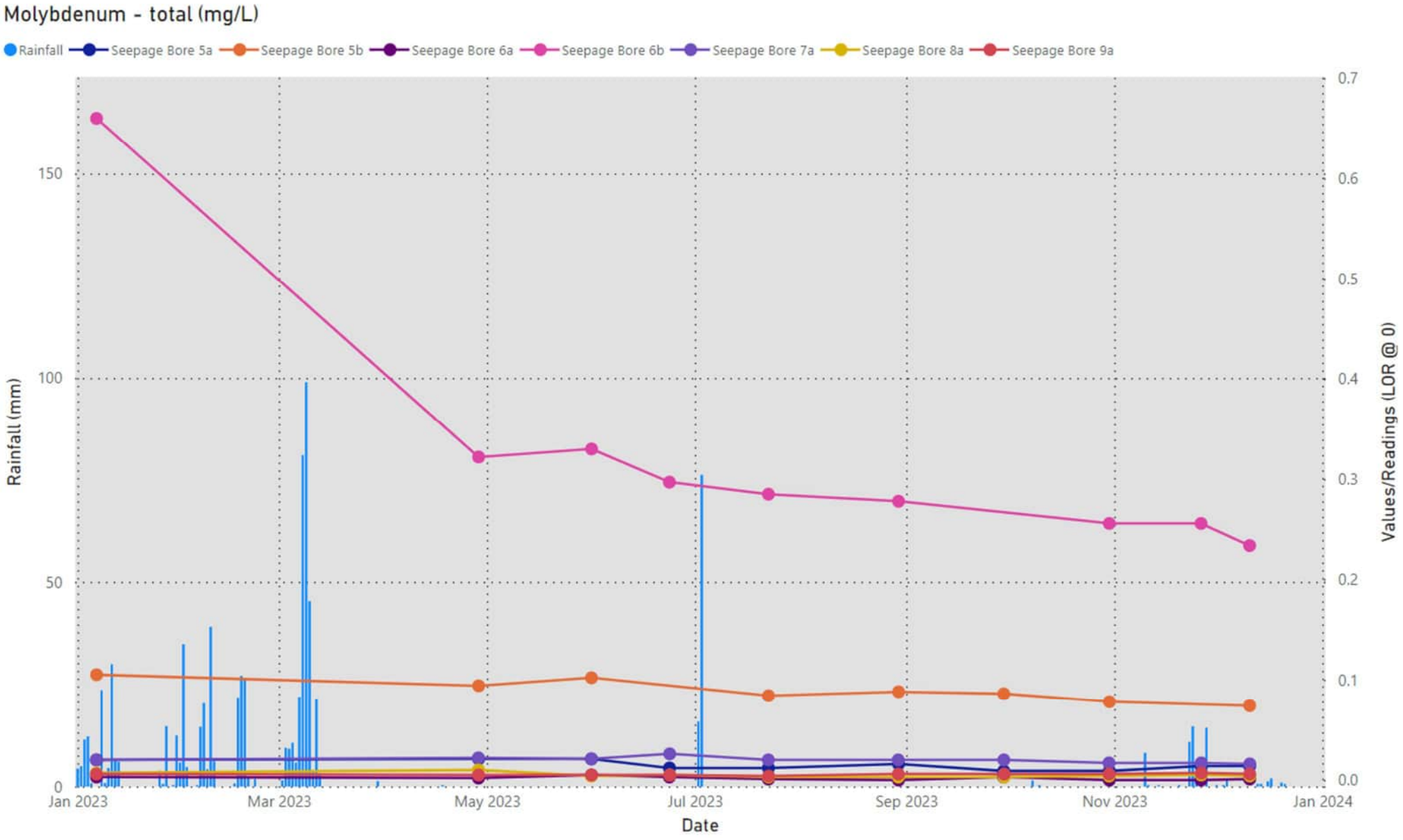

TDS (field) (ppm)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0K
1K
2K
3K
4K
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

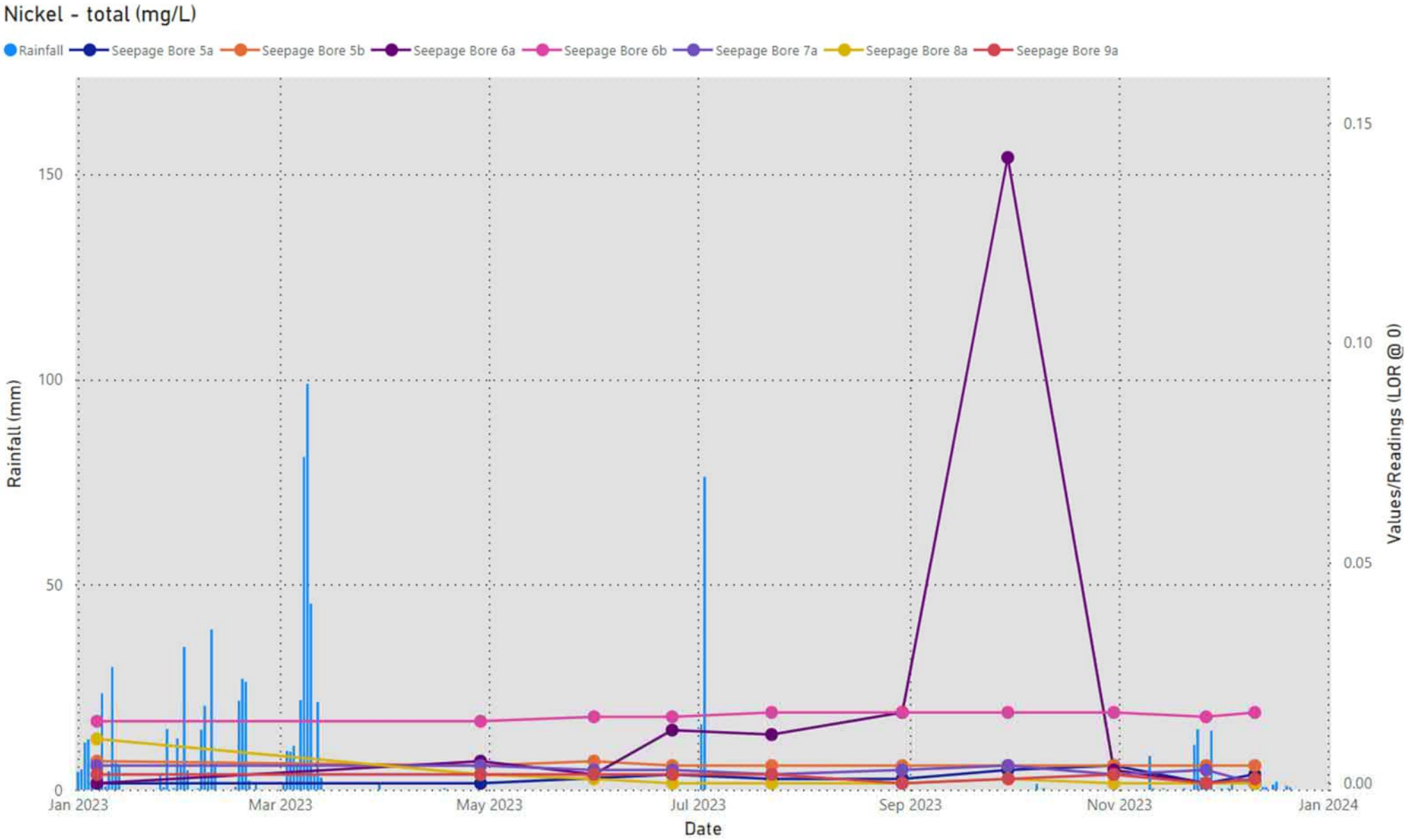

Barium - total (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

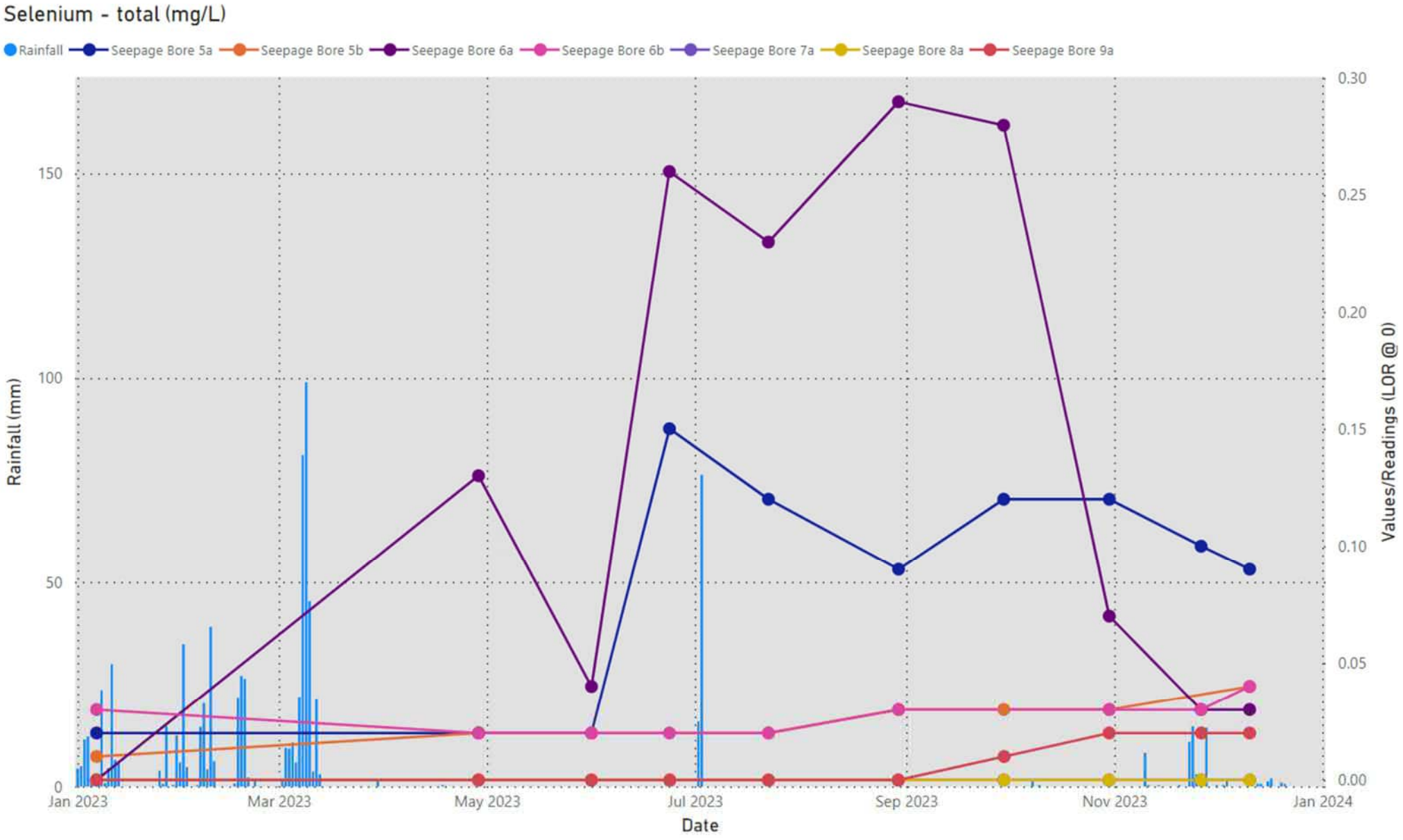

Chromium - total (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
150
100
50
0
0.15
0.10
0.05
0.00
Values/Readings (LOR @ 0)
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

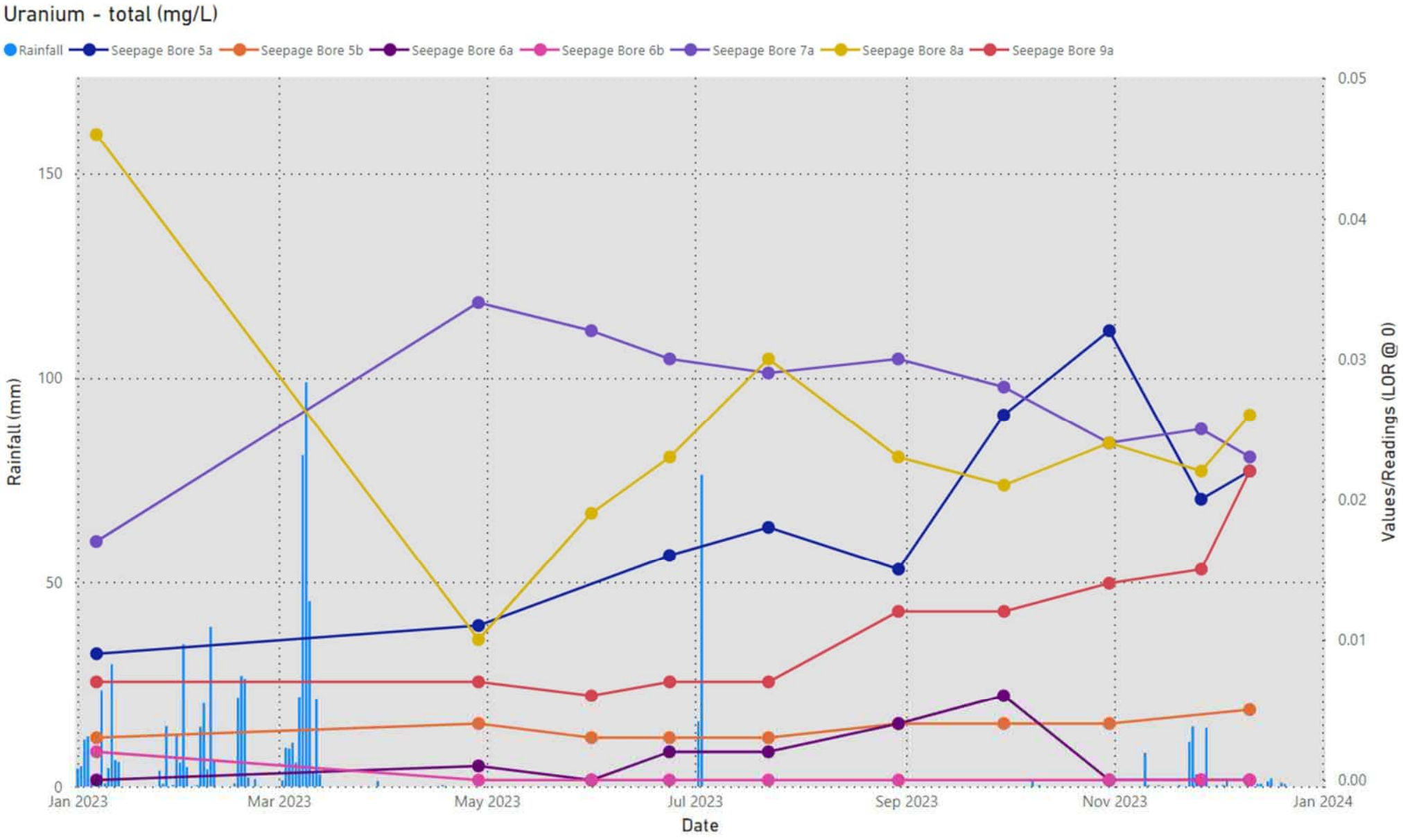

Cobalt - total (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
150
100
50
0
Values/Readings (LOR @ 0)
0.01
0.00
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

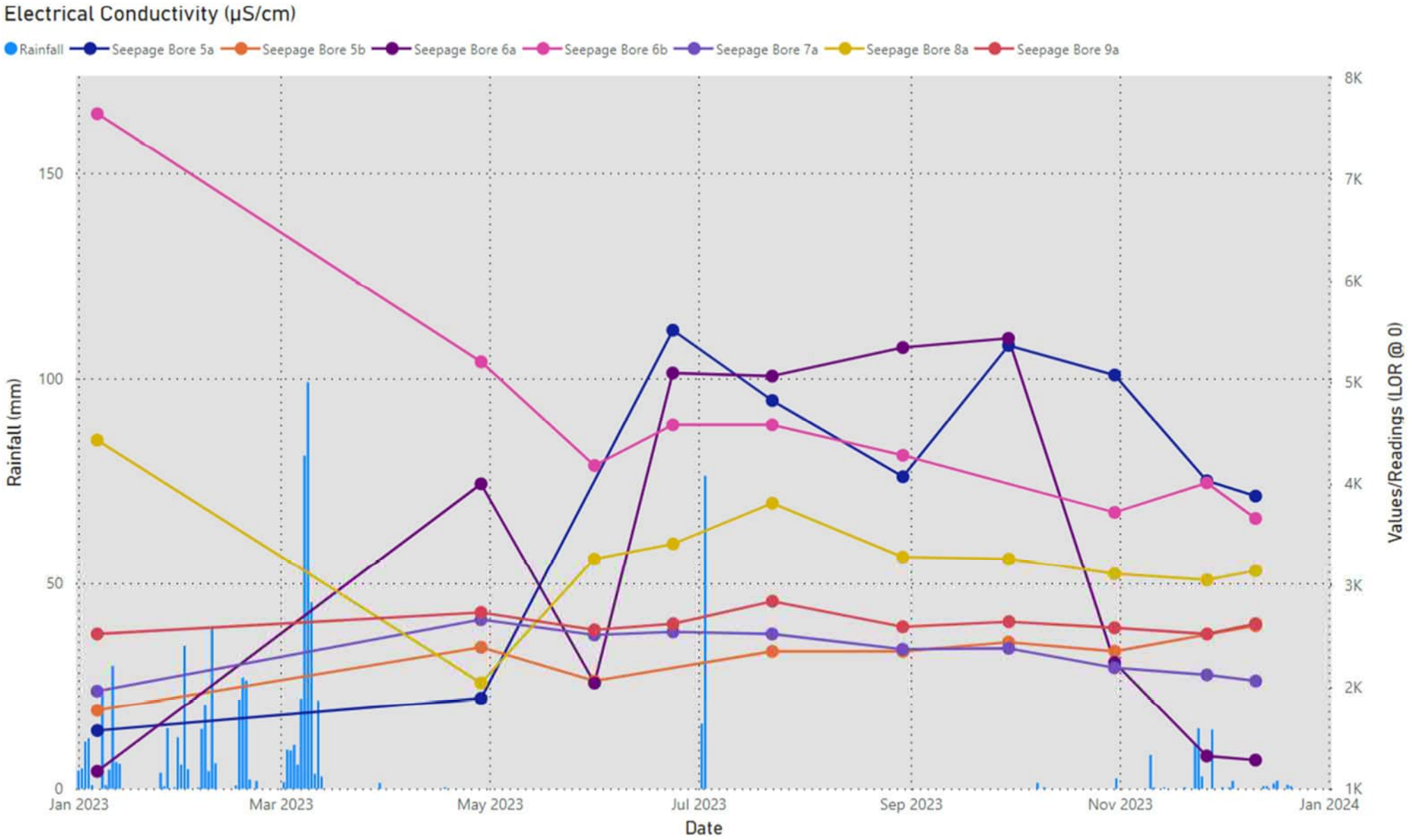

Copper - total (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0.00
0.02
0.04
0.06
0.08
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

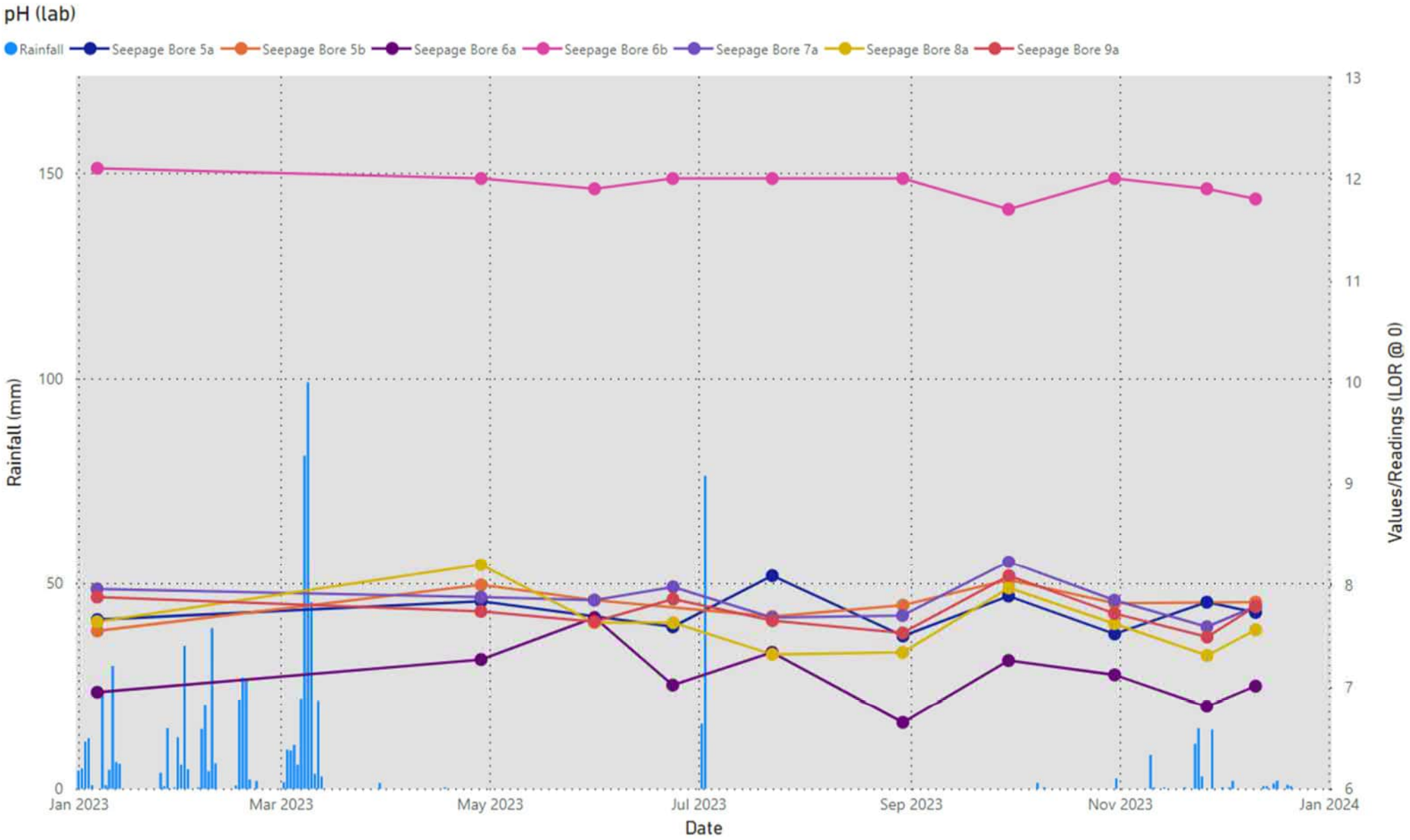

Molybdenum - total (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

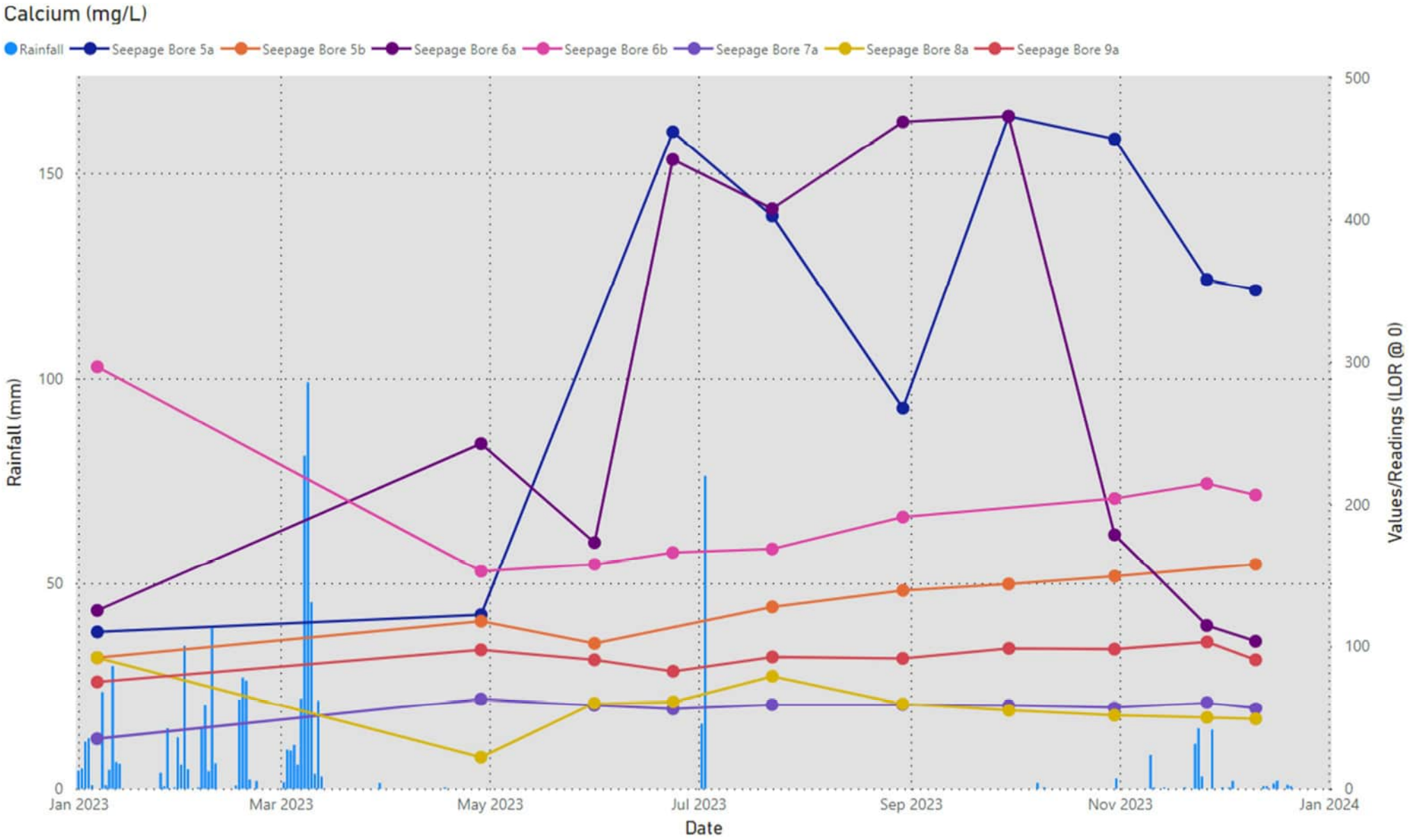

Nickel - total (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0.00
0.05
0.10
0.15
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

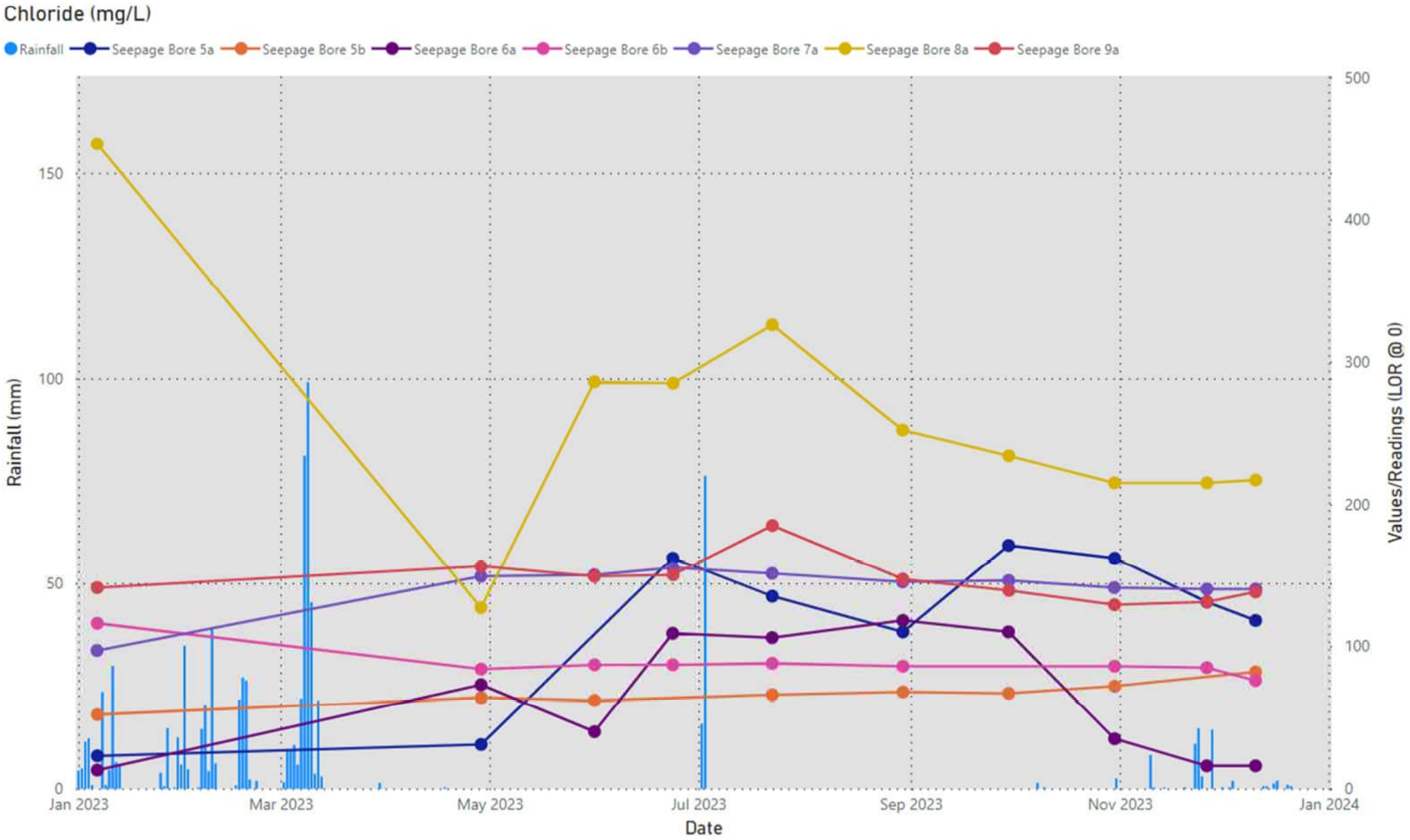

Selenium - total (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

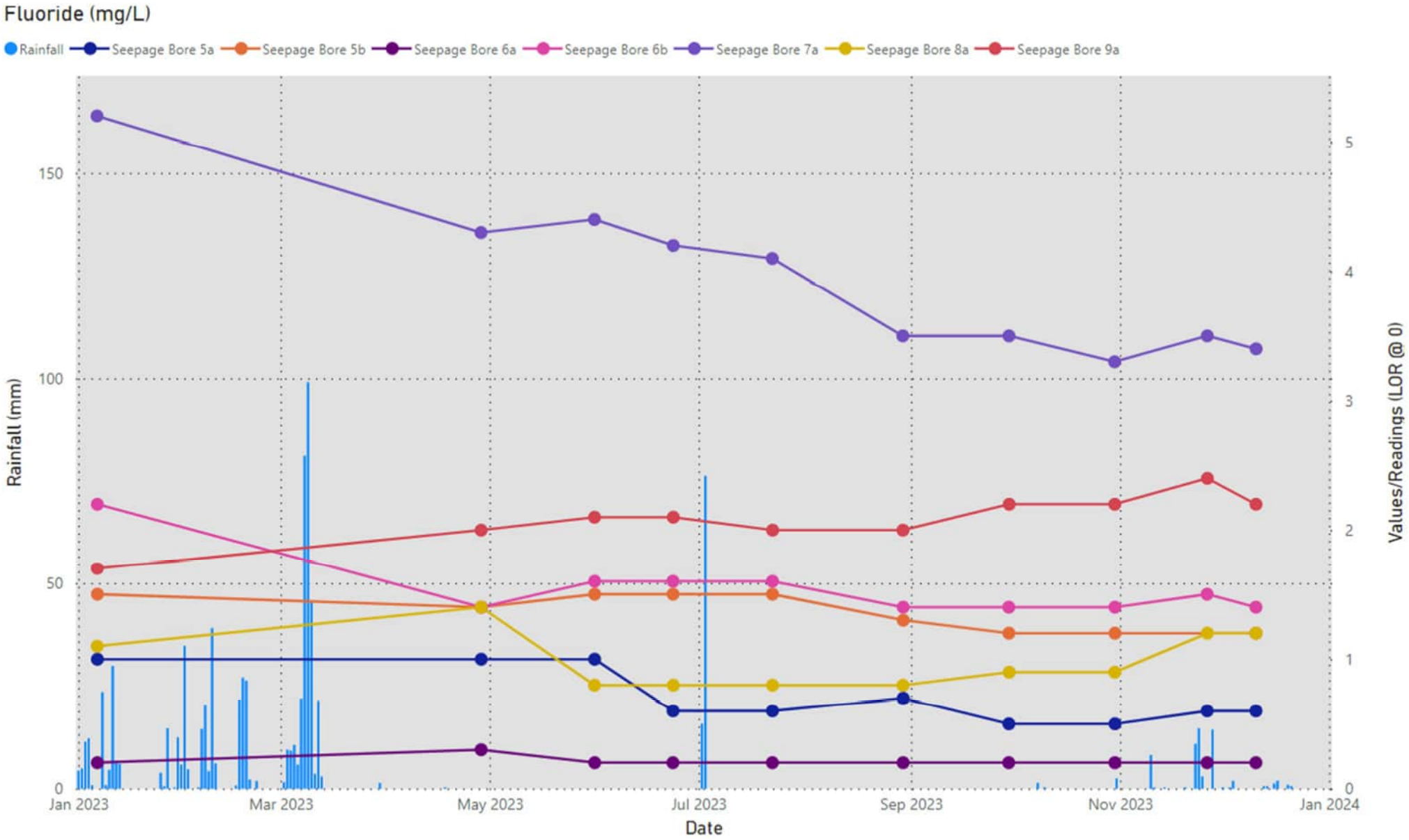

Uranium - total (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0.00
0.01
0.02
0.03
0.04
0.05
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

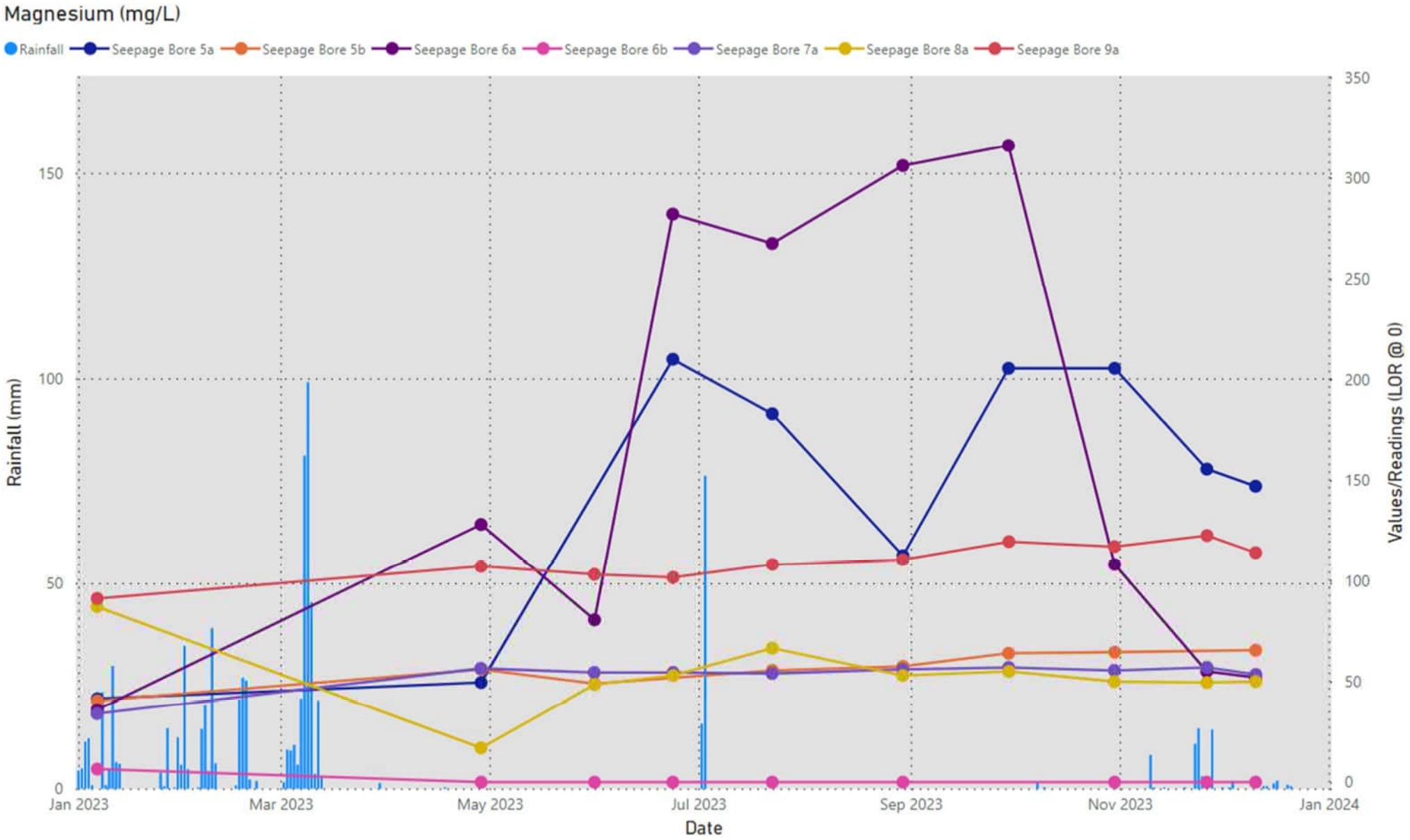

Electrical Conductivity (µS/cm)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
1K
2K
3K
4K
5K
6K
7K
8K
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

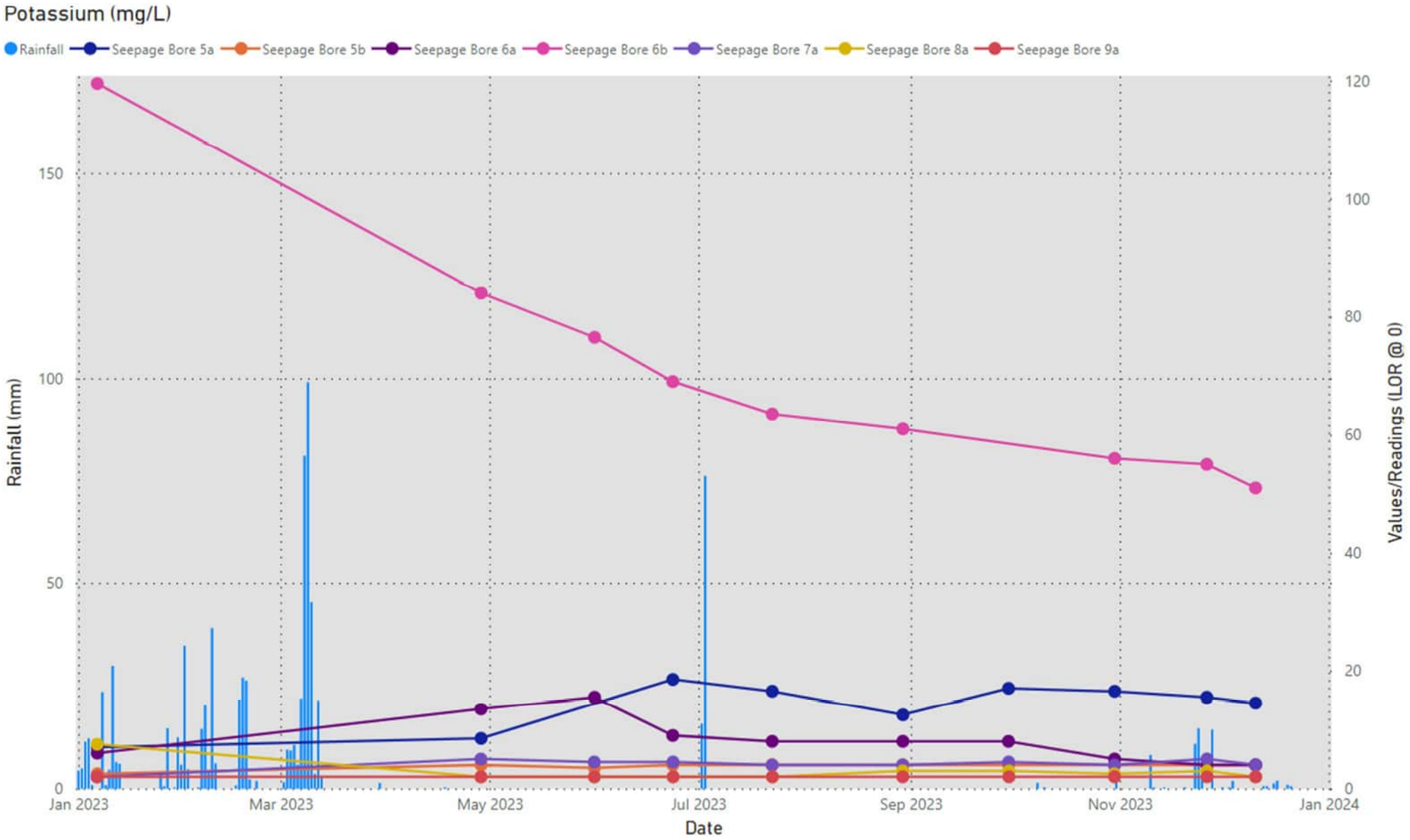

pH (lab)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
6
7
8
9
10
11
12
13
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024

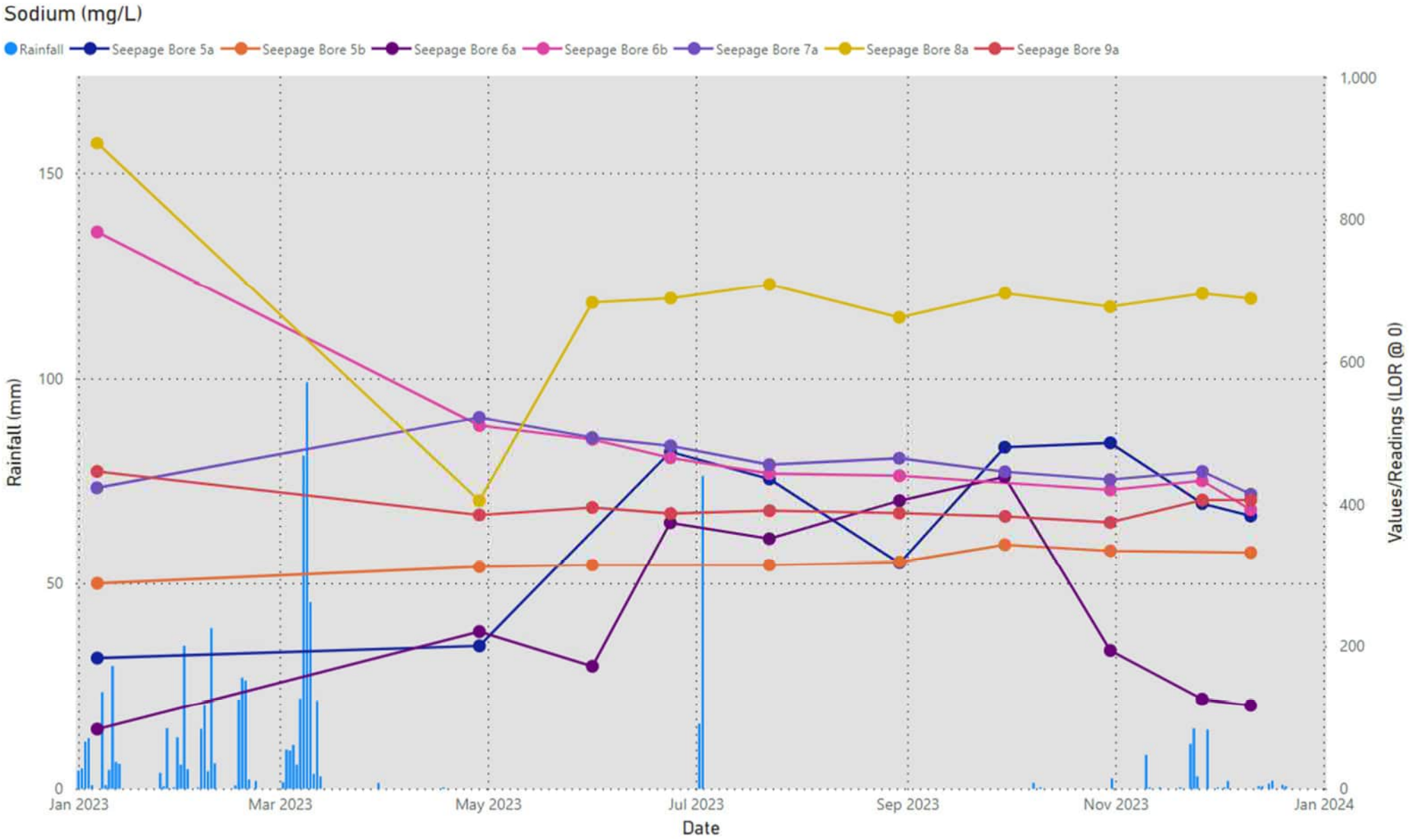

Calcium (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
Values/Readings (LOR @ 0)
0
50
100
150
0
100
200
300
400
500
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

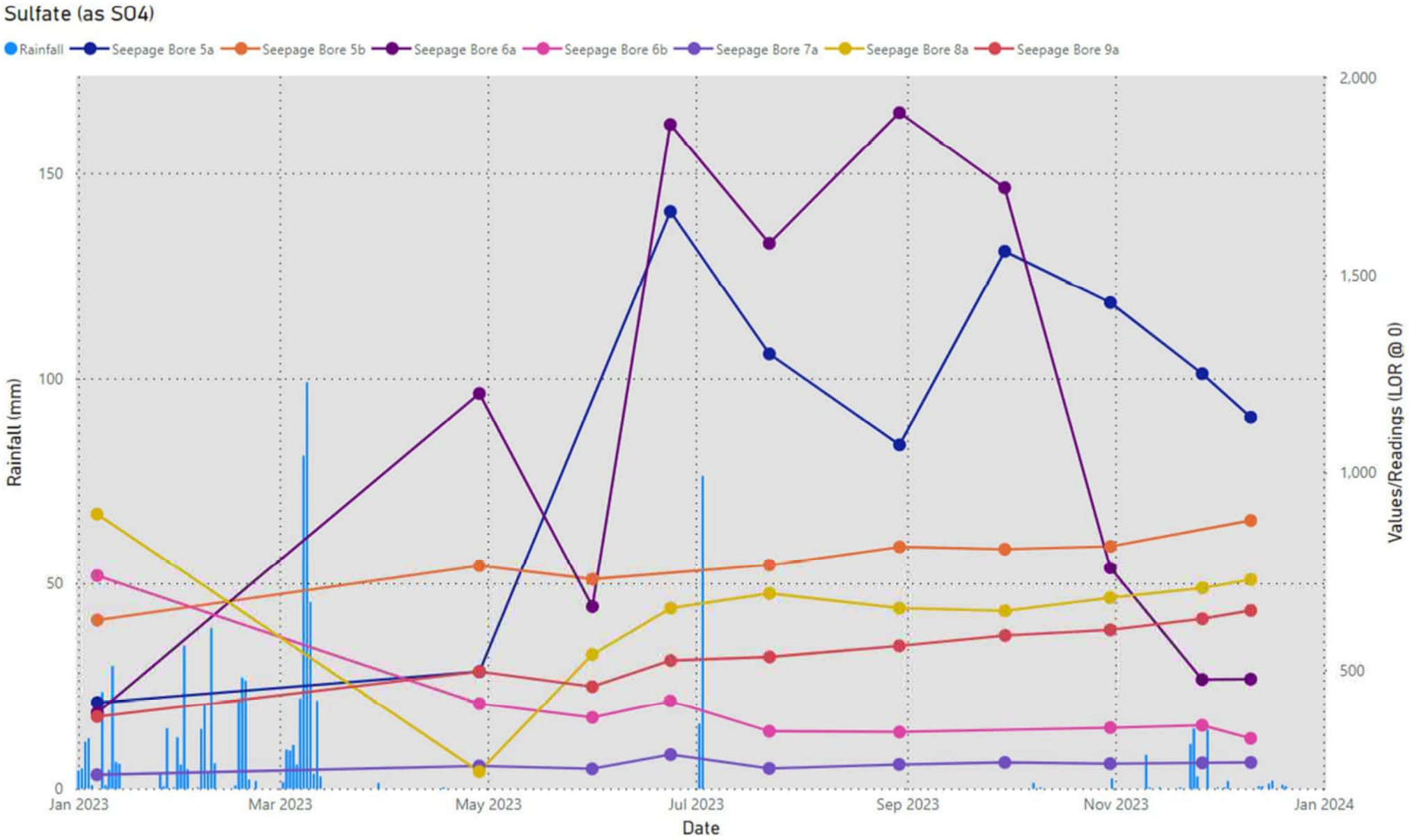

Chloride (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
Values/Readings (LOR @ 0)
0
50
100
150
0
100
200
300
400
500
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

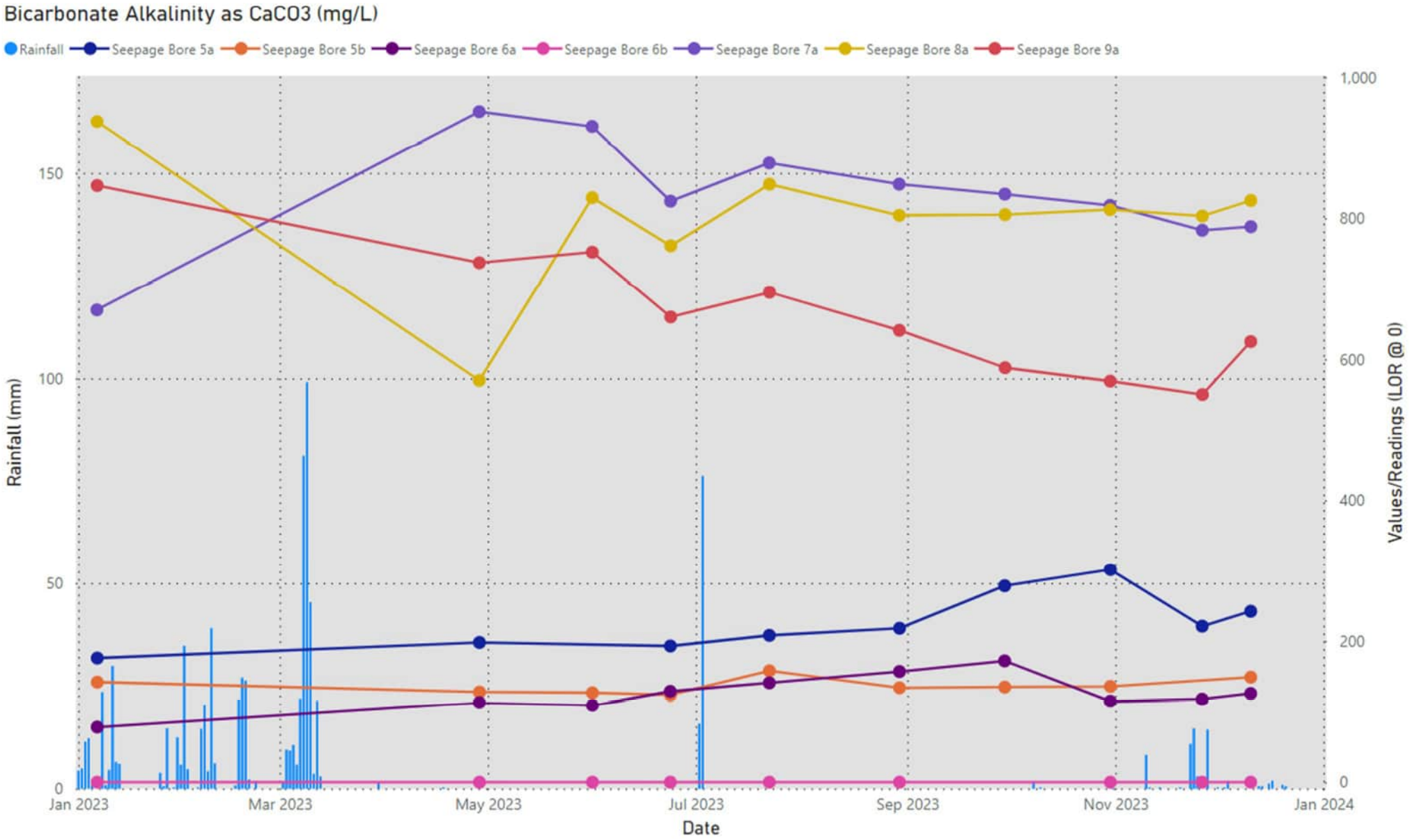

Fluoride (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
1
2
3
4
5
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024

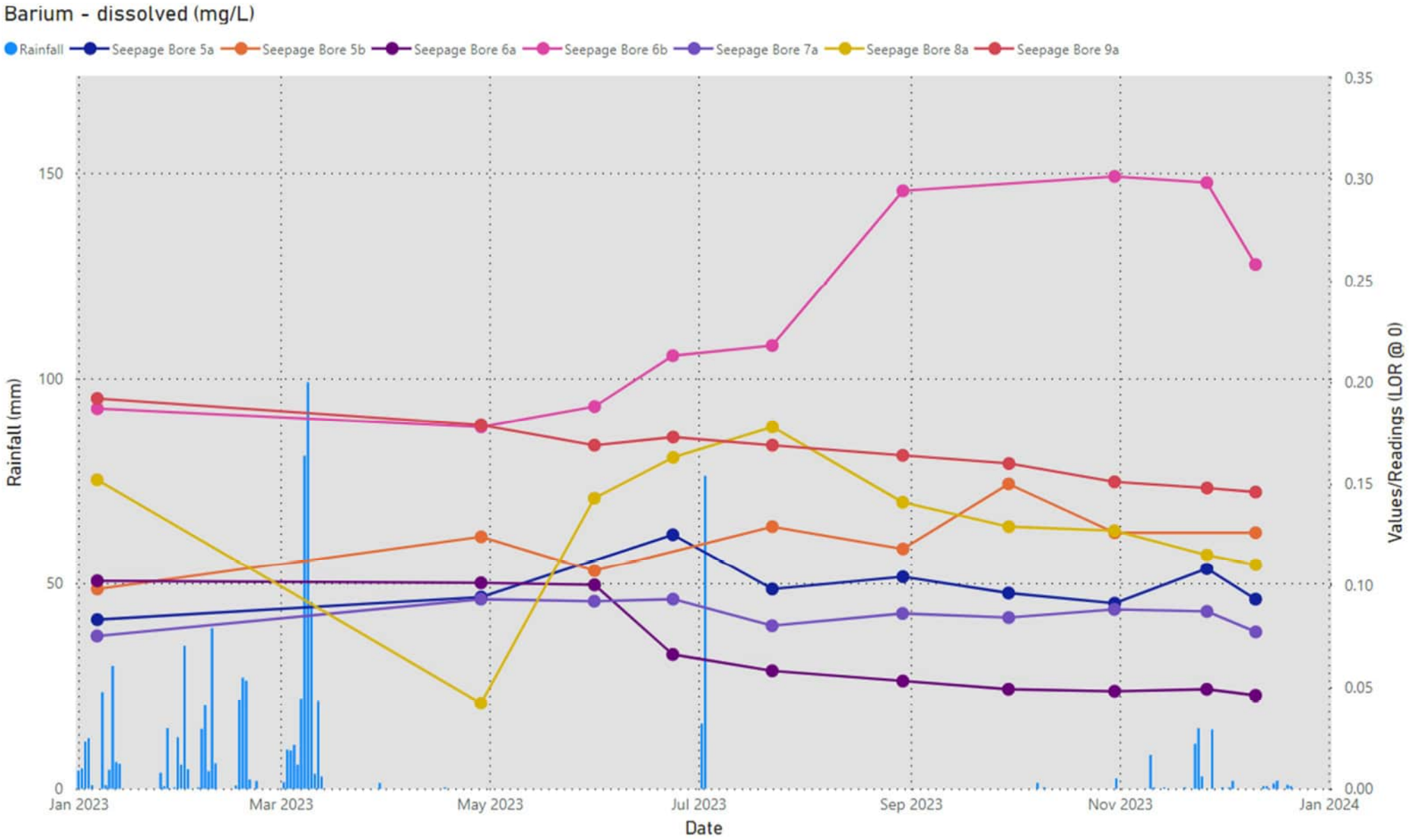

Magnesium (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
Values/Readings (LOR @ 0)
0
50
100
150
0
50
100
150
200
250
300
350
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

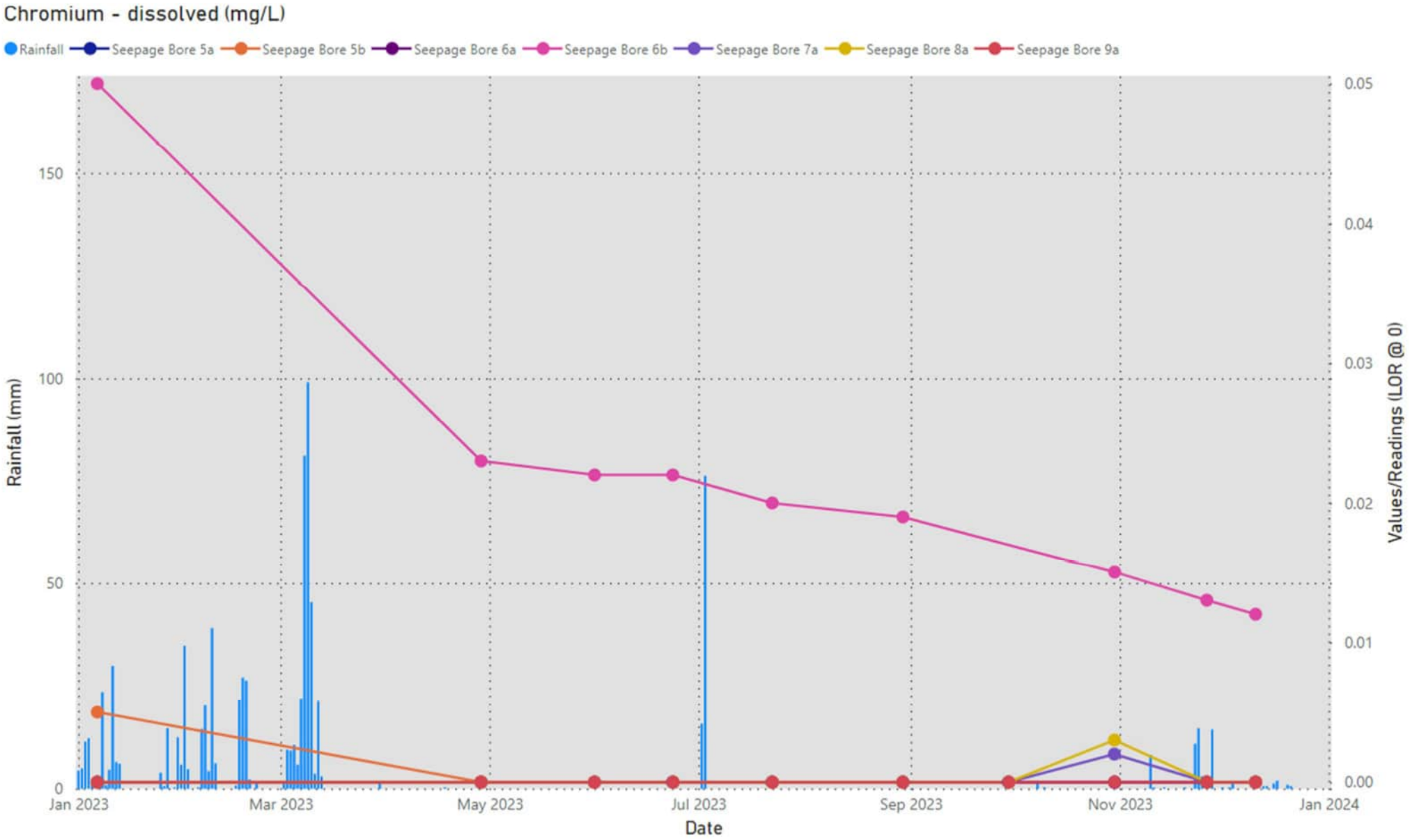

Potassium (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0
20
40
60
80
100
120
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024

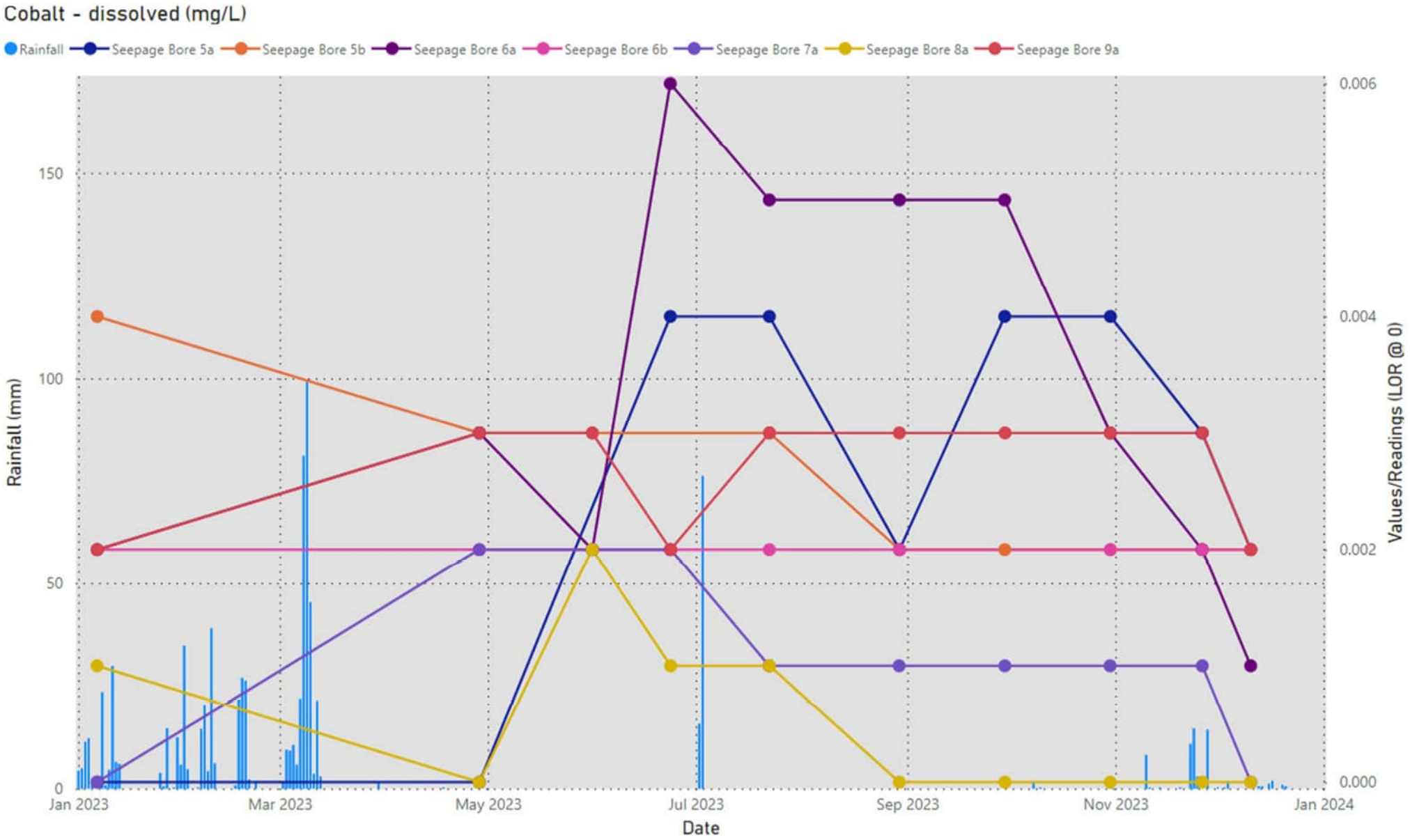

Sodium (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
150
100
50
0
Values/Readings (LOR @ 0)
1,000
800
600
400
200
0
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

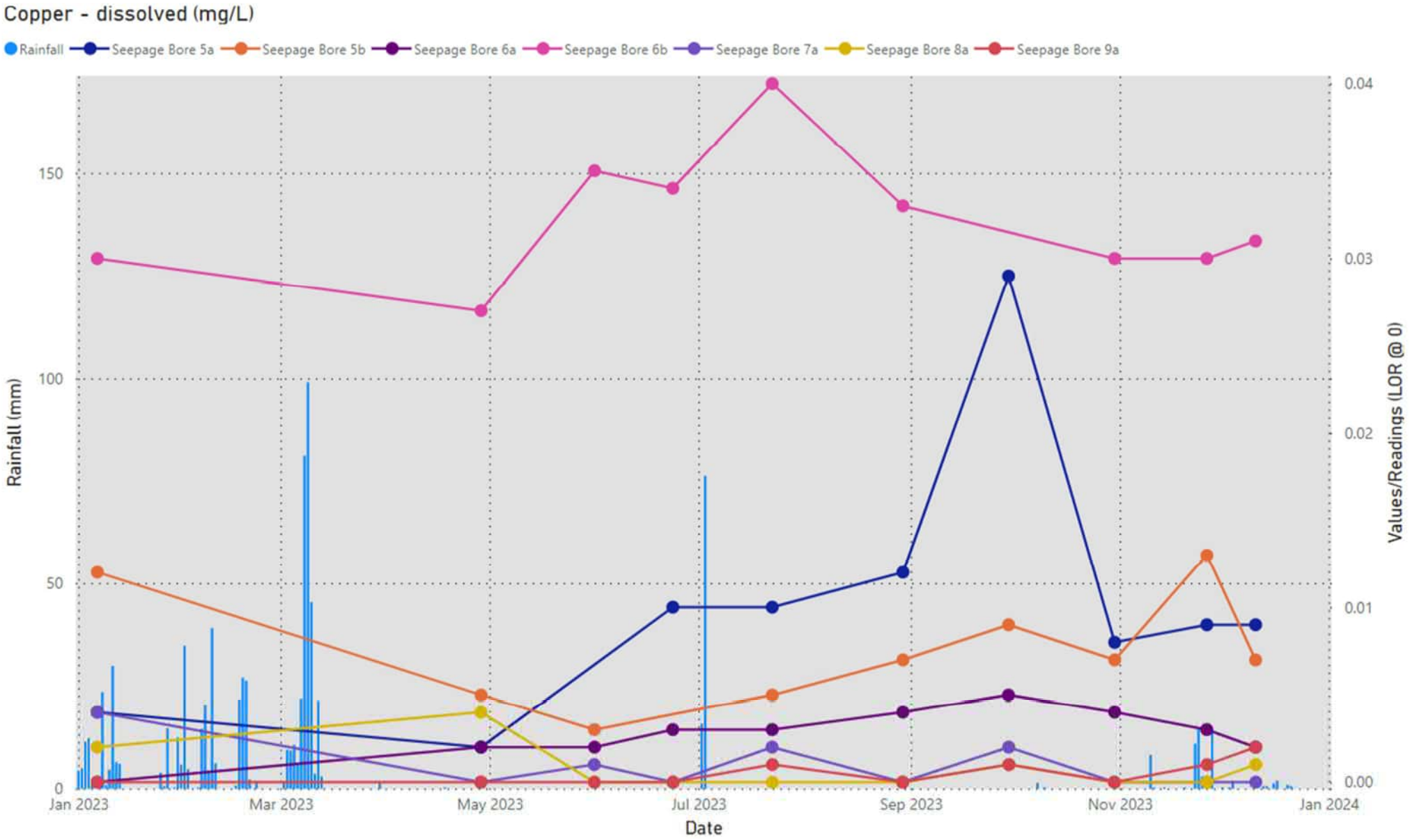

Sulfate (as SO4)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
500
1,000
1,500
2,000
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

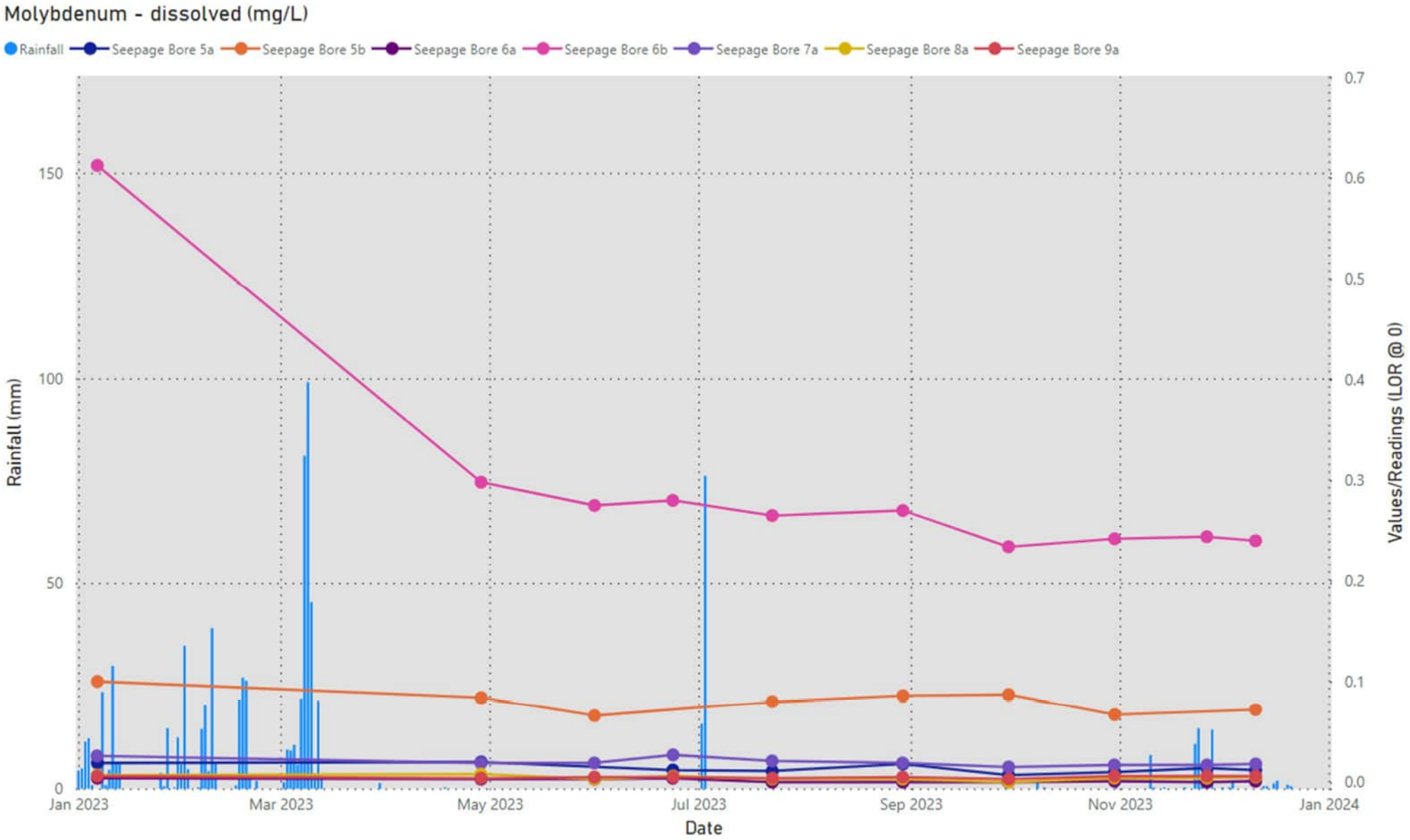

Bicarbonate Alkalinity as CaCO3 (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0
200
400
600
800
1,000
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

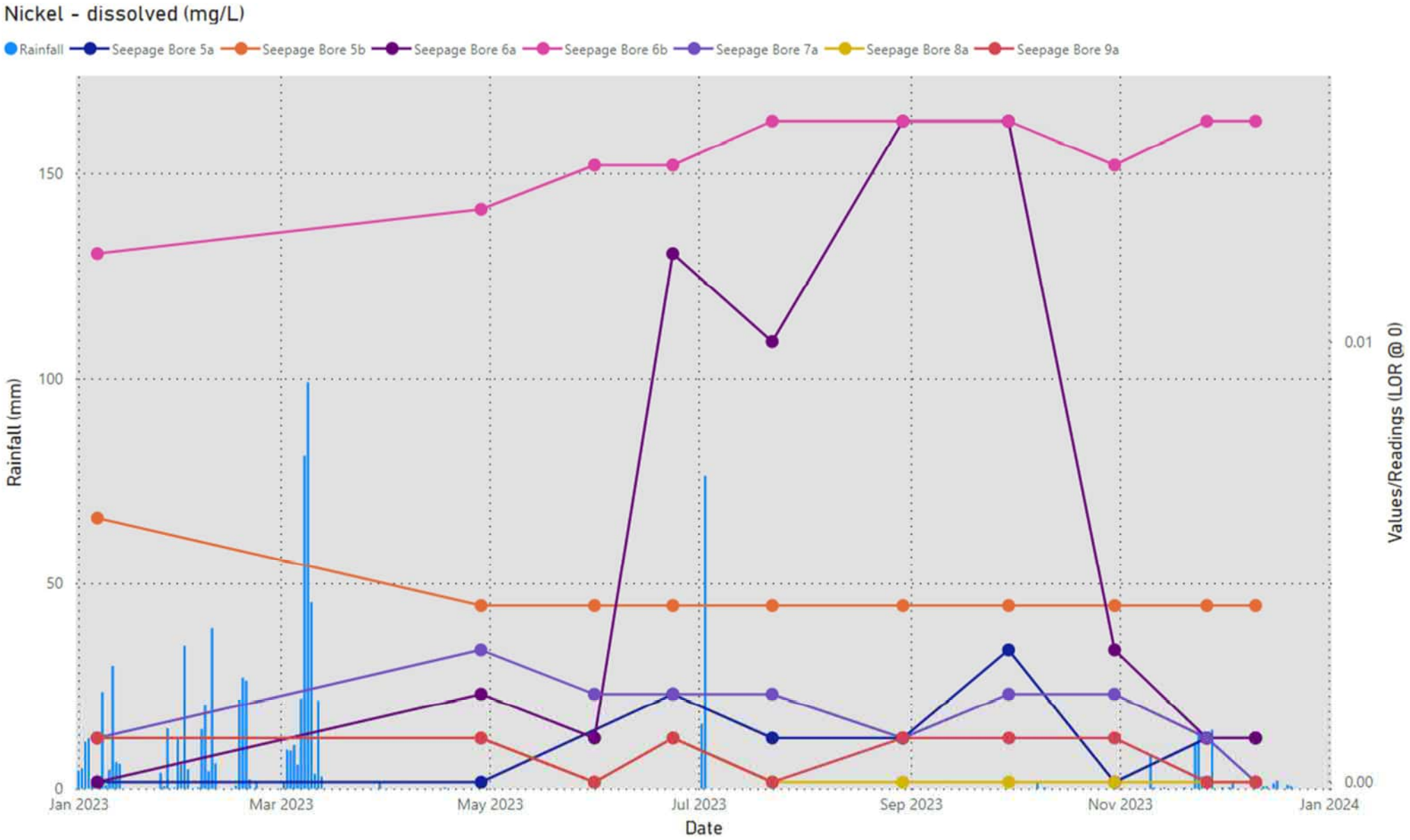

Barium - dissolved (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
Values/Readings (LOR @ 0)
Date
0
50
100
150
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024

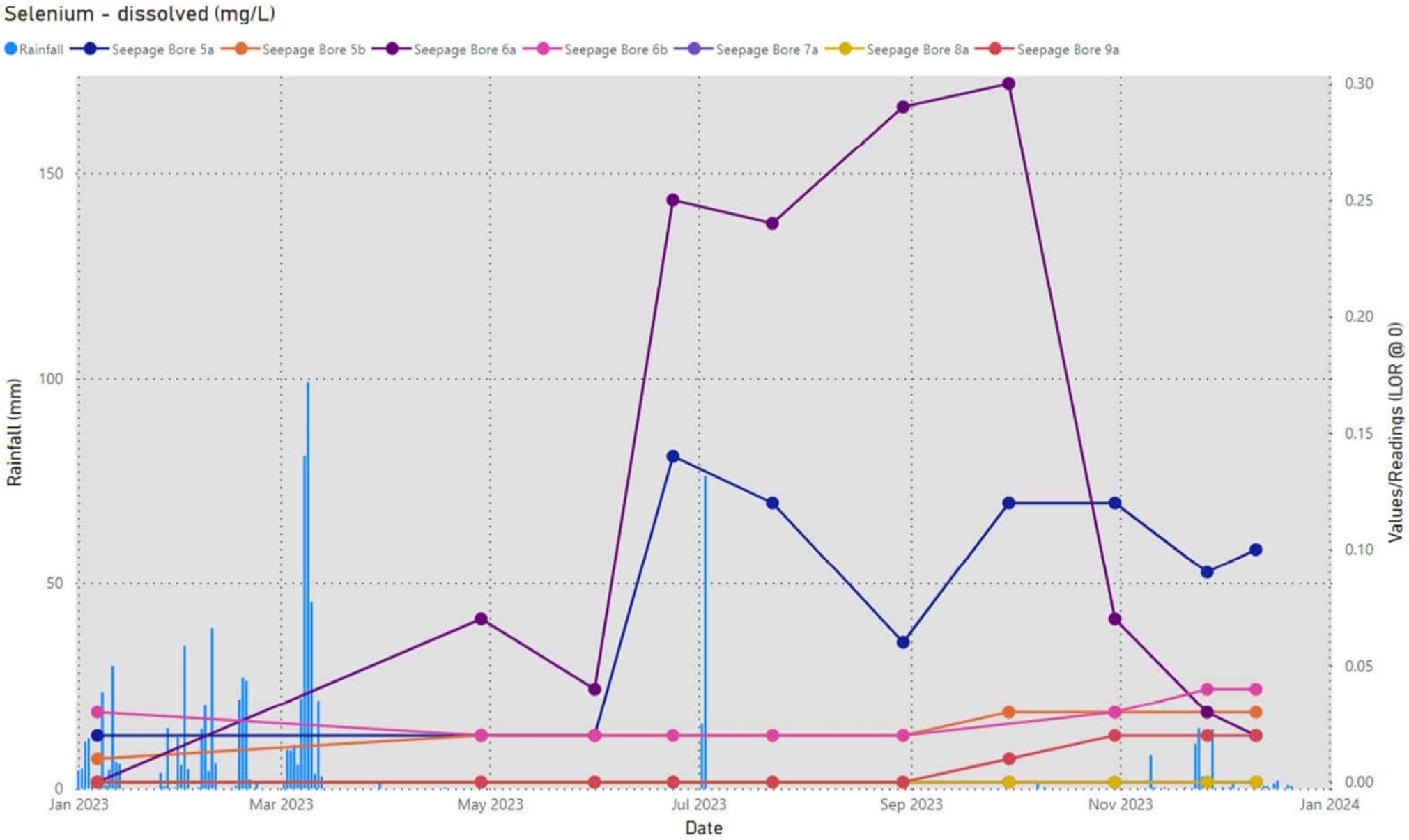

Chromium - dissolved (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0.00
0.01
0.02
0.03
0.04
0.05
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

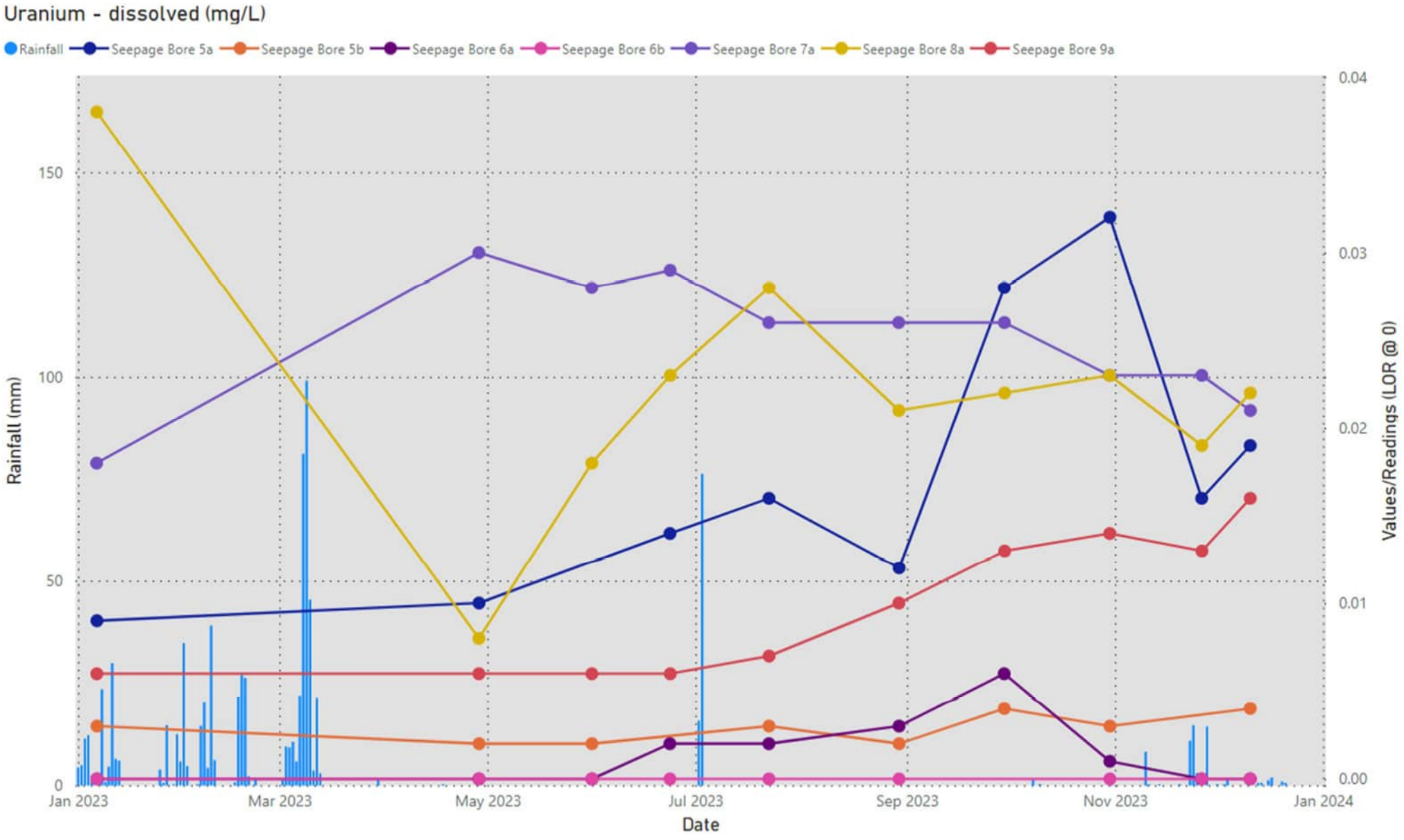

Cobalt - dissolved (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0.000
0.002
0.004
0.006
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date


Copper - dissolved (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0.00
0.01
0.02
0.03
0.04
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date


Molybdenum - dissolved (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
Values/Readings (LOR @ 0)
0
50
100
150
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

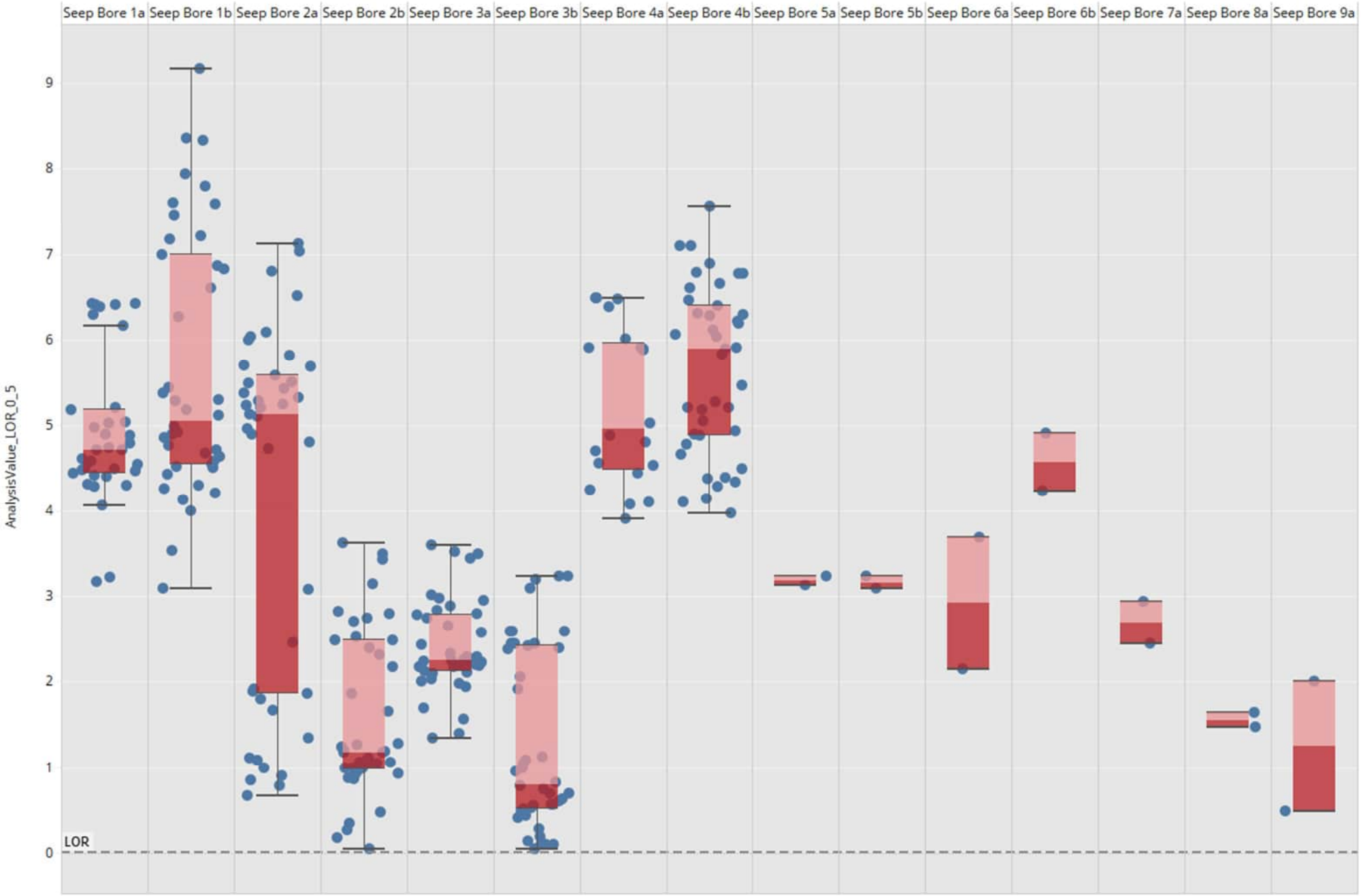

Nickel - dissolved (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
150
100
50
0
Values/Readings (LOR @ 0)
0.01
0.00
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date


Selenium - dissolved (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

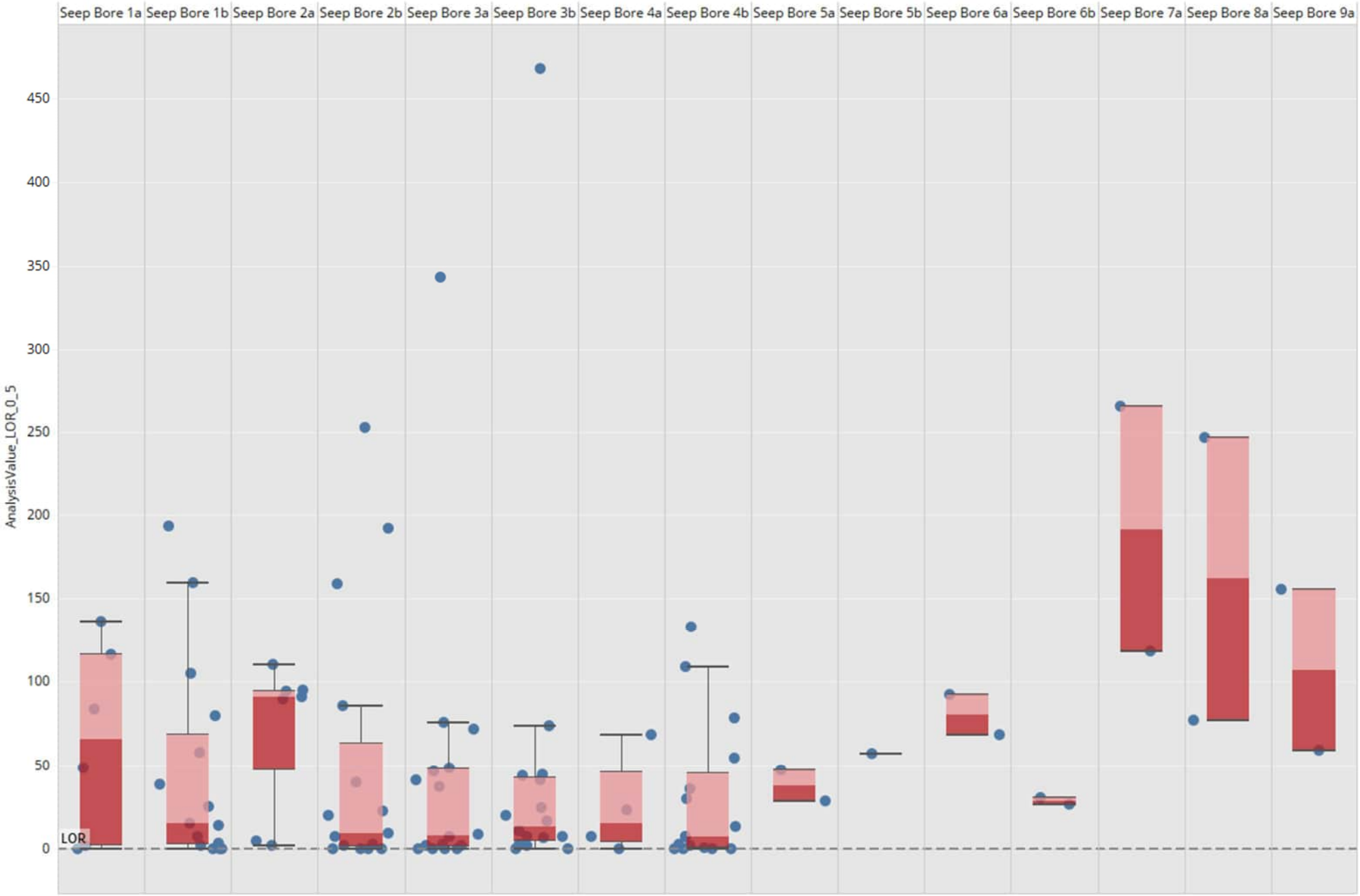

Uranium - dissolved (mg/L)
Rainfall
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
Rainfall (mm)
0
50
100
150
Values/Readings (LOR @ 0)
0.00
0.01
0.02
0.03
0.04
Jan 2023
Mar 2023
May 2023
Jul 2023
Sep 2023
Nov 2023
Jan 2024
Date

H.3 Water quality box & whisker plots

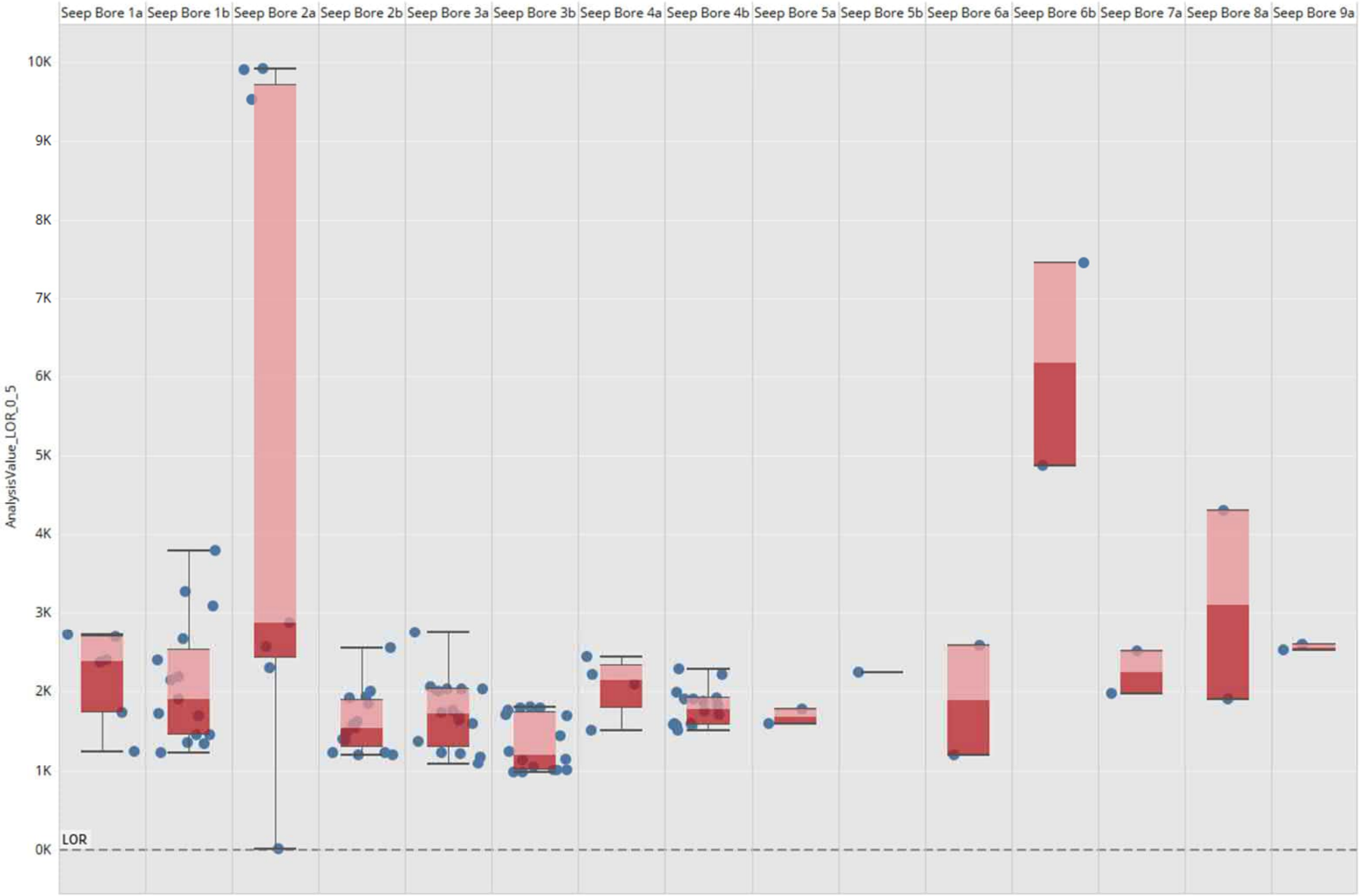
Depth to Water (mbRL)



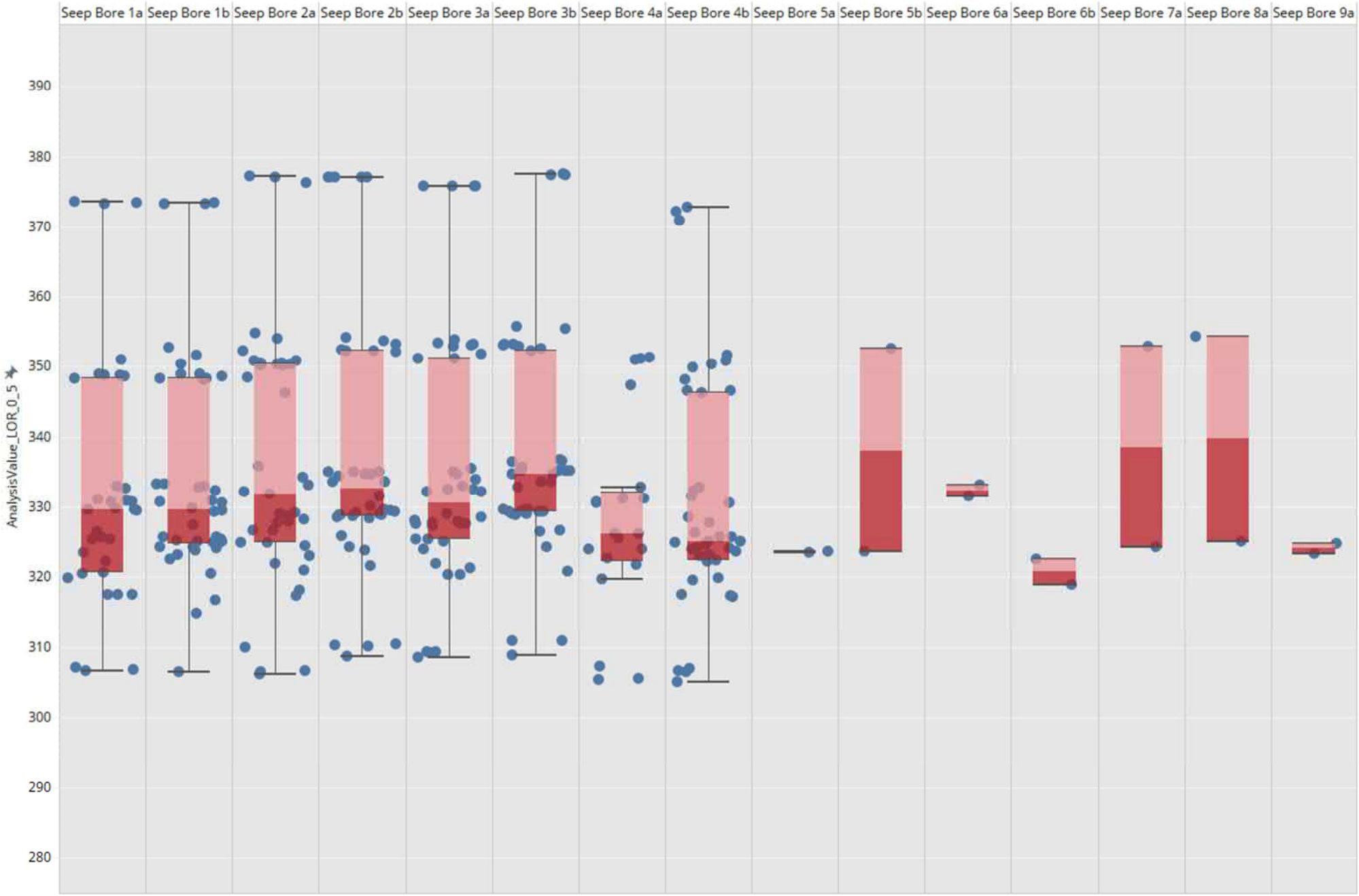
Dissolved Oxygen (field) (% sat)



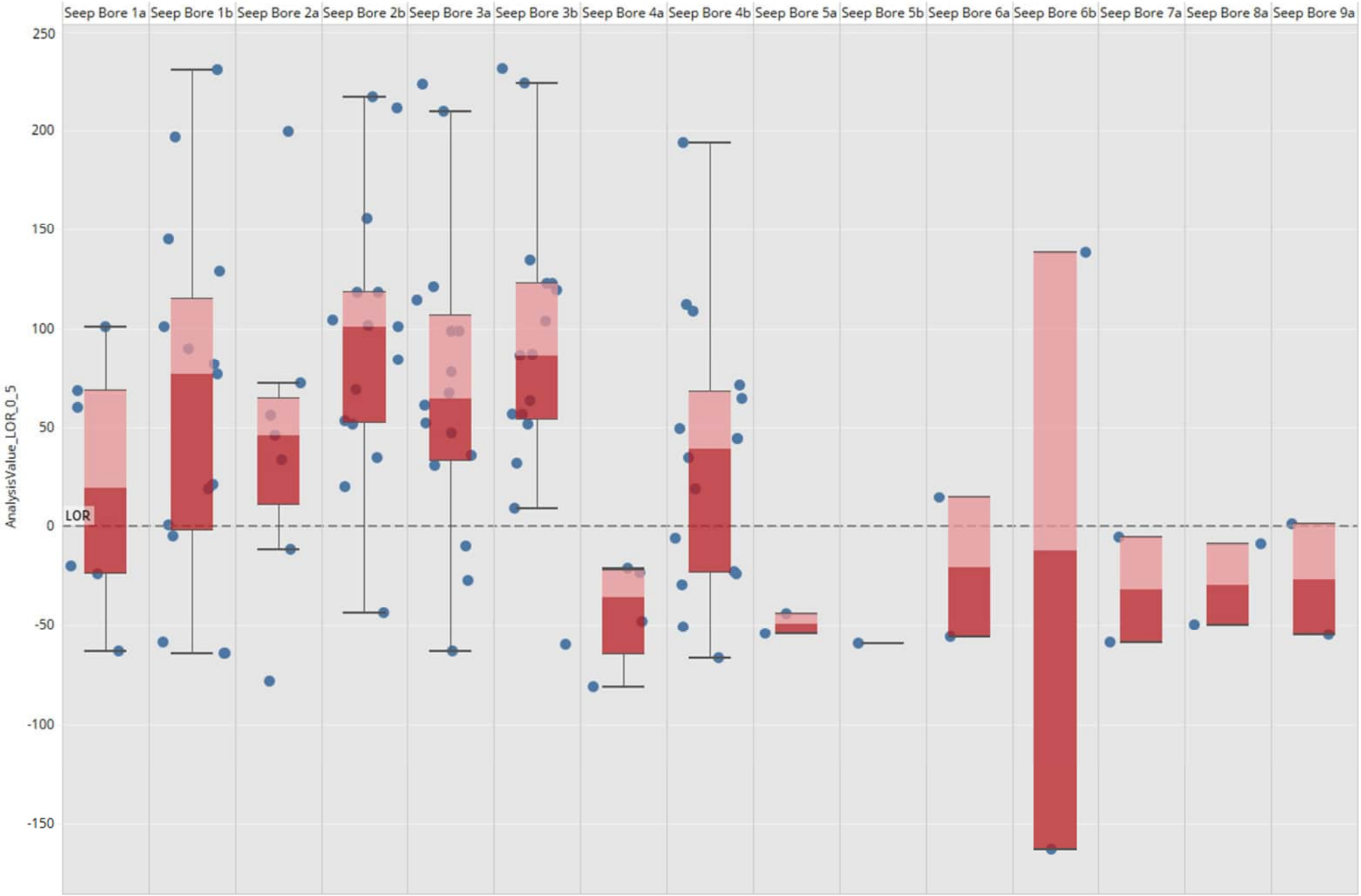
Electrical Conductivity (field) (µS/cm)



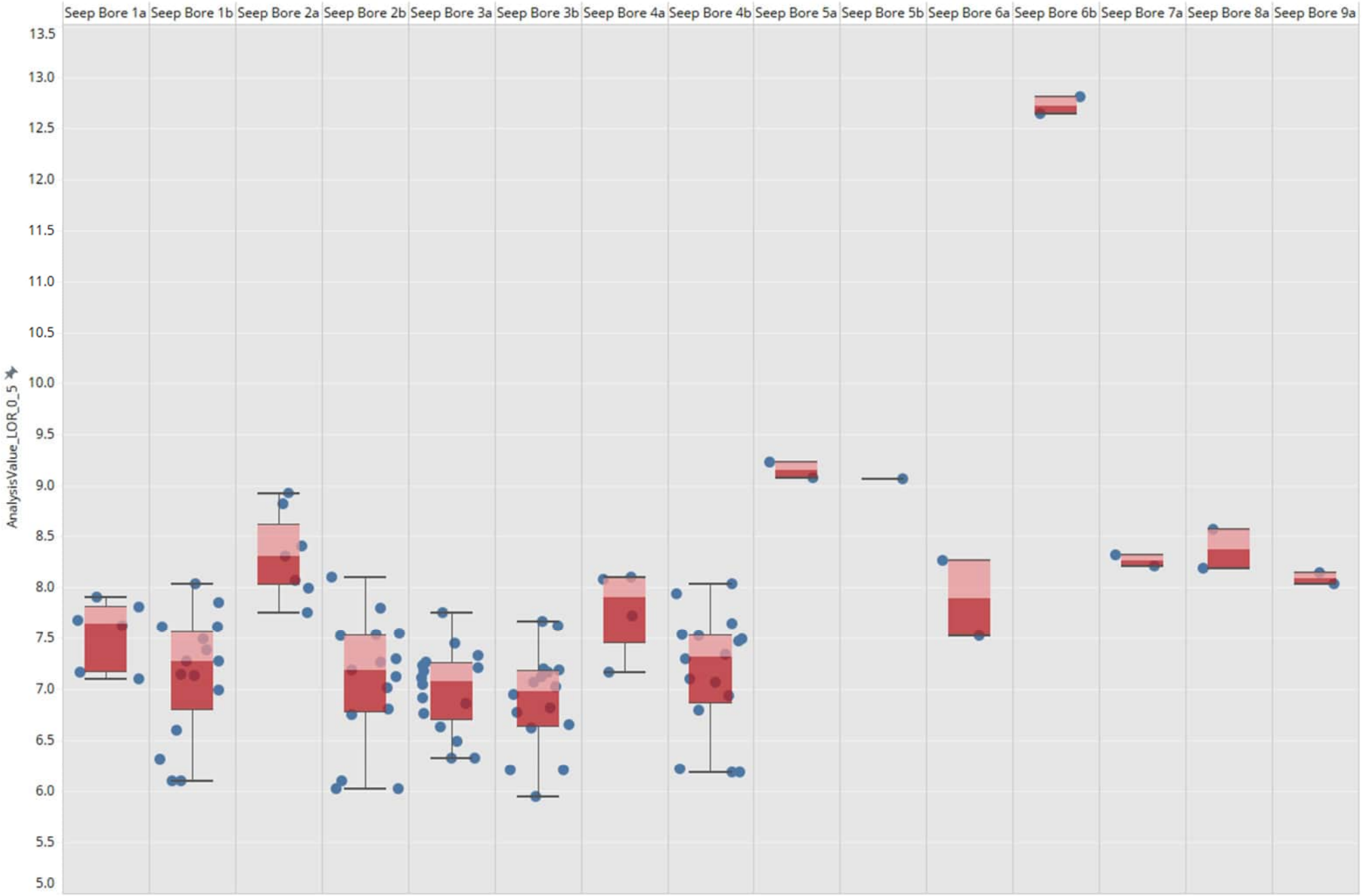
Groundwater Level (mAHD)



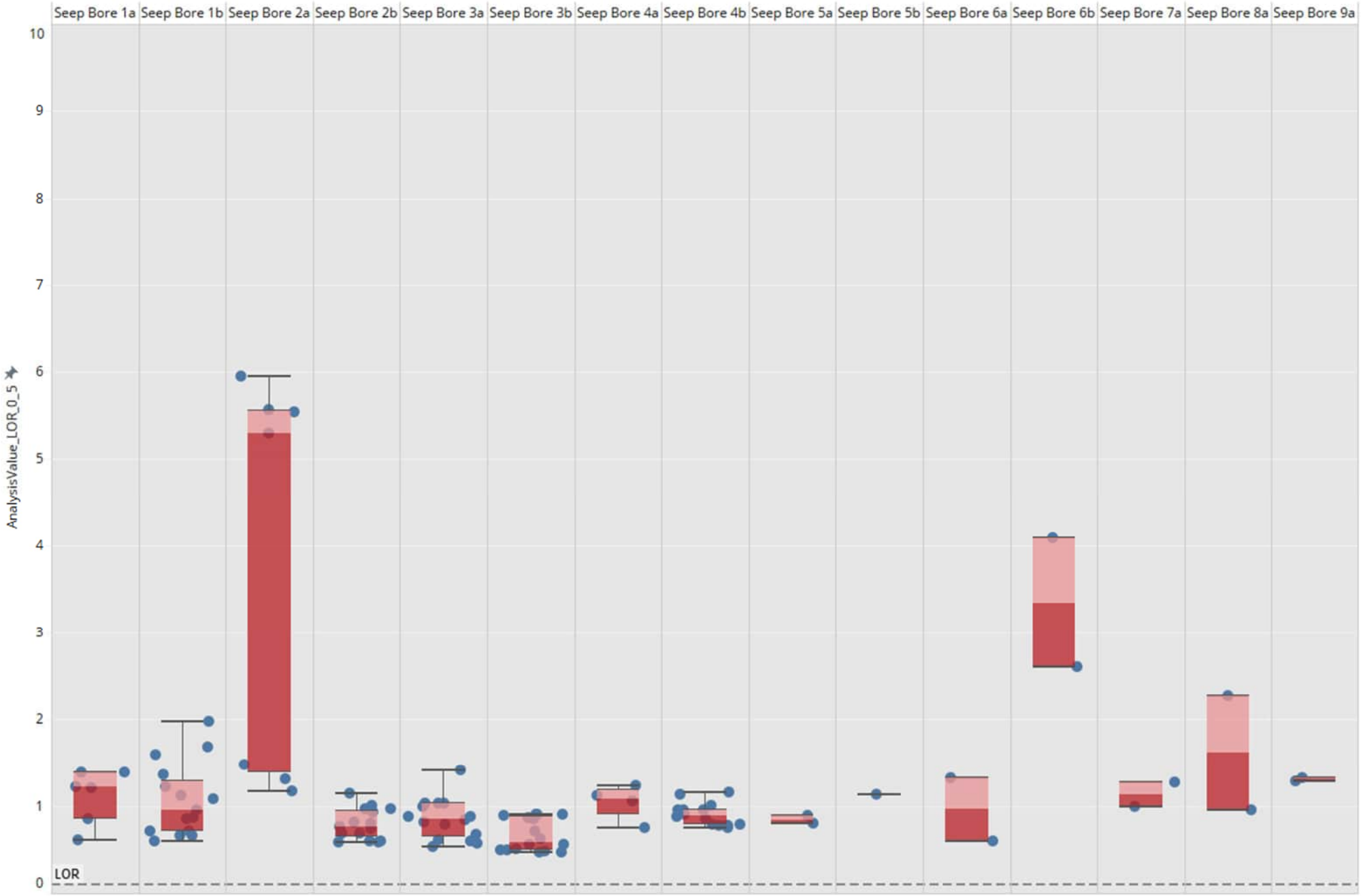
ORP (field) (mV)


Seep Bore 1a
Seep Bore 1b
Seep Bore 2a
Seep Bore 2b
Seep Bore 3a
Seep Bore 3b
Seep Bore 4a
Seep Bore 4b
Seep Bore 5a
Seep Bore 5b
Seep Bore 6a
Seep Bore 6b
Seep Bore 7a
Seep Bore 8a
Seep Bore 9a
AnalysisValue_LOR_0_5
250
200
150
100
50
0
-50
-100
-150
LOR

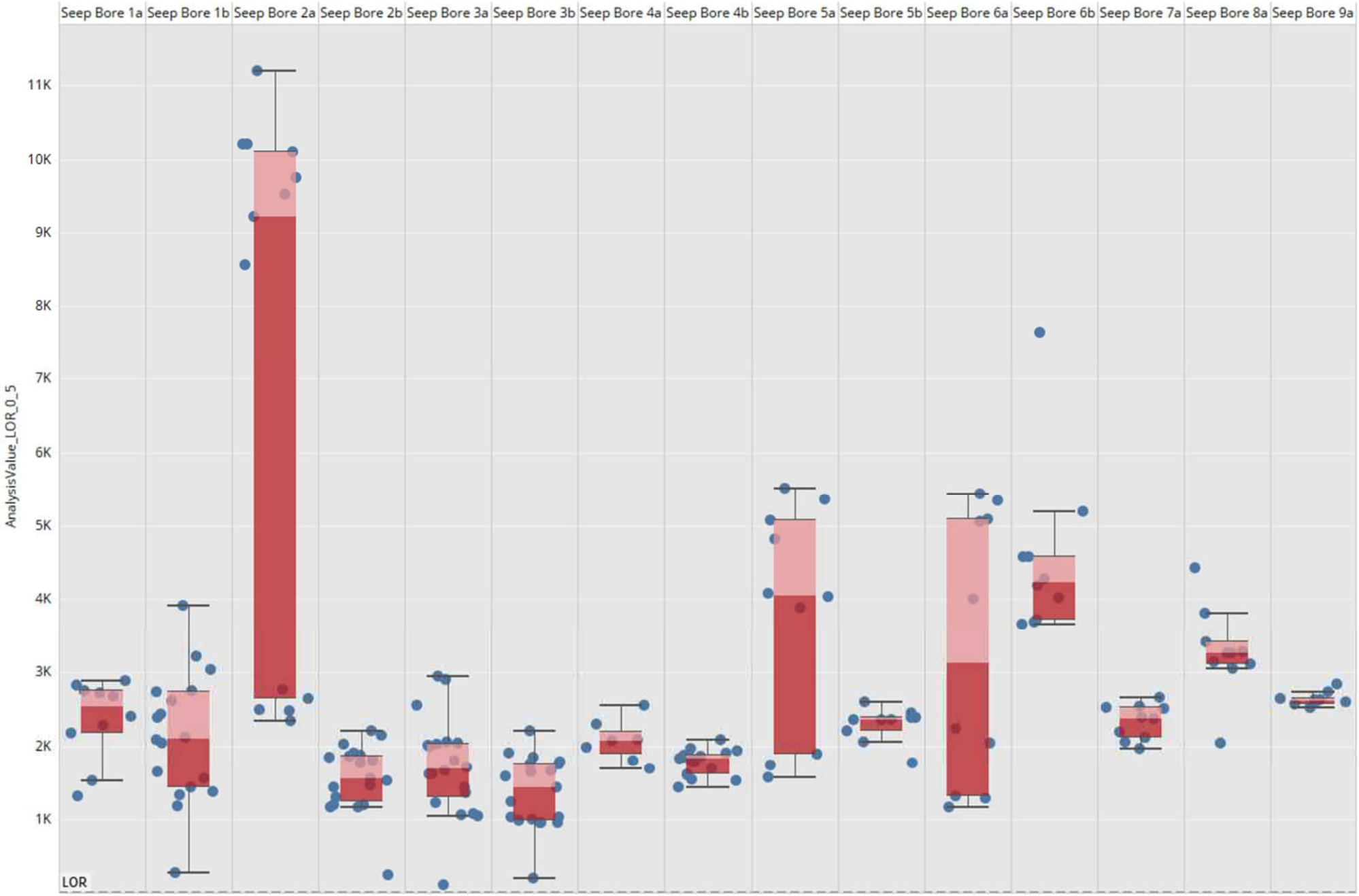
pH (field)


Seep Bore 1a
Seep Bore 1b
Seep Bore 2a
Seep Bore 2b
Seep Bore 3a
Seep Bore 3b
Seep Bore 4a
Seep Bore 4b
Seep Bore 5a
Seep Bore 5b
Seep Bore 6a
Seep Bore 6b
Seep Bore 7a
Seep Bore 8a
Seep Bore 9a
AnalysisValue_LOR_0_5
13.5
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0

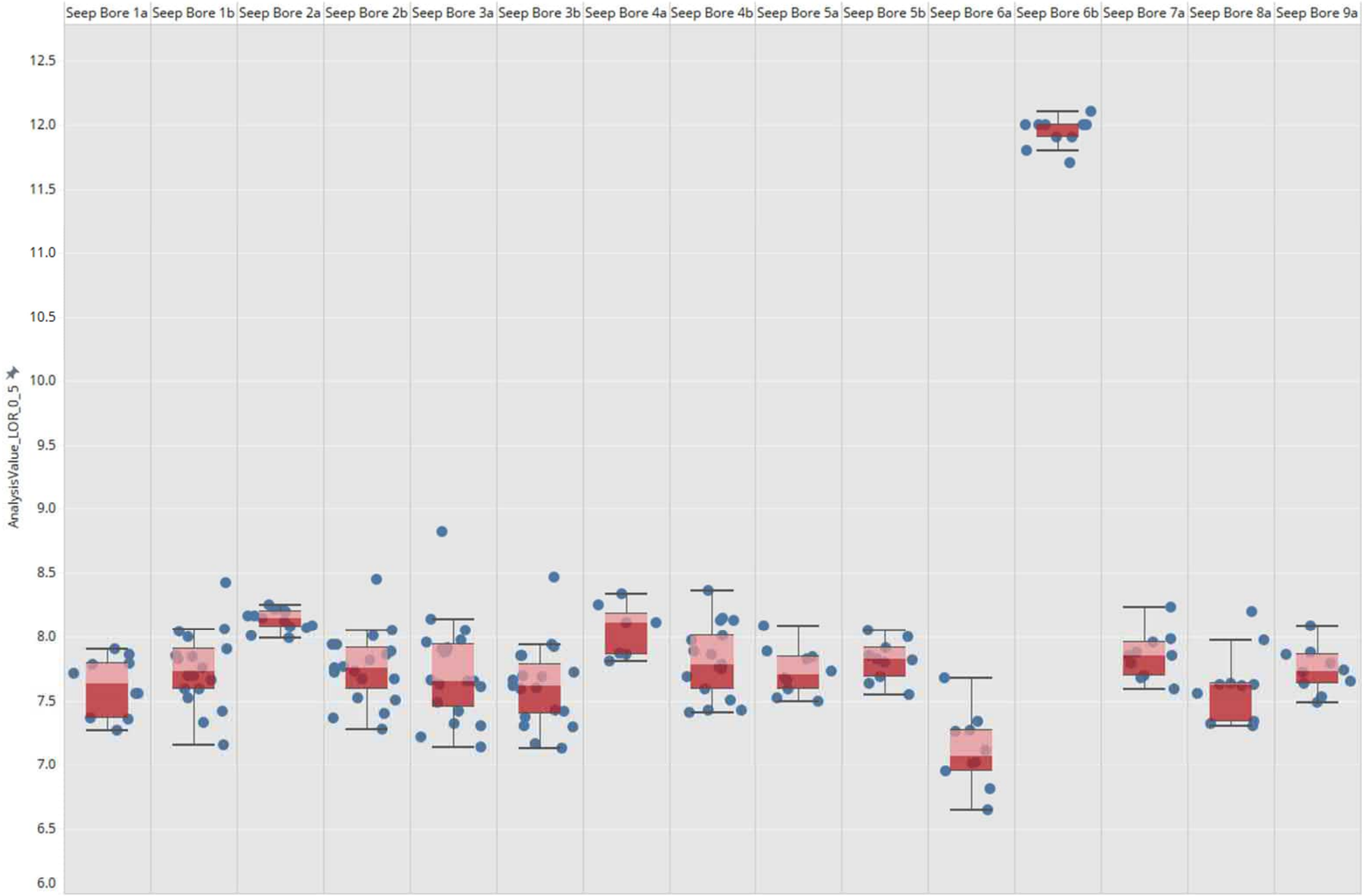
Salinity (field) (PSU)



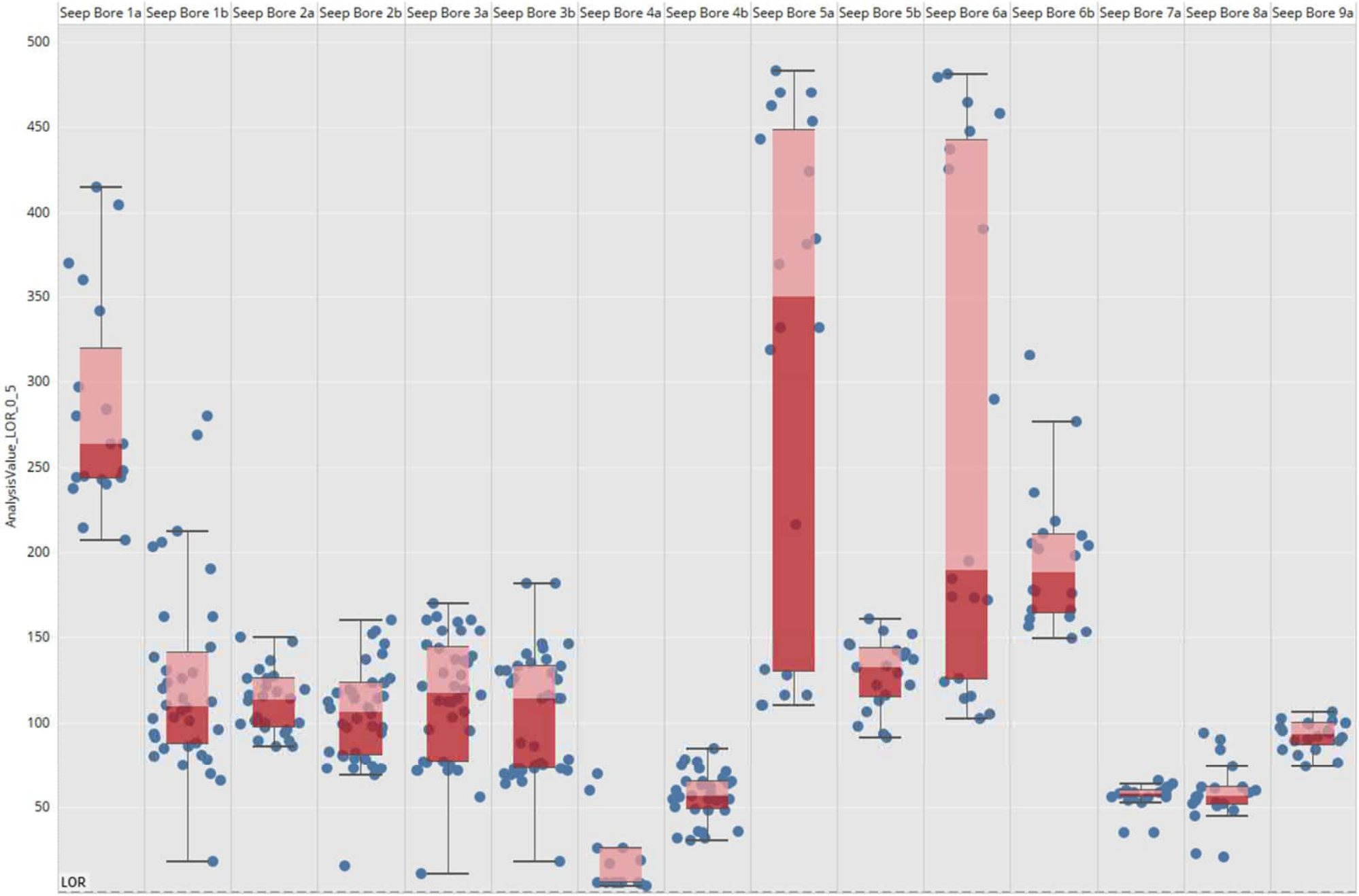
Electrical Conductivity (µS/cm)



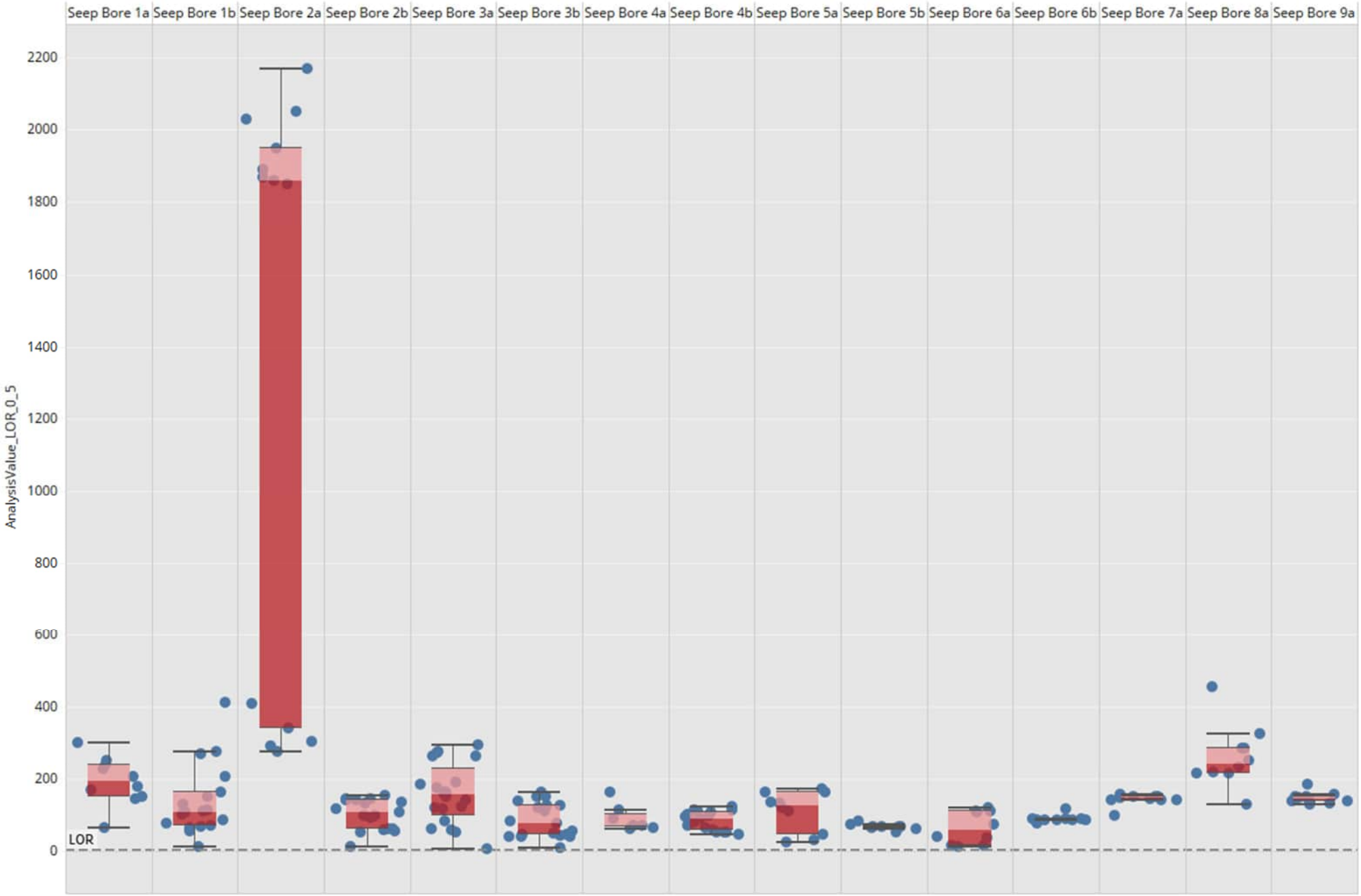
pH (lab)


Seep Bore 1a
Seep Bore 1b
Seep Bore 2a
Seep Bore 2b
Seep Bore 3a
Seep Bore 3b
Seep Bore 4a
Seep Bore 4b
Seep Bore 5a
Seep Bore 5b
Seep Bore 6a
Seep Bore 6b
Seep Bore 7a
Seep Bore 8a
Seep Bore 9a
AnalysisValue_LOR_0_5
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0

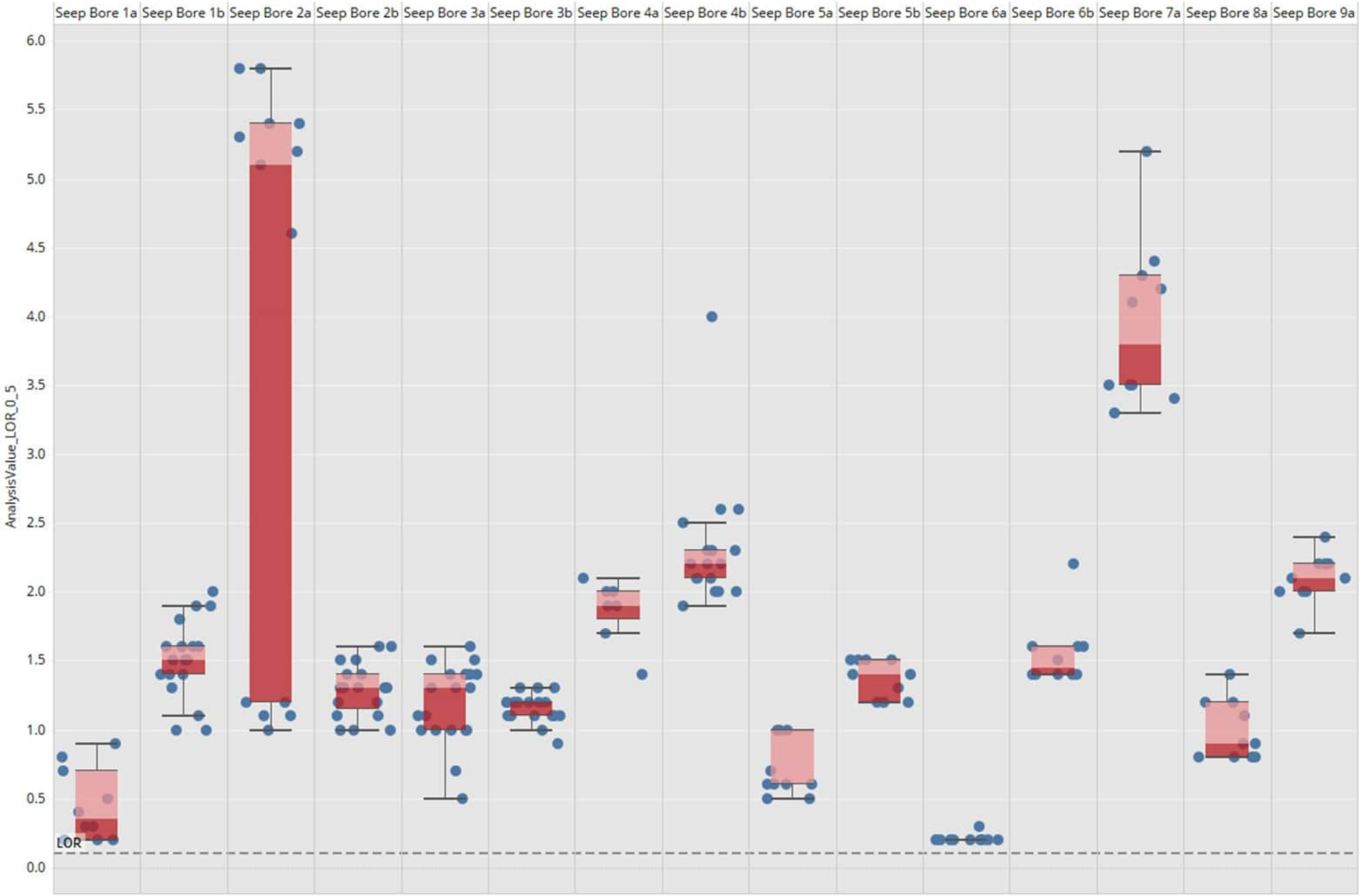
Calcium (mg/L)


Seep Bore 1a
Seep Bore 1b
Seep Bore 2a
Seep Bore 2b
Seep Bore 3a
Seep Bore 3b
Seep Bore 4a
Seep Bore 4b
Seep Bore 5a
Seep Bore 5b
Seep Bore 6a
Seep Bore 6b
Seep Bore 7a
Seep Bore 8a
Seep Bore 9a
AnalysisValue_LOR_0_5
500
450
400
350
300
250
200
150
100
50
LOR

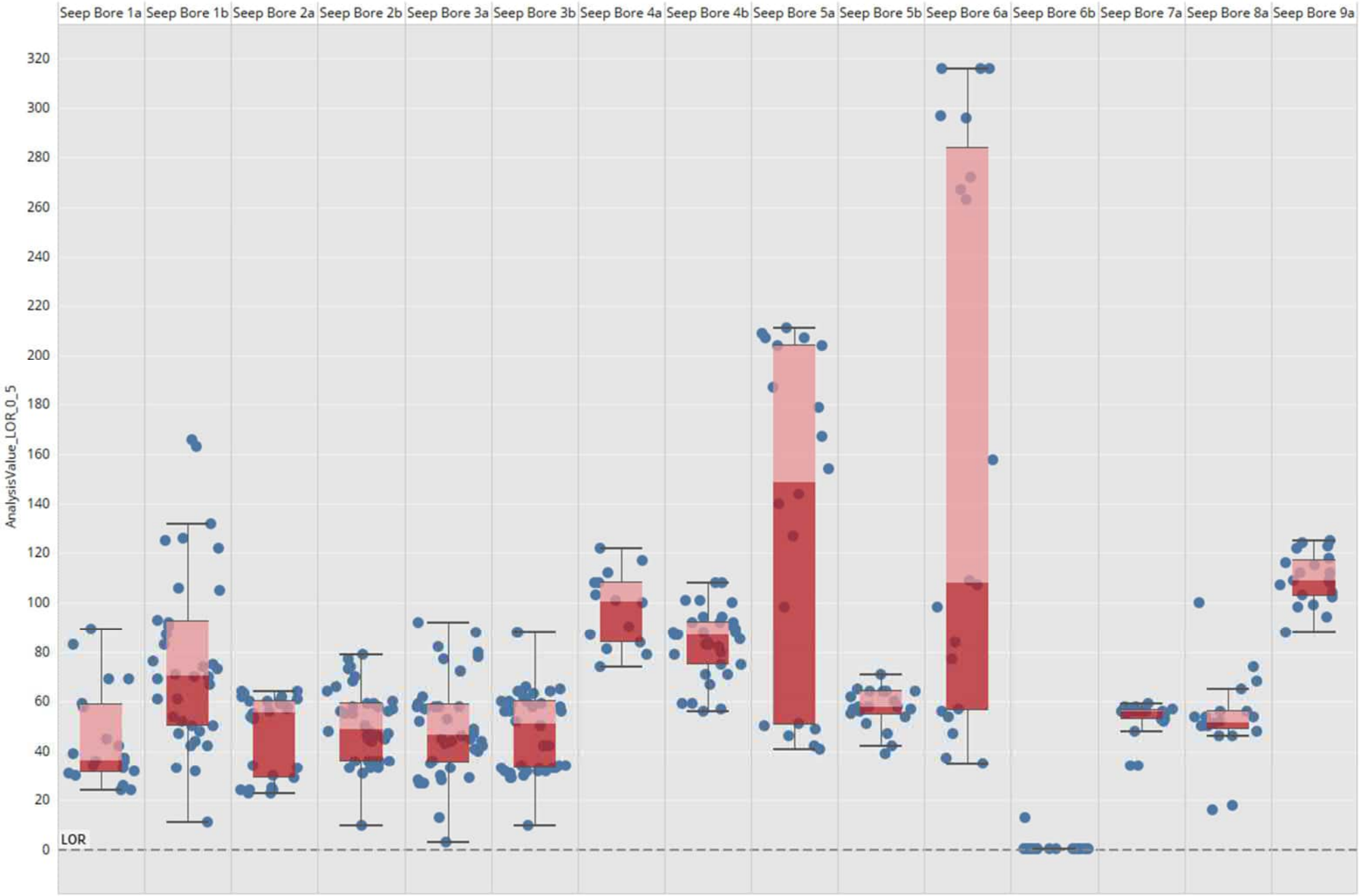
Chloride (mg/L)



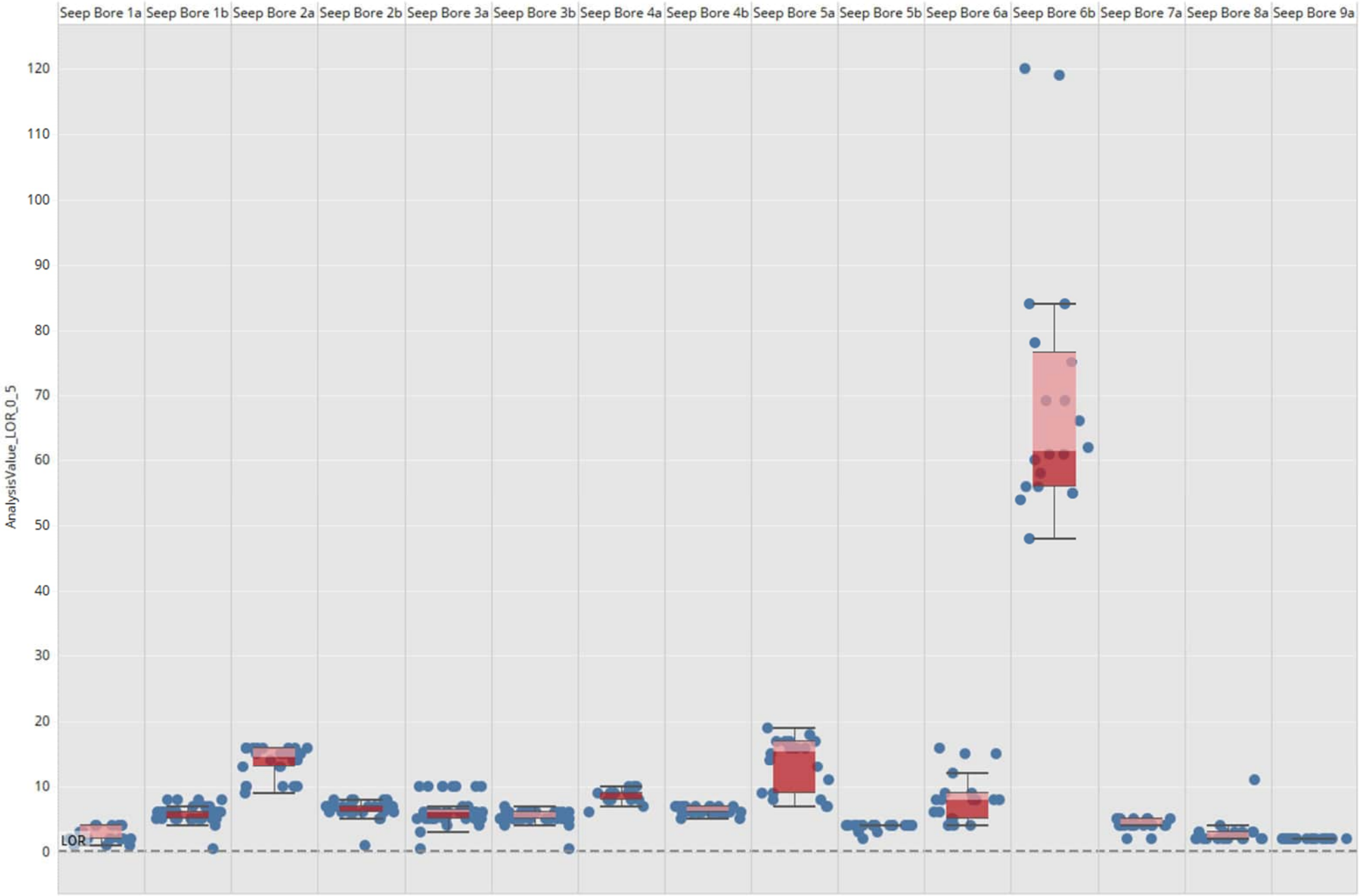
Fluoride (mg/L)



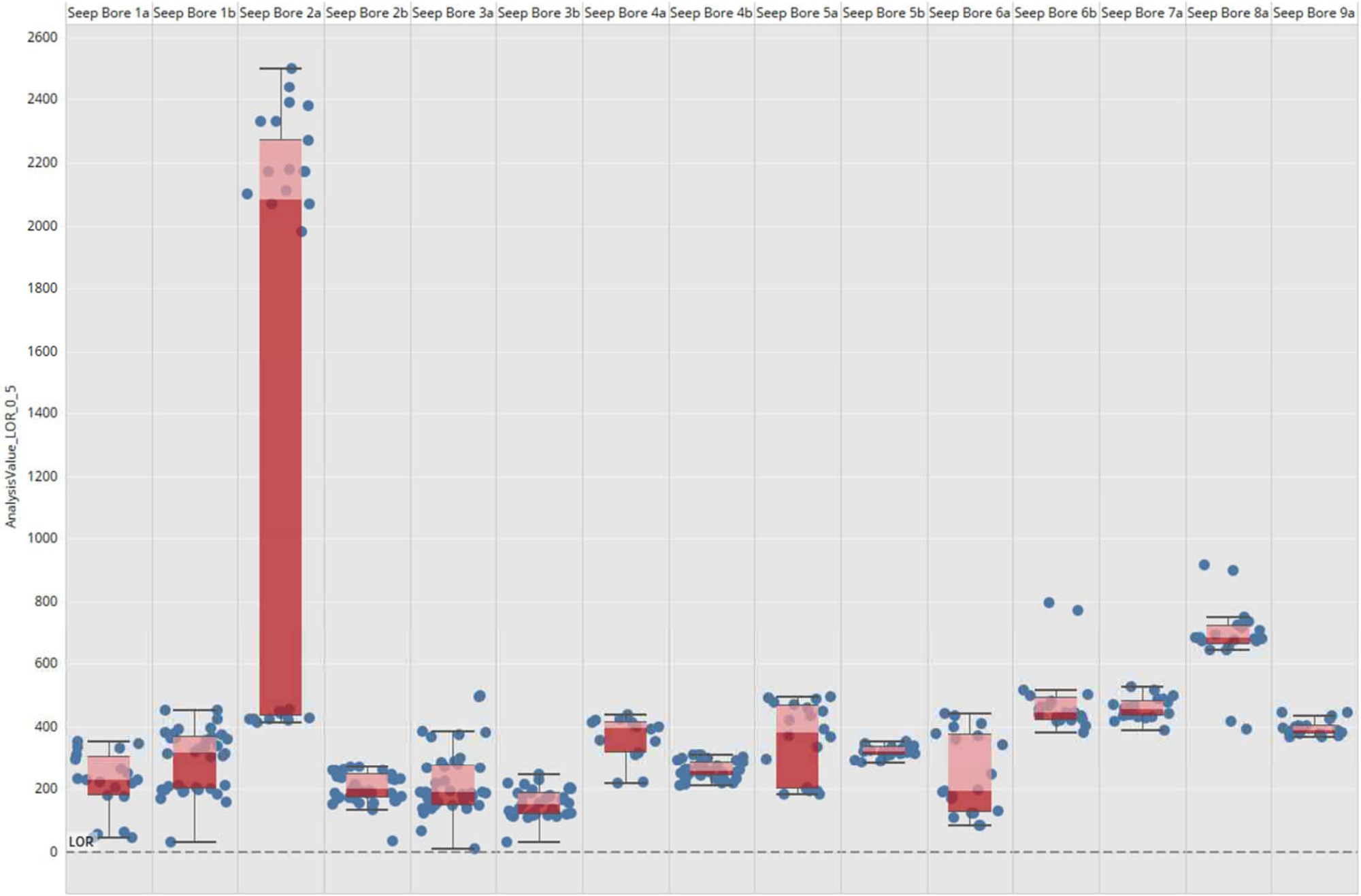
Magnesium (mg/L)



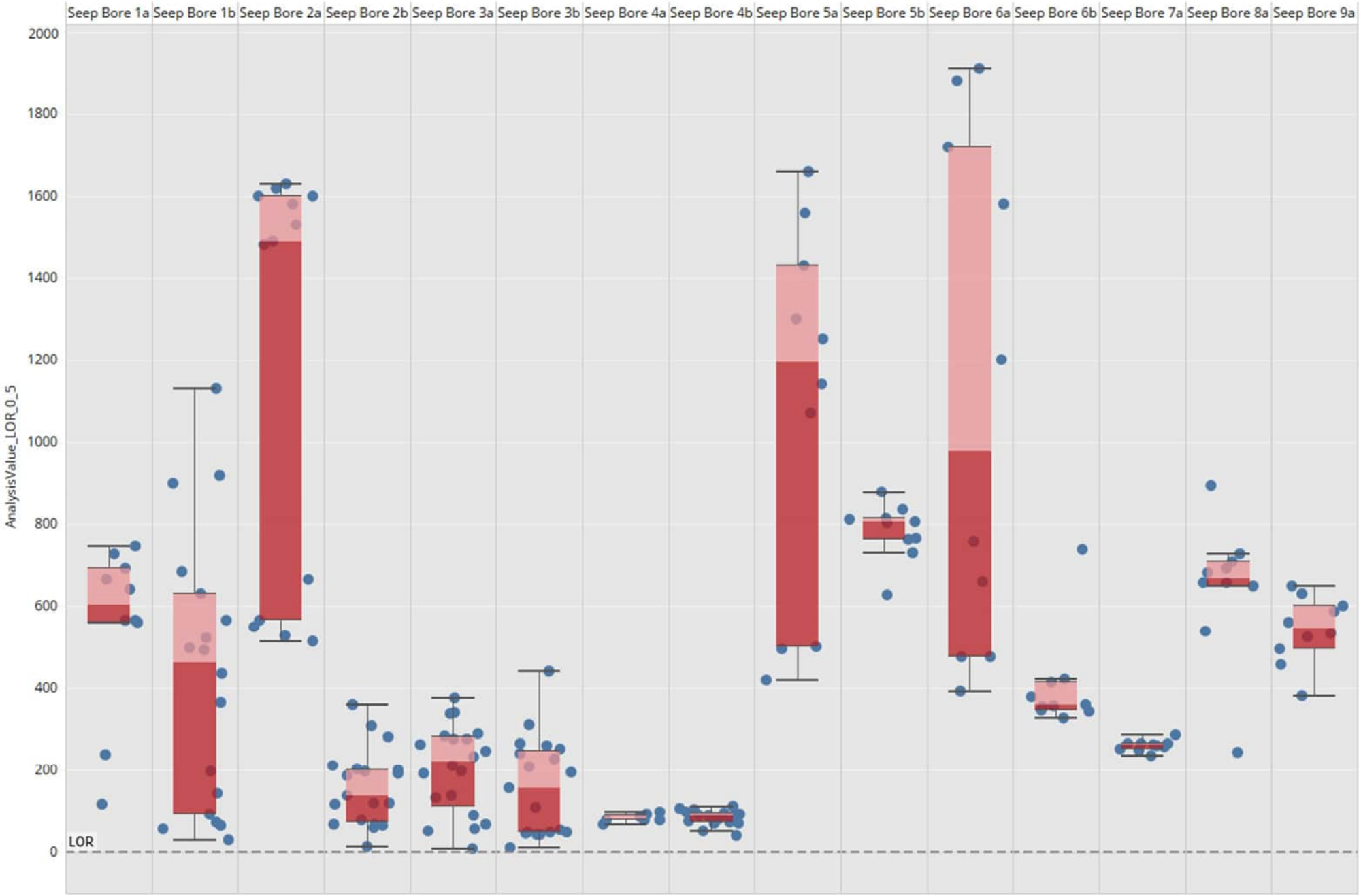
Potassium (mg/L)



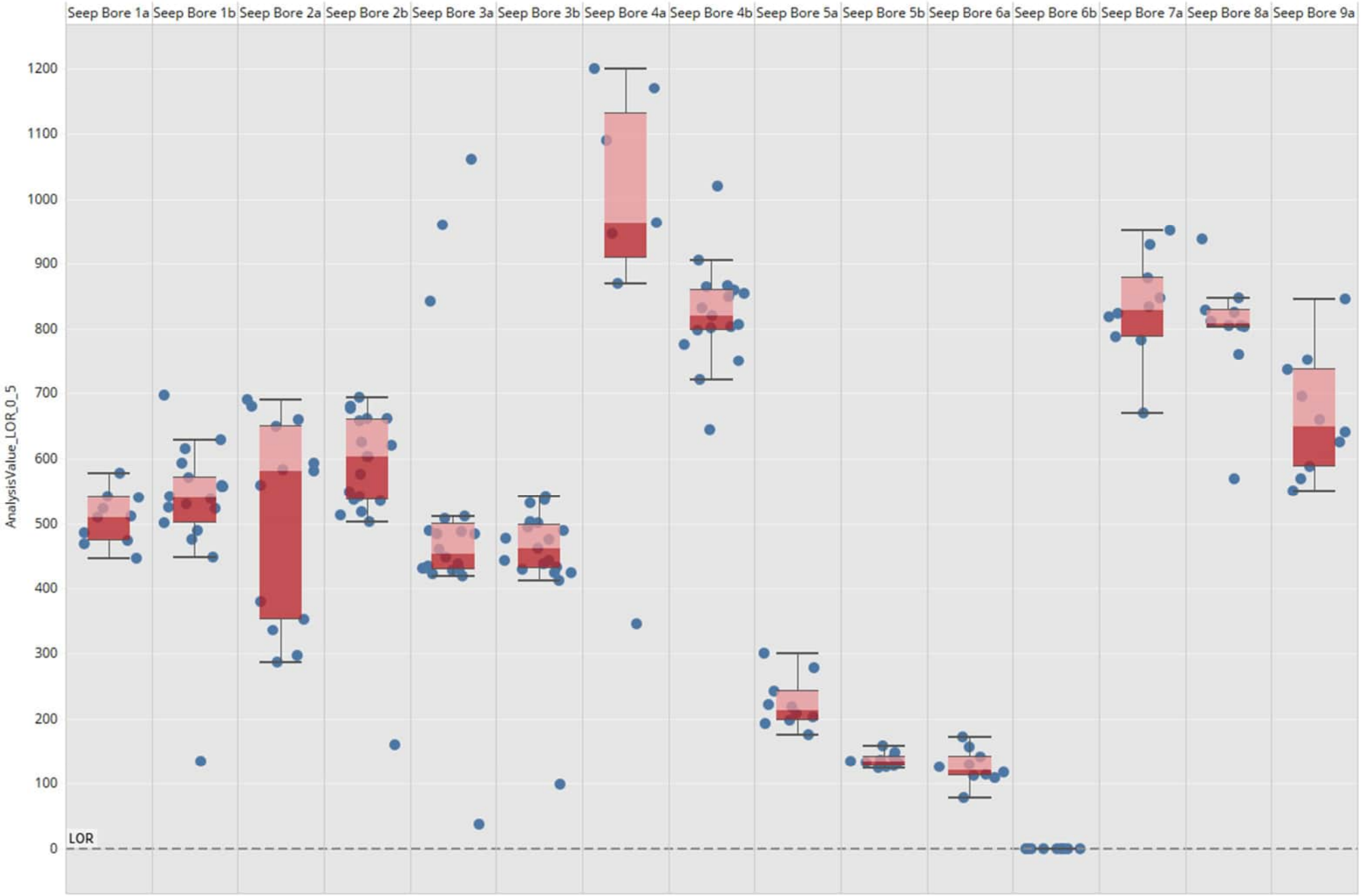
Sodium (mg/L)


Seep Bore 1a
Seep Bore 1b
Seep Bore 2a
Seep Bore 2b
Seep Bore 3a
Seep Bore 3b
Seep Bore 4a
Seep Bore 4b
Seep Bore 5a
Seep Bore 5b
Seep Bore 6a
Seep Bore 6b
Seep Bore 7a
Seep Bore 8a
Seep Bore 9a
AnalysisValue_LOR_0_5
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
LOR

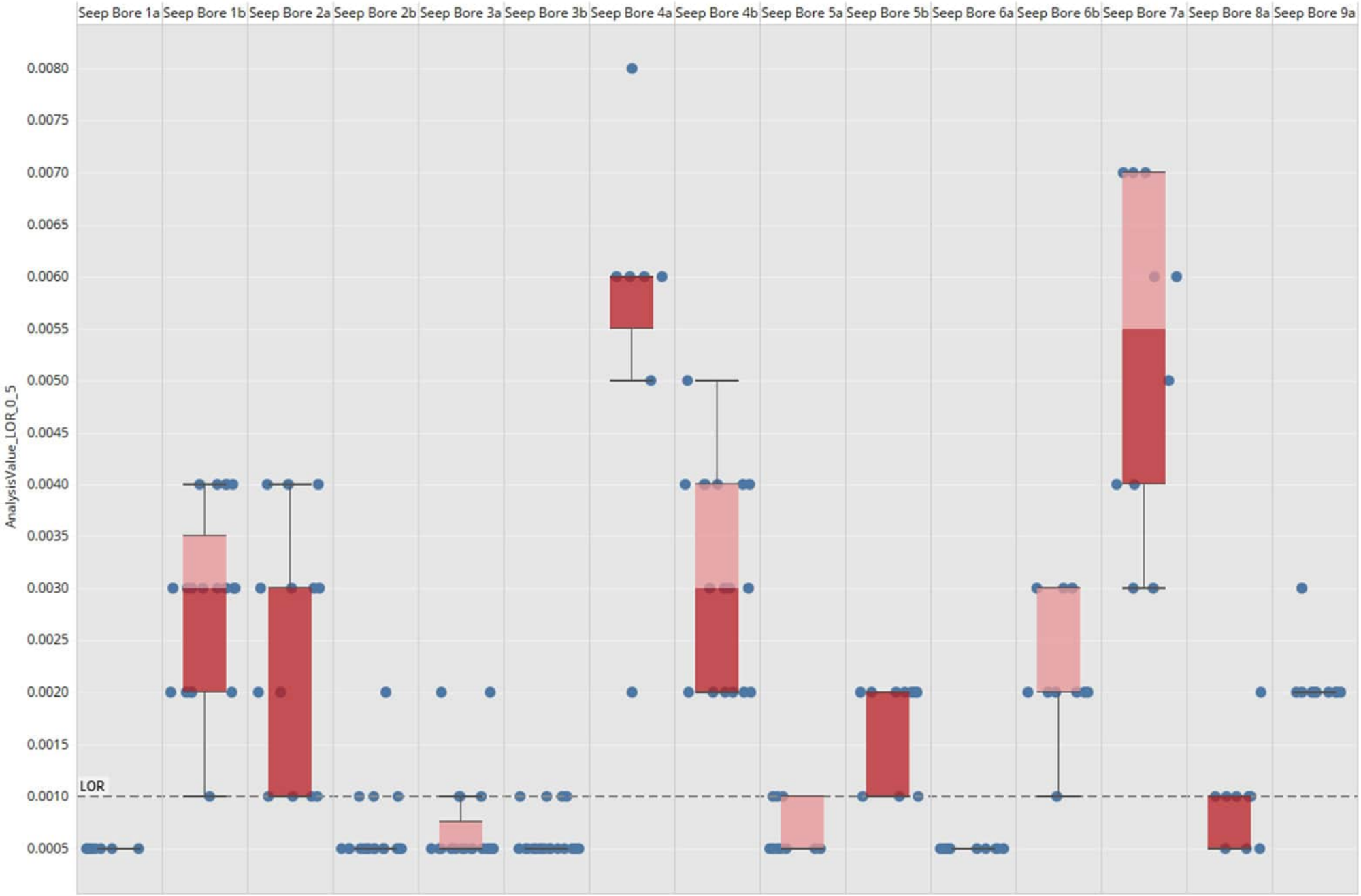
Sulfate (as SO4)



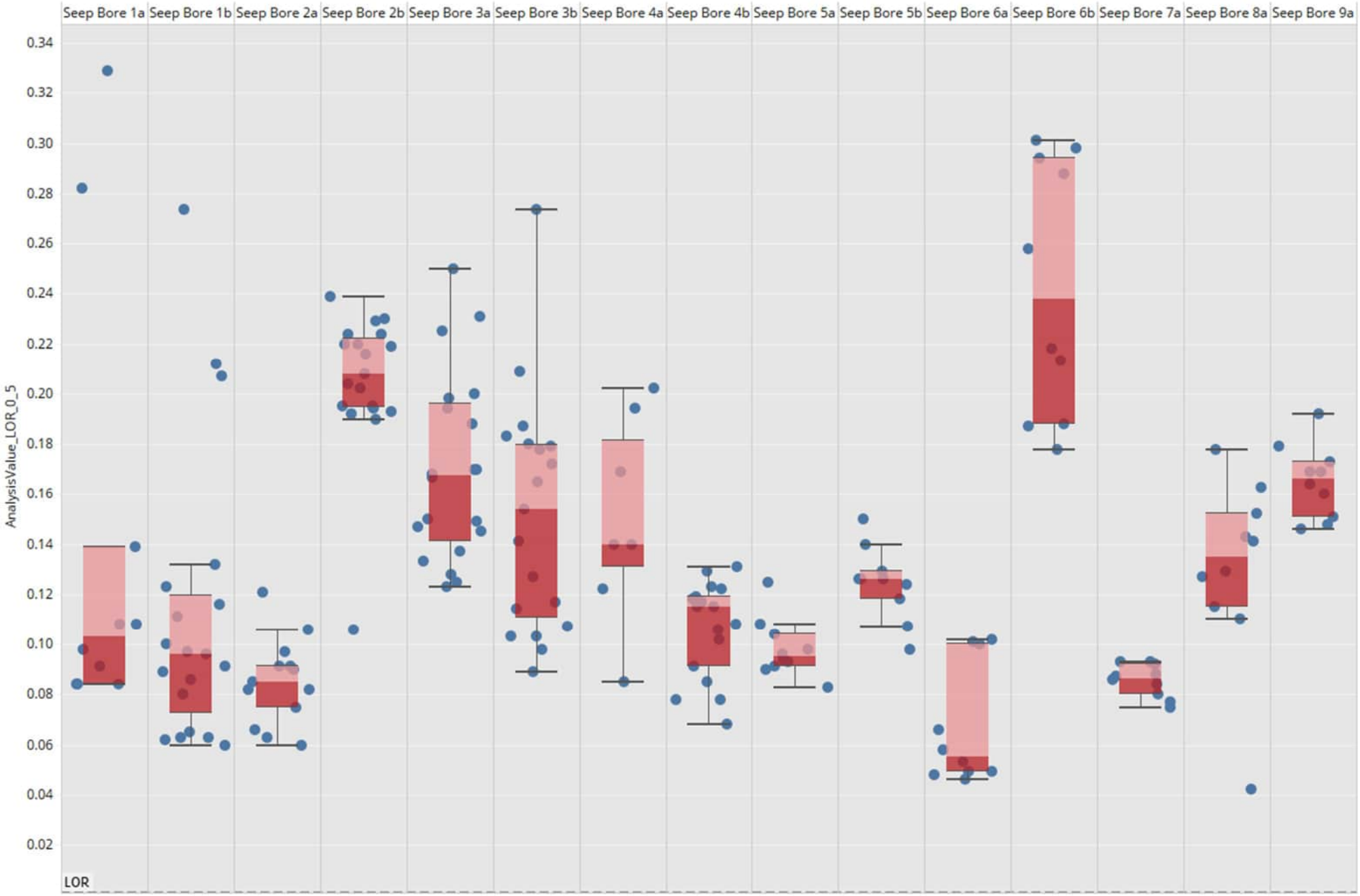
Bicarbonate Alkalinity as CaCO3 (mg/L)



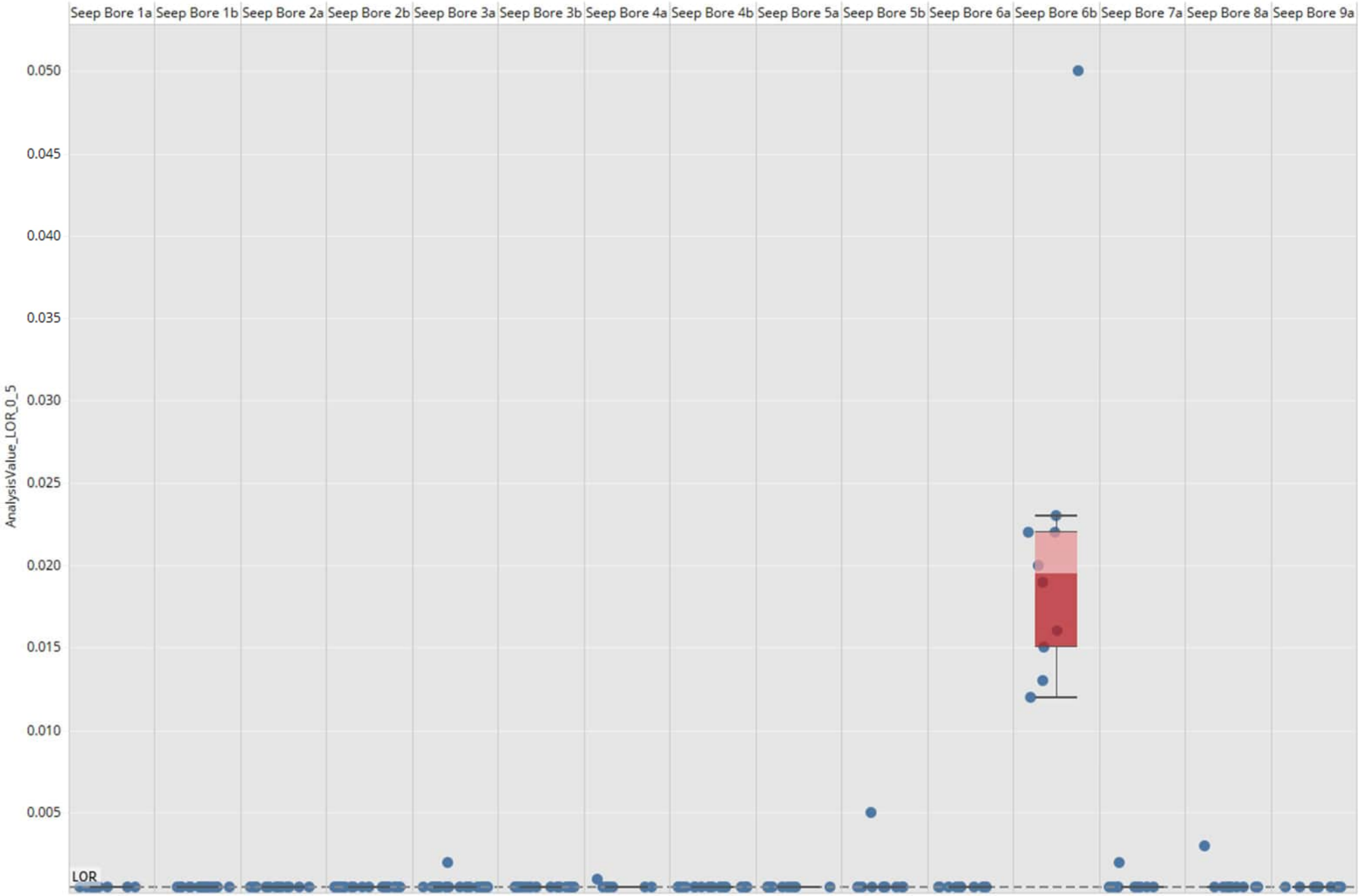
Arsenic - dissolved (mg/L)



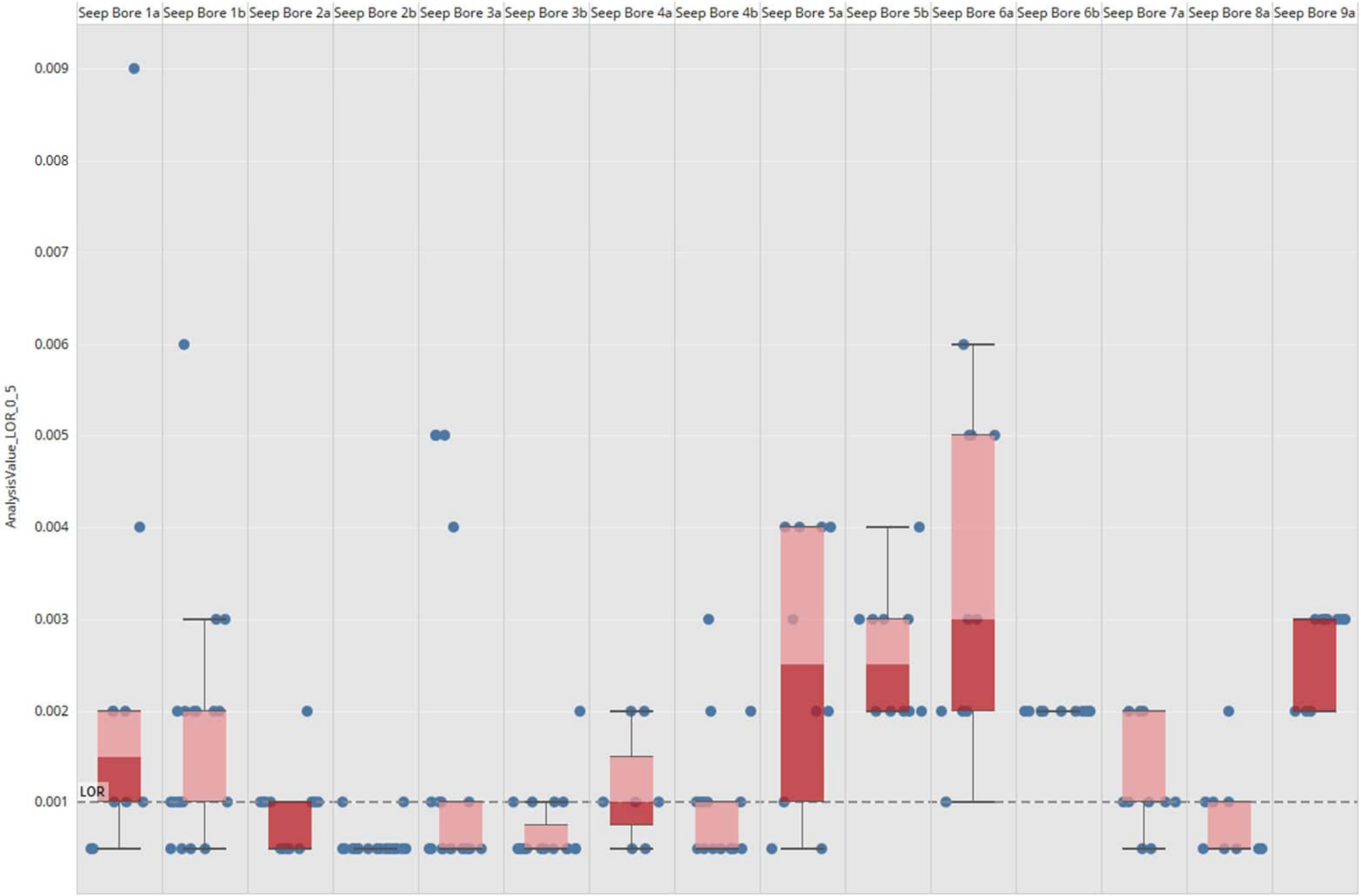
Barium - dissolved (mg/L)



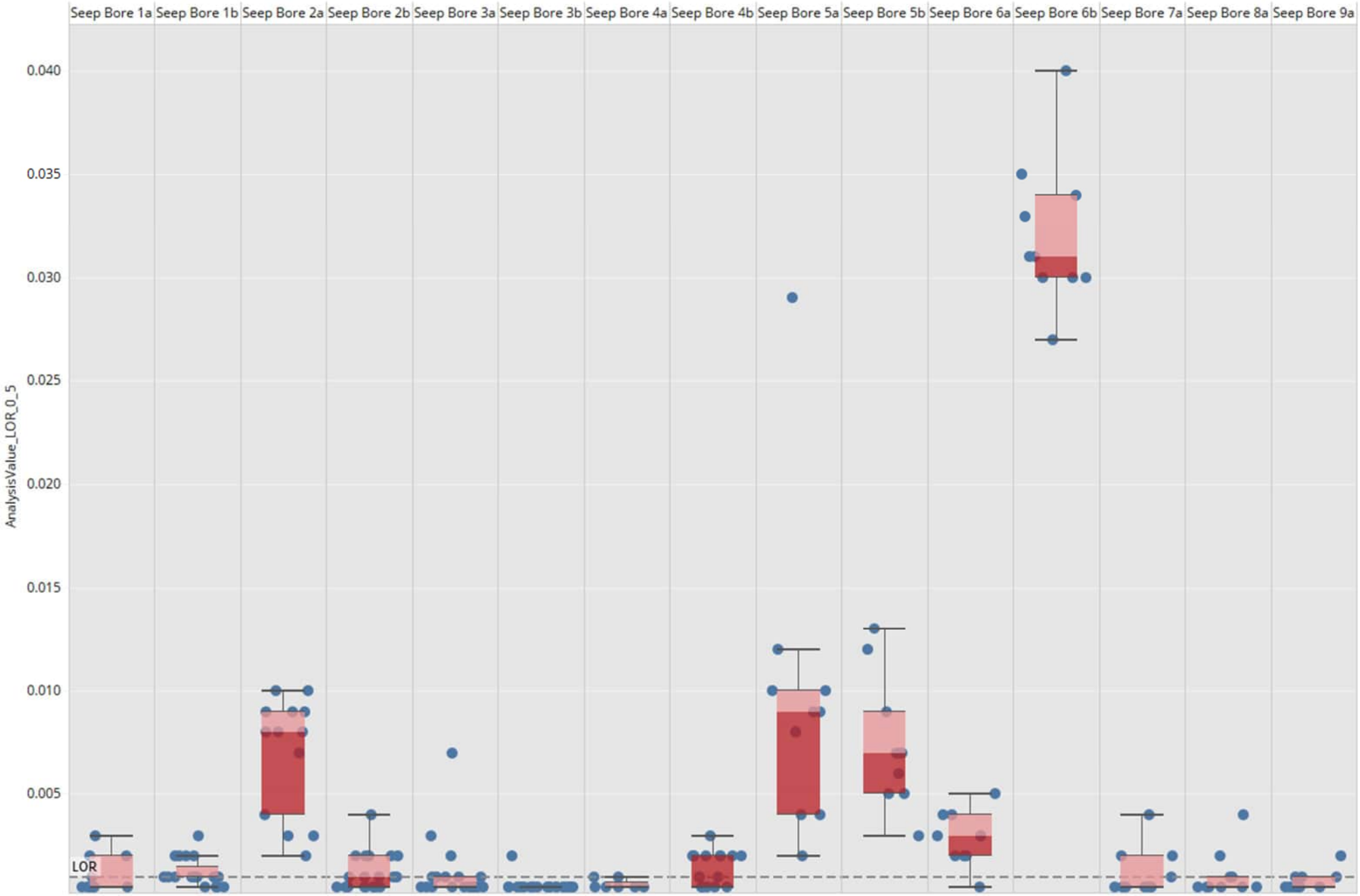
Chromium - dissolved (mg/L)



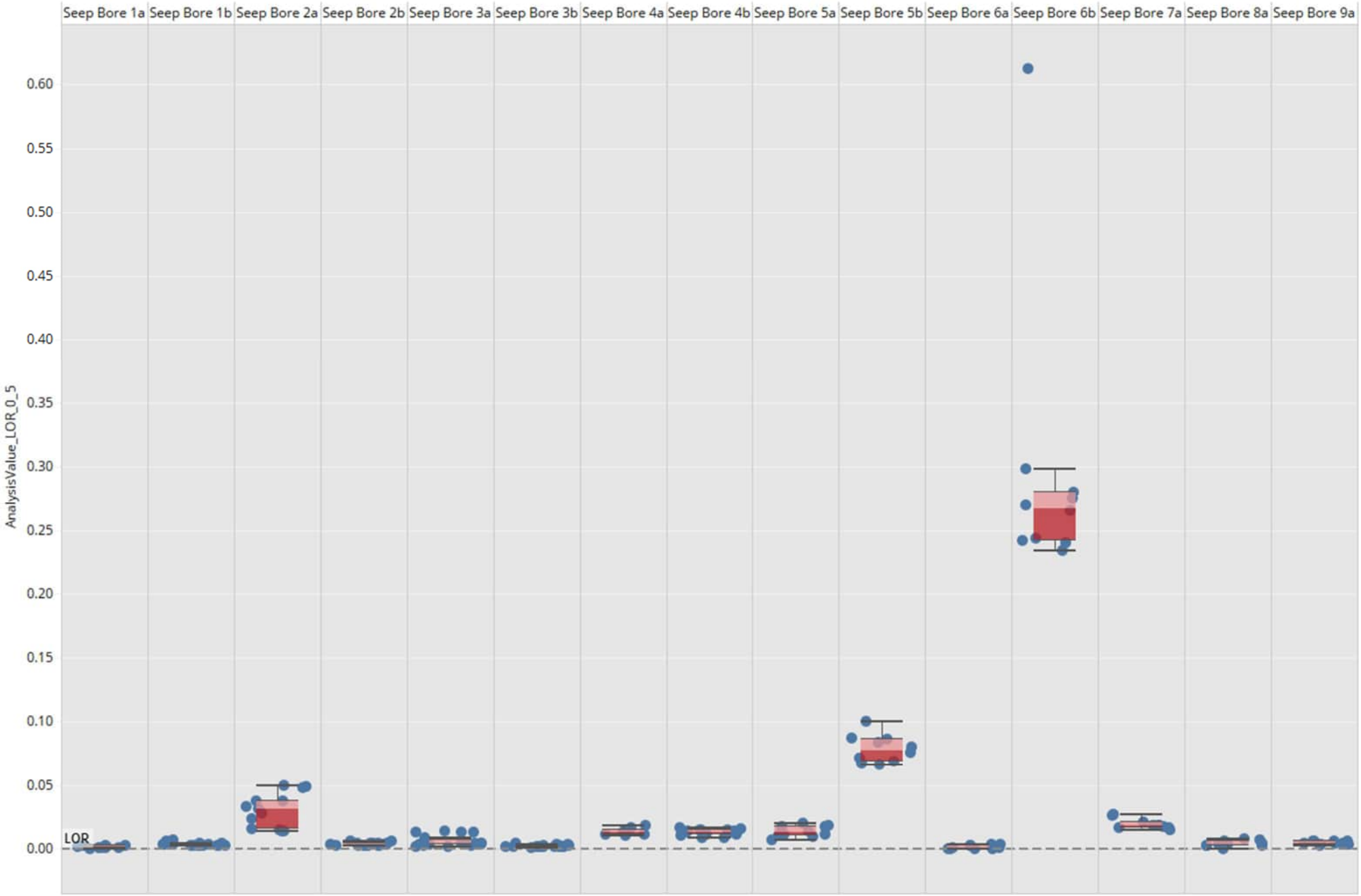
Cobalt - dissolved (mg/L)



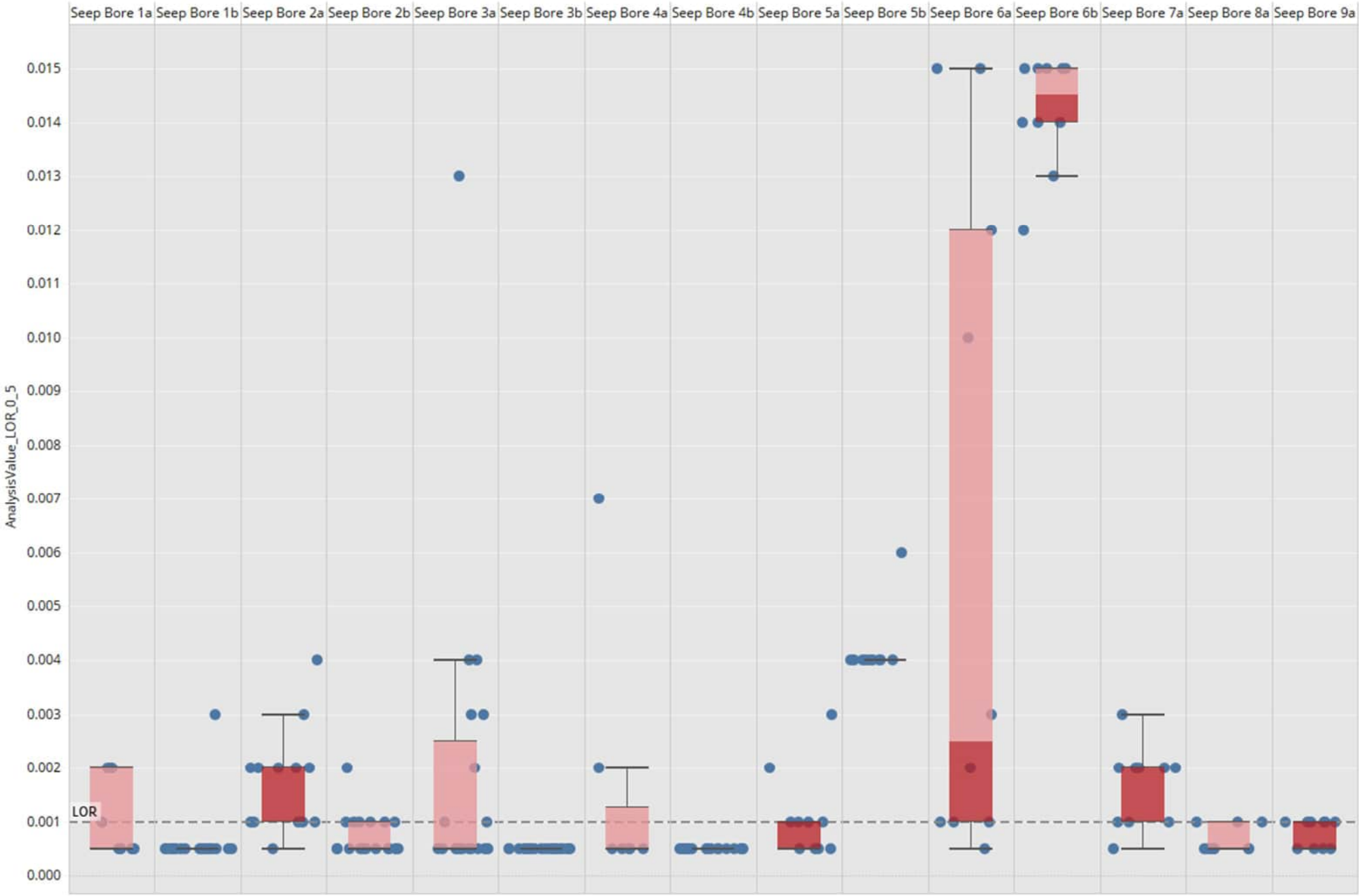
Copper - dissolved (mg/L)



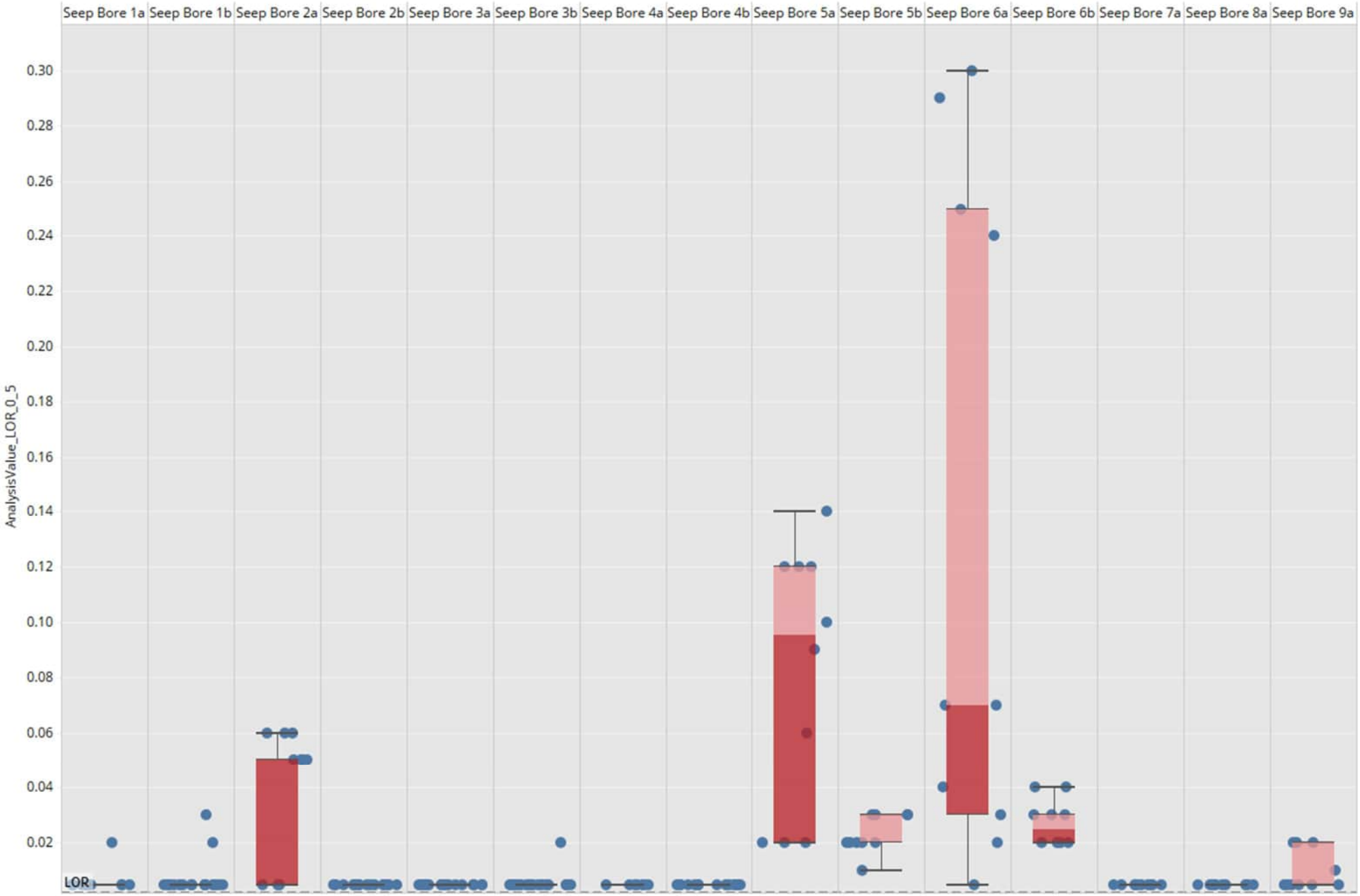
Molybdenum - dissolved (mg/L)



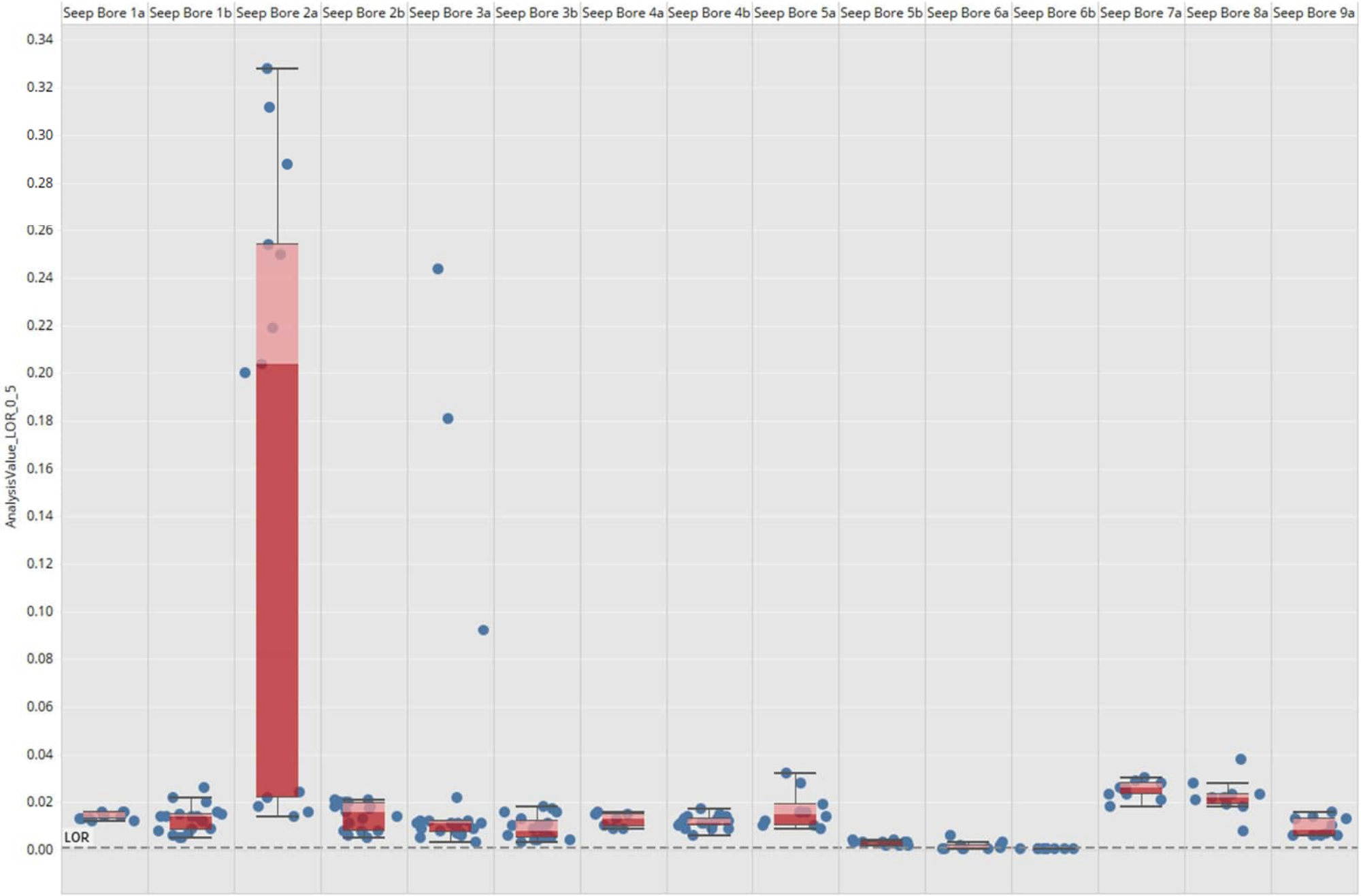
Nickel - dissolved (mg/L)



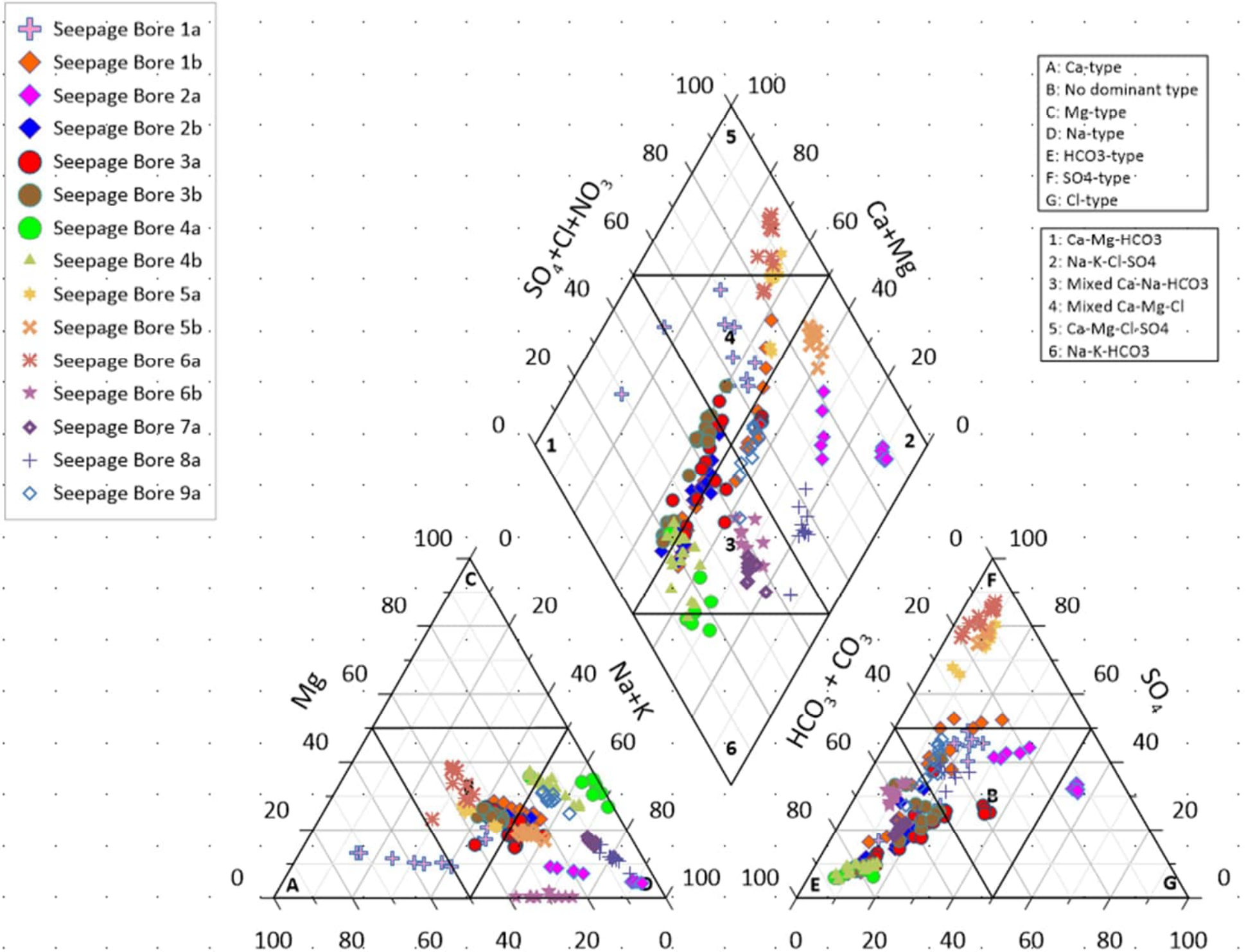
Selenium - dissolved (mg/L)

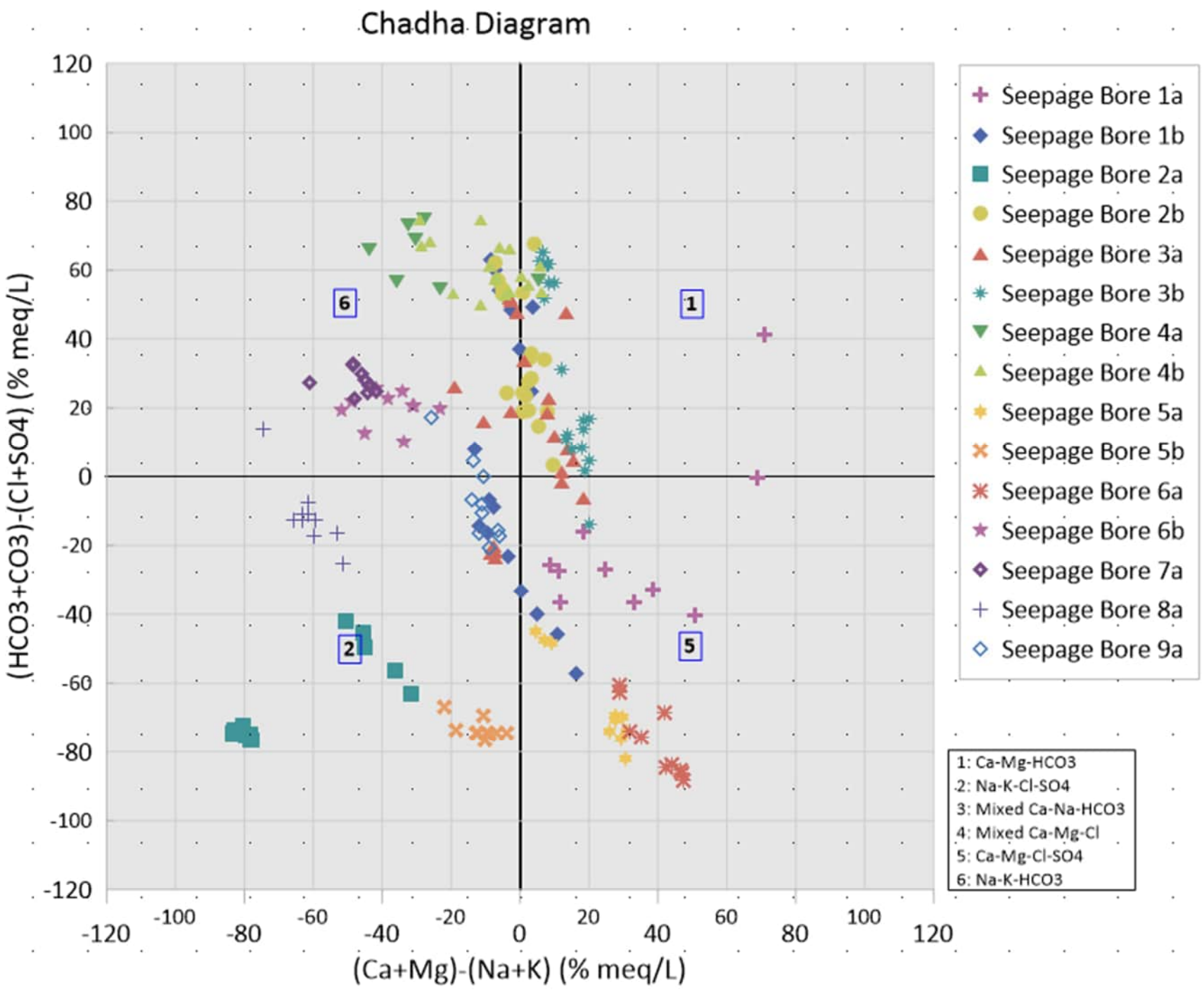


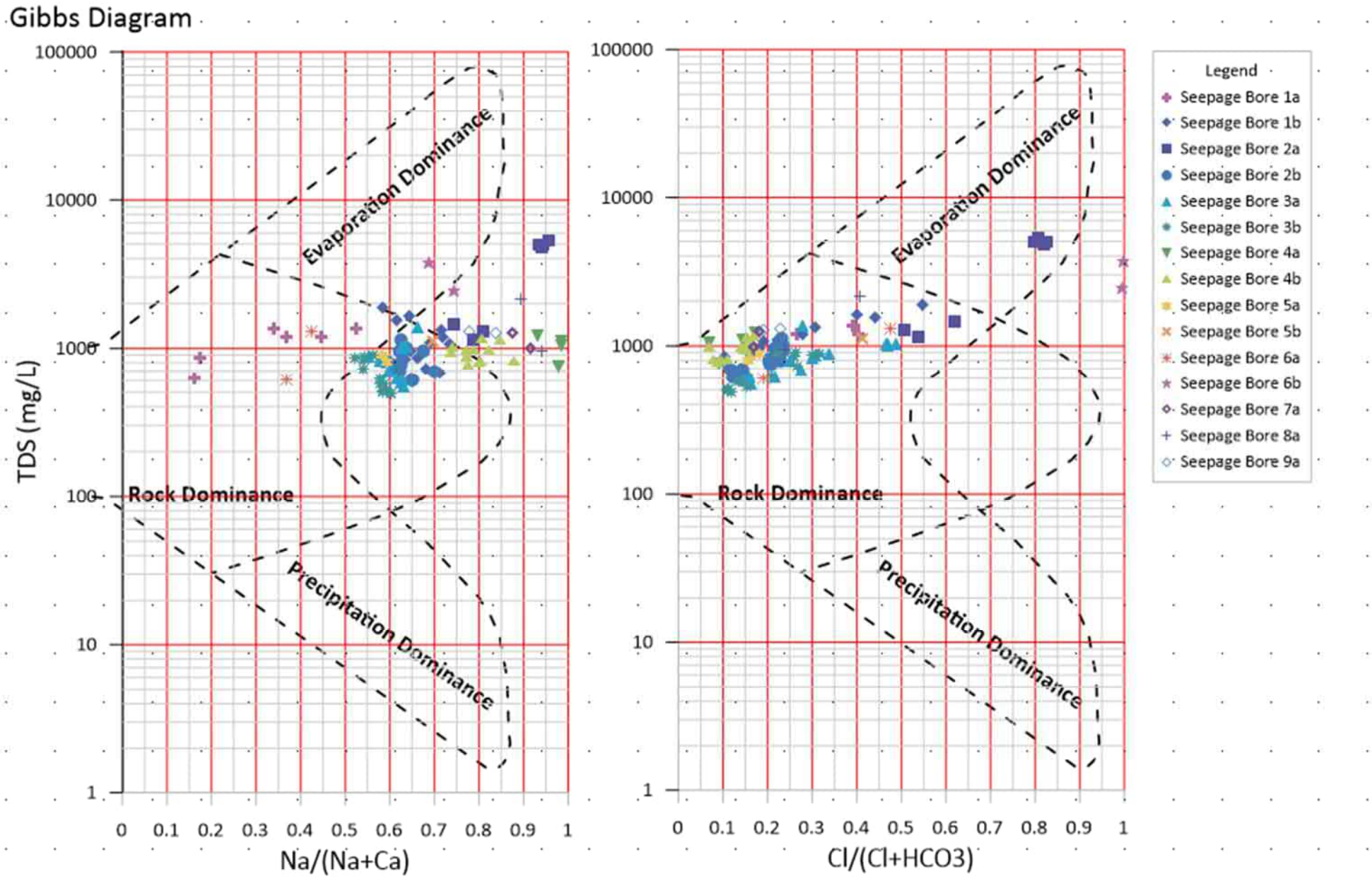
Uranium - dissolved (mg/L)

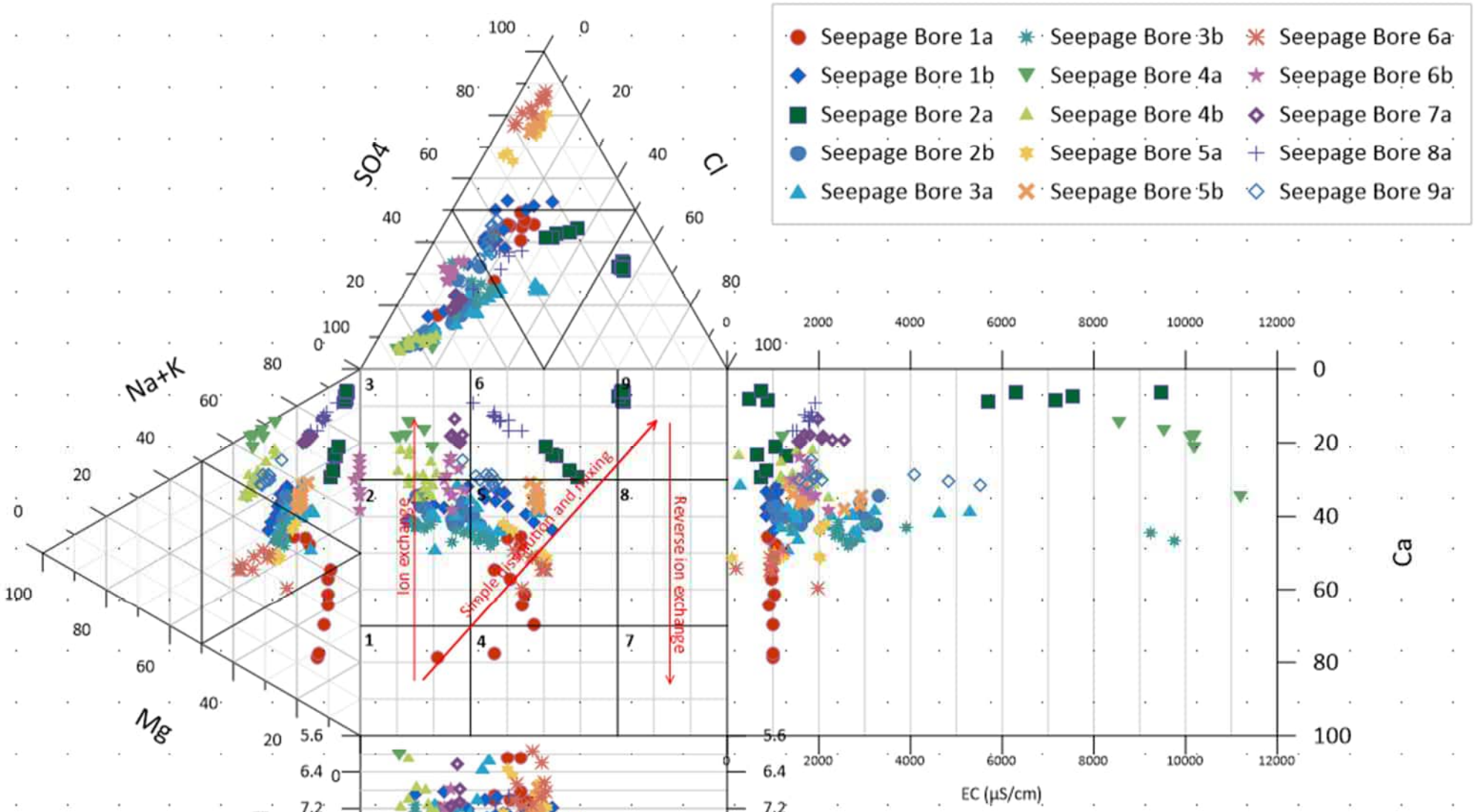


H.4 Hydrogeochemistry plots


Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
A: Ca-type
B: No dominant type
C: Mg-type
D: Na-type
E: HCO3-type
F: SO4-type
G: Cl-type
1: Ca-Mg-HCO3
2: Na-K-Cl-SO4
3: Mixed Ca-Na-HCO3
4: Mixed Ca-Mg-Cl
5: Ca-Mg-Cl-SO4
6: Na-K-HCO3
SO4+Cl+NO3
Ca+Mg
Mg
Na+K
HCO3+CO3
SO4


Chadha Diagram
(HCO3+CO3)-(Cl+SO4) (% meq/L)
(Ca+Mg)-(Na+K) (% meq/L)
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
1
2
5
6
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a
1: Ca-Mg-HCO3
2: Na-K-Cl-SO4
3: Mixed Ca-Na-HCO3
4: Mixed Ca-Mg-Cl
5: Ca-Mg-Cl-SO4
6: Na-K-HCO3


Gibbs Diagram
TDS (mg/L)
100000
10000
1000
100
10
1
Evaporation Dominance
Rock Dominance
Precipitation Dominance
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Na/(Na+Ca)
Cl/(Cl+HCO3)
Legend
Seepage Bore 1a
Seepage Bore 1b
Seepage Bore 2a
Seepage Bore 2b
Seepage Bore 3a
Seepage Bore 3b
Seepage Bore 4a
Seepage Bore 4b
Seepage Bore 5a
Seepage Bore 5b
Seepage Bore 6a
Seepage Bore 6b
Seepage Bore 7a
Seepage Bore 8a
Seepage Bore 9a



1: HCO3 and Ca dominant; frequently indicates recharging waters in limestone, sandstone and many other aquifers.
2: Ca and HCO3 are dominant, association with dolomite presumed if Mg is significant.
If Na is significant, an important ion exchange is presumed.
3: HCO3 and Na are dominant, indicates ion exchange water.
4: Ca and SO4 are dominant. Frequently indicates recharge water in lava, and otherwise mixed water or water exhibiting simple dissolution.
5: No dominant anion or cation, indicates water exhibiting dissolution or mixing.
6: SO4 and Na are dominant. Water type is not frequently encountered and indicates probable mixing, or uncommon dissolution influences.
7: Cl and Na dominant. Frequently encountered unless cement pollution is present. Otherwise, the water may result from reverse ion exchange of Na-Cl waters.
8: Cl and Na dominant, indicating the water is related to reverse ion exchange of Na-Cl waters.
9: Cl and Na dominant. Frequently indicates end-point waters through dissolution.

Appendix I Inflow calculations for open pits and underground works

I.1 North pit radius of influence and groundwater inflows

Plate I.1 North Pit stage-storage relationship

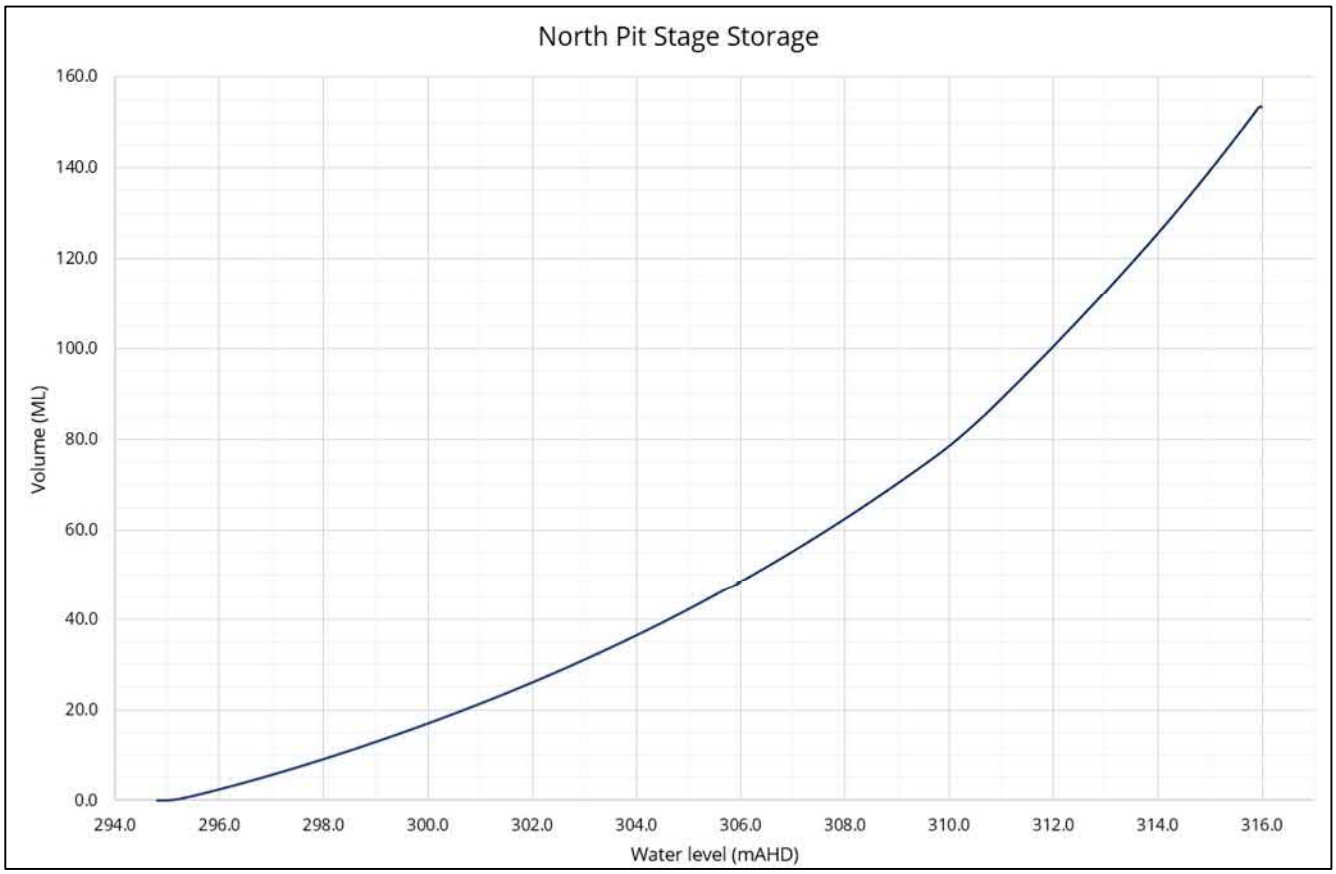


Plate I.2 North Pit groundwater inflows

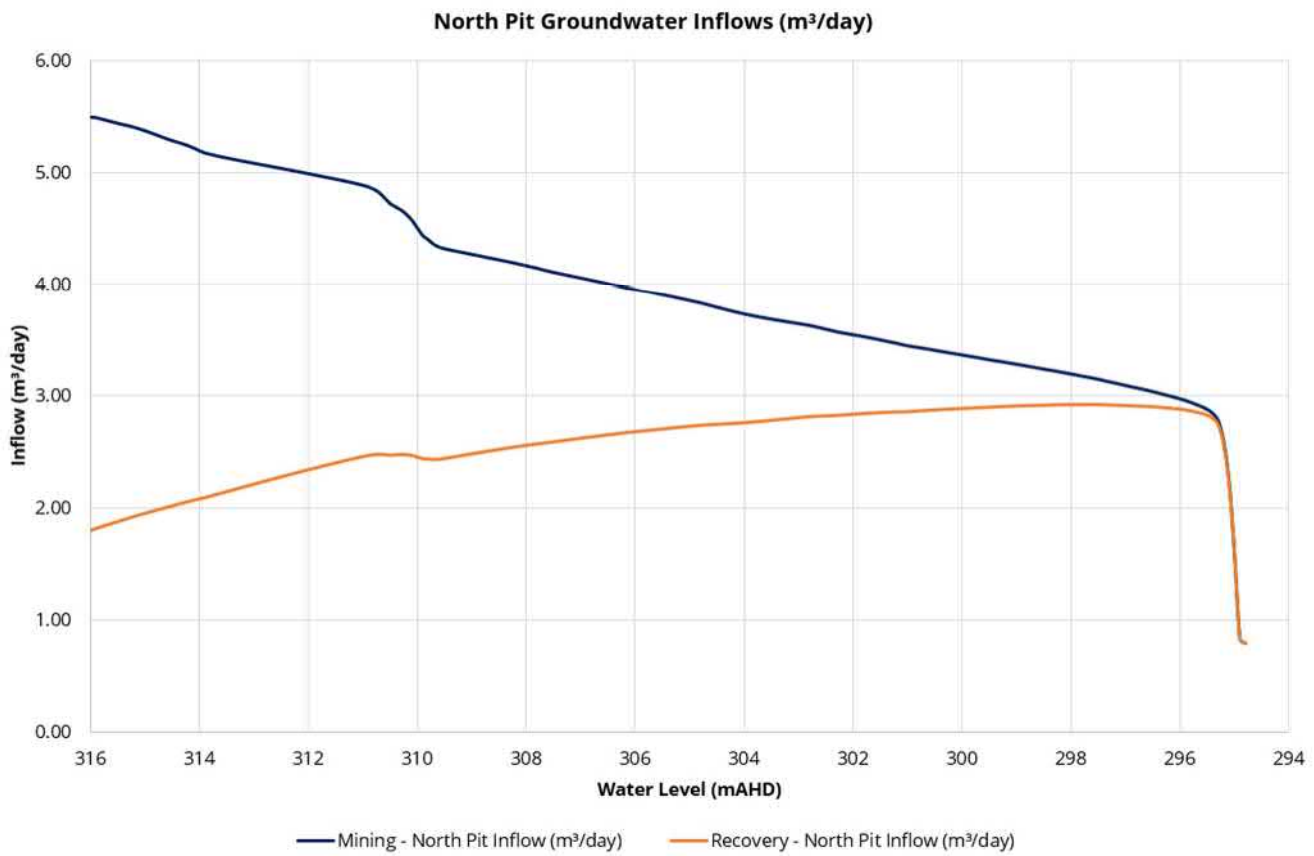
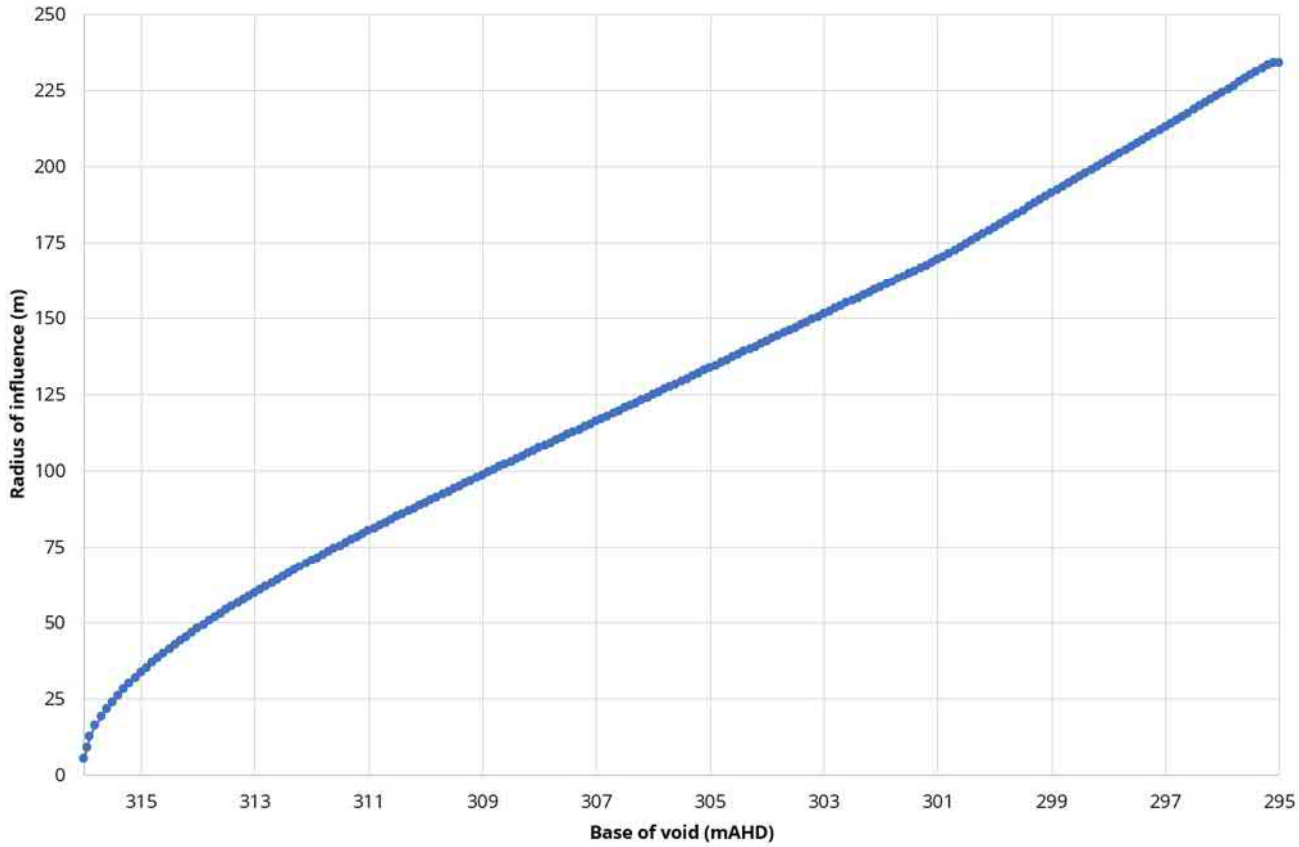


Plate I.3 North Pit radius of influence



I.2 South pit radius of influence and groundwater inflows

Plate I.4 South pit stage-storage relationship

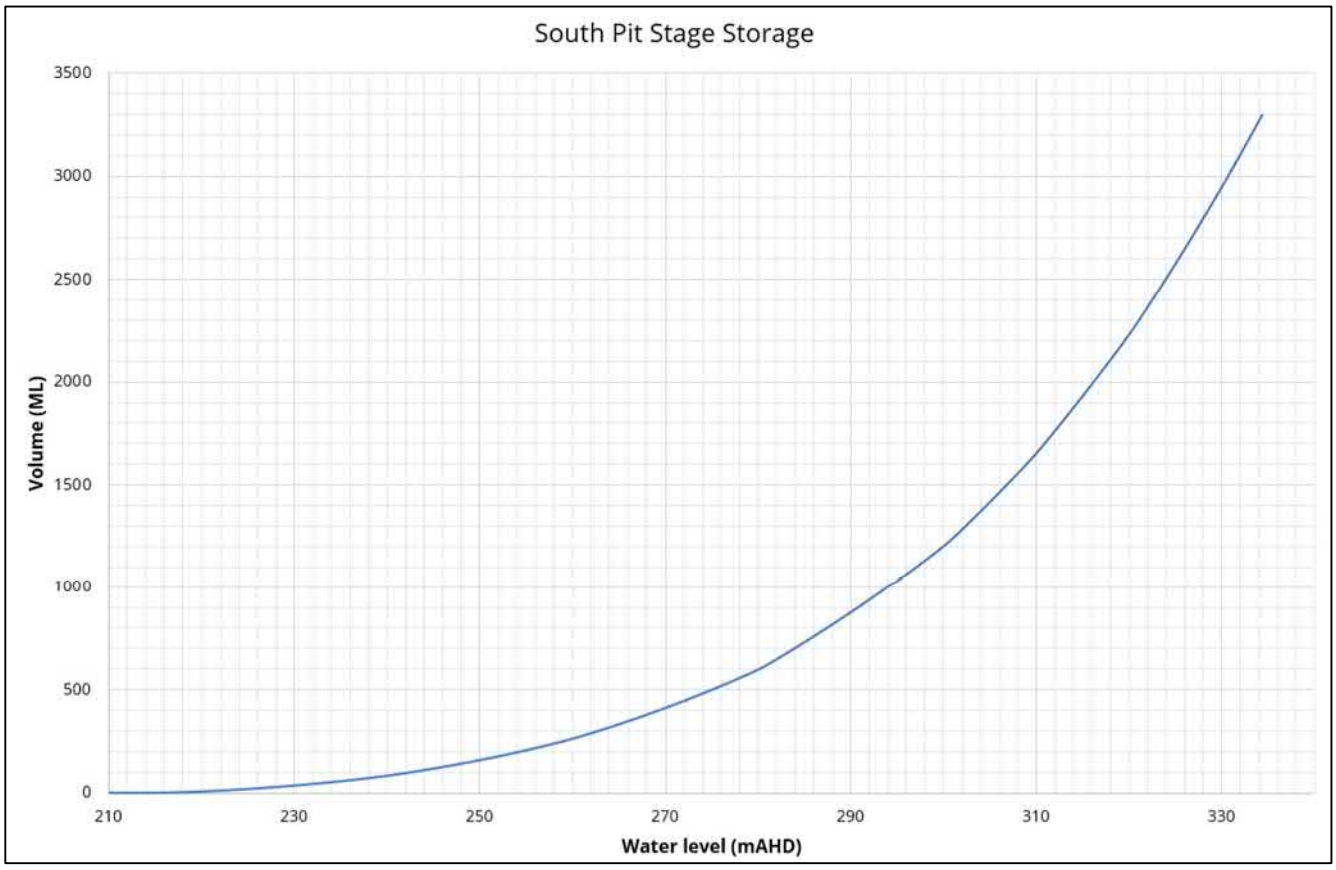


Plate I.5 South pit groundwater inflows

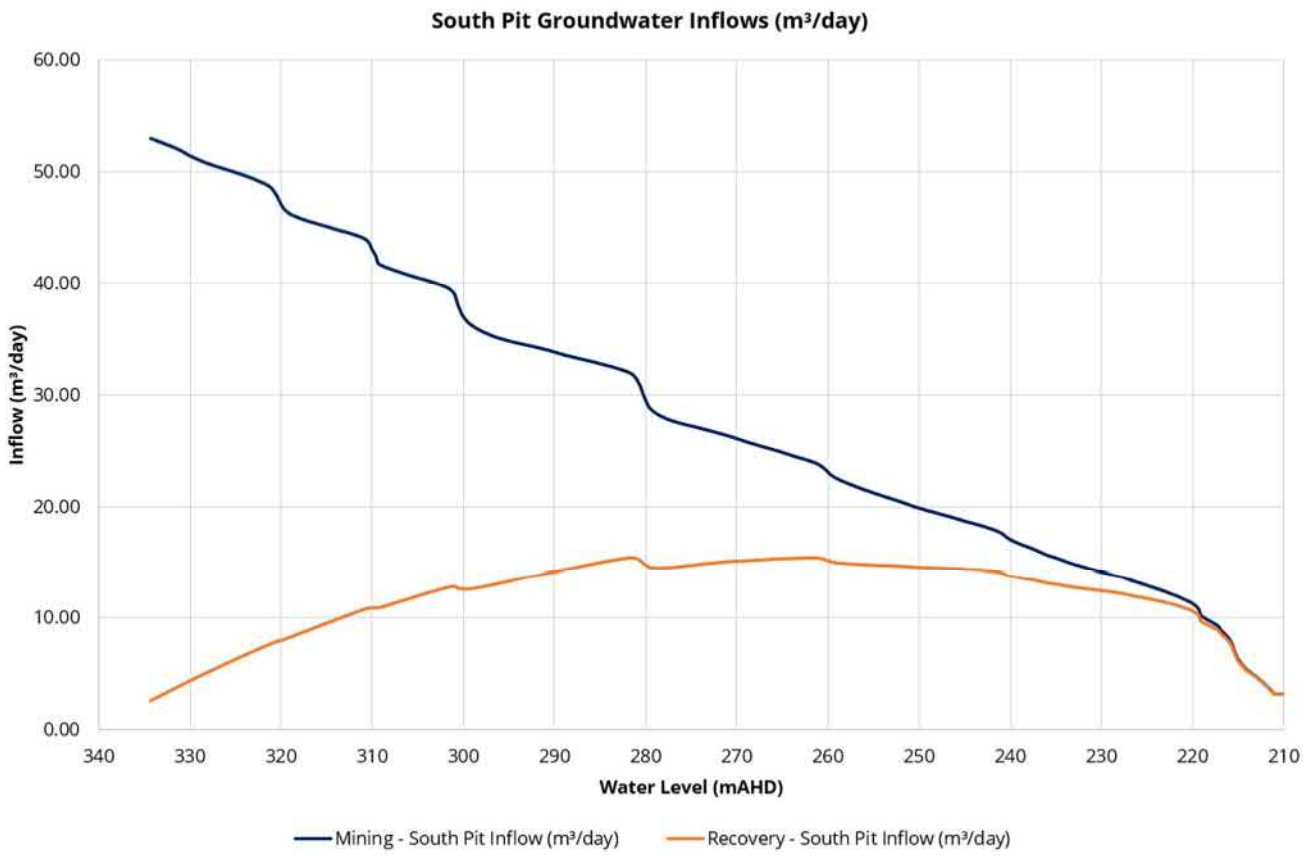
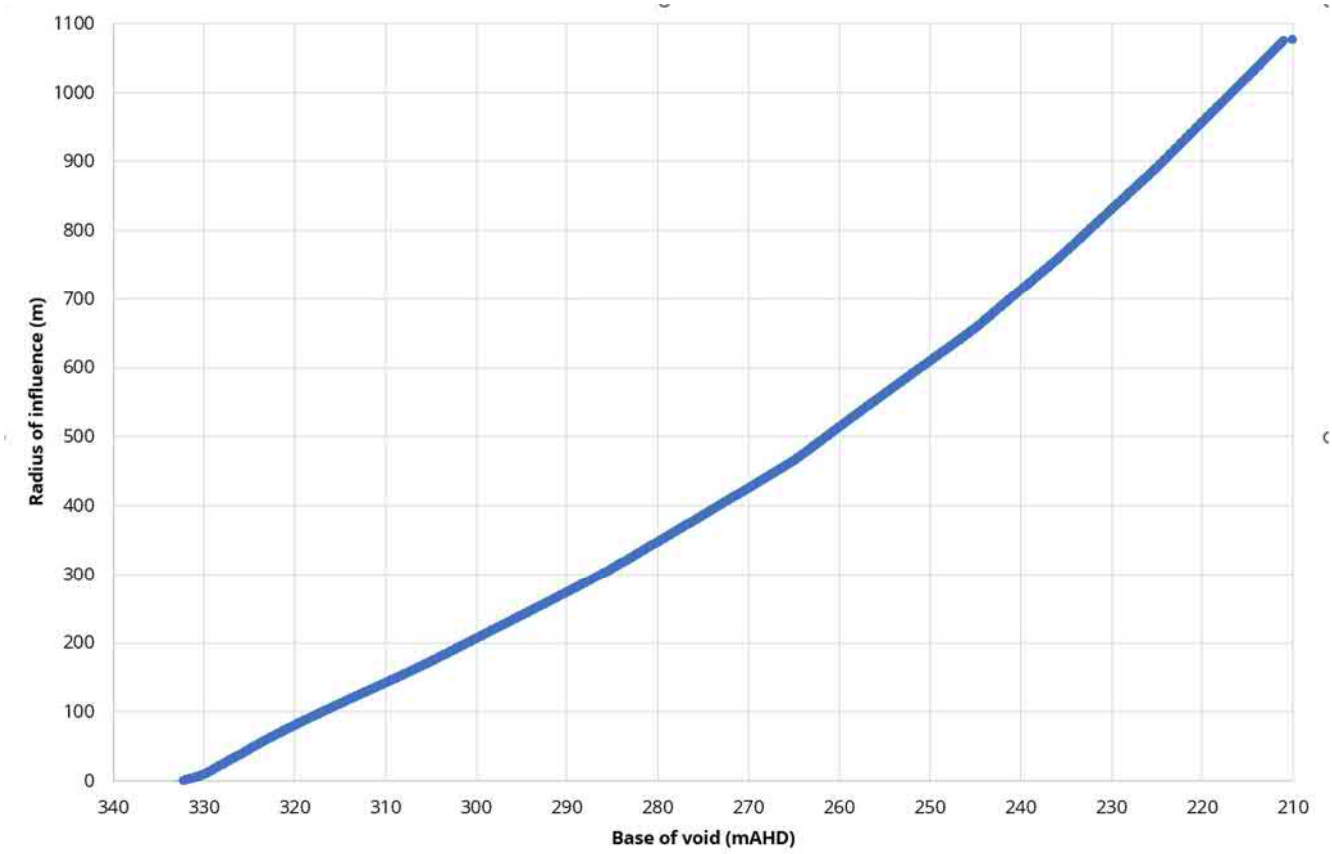


Plate I.6 South pit radius of influence



I.3 Underground workings radius of influence and groundwater inflows

Plate I.7 underground workings groundwater inflows

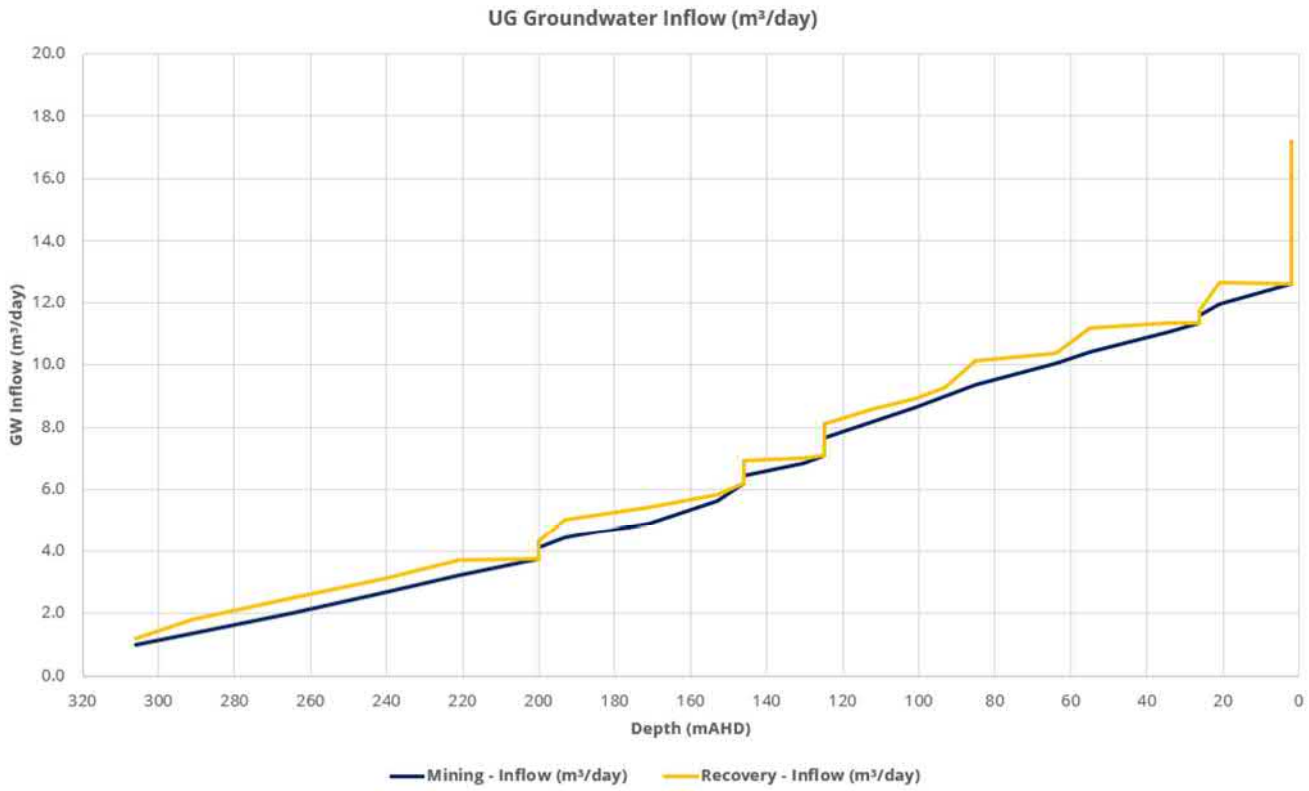
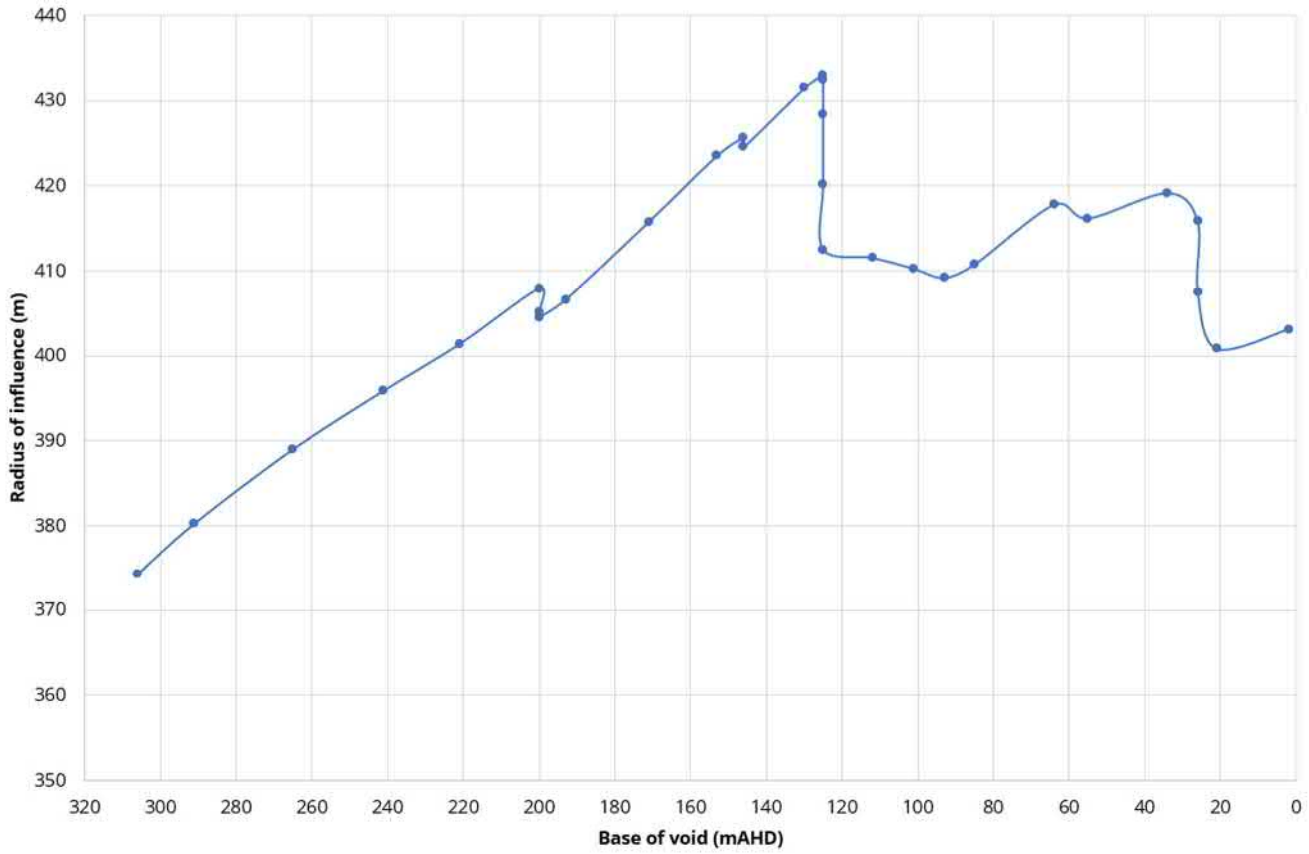


Plate I.8 underground workings radius of influence



Appendix J WQM results for open pits and WRD sediment dam

J.1 Water Quality Models

In 2023 and as part of the preparation of the PRCP for the BCP Project, ATC Williams developed water quality models (WQMs) for the North Pit, South Pit and WRD Sediment Dam by linking the output of the Goldsim WBM with a PHREEQC (USGS, ver. 3.6.2.15100) geochemical model. It is noted that these WQMs model did not include the proposed underground workings. However, the results of these WQMs are still considered relevant and representative.

PHREEQC is based on the equilibrium chemistry of aqueous solutions interacting with minerals, gases, solid solutions, exchangers, and sorption surfaces. The model is designed to perform a wide variety of aqueous geochemical calculations, including speciation, batch-reaction, one-dimensional reactive transport, and inverse geochemical calculations.

Solutes enter the open pits/sediment dam in rainfall runoff and groundwater inflow and may be removed from the voids in groundwater outflow and through geochemical reactions. The solute concentrations in the pit voids and sediment dam are defined by the fractions and solute concentrations of inflow water (from surface water runoff and groundwater inflow), the existing pit void/sediment dam water volumes and solute concentrations, evaporative processes and the occurring geochemical reactions.

Given the complexity of linking the Goldsim probabilistic output to PHREEQC, three different water balance scenarios were evaluated, corresponding with the following Goldsim™ WBM stochastical results:

- The median climatic conditions, corresponding with an occurrence probability of 50% (i.e. 50th percentile or P50).
- Interquartile climatic conditions, corresponding with 25th percentile ant 75th percentile climatic conditions.

Higher probabilities were not considered since increased rainfall, groundwater discharge into the pit void, and lower evaporation rates would result in improved water quality and represents a lower risk to the downstream environment or closure condition.

With respect to the geochemical process, two main scenarios were considered to evaluate the mixing of the different water types:

- A first scenario/model that only included the mixing of different water types (in terms of volumes and water quality) followed by evaporative processes in the voids/sediment dam. This model is denoted as the "mixing" model.
- A second scenario/model included speciation equilibrium modelling, i.e. the precipitation/dissolution of minerals from/into solution when the different water types are mixed. In the first instance, only the mineral phase considered was gypsum, whereby gypsum precipitation could occur if calcium and sulphate concentrations in the mixed water were sufficiently elevated. This model is denoted as the "equilibrium" model.

In the first instance, inflow water is mixed with existing pit voids/sediment dam water and solute concentrations are calculated though a mixing process, before evaporative losses increase the solute concentrations in the pit voids/sediment dams due to a reduction in water content. This mixed solution can be assessed without any equilibrium phases or equilibrated with gypsum. The resulting solution represents the pit void/sediment dam water quality that can outflow to either surface water or groundwater.

Assumptions made in the water quality model include the following (ATC Williams, March 2023):

- In general, surface water inflow into the pit void was equilibrated with standard atmosphere conditions (CO_2(g) -3.2, O_2(g) 0.67)) and groundwater with carbonate (CO_2(g) -1.5) to maintain the pH values of site water quality solutions used in this assessment.
- To reduce the number of parameters in the model and allows for the focus on bulk water chemistry, the models assume that no stratification occurs within the pit void.
- Concerning the equilibrium model, an equilibrium reaction with gypsum was the only parameter considered relevant for the loss of solids from solution in the pit voids and sediment dam.

J.2 Representative initial water quality conditions

Sediment Dam and final voids (North Pit and South Pit) are presented as a time series of modelled concentrations for the following parameters and compounds:

- pH
- salinity: total dissolved solids
- major ions: calcium, magnesium, sodium, potassium, sulphate, chloride and fluoride, bicarbonate alkalinity
- Metals/metalloids: arsenic, barium, chromium, copper, molybdenum, nickel, uranium and zinc

These parameters and compounds have been selected as they represent the post-closure water quality in the voids and sediment dam from a geochemical modelling perspective.

With respect to the two different geochemical processes modelled in PHREEQC:

- The mixing modelling affects levels/concentrations of all selected parameters/solutes, and corresponding time series are presented.
- The speciation equilibrium modelling only affects the results for pH, total dissolved solids, calcium and sulphate, as the precipitation or dissolution of gypsum influences the calcium and sulphate concentrations. Therefore, speciation equilibrium time series are only included for these parameters/solutes The speciation equilibrium modelling does not affect the concentrations of metals, compared to the mixing modelling.

With respect to the modelled water quality:

- Overall, the effect of gypsum precipitation on water quality in the open pits and sediment dam is evident. Concentrations of total dissolved solids, calcium and sulphate in the equilibrium model are markedly less than in the mixing model. Precipitation of gypsum in the final voids is considered likely.
- The long-term temporal changes in solute concentrations generally approximate a power or logarithmic trend, especially once concentrations have stabilised during the initial years. Power and logarithmic trends are characterised by an initial rapid change, which then trails off slowly over time.

J.3 WRD Sediment Dam water quality

Detailed time series of the modelled long-term water quality in the WRD Sediment Dam is provided at the end of this appendix. The following processes govern the long-term water quality in the WRD Sediment Dam:

- Rainfall runoff and evaporation.

- Due to the presence of the HDPE liner on the dam, there is no interaction with the groundwater (i.e. no groundwater in- or outflows).
- The water level in the WRD Sediment Dam reaches the spillway level over several periods. Post-closure, any spillover water will flow into the North Pit diversion and then into the receiving environment.
- The WRD Sediment Dam runs dry over several periods, due to the effect of evaporation exceeding the combined rainfall runoff and available water in storage.

Selected time series are presented in Plate J.1 and Plate J.2. The maximum and long-term modelled water quality in the WRD Sediment Dam is summarised in Table J.1.

Table J.1 Long-term modelled (2080) water quality in WRD Sediment Dam

Parameter/ solute	ANZECC 2000 WQG for Livestock Watering	Mixing Model						Speciation Equilibrium Model					
		P25		P50		P75		P25		P50		P75	
Physico-chemical		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
pH	6.5 - 8.5	8.22	7.91	8.22	7.91	8.22	7.91	8.36	8.36	8.36	8.36	8.36	8.36
TDS (mg/L)	4000	3004	2238	2918	2238	3023	2255	1397	162	1002	161	1426	189
Major Ions (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Calcium	1000	712.6	629.3	712.6	629.3	712.6	629.2	153.9	17.8	110.3	17.7	157.1	20.7
Magnesium	-	67.7	7.8	48.6	7.8	69.2	9.1	67.8	7.8	48.6	7.8	69.2	9.1
Sodium	-	159.0	18.4	123.9	18.3	162.3	21.4	159.0	18.4	123.9	18.3	162.4	21.4
Potassium	-	45.4	5.2	32.5	5.2	46.3	6.1	45.4	5.2	32.5	5.2	46.4	6.1
Sulphate	2000	1852.4	1548.2	1754.7	1548.0	1859.6	1554.7	715.2	82.7	512.4	82.3	730.2	96.2
Chloride	-	280.8	19.5	280.8	19.4	280.8	22.6	280.8	19.5	280.8	19.4	280.8	22.7
Fluoride	2	1.7	0.2	1.3	0.2	1.8	0.2	1.7	0.2	1.3	0.2	1.8	0.2
Bicarbonate	-	184.2	9.7	184.2	9.7	184.2	11.3	184.2	10.6	184.2	10.6	184.2	12.3
Metals (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Aluminium	5	0.0130	0.0000	0.0130	0.0000	0.0130	0.0000	0.0130	0.0000	0.0130	0.0000	0.0130	0.0000
Arsenic	0.5	0.0180	0.0006	0.0180	0.0006	0.0180	0.0008	0.0180	0.0006	0.0180	0.0006	0.0180	0.0008
Barium	-	0.0030	0.0002	0.0030	0.0002	0.0030	0.0002	0.0030	0.0002	0.0030	0.0002	0.0030	0.0002
Chromium	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Copper	0.5	0.0140	0.0016	0.0100	0.0016	0.0143	0.0019	0.0140	0.0016	0.0100	0.0016	0.0143	0.0019
Manganese	-	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Molybdenum	0.15	0.0712	0.0082	0.0510	0.0082	0.0727	0.0096	0.0713	0.0082	0.0510	0.0082	0.0727	0.0096
Nickel	1	0.0126	0.0015	0.0090	0.0014	0.0128	0.0017	0.0126	0.0015	0.0090	0.0014	0.0128	0.0017
Uranium	0.2	0.0838	0.0097	0.0601	0.0096	0.0855	0.0113	0.0838	0.0097	0.0601	0.0096	0.0856	0.0113
Zinc	20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

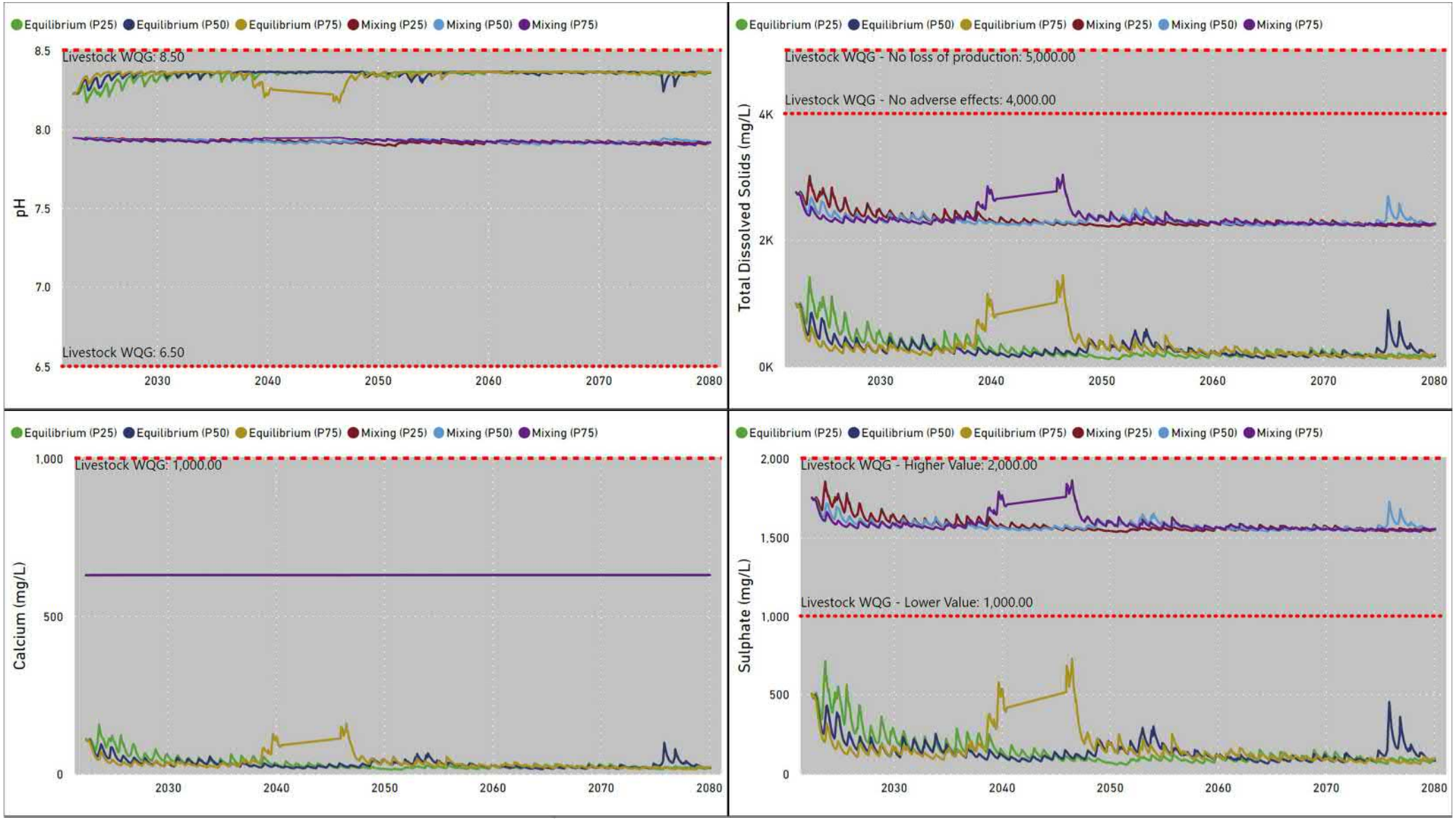


Plate J.1 WRD Sediment Dam modelled water quality – pH, TDS, calcium and sulphate

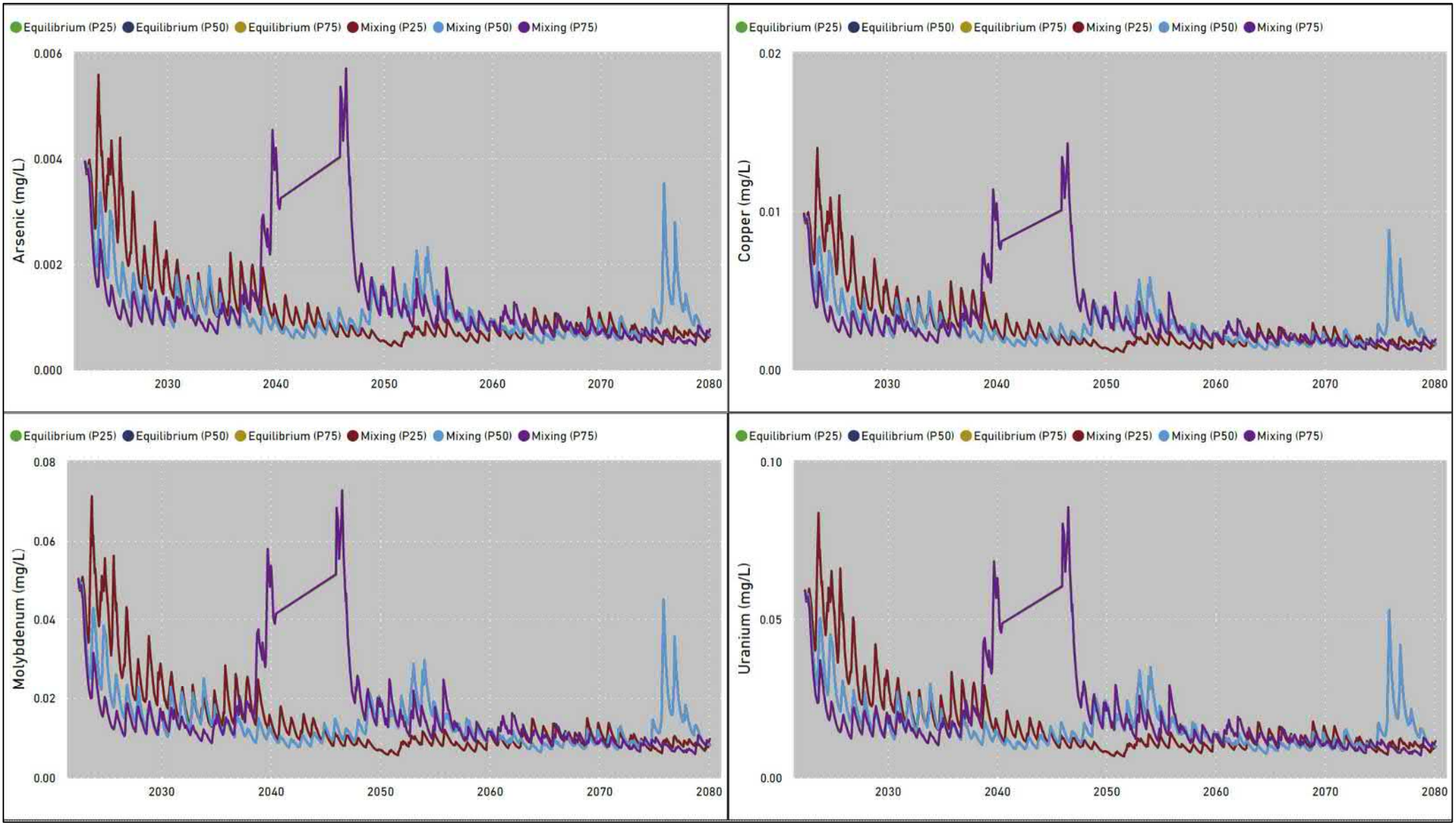


Plate J.2 WRD Sediment Dam modelled water quality – arsenic, copper, molybdenum and uranium

The modelled water quality results indicate the following:

- The solute concentrations at all times and for both models (i.e. mixing and equilibrium models) remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.
- The main processes that impact solute levels in the sediment dam are dilution due to rainfall runoff into the pit and concentration due to evaporation from the open pit. Due to the presence of the HDPE liner, groundwater inflow or outflow does not occur. The short-term or seasonal variations in solute concentrations can be correlated with the net balance between rainfall and evaporation.
- Under the 75th percentile climatic conditions, the WRD sediment Dam runs dry between early-2040 and end-2045. This affects the water quality in the WRD Sediment Dam.
- Physico-chemical parameters
  - pH levels: Long-term pH levels in the sediment dam stabilise relatively quickly and trend towards slightly alkaline conditions in the mixing and equilibrium models. pH levels are higher in the equilibrium model due to the geochemical gypsum equilibrium reactions and trend towards the pH of the runoff entering the sediment dam.
  - Total Dissolved Solids: Long-term TDS concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation).
- Major ions:
  - Calcium and sulphate: concentrations differ between the mixing and equilibrium models, with lower concentrations in the latter model due to gypsum equilibrium reactions.
  - Magnesium, sodium, potassium, chloride and fluoride: Gypsum equilibrium reactions do not affect solute concentrations. Concentrations are determined by the concentrations in the inflow water and evaporation from the open pit.
  - Long-term major ion concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation).
- Metals/metalloids
  - Modelled concentrations of meals/metalloids are not affected by gypsum speciation/equilibrium processes.
  - Solute concentrations in the pit are determined by the concentrations in the runoff water and evaporation from the open pit.
  - Long-term concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation).

J.4 North Pit water quality

The long-term water quality in the North Pit is governed by the following processes/interactions:

- Rainfall runoff from the pit catchment into the open pit.
- Direct rainfall into and evaporation from the open pit.
- Groundwater inflow into the open pit. Hydrogeological studies indicate that the North Pit will generally remain a groundwater sink.
- Groundwater seepage from the North Pit to the South Pit.
- The results of the WBM indicated that there would be no overflow from the North Pit.

Detailed time series of the modelled long-term water quality in the North Pit is provided in Appendix J. Selected time series are presented in Plate J.3 and Plate J.4.

The long-term modelled water quality in the North Pit is summarised in Table J.2.

Table J.2 Long-term modelled (Feb-2080) water quality in North Pit

Parameter/ solute	ANZECC 2000 WQG for Livestock Watering	Mixing Model						Speciation Equilibrium Model					
		P25		P50		P75		P25		P50		P75	
Physico-chemical		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
pH	6.5 - 8.5	8.20	7.71	8.20	7.72	8.20	7.74	8.20	7.88	8.20	7.93	8.20	7.96
TDS (mg/L)	4000	3766	3764	3320	3288	3020	3018	1772	1765	1316	1275	1014	1012
Major Ions (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Calcium	1000	758.2	758.1	717.8	716.5	700.7	690.6	163.7	162.8	122.7	118.6	95.8	95.5
Magnesium	-	88.2	88.0	64.6	62.6	48.8	48.7	88.3	88.0	64.6	62.6	48.9	48.7
Sodium	-	243.5	242.7	179.4	173.6	135.7	135.4	243.6	242.9	179.5	173.7	135.8	135.4
Potassium	-	61.6	61.3	44.8	43.5	34.3	34.3	61.6	61.4	44.8	43.6	34.4	34.3
Sulphate	2000	1768.7	1764.3	1724.0	1708.9	1720.3	1680.3	502.6	337.6	451.6	275.9	444.0	254.1
Chloride	-	458.6	458.3	357.6	312.6	357.6	224.7	458.9	458.5	357.6	312.7	357.6	224.8
Fluoride	2	1.8	1.3	1.5	1.1	1.5	0.9	1.8	1.4	1.5	1.1	1.5	0.9
Bicarbonate	-	391.1	390.8	275.8	270.0	204.8	204.6	413.6	413.3	293.4	287.4	218.9	218.7
Metals (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Aluminium	5	0.0601	0.0601	0.0408	0.0401	0.0286	0.0286	0.0601	0.0601	0.0409	0.0401	0.0286	0.0286
Arsenic	0.5	0.0087	0.0087	0.0062	0.0060	0.0046	0.0046	0.0087	0.0087	0.0062	0.0060	0.0046	0.0046
Barium	-	0.2476	0.2474	0.1902	0.1736	0.1902	0.1302	0.2477	0.2475	0.1902	0.1737	0.1902	0.1303
Chromium	1	0.0007	0.0003	0.0007	0.0002	0.0007	0.0001	0.0007	0.0003	0.0007	0.0002	0.0007	0.0001
Copper	0.5	0.0411	0.0399	0.0353	0.0305	0.0347	0.0263	0.0412	0.0399	0.0353	0.0305	0.0347	0.0263
Manganese	-	1.5012	0.6787	1.5012	0.4676	1.5012	0.3141	1.5012	0.6790	1.5012	0.4678	1.5012	0.3142
Molybdenum	0.15	0.0161	0.0140	0.0139	0.0109	0.0137	0.0095	0.0162	0.0140	0.0139	0.0109	0.0137	0.0095
Nickel	1	0.0108	0.0069	0.0096	0.0057	0.0094	0.0053	0.0108	0.0069	0.0096	0.0057	0.0095	0.0053
Uranium	0.2	0.0152	0.0151	0.0110	0.0107	0.0083	0.0083	0.0152	0.0151	0.0110	0.0107	0.0083	0.0083
Zinc	20	0.0140	0.0063	0.0140	0.0044	0.0140	0.0029	0.0140	0.0063	0.0140	0.0044	0.0140	0.0029

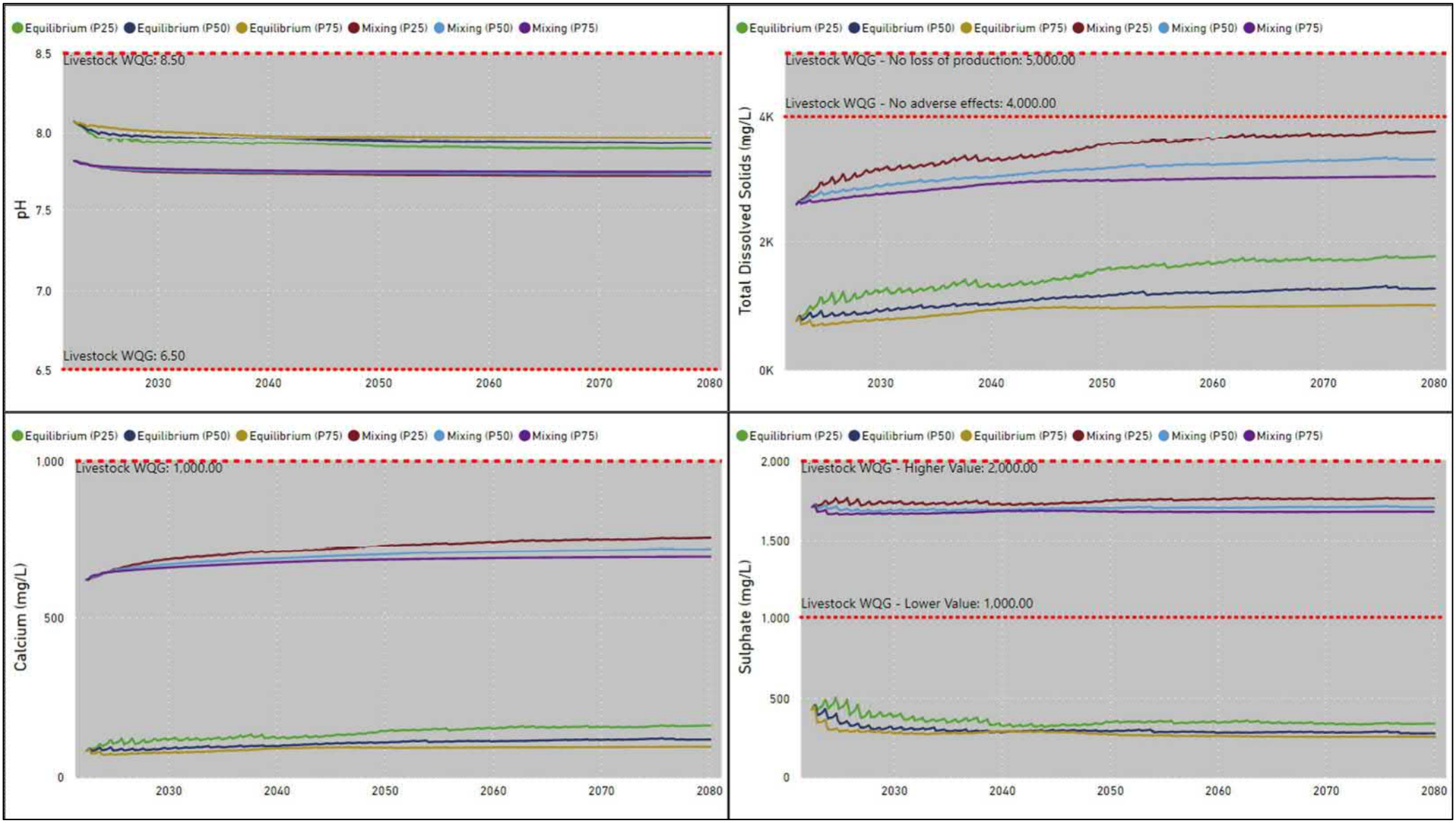


Plate J.3 North Pit modelled water quality – pH, TDS, calcium and sulphate

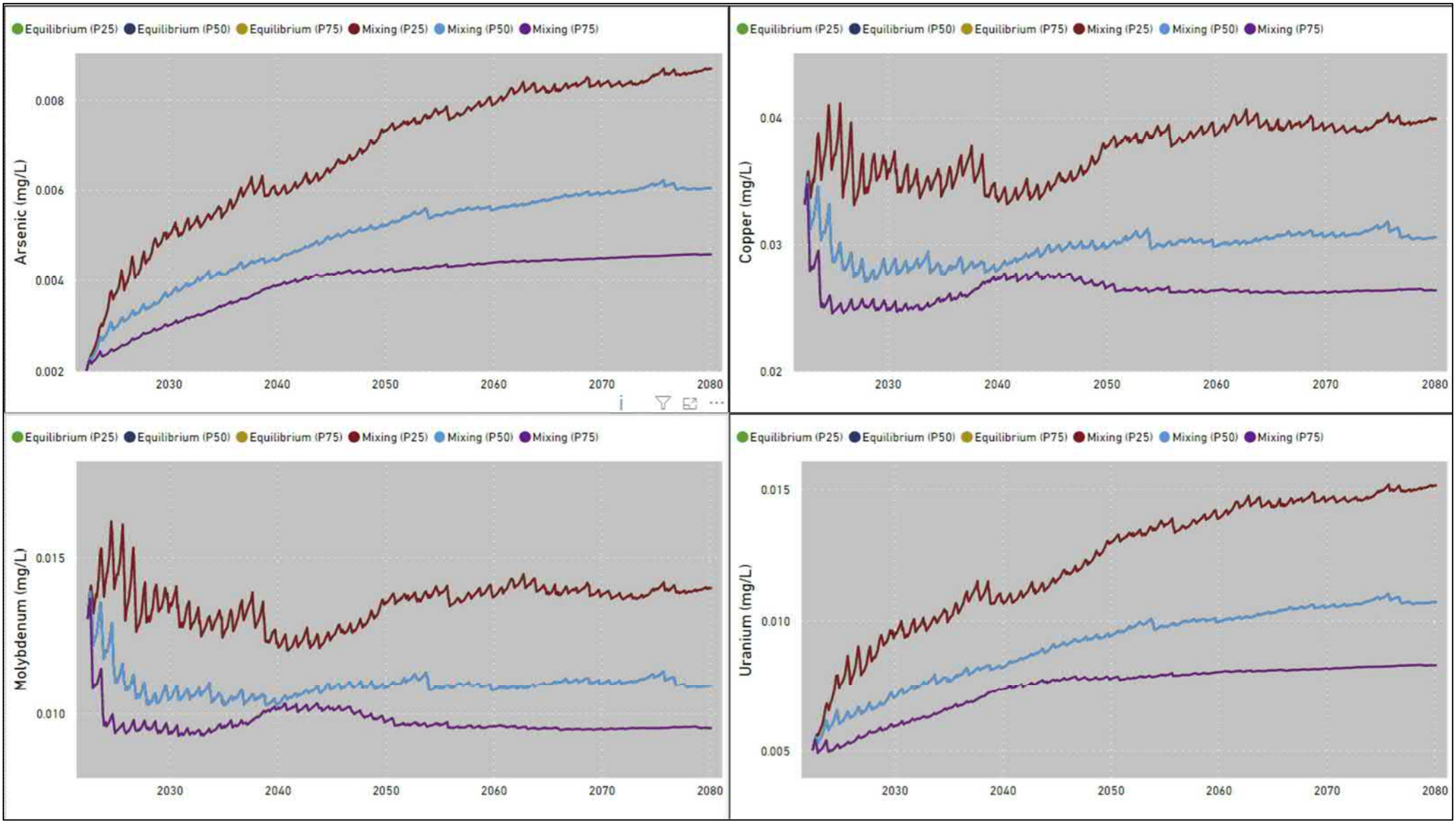


Plate J.4 North Pit modelled water quality – arsenic, copper, molybdenum and uranium

The modelled water quality results indicate the following:

- The solute concentrations at all times and for both models (i.e. mixing and equilibrium models) remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.
- The main physical processes that impact solute levels in the open pit are dilution due to rainfall runoff, groundwater inflow into the pit, and concentration due to evaporation from the open pit. Groundwater inflow only plays a minor role, with long-term groundwater inflows comprising only ±10% of total inflows into the open pit. Short-term variations in solute concentrations are related to the net flow balance between inflows and evaporation. Whilst groundwater inflow is only a minor component of pit inflows, it does buffer the effect of evaporation on solute concentrations.
- Physico-chemical parameters
  - pH levels: pH levels stabilise relatively quickly and trend towards near neutral/slightly alkaline conditions in the mixing and equilibrium models. pH levels are higher in the equilibrium model, due to the geochemical gypsum equilibrium reactions and trend towards the pH of the runoff entering the open pit.
  - Total Dissolved Solids: Long-term TDS concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation). The influence of the gypsum equilibrium is evident, with TDS concentrations lower in the equilibrium model than in the mixing model.
- Major ions:
  - Calcium and sulphate: concentrations differ between the mixing and equilibrium models, with lower concentrations in the latter model due to gypsum equilibrium reactions.
  - Magnesium, sodium, potassium, chloride and fluoride: Gypsum equilibrium reactions do not affect solute concentrations. Concentrations are determined by the concentrations in the inflow water and evaporation from the open pit.
  - Long-term major ion concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation) and the effect of evaporation buffered by groundwater inflow.
- Metals/metalloids
  - Modelled concentrations of meals/metalloids are not affected by gypsum speciation/equilibrium processes.
  - Solute concentrations in the pit are determined by the concentrations in the inflow water and evaporation from the open pit.
  - Long-term concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation) and the effect of evaporation buffered by groundwater inflow.

J.5 South Pit water quality

The long-term water quality in the South Pit is governed by the following processes/interactions:

- Rainfall runoff from the pit catchment into the open pit.
- Direct rainfall into and evaporation from the open pit.
- Groundwater inflow into the open pit. Hydrogeological studies indicate that the South Pit will generally remain a groundwater sink.
- Groundwater seepage from the North Pit to the South Pit.
- The results of the WBM indicated that there would be no overflow from the North Pit.

Detailed time series of the modelled long-term water quality in the South Pit are provided in Appendix J. Selected time series are presented in Plate J.5 to Plate J.8. The long-term modelled water quality is summarised in Table J.3 and Table J.4.

Table J.3 Long-term modelled (Feb-2080) water quality in South Pit (scenario 1)

Parameter/ solute	ANZECC 2000 WQG for Livestock Watering	Mixing Model						Speciation Equilibrium Model					
		P25		P50		P75		P25		P50		P75	
Physico-chemical		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
pH	6.5 - 8.5	8.20	7.79	8.20	7.79	8.20	7.79	8.20	8.04	8.20	8.04	8.20	8.05
TDS (mg/L)	4000	4154	3074	4154	2976	4154	2893	1981	1200	1981	1103	1981	1022
Major Ions (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Calcium	1000	696.1	651.7	696.1	648.3	696.1	645.4	140.4	98.0	140.4	94.9	140.4	92.6
Magnesium	-	81.5	57.1	81.5	53.0	81.5	49.7	81.5	57.1	81.5	53.0	81.5	49.7
Sodium	-	535.4	196.9	535.4	171.4	535.4	149.6	535.4	197.0	535.4	171.4	535.4	149.7
Potassium	-	27.3	21.9	27.3	21.4	27.3	21.1	27.3	21.9	27.3	21.4	27.3	21.1
Sulphate	2000	1984.2	1800.9	1984.2	1777.7	1984.2	1758.1	705.3	473.9	702.2	451.5	699.9	433.3
Chloride	-	801.4	244.0	801.4	205.8	801.4	173.2	801.4	244.2	801.4	205.9	801.4	173.3
Fluoride	2	1.2	0.8	1.2	0.7	1.2	0.7	1.2	0.8	1.2	0.7	1.2	0.7
Bicarbonate	-	101.5	101.5	98.2	98.2	95.8	95.8	108.1	108.1	104.6	104.6	102.2	102.2
Metals (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Aluminium	5	0.0130	0.0076	0.0130	0.0075	0.0130	0.0074	0.0130	0.0076	0.0130	0.0075	0.0130	0.0074
Arsenic	0.5	0.0060	0.0045	0.0060	0.0043	0.0060	0.0043	0.0060	0.0045	0.0060	0.0043	0.0060	0.0043
Barium	-	0.0509	0.0509	0.0482	0.0482	0.0481	0.0461	0.0509	0.0509	0.0482	0.0482	0.0481	0.0461
Chromium	1	0.0015	0.0004	0.0015	0.0003	0.0015	0.0002	0.0015	0.0004	0.0015	0.0003	0.0015	0.0002
Copper	0.5	0.0164	0.0132	0.0163	0.0126	0.0163	0.0122	0.0164	0.0132	0.0163	0.0127	0.0163	0.0122
Manganese	-	0.0070	0.0017	0.0070	0.0014	0.0070	0.0011	0.0070	0.0017	0.0070	0.0014	0.0070	0.0011
Molybdenum	0.15	0.0445	0.0253	0.0445	0.0248	0.0445	0.0245	0.0445	0.0253	0.0445	0.0248	0.0445	0.0245
Nickel	1	0.0190	0.0105	0.0190	0.0104	0.0190	0.0102	0.0190	0.0105	0.0190	0.0104	0.0190	0.0102
Uranium	0.2	0.0251	0.0118	0.0251	0.0105	0.0251	0.0095	0.0251	0.0118	0.0251	0.0106	0.0251	0.0095
Zinc	20	0.0461	0.0111	0.0461	0.0089	0.0461	0.0071	0.0461	0.0111	0.0461	0.0089	0.0461	0.0071

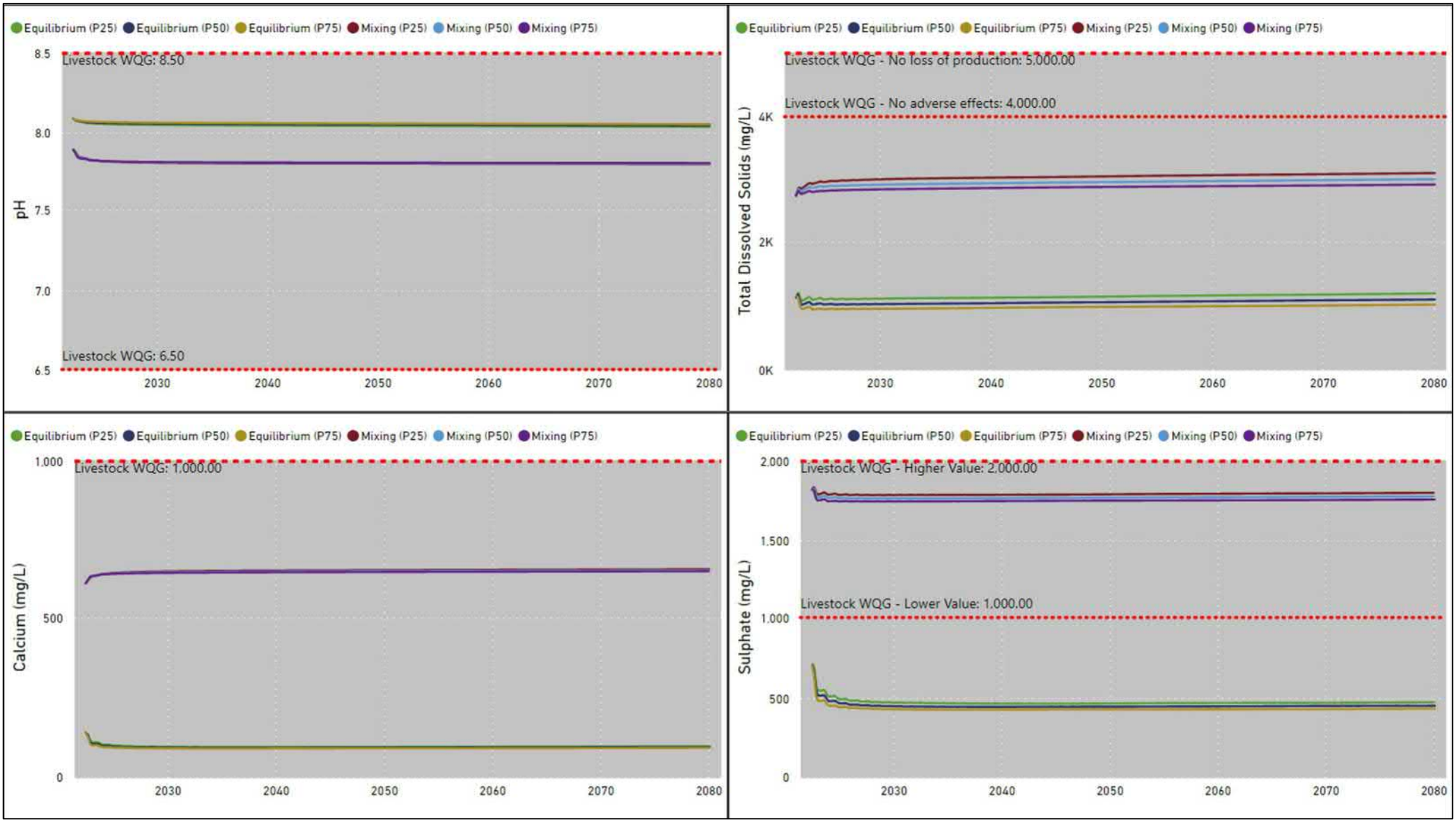


Plate J.5 South Pit (scenario 1) modelled water quality – pH, TDS, calcium and sulphate

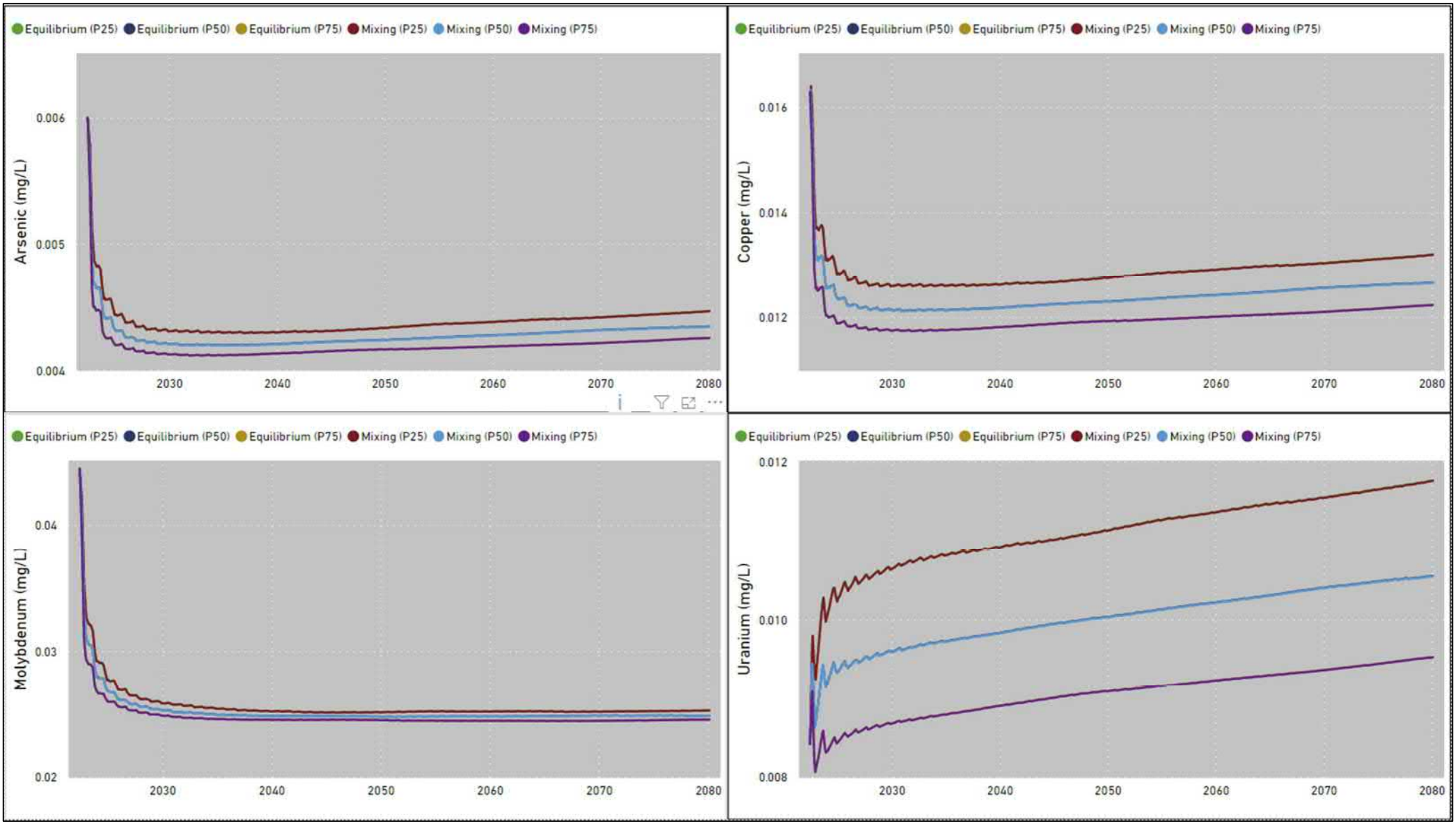


Plate J.6 South Pit (scenario 1) modelled water quality – arsenic, copper, molybdenum and uranium

Table J.4 Long-term modelled (Feb-2080) water quality in South Pit (scenario 2)

Parameter/ solute	ANZECC 2000 WQG for Livestock Watering	Mixing Model						Speciation Equilibrium Model					
		P25		P50		P75		P25		P50		P75	
Physico-chemical		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
pH	6.5 - 8.5	8.20	7.79	8.20	7.79	8.20	7.79	8.20	8.04	8.20	8.05	8.20	8.06
TDS (mg/L)	4000	4154	3044	4154	2943	4154	2857	1981	1169	1981	1070	1981	986
Major Ions (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Calcium	1000	696.1	650.7	696.1	647.2	696.1	644.1	140.4	96.9	140.4	93.7	140.4	91.2
Magnesium	-	81.5	55.8	81.5	51.6	81.5	48.1	81.5	55.8	81.5	51.6	81.5	48.1
Sodium	-	535.4	189.0	535.4	163.1	535.4	140.5	535.4	189.1	535.4	163.2	535.4	140.6
Potassium	-	27.3	21.7	27.3	21.2	27.3	20.9	27.3	21.7	27.3	21.2	27.3	20.9
Sulphate	2000	1984.2	1793.6	1984.2	1769.9	1984.2	1749.4	705.3	466.4	702.2	443.5	699.9	424.3
Chloride	-	801.4	232.4	801.4	193.5	801.4	159.8	801.4	232.5	801.4	193.6	801.4	159.8
Fluoride	2	1.2	0.8	1.2	0.7	1.2	0.7	1.2	0.8	1.2	0.7	1.2	0.7
Bicarbonate	-	100.3	100.3	96.8	96.8	94.2	94.2	106.8	106.8	103.2	103.2	100.5	100.5
Metals (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Aluminium	5	0.0130	0.0076	0.0130	0.0074	0.0130	0.0073	0.0130	0.0076	0.0130	0.0074	0.0130	0.0073
Arsenic	0.5	0.0060	0.0044	0.0060	0.0043	0.0060	0.0042	0.0060	0.0044	0.0060	0.0043	0.0060	0.0042
Barium	-	0.0500	0.0500	0.0481	0.0472	0.0481	0.0450	0.0500	0.0500	0.0481	0.0473	0.0481	0.0450
Chromium	1	0.0015	0.0003	0.0015	0.0003	0.0015	0.0002	0.0015	0.0003	0.0015	0.0003	0.0015	0.0002
Copper	0.5	0.0164	0.0130	0.0163	0.0124	0.0163	0.0120	0.0164	0.0130	0.0163	0.0125	0.0163	0.0120
Manganese	-	0.0070	0.0016	0.0070	0.0013	0.0070	0.0010	0.0070	0.0016	0.0070	0.0013	0.0070	0.0010
Molybdenum	0.15	0.0445	0.0251	0.0445	0.0246	0.0445	0.0243	0.0445	0.0251	0.0445	0.0246	0.0445	0.0243
Nickel	1	0.0190	0.0105	0.0190	0.0103	0.0190	0.0101	0.0190	0.0105	0.0190	0.0103	0.0190	0.0101
Uranium	0.2	0.0251	0.0114	0.0251	0.0101	0.0251	0.0091	0.0251	0.0114	0.0251	0.0101	0.0251	0.0091
Zinc	20	0.0461	0.0104	0.0461	0.0083	0.0461	0.0063	0.0461	0.0104	0.0461	0.0083	0.0461	0.0063

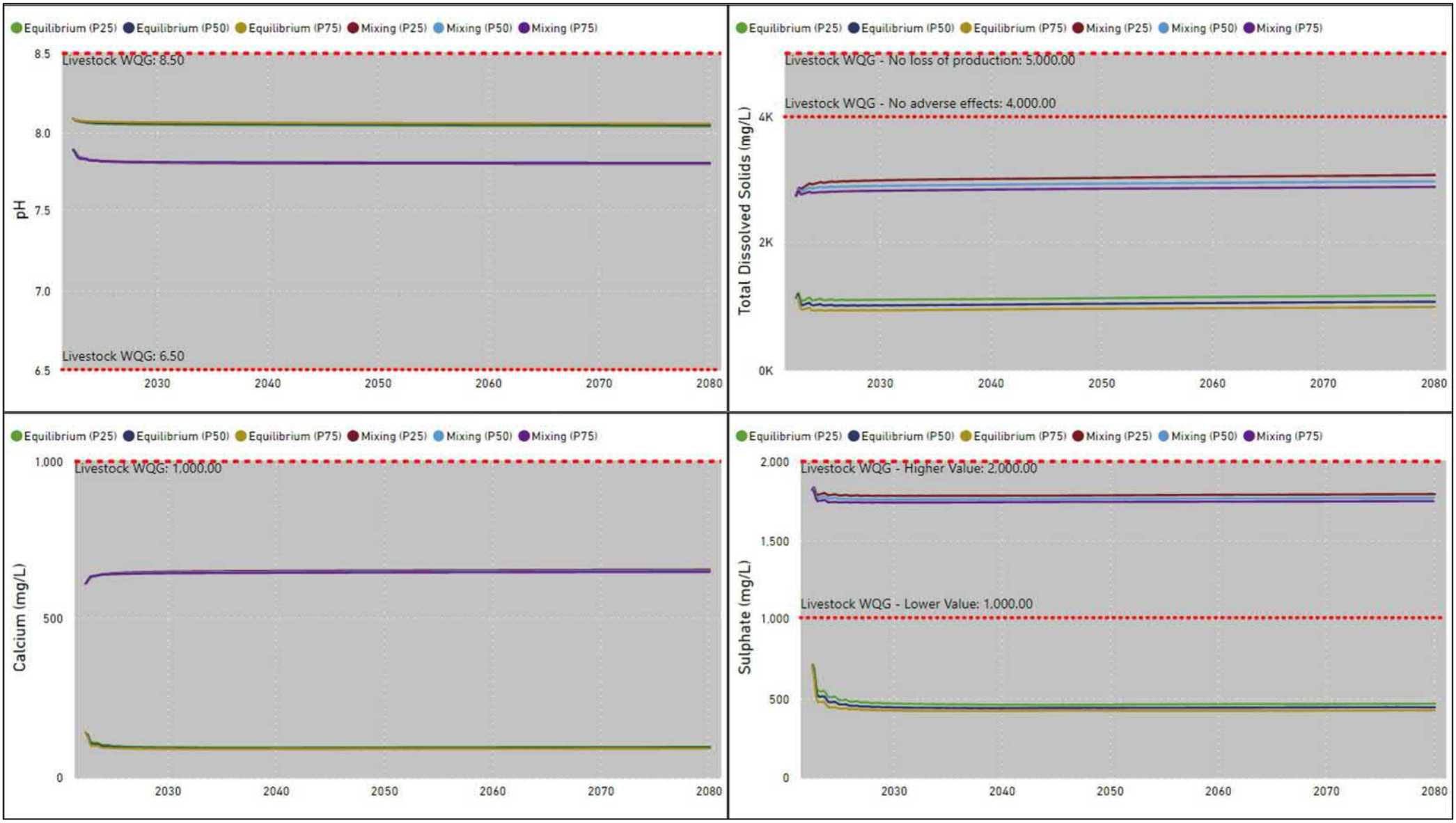


Plate J.7 South Pit (Scenario 2) modelled water quality – pH, TDS, calcium and sulphate

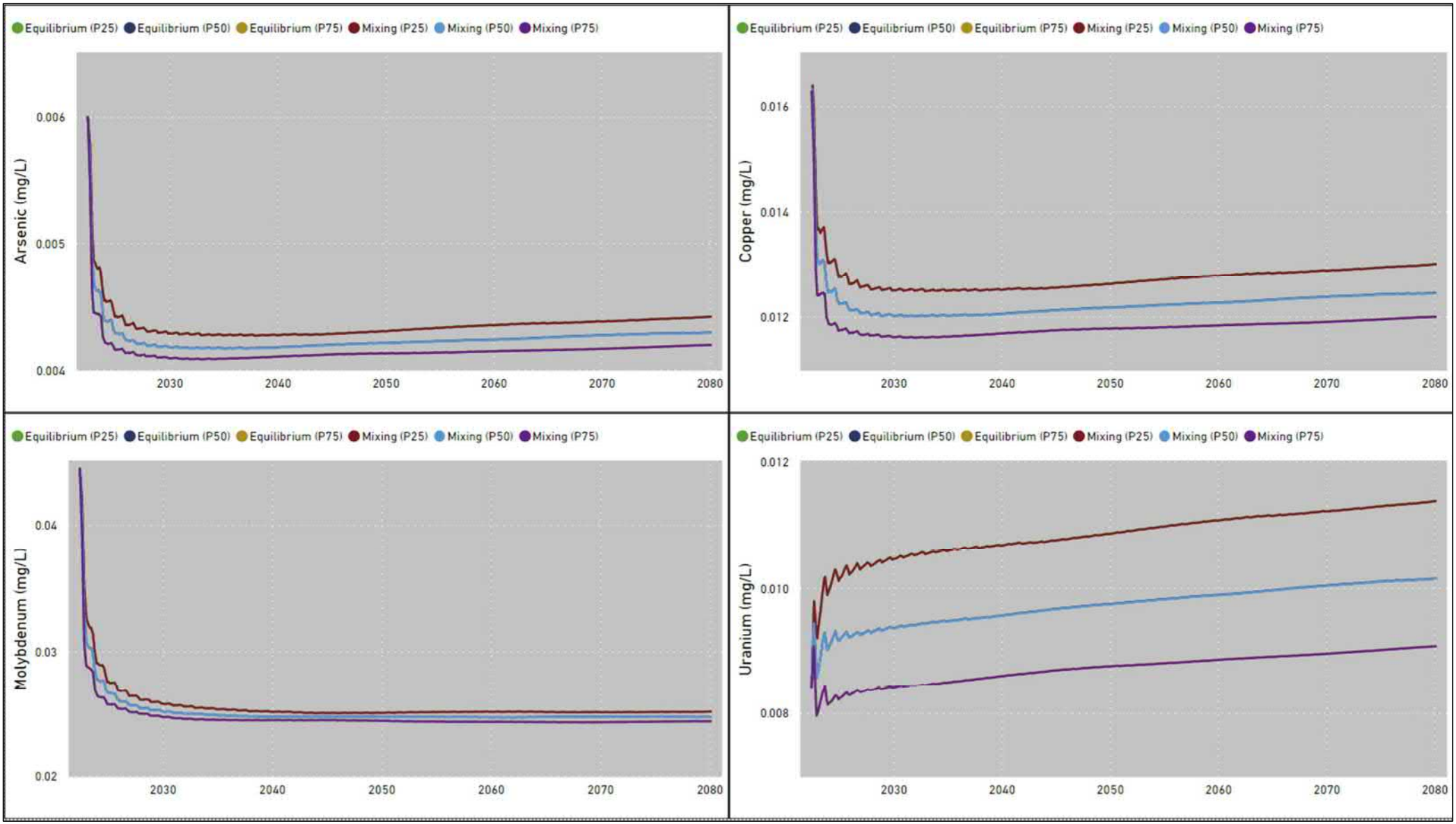


Plate J.8 South Pit (scenario 2) modelled water quality – arsenic, copper, molybdenum and uranium

The modelled water quality results indicate the following:

- There is little difference in modelled water quality between both scenarios. Water quality under scenario 2, which includes a larger amount of rainfall runoff from a large catchment area, is better than under scenario 1.
- The solute concentrations at all times and for both models (i.e. mixing and equilibrium models) and scenarios remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.
- The main physical processes that impact solute levels in the open pit are dilution due to rainfall runoff, groundwater inflow into the pit, and concentration due to evaporation from the open pit. Groundwater inflow plays a moderate role, with long-term groundwater inflows (combination of regional inflow and seepage from the North Pit) comprising ±20% of total inflows into the open pit. Short-term variations in solute concentrations are related to the net flow balance between inflows and evaporation. Groundwater inflow buffers the effect of evaporation on solute concentrations.
- Physico-chemical parameters
  - pH levels: pH levels in the South Pit stabilise relatively quickly and trend towards near-neutral/slightly alkaline conditions in the mixing and equilibrium models. pH levels are higher in the mixing model due to the geochemical gypsum equilibrium reactions and trend towards the pH of the runoff entering the open pit.
  - Total Dissolved Solids: Long-term TDS concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation). The influence of the gypsum equilibrium is evident, with TDS concentrations lower in the equilibrium model than in the mixing model.
- Major ions:
  - Calcium and sulphate: concentrations differ between the mixing and equilibrium models, with lower concentrations in the latter model due to gypsum equilibrium reactions.
  - Magnesium, sodium, potassium, chloride and fluoride: Gypsum equilibrium reactions do not affect solute concentrations. Concentrations are determined by the concentrations in the inflow water and evaporation from the open pit.
  - Long-term major ion concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation) and the effect of evaporation buffered by groundwater inflow.
- Metals/metalloids
  - Modelled concentrations of meals/metalloids are not affected by gypsum speciation/equilibrium processes.
  - Solute concentrations in the pit are determined by the concentrations in the inflow water and evaporation from the open pit.
  - Long-term major ion concentrations trend towards stable levels in both models, with short-term variations defined by seasonal climatic conditions (i.e. rainfall runoff versus evaporation) and the effect of evaporation buffered by groundwater inflow.

J.6 Summary

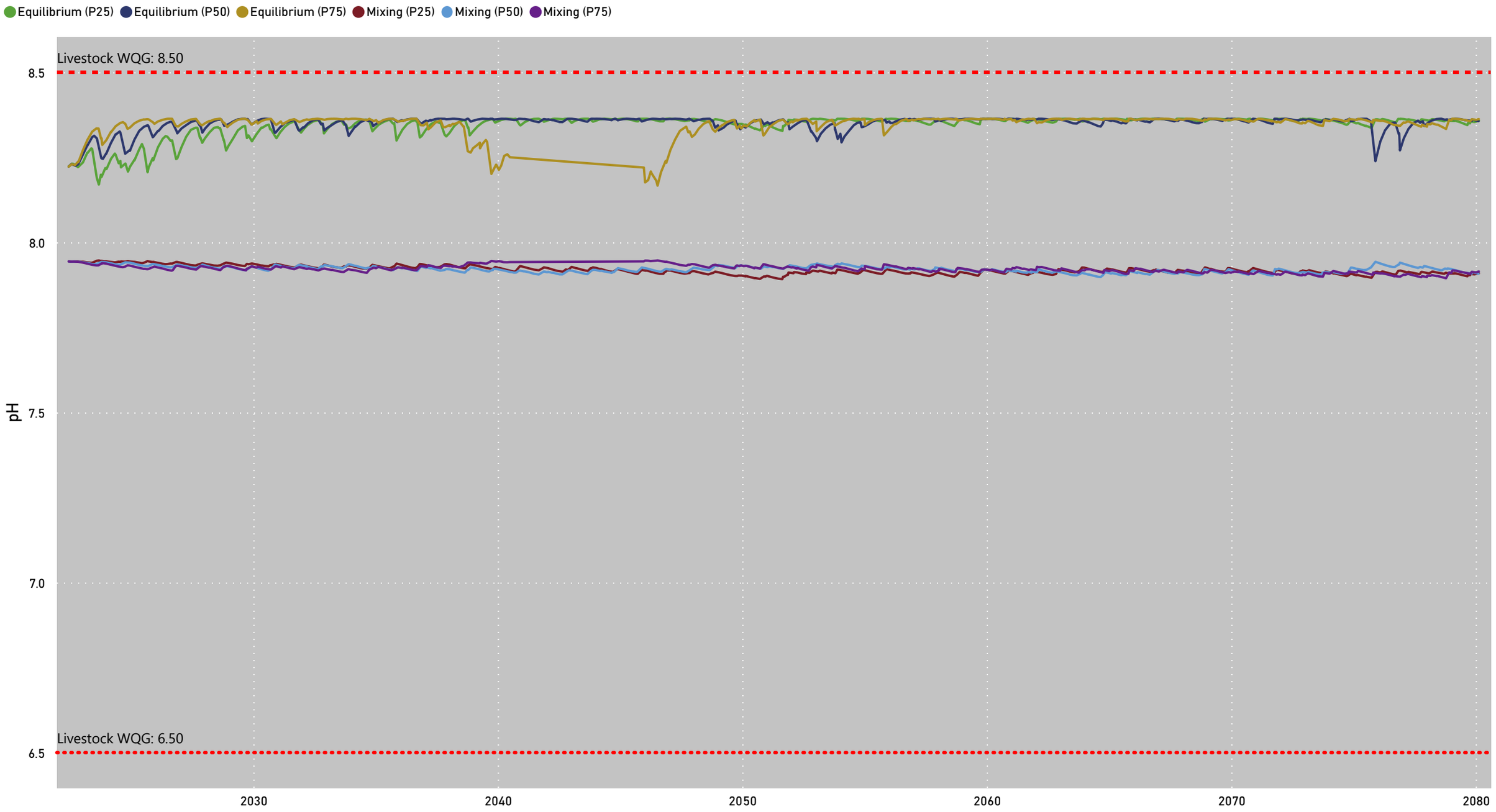
The water quality modelling indicates that the modelled solute concentrations at all times and for both models (i.e. mixing and equilibrium models) remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.

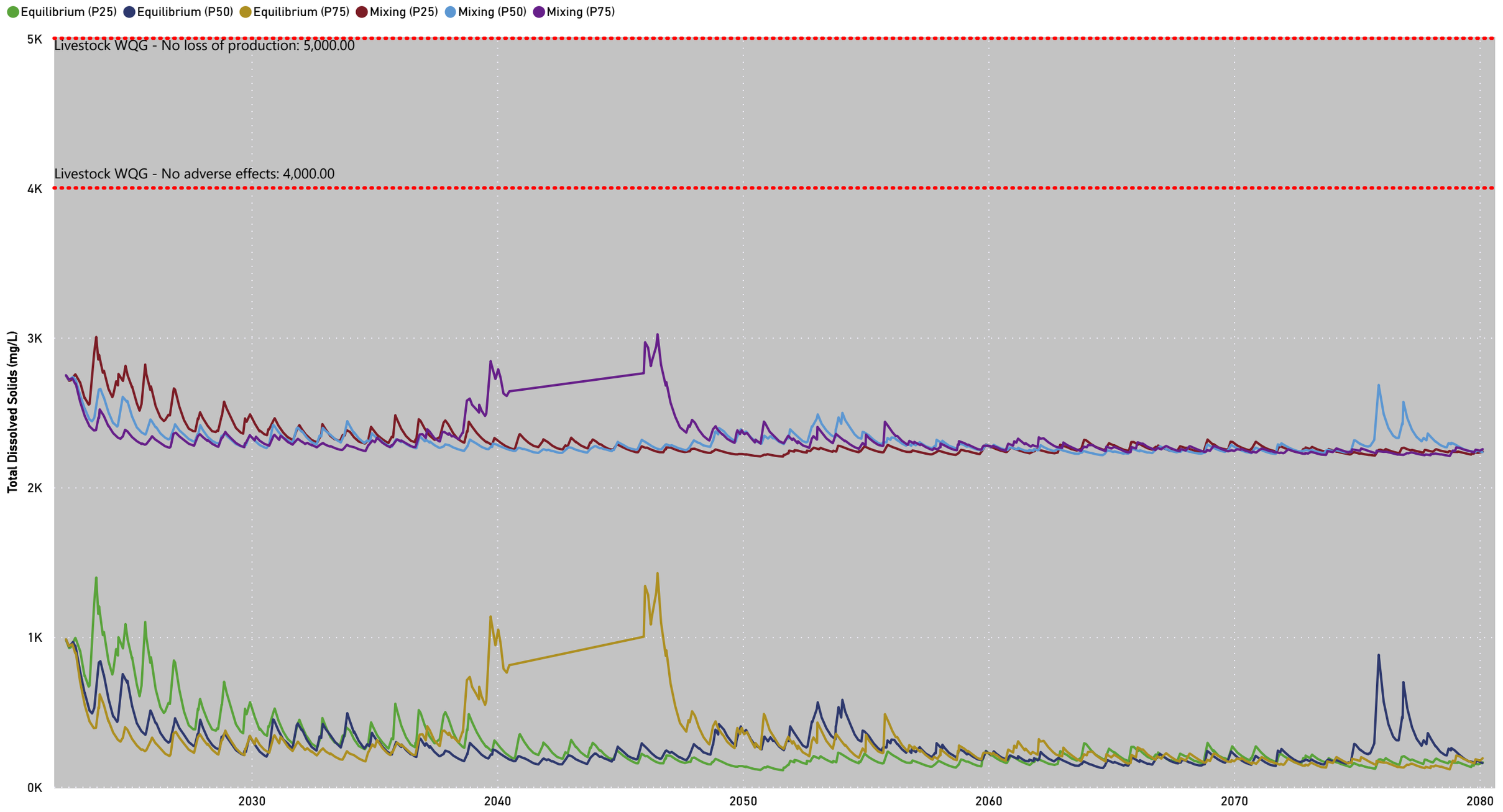
Long-term water quality in the pits and voids is determined by climatic conditions and geochemical reactions and tends to stabilise. The net flow balance between rainfall runoff plus groundwater inflow and evaporation determines short-term variations.

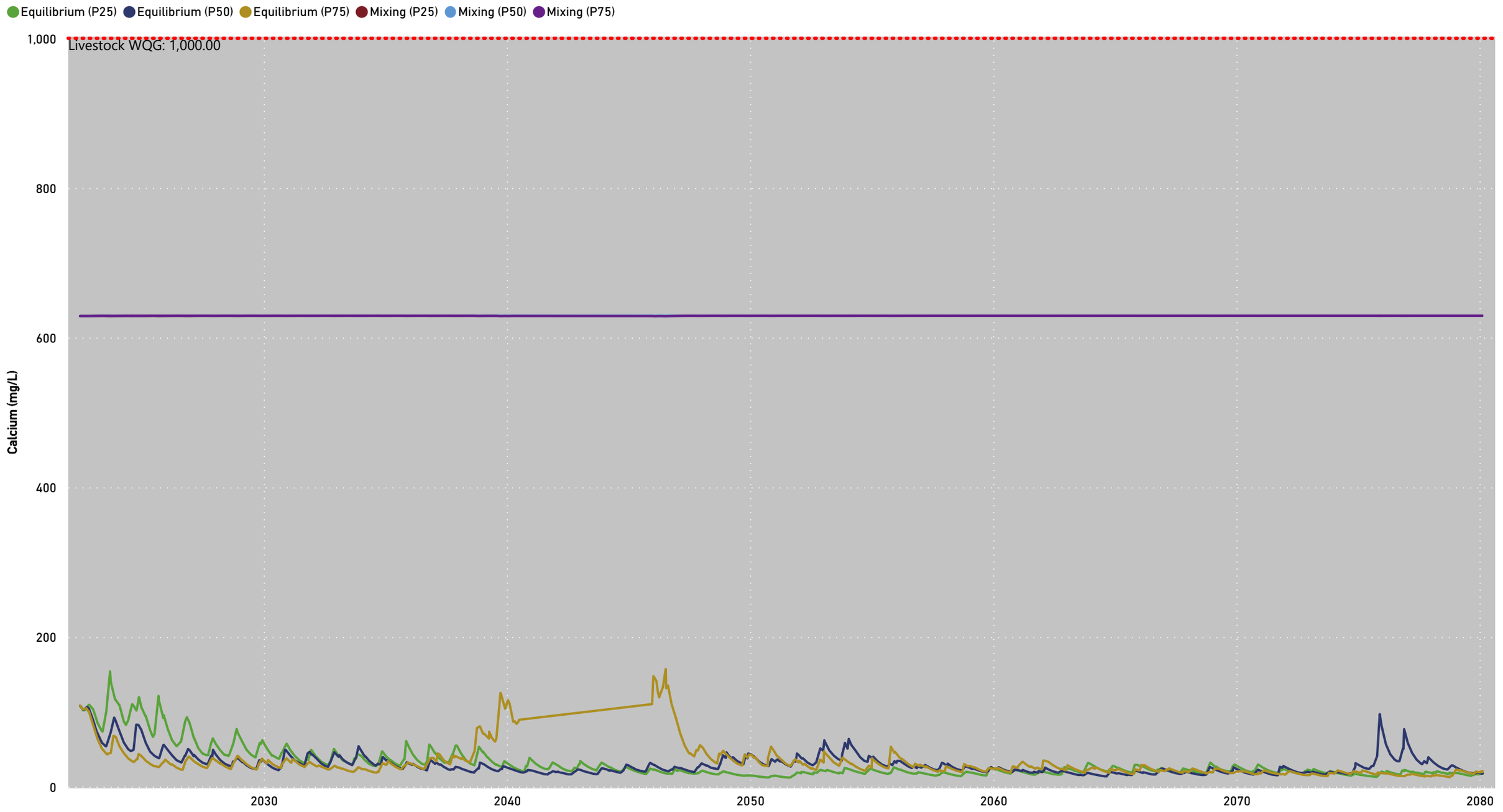
Based on the WQM results, the North Pit, South Pit and WRD Sediment Dam are considered suitable as PMLUs for livestock watering.

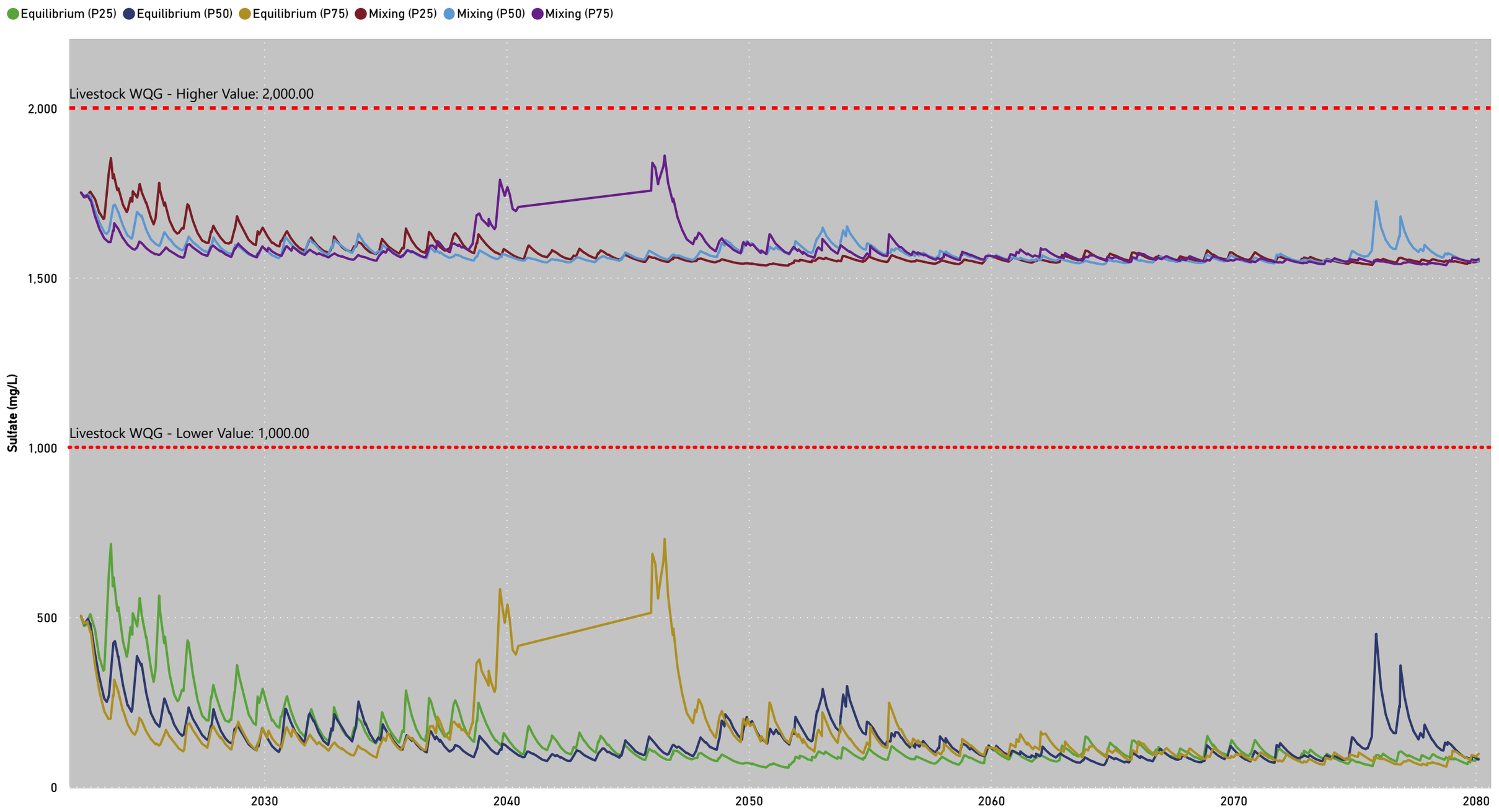
J.7 Charts and Plots

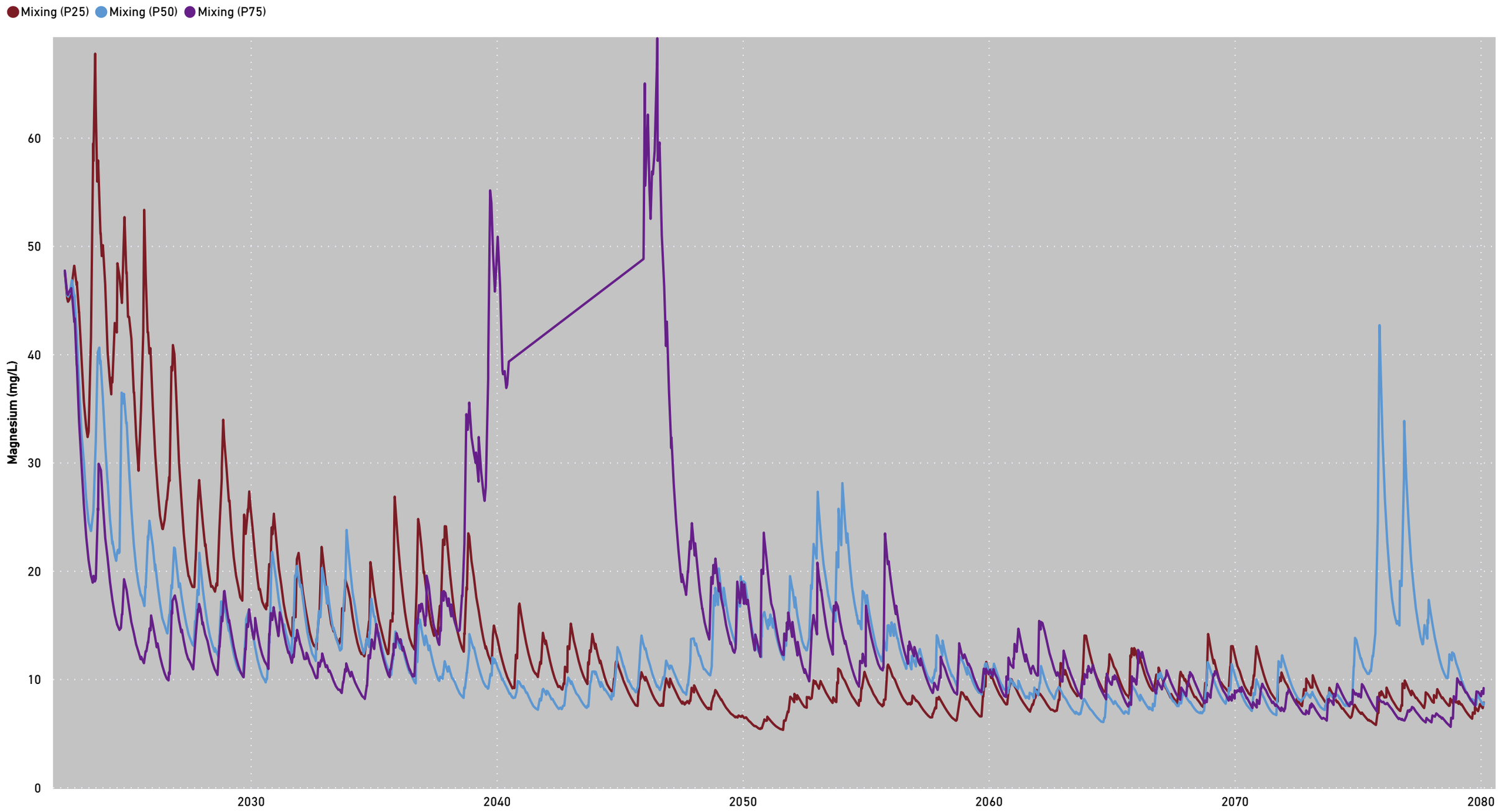
J.7.1 WRD Sediment Dam modelled long-term water quality

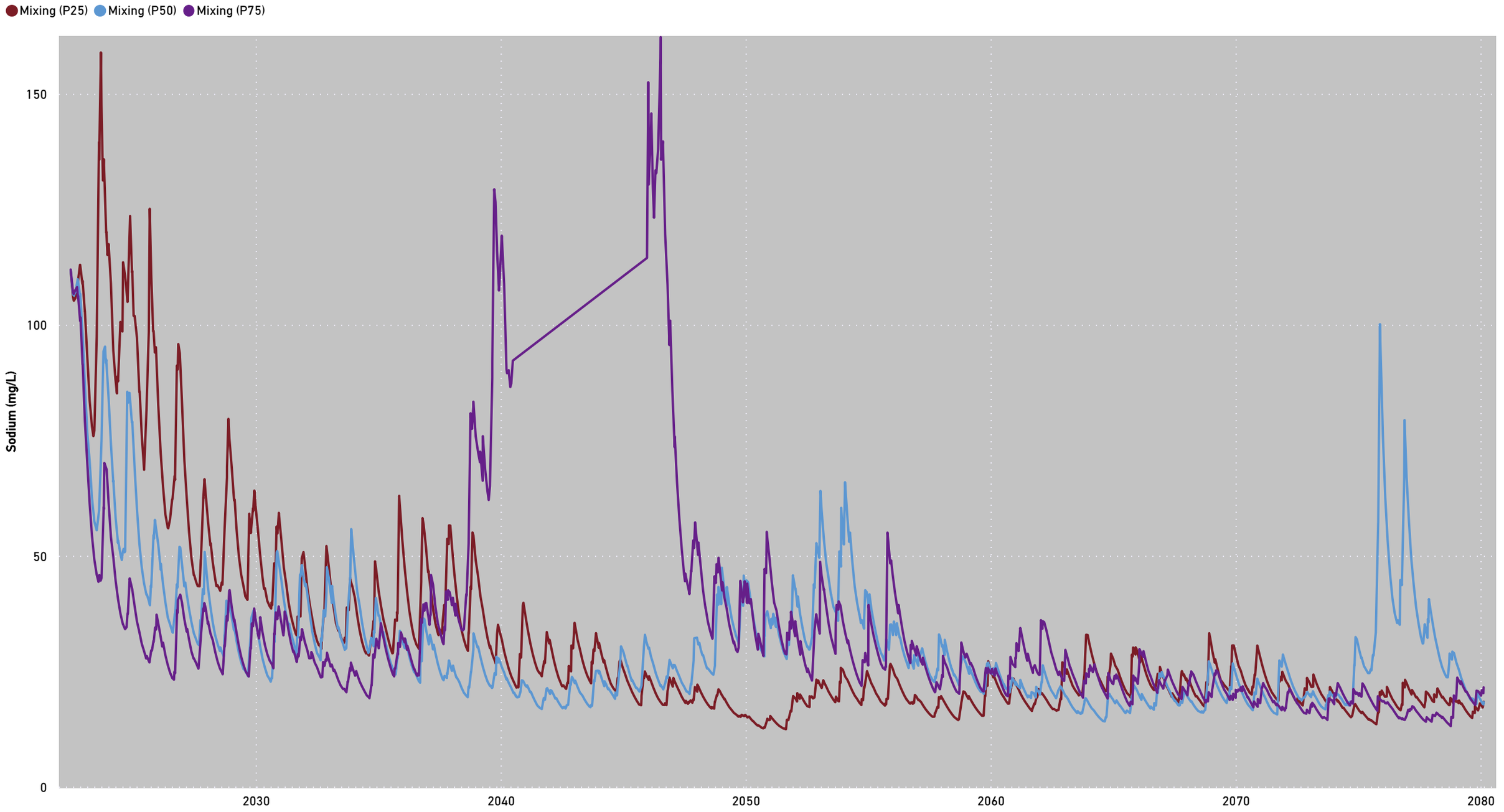

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 8.50
Livestock WQG: 6.50
pH
8.5
8.0
7.5
7.0
6.5
2030
2040
2050
2060
2070
2080

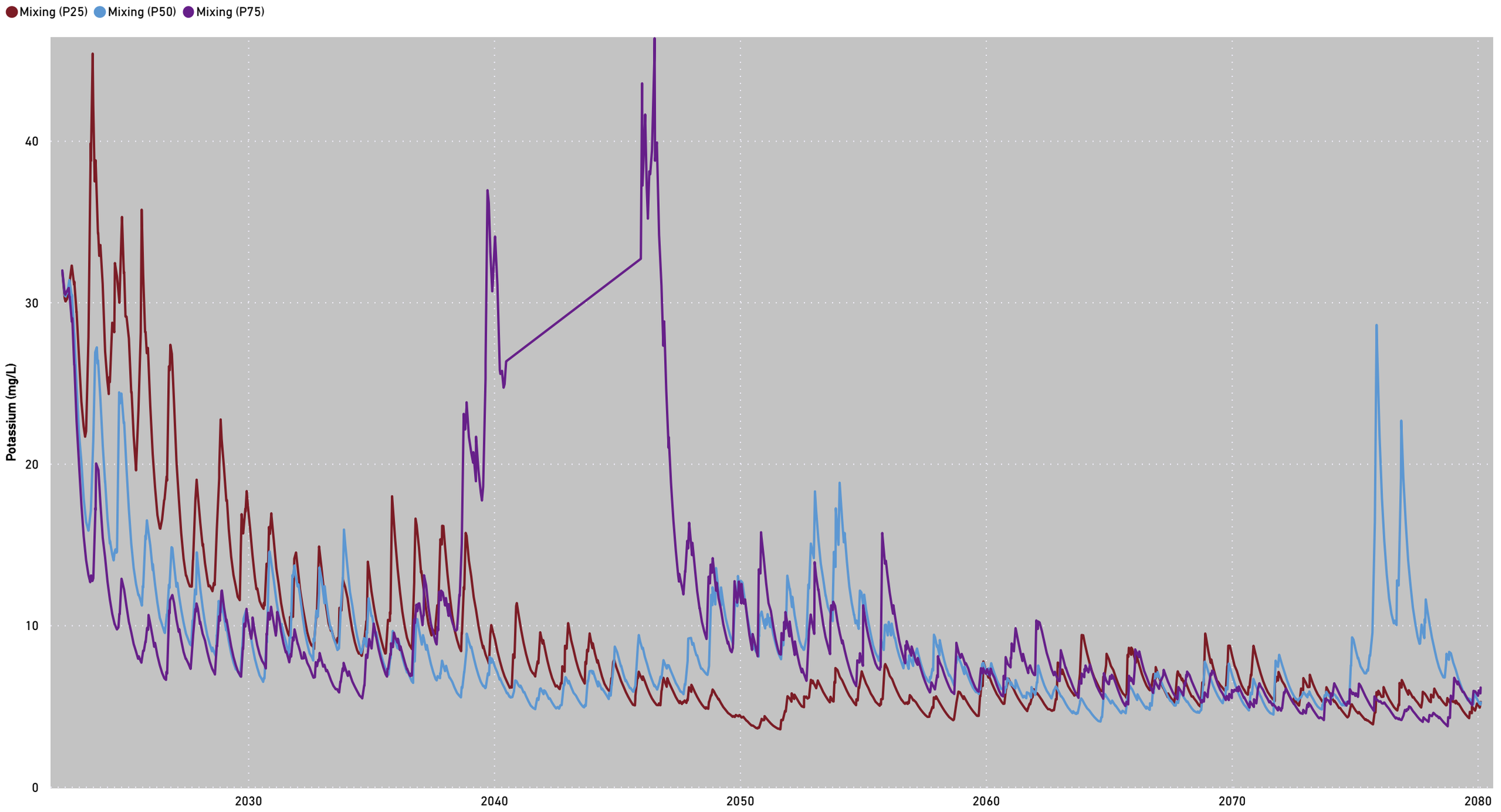

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - No loss of production: 5,000.00
Livestock WQG - No adverse effects: 4,000.00
Total Dissolved Solids (mg/L)
5K
4K
3K
2K
1K
0K
2030
2040
2050
2060
2070
2080

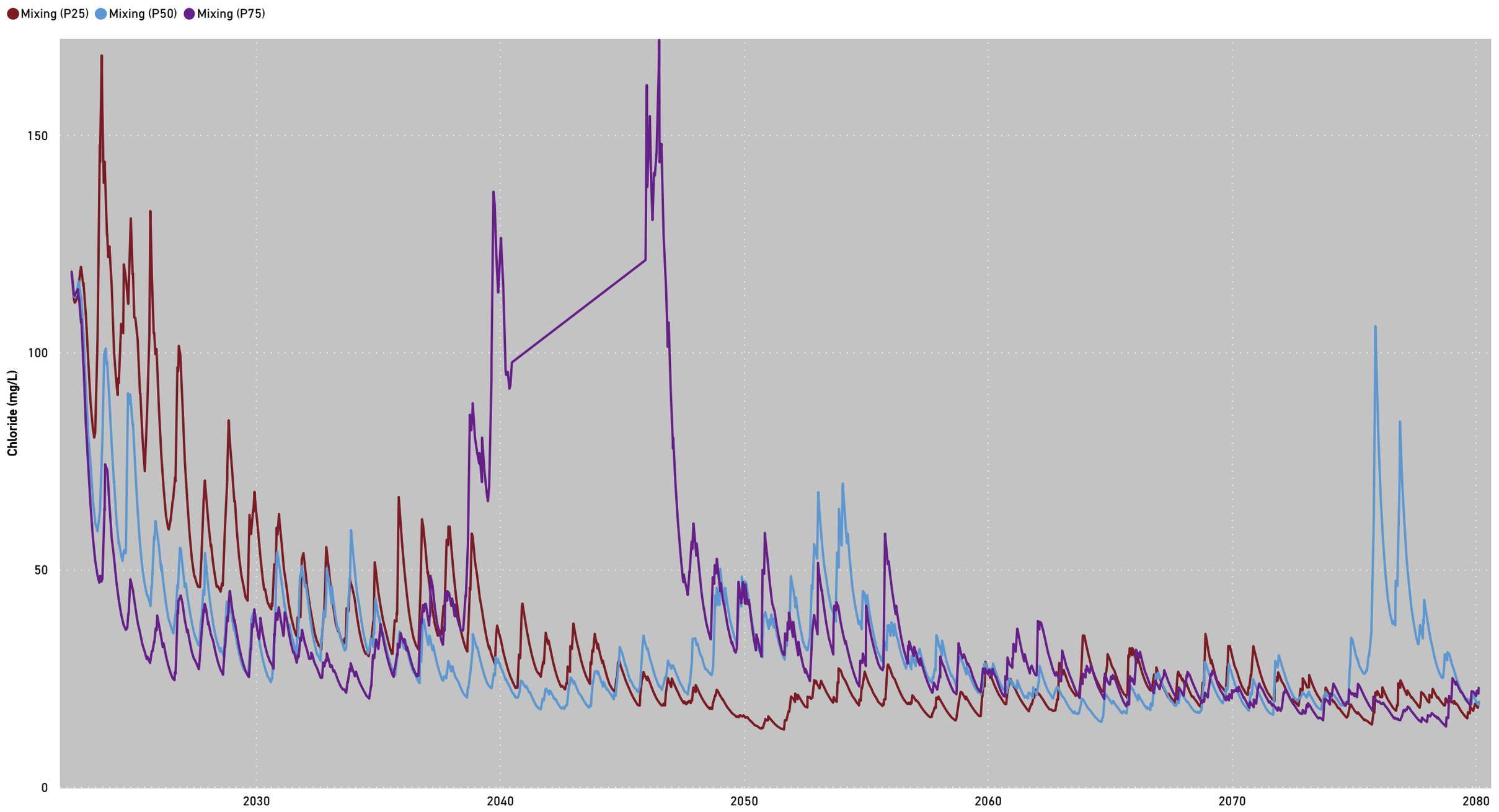

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 1,000.00
Calcium (mg/L)
1,000
800
600
400
200
0
2030
2040
2050
2060
2070
2080

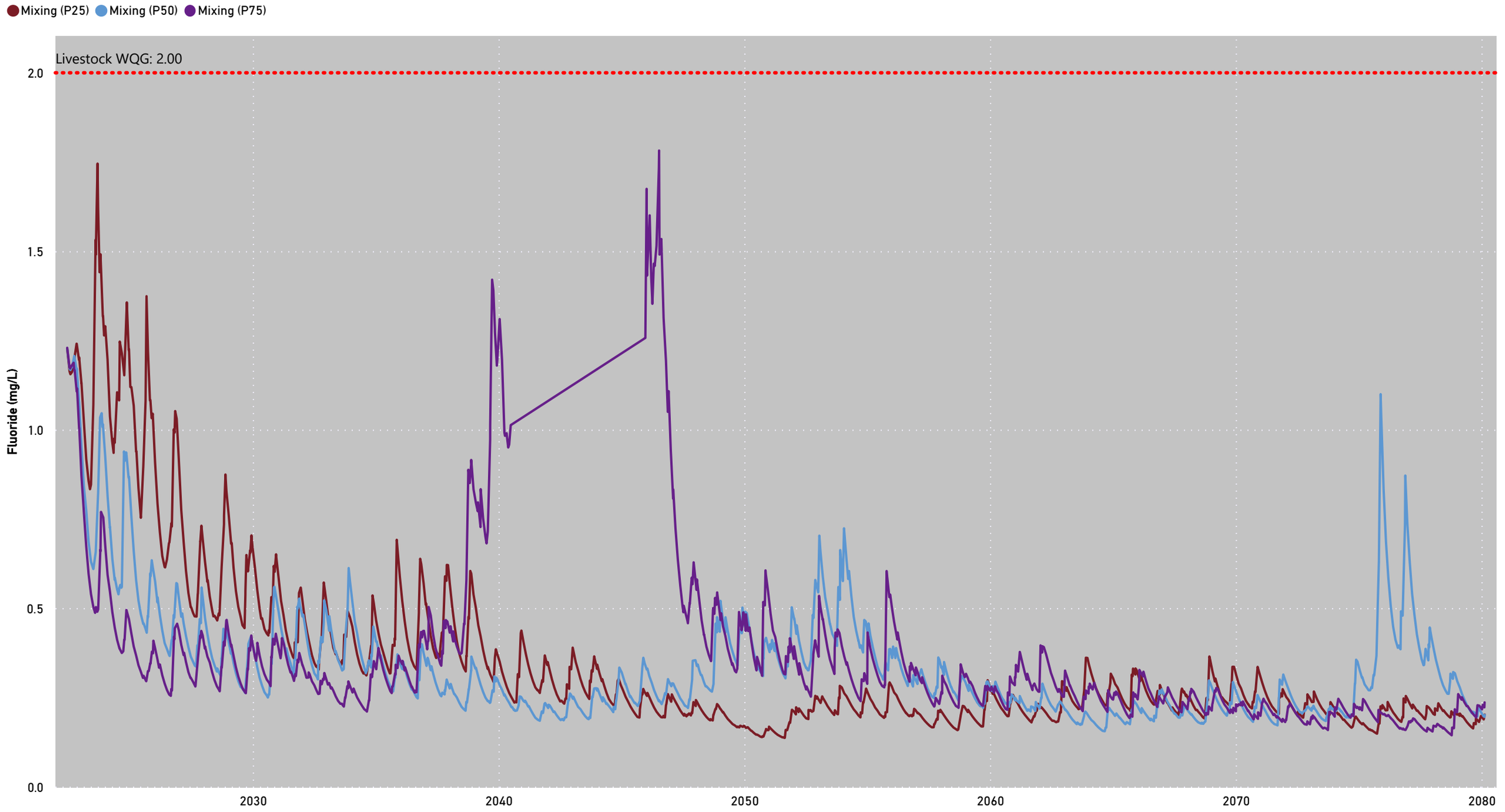

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - Higher Value: 2,000.00
Livestock WQG - Lower Value: 1,000.00
Sulfate (mg/L)
2,000
1,500
1,000
500
0
2030
2040
2050
2060
2070
2080

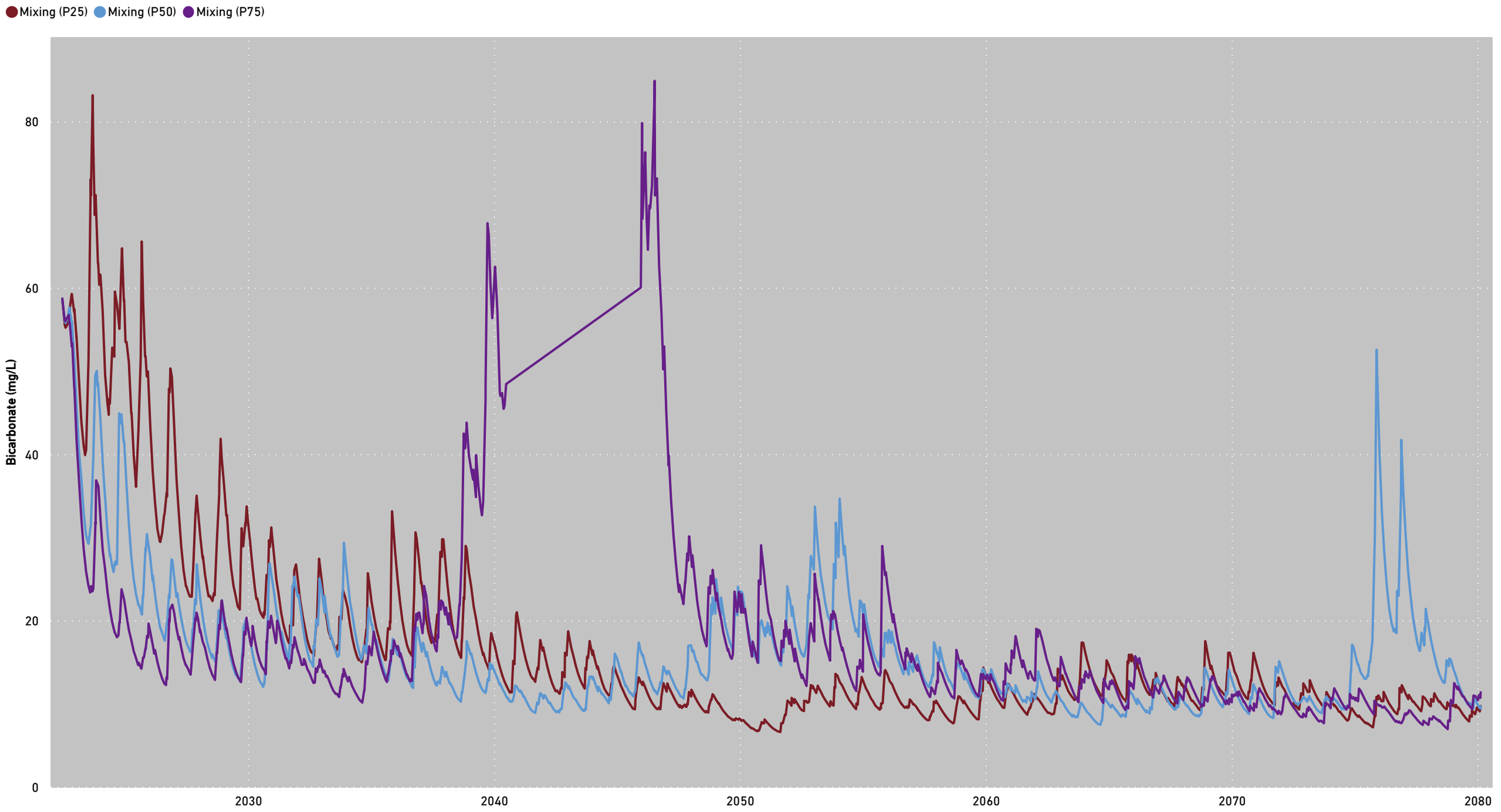

Mixing (P25)
Mixing (P50)
Mixing (P75)
Magnesium (mg/L)
0
10
20
30
40
50
60
2030
2040
2050
2060
2070
2080

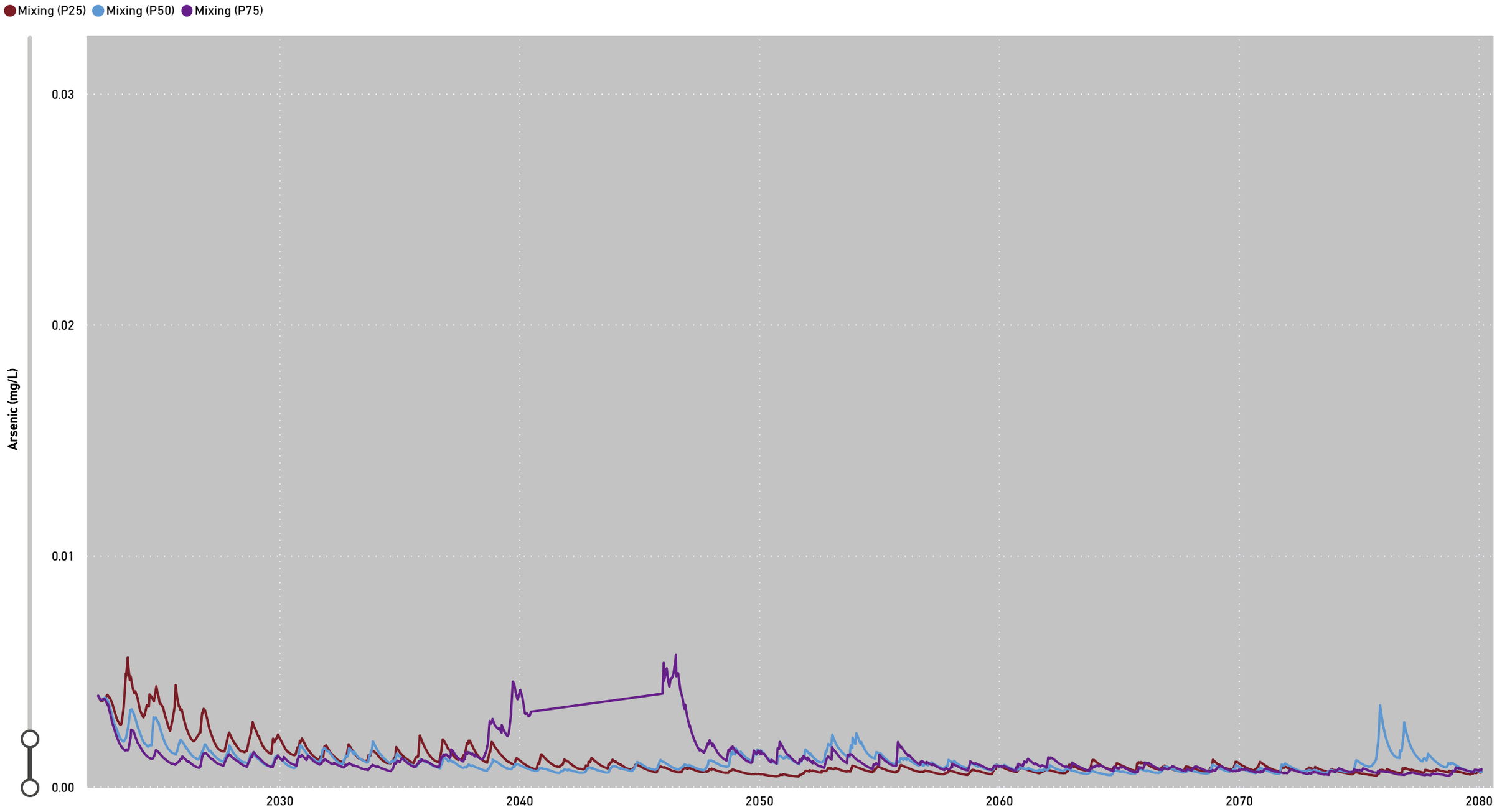

Mixing (P25)
Mixing (P50)
Mixing (P75)
Sodium (mg/L)
150
100
50
0
2030
2040
2050
2060
2070
2080

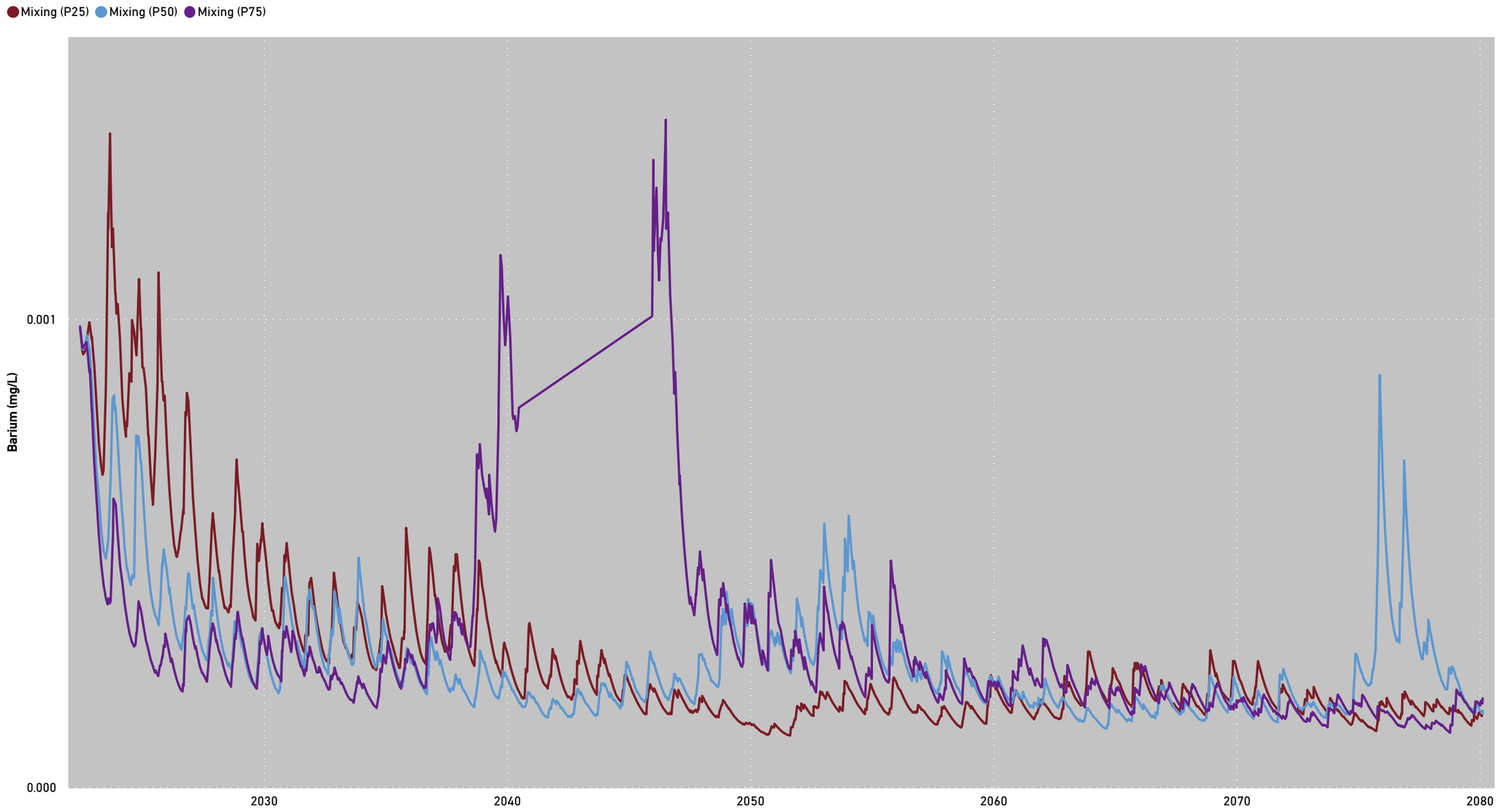

Mixing (P25)
Mixing (P50)
Mixing (P75)
Potassium (mg/L)
0
10
20
30
40
2030
2040
2050
2060
2070
2080

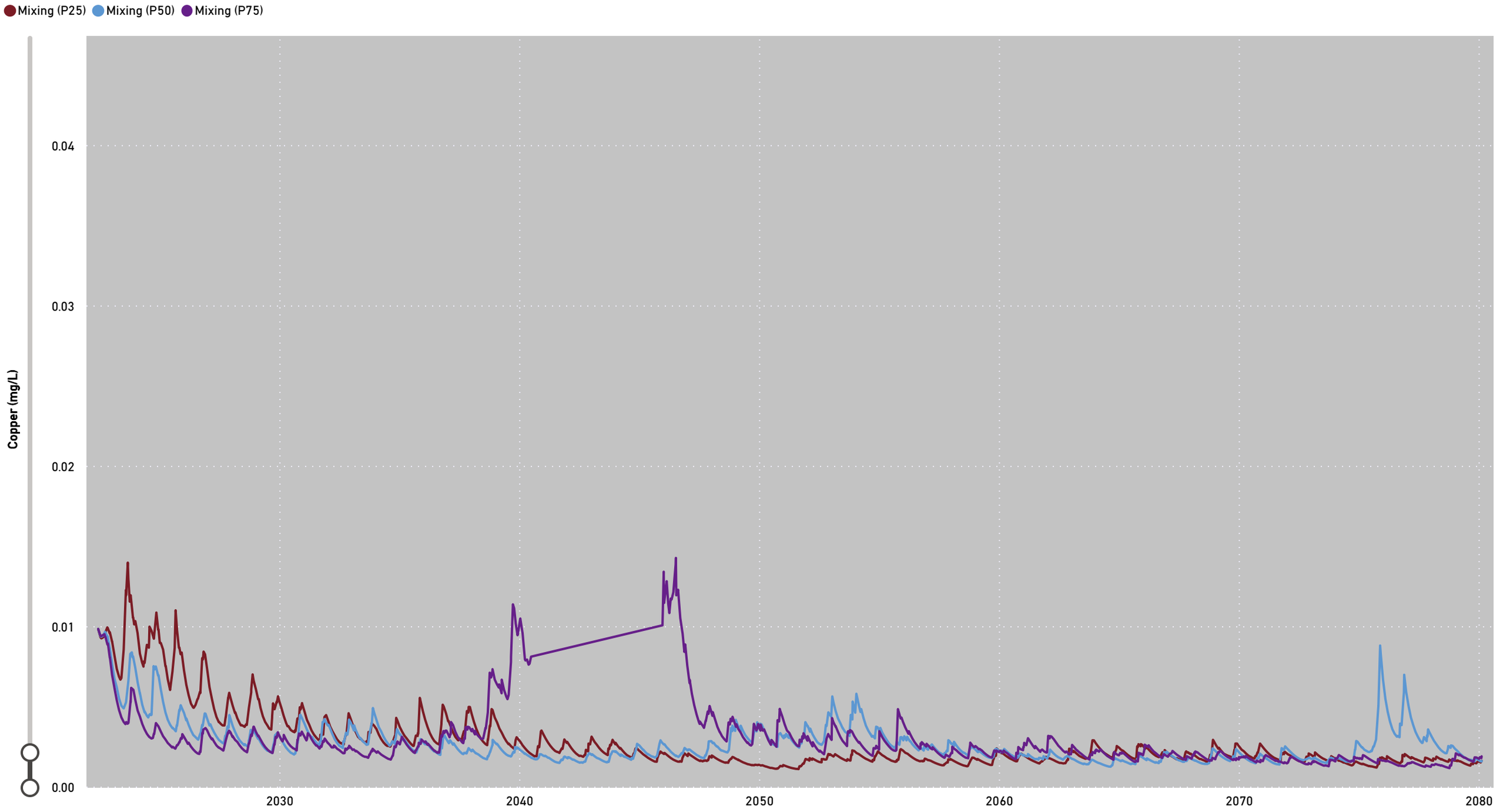

Mixing (P25)
Mixing (P50)
Mixing (P75)
Chloride (mg/L)
150
100
50
0
2030
2040
2050
2060
2070
2080

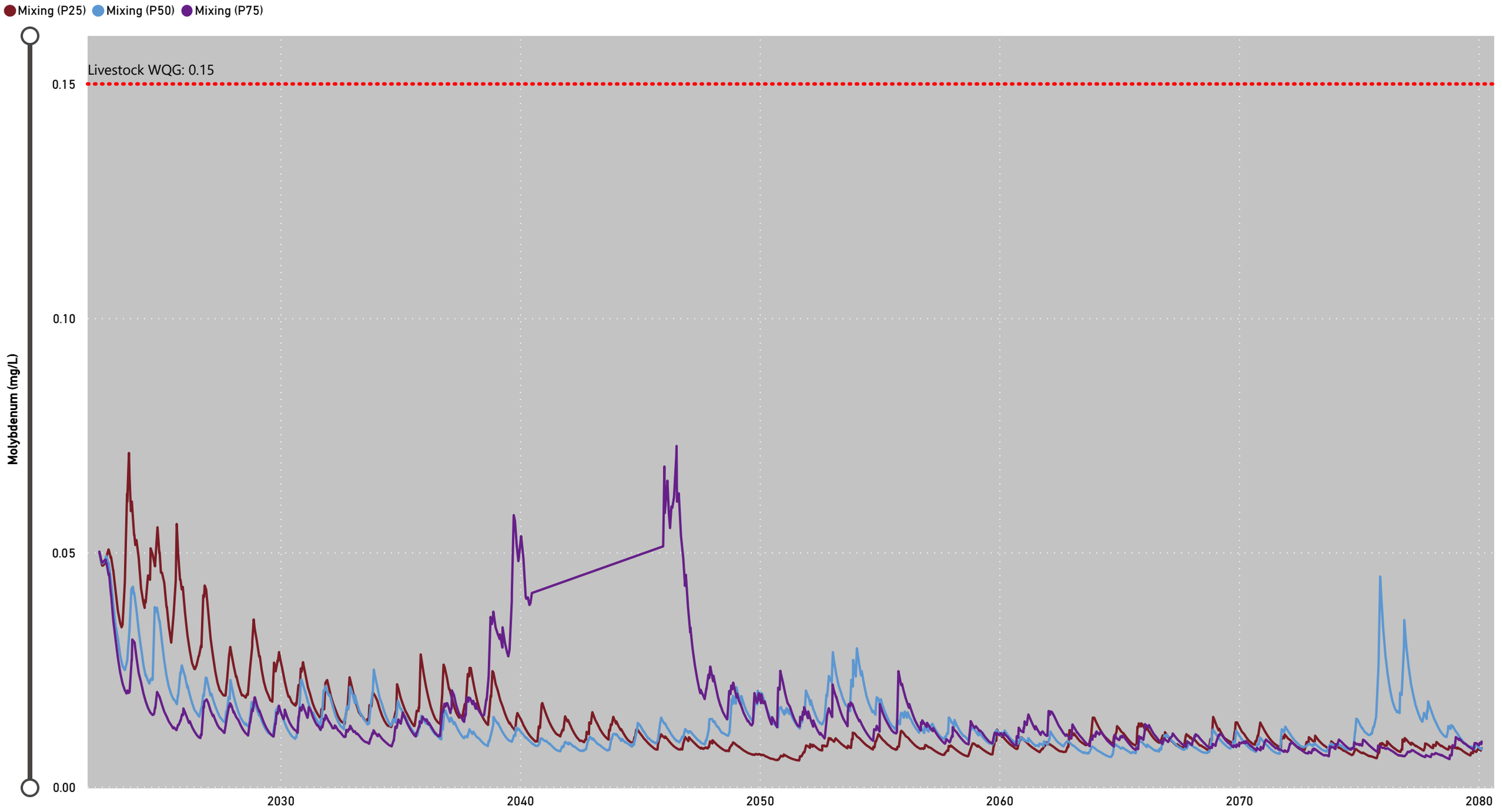

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 2.00
Fluoride (mg/L)
2.0
1.5
1.0
0.5
0.0
2030
2040
2050
2060
2070
2080

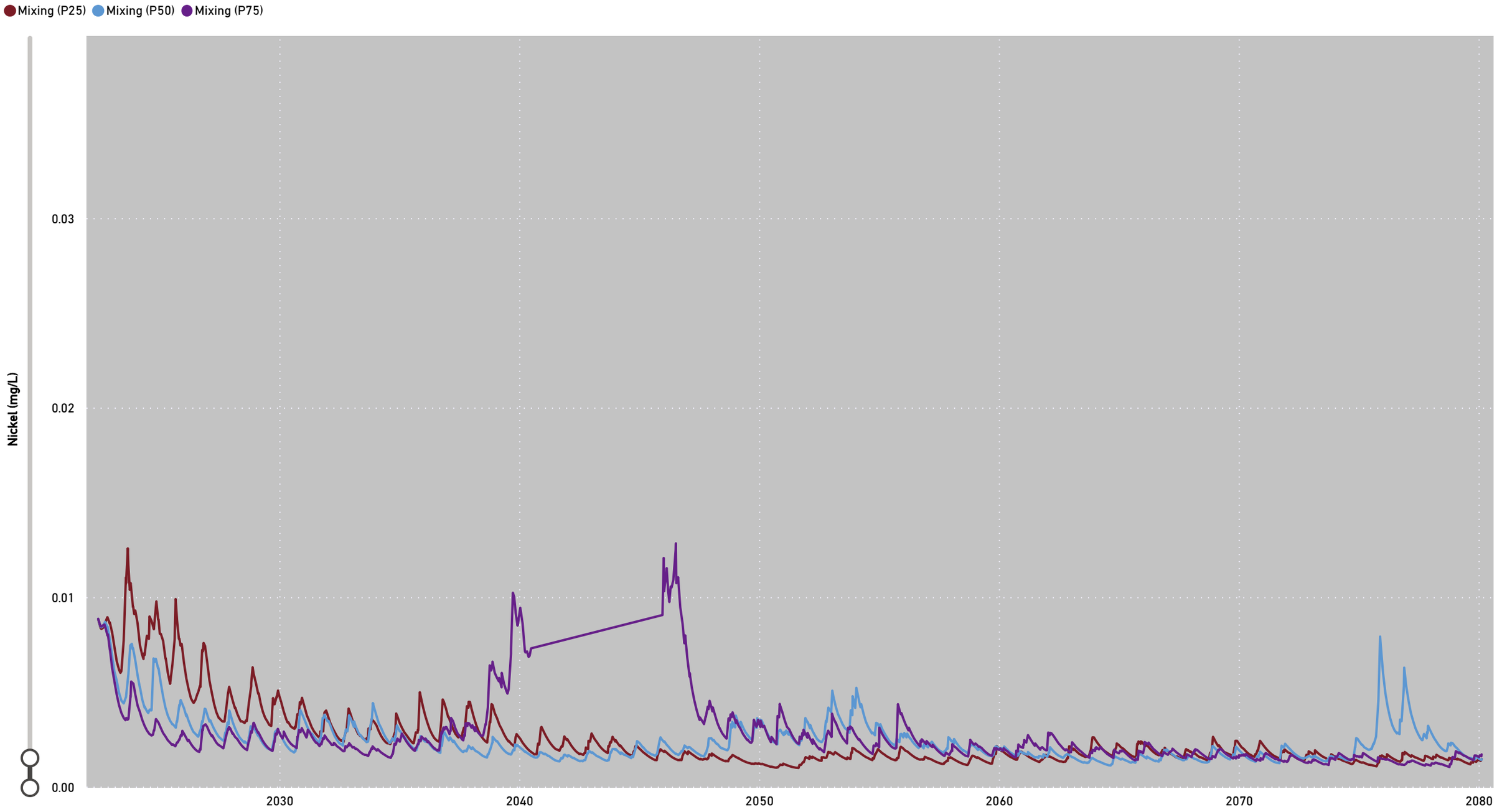

Mixing (P25)
Mixing (P50)
Mixing (P75)
Bicarbonate (mg/L)
0
20
40
60
80
2030
2040
2050
2060
2070
2080

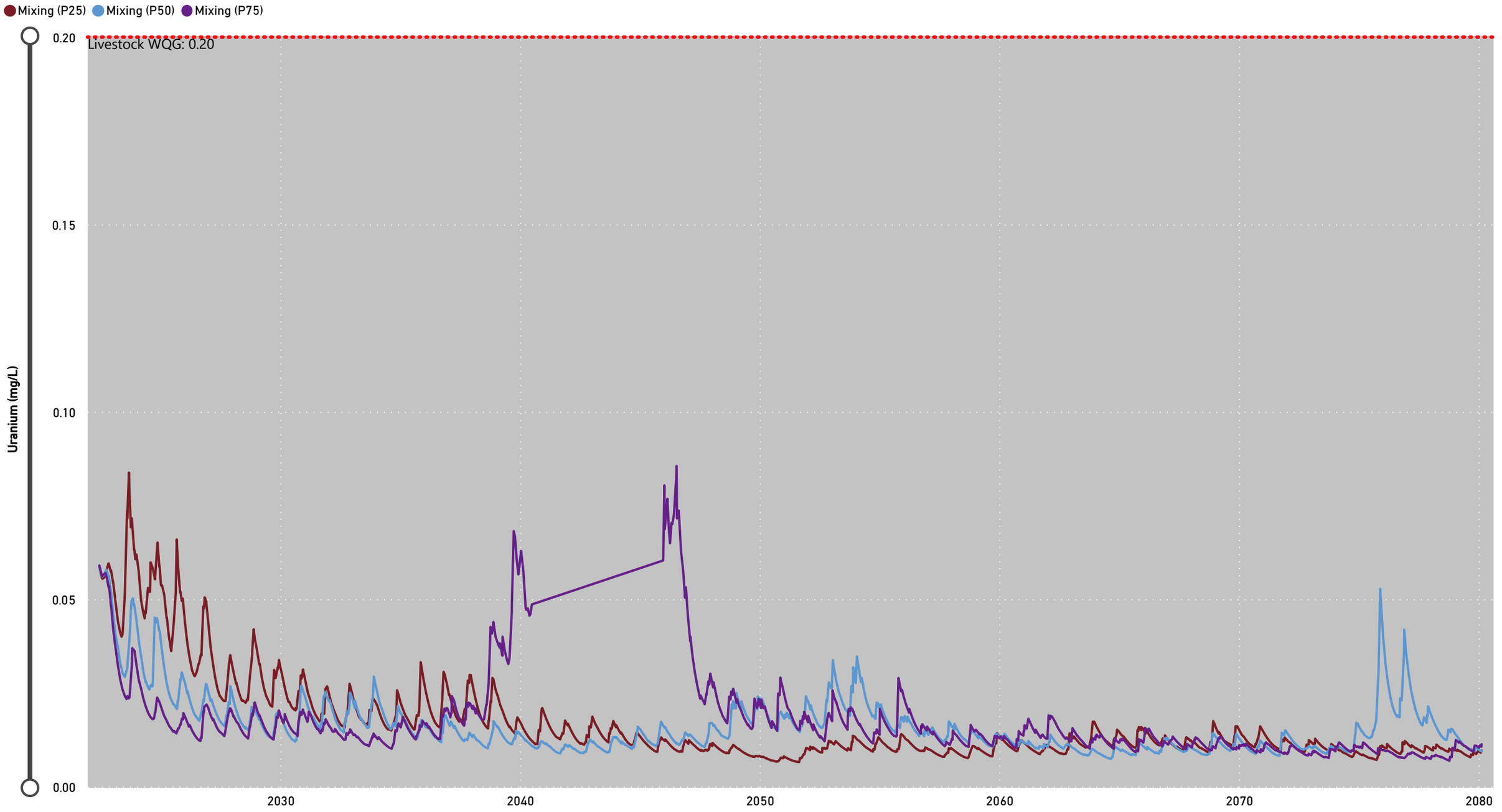

Mixing (P25)
Mixing (P50)
Mixing (P75)
Arsenic (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Barium (mg/L)
0.001
0.000
2030
2040
2050
2060
2070
2080

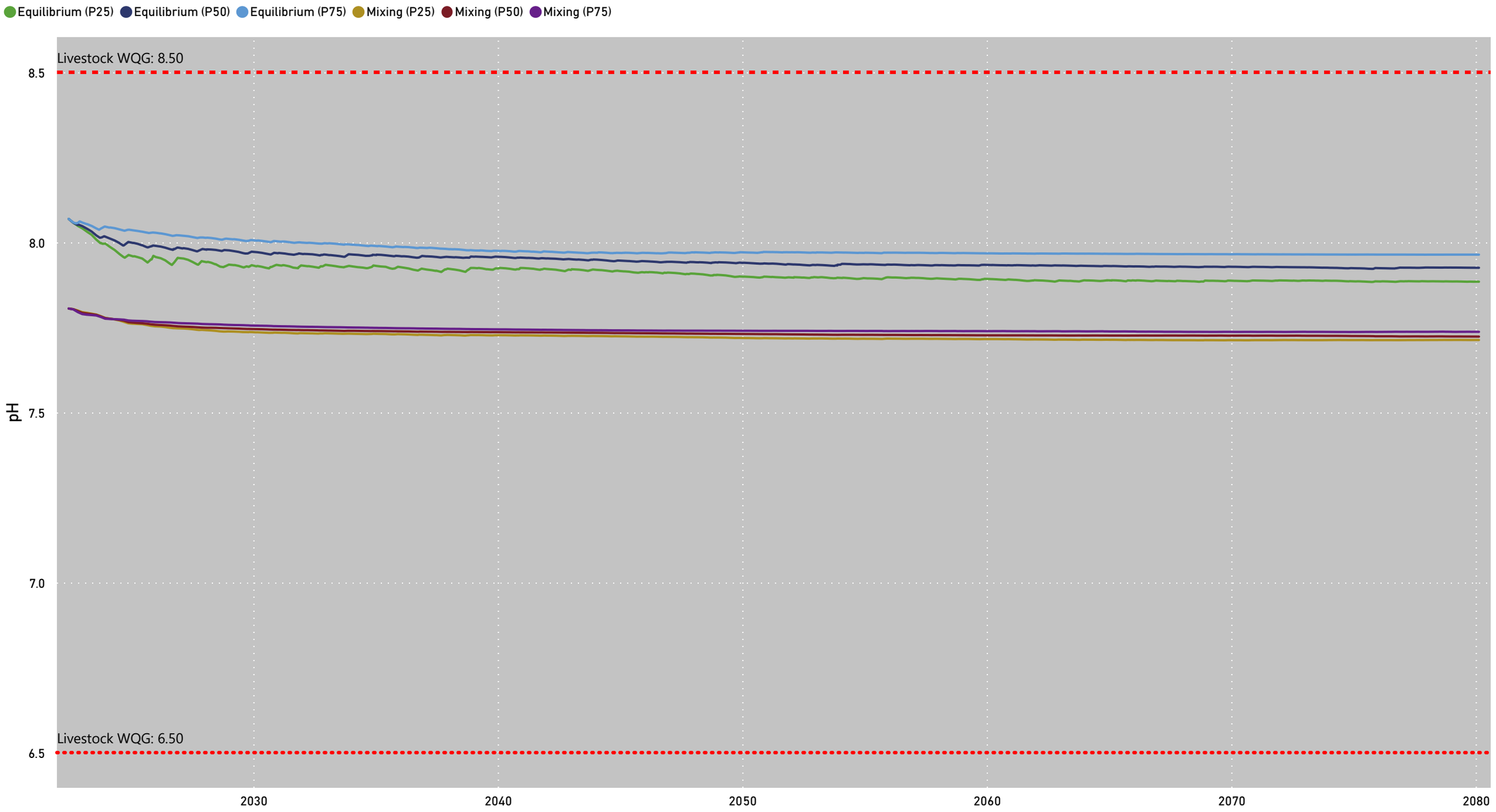

Mixing (P25)
Mixing (P50)
Mixing (P75)
Copper (mg/L)
0.04
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

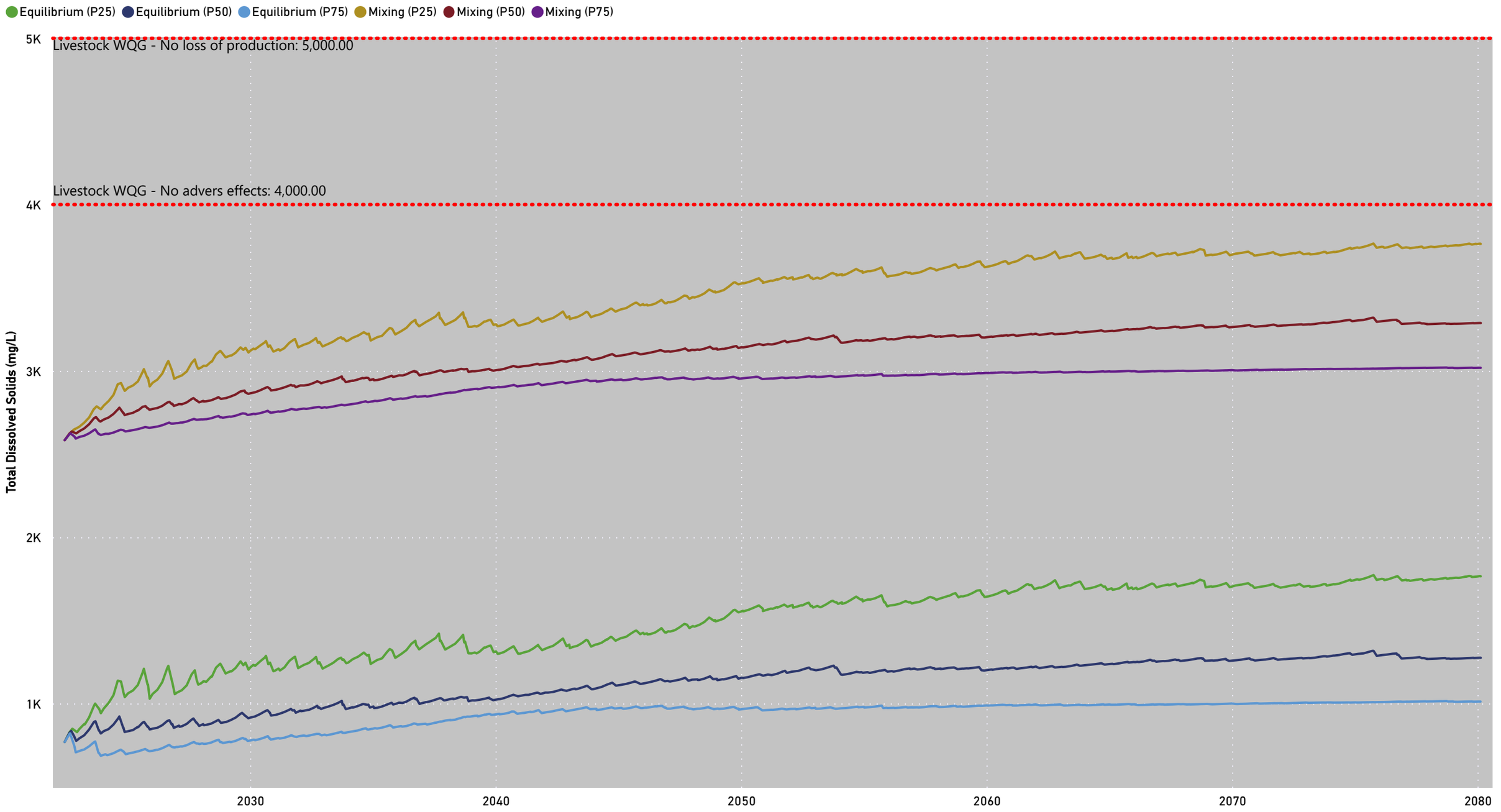

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 0.15
Molybdenum (mg/L)
0.15
0.10
0.05
0.00
2030
2040
2050
2060
2070
2080

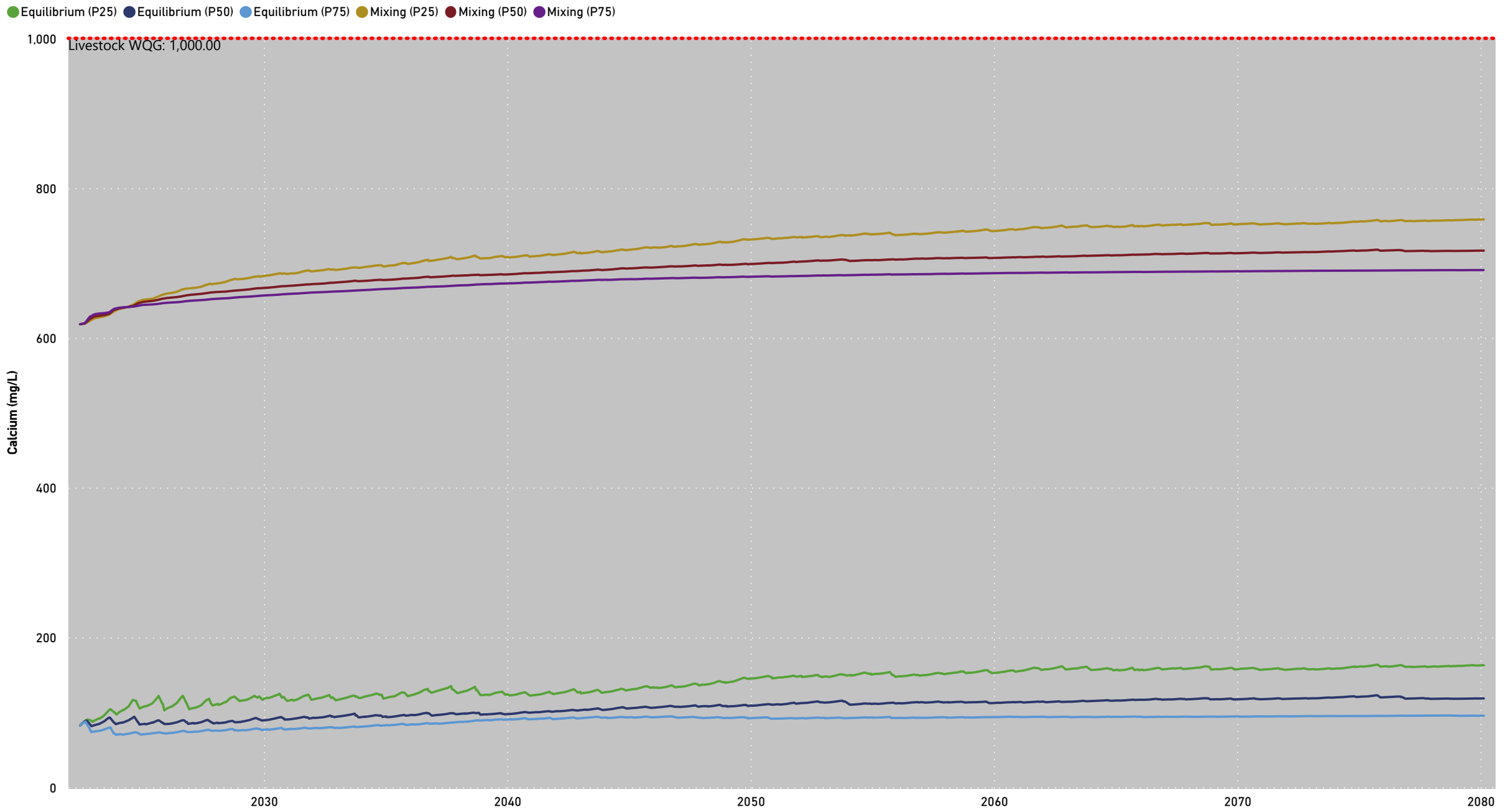

Mixing (P25)
Mixing (P50)
Mixing (P75)
Nickel (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

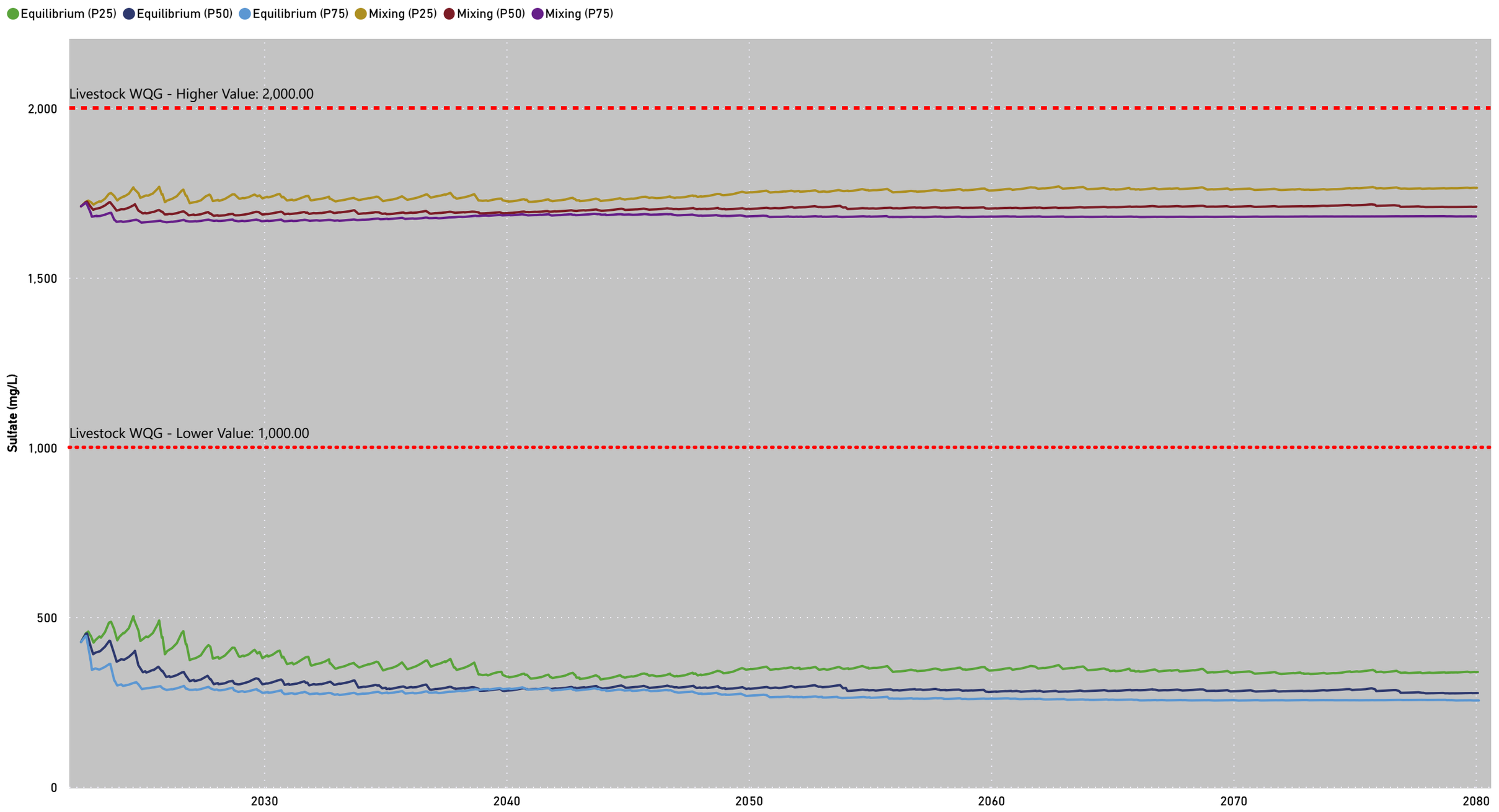

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 0.20
Uranium (mg/L)
0.20
0.15
0.10
0.05
0.00
2030
2040
2050
2060
2070
2080

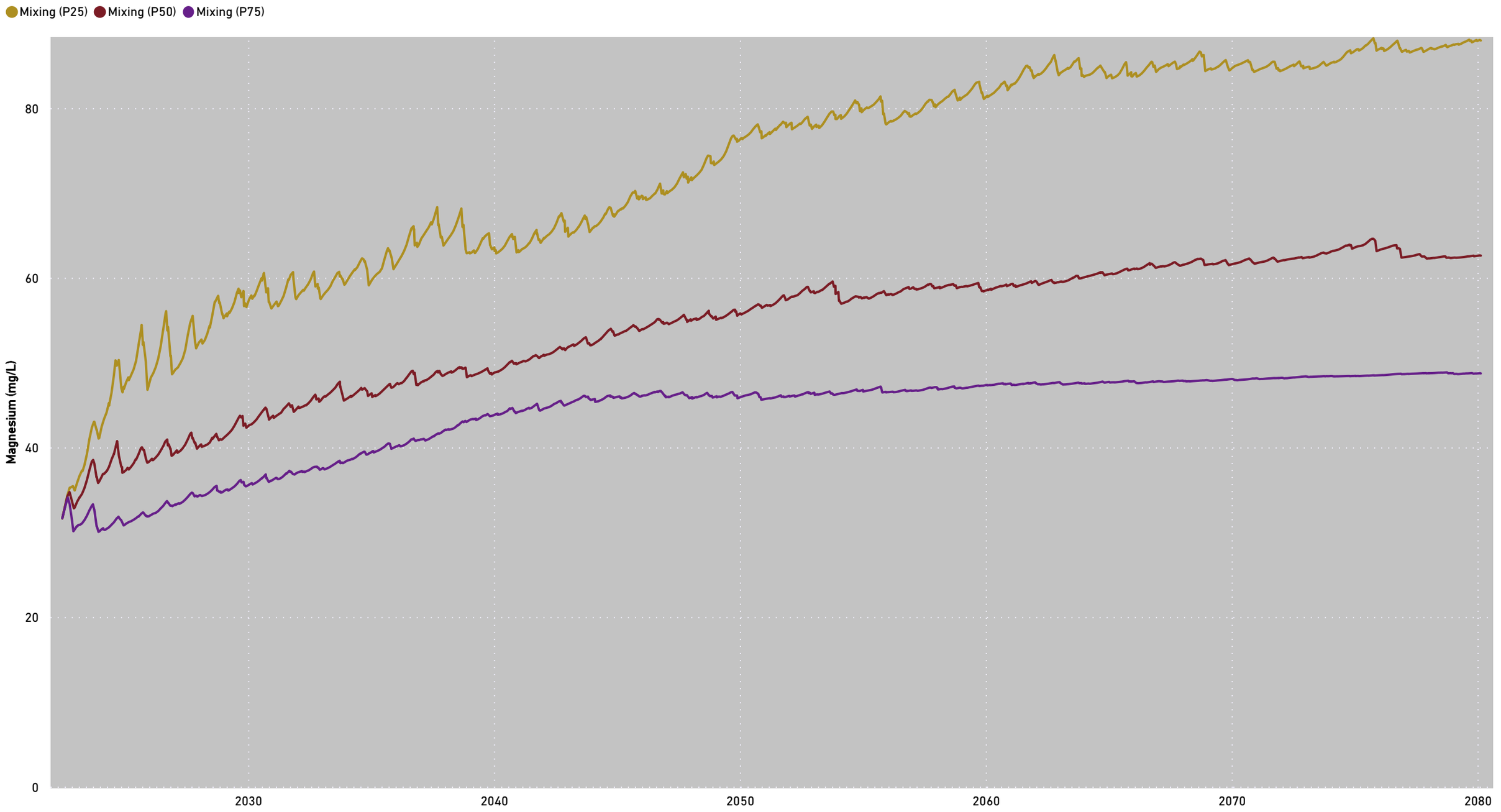
J.7.2 North Pit modelled long-term water quality

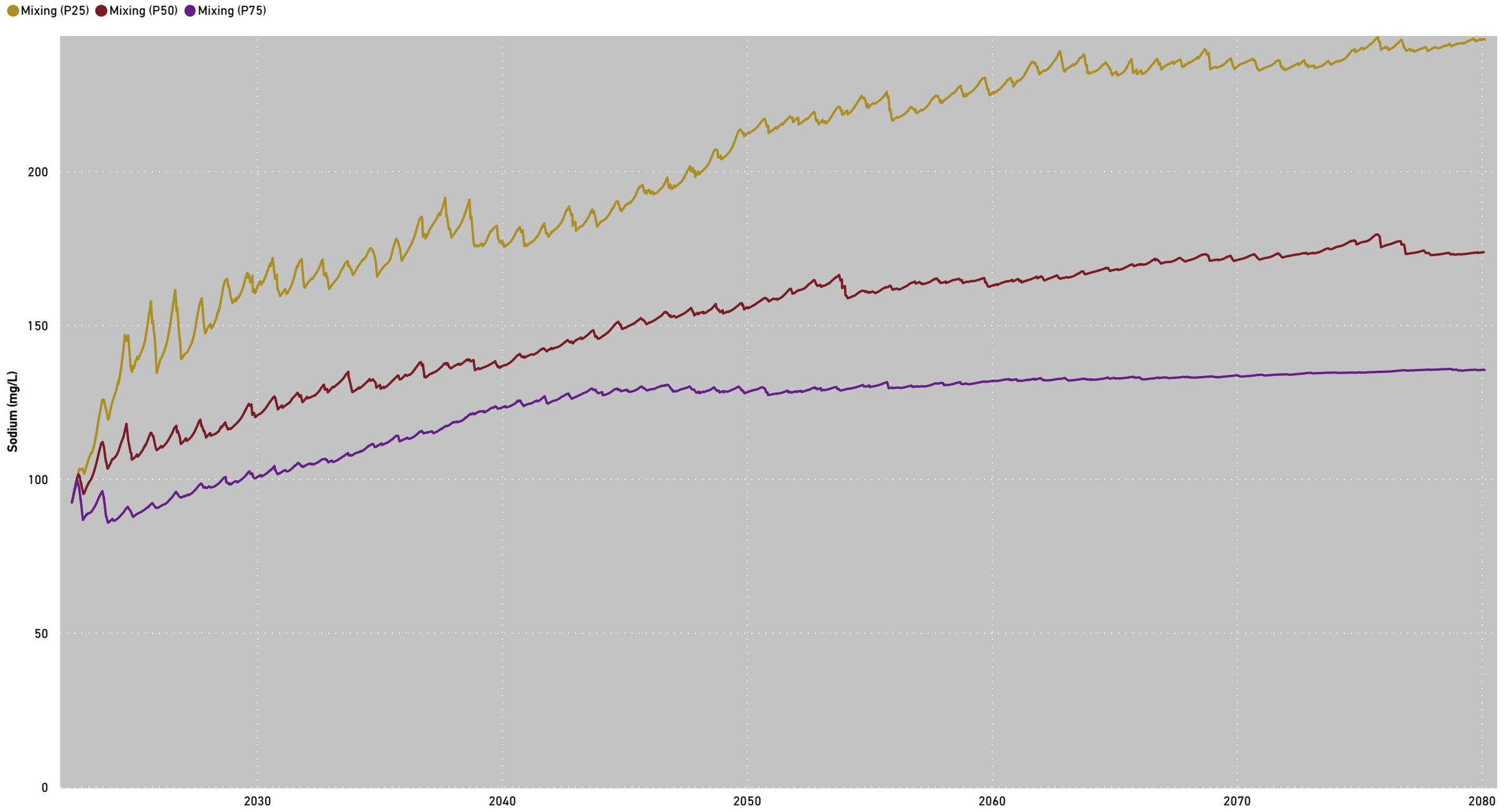

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 8.50
Livestock WQG: 6.50
pH
8.5
8.0
7.5
7.0
6.5
2030
2040
2050
2060
2070
2080

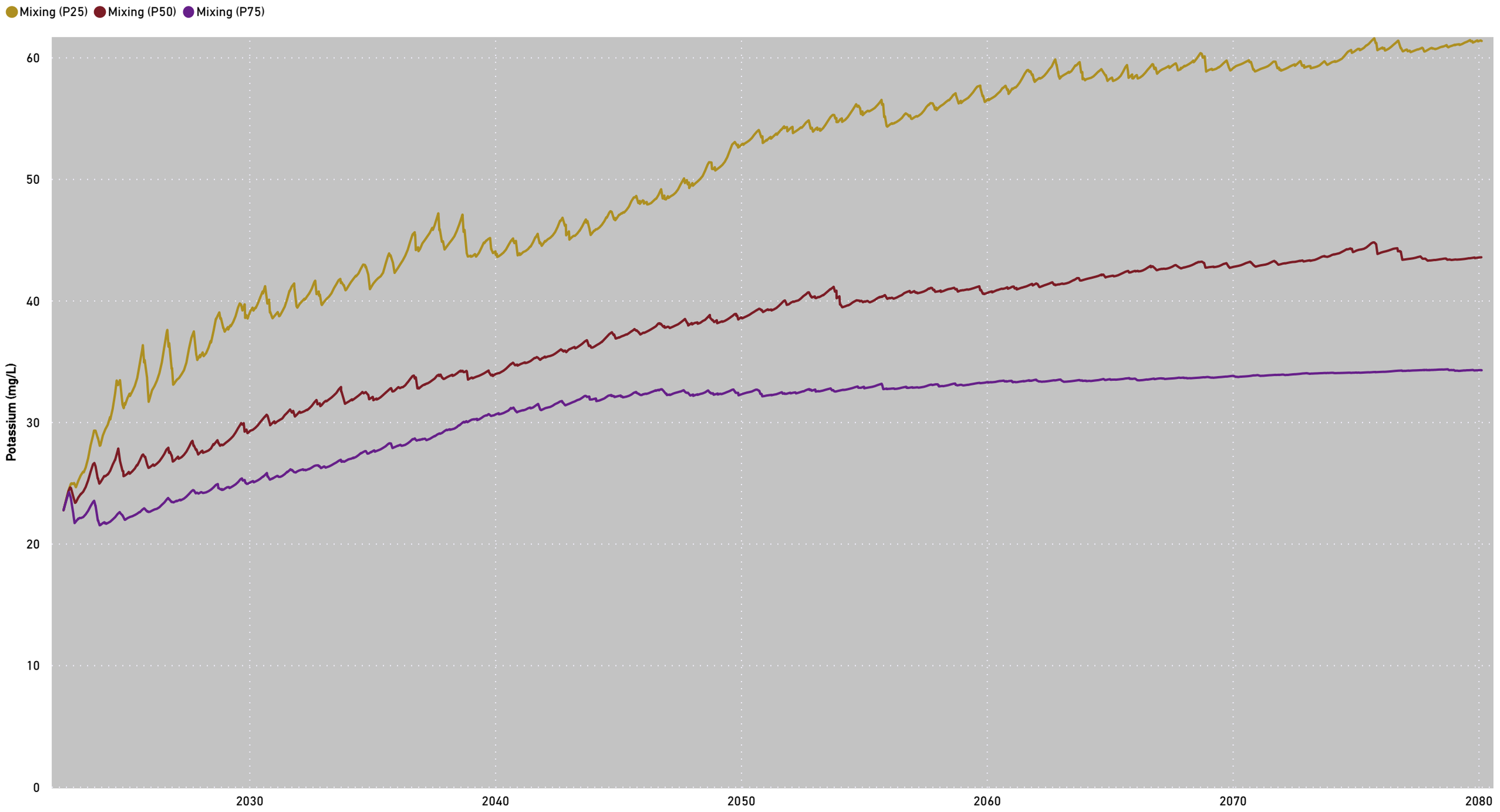

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - No loss of production: 5,000.00
Livestock WQG - No advers effects: 4,000.00
Total Dissolved Solids (mg/L)
5K
4K
3K
2K
1K
2030
2040
2050
2060
2070
2080

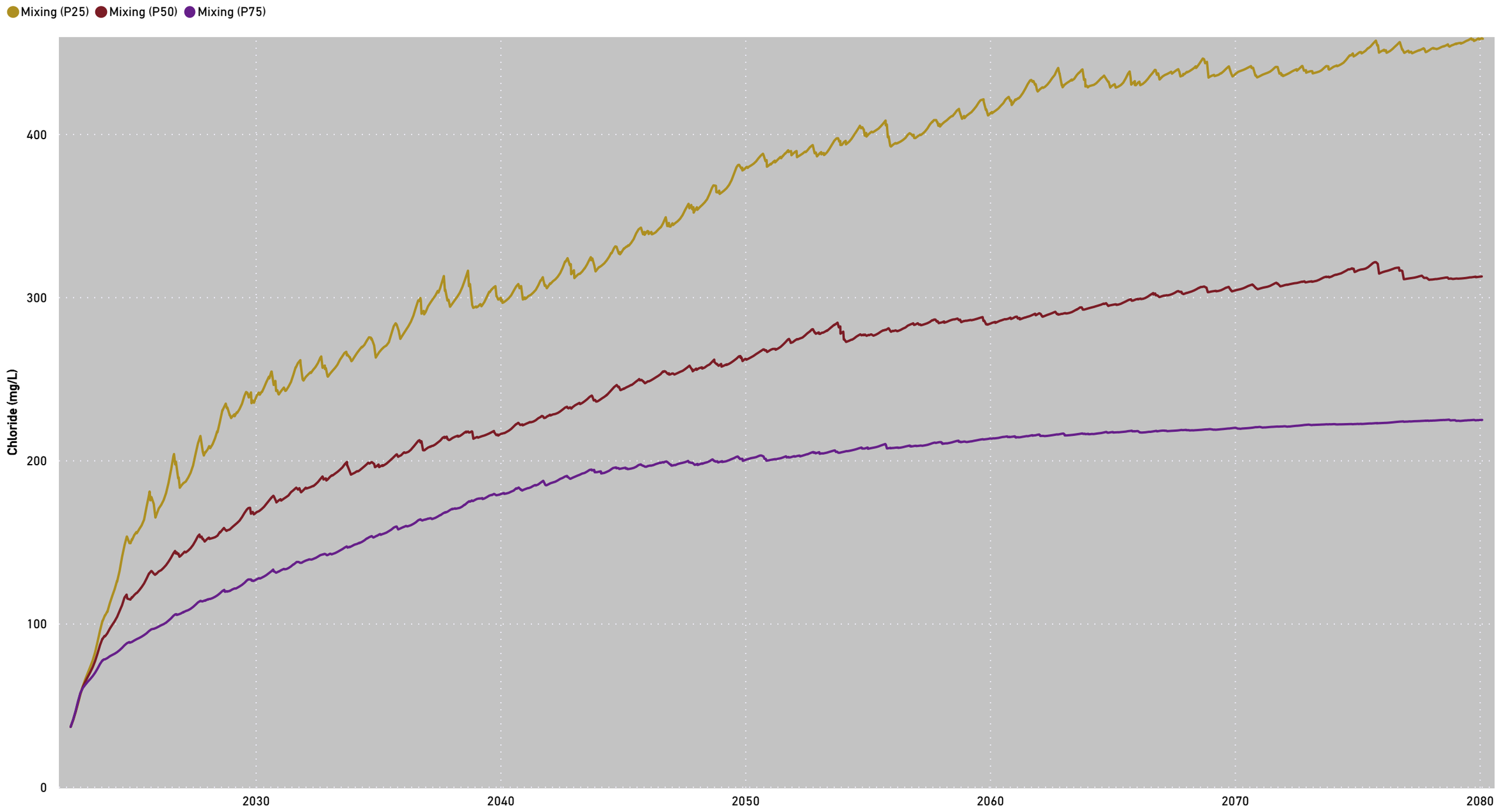

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 1,000.00
Calcium (mg/L)
1,000
800
600
400
200
0
2030
2040
2050
2060
2070
2080

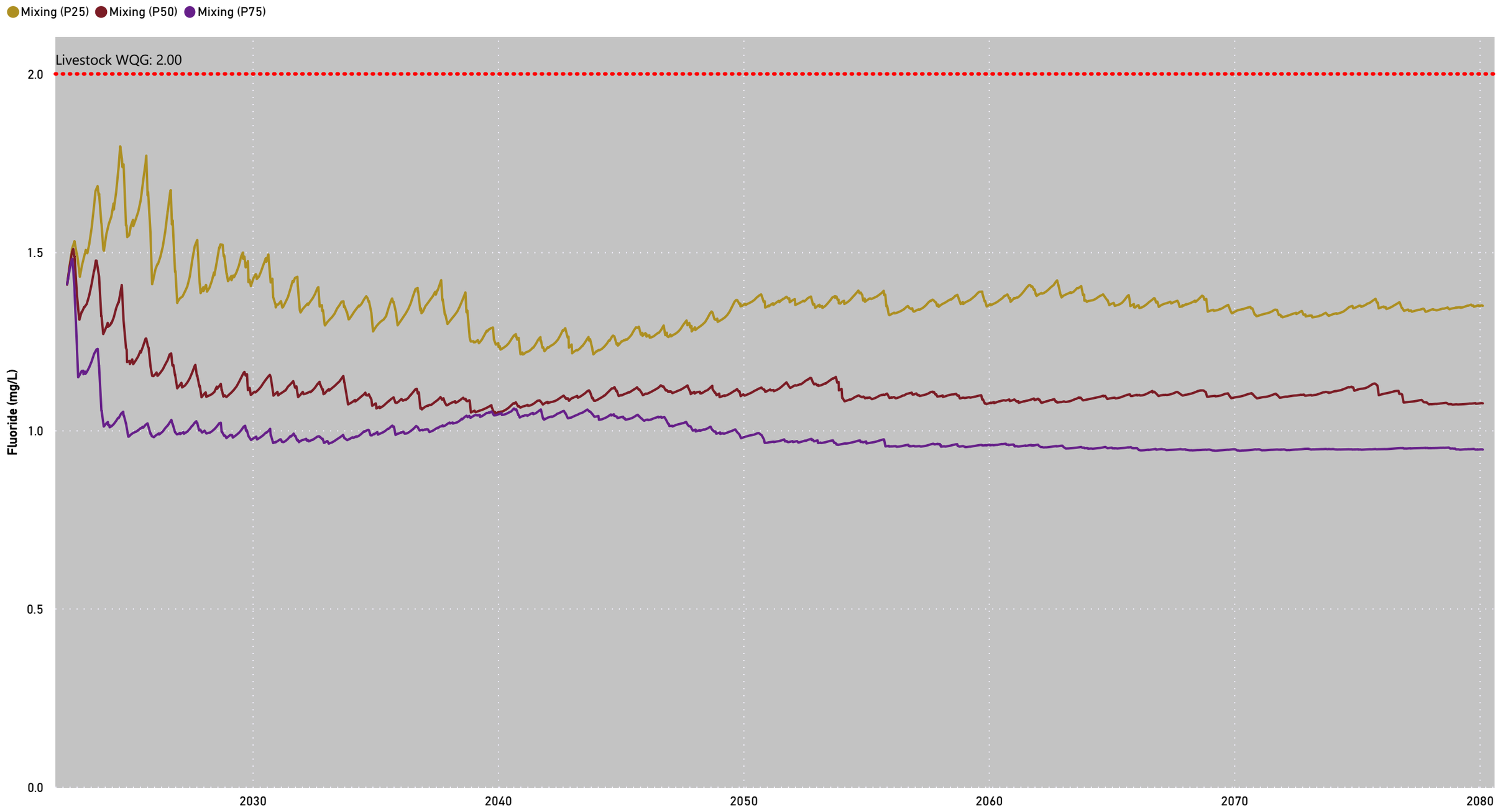

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - Higher Value: 2,000.00
Livestock WQG - Lower Value: 1,000.00
Sulfate (mg/L)
2,000
1,500
1,000
500
0
2030
2040
2050
2060
2070
2080

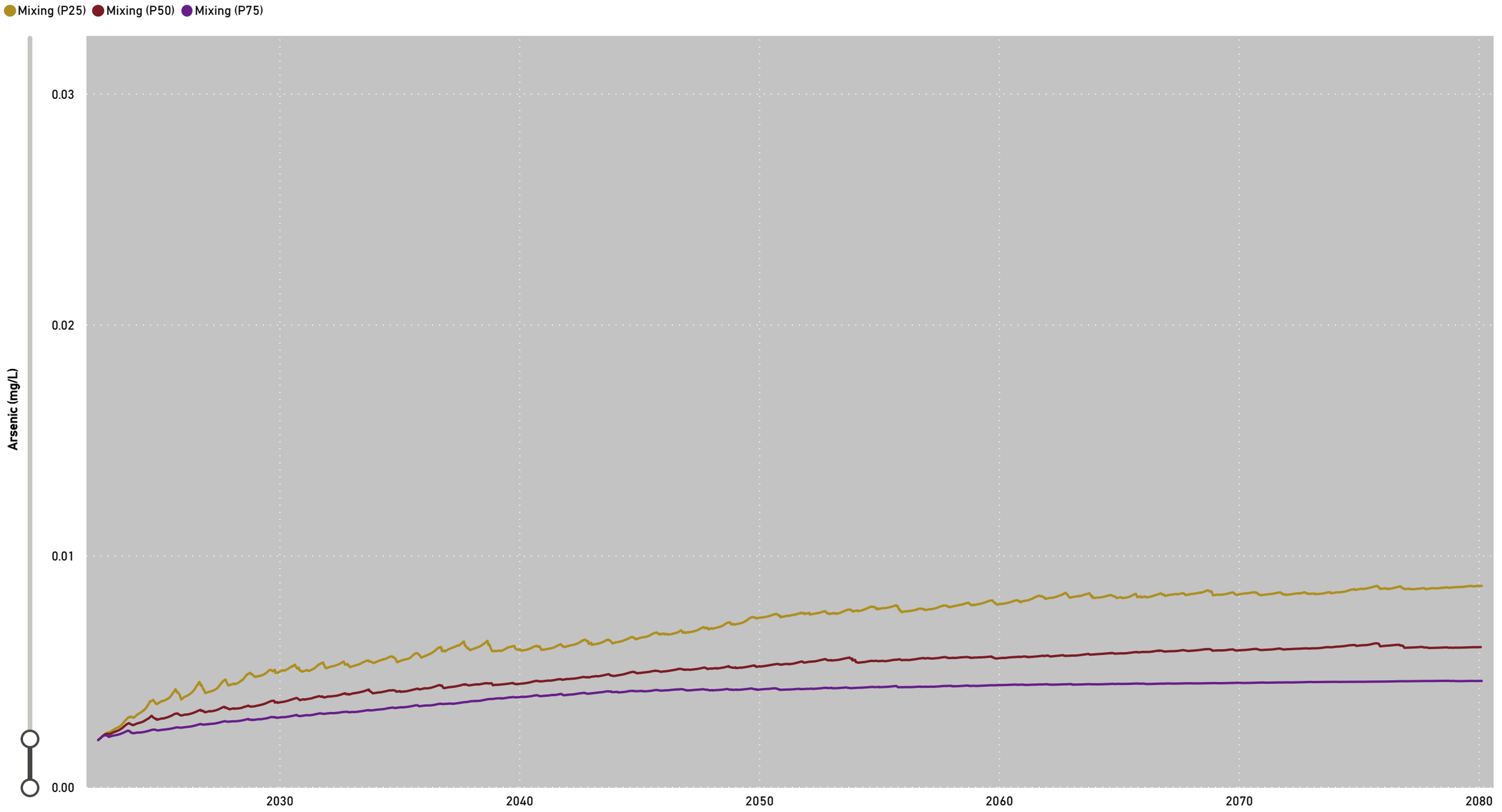

Mixing (P25)
Mixing (P50)
Mixing (P75)
Magnesium (mg/L)
0
20
40
60
80
2030
2040
2050
2060
2070
2080

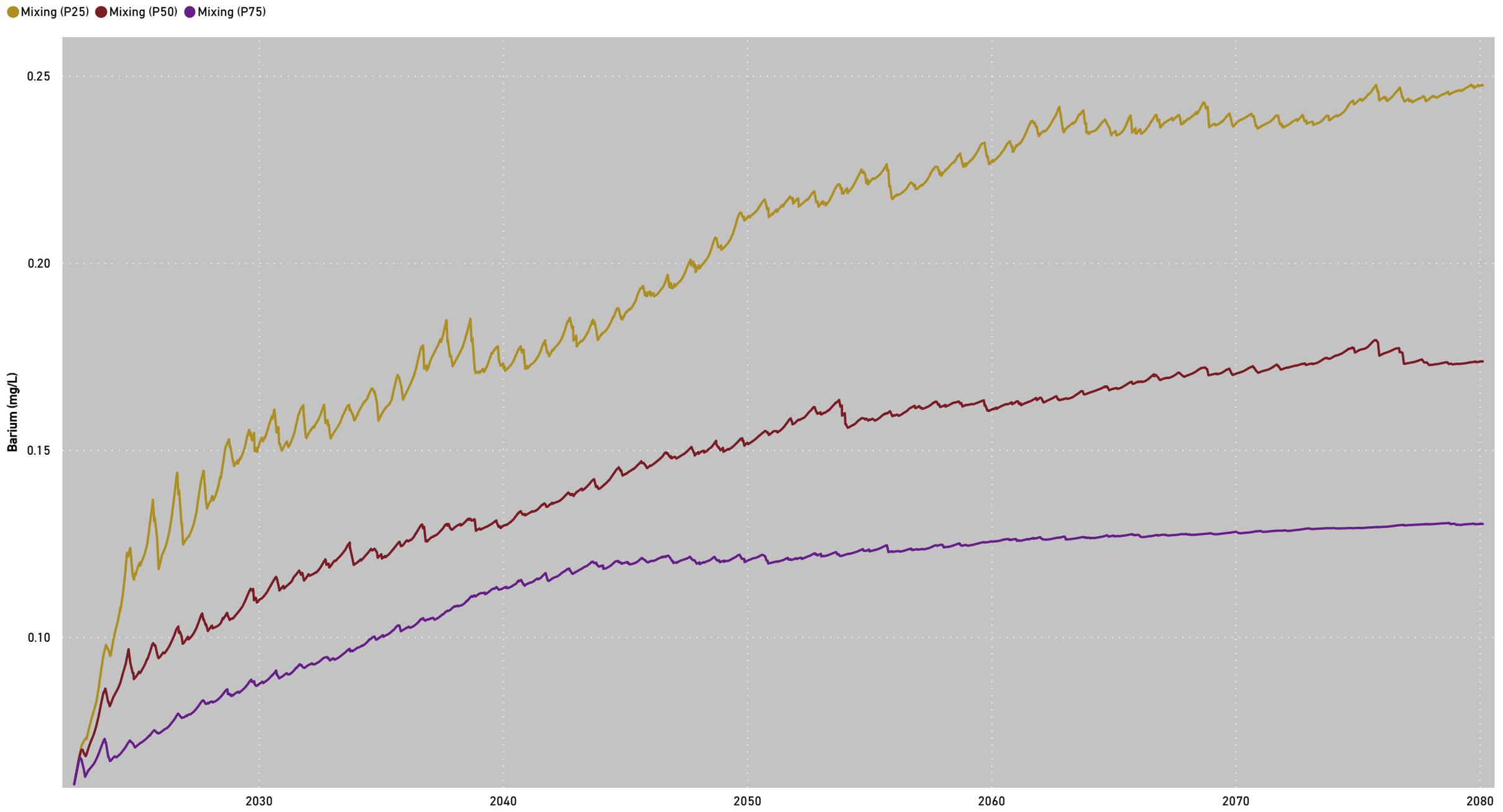

Mixing (P25)
Mixing (P50)
Mixing (P75)
Sodium (mg/L)
0
50
100
150
200
2030
2040
2050
2060
2070
2080

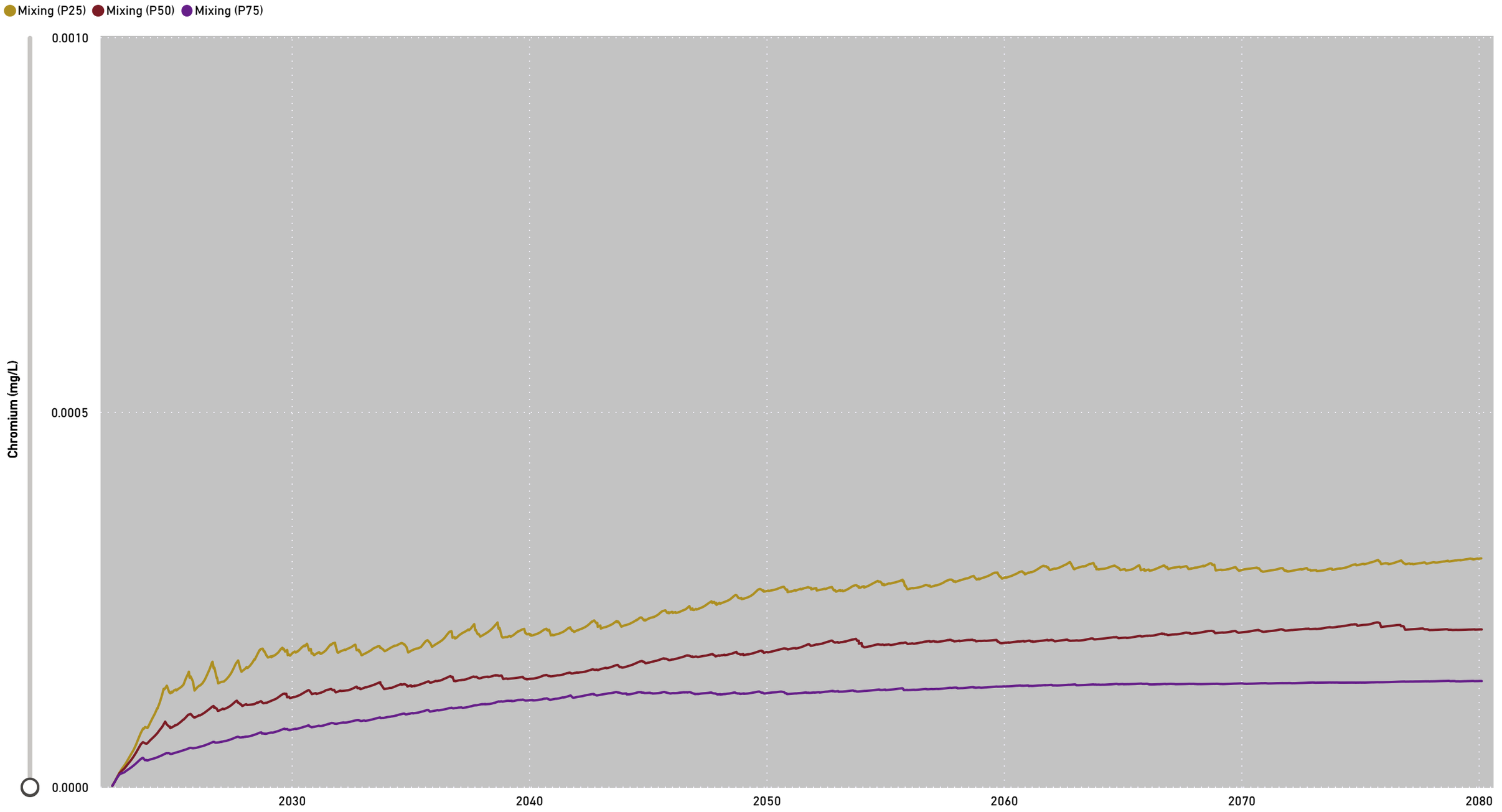

Mixing (P25)
Mixing (P50)
Mixing (P75)
Potassium (mg/L)
0
10
20
30
40
50
60
2030
2040
2050
2060
2070
2080

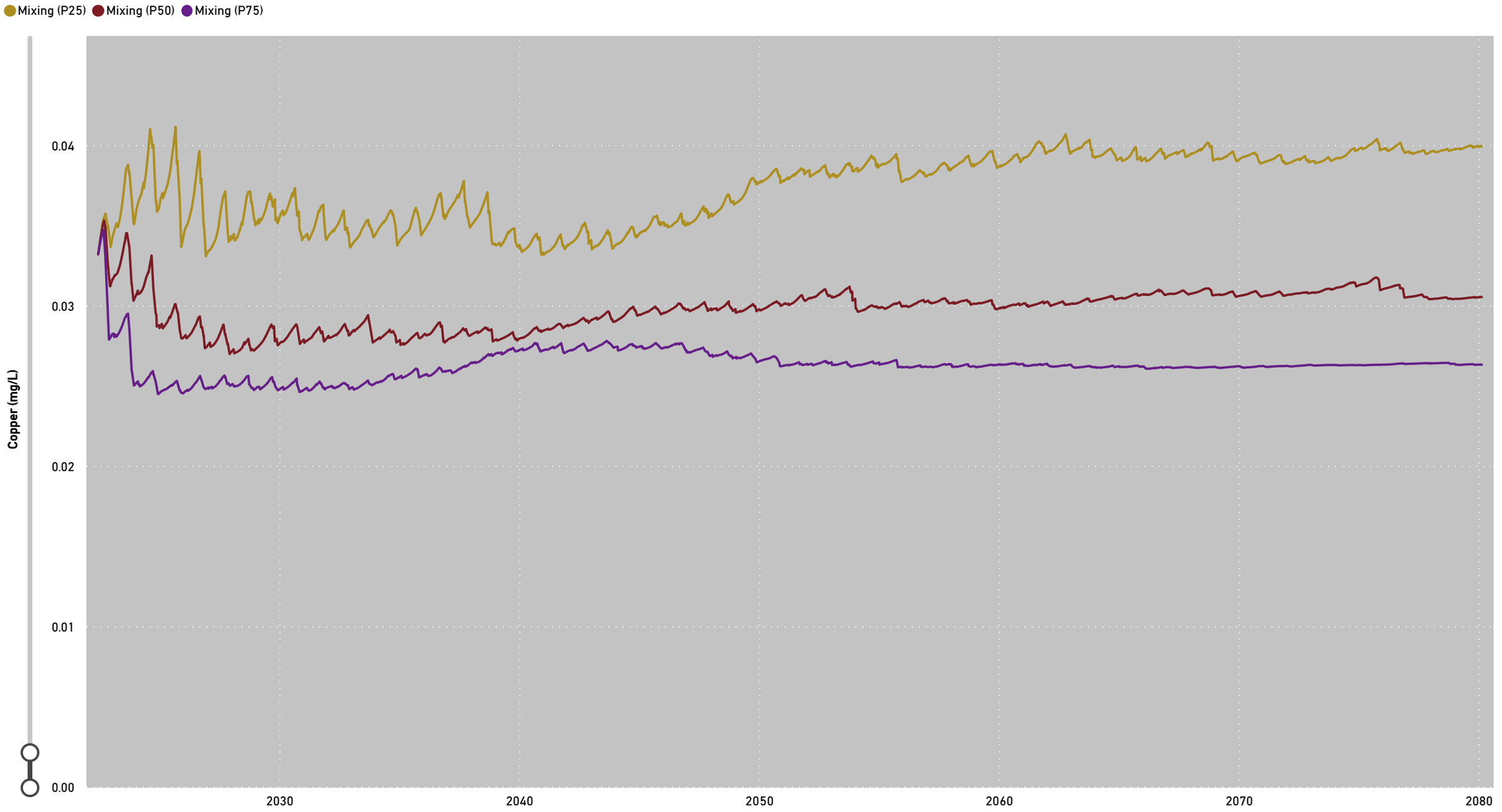

Mixing (P25)
Mixing (P50)
Mixing (P75)
Chloride (mg/L)
0
100
200
300
400
2030
2040
2050
2060
2070
2080

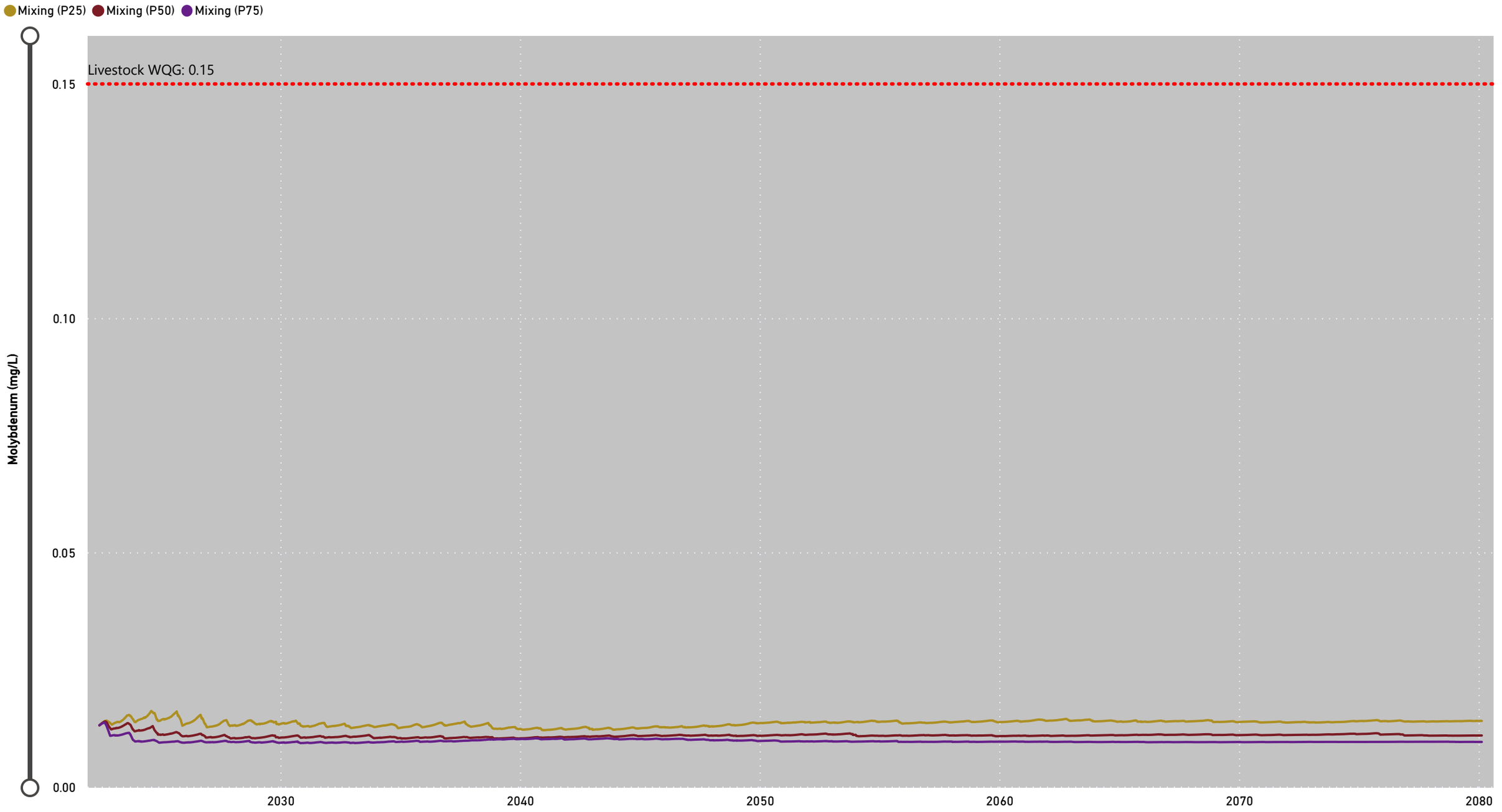

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 2.00
Fluoride (mg/L)
2.0
1.5
1.0
0.5
0.0
2030
2040
2050
2060
2070
2080

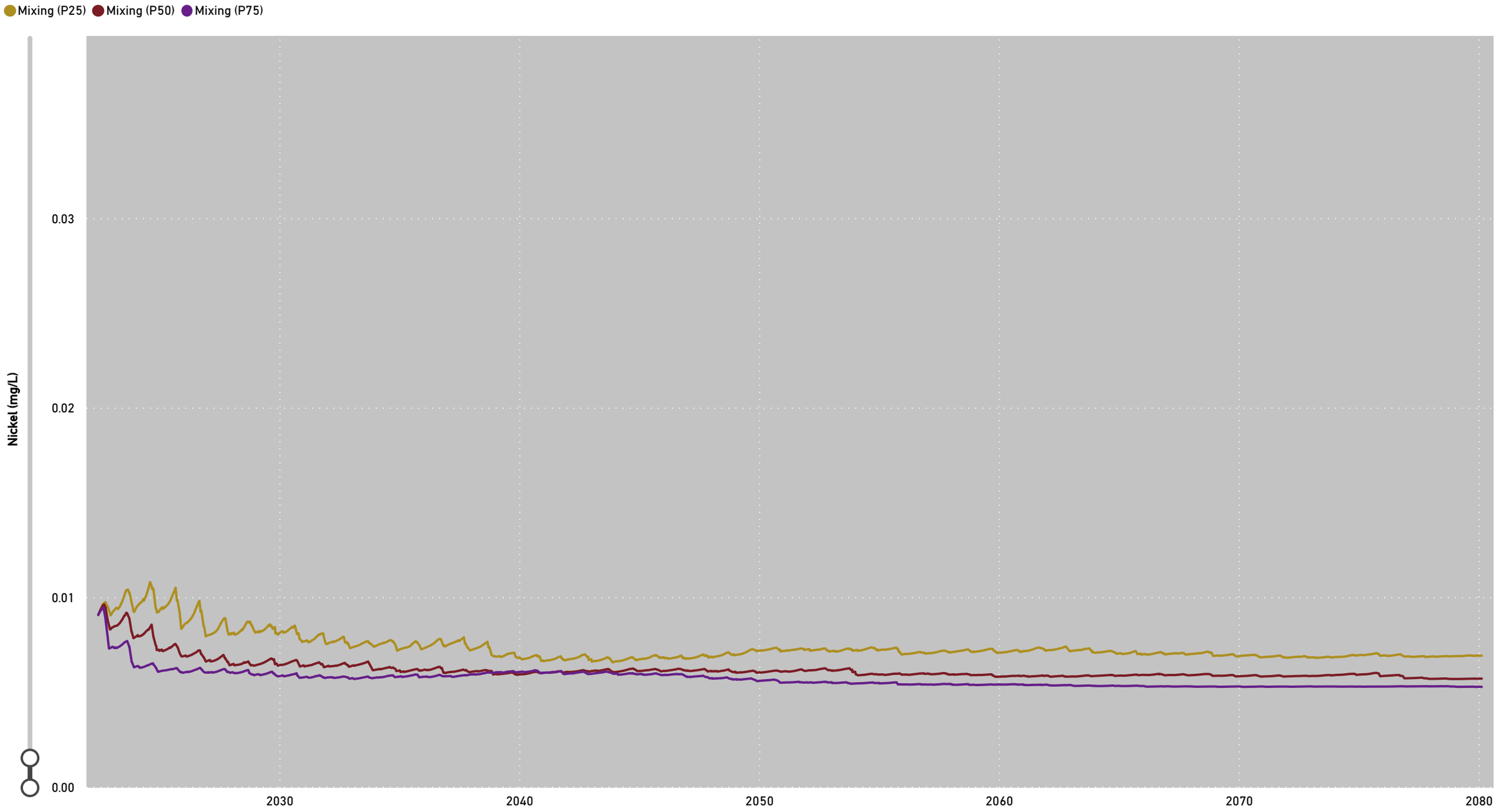

Mixing (P25)
Mixing (P50)
Mixing (P75)
Arsenic (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

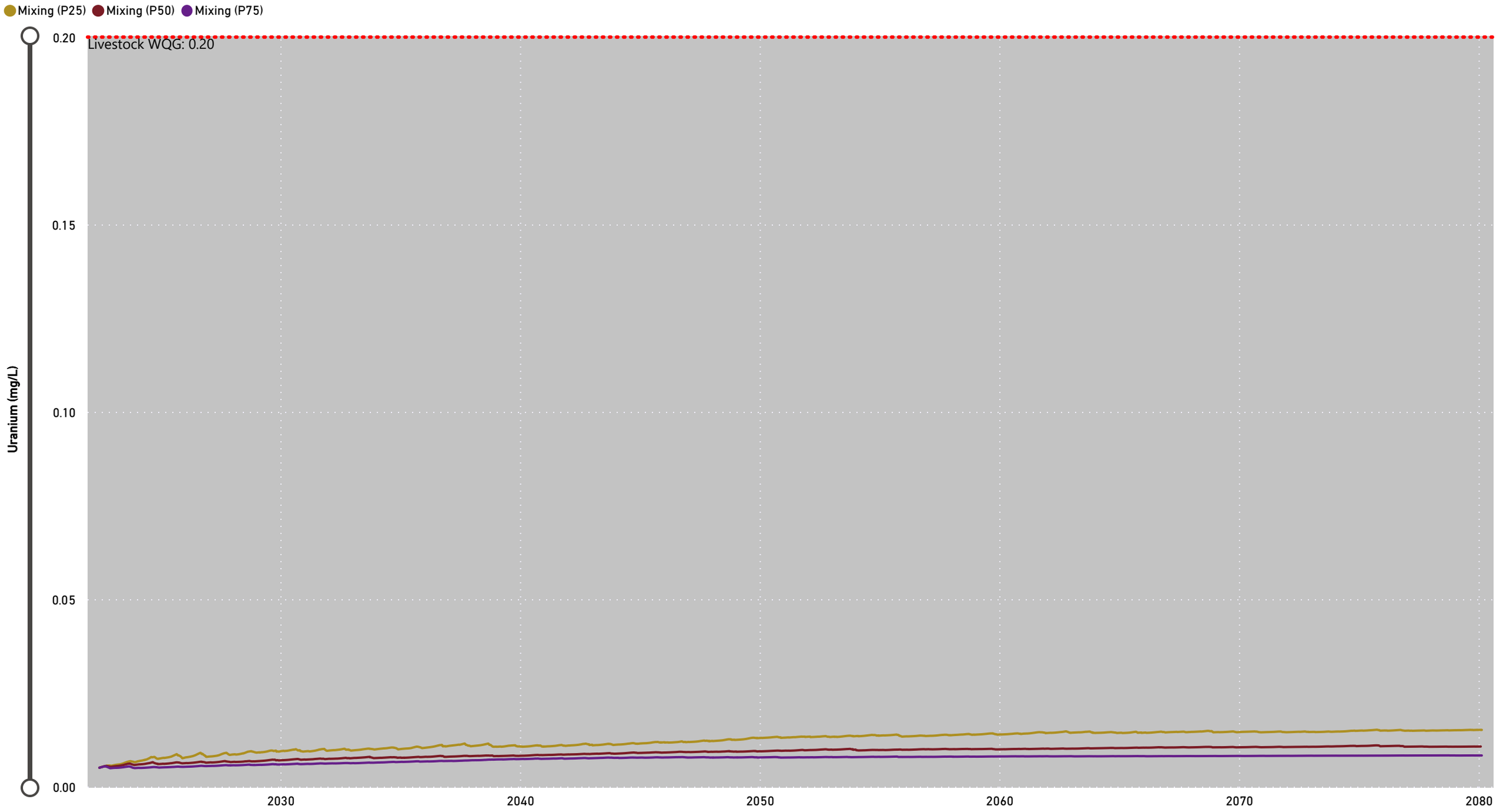

Mixing (P25)
Mixing (P50)
Mixing (P75)
Barium (mg/L)
0.25
0.20
0.15
0.10
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Chromium (mg/L)
0.0010
0.0005
0.0000
2030
2040
2050
2060
2070
2080

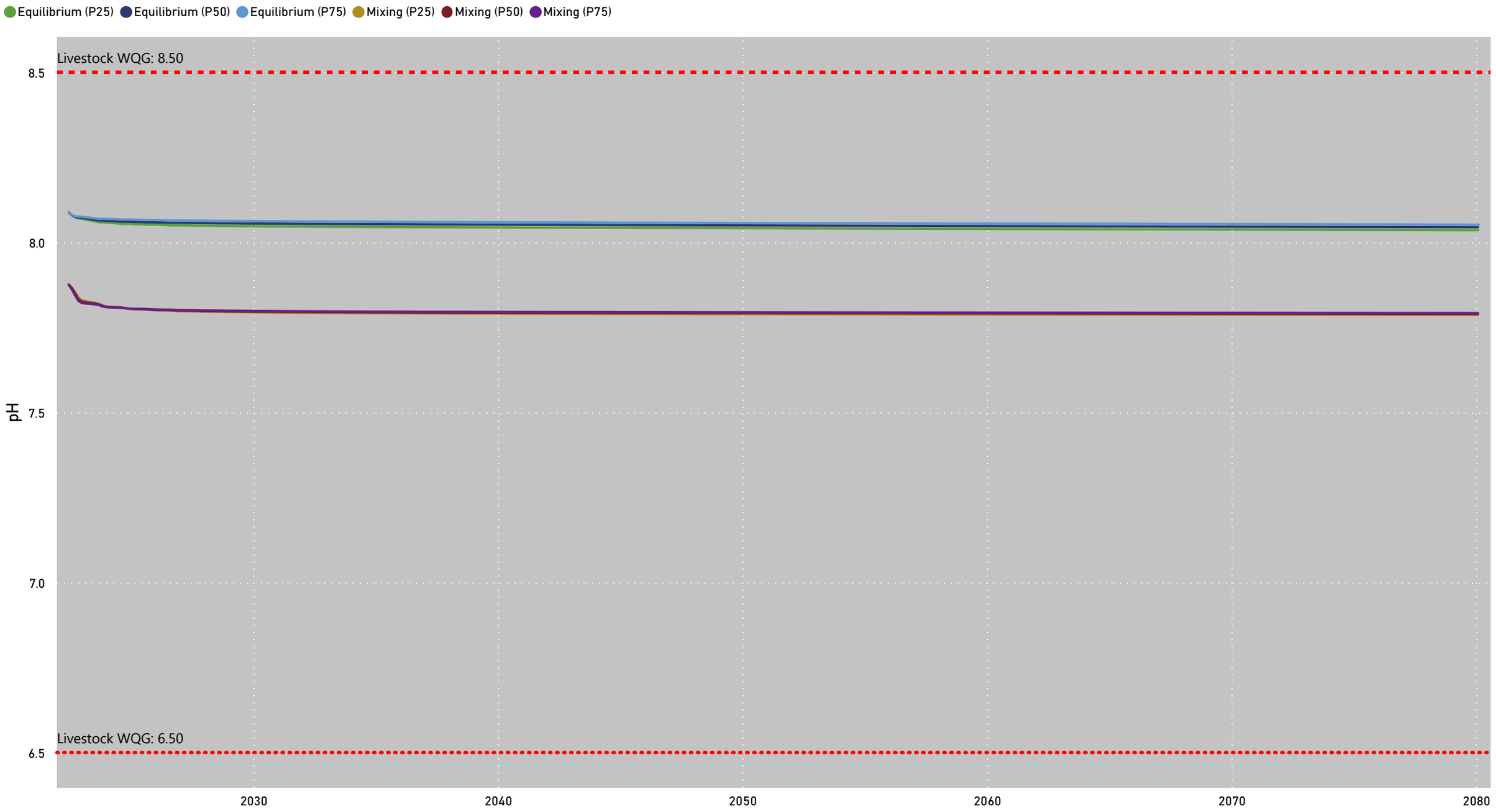

Mixing (P25)
Mixing (P50)
Mixing (P75)
Copper (mg/L)
0.04
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

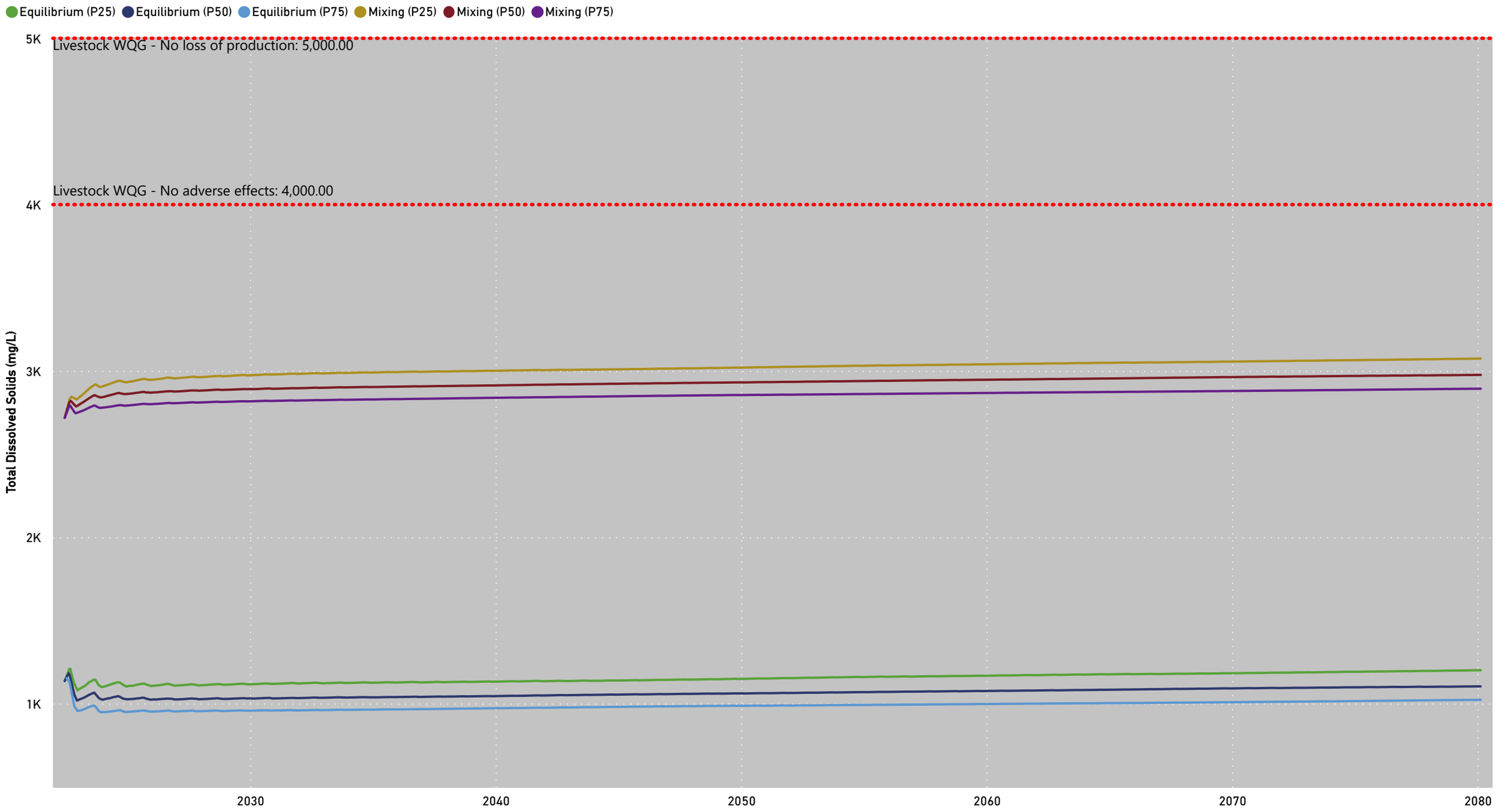

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 0.15
Molybdenum (mg/L)
0.15
0.10
0.05
0.00
2030
2040
2050
2060
2070
2080

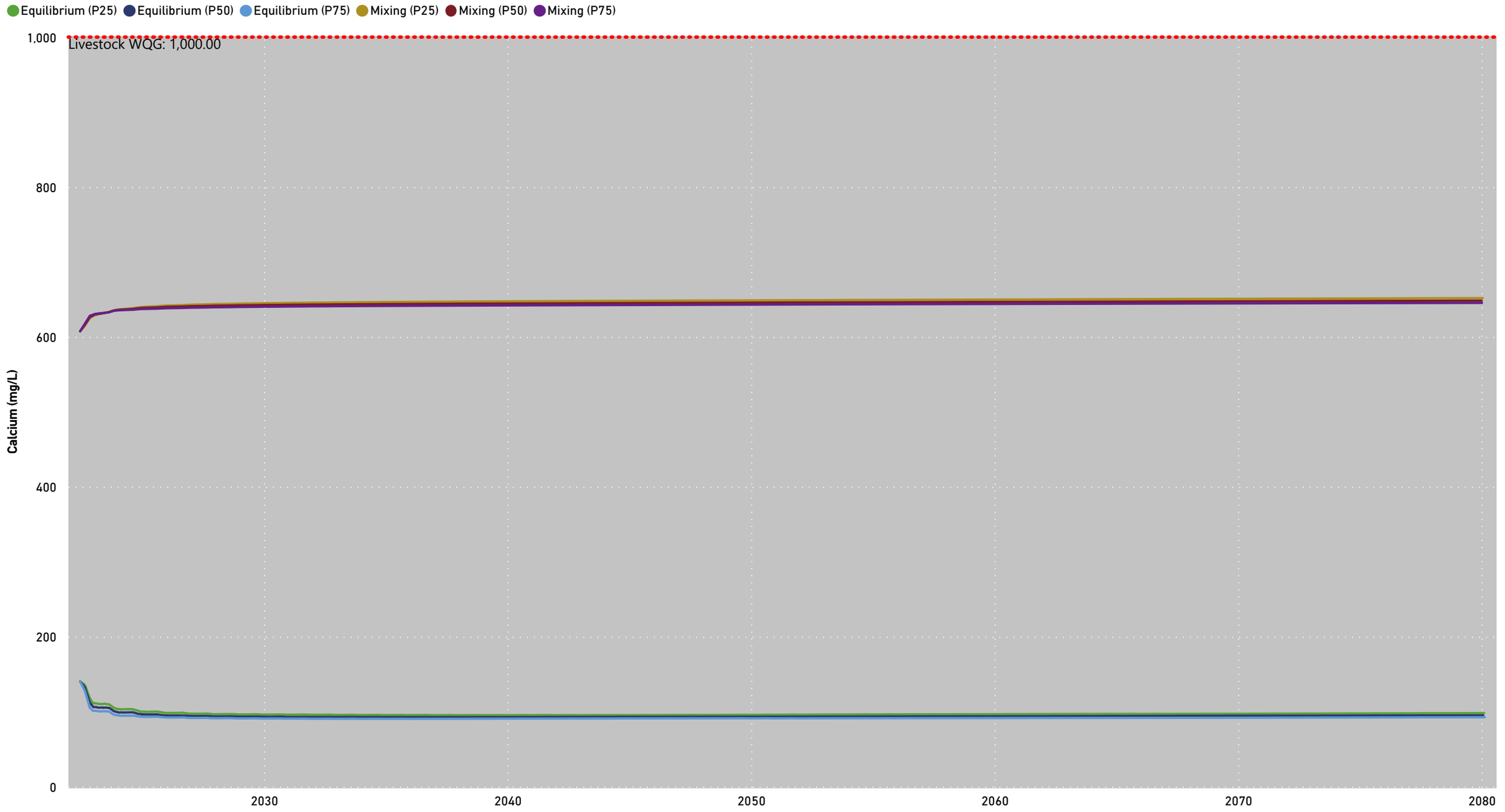

Mixing (P25)
Mixing (P50)
Mixing (P75)
Nickel (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

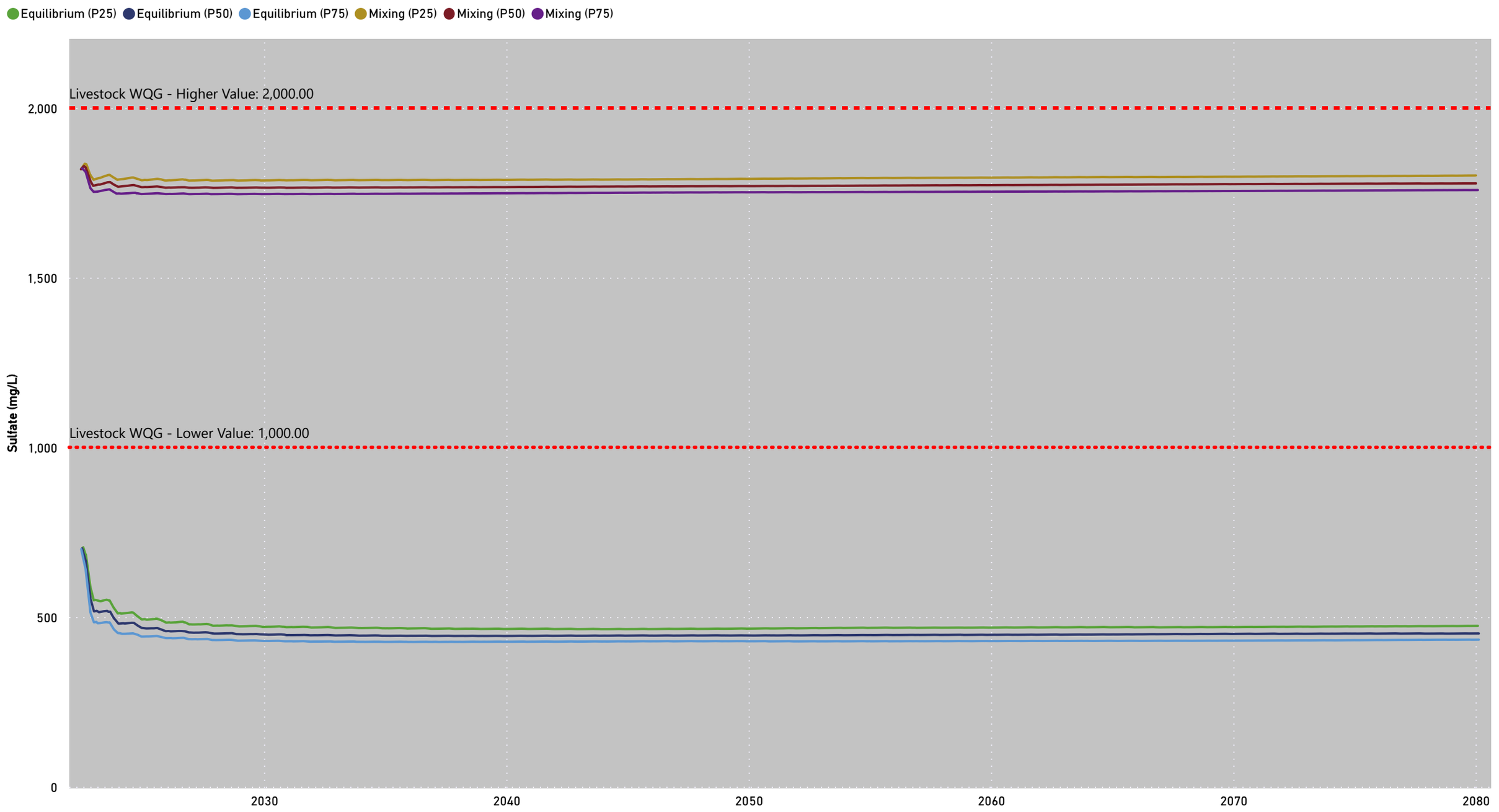

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 0.20
Uranium (mg/L)
0.20
0.15
0.10
0.05
0.00
2030
2040
2050
2060
2070
2080

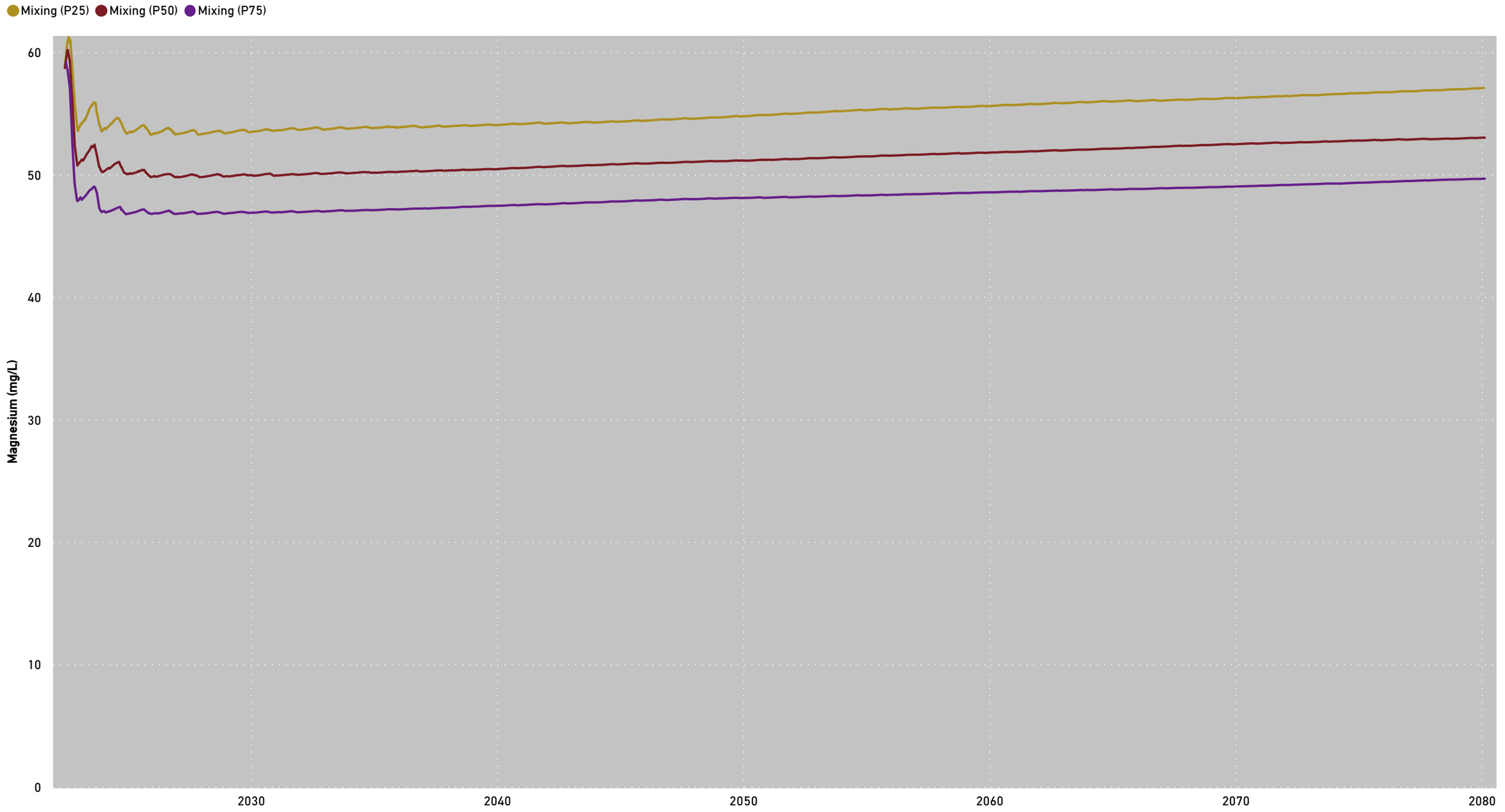
J.7.3 South Pit modelled long-term water quality (scenario 1)

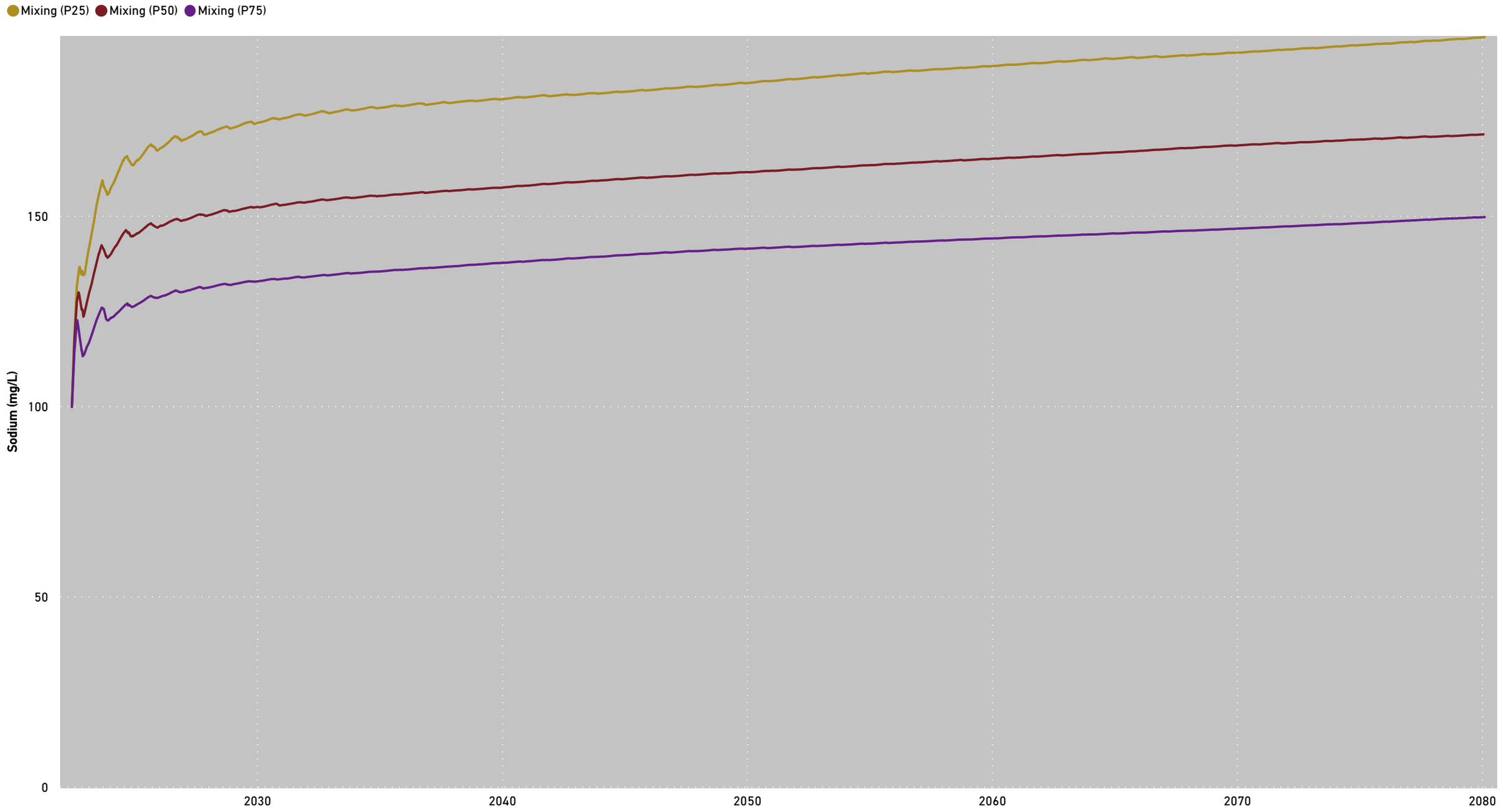

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 8.50
Livestock WQG: 6.50
pH
8.5
8.0
7.5
7.0
6.5
2030
2040
2050
2060
2070
2080

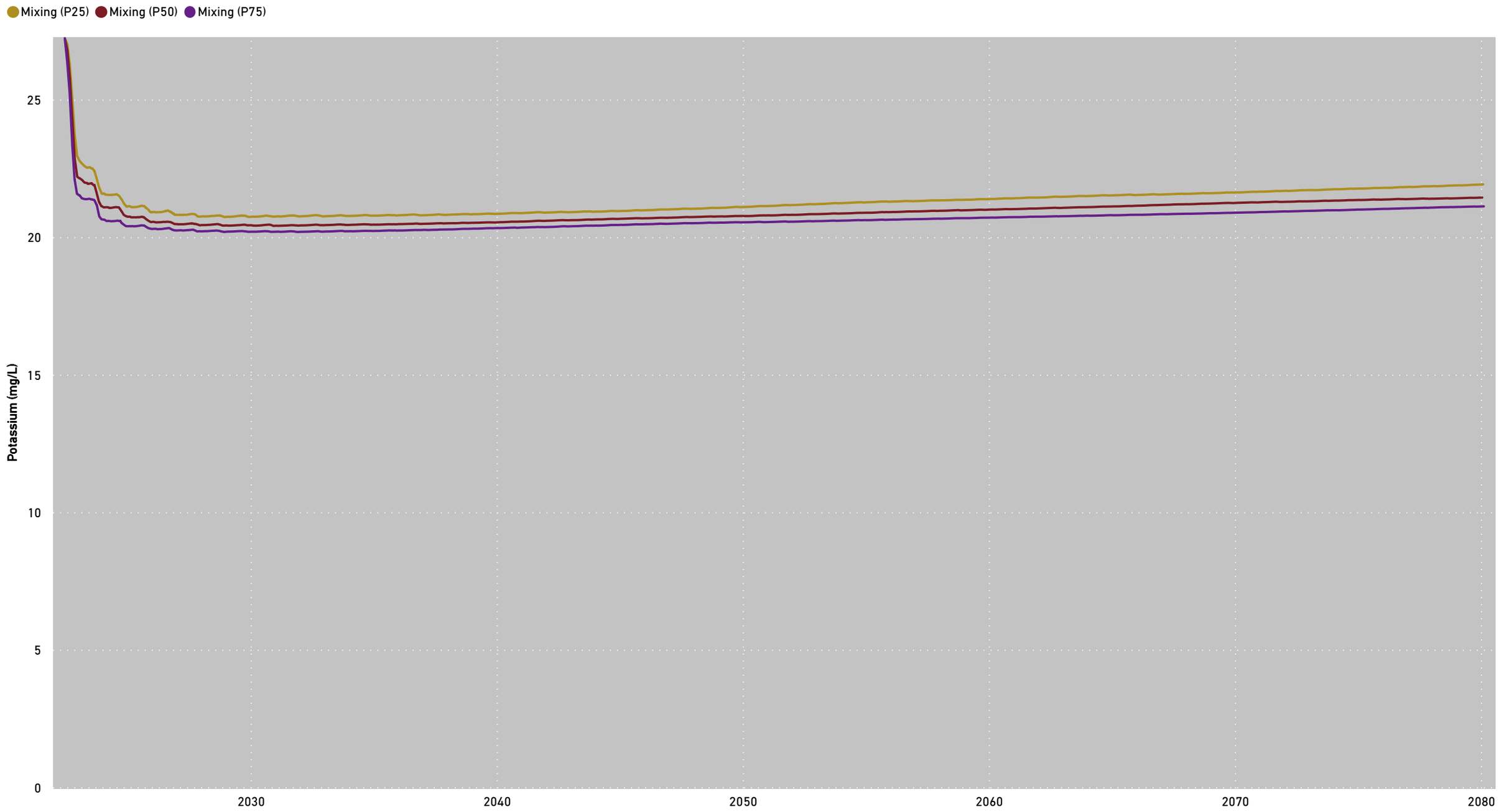

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - No loss of production: 5,000.00
Livestock WQG - No adverse effects: 4,000.00
Total Dissolved Solids (mg/L)
5K
4K
3K
2K
1K
2030
2040
2050
2060
2070
2080

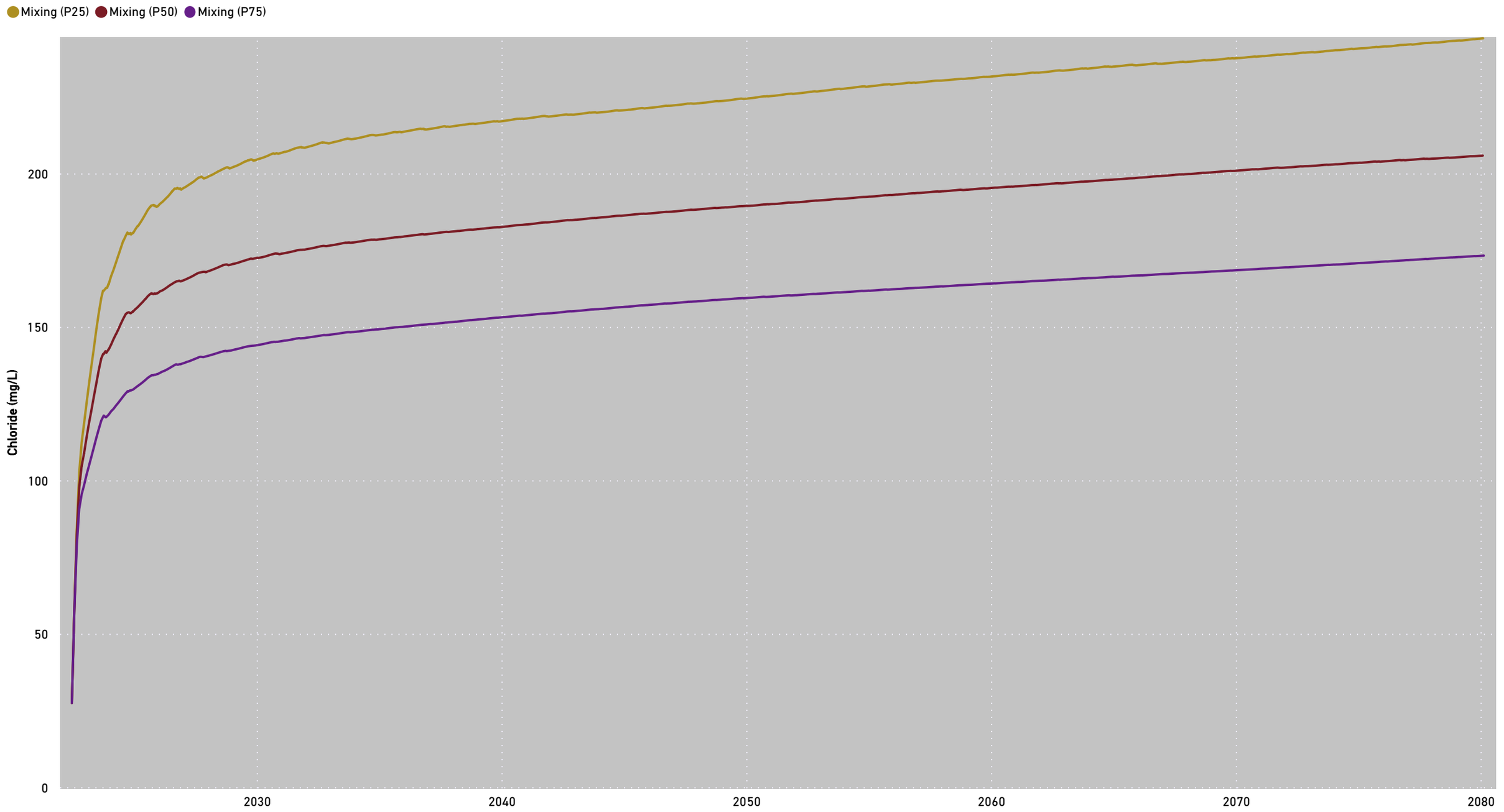

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 1,000.00
Calcium (mg/L)
1,000
800
600
400
200
0
2030
2040
2050
2060
2070
2080

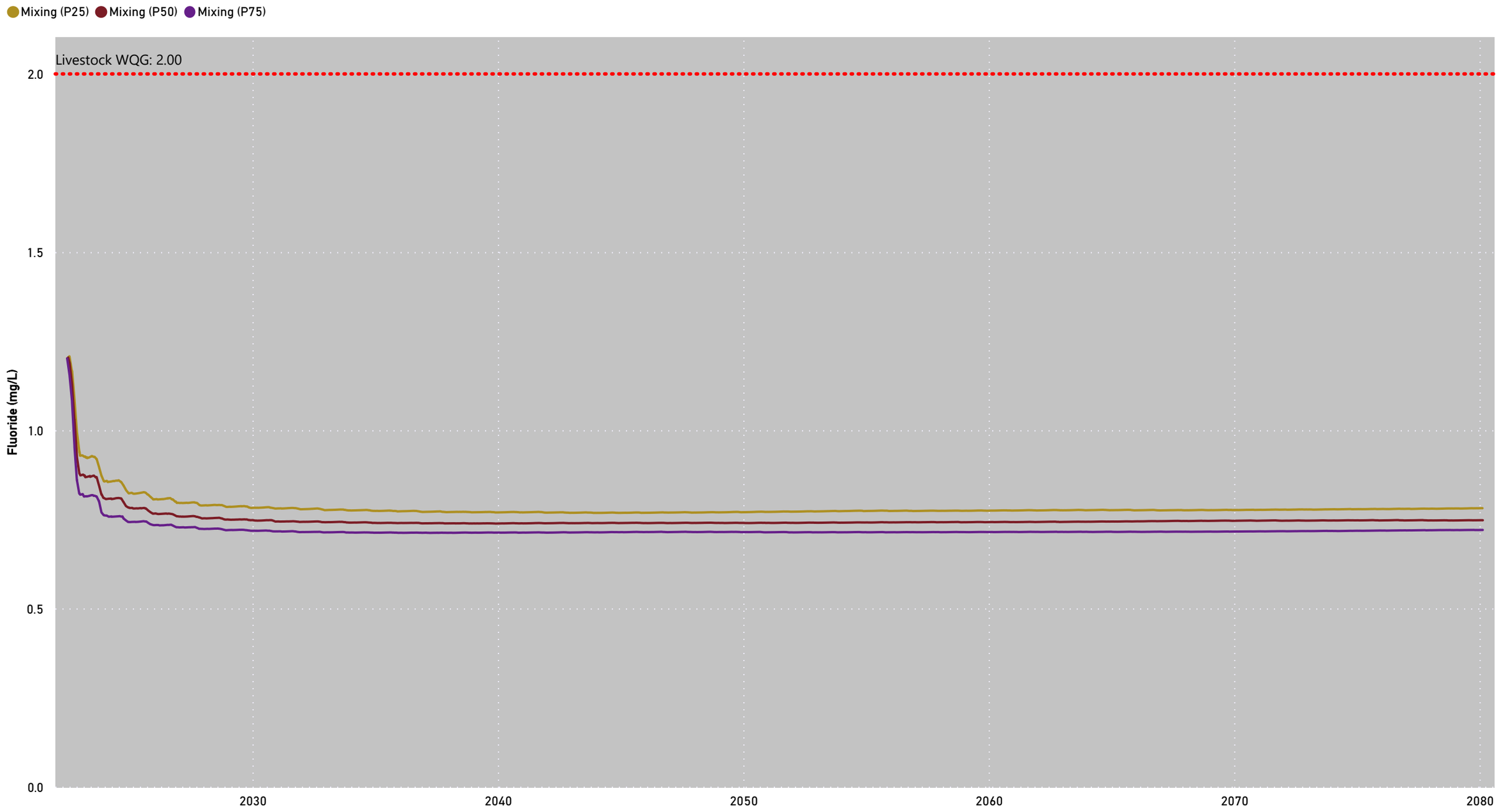

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - Higher Value: 2,000.00
Livestock WQG - Lower Value: 1,000.00
Sulfate (mg/L)
2,000
1,500
1,000
500
0
2030
2040
2050
2060
2070
2080

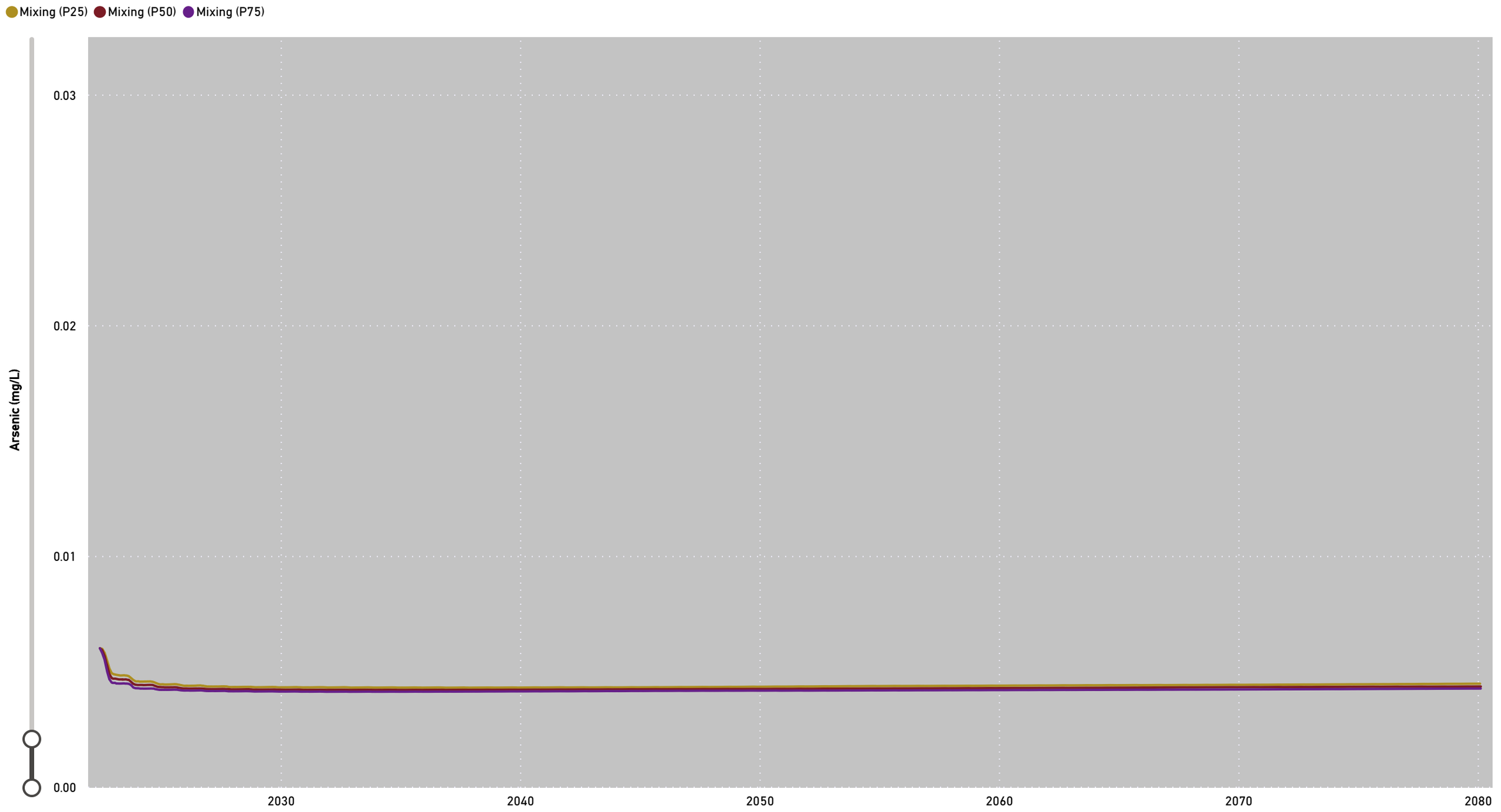

Mixing (P25)
Mixing (P50)
Mixing (P75)
Magnesium (mg/L)
60
50
40
30
20
10
0
2030
2040
2050
2060
2070
2080

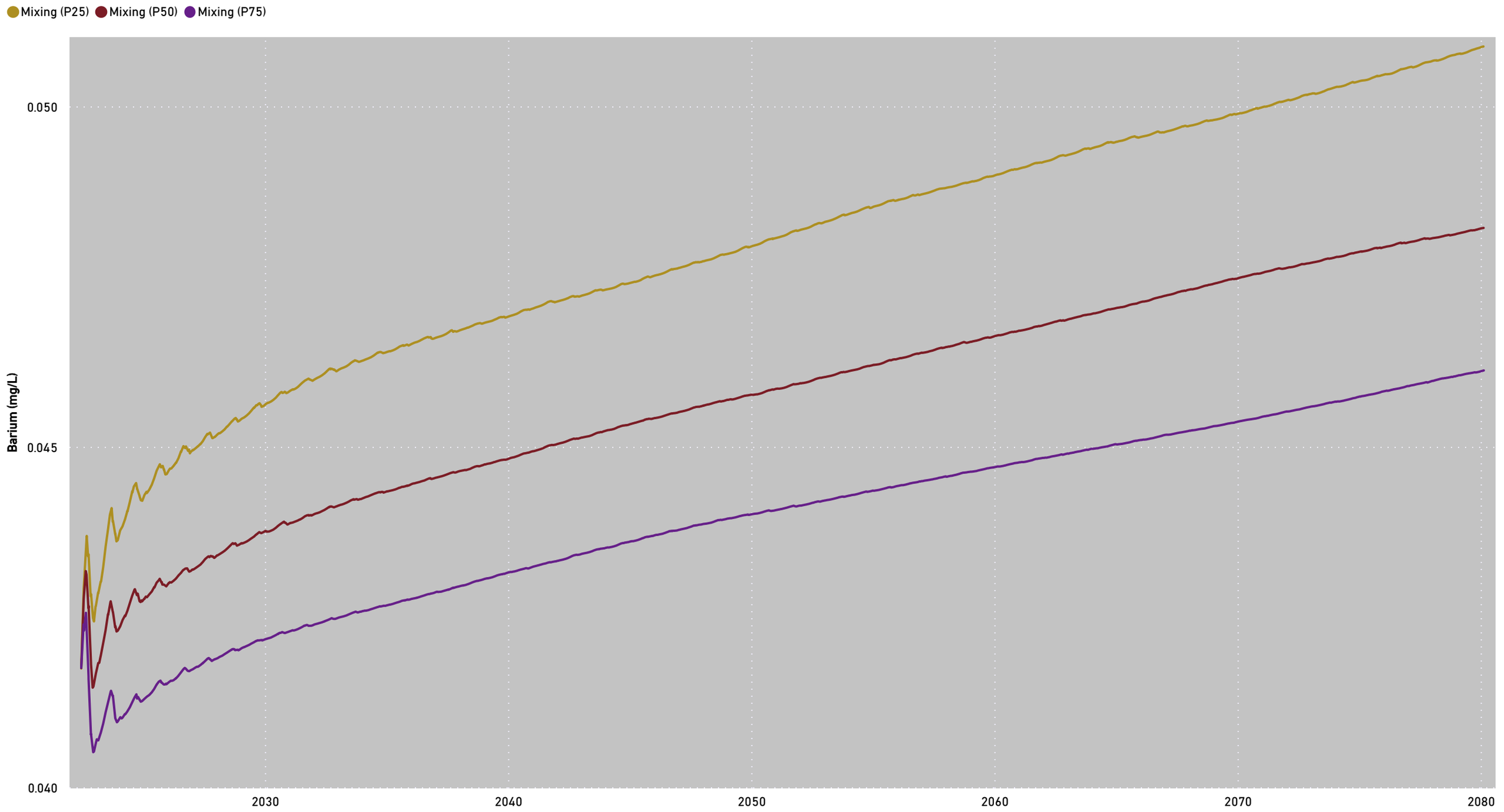

Mixing (P25)
Mixing (P50)
Mixing (P75)
Sodium (mg/L)
0
50
100
150
2030
2040
2050
2060
2070
2080

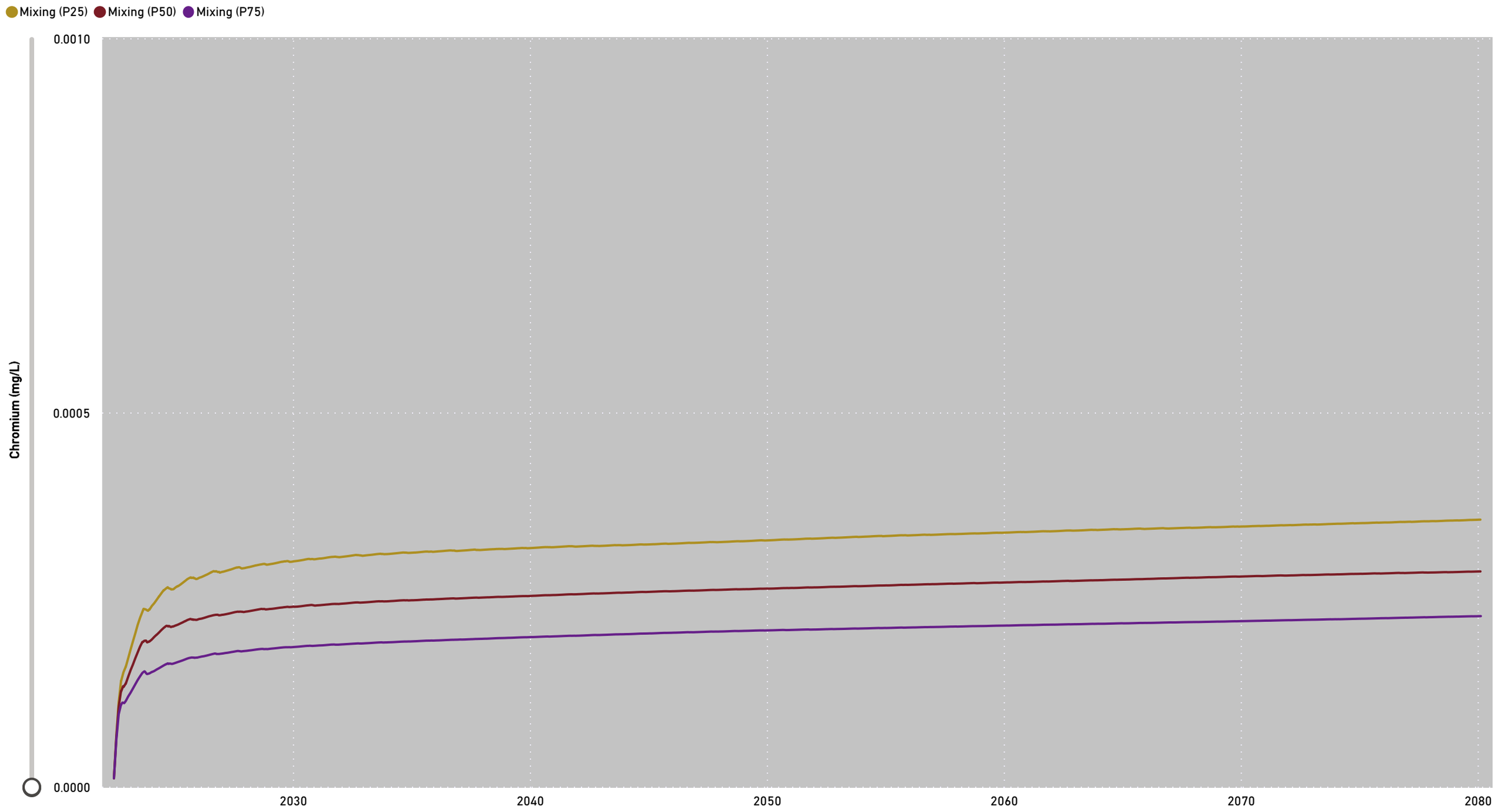

Mixing (P25)
Mixing (P50)
Mixing (P75)
Potassium (mg/L)
25
20
15
10
5
0
2030
2040
2050
2060
2070
2080

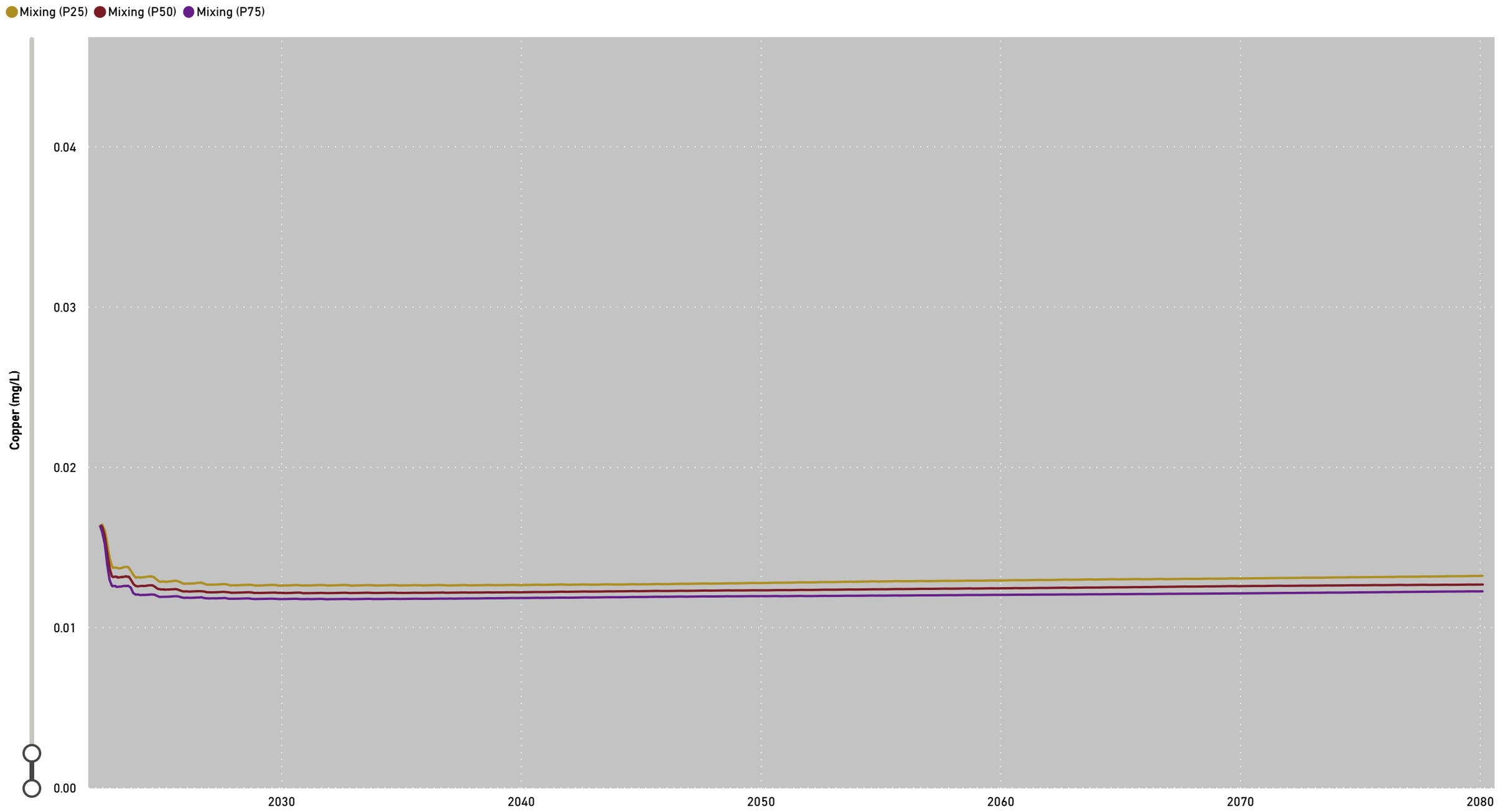

Mixing (P25)
Mixing (P50)
Mixing (P75)
Chloride (mg/L)
0
50
100
150
200
2030
2040
2050
2060
2070
2080

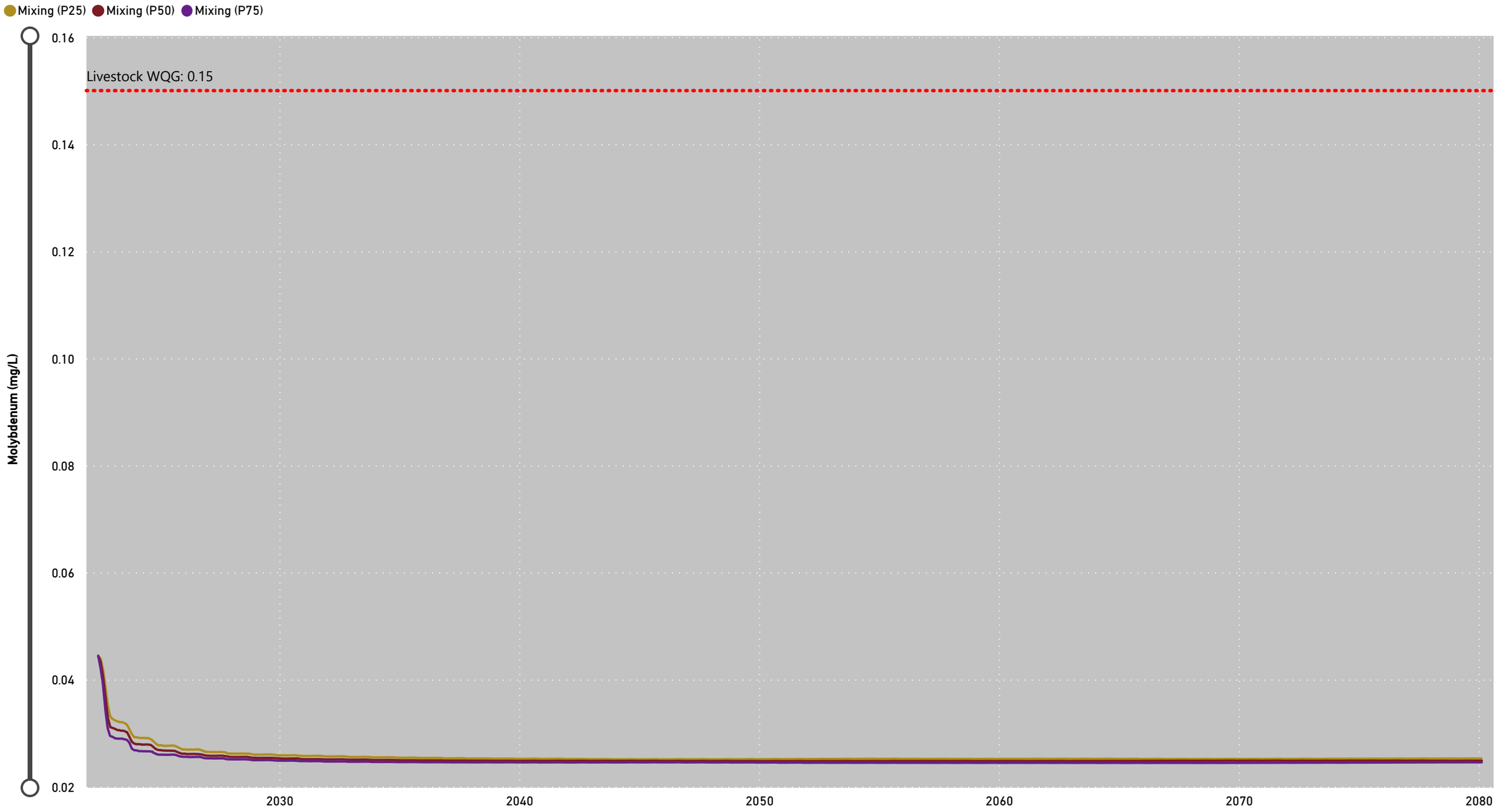

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 2.00
Fluoride (mg/L)
2.0
1.5
1.0
0.5
0.0
2030
2040
2050
2060
2070
2080

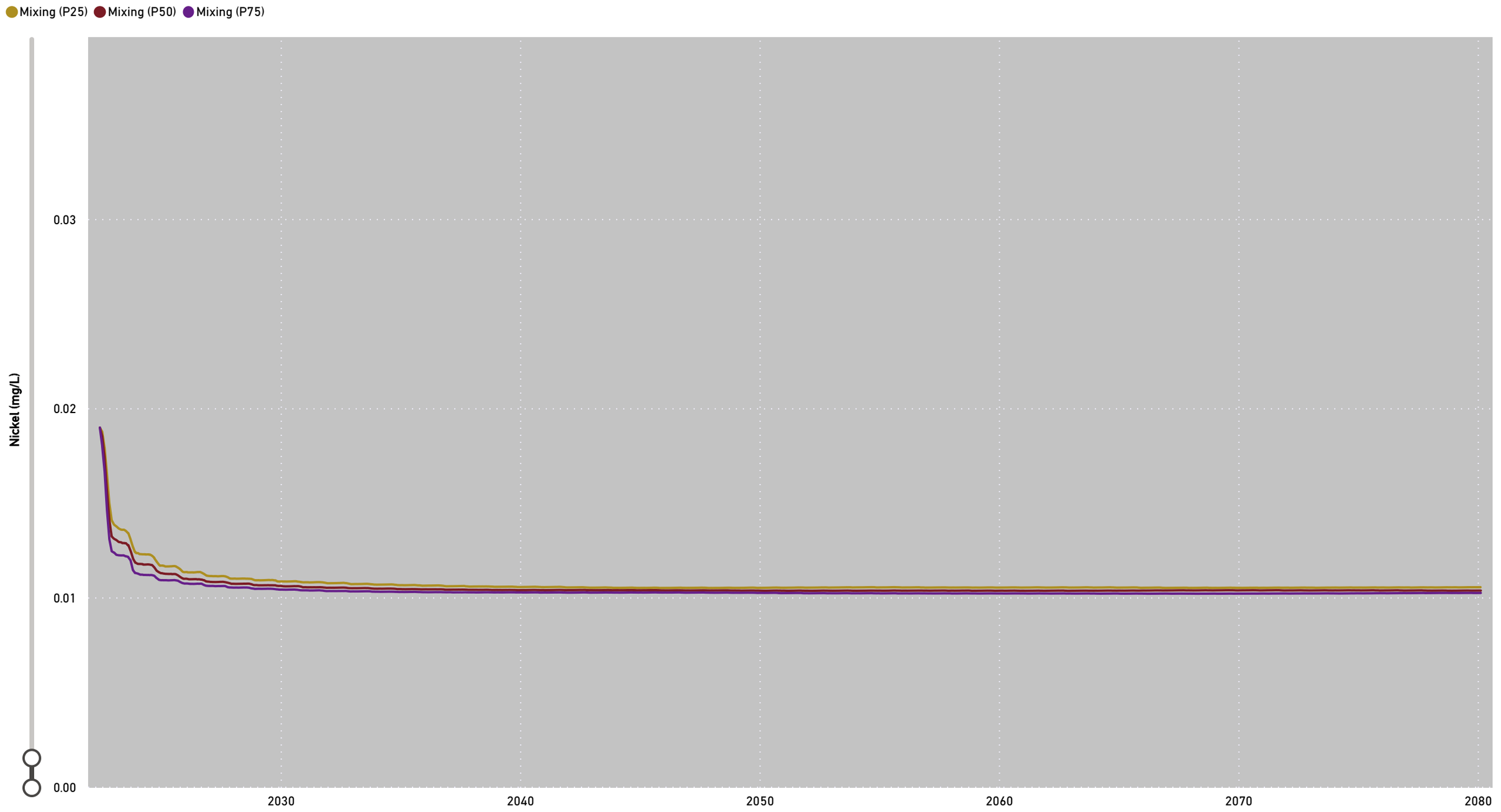

Mixing (P25)
Mixing (P50)
Mixing (P75)
Arsenic (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

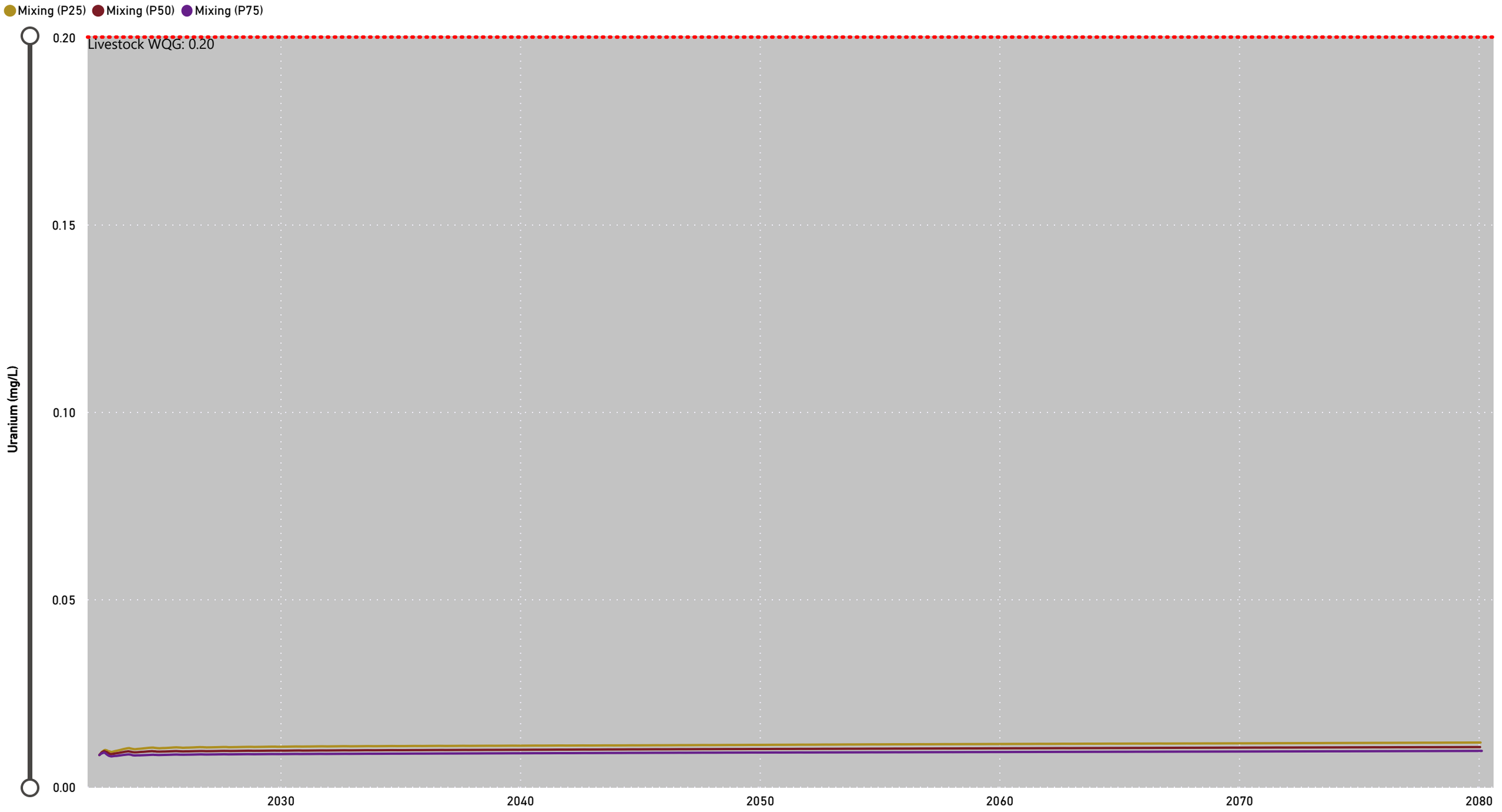

Mixing (P25)
Mixing (P50)
Mixing (P75)
Barium (mg/L)
0.050
0.045
0.040
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Chromium (mg/L)
0.0010
0.0005
0.0000
2030
2040
2050
2060
2070
2080

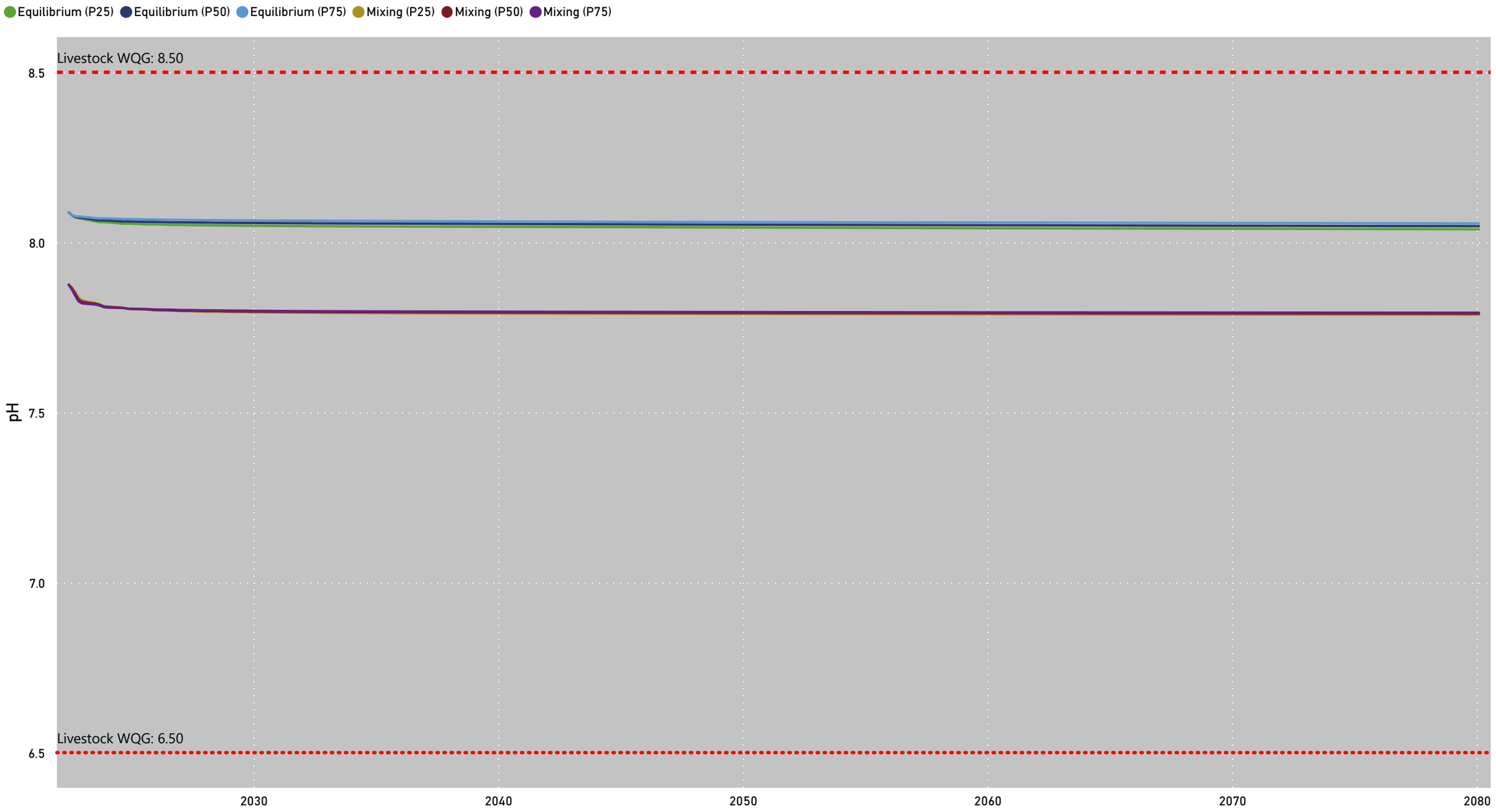

Mixing (P25)
Mixing (P50)
Mixing (P75)
Copper (mg/L)
0.04
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

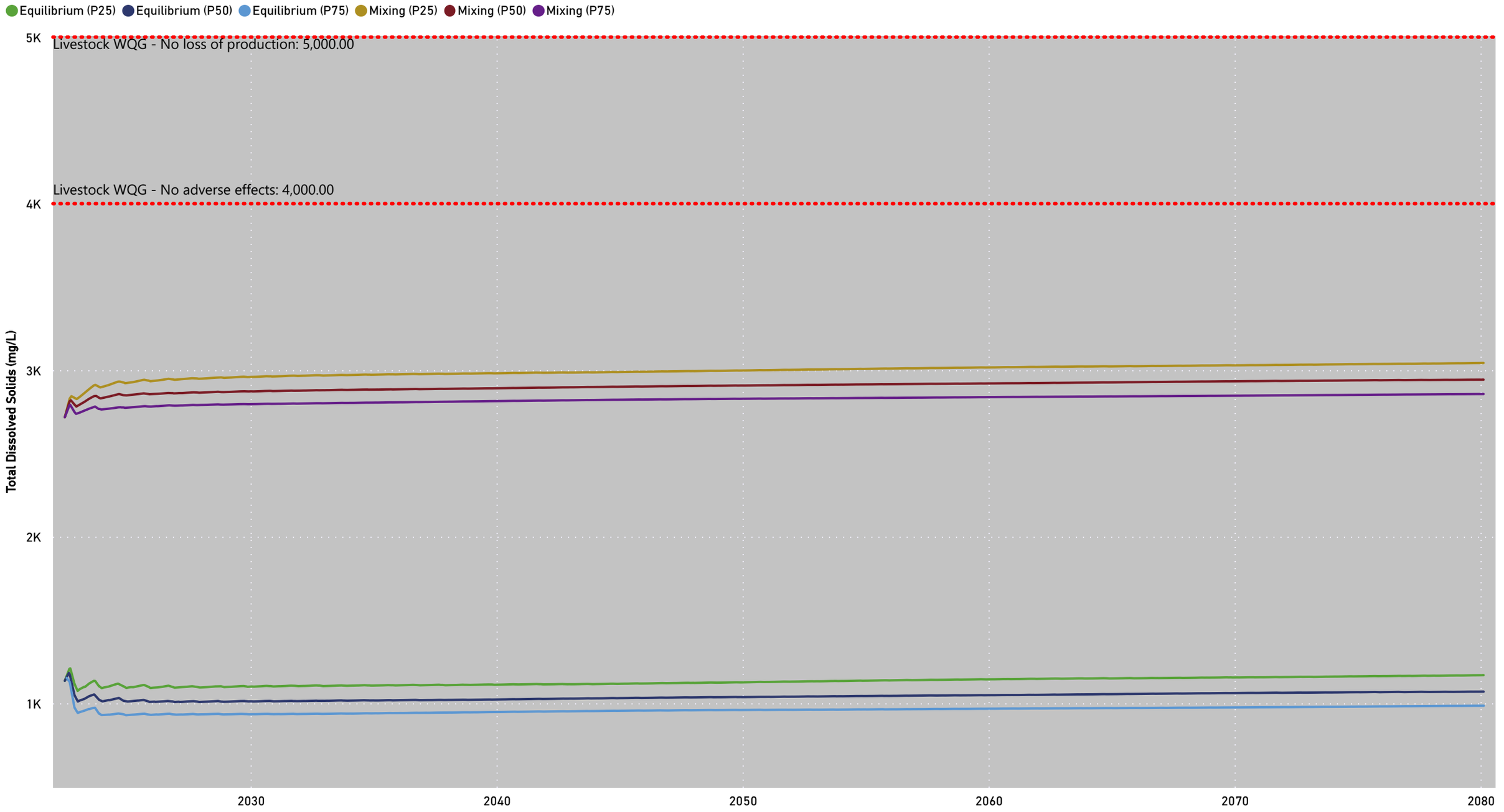

Mixing (P25)
Mixing (P50)
Mixing (P75)
Molybdenum (mg/L)
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
Livestock WQG: 0.15
2030
2040
2050
2060
2070
2080

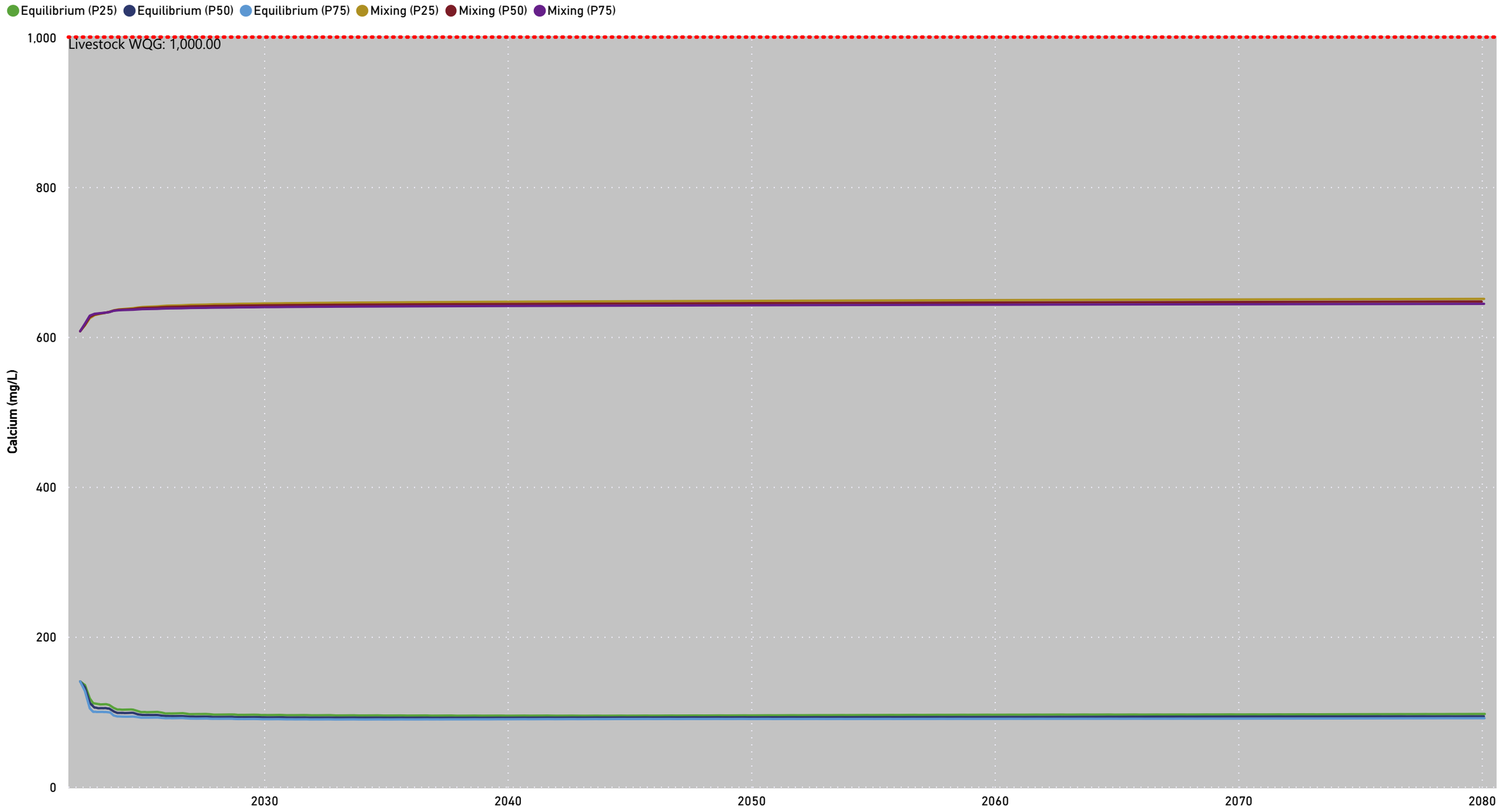

Mixing (P25)
Mixing (P50)
Mixing (P75)
Nickel (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

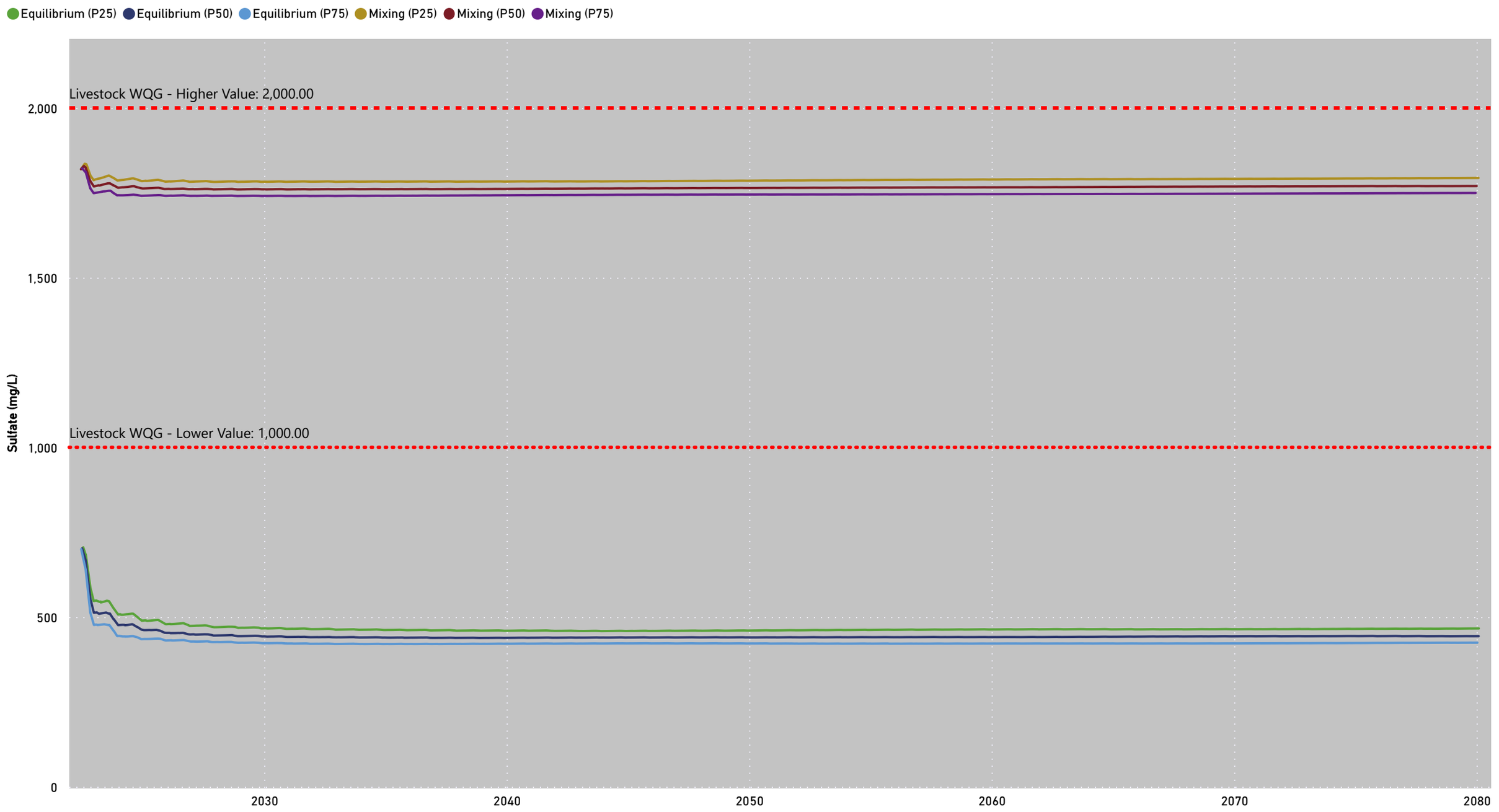

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 0.20
Uranium (mg/L)
0.20
0.15
0.10
0.05
0.00
2030
2040
2050
2060
2070
2080

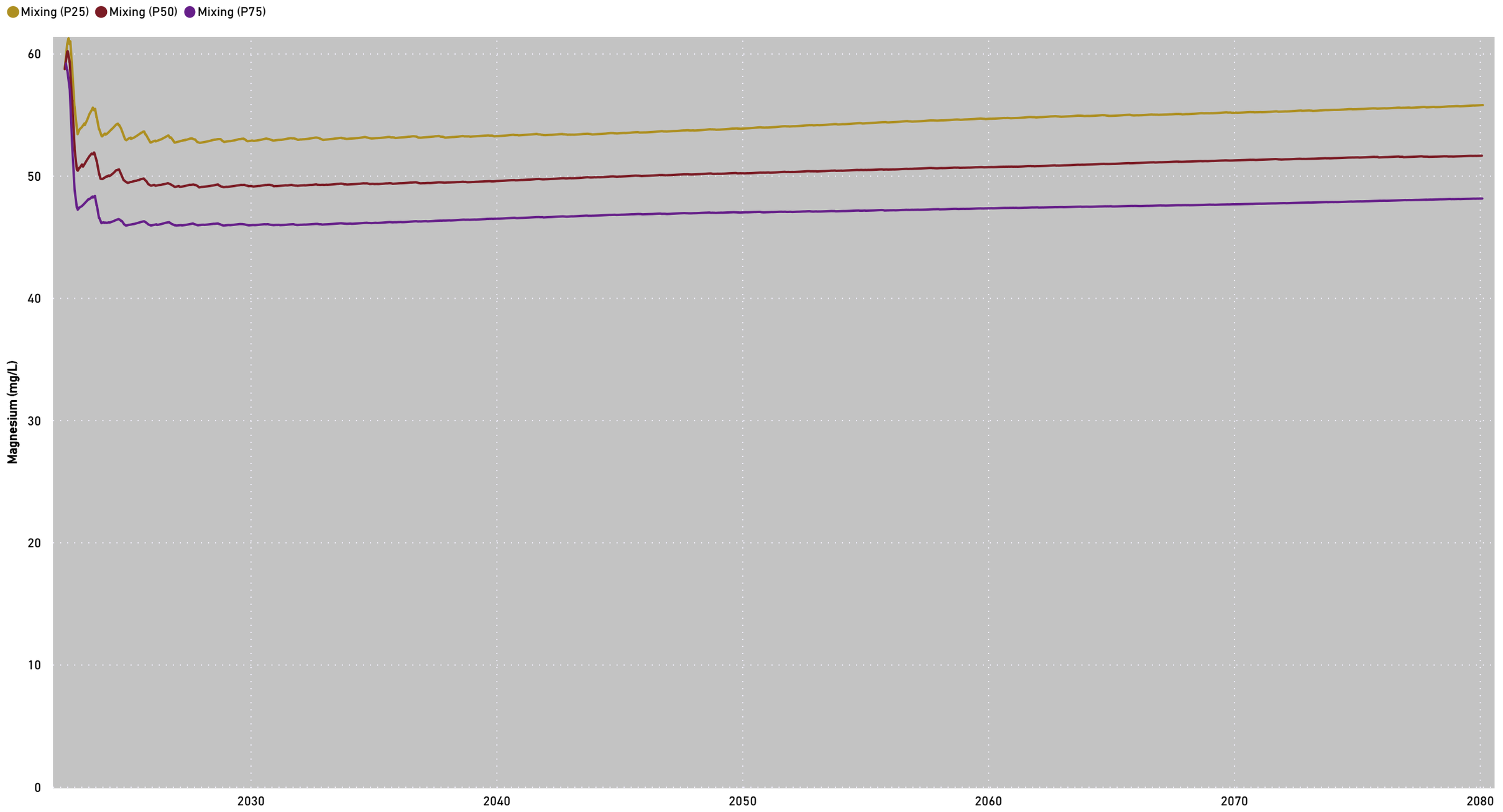
J.7.4 South Pit modelled long-term water quality (scenario 2)

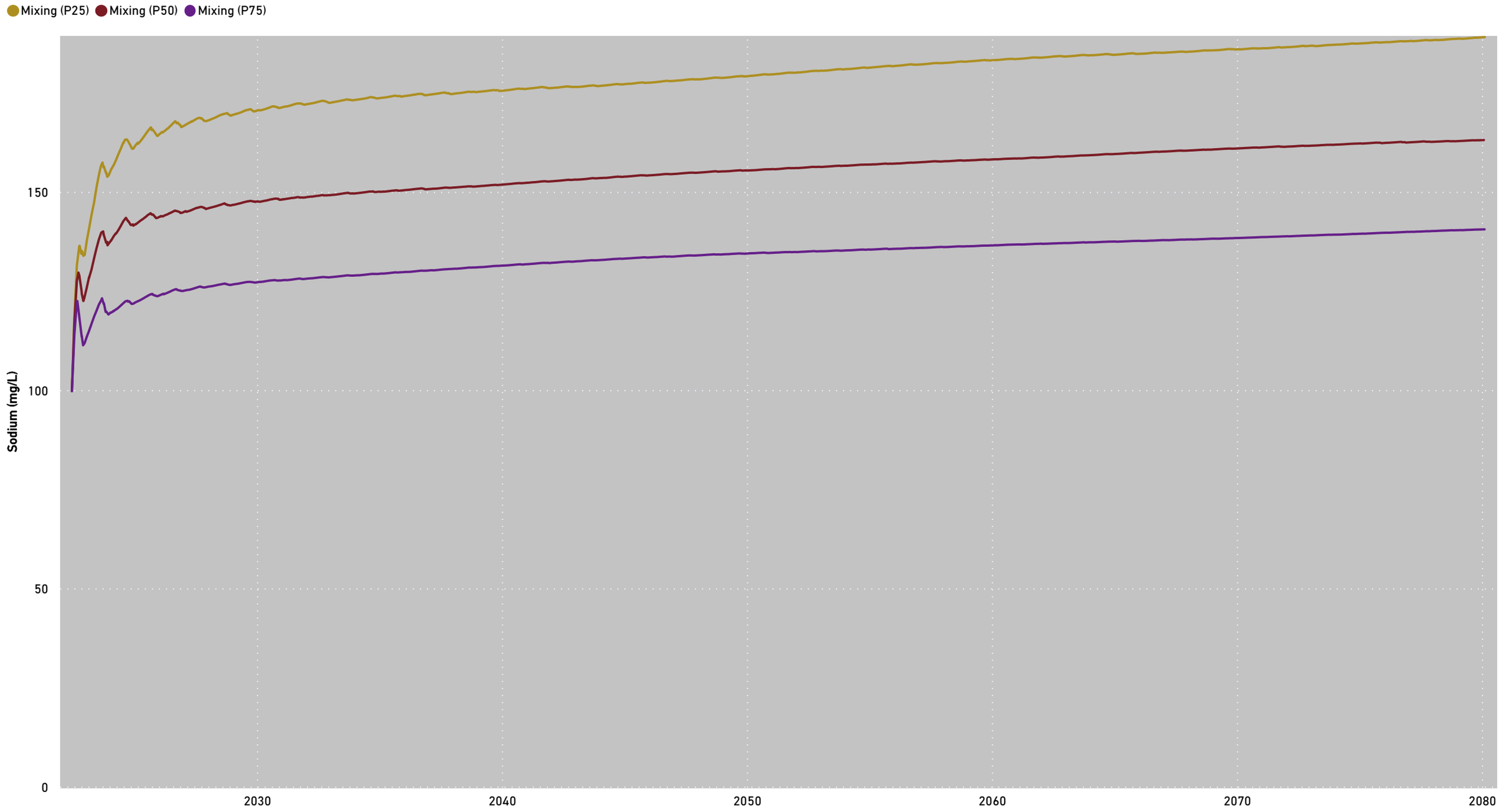

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 8.50
Livestock WQG: 6.50
pH
8.5
8.0
7.5
7.0
6.5
2030
2040
2050
2060
2070
2080

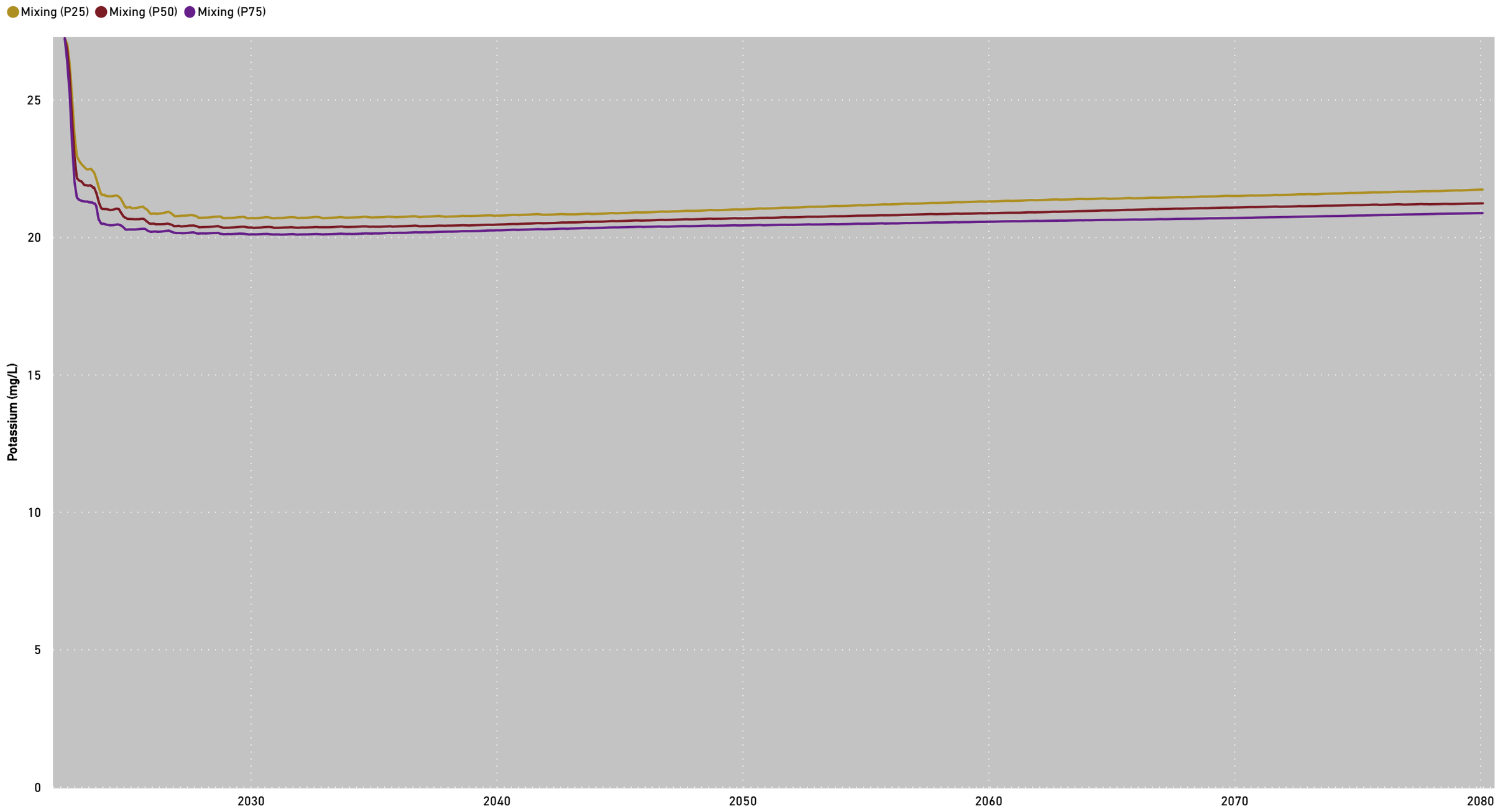

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - No loss of production: 5,000.00
Livestock WQG - No adverse effects: 4,000.00
Total Dissolved Solids (mg/L)
5K
4K
3K
2K
1K
2030
2040
2050
2060
2070
2080

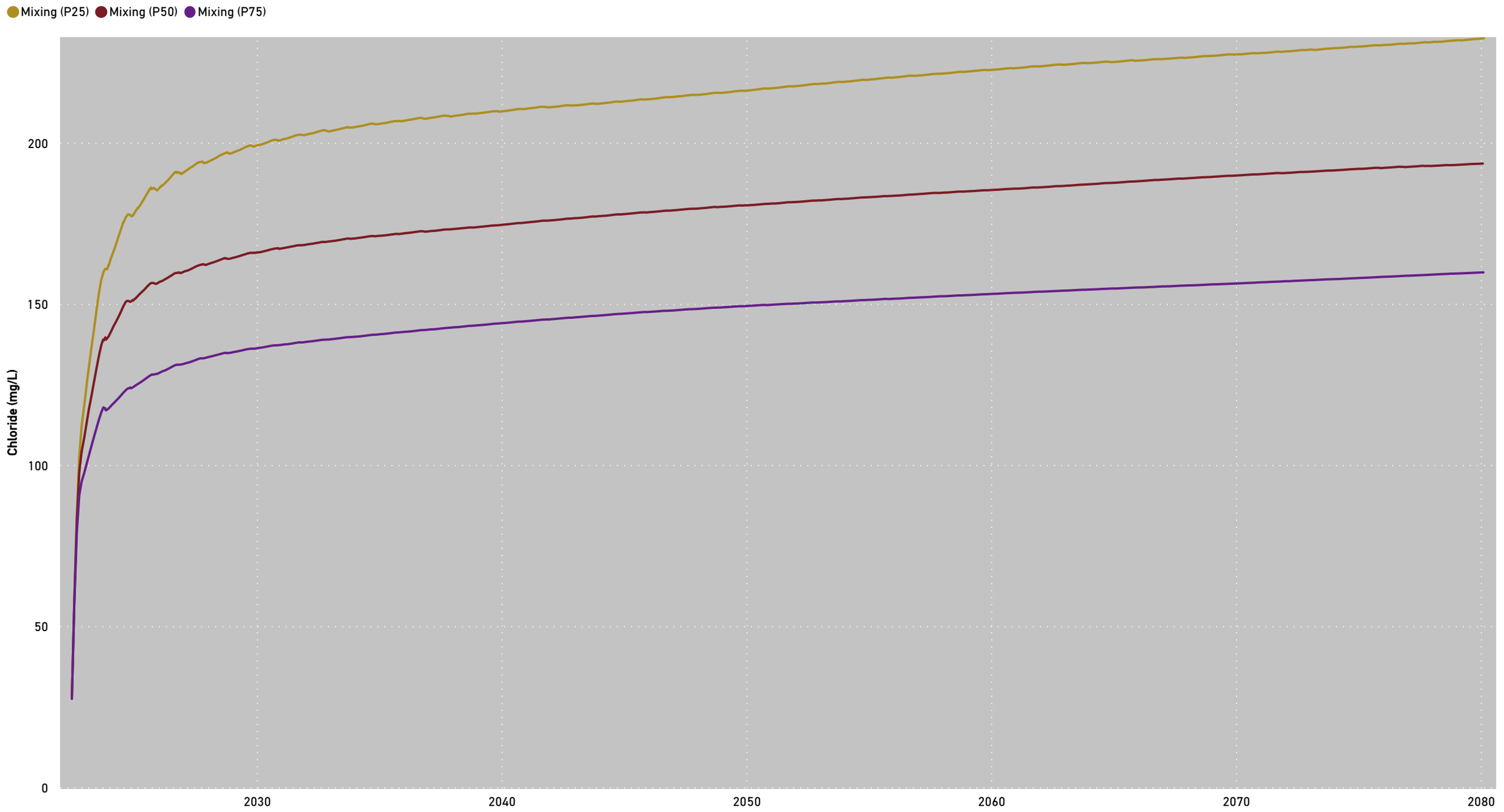

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 1,000.00
Calcium (mg/L)
1,000
800
600
400
200
0
2030
2040
2050
2060
2070
2080

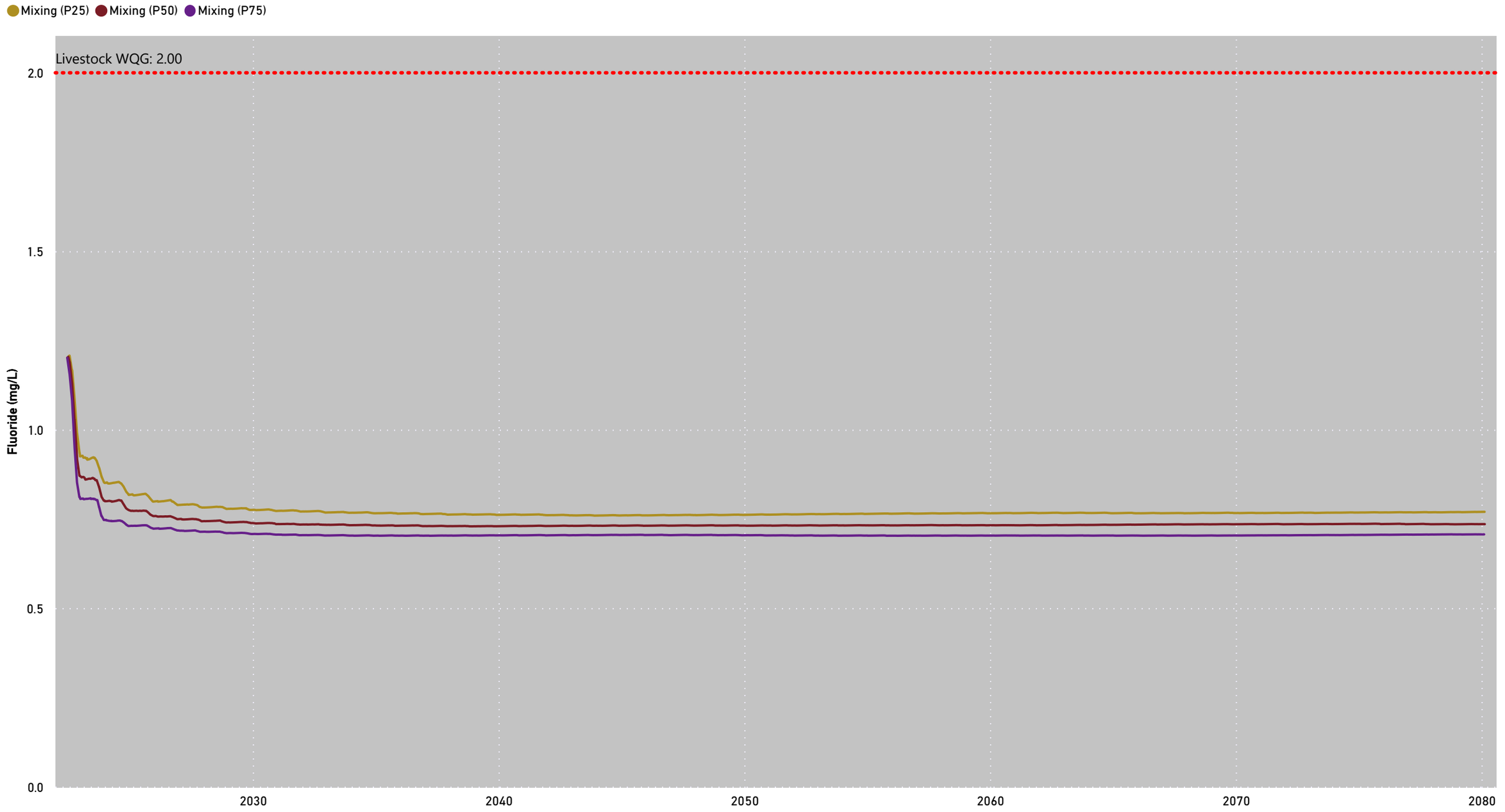

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG - Higher Value: 2,000.00
Livestock WQG - Lower Value: 1,000.00
Sulfate (mg/L)
2,000
1,500
1,000
500
0
2030
2040
2050
2060
2070
2080

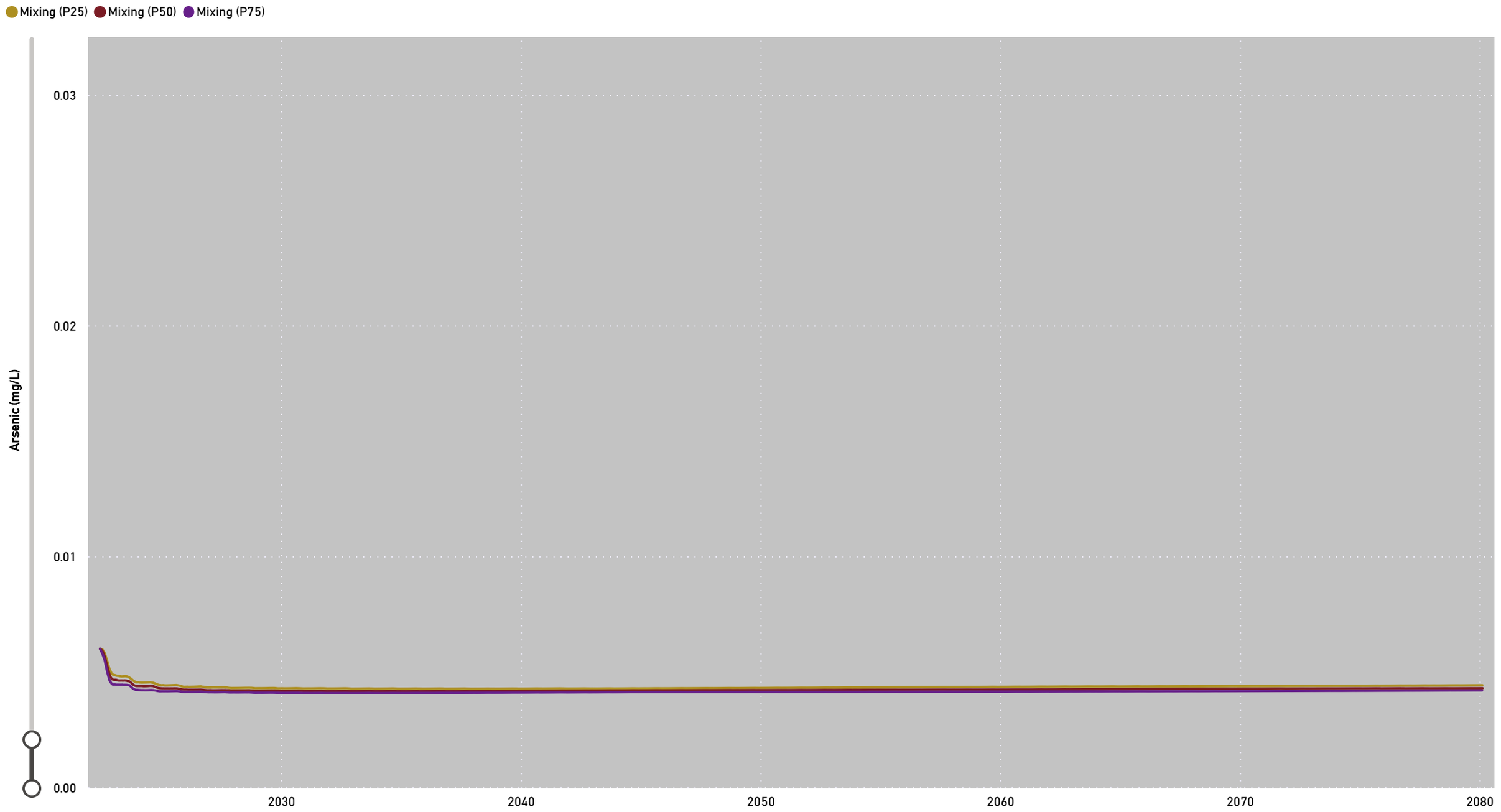

Mixing (P25)
Mixing (P50)
Mixing (P75)
Magnesium (mg/L)
60
50
40
30
20
10
0
2030
2040
2050
2060
2070
2080

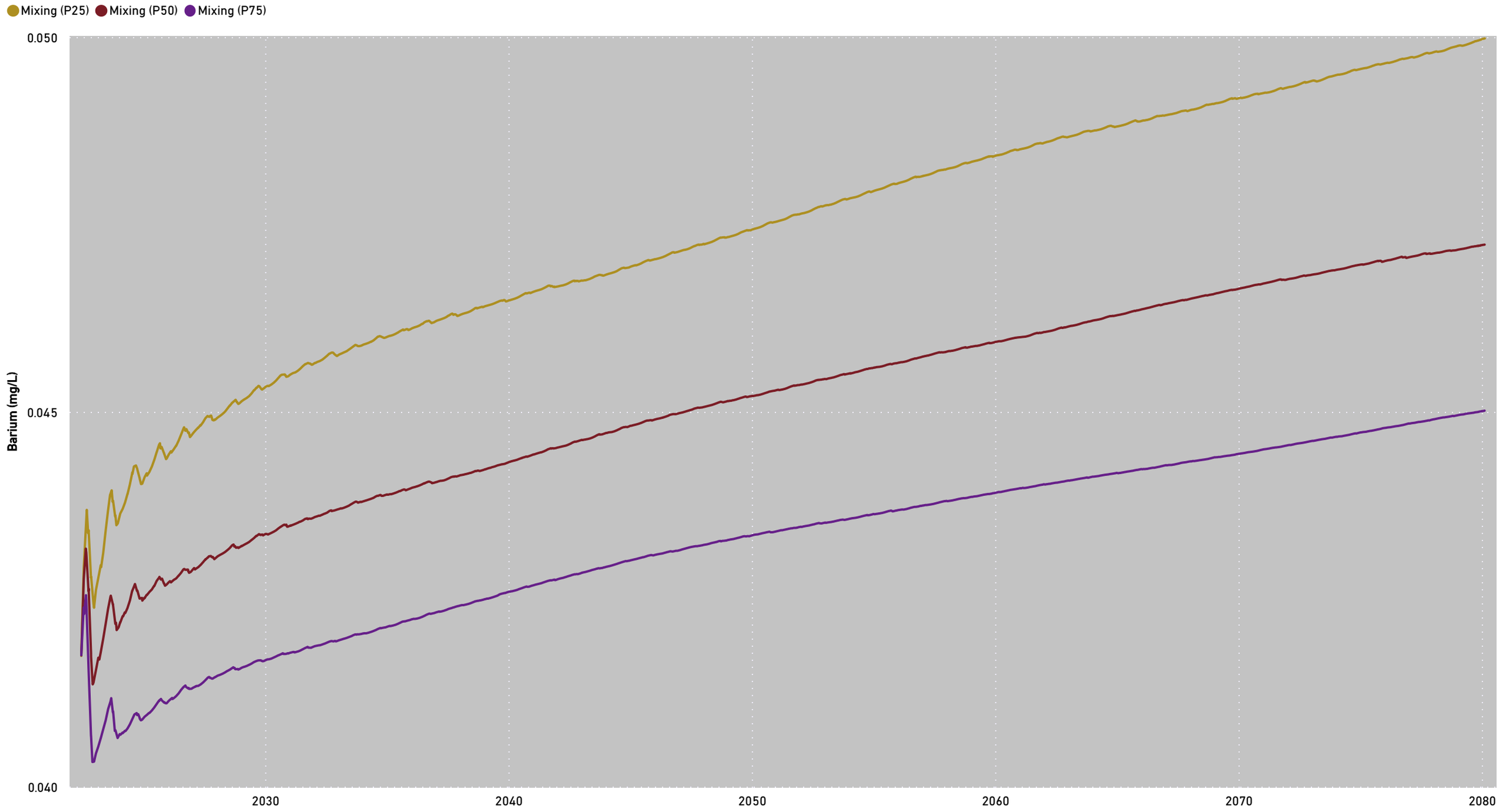

Mixing (P25)
Mixing (P50)
Mixing (P75)
Sodium (mg/L)
0
50
100
150
2030
2040
2050
2060
2070
2080

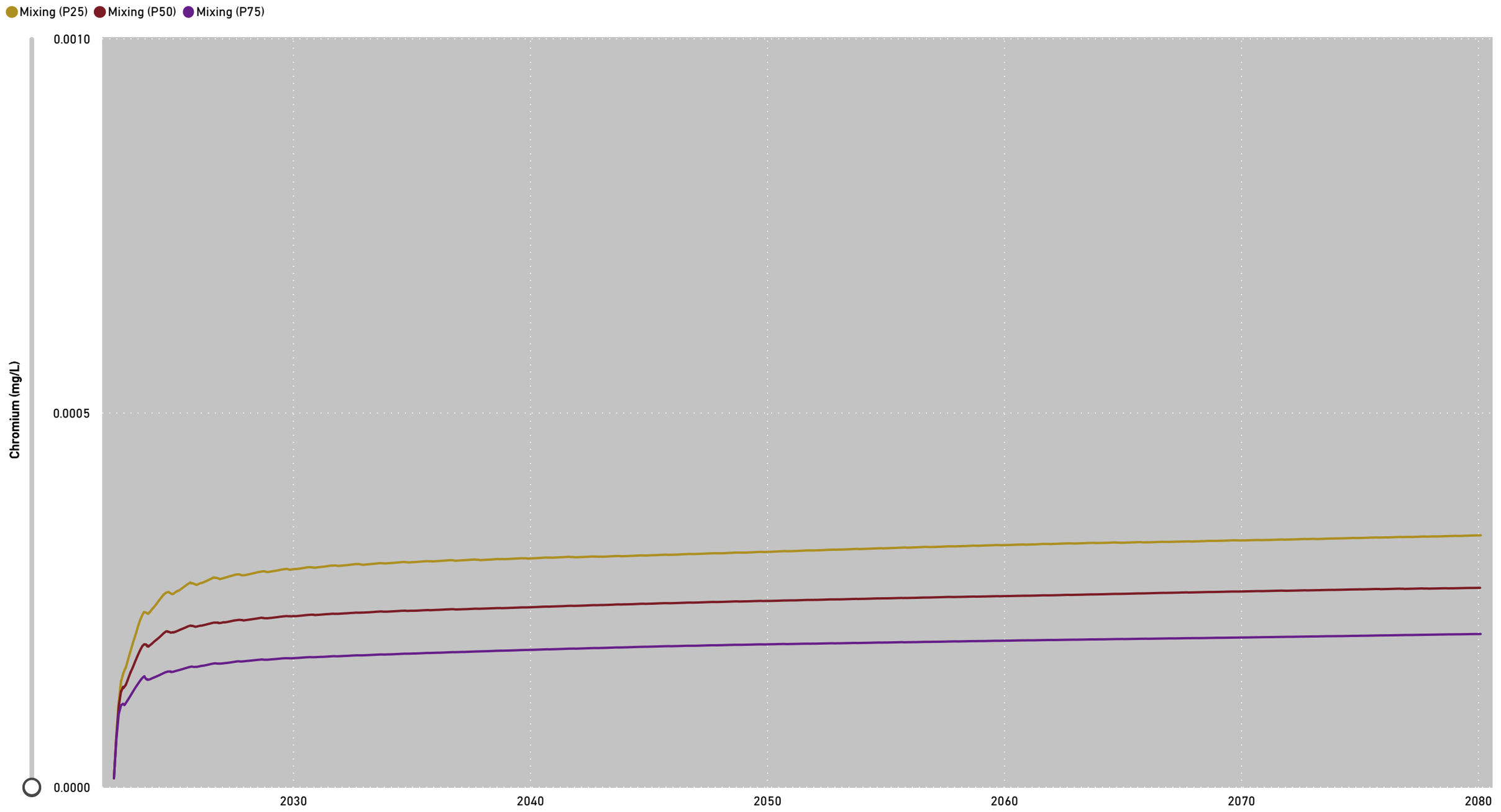

Mixing (P25)
Mixing (P50)
Mixing (P75)
Potassium (mg/L)
25
20
15
10
5
0
2030
2040
2050
2060
2070
2080

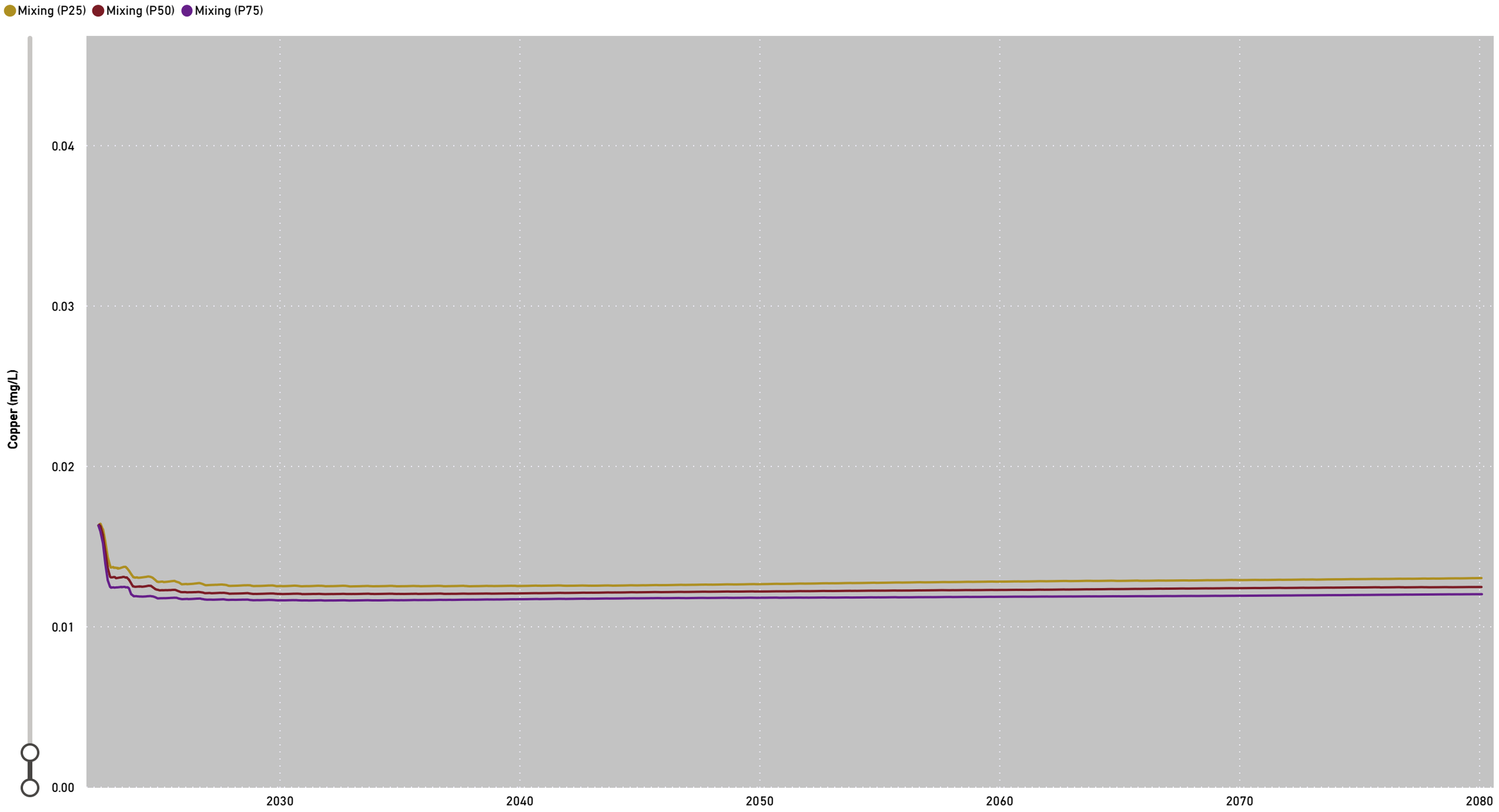

Mixing (P25)
Mixing (P50)
Mixing (P75)
Chloride (mg/L)
0
50
100
150
200
2030
2040
2050
2060
2070
2080

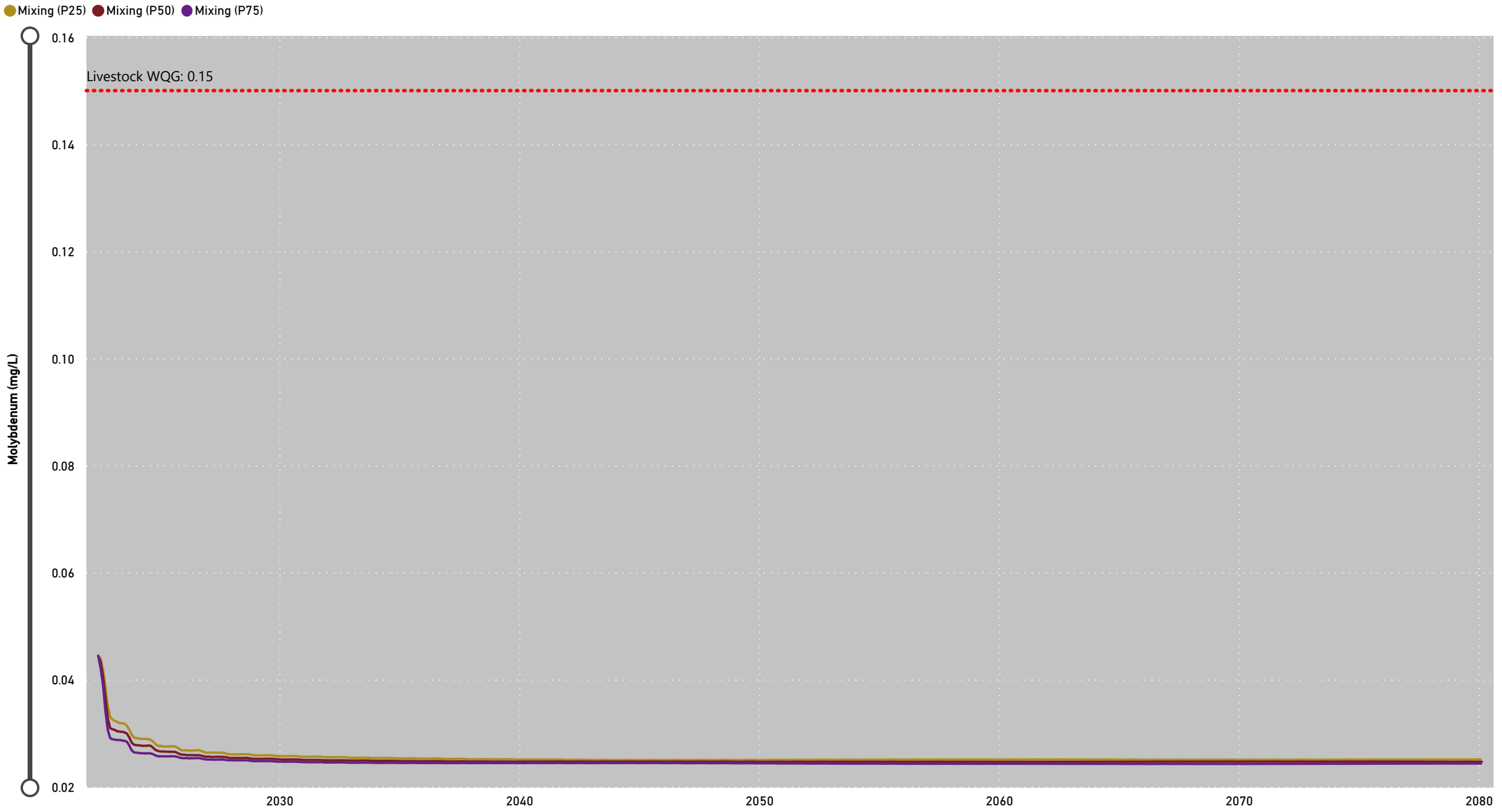

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 2.00
Fluoride (mg/L)
2.0
1.5
1.0
0.5
0.0
2030
2040
2050
2060
2070
2080

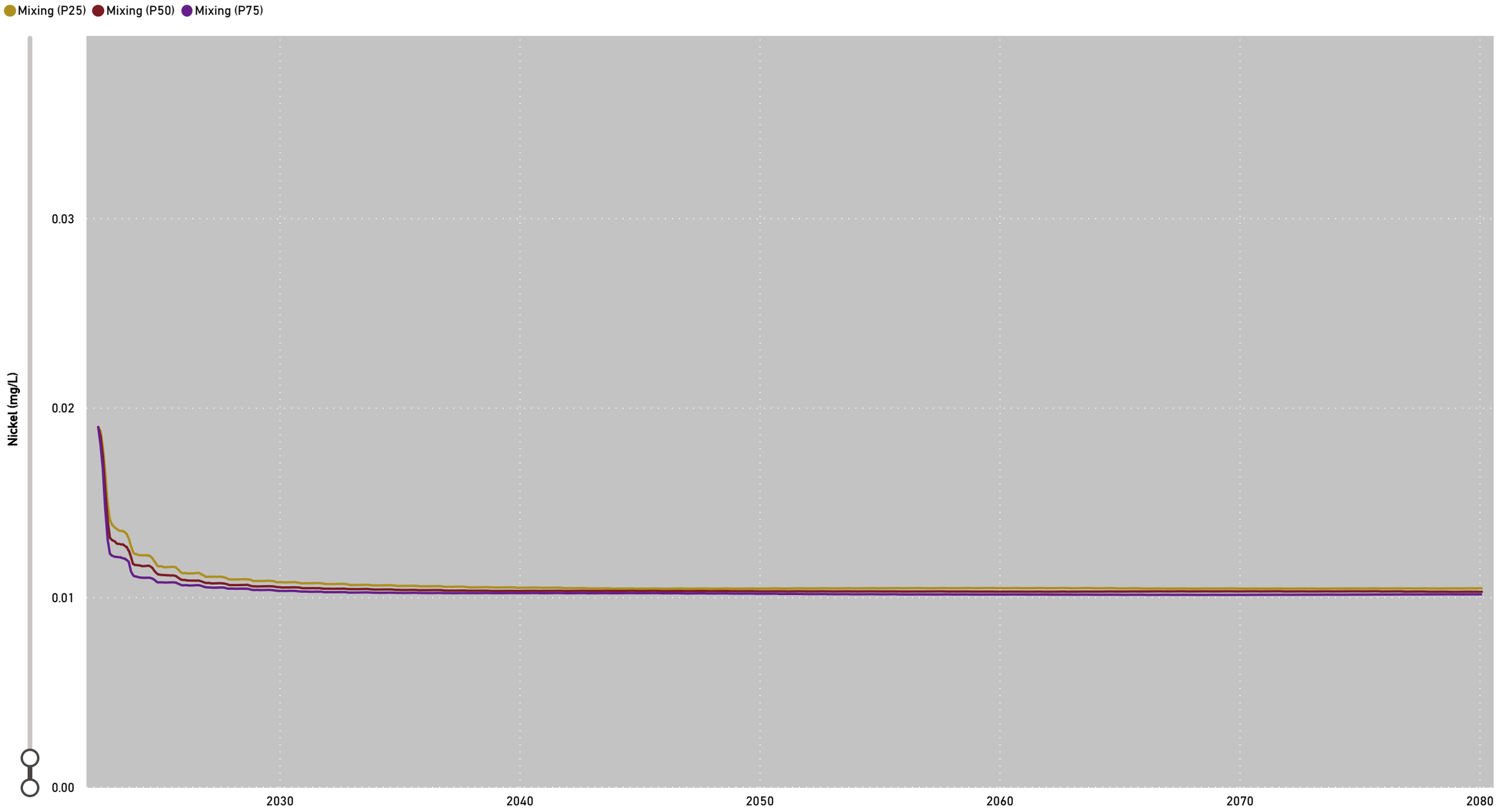

Mixing (P25)
Mixing (P50)
Mixing (P75)
Arsenic (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

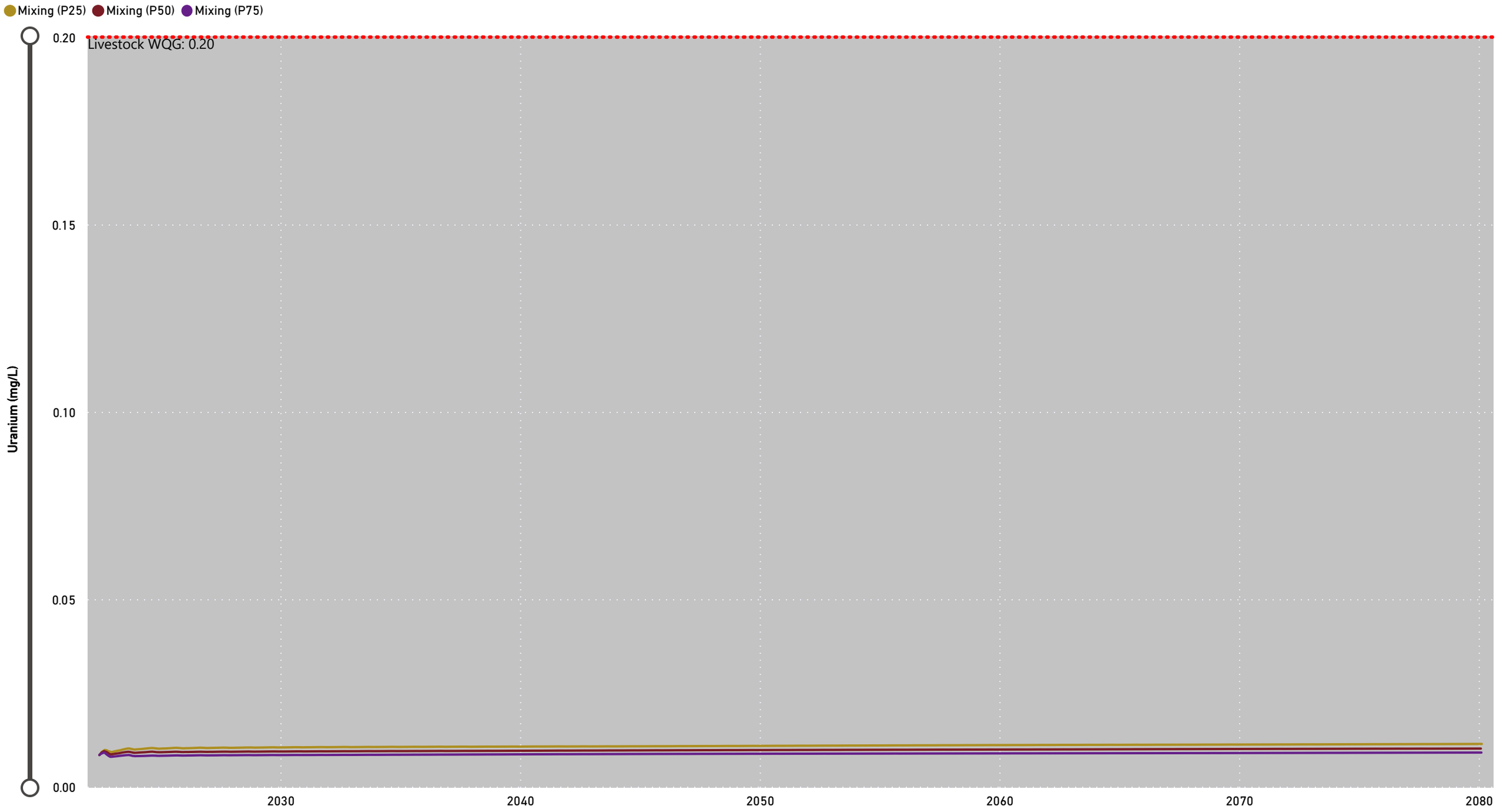

Mixing (P25)
Mixing (P50)
Mixing (P75)
Barium (mg/L)
0.050
0.045
0.040
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Chromium (mg/L)
0.0010
0.0005
0.0000
2030
2040
2050
2060
2070
2080


Mixing (P25)
Mixing (P50)
Mixing (P75)
Copper (mg/L)
0.04
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

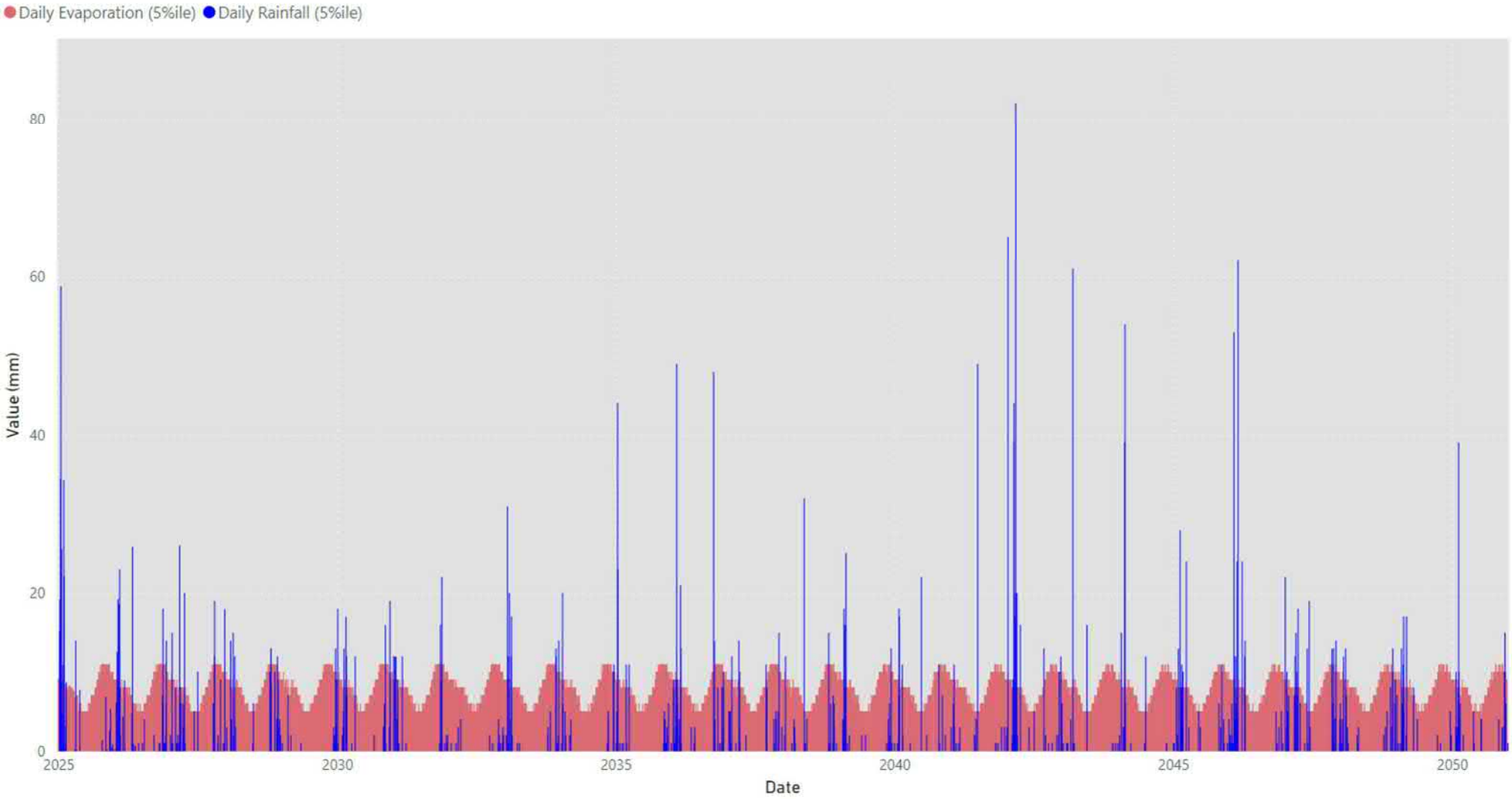

Mixing (P25)
Mixing (P50)
Mixing (P75)
Molybdenum (mg/L)
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
Livestock WQG: 0.15
2030
2040
2050
2060
2070
2080

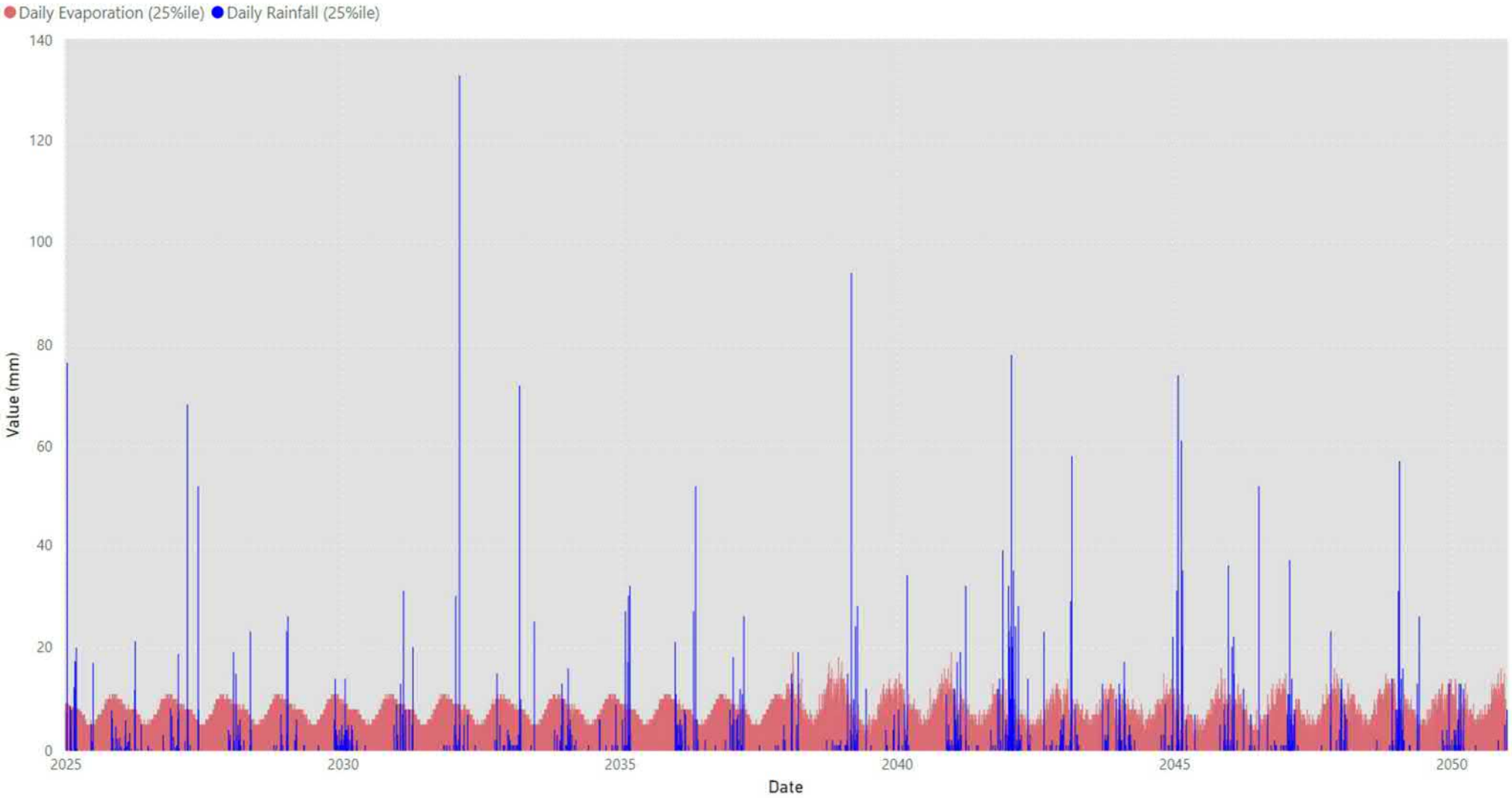

Mixing (P25)
Mixing (P50)
Mixing (P75)
Nickel (mg/L)
0.03
0.02
0.01
0.00
2030
2040
2050
2060
2070
2080

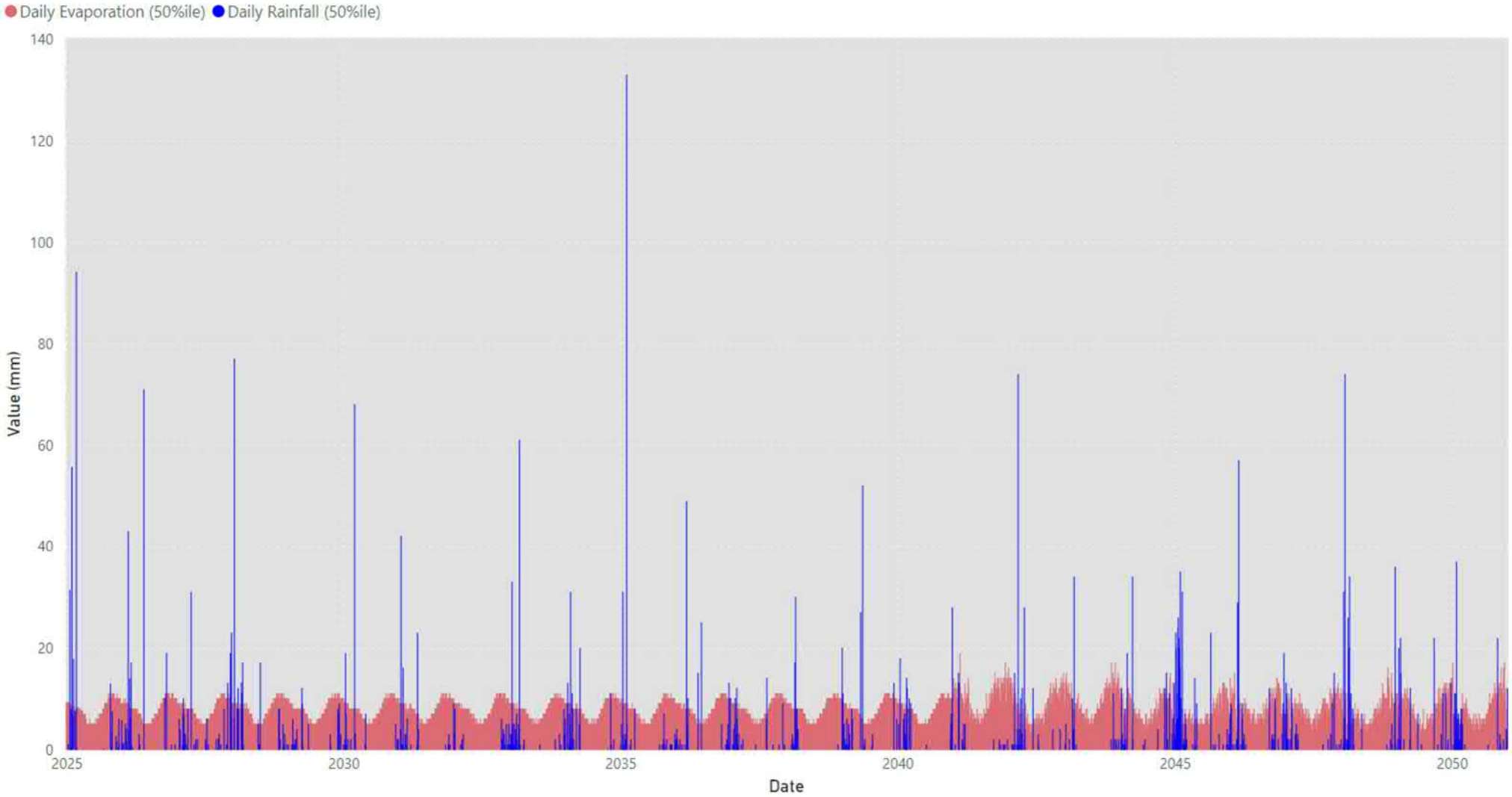

Mixing (P25)
Mixing (P50)
Mixing (P75)
Livestock WQG: 0.20
Uranium (mg/L)
0.20
0.15
0.10
0.05
0.00
2030
2040
2050
2060
2070
2080

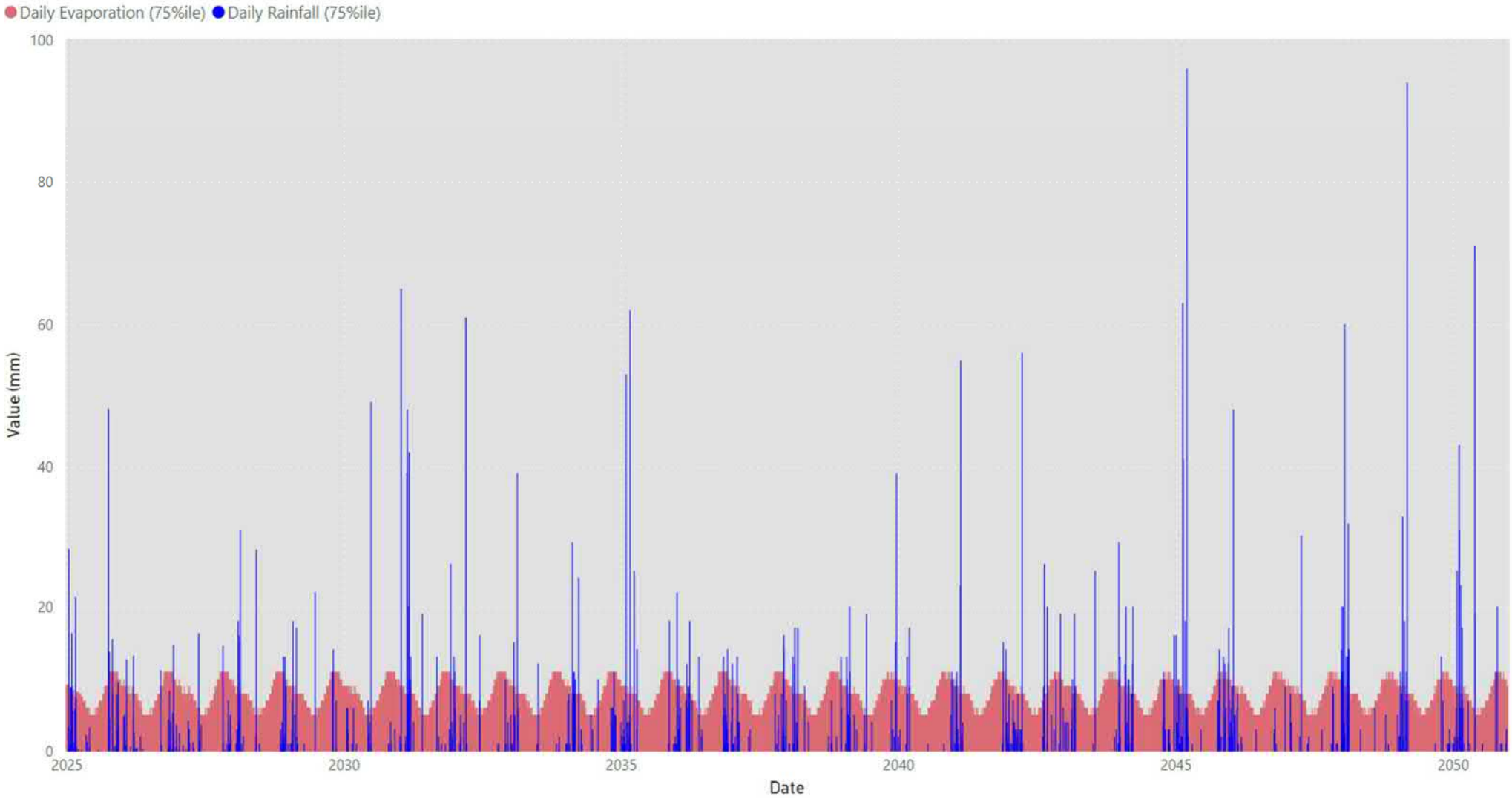
Appendix K WQM results for underground workings

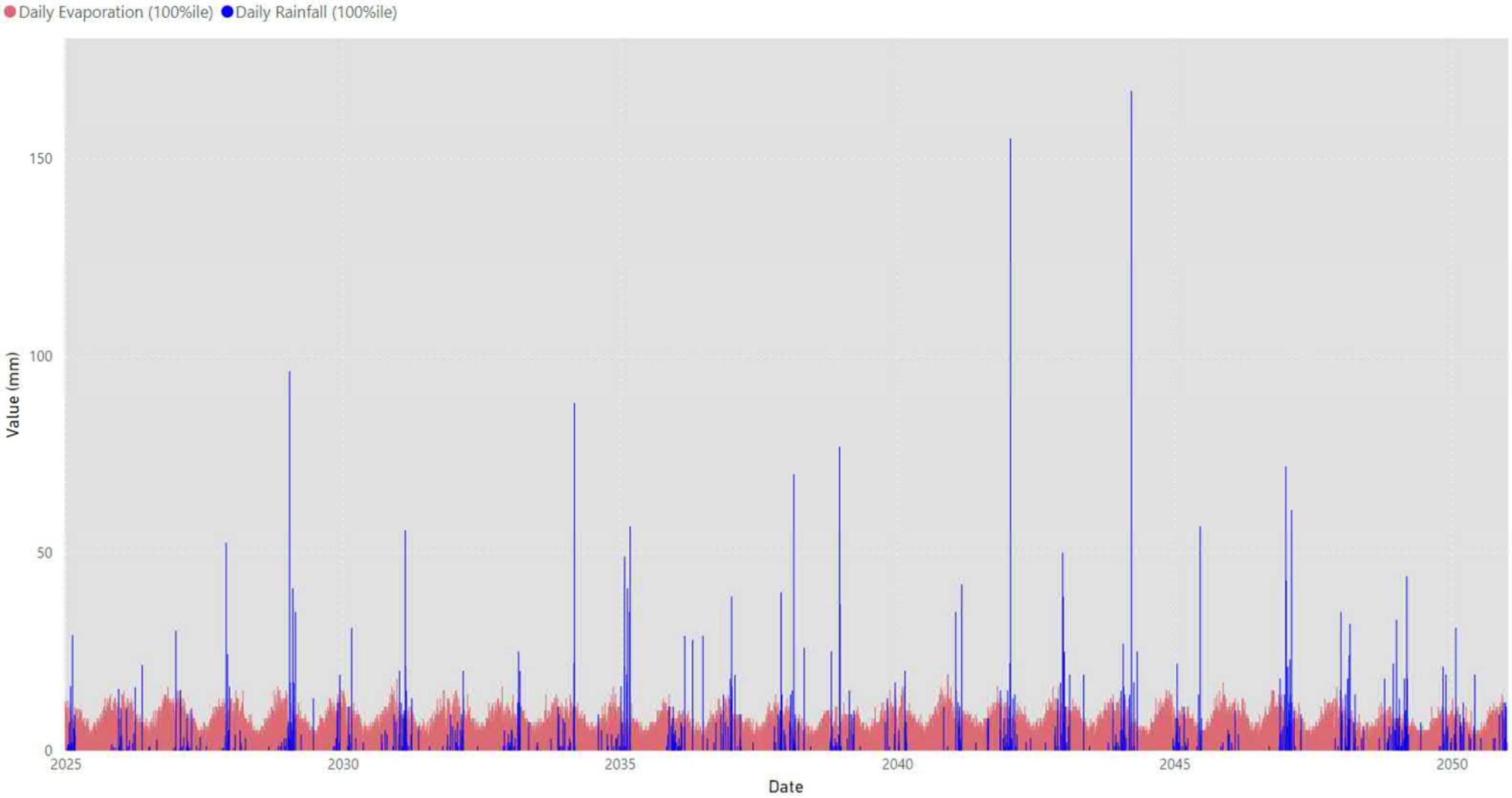
K.1 Climate data for UG water quality model


Daily Evaporation (5%ile)
Daily Rainfall (5%ile)
Value (mm)
0
20
40
60
80
2025
2030
2035
2040
2045
2050
Date


Daily Evaporation (25%ile)
Daily Rainfall (25%ile)
Value (mm)
140
120
100
80
60
40
20
0
2025
2030
2035
2040
2045
2050
Date

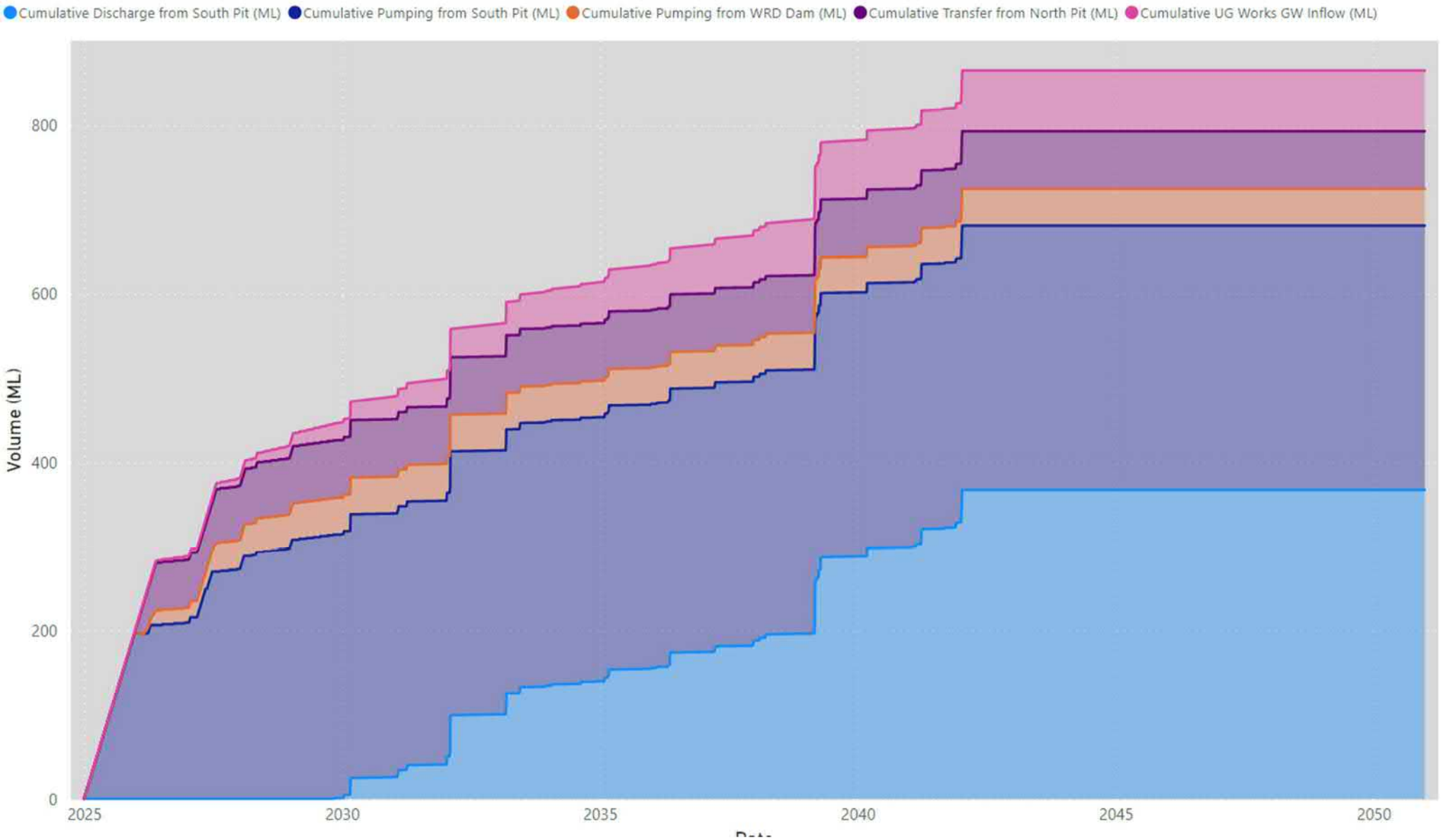

Daily Evaporation (50%ile)
Daily Rainfall (50%ile)
Value (mm)
140
120
100
80
60
40
20
0
2025
2030
2035
2040
2045
2050
Date

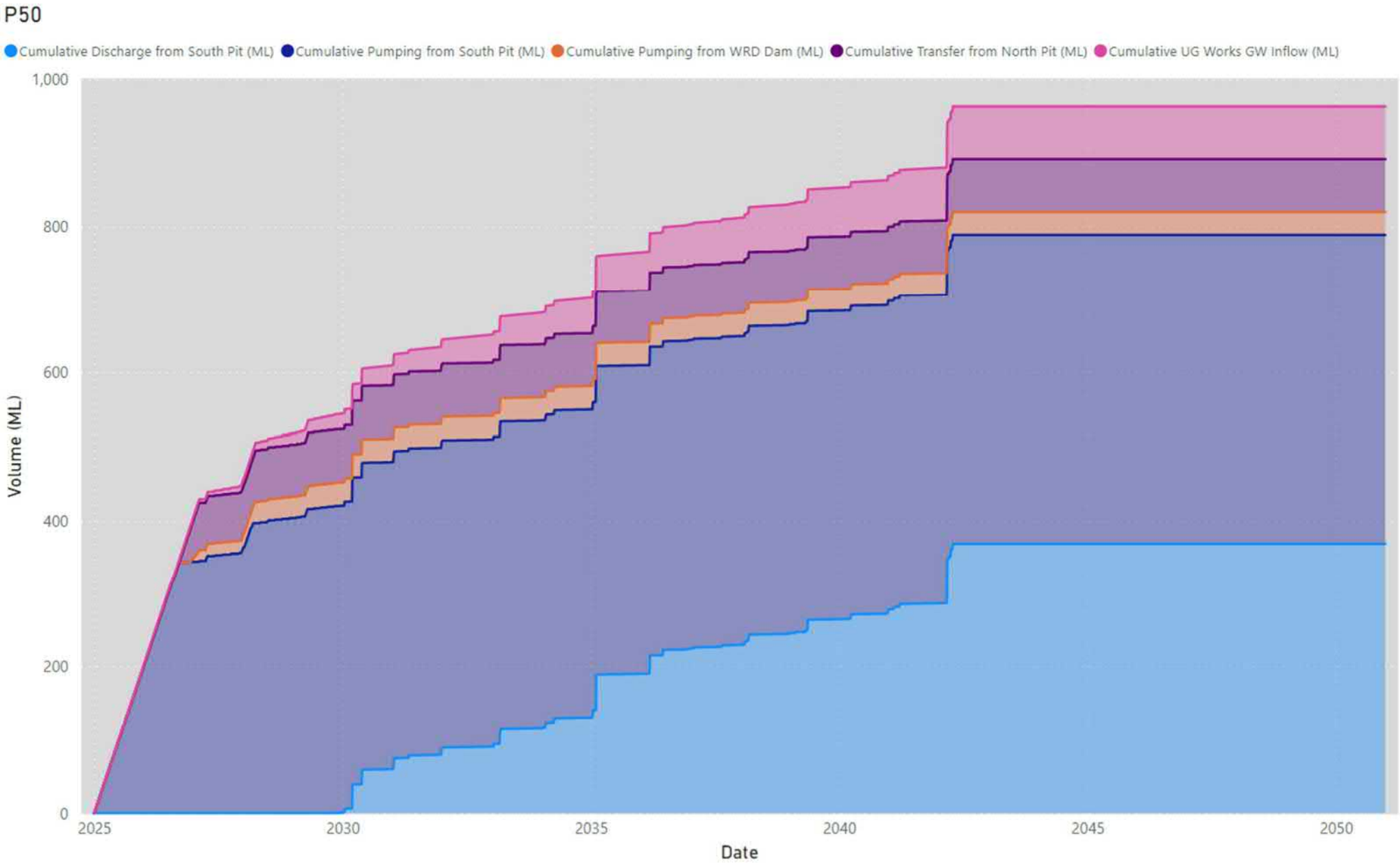

Daily Evaporation (75%ile)
Daily Rainfall (75%ile)
100
80
60
40
20
0
Value (mm)
2025
2030
2035
2040
2045
2050
Date

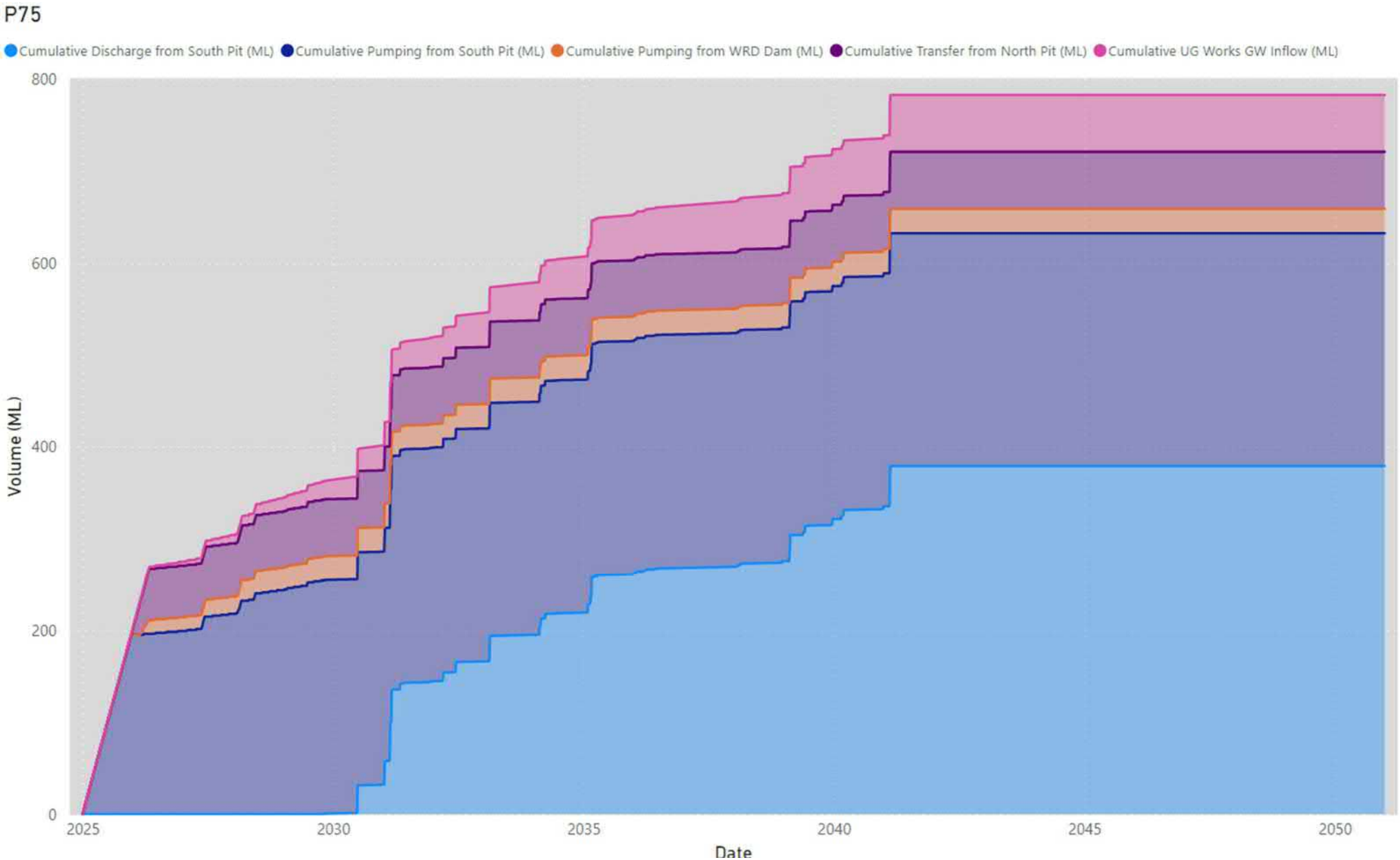

Daily Evaporation (100%ile)
Daily Rainfall (100%ile)
Value (mm)
150
100
50
0
2025
2030
2035
2040
2045
2050
Date

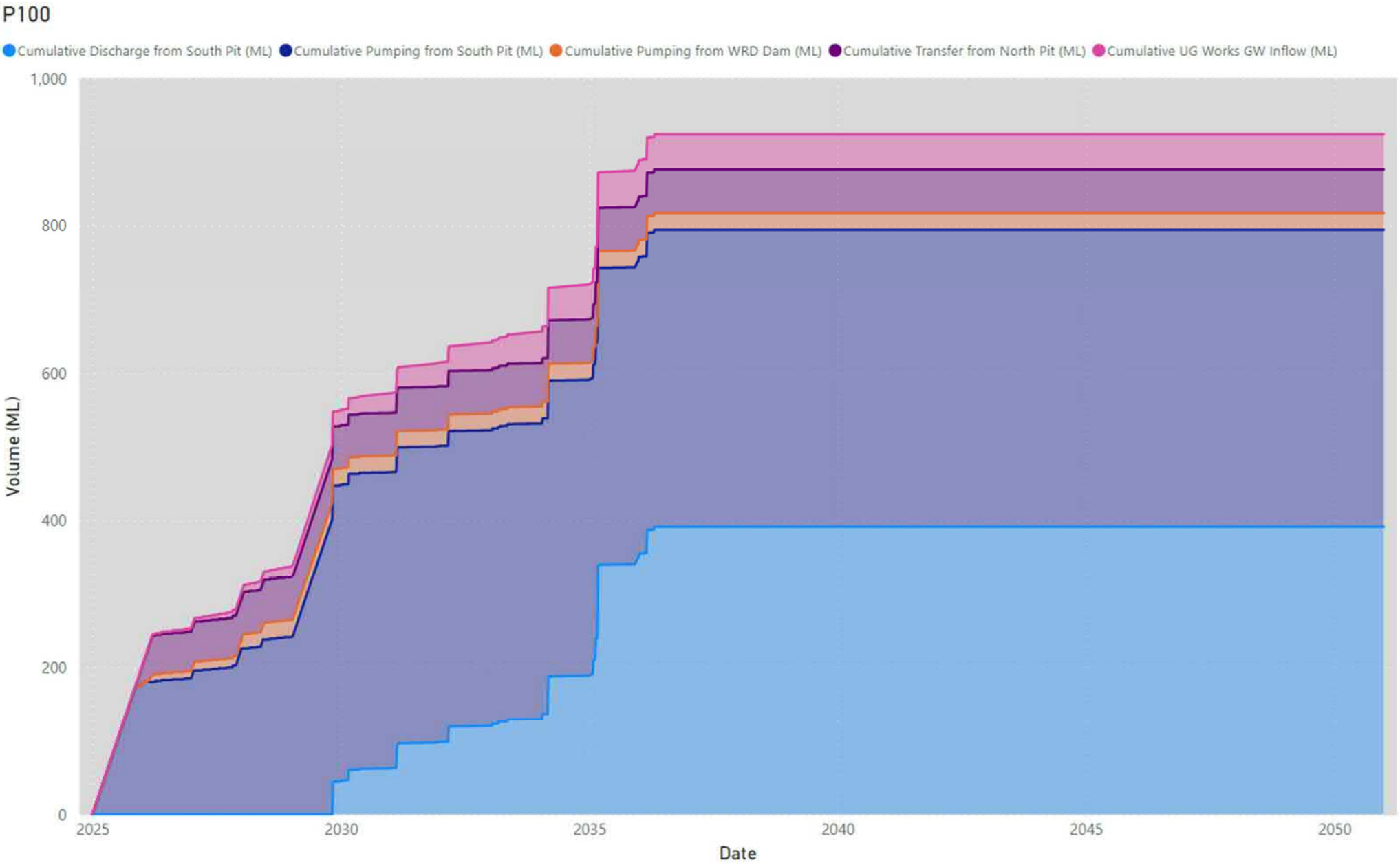
K.2 UG water quality model - volumes

P25

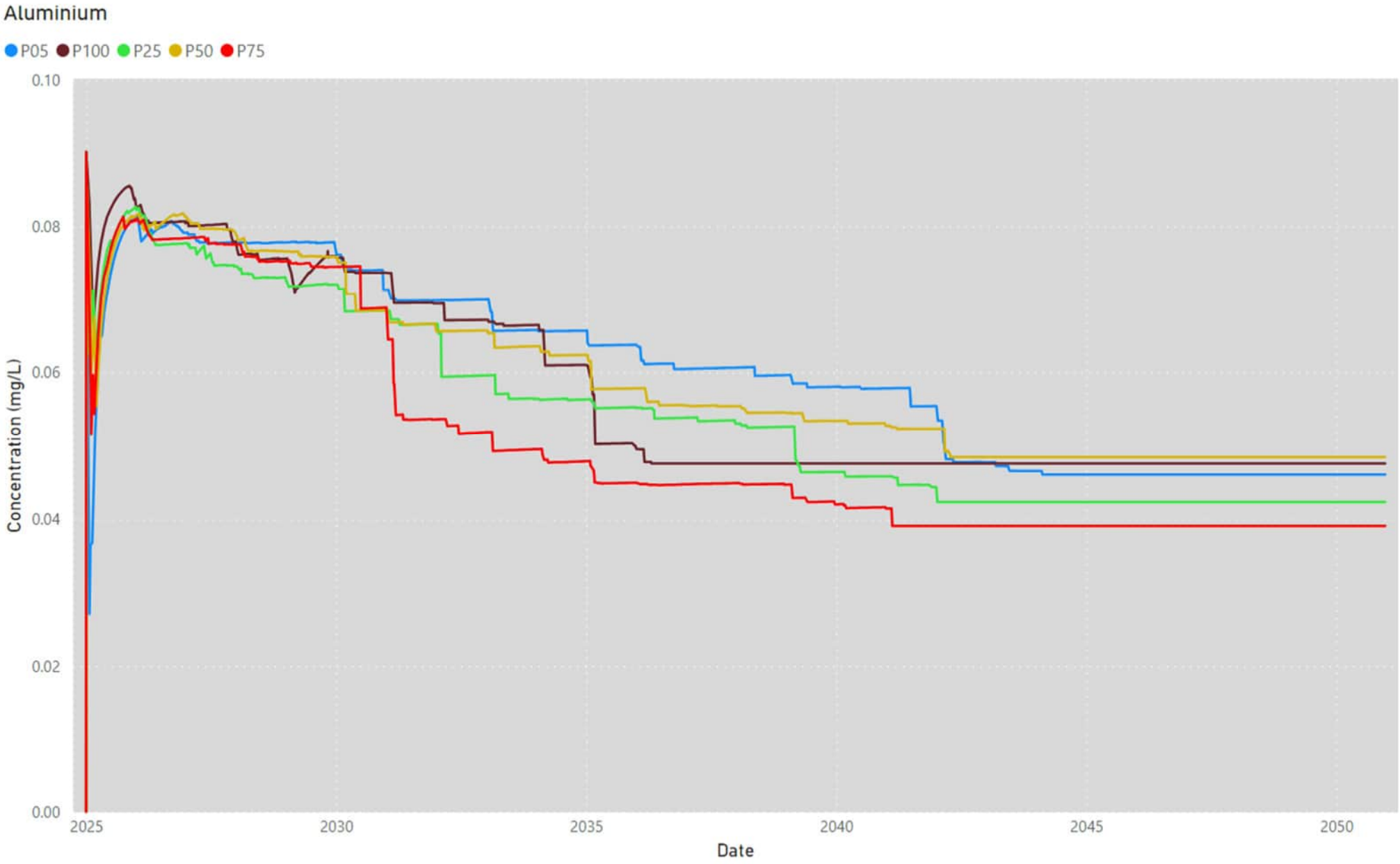

Cumulative Discharge from South Pit (ML)
Cumulative Pumping from South Pit (ML)
Cumulative Pumping from WRD Dam (ML)
Cumulative Transfer from North Pit (ML)
Cumulative UG Works GW Inflow (ML)
Volume (ML)
0
200
400
600
800
2025
2030
2035
2040
2045
2050

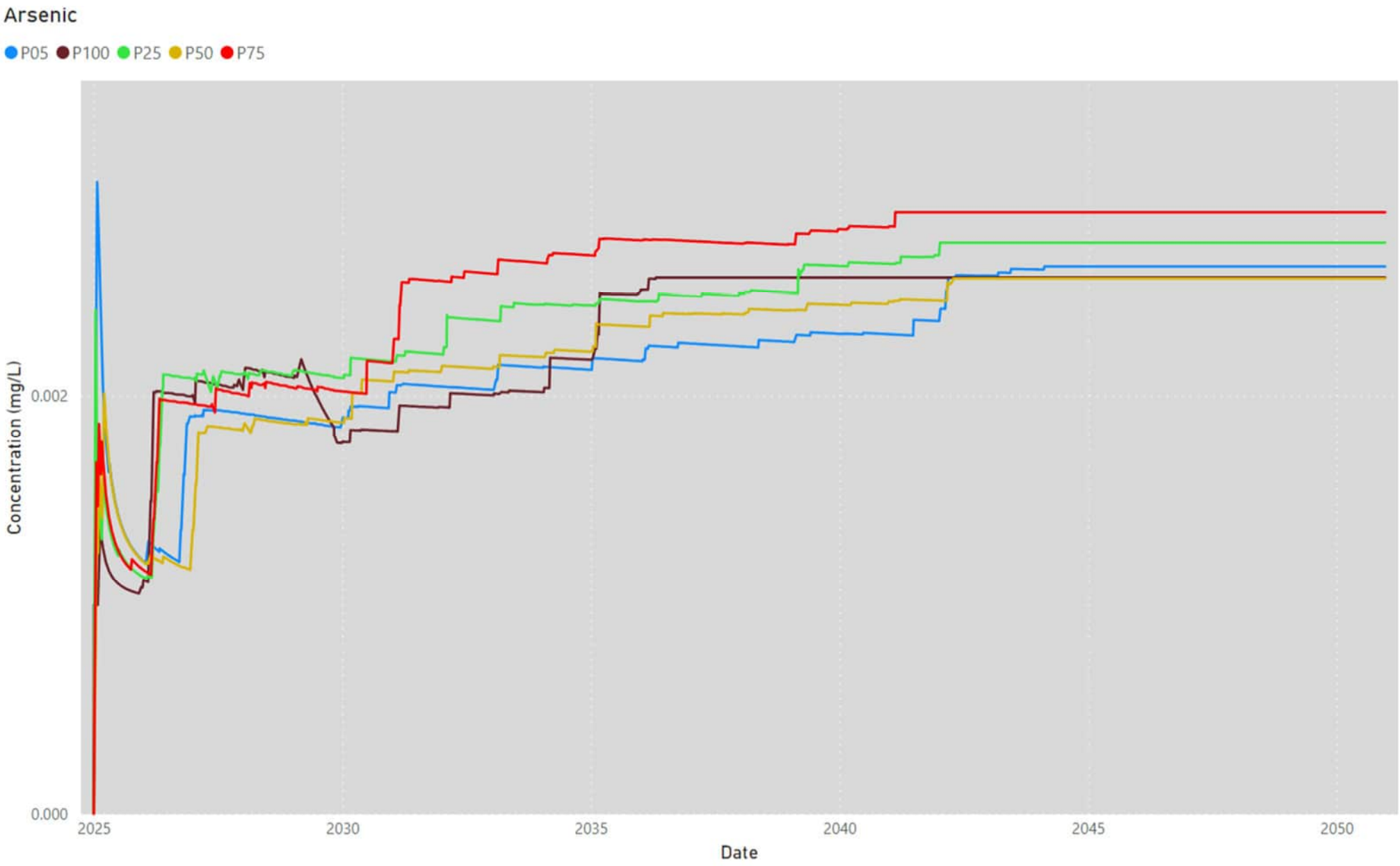

P50
Cumulative Discharge from South Pit (ML)
Cumulative Pumping from South Pit (ML)
Cumulative Pumping from WRD Dam (ML)
Cumulative Transfer from North Pit (ML)
Cumulative UG Works GW Inflow (ML)
1,000
800
600
400
200
0
Volume (ML)
2025
2030
2035
2040
2045
2050
Date

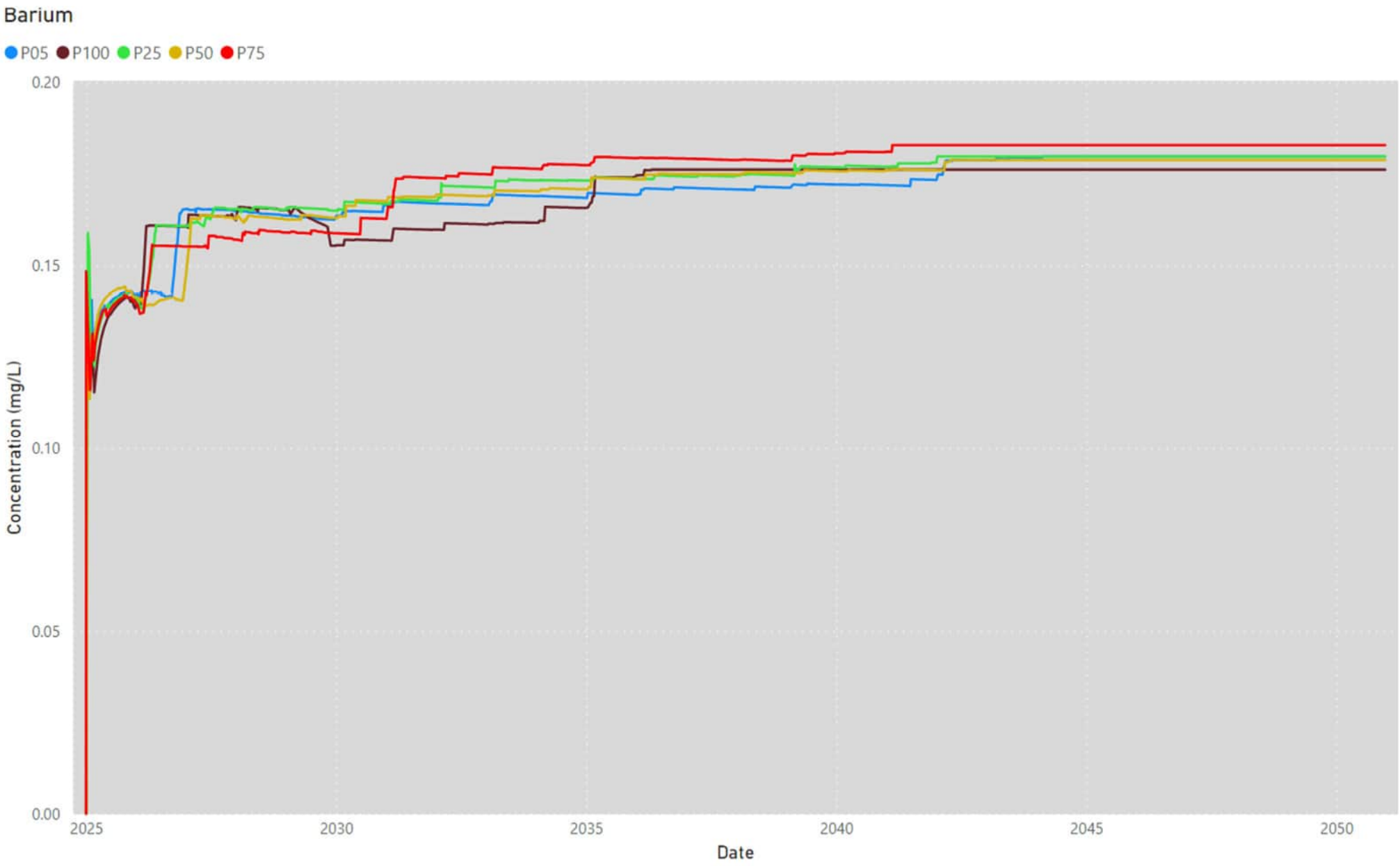

P75
Cumulative Discharge from South Pit (ML)
Cumulative Pumping from South Pit (ML)
Cumulative Pumping from WRD Dam (ML)
Cumulative Transfer from North Pit (ML)
Cumulative UG Works GW Inflow (ML)
Volume (ML)
800
600
400
200
0
2025
2030
2035
2040
2045
2050
Date

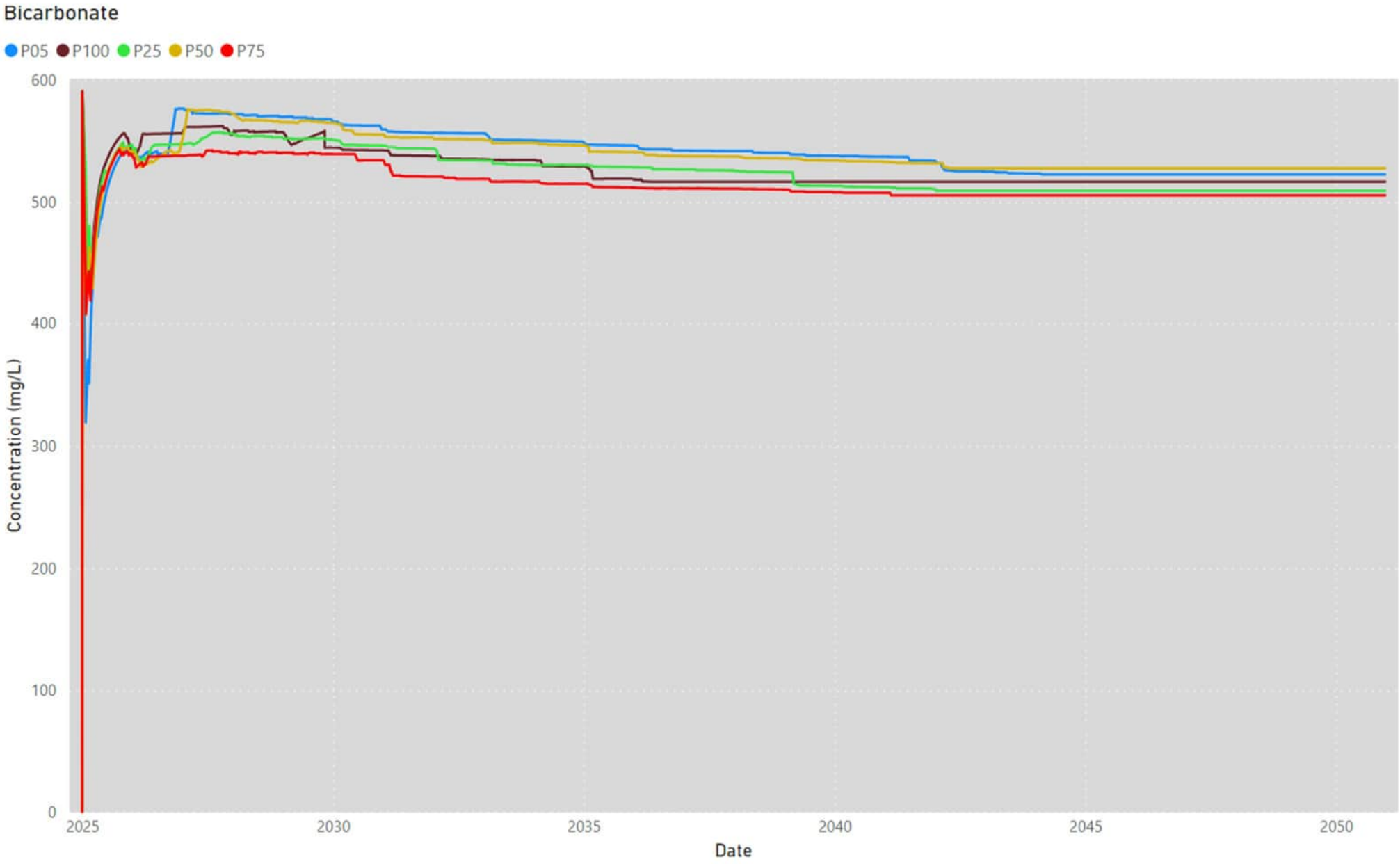

P100
Cumulative Discharge from South Pit (ML)
Cumulative Pumping from South Pit (ML)
Cumulative Pumping from WRD Dam (ML)
Cumulative Transfer from North Pit (ML)
Cumulative UG Works GW Inflow (ML)
1,000
800
600
400
200
0
Volume (ML)
2025
2030
2035
2040
2045
2050
Date

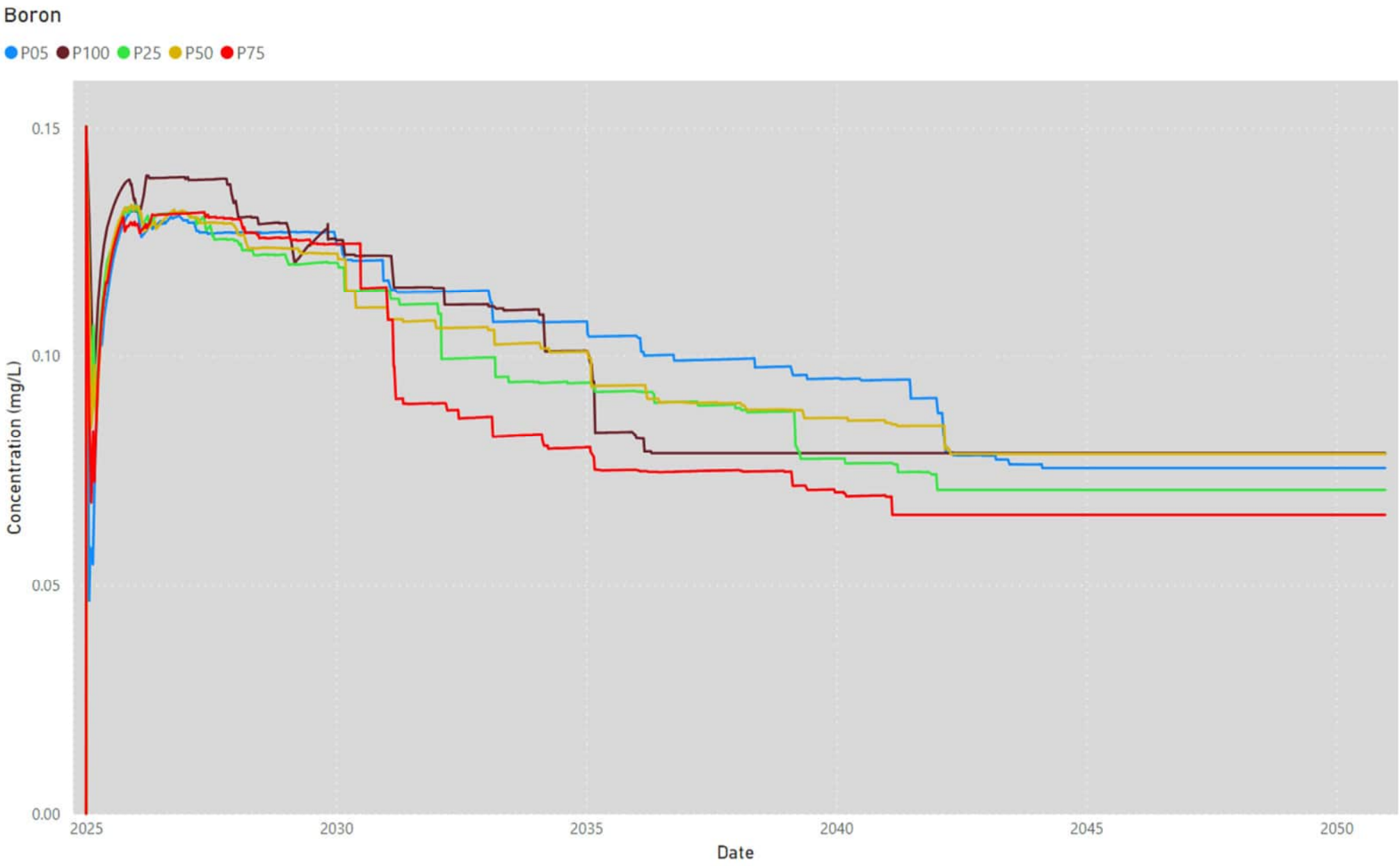
K.3 UG final void water quality charts

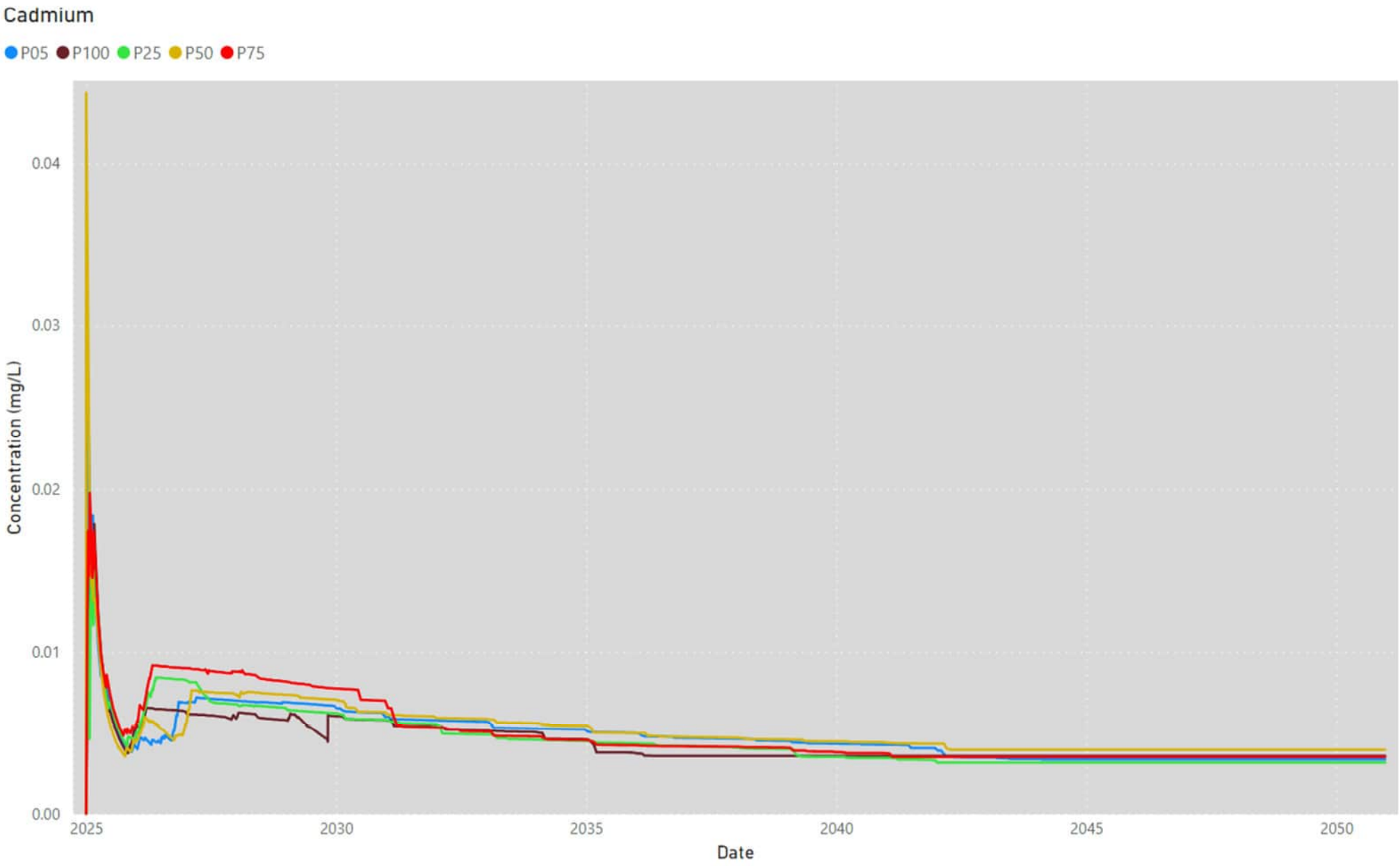

Aluminium
P05
P100
P25
P50
P75
0.10
0.08
0.06
0.04
0.02
0.00
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

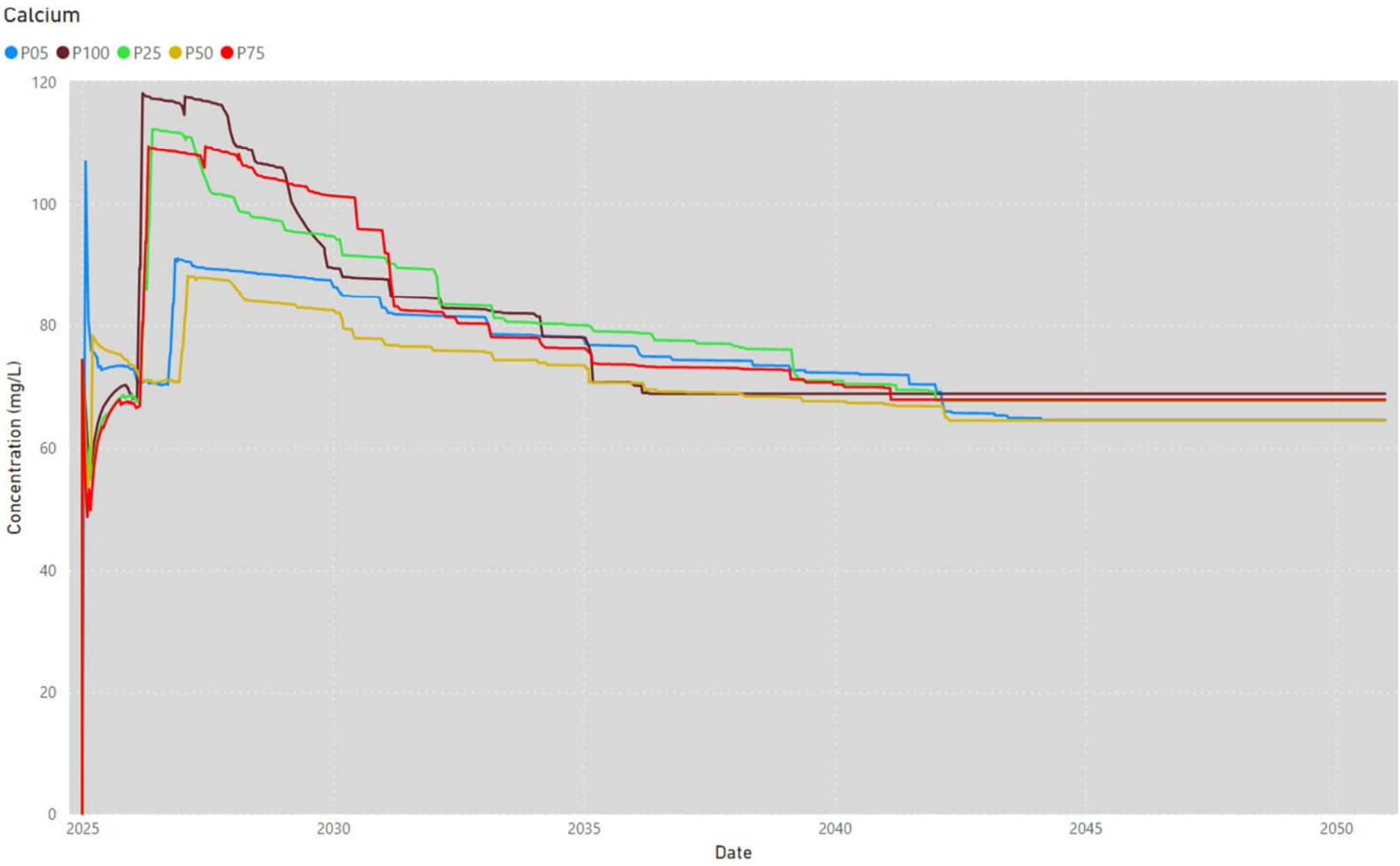

Arsenic
P05
P100
P25
P50
P75
Concentration (mg/L)
0.002
0.000
2025
2030
2035
2040
2045
2050
Date

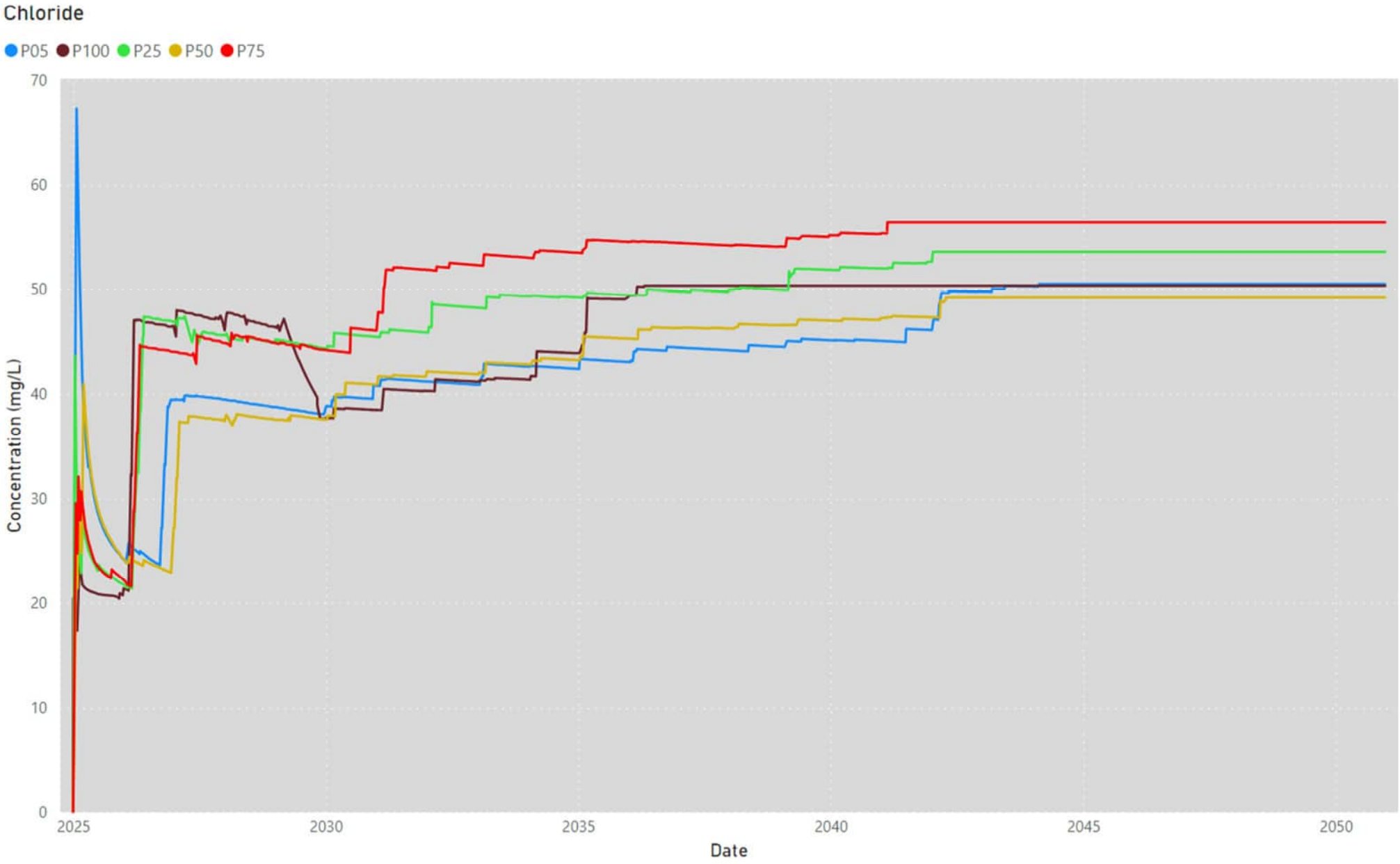

Barium
P05
P100
P25
P50
P75
0.20
0.15
0.10
0.05
0.00
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

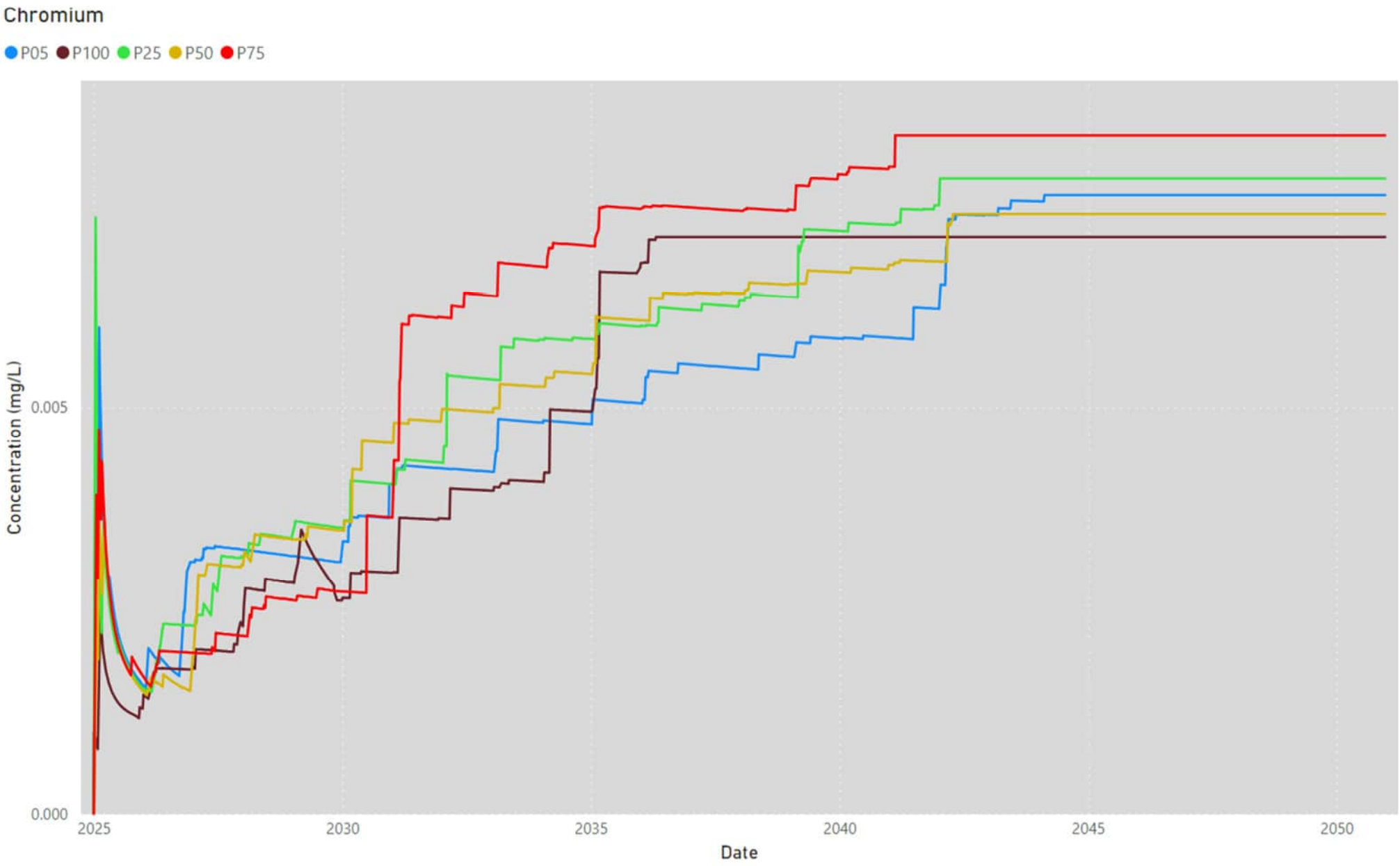

Bicarbonate
P05
P100
P25
P50
P75
600
500
400
300
200
100
0
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

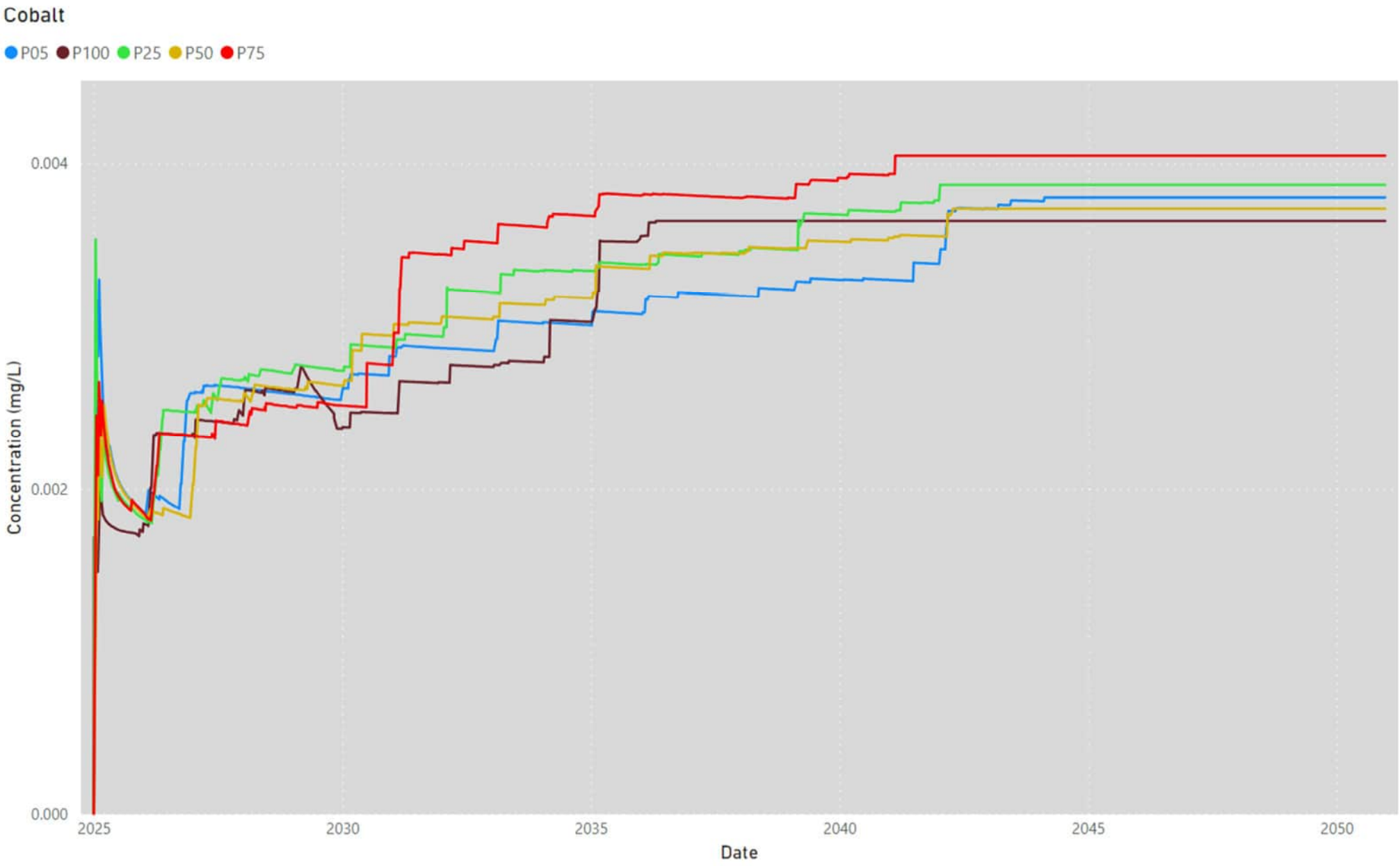

Boron
P05
P100
P25
P50
P75
0.15
0.10
0.05
0.00
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

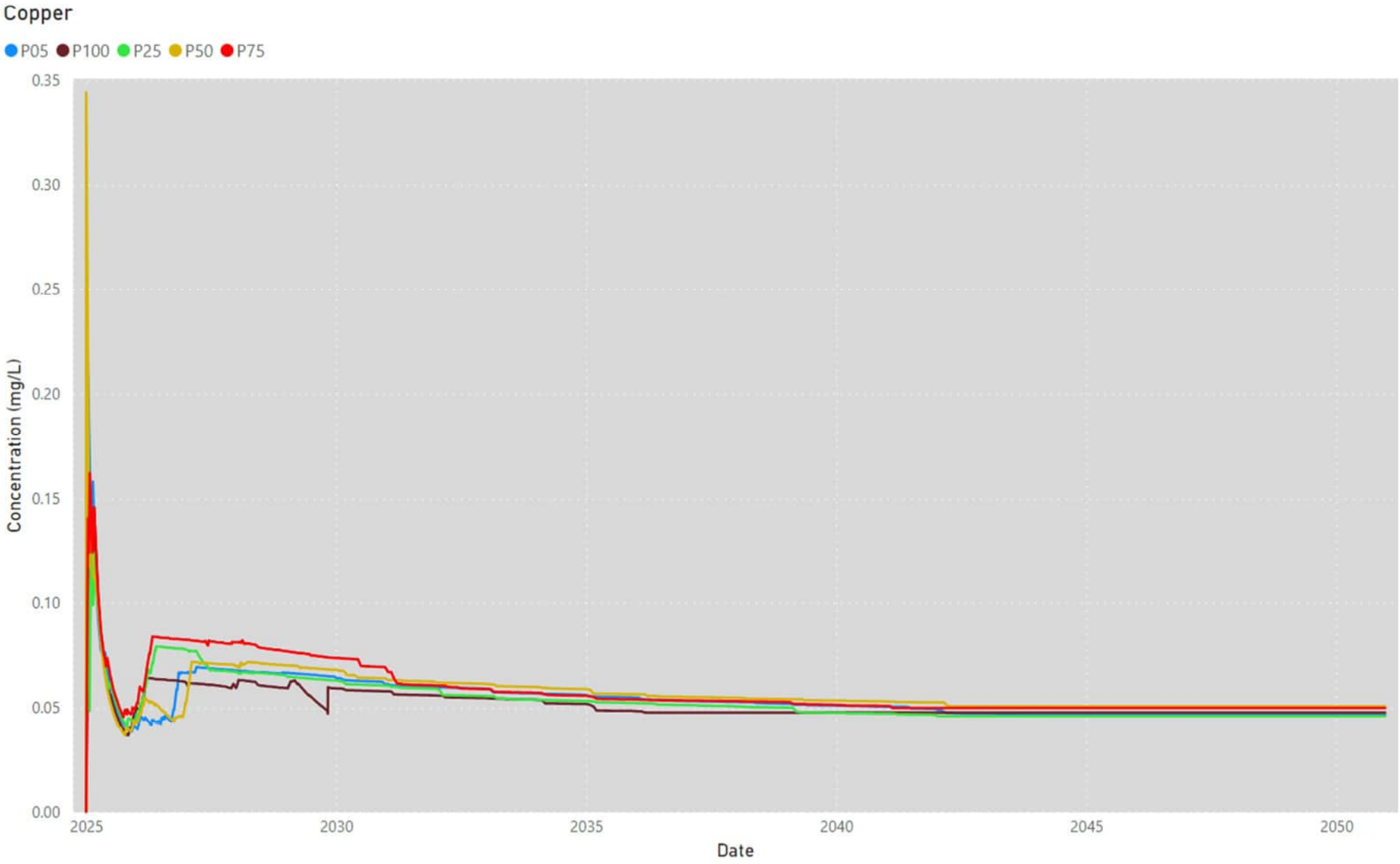

Cadmium
P05
P100
P25
P50
P75
0.04
0.03
0.02
0.01
0.00
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

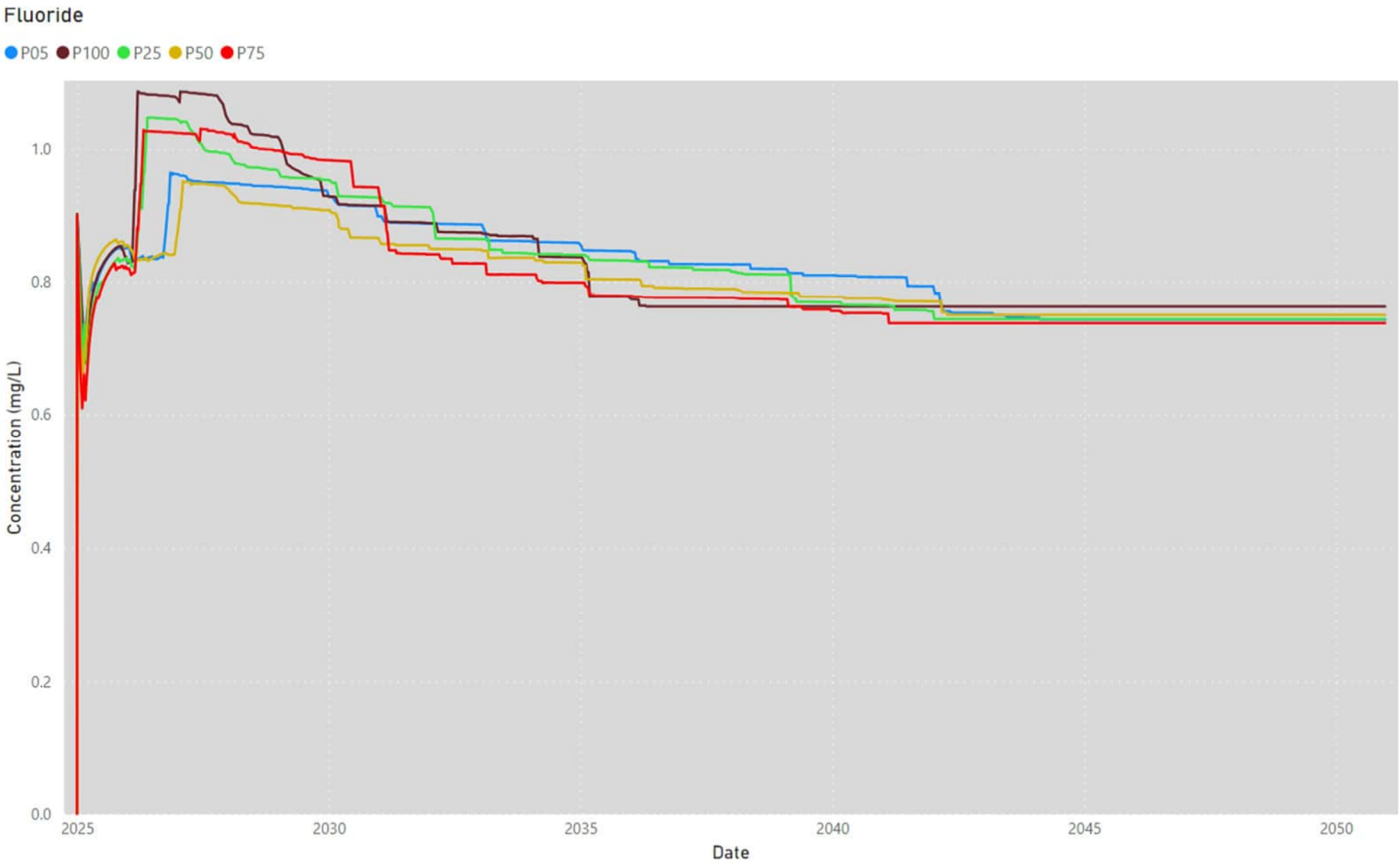

Calcium
P05
P100
P25
P50
P75
120
100
80
60
40
20
0
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

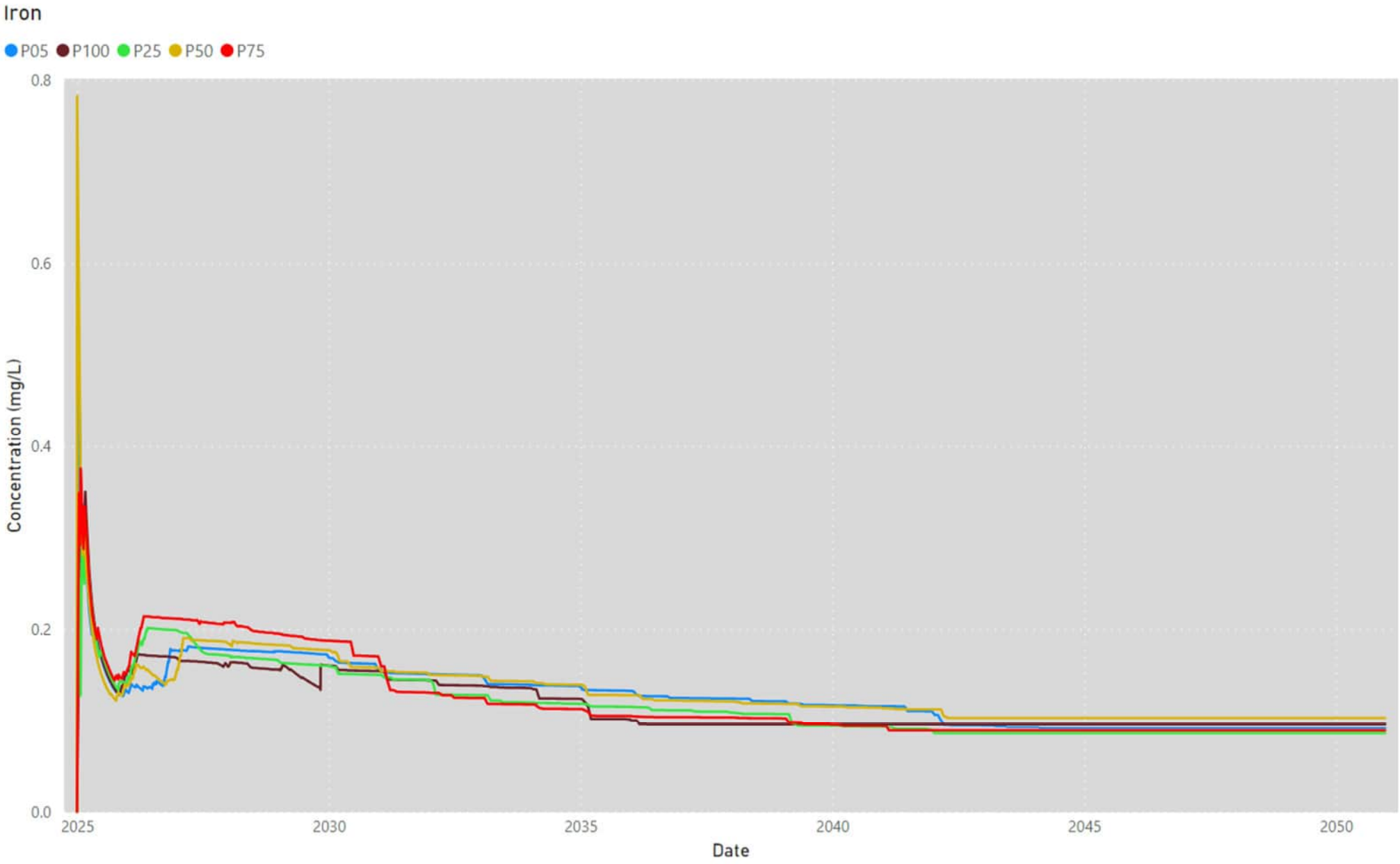

Chloride
P05
P100
P25
P50
P75
70
60
50
40
30
20
10
0
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

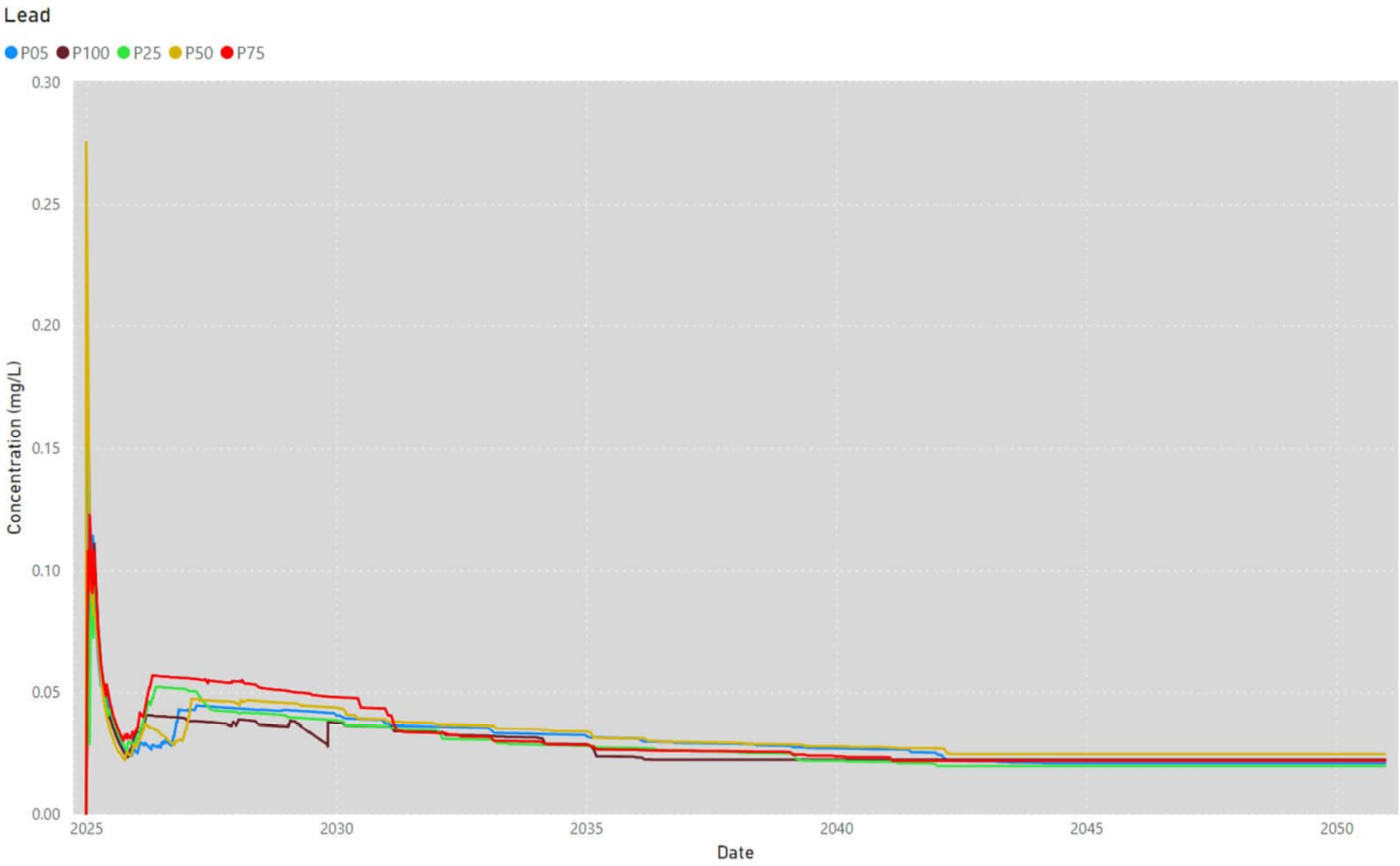

Chromium
P05
P100
P25
P50
P75
Concentration (mg/L)
0.005
0.000
2025
2030
2035
2040
2045
2050
Date

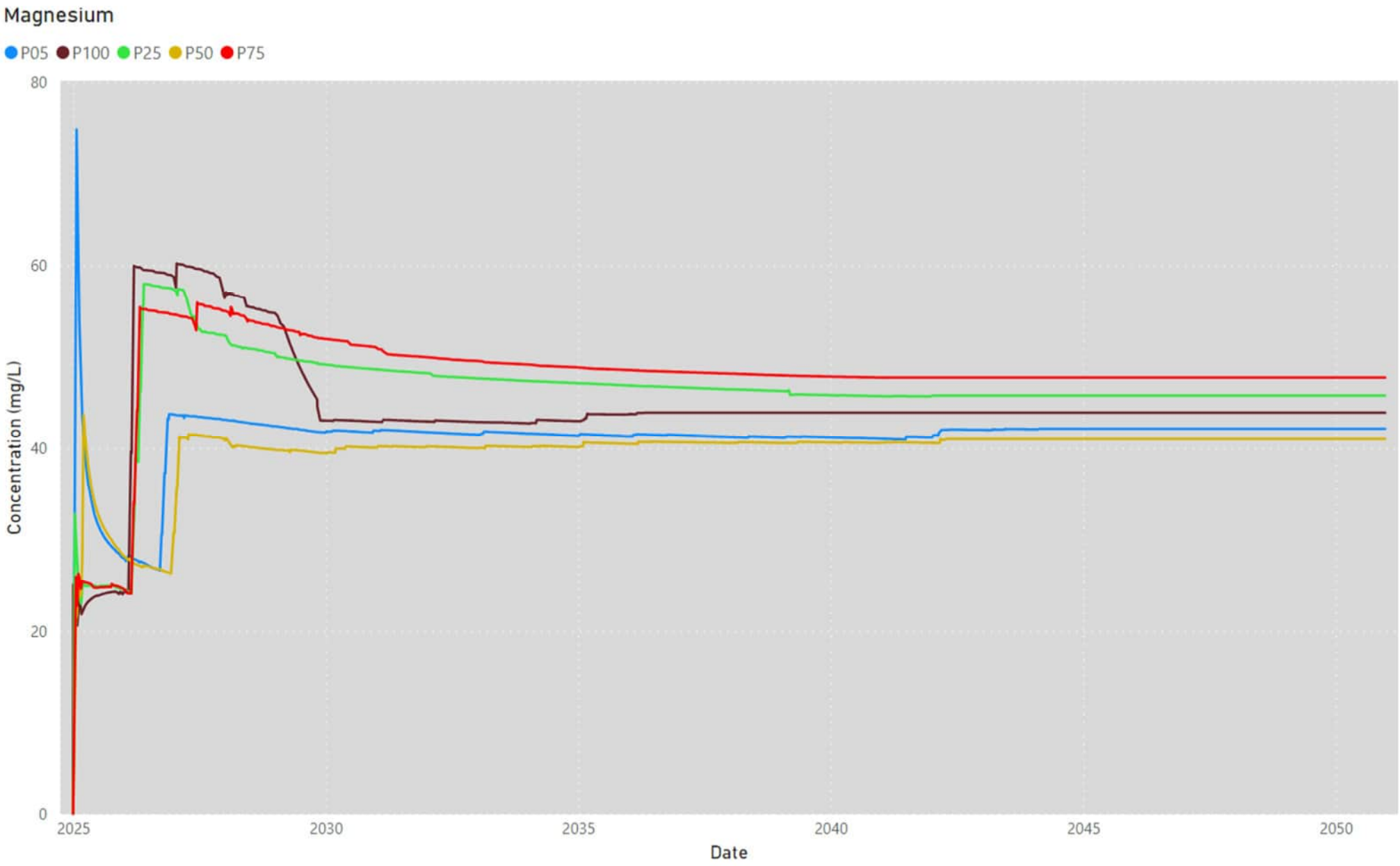

Cobalt
P05
P100
P25
P50
P75
0.004
0.002
0.000
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

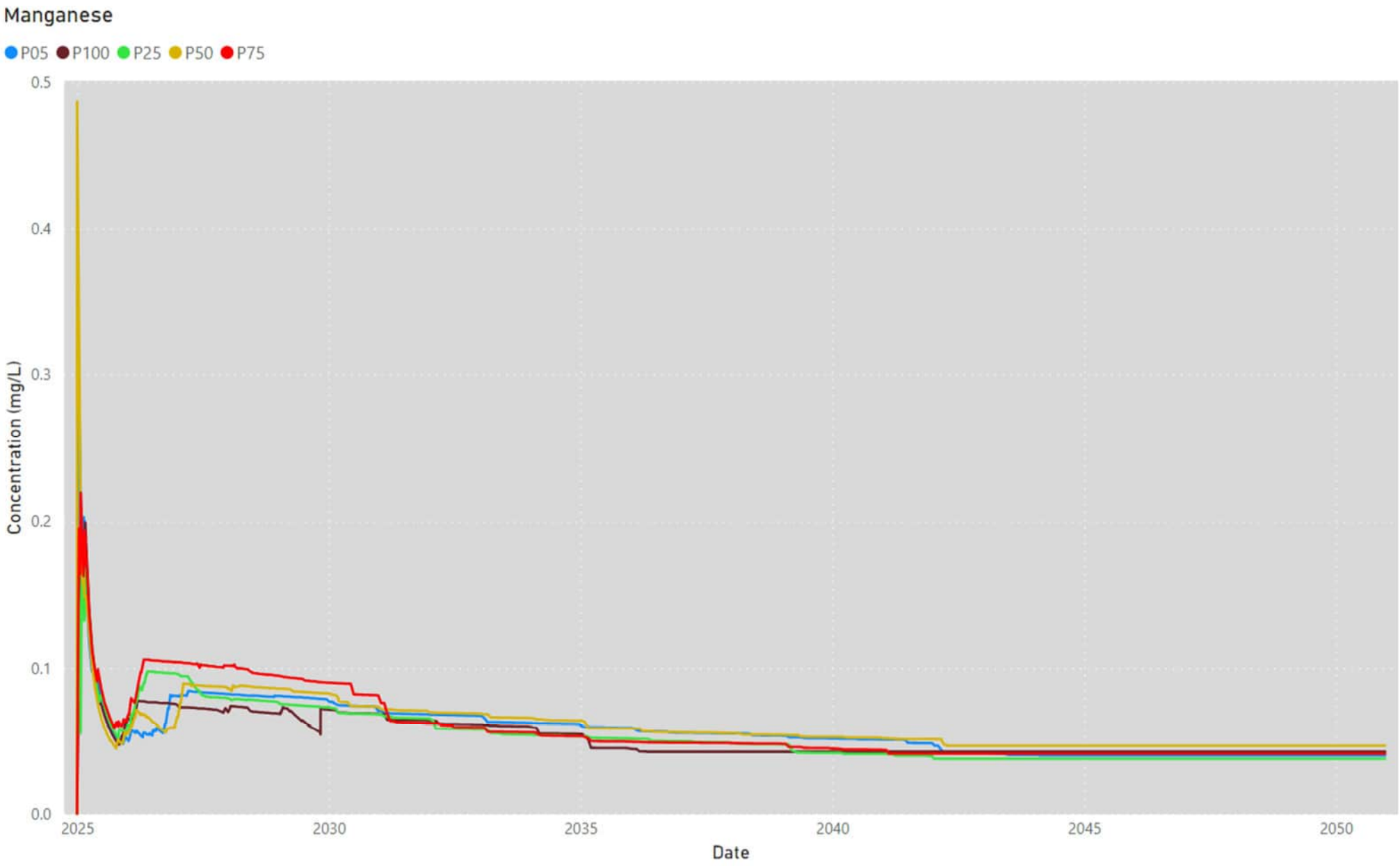

Copper
P05
P100
P25
P50
P75
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

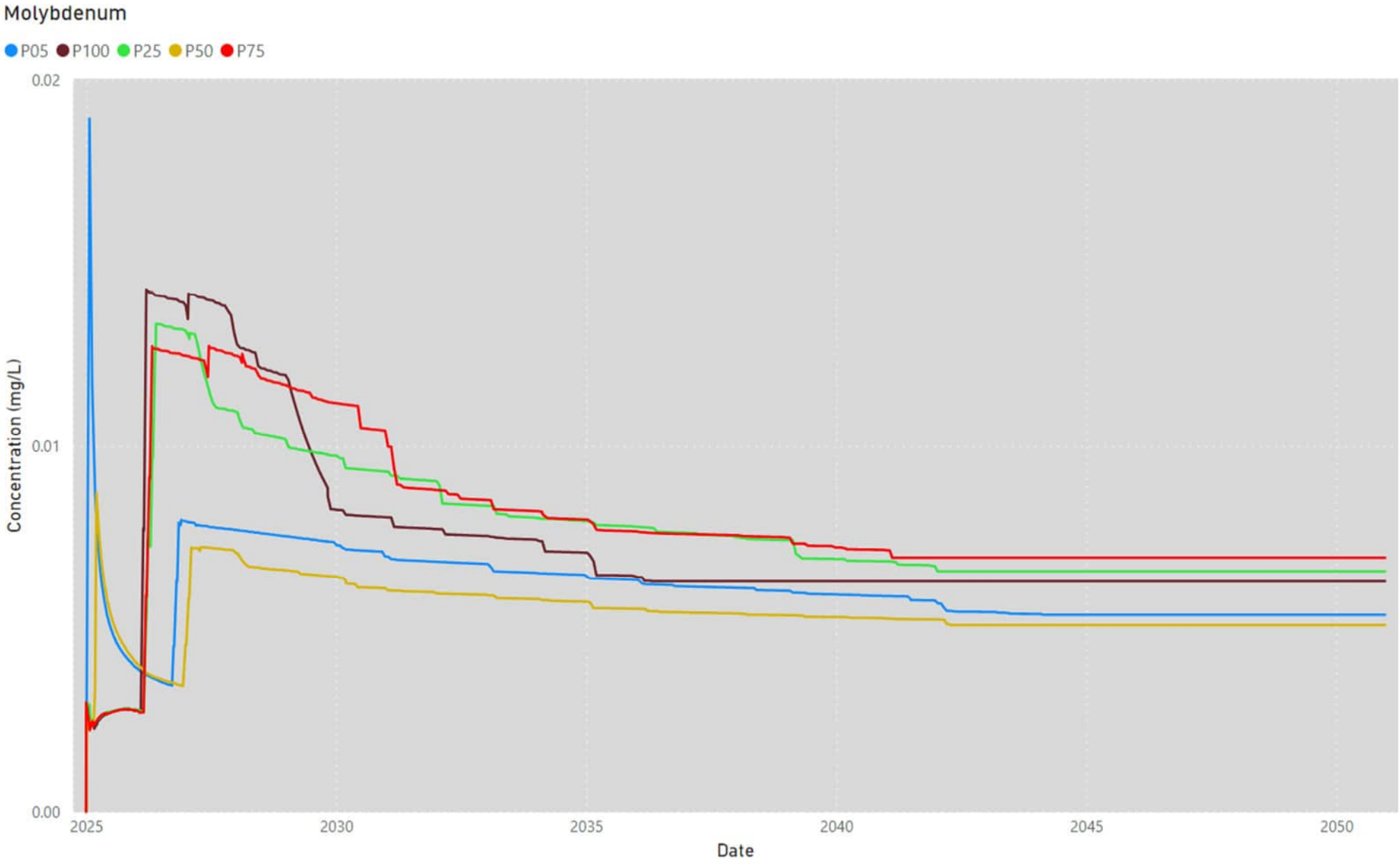

Fluoride
P05
P100
P25
P50
P75
Concentration (mg/L)
1.0
0.8
0.6
0.4
0.2
0.0
2025
2030
2035
2040
2045
2050
Date

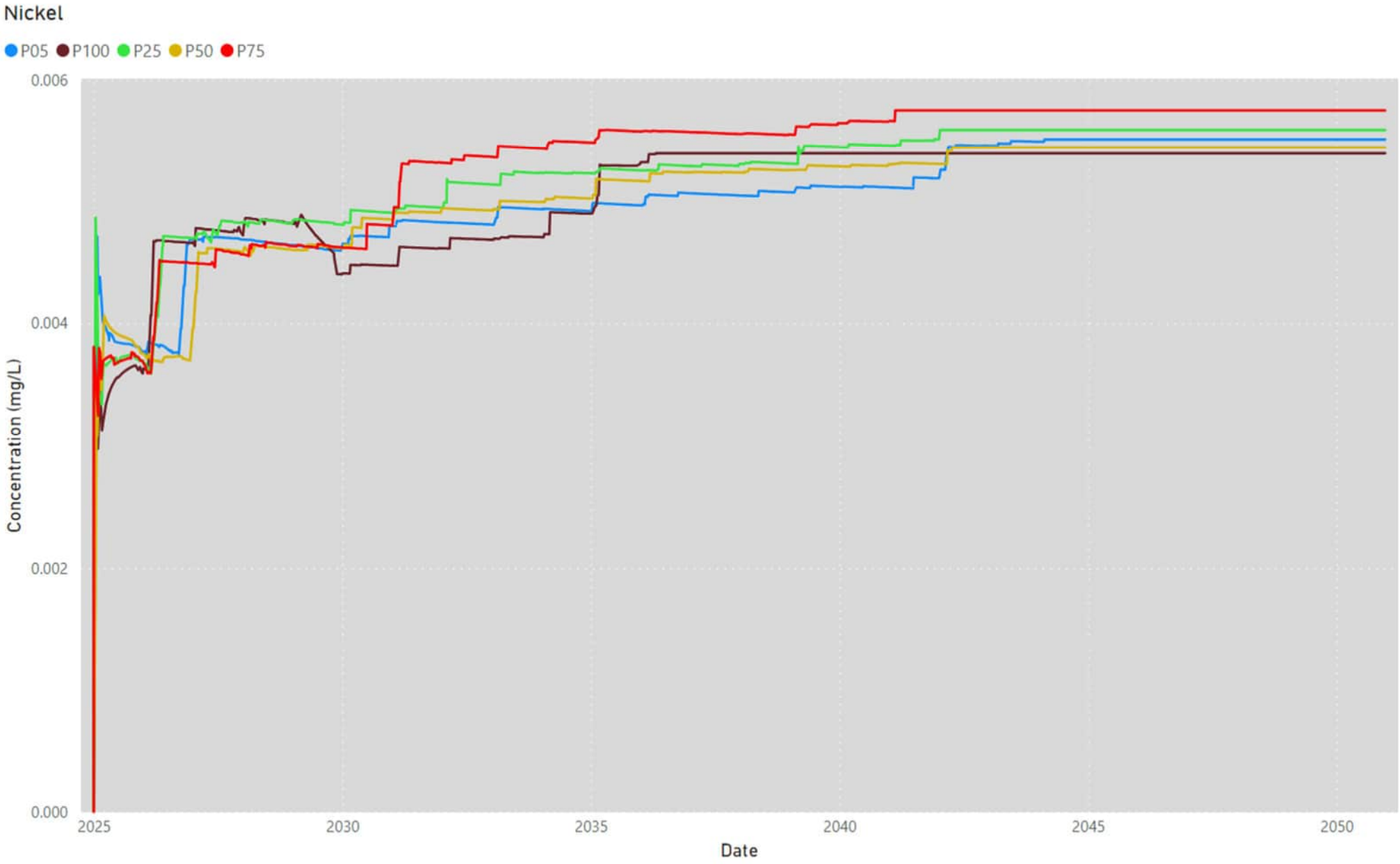

Iron
P05
P100
P25
P50
P75
0.8
0.6
0.4
0.2
0.0
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

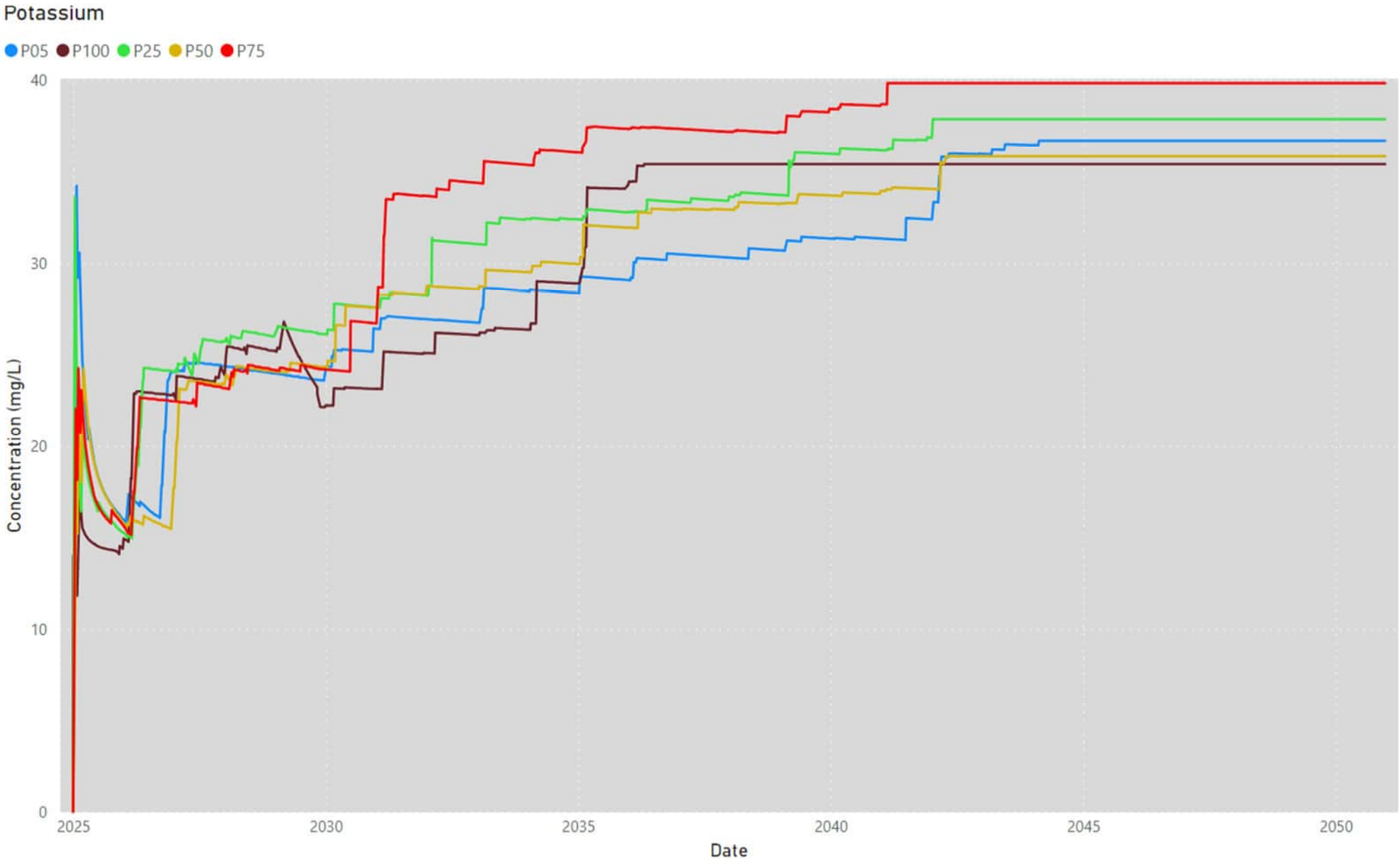

Lead
P05
P100
P25
P50
P75
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

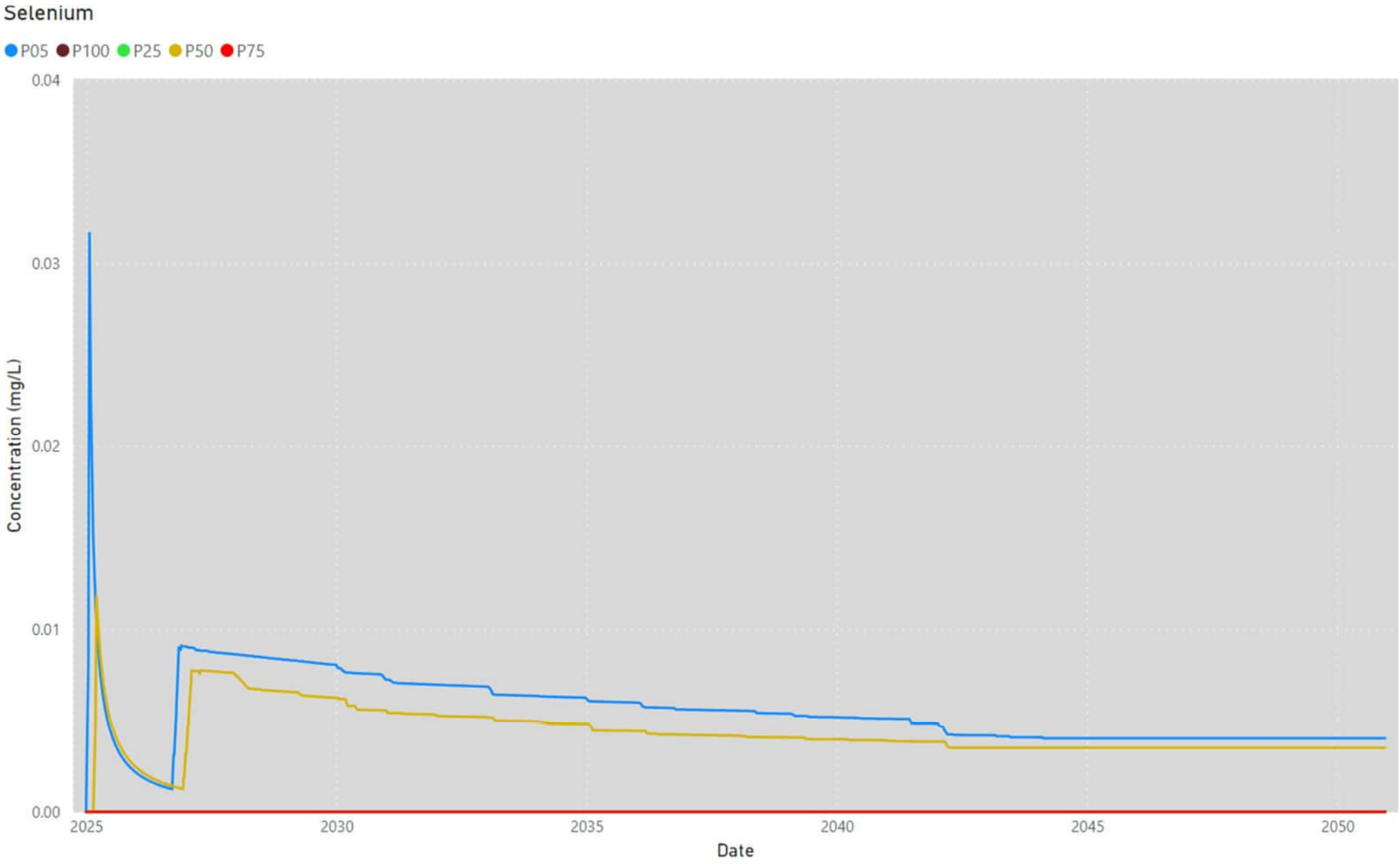

Magnesium
P05
P100
P25
P50
P75
80
60
40
20
0
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

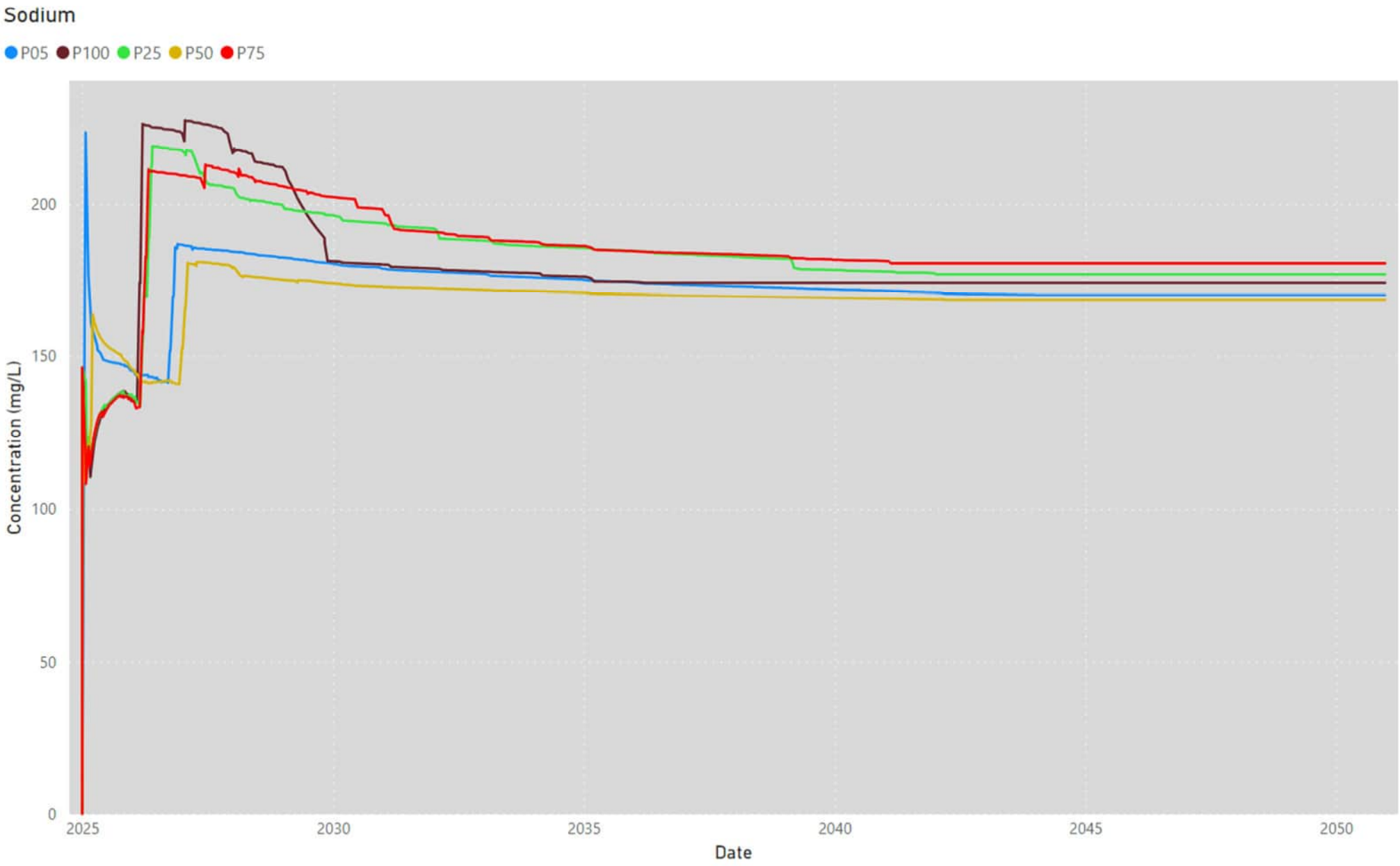

Manganese
P05
P100
P25
P50
P75
0.5
0.4
0.3
0.2
0.1
0.0
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

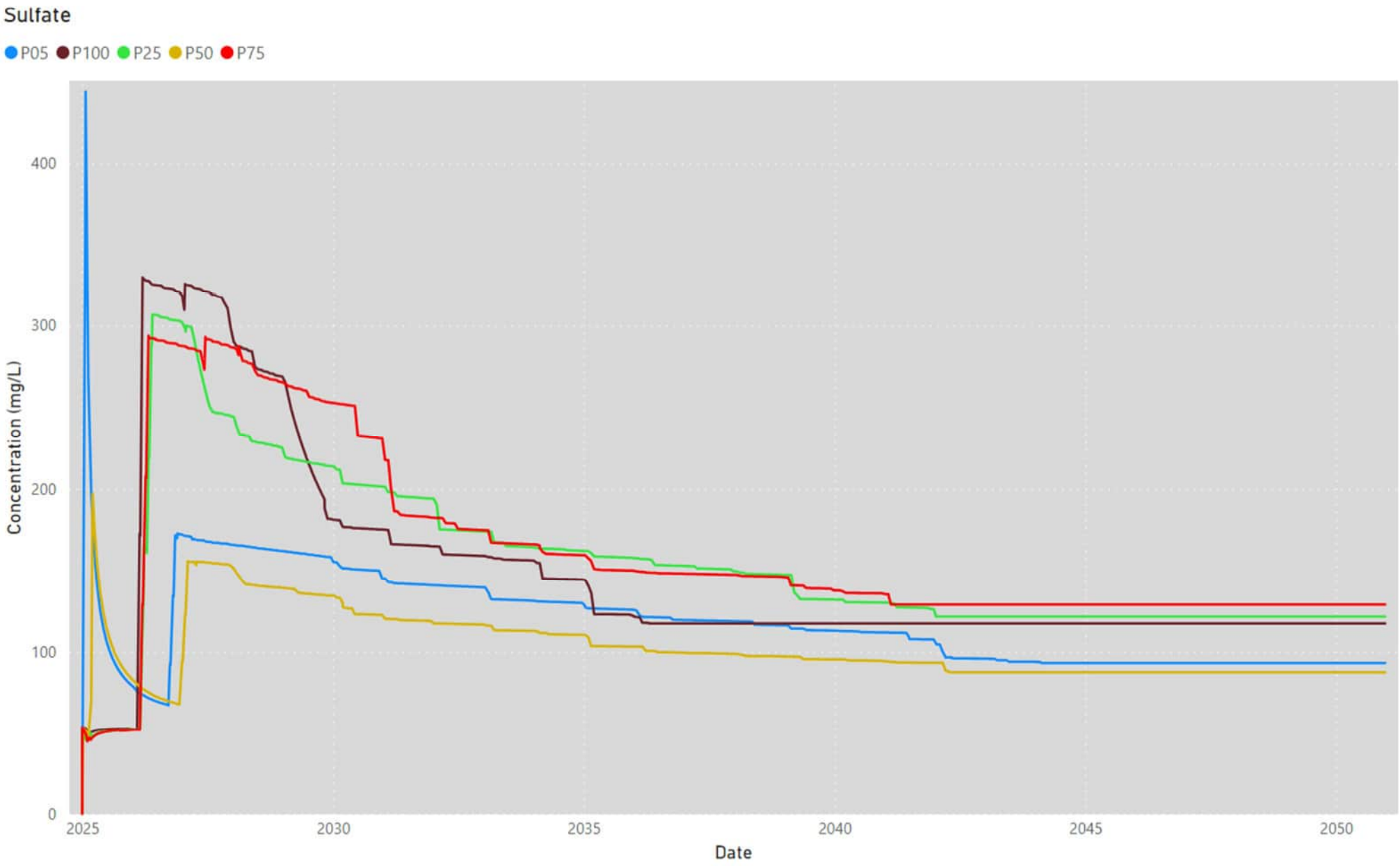

Molybdenum
P05
P100
P25
P50
P75
0.02
0.01
0.00
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

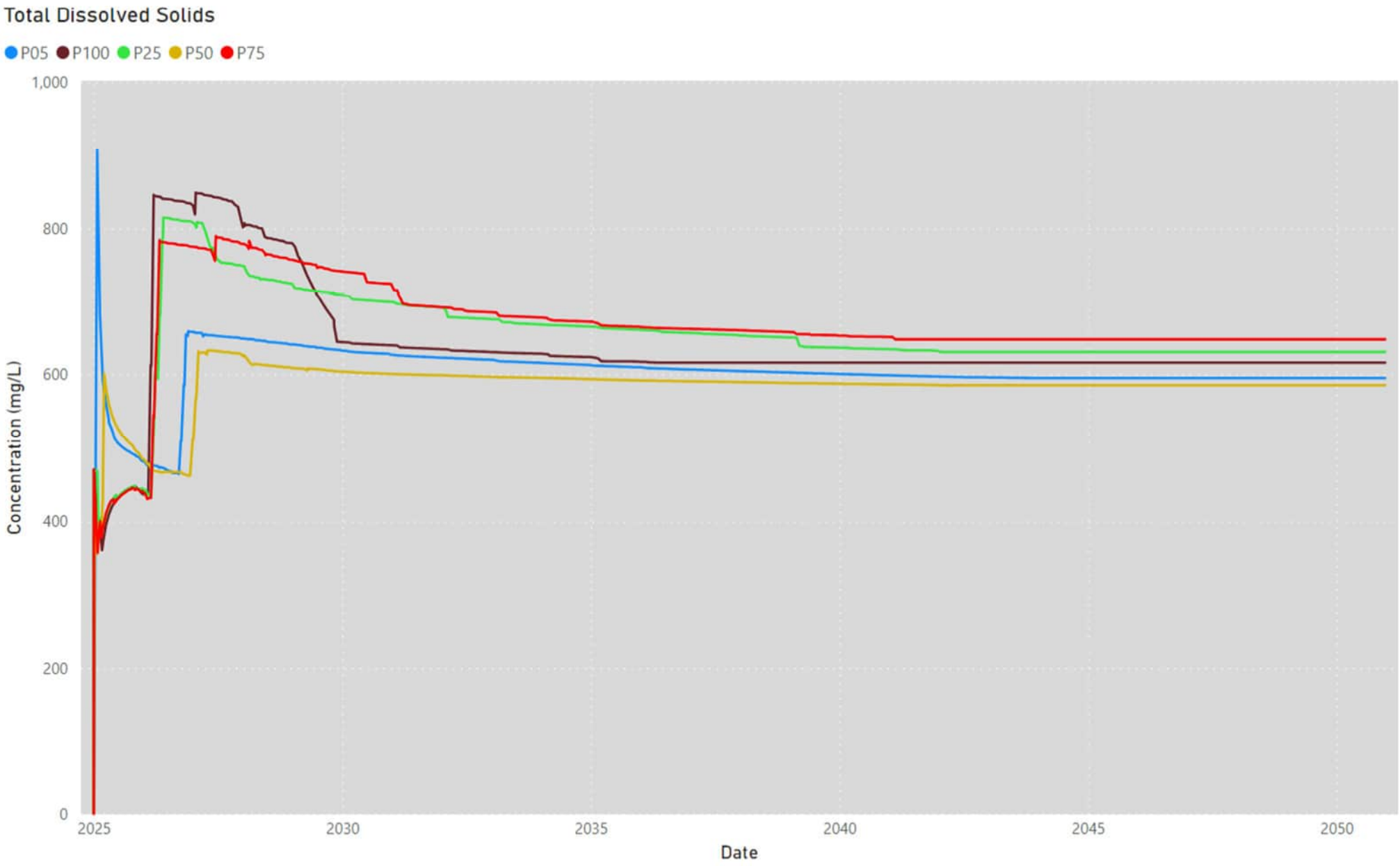

Nickel
P05
P100
P25
P50
P75
0.006
0.004
0.002
0.000
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

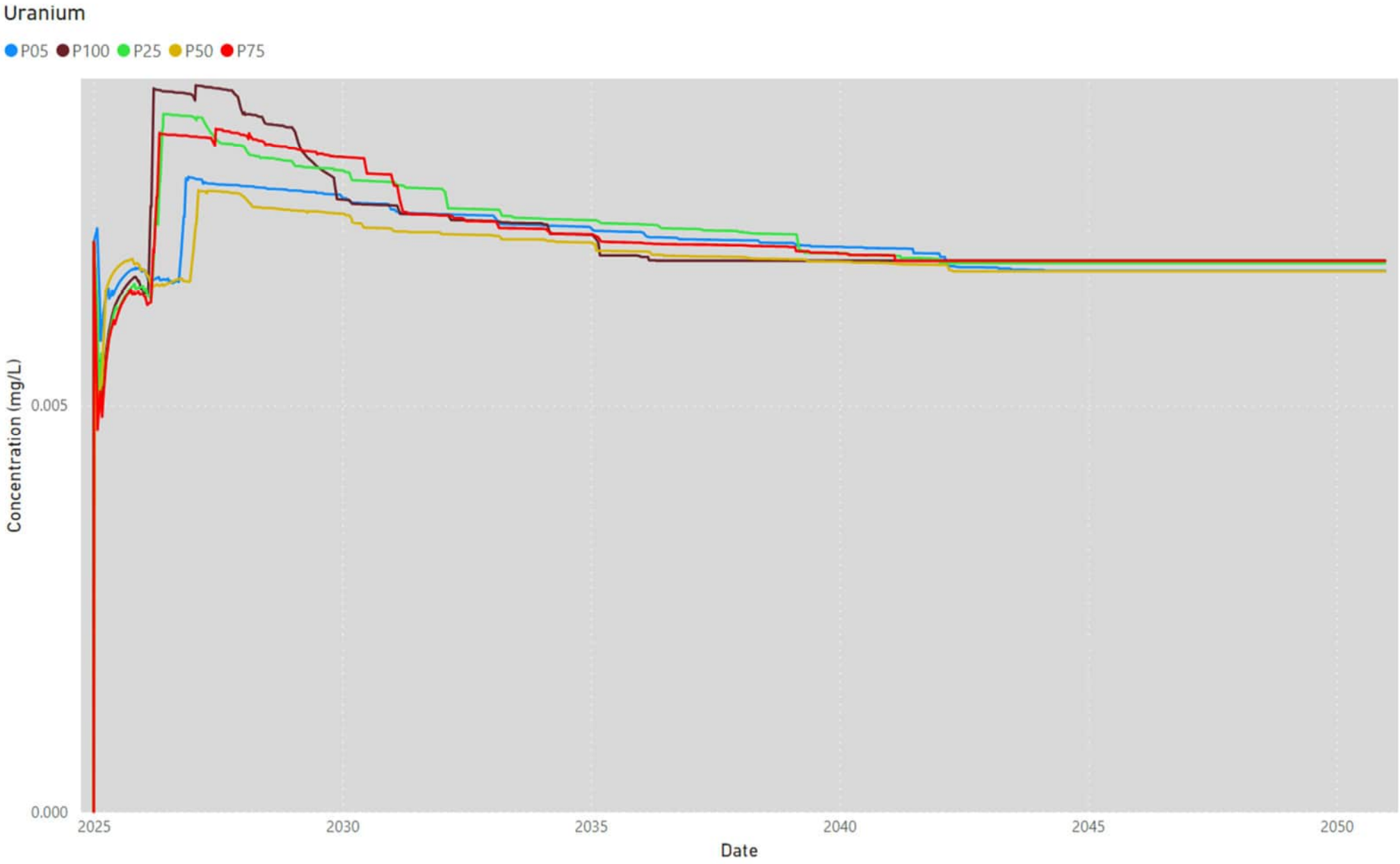

Potassium
P05
P100
P25
P50
P75
40
30
20
10
0
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

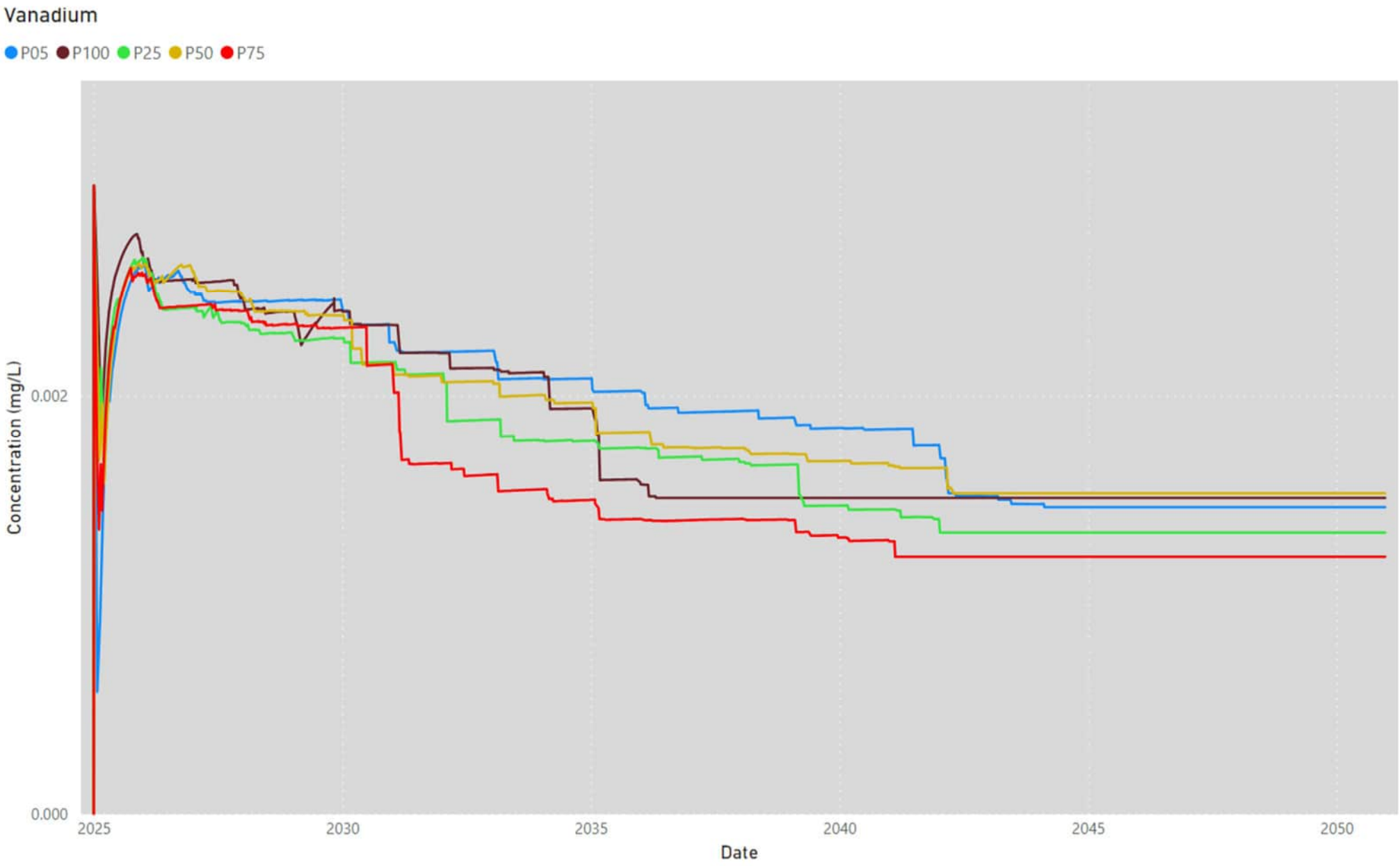

Selenium
P05
P100
P25
P50
P75
0.04
0.03
0.02
0.01
0.00
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date

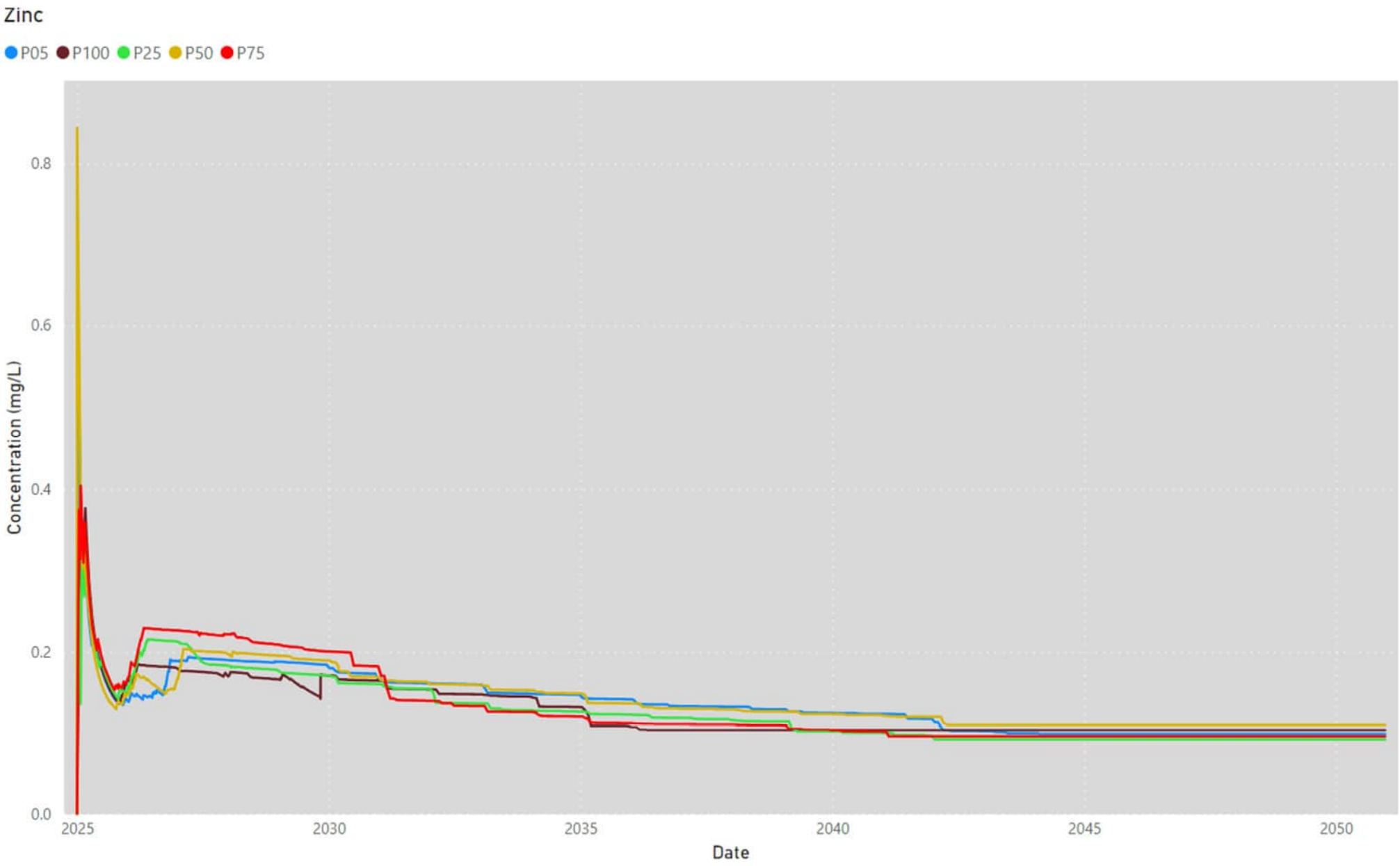

Sodium
P05
P100
P25
P50
P75
Concentration (mg/L)
0
50
100
150
200
2025
2030
2035
2040
2045
2050
Date


Sulfate
P05
P100
P25
P50
P75
Concentration (mg/L)
400
300
200
100
0
2025
2030
2035
2040
2045
2050
Date


Total Dissolved Solids
P05
P100
P25
P50
P75
1,000
800
600
400
200
0
Concentration (mg/L)
2025
2030
2035
2040
2045
2050
Date


Uranium
P05
P100
P25
P50
P75
Concentration (mg/L)
0.005
0.000
2025
2030
2035
2040
2045
2050
Date


Vanadium
P05
P100
P25
P50
P75
Concentration (mg/L)
0.002
0.000
2025
2030
2035
2040
2045
2050
Date


Zinc
P05
P100
P25
P50
P75
Concentration (mg/L)
0.0
0.2
0.4
0.6
0.8
2025
2030
2035
2040
2045
2050
Date

K.4 PAF disposal UG water quality model – Phreeqc input and output files

```
# P05 Scenario

SOLUTION 1 UG Water P05
    temp      25
    pH        8.112
    units     mg/L
    density   1
      Al    0.0789
      As    0.0026
      Ba    0.1797
      B     0.1282
      Ca    89.0
      Cl    50.5
      Mg    43.0
      Na    184.3
      K     36.7
      F     0.9477
      S(6)  165.8
      Cd    0.0070
      Cr    0.0076
      Co    0.0038
      Cu    0.0678
      Fe    0.1777
      Pb    0.0435
      Mn    0.0822
      Mo    0.0077
      Ni    0.0055
      Se    0.0086
      U     0.0077
      V     0.0025
      Zn    0.1896
      Alkalinity 483.2 as HCO3
    -water    1 # kg

SOLUTION 2 PAF Material
    temp      25
    pH        7.5
    units     mg/L
    density   1
      Al    0.020
      As    0
      Ba    0.020
      B     0
      Ca    67.0
      Cl    0
      Mg    8.0
      Na    1.0
      K     13.0
      F     0.300
      S(6)  197.0
      Cd    0.000
      Cr    0
      Co    0.007
      Cu    0.028
      Fe    0
      Pb    0
      Mn    0.040
      Mo    0.003
      Ni    0.004
      Se    0
      U     0
      V     0
      Zn    0
      Alkalinity 22 as HCO3
    -water    1 # kg

SOLUTION 3 NAF Material
    temp      25
    pH        7.6
    units     mg/L
    density   1
      Al    0.140
      As    0.029
      Ba    0.020
      B     0
      Ca    122.0
      Cl    0
      Mg    18.0
      Na    1.0
      K     16.0
      F     0.300
      S(6)  331.0
      Cd    0.000
      Cr    0
      Co    0.002
      Cu    0.019
      Fe    0.070
      Pb    0
      Mn    0.130
      Mo    0.005
      Ni    0.001
      Se    0
      U     0.001
      V     0
      Zn    0
      Alkalinity 28 as HCO3
    -water    1 # kg


SOLUTION 4 Make-up Material
    temp      25
    pH        7.7
    units     mg/L
    density   1
      Al    0.020
      As    0
      Ba    0.020
      B     0
      Ca    67.0
      Cl    0
      Mg    8.0
      Na    1.0
      K     13.0
      F     0.300
      S(6)  197.0
      Cd    0.000
      Cr    0
      Co    0.007
      Cu    0.028
      Fe    0
      Pb    0
      Mn    0.040
      Mo    0.003
      Ni    0.004
      Se    0
      U     0
      V     0
      Zn    0
      Alkalinity 22 as HCO3
    -water    1 # kg

# Mix the three solutions together

MIX 1 Mix within UG Works
    1    0.342
    2    0.105
    3    0.380
    4    0.173

SAVE Solution 5

SELECTED_OUTPUT 2
    -file                 D:\selected_output_3.txt
    -high_precision       true
    -reset                true
    -distance             false
    -time                 false
    -temperature          false
    -ionic_strength       false
    -water                false
    -totals               pH Al As Ba B Ca Cl Mg
                          Na K  F  S(6) Cd Cr Co
                          Cu Fe Pb Mn Mo  Ni Se
                          U V Zn Alkalinity
END
```

```
   Input file: P:\J23011 - BCP Underground EA (Aeris)\2. Tech Work Area\2.08 Water Quality
Model\2.08.02 PAF Assessment\BPC_UG_PAF_Disposal_P05.pqi
  Output file: P:\J23011 - BCP Underground EA (Aeris)\2. Tech Work Area\2.08 Water Quality
Model\2.08.02 PAF Assessment\BPC_UG_PAF_Disposal_P05.pqo
Database file: c:\phreeqc\database\minteq.v4.dat

------------------
Reading data base.
------------------

      SOLUTION_MASTER_SPECIES
      SOLUTION_SPECIES
      SOLUTION_SPECIES
      PHASES
      PHASES
      SURFACE_MASTER_SPECIES
      SURFACE_SPECIES
      END
-----------------------------------
Reading input data for simulation 1.
-----------------------------------

      DATABASE c:\phreeqc\database\minteq.v4.dat
      SOLUTION 1 UG Water P05
          temp      25
          pH        8.112
          units     mg/L
          density   1
            Al    0.0789
            As    0.0026
            Ba    0.1797
            B     0.1282
            Ca    89.0
            Cl    50.5
            Mg    43.0
            Na    184.3
            K     36.7
            F     0.9477
            S(6)  165.8
            Cd    0.0070
            Cr    0.0076
            Co    0.0038
            Cu    0.0678
            Fe    0.1777
            Pb    0.0435
            Mn    0.0822
            Mo    0.0077
            Ni    0.0055
            Se    0.0086
            U     0.0077
            V     0.0025
            Zn    0.1896
            Alkalinity 483.2 as HCO3
          water    1 # kg
      SOLUTION 2 PAF Material
          temp      25
          pH        7.5
          units     mg/L
          density   1
            Al    0.020
            As    0
            Ba    0.020
            B     0
            Ca    67.0
            Cl    0
            Mg    8.0
```

```
            Na    1.0
            K     13.0
            F     0.300
            S(6)  197.0
            Cd    0.000
            Cr    0
            Co    0.007
            Cu    0.028
            Fe    0
            Pb    0
            Mn    0.040
            Mo    0.003
            Ni    0.004
            Se    0
            U     0
            V     0
            Zn    0
            Alkalinity 22 as HCO3
        water    1 # kg
    SOLUTION 3 NAF Material
        temp      25
        pH        7.6
        units     mg/L
        density   1
            Al    0.140
            As    0.029
            Ba    0.020
            B     0
            Ca    122.0
            Cl    0
            Mg    18.0
            Na    1.0
            K     16.0
            F     0.300
            S(6)  331.0
            Cd    0.000
            Cr    0
            Co    0.002
            Cu    0.019
            Fe    0.070
            Pb    0
            Mn    0.130
            Mo    0.005
            Ni    0.001
            Se    0
            U     0.001
            V     0
            Zn    0
            Alkalinity 28 as HCO3
        water    1 # kg
    SOLUTION 4 Make-up Material
        temp      25
        pH        7.7
        units     mg/L
        density   1
            Al    0.020
            As    0
            Ba    0.020
            B     0
            Ca    67.0
            Cl    0
            Mg    8.0
            Na    1.0
            K     13.0
            F     0.300
            S(6)  197.0
            Cd    0.000
            Cr    0
            Co    0.007
            Cu    0.028
            Fe    0
            Pb    0
            Mn    0.040
            Mo    0.003
            Ni    0.004
            Se    0
            U     0
            V     0
            Zn    0
            Alkalinity 22 as HCO3
        water    1 # kg
    MIX 1 Mix within UG Works
        1    0.342
        2    0.105
        3    0.380
        4    0.173
    SAVE Solution 5
    SELECTED_OUTPUT 2
        file                 D:\selected_output_3.txt
        high_precision       true
        reset                true
        distance             false
        time                 false
        temperature          false
        ionic_strength       false
        water                false
        totals               pH Al As Ba B Ca Cl Mg
WARNING: Expected element name to begin with upper case letter.
                              Na K  F  S(6) Cd Cr Co
                              Cu Fe Pb Mn Mo  Ni Se
                              U V Zn Alkalinity
    END
------------------------------------------
Beginning of initial solution calculations.
------------------------------------------

Initial solution 1.     UG Water P05

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                2.927e-06   2.927e-06
      Alkalinity        7.927e-03   7.927e-03
      As                3.474e-08   3.474e-08
      B                 1.187e-05   1.187e-05
      Ba                1.310e-06   1.310e-06
      Ca                2.223e-03   2.223e-03
      Cd                6.234e-08   6.234e-08
      Cl                1.426e-03   1.426e-03
      Co                6.455e-08   6.455e-08
      Cr                1.463e-07   1.463e-07
      Cu                1.068e-06   1.068e-06
      F                 4.994e-05   4.994e-05
      Fe                3.185e-06   3.185e-06
      K                 9.397e-04   9.397e-04
      Mg                1.771e-03   1.771e-03
      Mn                1.498e-06   1.498e-06
      Mo                8.034e-08   8.034e-08
      Na                8.025e-03   8.025e-03
      Ni                9.381e-08   9.381e-08
      Pb                2.102e-07   2.102e-07
      S(6)              1.728e-03   1.728e-03
      Se                1.090e-07   1.090e-07
      U                 3.238e-08   3.238e-08
      V                 4.913e-08   4.913e-08
      Zn                2.903e-06   2.903e-06

----------------------------Description of solution----------------------------

                                       pH  =   8.112
                                       pe  =   4.000
                      Activity of water  =   1.000
                 Ionic strength (mol/kgw)  =   1.857e-02
                      Mass of water (kg)  =   1.000e+00
                 Total carbon (mol/kg)  =   7.851e-03
                    Total CO2 (mol/kg)  =   7.851e-03
                      Temperature (°C)  =  25.00
            Electrical balance (eq)  =   4.121e-03
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  14.96
                            Iterations  =  10
                               Total H  = 1.110215e+02
                               Total O  = 5.553736e+01

----------------------------Distribution of species----------------------------

                                          Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             1.496e-06   1.303e-06    -5.825    -5.885    -0.060     (0)
   H+              8.837e-09   7.727e-09    -8.054    -8.112    -0.058      0.00
   H2O             5.551e+01   9.996e-01     1.744    -0.000     0.000     18.07
Al            2.927e-06
   Al(OH)4-        2.911e-06   2.548e-06    -5.536    -5.594    -0.058     (0)
   Al(OH)3         1.554e-08   1.554e-08    -7.809    -7.809     0.000     (0)
   Al(OH)2+        6.800e-10   5.978e-10    -9.167    -9.223    -0.056     (0)
   AlF2+           3.073e-12   2.701e-12   -11.512   -11.568    -0.056     (0)
   AlF3            1.330e-12   1.330e-12   -11.876   -11.876     0.000     (0)
   AlOH+2          9.674e-13   5.777e-13   -12.014   -12.238    -0.224     (0)
   AlF+2           2.905e-13   1.735e-13   -12.537   -12.761    -0.224     (0)
   AlF4-           2.979e-14   2.608e-14   -13.526   -13.584    -0.058     (0)
   AlSO4+          3.135e-15   2.744e-15   -14.504   -14.562    -0.058     (0)
   Al+3            1.485e-15   4.435e-16   -14.828   -15.353    -0.525     (0)
   Al(SO4)2-       2.678e-17   2.344e-17   -16.572   -16.630    -0.058     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -52.377   -53.002    -0.625     (0)
As(3)         8.447e-21
   H3AsO3          7.836e-21   7.836e-21   -20.106   -20.106     0.000     (0)
   H2AsO3-         6.104e-22   5.201e-22   -21.214   -21.284    -0.069     (0)
   HAsO3-2         1.164e-25   6.139e-26   -24.934   -25.212    -0.278     (0)
   H4AsO3+         3.520e-29   3.000e-29   -28.453   -28.523    -0.069     (0)
   AsO3-3          1.293e-30   3.063e-31   -29.888   -30.514    -0.625     (0)
As(5)         3.474e-08
   HAsO4-2         3.326e-08   1.754e-08    -7.478    -7.756    -0.278     (0)
   H2AsO4-         1.450e-09   1.236e-09    -8.839    -8.908    -0.069     (0)
   AsO4-3          3.030e-11   7.177e-12   -10.519   -11.144    -0.625     (0)
   H3AsO4          1.652e-15   1.659e-15   -14.782   -14.780     0.002     (0)
B             1.187e-05
   H3BO3           1.083e-05   1.088e-05    -4.965    -4.963     0.002     (0)
   H2BO3-          9.441e-07   8.176e-07    -6.025    -6.087    -0.063     (0)
   CaH2BO3+        5.772e-08   4.998e-08    -7.239    -7.301    -0.063     (0)
   MgH2BO3+        2.943e-08   2.549e-08    -7.531    -7.594    -0.063     (0)
   NaH2BO3         9.018e-09   9.018e-09    -8.045    -8.045     0.000     (0)
   BF(OH)3-        1.961e-10   1.698e-10    -9.708    -9.770    -0.063     (0)
   BaH2BO3+        2.122e-11   1.838e-11   -10.673   -10.736    -0.063     (0)
   H5(BO3)2-       8.741e-12   7.570e-12   -11.058   -11.121    -0.063     (0)
   H8(BO3)3-       9.509e-15   8.234e-15   -14.022   -14.084    -0.063     (0)
   BF2(OH)2-       6.337e-15   5.488e-15   -14.198   -14.261    -0.063     (0)
   BF3OH-          7.454e-22   6.455e-22   -21.128   -21.190    -0.063     (0)
   BF4-            1.109e-27   9.603e-28   -26.955   -27.018    -0.063     (0)
Ba            1.310e-06
   Ba+2            1.245e-06   7.273e-07    -5.905    -6.138    -0.233     (0)
   BaHCO3+         5.078e-08   4.476e-08    -7.294    -7.349    -0.055     (0)
   BaCO3           1.458e-08   1.458e-08    -7.836    -7.836     0.000     (0)
   BaH2BO3+        2.122e-11   1.838e-11   -10.673   -10.736    -0.063     (0)
   BaOH+           4.713e-12   4.136e-12   -11.327   -11.383    -0.057     (0)
C(4)          7.851e-03
   HCO3-           7.330e-03   6.444e-03    -2.135    -2.191    -0.056     (0)
   CaHCO3+         1.446e-04   1.275e-04    -3.840    -3.895    -0.055     (0)
   H2CO3           1.120e-04   1.120e-04    -3.951    -3.951     0.000     (0)
   MgHCO3+         6.790e-05   5.929e-05    -4.168    -4.227    -0.059     (0)
   CO3-2           6.690e-05   3.910e-05    -4.175    -4.408    -0.233     (0)
   CaCO3           6.584e-05   6.584e-05    -4.182    -4.182     0.000     (0)
   MgCO3           2.924e-05   2.924e-05    -4.534    -4.534     0.000     (0)
   NaHCO3          2.522e-05   2.522e-05    -4.598    -4.598     0.000     (0)
   NaCO3-          5.764e-06   5.067e-06    -5.239    -5.295    -0.056     (0)
   ZnCO3           1.430e-06   1.430e-06    -5.845    -5.845     0.000     (0)
   CuCO3           8.643e-07   8.643e-07    -6.063    -6.063     0.000     (0)
   Cu(CO3)2-2      1.725e-07   9.095e-08    -6.763    -7.041    -0.278     (0)
   PbCO3           1.600e-07   1.600e-07    -6.796    -6.796     0.000     (0)
   ZnHCO3+         1.520e-07   1.295e-07    -6.818    -6.888    -0.069     (0)
   MnHCO3+         1.001e-07   8.785e-08    -6.999    -7.056    -0.057     (0)
   BaHCO3+         5.078e-08   4.476e-08    -7.294    -7.349    -0.055     (0)
   Pb(CO3)2-2      3.421e-08   1.804e-08    -7.466    -7.744    -0.278     (0)
   NiCO3           3.192e-08   3.192e-08    -7.496    -7.496     0.000     (0)
   UO2(CO3)3-4     3.013e-08   2.328e-09    -7.521    -8.633    -1.112     (0)
   NiHCO3+         2.040e-08   1.738e-08    -7.690    -7.760    -0.069     (0)
   CdCO3           1.840e-08   1.840e-08    -7.735    -7.735     0.000     (0)
   BaCO3           1.458e-08   1.458e-08    -7.836    -7.836     0.000     (0)
   CoCO3           1.276e-08   1.276e-08    -7.894    -7.894     0.000     (0)
   CoHCO3+         1.135e-08   9.674e-09    -7.945    -8.014    -0.069     (0)
   PbHCO3+         7.647e-09   6.516e-09    -8.117    -8.186    -0.069     (0)
   UO2(CO3)2-2     2.254e-09   1.188e-09    -8.647    -8.925    -0.278     (0)
   CuHCO3+         1.791e-09   1.526e-09    -8.747    -8.816    -0.069     (0)
   Cd(CO3)2-2      1.012e-09   5.334e-10    -8.995    -9.273    -0.278     (0)
   CdHCO3+         3.555e-10   3.030e-10    -9.449    -9.519    -0.069     (0)
   FeHCO3+         2.707e-10   2.386e-10    -9.568    -9.622    -0.055     (0)
   UO2CO3          1.523e-12   1.523e-12   -11.817   -11.817     0.000     (0)
Ca            2.223e-03
   Ca+2            1.818e-03   1.062e-03    -2.740    -2.974    -0.233     (0)
   CaSO4           1.940e-04   1.940e-04    -3.712    -3.712     0.000     (0)
   CaHCO3+         1.446e-04   1.275e-04    -3.840    -3.895    -0.055     (0)
   CaCO3           6.584e-05   6.584e-05    -4.182    -4.182     0.000     (0)
   CaF+            5.169e-07   4.536e-07    -6.287    -6.343    -0.057     (0)
   CaH2BO3+        5.772e-08   4.998e-08    -7.239    -7.301    -0.063     (0)
   CaOH+           3.133e-08   2.761e-08    -7.504    -7.559    -0.055     (0)
Cd            6.234e-08
   Cd+2            3.533e-08   2.065e-08    -7.452    -7.685    -0.233     (0)
   CdCO3           1.840e-08   1.840e-08    -7.735    -7.735     0.000     (0)
   CdSO4           3.859e-09   3.859e-09    -8.414    -8.414     0.000     (0)
   CdCl+           2.885e-09   2.459e-09    -8.540    -8.609    -0.069     (0)
   Cd(CO3)2-2      1.012e-09   5.334e-10    -8.995    -9.273    -0.278     (0)
   CdHCO3+         3.555e-10   3.030e-10    -9.449    -9.519    -0.069     (0)
   CdOH+           2.507e-10   2.137e-10    -9.601    -9.670    -0.069     (0)
   CdOHCl          1.314e-10   1.314e-10    -9.881    -9.881     0.000     (0)
   Cd(SO4)2-2      7.869e-11   4.149e-11   -10.104   -10.382    -0.278     (0)
   CdF+            1.502e-11   1.280e-11   -10.823   -10.893    -0.069     (0)
   CdCl2           1.278e-11   1.278e-11   -10.894   -10.894     0.000     (0)
   Cd(OH)2         1.756e-12   1.756e-12   -11.755   -11.755     0.000     (0)
   CdCl3-          1.180e-14   1.005e-14   -13.928   -13.998    -0.069     (0)
   CdF2            9.991e-16   9.991e-16   -15.000   -15.000     0.000     (0)
   Cd(OH)3-        1.640e-16   1.398e-16   -15.785   -15.855    -0.069     (0)
   Cd2OH+3         9.335e-17   2.211e-17   -16.030   -16.655    -0.625     (0)
   Cd(SeO3)2-2     2.202e-17   1.161e-17   -16.657   -16.935    -0.278     (0)
   CdSeO4          2.078e-17   2.078e-17   -16.682   -16.682     0.000     (0)
```

Cd(OH)4-2	5.652e-23	2.980e-23	-22.248	-22.526	-0.278	(0)
Cl	1.426e-03					
Cl-	1.426e-03	1.247e-03	-2.846	-2.904	-0.058	(0)
ZnOHCl	3.395e-09	3.395e-09	-8.469	-8.469	0.000	(0)
CdCl+	2.885e-09	2.459e-09	-8.540	-8.609	-0.069	(0)
ZnCl+	2.280e-09	1.990e-09	-8.642	-8.701	-0.059	(0)
MnCl+	1.222e-09	1.072e-09	-8.913	-8.970	-0.057	(0)
CuCl	2.886e-10	2.886e-10	-9.540	-9.540	0.000	(0)
CdOHCl	1.314e-10	1.314e-10	-9.881	-9.881	0.000	(0)
CoCl+	9.768e-11	8.324e-11	-10.010	-10.080	-0.069	(0)
CuCl2-	8.610e-11	7.517e-11	-10.065	-10.124	-0.059	(0)
NiCl+	8.192e-11	6.980e-11	-10.087	-10.156	-0.069	(0)
PbCl+	7.065e-11	6.020e-11	-10.151	-10.220	-0.069	(0)
CdCl2	1.278e-11	1.278e-11	-10.894	-10.894	0.000	(0)
CuCl+	8.496e-12	7.418e-12	-11.071	-11.130	-0.059	(0)
ZnCl2	3.933e-12	3.933e-12	-11.405	-11.405	0.000	(0)
MnCl2	1.889e-12	1.889e-12	-11.724	-11.724	0.000	(0)
PbCl2	3.353e-13	3.353e-13	-12.475	-12.475	0.000	(0)
CuCl3-2	3.380e-14	2.004e-14	-13.471	-13.698	-0.227	(0)
CdCl3-	1.180e-14	1.005e-14	-13.928	-13.998	-0.069	(0)
ZnCl3-	4.461e-15	3.895e-15	-14.351	-14.409	-0.059	(0)
CuCl2	3.207e-15	3.207e-15	-14.494	-14.494	0.000	(0)
MnCl3-	7.391e-16	6.485e-16	-15.131	-15.188	-0.057	(0)
NiCl2	4.382e-16	4.382e-16	-15.358	-15.358	0.000	(0)
PbCl3-	1.953e-16	1.664e-16	-15.709	-15.779	-0.069	(0)
CrCl+2	5.693e-17	3.002e-17	-16.245	-16.523	-0.278	(0)
ZnCl4-2	4.097e-18	2.428e-18	-17.388	-17.615	-0.227	(0)
CrOHCl2	9.266e-19	9.266e-19	-18.033	-18.033	0.000	(0)
PbCl4-2	1.799e-19	9.483e-20	-18.745	-19.023	-0.278	(0)
FeCl+2	1.735e-19	1.029e-19	-18.761	-18.988	-0.227	(0)
CuCl3-	4.273e-20	3.731e-20	-19.369	-19.428	-0.059	(0)
UO2Cl+	2.322e-20	1.979e-20	-19.634	-19.704	-0.069	(0)
CrCl2+	4.167e-21	3.551e-21	-20.380	-20.450	-0.069	(0)
FeCl2+	6.529e-22	5.728e-22	-21.185	-21.242	-0.057	(0)
VOCl+	6.415e-23	5.467e-23	-22.193	-22.262	-0.069	(0)
CuCl4-2	3.933e-25	2.331e-25	-24.405	-24.632	-0.227	(0)
FeCl3	7.142e-26	7.142e-26	-25.146	-25.146	0.000	(0)
CrO3Cl-	2.952e-26	2.516e-26	-25.530	-25.599	-0.069	(0)
CoCl+2	3.697e-37	1.949e-37	-36.432	-36.710	-0.278	(0)
UCl+3	0.000e+00	0.000e+00	-48.820	-49.445	-0.625	(0)
Co(2)	6.455e-08					
Co+2	3.660e-08	1.930e-08	-7.436	-7.714	-0.278	(0)
CoCO3	1.276e-08	1.276e-08	-7.894	-7.894	0.000	(0)
CoHCO3+	1.135e-08	9.674e-09	-7.945	-8.014	-0.069	(0)
CoSO4	3.069e-09	3.069e-09	-8.513	-8.513	0.000	(0)
CoOH+	5.887e-10	5.016e-10	-9.230	-9.300	-0.069	(0)
CoCl+	9.768e-11	8.324e-11	-10.010	-10.080	-0.069	(0)
Co(OH)2	5.190e-11	5.190e-11	-10.285	-10.285	0.000	(0)
CoF+	2.801e-11	2.387e-11	-10.553	-10.622	-0.069	(0)
Co(OH)3-	1.583e-15	1.349e-15	-14.800	-14.870	-0.069	(0)
CoOOH-	3.974e-16	3.386e-16	-15.401	-15.470	-0.069	(0)
CoSeO4	5.228e-17	5.228e-17	-16.282	-16.282	0.000	(0)
Co2OH+3	2.048e-18	4.852e-19	-17.689	-18.314	-0.625	(0)
Co(OH)4-2	5.282e-22	2.785e-22	-21.277	-21.555	-0.278	(0)
Co4(OH)4+4	1.635e-28	1.263e-29	-27.787	-28.899	-1.112	(0)
Co(3)	9.646e-30					
CoOH+2	9.646e-30	5.086e-30	-29.016	-29.294	-0.278	(0)
Co+3	2.573e-36	7.683e-37	-35.590	-36.114	-0.525	(0)
CoCl+2	3.697e-37	1.949e-37	-36.432	-36.710	-0.278	(0)
Cr(2)	8.429e-25					
Cr+2	8.429e-25	4.444e-25	-24.074	-24.352	-0.278	(0)
Cr(3)	1.463e-07					
Cr(OH)2+	9.862e-08	8.404e-08	-7.006	-7.076	-0.069	(0)
Cr(OH)3	4.112e-08	4.112e-08	-7.386	-7.386	0.000	(0)
CrO2-	2.967e-09	2.529e-09	-8.528	-8.597	-0.069	(0)
Cr(OH)4-	2.503e-09	2.133e-09	-8.602	-8.671	-0.069	(0)
Cr(OH)+2	1.006e-09	5.302e-10	-8.998	-9.276	-0.278	(0)
CrOHSO4	1.003e-10	1.003e-10	-9.999	-9.999	0.000	(0)
CrF+2	2.187e-13	1.153e-13	-12.660	-12.938	-0.278	(0)
Cr+3	7.853e-14	1.860e-14	-13.105	-13.730	-0.625	(0)
CrSO4+	4.064e-14	3.463e-14	-13.391	-13.461	-0.069	(0)
CrCl+2	5.693e-17	3.002e-17	-16.245	-16.523	-0.278	(0)
Cr2(OH)2SO4+2	9.115e-18	4.806e-18	-17.040	-17.318	-0.278	(0)
CrOHCl2	9.266e-19	9.266e-19	-18.033	-18.033	0.000	(0)
Cr2(OH)2(SO4)2	2.276e-19	2.276e-19	-18.643	-18.643	0.000	(0)
CrCl2+	4.167e-21	3.551e-21	-20.380	-20.450	-0.069	(0)
Cr(6)	2.963e-14					
CrO4-2	2.841e-14	1.660e-14	-13.547	-13.780	-0.233	(0)
NaCrO4-	6.738e-16	5.741e-16	-15.171	-15.241	-0.069	(0)
HCrO4-	4.871e-16	4.151e-16	-15.312	-15.382	-0.069	(0)
KCrO4-	5.913e-17	5.039e-17	-16.228	-16.298	-0.069	(0)
H2CrO4	2.600e-24	2.600e-24	-23.585	-23.585	0.000	(0)
CrO3SO4-2	1.477e-24	7.790e-25	-23.831	-24.108	-0.278	(0)
CrO3Cl-	2.952e-26	2.516e-26	-25.530	-25.599	-0.069	(0)
Cr2O7-2	1.133e-29	5.976e-30	-28.946	-29.224	-0.278	(0)
Cu(1)	5.905e-10					
CuCl	2.886e-10	2.886e-10	-9.540	-9.540	0.000	(0)
Cu+	2.158e-10	1.839e-10	-9.666	-9.735	-0.069	(0)
CuCl2-	8.610e-11	7.517e-11	-10.065	-10.124	-0.059	(0)
CuCl3-2	3.380e-14	2.004e-14	-13.471	-13.698	-0.227	(0)
Cu(2)	1.067e-06					
CuCO3	8.643e-07	8.643e-07	-6.063	-6.063	0.000	(0)
Cu(CO3)2-2	1.725e-07	9.095e-08	-6.763	-7.041	-0.278	(0)
CuOH+	1.771e-08	1.546e-08	-7.752	-7.811	-0.059	(0)
Cu+2	6.424e-09	3.754e-09	-8.192	-8.425	-0.233	(0)
Cu(OH)2	4.019e-09	4.019e-09	-8.396	-8.396	0.000	(0)
CuHCO3+	1.791e-09	1.526e-09	-8.747	-8.816	-0.069	(0)
CuSO4	6.855e-10	6.855e-10	-9.164	-9.164	0.000	(0)
Cu(OH)3-	1.260e-11	1.074e-11	-10.900	-10.969	-0.069	(0)
Cu2(OH)2+2	1.139e-11	6.007e-12	-10.943	-11.221	-0.278	(0)
CuF+	1.087e-11	9.265e-12	-10.964	-11.033	-0.069	(0)
CuCl+	8.496e-12	7.418e-12	-11.071	-11.130	-0.059	(0)
CuCl2	3.207e-15	3.207e-15	-14.494	-14.494	0.000	(0)
Cu(OH)4-2	2.088e-16	1.101e-16	-15.680	-15.958	-0.278	(0)
CuCl3-	4.273e-20	3.731e-20	-19.369	-19.428	-0.059	(0)
CuCl4-2	3.933e-25	2.331e-25	-24.405	-24.632	-0.227	(0)
F	4.994e-05					
F-	4.474e-05	3.911e-05	-4.349	-4.408	-0.058	(0)
MgF+	4.508e-06	3.946e-06	-5.346	-5.404	-0.058	(0)
CaF+	5.169e-07	4.536e-07	-6.287	-6.343	-0.057	(0)
NaF	1.718e-07	1.718e-07	-6.765	-6.765	0.000	(0)
MnF+	1.213e-09	1.064e-09	-8.916	-8.973	-0.057	(0)
ZnF+	5.821e-10	4.961e-10	-9.235	-9.304	-0.069	(0)
HF	4.470e-10	4.470e-10	-9.350	-9.350	0.000	(0)
BF(OH)3-	1.961e-10	1.698e-10	-9.708	-9.770	-0.063	(0)
CoF+	2.801e-11	2.387e-11	-10.553	-10.622	-0.069	(0)
NiF+	2.523e-11	2.150e-11	-10.598	-10.668	-0.069	(0)
CdF+	1.502e-11	1.280e-11	-10.823	-10.893	-0.069	(0)
CuF+	1.087e-11	9.265e-12	-10.964	-11.033	-0.069	(0)
PbF+	4.402e-12	3.751e-12	-11.356	-11.426	-0.069	(0)
AlF2+	3.073e-12	2.701e-12	-11.512	-11.568	-0.056	(0)
AlF3	1.330e-12	1.330e-12	-11.876	-11.876	0.000	(0)
AlF+2	2.905e-13	1.735e-13	-12.537	-12.761	-0.224	(0)
CrF+2	2.187e-13	1.153e-13	-12.660	-12.938	-0.278	(0)
HF2-	7.634e-14	6.648e-14	-13.117	-13.177	-0.060	(0)
AlF4-	2.979e-14	2.608e-14	-13.526	-13.584	-0.058	(0)
BF2(OH)2-	6.337e-15	5.488e-15	-14.198	-14.261	-0.063	(0)
PbF2	2.888e-15	2.888e-15	-14.539	-14.539	0.000	(0)
CdF2	9.991e-16	9.991e-16	-15.000	-15.000	0.000	(0)
FeF+2	1.977e-16	1.172e-16	-15.704	-15.931	-0.227	(0)
FeF2+	1.398e-16	1.227e-16	-15.855	-15.911	-0.057	(0)
UO2F+	6.200e-17	5.284e-17	-16.208	-16.277	-0.069	(0)
FeF3	6.769e-18	6.769e-18	-17.169	-17.169	0.000	(0)
UO2F2	5.960e-18	5.960e-18	-17.225	-17.225	0.000	(0)
VO2F	2.244e-18	2.244e-18	-17.649	-17.649	0.000	(0)
H2F2	5.354e-19	5.354e-19	-18.271	-18.271	0.000	(0)
PbF3-	2.514e-19	2.142e-19	-18.600	-18.669	-0.069	(0)
UO2F3-	6.872e-20	5.856e-20	-19.163	-19.232	-0.069	(0)
VO2F2-	3.741e-20	3.188e-20	-19.427	-19.497	-0.069	(0)
VOF+	4.303e-21	3.667e-21	-20.366	-20.436	-0.069	(0)
BF3OH-	7.454e-22	6.455e-22	-21.128	-21.190	-0.063	(0)
VOF2	5.378e-23	5.378e-23	-22.269	-22.269	0.000	(0)
UO2F4-2	3.451e-23	1.820e-23	-22.462	-22.740	-0.278	(0)
VO2F3-2	2.950e-23	1.555e-23	-22.530	-22.808	-0.278	(0)
PbF4-2	7.607e-24	4.011e-24	-23.119	-23.397	-0.278	(0)
VOF3-	8.759e-26	7.464e-26	-25.058	-25.127	-0.069	(0)
VO2F4-3	1.264e-27	2.993e-28	-26.898	-27.524	-0.625	(0)
BF4-	1.109e-27	9.603e-28	-26.955	-27.018	-0.063	(0)
VOF4-2	2.235e-29	1.178e-29	-28.651	-28.929	-0.278	(0)
UF3+	1.605e-40	1.368e-40	-39.795	-39.864	-0.069	(0)
UF2+2	0.000e+00	0.000e+00	-40.378	-40.656	-0.278	(0)
UF4	0.000e+00	0.000e+00	-42.232	-42.232	0.000	(0)
UF+3	0.000e+00	0.000e+00	-42.723	-43.349	-0.625	(0)
UF5-	0.000e+00	0.000e+00	-44.972	-45.041	-0.069	(0)
UF6-2	0.000e+00	0.000e+00	-46.691	-46.969	-0.278	(0)
Fe(2)	5.598e-09					
Fe+2	5.578e-09	2.941e-09	-8.254	-8.532	-0.278	(0)
FeSO4	5.754e-10	5.754e-10	-9.240	-9.240	0.000	(0)
FeHCO3+	2.707e-10	2.386e-10	-9.568	-9.622	-0.055	(0)
FeOH+	1.738e-10	1.525e-10	-9.760	-9.817	-0.057	(0)
Fe(OH)2	1.578e-13	1.578e-13	-12.802	-12.802	0.000	(0)
Fe(OH)3-	7.409e-14	6.501e-14	-13.130	-13.187	-0.057	(0)
Fe(3)	3.179e-06					
Fe(OH)3	1.629e-06	1.629e-06	-5.788	-5.788	0.000	(0)
Fe(OH)2+	1.325e-06	1.165e-06	-5.878	-5.934	-0.056	(0)
Fe(OH)4-	2.248e-07	1.976e-07	-6.648	-6.704	-0.056	(0)
FeOH+2	3.877e-12	2.298e-12	-11.412	-11.639	-0.227	(0)
FeF+2	1.977e-16	1.172e-16	-15.704	-15.931	-0.227	(0)
FeF2+	1.398e-16	1.227e-16	-15.855	-15.911	-0.057	(0)
FeSO4+	2.785e-17	2.443e-17	-16.555	-16.612	-0.057	(0)
Fe+3	9.149e-18	2.732e-18	-17.039	-17.564	-0.525	(0)
FeF3	6.769e-18	6.769e-18	-17.169	-17.169	0.000	(0)
Fe(SO4)2-	4.887e-19	4.164e-19	-18.311	-18.380	-0.069	(0)
FeCl+2	1.735e-19	1.029e-19	-18.761	-18.988	-0.227	(0)
Fe2(OH)2+4	2.262e-21	1.748e-22	-20.645	-21.757	-1.112	(0)
FeHSeO3+2	6.941e-22	3.659e-22	-21.159	-21.437	-0.278	(0)
FeCl2+	6.529e-22	5.728e-22	-21.185	-21.242	-0.057	(0)
Fe3(OH)4+5	1.607e-25	2.943e-27	-24.794	-26.531	-1.737	(0)
FeCl3	7.142e-26	7.142e-26	-25.146	-25.146	0.000	(0)
H(0)	8.417e-28					
H2	4.209e-28	4.227e-28	-27.376	-27.374	0.002	(0)
K	9.397e-04					
K+	9.344e-04	8.170e-04	-3.029	-3.088	-0.058	(0)
KSO4-	5.244e-06	4.610e-06	-5.280	-5.336	-0.056	(0)
KCrO4-	5.913e-17	5.039e-17	-16.228	-16.298	-0.069	(0)
Mg	1.771e-03					
Mg+2	1.538e-03	8.991e-04	-2.813	-3.046	-0.233	(0)
MgSO4	1.304e-04	1.304e-04	-3.885	-3.885	0.000	(0)
MgHCO3+	6.790e-05	5.929e-05	-4.168	-4.227	-0.059	(0)
MgCO3	2.924e-05	2.924e-05	-4.534	-4.534	0.000	(0)
MgF+	4.508e-06	3.946e-06	-5.346	-5.404	-0.058	(0)
MgOH+	5.278e-07	4.663e-07	-6.278	-6.331	-0.054	(0)
MgH2BO3+	2.943e-08	2.549e-08	-7.531	-7.594	-0.063	(0)
Mn(2)	1.498e-06					
Mn+2	1.296e-06	6.832e-07	-5.887	-6.165	-0.278	(0)
MnHCO3+	1.001e-07	8.785e-08	-6.999	-7.056	-0.057	(0)
MnSO4	9.685e-08	9.685e-08	-7.014	-7.014	0.000	(0)
MnOH+	2.548e-09	2.236e-09	-8.594	-8.651	-0.057	(0)
MnCl+	1.222e-09	1.072e-09	-8.913	-8.970	-0.057	(0)
MnF+	1.213e-09	1.064e-09	-8.916	-8.973	-0.057	(0)
MnCl2	1.889e-12	1.889e-12	-11.724	-11.724	0.000	(0)
MnSeO4	9.939e-16	9.939e-16	-15.003	-15.003	0.000	(0)
MnCl3-	7.391e-16	6.485e-16	-15.131	-15.188	-0.057	(0)
Mn(OH)3-	2.672e-17	2.345e-17	-16.573	-16.630	-0.057	(0)
Mn(OH)4-2	1.664e-22	9.860e-23	-21.779	-22.006	-0.227	(0)
MnSe	2.851e-39	2.851e-39	-38.545	-38.545	0.000	(0)
Mn(3)	1.022e-27					
Mn+3	1.022e-27	3.052e-28	-26.991	-27.515	-0.525	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-43.465	-43.692	-0.227	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-49.003	-49.064	-0.061	(0)
Mo	8.034e-08					
MoO4-2	8.033e-08	4.695e-08	-7.095	-7.328	-0.233	(0)
HMoO4-	8.471e-12	7.218e-12	-11.072	-11.142	-0.069	(0)
H2MoO4	4.085e-16	4.085e-16	-15.389	-15.389	0.000	(0)
AlMo6O21-3	0.000e+00	0.000e+00	-52.377	-53.002	-0.625	(0)
Mo7O24-6	0.000e+00	0.000e+00	-60.702	-63.204	-2.502	(0)
HMo7O24-5	0.000e+00	0.000e+00	-63.192	-64.929	-1.737	(0)
H2Mo7O24-4	0.000e+00	0.000e+00	-67.147	-68.259	-1.112	(0)
H3Mo7O24-3	0.000e+00	0.000e+00	-72.500	-73.125	-0.625	(0)
Na	8.025e-03					
Na+	7.960e-03	6.960e-03	-2.099	-2.157	-0.058	(0)
NaSO4-	3.389e-05	2.979e-05	-4.470	-4.526	-0.056	(0)
NaHCO3	2.522e-05	2.522e-05	-4.598	-4.598	0.000	(0)
NaCO3-	5.764e-06	5.067e-06	-5.239	-5.295	-0.056	(0)
NaF	1.718e-07	1.718e-07	-6.765	-6.765	0.000	(0)
NaH2BO3	9.018e-09	9.018e-09	-8.045	-8.045	0.000	(0)
NaCrO4-	6.738e-16	5.741e-16	-15.171	-15.241	-0.069	(0)
Ni	9.381e-08					
Ni+2	3.744e-08	2.188e-08	-7.427	-7.660	-0.233	(0)
NiCO3	3.192e-08	3.192e-08	-7.496	-7.496	0.000	(0)
NiHCO3+	2.040e-08	1.738e-08	-7.690	-7.760	-0.069	(0)
NiSO4	3.480e-09	3.480e-09	-8.458	-8.458	0.000	(0)
NiOH+	4.211e-10	3.589e-10	-9.376	-9.445	-0.069	(0)
NiCl+	8.192e-11	6.980e-11	-10.087	-10.156	-0.069	(0)
Ni(OH)2	3.713e-11	3.713e-11	-10.430	-10.430	0.000	(0)
NiF+	2.523e-11	2.150e-11	-10.598	-10.668	-0.069	(0)
Ni(SO4)2-2	1.742e-13	9.186e-14	-12.759	-13.037	-0.278	(0)
Ni(OH)3-	5.677e-14	4.837e-14	-13.246	-13.315	-0.069	(0)
NiCl2	4.382e-16	4.382e-16	-15.358	-15.358	0.000	(0)
NiSeO4	5.532e-17	5.532e-17	-16.257	-16.257	0.000	(0)
O(0)	5.646e-38					
O2	2.823e-38	2.835e-38	-37.549	-37.547	0.002	(0)
Pb	2.102e-07					
PbCO3	1.600e-07	1.600e-07	-6.796	-6.796	0.000	(0)
Pb(CO3)2-2	3.421e-08	1.804e-08	-7.466	-7.744	-0.278	(0)
PbHCO3+	7.647e-09	6.516e-09	-8.117	-8.186	-0.069	(0)
PbOH+	5.226e-09	4.453e-09	-8.282	-8.351	-0.069	(0)
Pb+2	2.329e-09	1.361e-09	-8.633	-8.866	-0.233	(0)
PbSO4	5.313e-10	5.313e-10	-9.275	-9.275	0.000	(0)
Pb(OH)2	1.834e-10	1.834e-10	-9.736	-9.736	0.000	(0)
PbCl+	7.065e-11	6.020e-11	-10.151	-10.220	-0.069	(0)
Pb(SO4)2-2	4.840e-12	2.552e-12	-11.315	-11.593	-0.278	(0)
PbF+	4.402e-12	3.751e-12	-11.356	-11.426	-0.069	(0)
PbCl2	3.353e-13	3.353e-13	-12.475	-12.475	0.000	(0)
Pb(OH)3-	2.804e-13	2.390e-13	-12.552	-12.622	-0.069	(0)
PbF2	2.888e-15	2.888e-15	-14.539	-14.539	0.000	(0)
Pb2OH+3	4.055e-16	9.605e-17	-15.392	-16.017	-0.625	(0)
PbCl3-	1.953e-16	1.664e-16	-15.709	-15.779	-0.069	(0)
Pb(OH)4-2	1.446e-16	7.624e-17	-15.840	-16.118	-0.278	(0)
Pb3(OH)4+2	1.733e-18	9.138e-19	-17.761	-18.039	-0.278	(0)
PbF3-	2.514e-19	2.142e-19	-18.600	-18.669	-0.069	(0)
PbCl4-2	1.799e-19	9.483e-20	-18.745	-19.023	-0.278	(0)

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   Pb4(OH)4+4      1.278e-22   9.879e-24   -21.893   -23.005    -1.112     (0)
   PbF4-2          7.607e-24   4.011e-24   -23.119   -23.397    -0.278     (0)
S(6)          1.728e-03
   SO4-2           1.364e-03   7.971e-04    -2.865    -3.098    -0.233     (0)
   CaSO4           1.940e-04   1.940e-04    -3.712    -3.712     0.000     (0)
   MgSO4           1.304e-04   1.304e-04    -3.885    -3.885     0.000     (0)
   NaSO4-          3.389e-05   2.979e-05    -4.470    -4.526    -0.056     (0)
   KSO4-           5.244e-06   4.610e-06    -5.280    -5.336    -0.056     (0)
   ZnSO4           1.108e-07   1.108e-07    -6.955    -6.955     0.000     (0)
   MnSO4           9.685e-08   9.685e-08    -7.014    -7.014     0.000     (0)
   CdSO4           3.859e-09   3.859e-09    -8.414    -8.414     0.000     (0)
   NiSO4           3.480e-09   3.480e-09    -8.458    -8.458     0.000     (0)
   CoSO4           3.069e-09   3.069e-09    -8.513    -8.513     0.000     (0)
   Zn(SO4)2-2      1.459e-09   7.695e-10    -8.836    -9.114    -0.278     (0)
   HSO4-           6.876e-10   6.019e-10    -9.163    -9.220    -0.058     (0)
   CuSO4           6.855e-10   6.855e-10    -9.164    -9.164     0.000     (0)
   FeSO4           5.754e-10   5.754e-10    -9.240    -9.240     0.000     (0)
   PbSO4           5.313e-10   5.313e-10    -9.275    -9.275     0.000     (0)
   CrOHSO4         1.003e-10   1.003e-10    -9.999    -9.999     0.000     (0)
   Cd(SO4)2-2      7.869e-11   4.149e-11   -10.104   -10.382    -0.278     (0)
   Pb(SO4)2-2      4.840e-12   2.552e-12   -11.315   -11.593    -0.278     (0)
   Ni(SO4)2-2      1.742e-13   9.186e-14   -12.759   -13.037    -0.278     (0)
   CrSO4+          4.064e-14   3.463e-14   -13.391   -13.461    -0.069     (0)
   AlSO4+          3.135e-15   2.744e-15   -14.504   -14.562    -0.058     (0)
   FeSO4+          2.785e-17   2.443e-17   -16.555   -16.612    -0.057     (0)
   Al(SO4)2-       2.678e-17   2.344e-17   -16.572   -16.630    -0.058     (0)
   UO2SO4          1.181e-17   1.181e-17   -16.928   -16.928     0.000     (0)
   Cr2(OH)2SO4+2   9.115e-18   4.806e-18   -17.040   -17.318    -0.278     (0)
   VO2SO4-         7.308e-19   6.227e-19   -18.136   -18.206    -0.069     (0)
   Fe(SO4)2-       4.887e-19   4.164e-19   -18.311   -18.380    -0.069     (0)
   UO2(SO4)2-2     2.353e-19   1.241e-19   -18.628   -18.906    -0.278     (0)
   Cr2(OH)2(SO4)2   2.276e-19   2.276e-19   -18.643   -18.643     0.000     (0)
   VOSO4           3.431e-21   3.431e-21   -20.465   -20.465     0.000     (0)
   CrO3SO4-2       1.477e-24   7.790e-25   -23.831   -24.108    -0.278     (0)
   VSO4+           2.047e-35   1.744e-35   -34.689   -34.758    -0.069     (0)
   U(SO4)2         0.000e+00   0.000e+00   -43.938   -43.938     0.000     (0)
   USO4+2          0.000e+00   0.000e+00   -44.462   -44.740    -0.278     (0)
Se(-2)        9.185e-36
   HSe-            9.182e-36   7.824e-36   -35.037   -35.107    -0.069     (0)
   MnSe            2.851e-39   2.851e-39   -38.545   -38.545     0.000     (0)
   H2Se            4.693e-40   4.693e-40   -39.329   -39.329     0.000     (0)
   Se-2            0.000e+00   0.000e+00   -41.717   -41.995    -0.278     (0)
Se(4)         1.090e-07
   HSeO3-          5.949e-08   5.069e-08    -7.226    -7.295    -0.069     (0)
   SeO3-2          4.953e-08   2.612e-08    -7.305    -7.583    -0.278     (0)
   H2SeO3          1.671e-13   1.671e-13   -12.777   -12.777     0.000     (0)
   Cd(SeO3)2-2     2.202e-17   1.161e-17   -16.657   -16.935    -0.278     (0)
   FeHSeO3+2       6.941e-22   3.659e-22   -21.159   -21.437    -0.278     (0)
Se(6)         9.249e-12
   SeO4-2          9.248e-12   5.405e-12   -11.034   -11.267    -0.233     (0)
   MnSeO4          9.939e-16   9.939e-16   -15.003   -15.003     0.000     (0)
   ZnSeO4          5.320e-16   5.320e-16   -15.274   -15.274     0.000     (0)
   NiSeO4          5.532e-17   5.532e-17   -16.257   -16.257     0.000     (0)
   CoSeO4          5.228e-17   5.228e-17   -16.282   -16.282     0.000     (0)
   CdSeO4          2.078e-17   2.078e-17   -16.682   -16.682     0.000     (0)
   HSeO4-          2.456e-18   2.093e-18   -17.610   -17.679    -0.069     (0)
   Zn(SeO4)2-2     5.529e-27   2.915e-27   -26.257   -26.535    -0.278     (0)
U(3)          0.000e+00
   U+3             0.000e+00   0.000e+00   -60.412   -61.037    -0.625     (0)
U(4)          1.852e-21
   U(OH)5-         1.852e-21   1.578e-21   -20.732   -20.802    -0.069     (0)
   U(OH)4          5.108e-25   5.108e-25   -24.292   -24.292     0.000     (0)
   U(OH)3+         1.694e-29   1.443e-29   -28.771   -28.841    -0.069     (0)
   U(OH)2+2        9.785e-35   5.159e-35   -34.009   -34.287    -0.278     (0)
   UF3+            1.605e-40   1.368e-40   -39.795   -39.864    -0.069     (0)
   UOH+3           0.000e+00   0.000e+00   -40.101   -40.726    -0.625     (0)
   UF2+2           0.000e+00   0.000e+00   -40.378   -40.656    -0.278     (0)
   UF4             0.000e+00   0.000e+00   -42.232   -42.232     0.000     (0)
   UF+3            0.000e+00   0.000e+00   -42.723   -43.349    -0.625     (0)
   U(SO4)2         0.000e+00   0.000e+00   -43.938   -43.938     0.000     (0)
   USO4+2          0.000e+00   0.000e+00   -44.462   -44.740    -0.278     (0)
   UF5-            0.000e+00   0.000e+00   -44.972   -45.041    -0.069     (0)
   UF6-2           0.000e+00   0.000e+00   -46.691   -46.969    -0.278     (0)
   U+4             0.000e+00   0.000e+00   -47.129   -48.241    -1.112     (0)
   UCl+3           0.000e+00   0.000e+00   -48.820   -49.445    -0.625     (0)
   U6(OH)15+9      0.000e+00   0.000e+00  -179.295  -184.924    -5.629     (0)
U(5)          7.000e-19
   UO2+            7.000e-19   5.965e-19   -18.155   -18.224    -0.069     (0)
U(6)          3.238e-08
   UO2(CO3)3-4     3.013e-08   2.328e-09    -7.521    -8.633    -1.112     (0)
   UO2(CO3)2-2     2.254e-09   1.188e-09    -8.647    -8.925    -0.278     (0)
   UO2CO3          1.523e-12   1.523e-12   -11.817   -11.817     0.000     (0)
   UO2OH+          1.883e-15   1.605e-15   -14.725   -14.795    -0.069     (0)
   UO2F+           6.200e-17   5.284e-17   -16.208   -16.277    -0.069     (0)
   UO2+2           1.674e-17   9.785e-18   -16.776   -17.009    -0.233     (0)
   UO2SO4          1.181e-17   1.181e-17   -16.928   -16.928     0.000     (0)
   UO2F2           5.960e-18   5.960e-18   -17.225   -17.225     0.000     (0)
   UO2(SO4)2-2     2.353e-19   1.241e-19   -18.628   -18.906    -0.278     (0)
   UO2F3-          6.872e-20   5.856e-20   -19.163   -19.232    -0.069     (0)
   UO2Cl+          2.322e-20   1.979e-20   -19.634   -19.704    -0.069     (0)
   UO2F4-2         3.451e-23   1.820e-23   -22.462   -22.740    -0.278     (0)
   (UO2)2(OH)2+2   8.106e-24   4.274e-24   -23.091   -23.369    -0.278     (0)
   (UO2)3(OH)5+    1.036e-26   8.828e-27   -25.985   -26.054    -0.069     (0)
V(2)          0.000e+00
   VOH+            0.000e+00   0.000e+00   -40.950   -41.019    -0.069     (0)
   V+2             0.000e+00   0.000e+00   -42.366   -42.644    -0.278     (0)
V(3)          8.266e-14
   V(OH)3          8.266e-14   8.266e-14   -13.083   -13.083     0.000     (0)
   V(OH)2+         4.845e-25   4.128e-25   -24.315   -24.384    -0.069     (0)
   VOH+2           5.740e-29   3.027e-29   -28.241   -28.519    -0.278     (0)
   V+3             1.957e-34   4.636e-35   -33.708   -34.334    -0.625     (0)
   VSO4+           2.047e-35   1.744e-35   -34.689   -34.758    -0.069     (0)
   V2(OH)3+3       0.000e+00   0.000e+00   -53.826   -54.451    -0.625     (0)
   V2(OH)2+4       0.000e+00   0.000e+00   -55.126   -56.238    -1.112     (0)
V(4)          4.803e-18
   V(OH)3+         4.765e-18   4.061e-18   -17.322   -17.391    -0.069     (0)
   VO+2            2.964e-20   1.563e-20   -19.528   -19.806    -0.278     (0)
   VOF+            4.303e-21   3.667e-21   -20.366   -20.436    -0.069     (0)
   VOSO4           3.431e-21   3.431e-21   -20.465   -20.465     0.000     (0)
   VOCl+           6.415e-23   5.467e-23   -22.193   -22.262    -0.069     (0)
   VOF2            5.378e-23   5.378e-23   -22.269   -22.269     0.000     (0)
   VOF3-           8.759e-26   7.464e-26   -25.058   -25.127    -0.069     (0)
   VOF4-2          2.235e-29   1.178e-29   -28.651   -28.929    -0.278     (0)
   H2V2O4+2        1.569e-30   8.271e-31   -29.804   -30.082    -0.278     (0)
V(5)          4.913e-08
   H2VO4-          3.221e-08   2.744e-08    -7.492    -7.562    -0.069     (0)
   HVO4-2          1.692e-08   8.921e-09    -7.772    -8.050    -0.278     (0)
   H3VO4           2.120e-12   2.120e-12   -11.674   -11.674     0.000     (0)
   H3V2O7-         4.411e-13   3.759e-13   -12.355   -12.425    -0.069     (0)
   HV2O7-3         3.503e-13   8.299e-14   -12.456   -13.081    -0.625     (0)
   VO4-3           2.443e-14   5.787e-15   -13.612   -14.238    -0.625     (0)
   V2O7-4          3.741e-15   2.891e-16   -14.427   -15.539    -1.112     (0)
   V3O9-3          9.147e-17   2.167e-17   -16.039   -16.664    -0.625     (0)
   VO2+            3.742e-17   3.272e-17   -16.427   -16.485    -0.058     (0)
   VO2F            2.244e-18   2.244e-18   -17.649   -17.649     0.000     (0)
   VO2SO4-         7.308e-19   6.227e-19   -18.136   -18.206    -0.069     (0)
   VO2F2-          3.741e-20   3.188e-20   -19.427   -19.497    -0.069     (0)
   V4O12-4         3.209e-21   2.480e-22   -20.494   -21.606    -1.112     (0)
   VO2F3-2         2.950e-23   1.555e-23   -22.530   -22.808    -0.278     (0)
   VO2F4-3         1.264e-27   2.993e-28   -26.898   -27.524    -0.625     (0)
   V10O28-6        0.000e+00   0.000e+00   -56.654   -59.156    -2.502     (0)
   HV10O28-5       0.000e+00   0.000e+00   -57.344   -59.081    -1.737     (0)
   H2V10O28-4      0.000e+00   0.000e+00   -60.874   -61.986    -1.112     (0)
Zn            2.903e-06
   ZnCO3           1.430e-06   1.430e-06    -5.845    -5.845     0.000     (0)
   Zn+2            1.088e-06   6.356e-07    -5.964    -6.197    -0.233     (0)
   ZnHCO3+         1.520e-07   1.295e-07    -6.818    -6.888    -0.069     (0)
   ZnSO4           1.108e-07   1.108e-07    -6.955    -6.955     0.000     (0)
   ZnOH+           9.717e-08   8.280e-08    -7.012    -7.082    -0.069     (0)
   Zn(OH)2         1.709e-08   1.709e-08    -7.767    -7.767     0.000     (0)
   ZnOHCl          3.395e-09   3.395e-09    -8.469    -8.469     0.000     (0)
   ZnCl+           2.280e-09   1.990e-09    -8.642    -8.701    -0.059     (0)
   Zn(SO4)2-2      1.459e-09   7.695e-10    -8.836    -9.114    -0.278     (0)
   ZnF+            5.821e-10   4.961e-10    -9.235    -9.304    -0.069     (0)
   Zn(OH)3-        1.310e-10   1.116e-10    -9.883    -9.952    -0.069     (0)
   ZnCl2           3.933e-12   3.933e-12   -11.405   -11.405     0.000     (0)
   Zn(OH)4-2       1.098e-14   5.788e-15   -13.960   -14.238    -0.278     (0)
   ZnCl3-          4.461e-15   3.895e-15   -14.351   -14.409    -0.059     (0)
   ZnSeO4          5.320e-16   5.320e-16   -15.274   -15.274     0.000     (0)
   ZnCl4-2         4.097e-18   2.428e-18   -17.388   -17.615    -0.227     (0)
   Zn(SeO4)2-2     5.529e-27   2.915e-27   -26.257   -26.535    -0.278     (0)

----------------------------Saturation indices----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.82      8.98   10.80  Al(OH)3
  Al2(MoO4)3      -55.06    -52.69    2.37  Al2(MoO4)3
  Al2O3            -1.69     17.97   19.65  Al2O3
  Al4(OH)10SO4     -6.09     16.61   22.70  Al4(OH)10SO4
  AlAsO4:2H2O     -10.60     -5.80    4.80  AlAsO4:2H2O
  AlOHSO4          -7.11    -10.34   -3.23  AlOHSO4
  Alunite          -5.27     -6.67   -1.40  KAl3(SO4)2(OH)6
  Anglesite        -4.17    -11.96   -7.79  PbSO4
  Anhydrite        -1.71     -6.07   -4.36  CaSO4
  Antlerite        -4.72      4.07    8.79  Cu3(OH)4SO4
  Aragonite         0.92     -7.38   -8.30  CaCO3
  Arsenolite      -77.66    -80.42   -2.76  As4O6
  Artinite         -3.88      5.72    9.60  MgCO3:Mg(OH)2:3H2O
  As2O5           -36.27    -29.56    6.71  As2O5
  Atacamite        -2.81      4.58    7.39  Cu2(OH)3Cl
  Azurite          -0.96    -17.87  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -14.31     10.08   24.39  Ba(OH)2:8H2O
  Ba2V2O7:2H2O    -12.45      3.42   15.87  Ba2V2O7:2H2O
  Ba3(AsO4)2        9.61      0.70   -8.91  Ba3(AsO4)2
  Ba3(VO4)2:4H2O  -19.43     13.51   32.94  Ba3(VO4)2:4H2O
  BaCrO4          -10.25    -19.92   -9.67  BaCrO4
  BaF2             -9.13    -14.95   -5.82  BaF2
  BaMoO4           -6.51    -13.47   -6.96  BaMoO4
  Barite            0.74     -9.24   -9.98  BaSO4
  BaSeO3           -7.15     -5.32    1.83  BaSeO3
  BaSeO4           -9.95    -17.41   -7.46  BaSeO4
  Bianchite        -7.53     -9.30   -1.76  ZnSO4:6H2O
  Birnessite       -9.16      8.93   18.09  MnO2
  Bixbyite         -5.71     -6.36   -0.64  Mn2O3
  Boehmite          0.40      8.98    8.58  AlOOH
  Brochantite      -3.35     11.87   15.22  Cu4(OH)6SO4
  Brucite          -3.67     13.18   16.84  Mg(OH)2
  Bunsenite        -3.88      8.56   12.45  NiO
  Ca(VO3)2         -9.16     -3.50    5.66  Ca(VO3)2
  Ca2V2O7          -7.75      9.75   17.50  Ca2V2O7
  Ca2V2O7:2H2O    -11.80      9.75   21.55  Ca2V2O7:2H2O
  Ca3(AsO4)2:4H2O -12.11     10.19   22.30  Ca3(AsO4)2:4H2O
  Ca3(VO4)2       -15.96     23.00   38.96  Ca3(VO4)2
  Ca3(VO4)2:4H2O  -16.86     23.00   39.86  Ca3(VO4)2:4H2O
  CaCrO4          -14.49    -16.75   -2.27  CaCrO4
  Calcite           1.10     -7.38   -8.48  CaCO3
  CaMoO4           -2.35    -10.30   -7.95  CaMoO4
  Carnotite        -4.36     -4.13    0.23  KUO2VO4
  CaSeO3:2H2O      -4.97     -2.16    2.81  CaSeO3:2H2O
  CaSeO4:2H2O     -11.22    -14.24   -3.02  CaSeO4:2H2O
  Cd(BO2)2        -11.23     -1.39    9.84  Cd(BO2)2
  Cd(OH)2          -5.11      8.54   13.64  Cd(OH)2
  Cd(OH)2(am)      -5.19      8.54   13.73  Cd(OH)2
  Cd3(OH)2(SO4)2  -19.74    -13.03    6.71  Cd3(OH)2(SO4)2
  Cd3(OH)4SO4     -16.27      6.29   22.56  Cd3(OH)4SO4
  Cd4(OH)6SO4     -13.57     14.83   28.40  Cd4(OH)6SO4
  CdCl2           -12.83    -13.49   -0.66  CdCl2
  CdCl2:1H2O      -11.80    -13.49   -1.69  CdCl2:1H2O
  CdCl2:2.5H2O    -11.58    -13.49   -1.91  CdCl2:2.5H2O
  CdF2            -15.29    -16.50   -1.21  CdF2
  Cdmetal(alpha)  -29.20    -15.69   13.51  Cd
  Cdmetal(gamma)  -29.30    -15.69   13.62  Cd
  CdMoO4           -0.86    -15.01  -14.15  CdMoO4
  CdOHCl           -6.01     -2.48    3.54  CdOHCl
  CdSe            -14.48    -34.68  -20.20  CdSe
  CdSeO4:2H2O     -17.10    -18.95   -1.85  CdSeO4:2H2O
  CdSO4           -10.61    -10.78   -0.17  CdSO4
  CdSO4:1H2O       -9.06    -10.78   -1.73  CdSO4:1H2O
  CdSO4:2.67H2O    -8.91    -10.78   -1.87  CdSO4:2.67H2O
  Cerussite        -0.14    -13.27  -13.13  PbCO3
  CH4(g)          -76.48   -117.53  -41.05  CH4
  Chalcanthite     -8.88    -11.52   -2.64  CuSO4:5H2O
  Claudetite      -77.36    -80.42   -3.06  As4O6
  Clausthalite     -8.76    -35.86  -27.10  PbSe
  Co(BO2)2        -28.49     -1.42   27.07  Co(BO2)2
  Co(OH)2          -4.58      8.51   13.09  Co(OH)2
  Co(OH)3          -9.47    -11.78   -2.31  Co(OH)3
  CO2(g)           -2.48    -20.63  -18.15  CO2
  Co3(AsO4)2      -17.07     -4.03   13.03  Co3(AsO4)2
  Co3O4            -4.55    -15.05  -10.50  Co3O4
  CoCl2           -21.79    -13.52    8.27  CoCl2
  CoCl2:6H2O      -16.06    -13.52    2.54  CoCl2:6H2O
  CoCO3            -2.14    -12.12   -9.98  CoCO3
  CoF2            -14.93    -16.53   -1.60  CoF2
  CoF3            -47.88    -49.34   -1.46  CoF3
  CoFe2O4          25.58     22.05   -3.53  CoFe2O4
  CoMoO4           -7.28    -15.04   -7.76  CoMoO4
  CoO              -5.08      8.51   13.59  CoO
  CoSe            -18.51    -34.71  -16.20  CoSe
  CoSeO3           -8.22     -6.90    1.32  CoSeO3
  CoSeO4:6H2O     -17.45    -18.98   -1.53  CoSeO4:6H2O
  CoSO4           -13.62    -10.81    2.80  CoSO4
  CoSO4:6H2O       -8.34    -10.81   -2.47  CoSO4:6H2O
  Cotunnite        -9.89    -14.67   -4.78  PbCl2
  Cr(OH)2         -18.95     -8.13   10.82  Cr(OH)2
  Cr(OH)3          -0.30      1.04    1.34  Cr(OH)3
  Cr(OH)3(am)       1.79      1.04   -0.75  Cr(OH)3
  Cr2O3             4.43      2.07   -2.36  Cr2O3
  CrCl2           -44.25    -30.16   14.09  CrCl2
  CrCl3           -47.13    -32.01   15.11  CrCl3
  CrF3            -25.19    -36.52  -11.34  CrF3
  Crmetal         -62.84    -32.35   30.48  Cr
  CrO3            -26.79    -30.00   -3.21  CrO3
  Cryolite        -14.43    -48.27  -33.84  Na3AlF6
  Cu(OH)2          -0.88      7.80    8.67  Cu(OH)2
  Cu2Se(alpha)     -0.67    -46.47  -45.80  Cu2Se
  Cu2SO4          -20.62    -22.57   -1.95  Cu2SO4
  Cu3(AsO4)2:2H2O -12.26     -6.16    6.10  Cu3(AsO4)2:2H2O
  Cu3Se2          -18.39    -81.89  -63.49  Cu3Se2
  CuCO3            -1.33    -12.83  -11.50  CuCO3
  CuCrO4          -16.77    -22.21   -5.44  CuCrO4
  CuF              -9.24    -14.14   -4.91  CuF
  CuF2            -18.36    -17.24    1.12  CuF2
```

CuF2:2H2O	-12.69	-17.24	-4.55	CuF2:2H2O
Cumetal	-4.98	-13.74	-8.76	Cu
CuMoO4	-2.68	-15.75	-13.08	CuMoO4
CuOCuSO4	-14.03	-3.73	10.30	CuOCuSO4
Cupricferrite	15.35	21.34	5.99	CuFe2O4
Cuprite	-1.84	-3.25	-1.41	Cu2O
Cuprousferrite	14.07	5.15	-8.92	CuFeO2
CuSe	-2.32	-35.42	-33.10	CuSe
CuSe2	-21.05	-54.41	-33.37	CuSe2
CuSeO3:2H2O	-8.12	-7.61	0.51	CuSeO3:2H2O
CuSeO4:5H2O	-17.25	-19.69	-2.44	CuSeO4:5H2O
CuSO4	-14.46	-11.52	2.94	CuSO4
Diaspore	2.11	8.98	6.87	AlOOH
Dolomite(disordered)	1.70	-14.84	-16.54	CaMg(CO3)2
Dolomite(ordered)	2.25	-14.84	-17.09	CaMg(CO3)2
Epsomite	-4.02	-6.15	-2.13	MgSO4:7H2O
Fe(OH)2	-5.87	7.69	13.56	Fe(OH)2
Fe(OH)2.7Cl.3	6.51	3.47	-3.04	Fe(OH)2.7Cl.3
Fe(VO3)2	-5.33	-9.05	-3.72	Fe(VO3)2
Fe2(OH)4SeO3	-3.42	-1.86	1.55	Fe2(OH)4SeO3
Fe2(SeO3)3:2H2O	-12.05	-32.68	-20.63	Fe2(SeO3)3:2H2O
Fe2(SO4)3	-40.69	-44.42	-3.73	Fe2(SO4)3
Fe3(OH)8	1.01	21.24	20.22	Fe3(OH)8
FeAsO4:2H2O	-8.41	-8.01	0.40	FeAsO4:2H2O
FeCr2O4	2.57	9.77	7.20	FeCr2O4
FeMoO4	-5.77	-15.86	-10.09	FeMoO4
Ferrihydrite	3.58	6.77	3.19	Fe(OH)3
Ferroselite	-35.92	-54.52	-18.60	FeSe2
FeSe	-24.53	-35.53	-11.00	FeSe
Fluorite	-1.29	-11.79	-10.50	CaF2
Gibbsite	0.69	8.98	8.29	Al(OH)3
Goethite	6.28	6.77	0.49	FeOOH
Goslarite	-7.29	-9.30	-2.01	ZnSO4:7H2O
Gummite	-8.46	-0.79	7.67	UO3
Gypsum	-1.46	-6.07	-4.61	CaSO4:2H2O
H-Jarosite	-6.23	-18.33	-12.10	(H3O)Fe3(SO4)2(OH)6
H2MoO4	-10.68	-23.55	-12.88	H2MoO4
H2Se(g)	-38.26	-43.22	-4.96	H2Se
Halite	-6.66	-5.06	1.60	NaCl
Hausmannite	-6.63	54.40	61.03	Mn3O4
Hematite	14.96	13.54	-1.42	Fe2O3
Hercynite	2.76	25.66	22.89	FeAl2O4
Huntite	0.22	-29.74	-29.97	CaMg3(CO3)4
Hydrocerussite	-0.42	-19.19	-18.77	Pb3(OH)2(CO3)2
Hydromagnesite	-7.87	-16.64	-8.77	Mg5(CO3)4(OH)2:4H2O
K-Alum	-19.47	-24.64	-5.17	KAl(SO4)2:12H2O
K-Jarosite	1.50	-13.30	-14.80	KFe3(SO4)2(OH)6
K2Cr2O7	-32.72	-49.96	-17.24	K2Cr2O7
K2CrO4	-19.44	-19.96	-0.51	K2CrO4
K2MoO4	-16.77	-13.50	3.26	K2MoO4
K2SeO4	-16.71	-17.44	-0.73	K2SeO4
Langite	-5.62	11.87	17.49	Cu4(OH)6SO4:H2O
Larnakite	-4.17	-4.61	-0.43	PbO:PbSO4
Laurionite	-4.28	-3.66	0.62	PbOHCl
Lepidocrocite	5.40	6.77	1.37	FeOOH
Lime	-19.45	13.25	32.70	CaO
Litharge	-5.34	7.36	12.69	PbO
Maghemite	7.16	13.54	6.39	Fe2O3
Magnesioferrite	9.86	26.72	16.86	Fe2MgO4
Magnesite	0.01	-7.45	-7.46	MgCO3
Magnetite	17.83	21.24	3.40	Fe3O4
Malachite	0.27	-5.04	-5.31	Cu2(OH)2CO3
Manganite	-3.17	22.17	25.34	MnOOH
Massicot	-5.54	7.36	12.89	PbO
Matlockite	-7.20	-16.18	-8.97	PbClF
Melanothallite	-20.49	-14.23	6.26	CuCl2

Melanterite	-9.42	-11.63	-2.21	FeSO4:7H2O
Mg(OH)2(active)	-5.62	13.18	18.79	Mg(OH)2
Mg(VO3)2	-14.85	-3.57	11.28	Mg(VO3)2
Mg2V2O7	-16.75	9.61	26.36	Mg2V2O7
MgCr2O4	-0.95	15.25	16.20	MgCr2O4
MgCrO4	-22.21	-16.83	5.38	MgCrO4
MgF2	-3.73	-11.86	-8.13	MgF2
MgMoO4	-8.52	-10.37	-1.85	MgMoO4
MgSeO3:6H2O	-5.29	-2.23	3.06	MgSeO3:6H2O
MgSeO4:6H2O	-13.11	-14.31	-1.20	MgSeO4:6H2O
Minium	-27.23	46.30	73.52	Pb3O4
Mirabilite	-6.30	-7.42	-1.11	Na2SO4:10H2O
Mn(VO3)2	-11.59	-6.69	4.90	Mn(VO3)2
Mn2(SO4)3	-58.62	-64.33	-5.71	Mn2(SO4)3
Mn3(AsO4)2:8H2O	-11.89	0.61	12.50	Mn3(AsO4)2:8H2O
MnCl2:4H2O	-14.69	-11.97	2.72	MnCl2:4H2O
MnSe	-36.66	-33.16	3.50	MnSe
MnSeO3	-6.48	-5.35	1.13	MnSeO3
MnSeO3:2H2O	-6.33	-5.35	0.98	MnSeO3:2H2O
MnSeO4:5H2O	-15.38	-17.43	-2.05	MnSeO4:5H2O
MnSO4	-11.85	-9.26	2.58	MnSO4
Monteponite	-6.56	8.54	15.10	CdO
MoO3	-15.55	-23.55	-8.00	MoO3
Morenosite	-8.61	-10.76	-2.14	NiSO4:7H2O
Na-Jarosite	-1.17	-12.37	-11.20	NaFe3(SO4)2(OH)6
Na2Cr2O7	-38.20	-48.10	-9.90	Na2Cr2O7
Na2CrO4	-21.02	-18.09	2.93	Na2CrO4
Na2Mo2O7	-18.60	-35.20	-16.60	Na2Mo2O7
Na2MoO4	-13.13	-11.64	1.49	Na2MoO4
Na2MoO4:2H2O	-12.87	-11.64	1.22	Na2MoO4:2H2O
Na2SeO3:5H2O	-13.80	-3.50	10.30	Na2SeO3:5H2O
Na2SeO4	-16.86	-15.58	1.28	Na2SeO4
Na3VO4	-27.19	9.49	36.68	Na3VO4
Na4V2O7	-30.33	7.07	37.40	Na4V2O7
Nantokite	-5.91	-12.64	-6.73	CuCl
Natron	-7.41	-8.72	-1.31	Na2CO3:10H2O
NaVO3	-6.28	-2.42	3.86	NaVO3
Nesquehonite	-2.78	-7.45	-4.67	MgCO3:3H2O
Ni(OH)2	-4.23	8.56	12.79	Ni(OH)2
Ni3(AsO4)2:8H2O	-19.57	-3.87	15.70	Ni3(AsO4)2:8H2O
Ni4(OH)6SO4	-17.07	14.93	32.00	Ni4(OH)6SO4
NiCO3	-5.20	-12.07	-6.87	NiCO3
NiMoO4	-3.85	-14.99	-11.14	NiMoO4
NiSe	-16.95	-34.65	-17.70	NiSe
NiSeO3:2H2O	-9.66	-6.84	2.81	NiSeO3:2H2O
NiSeO4:6H2O	-17.41	-18.93	-1.52	NiSeO4:6H2O
Nsutite	-8.57	8.93	17.50	MnO2
O2(g)	-34.64	48.45	83.09	O2
Otavite	-0.09	-12.09	-12.00	CdCO3
Pb(BO2)2	-9.09	-2.57	6.52	Pb(BO2)2
Pb(OH)2	-0.79	7.36	8.15	Pb(OH)2
Pb10(OH)6O(CO3)6	-41.45	-50.21	-8.76	Pb10(OH)6O(CO3)6
Pb2(OH)3Cl	-5.09	3.70	8.79	Pb2(OH)3Cl
Pb2O(OH)2	-11.47	14.72	26.19	Pb2O(OH)2
Pb2O3	-22.10	38.94	61.04	Pb2O3
Pb2OCO3	-5.36	-5.92	-0.56	Pb2OCO3
Pb2V2O7	-0.13	-2.03	-1.90	Pb2V2O7
Pb3(AsO4)2	-13.29	-7.49	5.80	Pb3(AsO4)2
Pb3(VO4)2	-0.81	5.33	6.14	Pb3(VO4)2
Pb3O2CO3	-9.58	1.44	11.02	Pb3O2CO3
Pb3O2SO4	-7.94	2.75	10.69	Pb3O2SO4
Pb4(OH)6SO4	-10.99	10.11	21.10	Pb4(OH)6SO4
Pb4O3SO4	-11.77	10.11	21.88	Pb4O3SO4
PbCrO4	-10.05	-22.65	-12.60	PbCrO4
PbF2	-10.24	-17.68	-7.44	PbF2
Pbmetal	-21.11	-16.87	4.25	Pb

PbMoO4	-0.57	-16.19	-15.62	PbMoO4
PbO:0.3H2O	-5.62	7.36	12.98	PbO:0.33H2O
PbSeO4	-13.29	-20.13	-6.84	PbSeO4
Periclase	-8.41	13.18	21.58	MgO
Phosgenite	-8.14	-27.95	-19.81	PbCl2:PbCO3
Plattnerite	-18.02	31.58	49.60	PbO2
Portlandite	-9.55	13.25	22.80	Ca(OH)2
Pyrochroite	-5.14	10.06	15.19	Mn(OH)2
Pyrolusite	-7.10	34.28	41.38	MnO2
Retgersite	-8.72	-10.76	-2.04	NiSO4:6H2O
Rhodochrosite	0.01	-10.57	-10.58	MnCO3
Rutherfordine	-6.92	-21.42	-14.50	UO2CO3
Schoepite	-6.78	-0.79	5.99	UO2(OH)2:H2O
Semetal(am)	-11.88	-18.99	-7.11	Se
Semetal(hex	-11.29	-18.99	-7.71	Se
SeO2	-15.53	-15.41	0.12	SeO2
SeO3	-48.54	-27.49	21.04	SeO3
Siderite	-2.70	-12.94	-10.24	FeCO3
Smithsonite	-0.60	-10.60	-10.00	ZnCO3
Spinel	-5.70	31.14	36.85	MgAl2O4
Tenorite	0.15	7.80	7.64	CuO
Thenardite	-7.73	-7.41	0.32	Na2SO4
Thermonatrite	-9.36	-8.72	0.64	Na2CO3:H2O
Tyuyamunite	-9.15	-5.07	4.08	Ca(UO2)2(VO4)2
U3O8	-20.02	1.07	21.08	U3O8
U4O9	-35.93	-38.95	-3.02	U4O9
UF4	-36.33	-65.87	-29.54	UF4
UF4:2.5H2O	-33.15	-65.87	-32.72	UF4:2.5H2O
UO2(am)	-16.73	-15.79	0.93	UO2
UO2(OH)2(beta)	-6.40	-0.79	5.61	UO2(OH)2
UO2SeO4:4H2O	-26.03	-28.28	-2.25	UO2SeO4:4H2O
UO3	-8.49	-0.79	7.70	UO3
Uraninite	-11.12	-15.79	-4.67	UO2
V(OH)3	-17.59	-10.00	7.59	V(OH)3
V2O5	-15.39	-16.75	-1.36	V2O5
V3O5	-36.81	-34.97	1.84	V3O5
V4O7	-45.74	-38.55	7.19	V4O7
V6O13	-37.83	-98.69	-60.86	V6O13
VCl2	-63.02	-44.14	18.87	VCl2
VCl3	-66.48	-43.05	23.43	VCl3
VF4	-68.59	-53.66	14.93	VF4
Vmetal	-90.36	-46.33	44.03	V
VO	-36.87	-22.11	14.76	VO
VO(OH)2	-8.73	-3.58	5.15	VO(OH)2
VO2Cl	-22.23	-19.39	2.84	VO2Cl
VOCl	-32.17	-21.01	11.15	VOCl
VOCl2	-38.37	-25.61	12.76	VOCl2
VOSO4	-26.51	-22.90	3.61	VOSO4
Witherite	-1.98	-10.55	-8.57	BaCO3
Zincite	-1.31	10.03	11.33	ZnO
Zincosite	-13.22	-9.30	3.93	ZnSO4
Zn(BO2)2	-8.19	0.10	8.29	Zn(BO2)2
Zn(OH)2	-2.17	10.03	12.20	Zn(OH)2
Zn(OH)2(am)	-2.45	10.03	12.47	Zn(OH)2
Zn(OH)2(beta)	-1.73	10.03	11.75	Zn(OH)2
Zn(OH)2(epsilon)	-1.51	10.03	11.53	Zn(OH)2
Zn(OH)2(gamma)	-1.71	10.03	11.73	Zn(OH)2
Zn2(OH)2SO4	-6.77	0.73	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-6.15	9.04	15.19	Zn2(OH)3Cl
Zn3(AsO4)2:2.5H2O	-13.13	0.52	13.65	Zn3(AsO4)2:2.5H2O
Zn3O(SO4)2	-27.48	-8.56	18.91	Zn3O(SO4)2
Zn4(OH)6SO4	-7.61	20.79	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-10.40	28.10	38.50	Zn5(OH)8Cl2
ZnCl2	-19.06	-12.01	7.05	ZnCl2
ZnCO3:1H2O	-0.34	-10.60	-10.26	ZnCO3:1H2O
ZnF2	-14.48	-15.01	-0.53	ZnF2

Znmetal	-39.99	-14.20	25.79	Zn
ZnMoO4	-3.40	-13.53	-10.13	ZnMoO4
ZnO(active)	-1.16	10.03	11.19	ZnO
ZnSe	-18.79	-33.19	-14.40	ZnSe
ZnSeO4:6H2O	-15.95	-17.47	-1.52	ZnSeO4:6H2O
ZnSO4:1H2O	-8.66	-9.30	-0.64	ZnSO4:1H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

Initial solution 2. PAF Material

----------Solution composition----------

Elements	Molality	Moles
Al	7.415e-07	7.415e-07
Alkalinity	3.607e-04	3.607e-04
Ba	1.457e-07	1.457e-07
Ca	1.672e-03	1.672e-03
Co	1.188e-07	1.188e-07
Cu	4.408e-07	4.408e-07
F	1.580e-05	1.580e-05
K	3.326e-04	3.326e-04
Mg	3.293e-04	3.293e-04
Mn	7.283e-07	7.283e-07
Mo	3.128e-08	3.128e-08
Na	4.351e-05	4.351e-05
Ni	6.818e-08	6.818e-08
S(6)	2.051e-03	2.051e-03

----------Description of solution----------

```
                                    pH  =   7.500
                                    pe  =   4.000
                       Activity of water  =   1.000
                  Ionic strength (mol/kgw)  =   7.200e-03
                        Mass of water (kg)  =   1.000e+00
                   Total carbon (mol/kg)  =   3.782e-04
                      Total CO2 (mol/kg)  =   3.782e-04
                        Temperature (°C)  =  25.00
                 Electrical balance (eq)  =  -9.478e-05
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  -1.25
                             Iterations  =  13 (23 overall)
                                Total H  = 1.110141e+02
                                Total O  = 5.551618e+01
```

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
OH-	3.487e-07	3.184e-07	-6.458	-6.497	-0.039	(0)
H+	3.458e-08	3.162e-08	-7.461	-7.500	-0.039	0.00
H2O	5.551e+01	9.999e-01	1.744	-0.000	0.000	18.07
Al	7.415e-07					
Al(OH)4-	7.221e-07	6.609e-07	-6.141	-6.180	-0.038	(0)
Al(OH)3	1.649e-08	1.649e-08	-7.783	-7.783	0.000	(0)
Al(OH)2+	2.830e-09	2.595e-09	-8.548	-8.586	-0.038	(0)
AlF2+	2.736e-11	2.509e-11	-10.563	-10.600	-0.038	(0)
AlOH+2	1.451e-11	1.026e-11	-10.838	-10.989	-0.150	(0)
AlF+2	6.374e-12	4.507e-12	-11.196	-11.346	-0.150	(0)
AlF3	4.418e-12	4.418e-12	-11.355	-11.355	0.000	(0)
AlSO4+	3.315e-13	3.034e-13	-12.480	-12.518	-0.038	(0)
Al+3	7.201e-14	3.223e-14	-13.143	-13.492	-0.349	(0)
AlF4-	3.383e-14	3.096e-14	-13.471	-13.509	-0.038	(0)

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   Al(SO4)2-       4.307e-15   3.942e-15   -14.366   -14.404    -0.038     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -49.070   -49.460    -0.390     (0)
Ba            1.457e-07
   Ba+2            1.453e-07   1.017e-07    -6.838    -6.993    -0.155     (0)
   BaHCO3+         3.363e-10   3.088e-10    -9.473    -9.510    -0.037     (0)
   BaCO3           2.459e-11   2.459e-11   -10.609   -10.609     0.000     (0)
   BaOH+           1.542e-13   1.413e-13   -12.812   -12.850    -0.038     (0)
C(4)          3.782e-04
   HCO3-           3.469e-04   3.181e-04    -3.460    -3.497    -0.038     (0)
   H2CO3           2.262e-05   2.262e-05    -4.645    -4.645     0.000     (0)
   CaHCO3+         6.292e-06   5.777e-06    -5.201    -5.238    -0.037     (0)
   CaCO3           7.289e-07   7.289e-07    -6.137    -6.137     0.000     (0)
   MgHCO3+         7.079e-07   6.472e-07    -6.150    -6.189    -0.039     (0)
   CO3-2           6.741e-07   4.716e-07    -6.171    -6.326    -0.155     (0)
   CuCO3           2.133e-07   2.133e-07    -6.671    -6.671     0.000     (0)
   MgCO3           7.799e-08   7.799e-08    -7.108    -7.108     0.000     (0)
   NaHCO3          7.071e-09   7.071e-09    -8.151    -8.151     0.000     (0)
   MnHCO3+         2.944e-09   2.697e-09    -8.531    -8.569    -0.038     (0)
   CoHCO3+         1.830e-09   1.657e-09    -8.738    -8.781    -0.043     (0)
   CuHCO3+         1.703e-09   1.542e-09    -8.769    -8.812    -0.043     (0)
   NiHCO3+         1.700e-09   1.539e-09    -8.770    -8.813    -0.043     (0)
   NiCO3           6.904e-10   6.904e-10    -9.161    -9.161     0.000     (0)
   CoCO3           5.337e-10   5.337e-10    -9.273    -9.273     0.000     (0)
   Cu(CO3)2-2      4.033e-10   2.707e-10    -9.394    -9.567    -0.173     (0)
   NaCO3-          3.785e-10   3.471e-10    -9.422    -9.460    -0.038     (0)
   BaHCO3+         3.363e-10   3.088e-10    -9.473    -9.510    -0.037     (0)
   BaCO3           2.459e-11   2.459e-11   -10.609   -10.609     0.000     (0)
Ca            1.672e-03
   Ca+2            1.394e-03   9.753e-04    -2.856    -3.011    -0.155     (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000     (0)
   CaHCO3+         6.292e-06   5.777e-06    -5.201    -5.238    -0.037     (0)
   CaCO3           7.289e-07   7.289e-07    -6.137    -6.137     0.000     (0)
   CaF+            1.625e-07   1.489e-07    -6.789    -6.827    -0.038     (0)
   CaOH+           6.748e-09   6.196e-09    -8.171    -8.208    -0.037     (0)
Co(2)         1.188e-07
   Co+2            9.974e-08   6.695e-08    -7.001    -7.174    -0.173     (0)
   CoSO4           1.620e-08   1.620e-08    -7.791    -7.791     0.000     (0)
   CoHCO3+         1.830e-09   1.657e-09    -8.738    -8.781    -0.043     (0)
   CoCO3           5.337e-10   5.337e-10    -9.273    -9.273     0.000     (0)
   CoOH+           4.699e-10   4.253e-10    -9.328    -9.371    -0.043     (0)
   CoF+            3.271e-11   2.961e-11   -10.485   -10.529    -0.043     (0)
   Co(OH)2         1.076e-11   1.076e-11   -10.968   -10.968     0.000     (0)
   Co(OH)3-        7.550e-17   6.834e-17   -16.122   -16.165    -0.043     (0)
   CoOOH-          1.894e-17   1.715e-17   -16.723   -16.766    -0.043     (0)
   Co2OH+3         3.499e-18   1.427e-18   -17.456   -17.846    -0.390     (0)
   Co(OH)4-2       5.137e-24   3.448e-24   -23.289   -23.462    -0.173     (0)
   Co4(OH)4+4      3.216e-29   6.530e-30   -28.493   -29.185    -0.692     (0)
Co(3)         6.424e-30
   CoOH+2          6.424e-30   4.312e-30   -29.192   -29.365    -0.173     (0)
   Co+3            5.955e-36   2.665e-36   -35.225   -35.574    -0.349     (0)
Cu(1)         4.157e-09
   Cu+             4.157e-09   3.762e-09    -8.381    -8.425    -0.043     (0)
Cu(2)         4.366e-07
   CuCO3           2.133e-07   2.133e-07    -6.671    -6.671     0.000     (0)
   Cu+2            1.098e-07   7.682e-08    -6.959    -7.115    -0.155     (0)
   CuOH+           8.460e-08   7.735e-08    -7.073    -7.112    -0.039     (0)
   CuSO4           2.134e-08   2.134e-08    -7.671    -7.671     0.000     (0)
   Cu(OH)2         4.914e-09   4.914e-09    -8.309    -8.309     0.000     (0)
   CuHCO3+         1.703e-09   1.542e-09    -8.769    -8.812    -0.043     (0)
   Cu(CO3)2-2      4.033e-10   2.707e-10    -9.394    -9.567    -0.173     (0)
   Cu2(OH)2+2      2.239e-10   1.503e-10    -9.650    -9.823    -0.173     (0)
   CuF+            7.488e-11   6.778e-11   -10.126   -10.169    -0.043     (0)
   Cu(OH)3-        3.545e-12   3.209e-12   -11.450   -11.494    -0.043     (0)
   Cu(OH)4-2       1.198e-17   8.042e-18   -16.922   -17.095    -0.173     (0)
F             1.580e-05
   F-              1.529e-05   1.398e-05    -4.816    -4.854    -0.039     (0)
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   MgF+            3.409e-07   3.120e-07    -6.467    -6.506    -0.038     (0)
   CaF+            1.625e-07   1.489e-07    -6.789    -6.827    -0.038     (0)
   HF              6.541e-10   6.541e-10    -9.184    -9.184     0.000     (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000     (0)
   MnF+            2.582e-10   2.366e-10    -9.588    -9.626    -0.038     (0)
   CuF+            7.488e-11   6.778e-11   -10.126   -10.169    -0.043     (0)
   CoF+            3.271e-11   2.961e-11   -10.485   -10.529    -0.043     (0)
   AlF2+           2.736e-11   2.509e-11   -10.563   -10.600    -0.038     (0)
   NiF+            1.523e-11   1.379e-11   -10.817   -10.861    -0.043     (0)
   AlF+2           6.374e-12   4.507e-12   -11.196   -11.346    -0.150     (0)
   AlF3            4.418e-12   4.418e-12   -11.355   -11.355     0.000     (0)
   HF2-            3.808e-14   3.478e-14   -13.419   -13.459    -0.039     (0)
   AlF4-           3.383e-14   3.096e-14   -13.471   -13.509    -0.038     (0)
   H2F2            1.146e-18   1.146e-18   -17.941   -17.941     0.000     (0)
H(0)          1.414e-26
   H2              7.068e-27   7.079e-27   -26.151   -26.150     0.001     (0)
K             3.326e-04
   K+              3.298e-04   3.016e-04    -3.482    -3.521    -0.039     (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038     (0)
Mg            3.293e-04
   Mg+2            2.842e-04   1.988e-04    -3.546    -3.702    -0.155     (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000     (0)
   MgHCO3+         7.079e-07   6.472e-07    -6.150    -6.189    -0.039     (0)
   MgF+            3.409e-07   3.120e-07    -6.467    -6.506    -0.038     (0)
   MgCO3           7.799e-08   7.799e-08    -7.108    -7.108     0.000     (0)
   MgOH+           2.742e-08   2.520e-08    -7.562    -7.599    -0.037     (0)
Mn(2)         7.283e-07
   Mn+2            6.331e-07   4.250e-07    -6.199    -6.372    -0.173     (0)
   MnSO4           9.164e-08   9.164e-08    -7.038    -7.038     0.000     (0)
   MnHCO3+         2.944e-09   2.697e-09    -8.531    -8.569    -0.038     (0)
   MnOH+           3.710e-10   3.399e-10    -9.431    -9.469    -0.038     (0)
   MnF+            2.582e-10   2.366e-10    -9.588    -9.626    -0.038     (0)
   Mn(OH)3-        2.324e-19   2.129e-19   -18.634   -18.672    -0.038     (0)
   Mn(OH)4-2       3.106e-25   2.189e-25   -24.508   -24.660    -0.152     (0)
Mn(3)         4.241e-28
   Mn+3            4.241e-28   1.898e-28   -27.373   -27.722    -0.349     (0)
Mn(6)         0.000e+00
   MnO4-2          0.000e+00   0.000e+00   -48.642   -48.794    -0.152     (0)
Mn(7)         0.000e+00
   MnO4-           0.000e+00   0.000e+00   -54.126   -54.166    -0.040     (0)
Mo            3.128e-08
   MoO4-2          3.126e-08   2.187e-08    -7.505    -7.660    -0.155     (0)
   HMoO4-          1.520e-11   1.376e-11   -10.818   -10.861    -0.043     (0)
   H2MoO4          3.188e-15   3.188e-15   -14.497   -14.497     0.000     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -49.070   -49.460    -0.390     (0)
   Mo7O24-6        0.000e+00   0.000e+00   -59.073   -60.631    -1.558     (0)
   HMo7O24-5       0.000e+00   0.000e+00   -60.662   -61.744    -1.082     (0)
   H2Mo7O24-4      0.000e+00   0.000e+00   -63.769   -64.462    -0.692     (0)
   H3Mo7O24-3      0.000e+00   0.000e+00   -68.326   -68.716    -0.390     (0)
Na            4.351e-05
   Na+             4.322e-05   3.953e-05    -4.364    -4.403    -0.039     (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   NaHCO3          7.071e-09   7.071e-09    -8.151    -8.151     0.000     (0)
   NaCO3-          3.785e-10   3.471e-10    -9.422    -9.460    -0.038     (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000     (0)
Ni            6.818e-08
   Ni+2            5.610e-08   3.924e-08    -7.251    -7.406    -0.155     (0)
   NiSO4           9.495e-09   9.495e-09    -8.023    -8.023     0.000     (0)
   NiHCO3+         1.700e-09   1.539e-09    -8.770    -8.813    -0.043     (0)
   NiCO3           6.904e-10   6.904e-10    -9.161    -9.161     0.000     (0)
   NiOH+           1.738e-10   1.573e-10    -9.760    -9.803    -0.043     (0)
   NiF+            1.523e-11   1.379e-11   -10.817   -10.861    -0.043     (0)
   Ni(OH)2         3.978e-12   3.978e-12   -11.400   -11.400     0.000     (0)
   Ni(SO4)2-2      5.679e-13   3.812e-13   -12.246   -12.419    -0.173     (0)
   Ni(OH)3-        1.399e-15   1.267e-15   -14.854   -14.897    -0.043     (0)
O(0)          2.019e-40
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   O2              1.010e-40   1.011e-40   -39.996   -39.995     0.001     (0)
S(6)          2.051e-03
   SO4-2           1.733e-03   1.213e-03    -2.761    -2.916    -0.155     (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000     (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000     (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038     (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   MnSO4           9.164e-08   9.164e-08    -7.038    -7.038     0.000     (0)
   CuSO4           2.134e-08   2.134e-08    -7.671    -7.671     0.000     (0)
   CoSO4           1.620e-08   1.620e-08    -7.791    -7.791     0.000     (0)
   NiSO4           9.495e-09   9.495e-09    -8.023    -8.023     0.000     (0)
   HSO4-           4.094e-09   3.747e-09    -8.388    -8.426    -0.038     (0)
   Ni(SO4)2-2      5.679e-13   3.812e-13   -12.246   -12.419    -0.173     (0)
   AlSO4+          3.315e-13   3.034e-13   -12.480   -12.518    -0.038     (0)
   Al(SO4)2-       4.307e-15   3.942e-15   -14.366   -14.404    -0.038     (0)

----------------------------Saturation indices----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.79      9.01   10.80  Al(OH)3
  Al2(MoO4)3      -52.33    -49.96    2.37  Al2(MoO4)3
  Al2O3            -1.64     18.02   19.65  Al2O3
  Al4(OH)10SO4     -4.58     18.12   22.70  Al4(OH)10SO4
  AlOHSO4          -5.68     -8.91   -3.23  AlOHSO4
  Alunite          -3.43     -4.83   -1.40  KAl3(SO4)2(OH)6
  Anhydrite        -1.57     -5.93   -4.36  CaSO4
  Antlerite        -3.05      5.74    8.79  Cu3(OH)4SO4
  Aragonite        -1.04     -9.34   -8.30  CaCO3
  Artinite         -8.33      1.27    9.60  MgCO3:Mg(OH)2:3H2O
  Azurite          -2.09    -19.00  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -16.39      8.01   24.39  Ba(OH)2:8H2O
  BaF2            -10.88    -16.70   -5.82  BaF2
  BaMoO4           -7.69    -14.65   -6.96  BaMoO4
  Barite            0.07     -9.91   -9.98  BaSO4
  Birnessite      -11.81      6.28   18.09  MnO2
  Bixbyite         -9.80    -10.44   -0.64  Mn2O3
  Boehmite          0.43      9.01    8.58  AlOOH
  Brochantite      -1.60     13.63   15.22  Cu4(OH)6SO4
  Brucite          -5.55     11.30   16.84  Mg(OH)2
  Bunsenite        -4.85      7.59   12.45  NiO
  Calcite          -0.86     -9.34   -8.48  CaCO3
  CaMoO4           -2.72    -10.67   -7.95  CaMoO4
  CH4(g)          -72.28   -113.33  -41.05  CH4
  Chalcanthite     -7.39    -10.03   -2.64  CuSO4:5H2O
  Co(OH)2          -5.27      7.83   13.09  Co(OH)2
  Co(OH)3         -10.77    -13.07   -2.31  Co(OH)3
  CO2(g)           -3.18    -21.33  -18.15  CO2
  Co3O4            -7.83    -18.32  -10.50  Co3O4
  CoCO3            -3.52    -13.50   -9.98  CoCO3
  CoF2            -15.29    -16.88   -1.60  CoF2
  CoF3            -48.68    -50.14   -1.46  CoF3
  CoMoO4           -7.07    -14.83   -7.76  CoMoO4
  CoO              -5.76      7.83   13.59  CoO
  CoSO4           -12.89    -10.09    2.80  CoSO4
  CoSO4:6H2O       -7.62    -10.09   -2.47  CoSO4:6H2O
  Cryolite        -21.99    -55.83  -33.84  Na3AlF6
  Cu(OH)2          -0.79      7.89    8.67  Cu(OH)2
  Cu2SO4          -17.82    -19.77   -1.95  Cu2SO4
  CuCO3            -1.94    -13.44  -11.50  CuCO3
  CuF              -8.37    -13.28   -4.91  CuF
  CuF2            -17.94    -16.82    1.12  CuF2
  CuF2:2H2O       -12.27    -16.82   -4.55  CuF2:2H2O
  Cumetal          -3.67    -12.42   -8.76  Cu
  CuMoO4           -1.70    -14.77  -13.08  CuMoO4
  CuOCuSO4        -12.45     -2.15   10.30  CuOCuSO4
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  Cuprite          -0.44     -1.85   -1.41  Cu2O
  CuSO4           -12.97    -10.03    2.94  CuSO4
  Diaspore          2.14      9.01    6.87  AlOOH
  Dolomite(disordered)  -2.83    -19.37  -16.54  CaMg(CO3)2
  Dolomite(ordered)  -2.28    -19.37  -17.09  CaMg(CO3)2
  Epsomite         -4.49     -6.62   -2.13  MgSO4:7H2O
  Fluorite         -2.22    -12.72  -10.50  CaF2
  Gibbsite          0.72      9.01    8.29  Al(OH)3
  Gypsum           -1.32     -5.93   -4.61  CaSO4:2H2O
  H2MoO4           -9.78    -22.66  -12.88  H2MoO4
  Hausmannite     -12.15     48.88   61.03  Mn3O4
  Huntite          -9.45    -39.42  -29.97  CaMg3(CO3)4
  Hydromagnesite  -20.05    -28.81   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum          -17.68    -22.85   -5.17  KAl(SO4)2:12H2O
  K2MoO4          -17.96    -14.70    3.26  K2MoO4
  Langite          -3.86     13.63   17.49  Cu4(OH)6SO4:H2O
  Lime            -20.71     11.99   32.70  CaO
  Magnesite        -2.57    -10.03   -7.46  MgCO3
  Malachite        -0.25     -5.56   -5.31  Cu2(OH)2CO3
  Manganite        -5.21     20.13   25.34  MnOOH
  Mg(OH)2(active)  -7.50     11.30   18.79  Mg(OH)2
  MgF2             -5.28    -13.41   -8.13  MgF2
  MgMoO4           -9.51    -11.36   -1.85  MgMoO4
  Mirabilite      -10.61    -11.72   -1.11  Na2SO4:10H2O
  Mn2(SO4)3       -58.48    -64.19   -5.71  Mn2(SO4)3
  MnSO4           -11.87     -9.29    2.58  MnSO4
  MoO3            -14.66    -22.66   -8.00  MoO3
  Morenosite       -8.18    -10.32   -2.14  NiSO4:7H2O
  Na2Mo2O7        -22.53    -39.13  -16.60  Na2Mo2O7
  Na2MoO4         -17.96    -16.47    1.49  Na2MoO4
  Na2MoO4:2H2O    -17.69    -16.47    1.22  Na2MoO4:2H2O
  Natron          -13.82    -15.13   -1.31  Na2CO3:10H2O
  Nesquehonite     -5.36    -10.03   -4.67  MgCO3:3H2O
  Ni(OH)2          -5.20      7.59   12.79  Ni(OH)2
  Ni4(OH)6SO4     -19.54     12.46   32.00  Ni4(OH)6SO4
  NiCO3            -6.86    -13.73   -6.87  NiCO3
  NiMoO4           -3.92    -15.07  -11.14  NiMoO4
  Nsutite         -11.23      6.28   17.50  MnO2
  O2(g)           -37.09     46.00   83.09  O2
  Periclase       -10.29     11.30   21.58  MgO
  Portlandite     -10.81     11.99   22.80  Ca(OH)2
  Pyrochroite      -6.57      8.63   15.19  Mn(OH)2
  Pyrolusite       -9.75     31.63   41.38  MnO2
  Retgersite       -8.28    -10.32   -2.04  NiSO4:6H2O
  Rhodochrosite    -2.12    -12.70  -10.58  MnCO3
  Spinel           -7.53     29.31   36.85  MgAl2O4
  Tenorite          0.24      7.89    7.64  CuO
  Thenardite      -12.04    -11.72    0.32  Na2SO4
  Thermonatrite   -15.77    -15.13    0.64  Na2CO3:H2O
  Witherite        -4.75    -13.32   -8.57  BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 3.     NAF Material

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                5.191e-06   5.191e-06
      Alkalinity        4.591e-04   4.591e-04
      As                3.873e-07   3.873e-07
      Ba                1.457e-07   1.457e-07
      Ca                3.046e-03   3.046e-03
      Co                3.395e-08   3.395e-08
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      Cu                2.992e-07   2.992e-07
      F                 1.580e-05   1.580e-05
      Fe                1.254e-06   1.254e-06
      K                 4.094e-04   4.094e-04
      Mg                7.410e-04   7.410e-04
      Mn                2.368e-06   2.368e-06
      Mo                5.214e-08   5.214e-08
      Na                4.352e-05   4.352e-05
      Ni                1.705e-08   1.705e-08
      S(6)              3.447e-03   3.447e-03
      U                 4.203e-09   4.203e-09

----------------------------Description of solution----------------------------

                                       pH  =   7.600
                                       pe  =   4.000
                      Activity of water  =   1.000
                 Ionic strength (mol/kgw)  =   1.193e-02
                      Mass of water (kg)  =   1.000e+00
                 Total carbon (mol/kg)  =   4.552e-04
                    Total CO2 (mol/kg)  =   4.552e-04
                      Temperature (°C)  =  25.00
              Electrical balance (eq)  =   6.787e-04
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =   5.48
                             Iterations  =  11 (34 overall)
                                Total H  = 1.110142e+02
                                Total O  = 5.552201e+01

----------------------------Distribution of species----------------------------

                                          Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             4.492e-07   4.008e-07    -6.348    -6.397    -0.049     (0)
   H+              2.808e-08   2.512e-08    -7.552    -7.600    -0.048     0.00
   H2O             5.551e+01   9.999e-01     1.744    -0.000     0.000    18.07
Al              5.191e-06
   Al(OH)4-        5.088e-06   4.556e-06    -5.293    -5.341    -0.048     (0)
   Al(OH)3         9.030e-08   9.030e-08    -7.044    -7.044     0.000     (0)
   Al(OH)2+        1.257e-08   1.129e-08    -7.901    -7.947    -0.047     (0)
   AlF2+           6.958e-11   6.249e-11   -10.158   -10.204    -0.047     (0)
   AlOH+2          5.451e-11   3.546e-11   -10.264   -10.450    -0.187     (0)
   AlF+2           1.811e-11   1.178e-11   -10.742   -10.929    -0.187     (0)
   AlF3            1.048e-11   1.048e-11   -10.980   -10.980     0.000     (0)
   AlSO4+          1.328e-12   1.189e-12   -11.877   -11.925    -0.048     (0)
   Al+3            2.412e-13   8.848e-14   -12.618   -13.053    -0.436     (0)
   AlF4-           7.812e-14   6.995e-14   -13.107   -13.155    -0.048     (0)
   Al(SO4)2-       2.463e-14   2.206e-14   -13.608   -13.656    -0.048     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -48.018   -48.520    -0.501     (0)
As(3)           1.024e-17
   H3AsO3          1.000e-17   1.000e-17   -17.000   -17.000     0.000     (0)
   H2AsO3-         2.322e-19   2.043e-19   -18.634   -18.690    -0.056     (0)
   HAsO3-2         1.239e-23   7.417e-24   -22.907   -23.130    -0.223     (0)
   H4AsO3+         1.416e-25   1.245e-25   -24.849   -24.905    -0.056     (0)
   AsO3-3          3.611e-29   1.138e-29   -28.442   -28.944    -0.501     (0)
As(5)           3.873e-07
   HAsO4-2         3.350e-07   2.005e-07    -6.475    -6.698    -0.223     (0)
   H2AsO4-         5.222e-08   4.594e-08    -7.282    -7.338    -0.056     (0)
   AsO4-3          8.009e-11   2.524e-11   -10.096   -10.598    -0.501     (0)
   H3AsO4          2.000e-13   2.005e-13   -12.699   -12.698     0.001     (0)
Ba              1.457e-07
   Ba+2            1.453e-07   9.304e-08    -6.838    -7.031    -0.194     (0)
   BaHCO3+         3.699e-10   3.328e-10    -9.432    -9.478    -0.046     (0)
   BaCO3           3.336e-11   3.336e-11   -10.477   -10.477     0.000     (0)
   BaOH+           1.815e-13   1.628e-13   -12.741   -12.788    -0.047     (0)
C(4)            4.552e-04
   HCO3-           4.171e-04   3.746e-04    -3.380    -3.426    -0.047     (0)
   H2CO3           2.116e-05   2.116e-05    -4.674    -4.674     0.000     (0)
   CaHCO3+         1.200e-05   1.080e-05    -4.921    -4.967    -0.046     (0)
   CaCO3           1.715e-06   1.715e-06    -5.766    -5.766     0.000     (0)
   MgHCO3+         1.687e-06   1.508e-06    -5.773    -5.822    -0.049     (0)
   CO3-2           1.092e-06   6.991e-07    -5.962    -6.155    -0.194     (0)
   MgCO3           2.288e-07   2.288e-07    -6.641    -6.641     0.000     (0)
   CuCO3           1.600e-07   1.600e-07    -6.796    -6.796     0.000     (0)
   MnHCO3+         9.921e-09   8.899e-09    -8.003    -8.051    -0.047     (0)
   NaHCO3          8.124e-09   8.124e-09    -8.090    -8.090     0.000     (0)
   UO2(CO3)2-2     3.482e-09   2.084e-09    -8.458    -8.681    -0.223     (0)
   CuHCO3+         1.044e-09   9.187e-10    -8.981    -9.037    -0.056     (0)
   UO2(CO3)3-4     5.687e-10   7.303e-11    -9.245   -10.136    -0.891     (0)
   NaCO3-          5.590e-10   5.020e-10    -9.253    -9.299    -0.047     (0)
   CoHCO3+         5.432e-10   4.778e-10    -9.265    -9.321    -0.056     (0)
   Cu(CO3)2-2      5.030e-10   3.011e-10    -9.298    -9.521    -0.223     (0)
   NiHCO3+         4.493e-10   3.952e-10    -9.347    -9.403    -0.056     (0)
   BaHCO3+         3.699e-10   3.328e-10    -9.432    -9.478    -0.046     (0)
   NiCO3           2.232e-10   2.232e-10    -9.651    -9.651     0.000     (0)
   CoCO3           1.938e-10   1.938e-10    -9.713    -9.713     0.000     (0)
   UO2CO3          1.494e-10   1.494e-10    -9.826    -9.826     0.000     (0)
   FeHCO3+         1.083e-10   9.748e-11    -9.965   -10.011    -0.046     (0)
   BaCO3           3.336e-11   3.336e-11   -10.477   -10.477     0.000     (0)
Ca              3.046e-03
   Ca+2            2.418e-03   1.548e-03    -2.617    -2.810    -0.194     (0)
   CaSO4           6.140e-04   6.140e-04    -3.212    -3.212     0.000     (0)
   CaHCO3+         1.200e-05   1.080e-05    -4.921    -4.967    -0.046     (0)
   CaCO3           1.715e-06   1.715e-06    -5.766    -5.766     0.000     (0)
   CaF+            2.509e-07   2.251e-07    -6.600    -6.648    -0.047     (0)
   CaOH+           1.376e-08   1.238e-08    -7.861    -7.907    -0.046     (0)
Co(2)           3.395e-08
   Co+2            2.739e-08   1.640e-08    -7.562    -7.785    -0.223     (0)
   CoSO4           5.664e-09   5.664e-09    -8.247    -8.247     0.000     (0)
   CoHCO3+         5.432e-10   4.778e-10    -9.265    -9.321    -0.056     (0)
   CoCO3           1.938e-10   1.938e-10    -9.713    -9.713     0.000     (0)
   CoOH+           1.491e-10   1.311e-10    -9.827    -9.882    -0.056     (0)
   CoF+            7.852e-12   6.907e-12   -11.105   -11.161    -0.056     (0)
   Co(OH)2         4.175e-12   4.175e-12   -11.379   -11.379     0.000     (0)
   Co(OH)3-        3.796e-17   3.339e-17   -16.421   -16.476    -0.056     (0)
   CoOOH-          9.525e-18   8.379e-18   -17.021   -17.077    -0.056     (0)
   Co2OH+3         3.419e-19   1.078e-19   -18.466   -18.968    -0.501     (0)
   Co(OH)4-2       3.543e-24   2.121e-24   -23.451   -23.673    -0.223     (0)
   Co4(OH)4+4      4.595e-31   5.900e-32   -30.338   -31.229    -0.891     (0)
Co(3)           2.221e-30
   CoOH+2          2.221e-30   1.330e-30   -29.653   -29.876    -0.223     (0)
   Co+3            1.780e-36   6.528e-37   -35.750   -36.185    -0.436     (0)
Cu(1)           2.164e-09
   Cu+             2.164e-09   1.904e-09    -8.665    -8.720    -0.056     (0)
Cu(2)           2.970e-07
   CuCO3           1.600e-07   1.600e-07    -6.796    -6.796     0.000     (0)
   Cu+2            6.070e-08   3.887e-08    -7.217    -7.410    -0.194     (0)
   CuOH+           5.512e-08   4.927e-08    -7.259    -7.307    -0.049     (0)
   CuSO4           1.542e-08   1.542e-08    -7.812    -7.812     0.000     (0)
   Cu(OH)2         3.940e-09   3.940e-09    -8.404    -8.404     0.000     (0)
   CuHCO3+         1.044e-09   9.187e-10    -8.981    -9.037    -0.056     (0)
   Cu(CO3)2-2      5.030e-10   3.011e-10    -9.298    -9.521    -0.223     (0)
   Cu2(OH)2+2      1.019e-10   6.097e-11    -9.992   -10.215    -0.223     (0)
   CuF+            3.714e-11   3.267e-11   -10.430   -10.486    -0.056     (0)
   Cu(OH)3-        3.683e-12   3.239e-12   -11.434   -11.490    -0.056     (0)
   Cu(OH)4-2       1.707e-17   1.022e-17   -16.768   -16.991    -0.223     (0)
F               1.580e-05
   F-              1.489e-05   1.332e-05    -4.827    -4.876    -0.048     (0)
   MgF+            6.566e-07   5.879e-07    -6.183    -6.231    -0.048     (0)
   CaF+            2.509e-07   2.251e-07    -6.600    -6.648    -0.047     (0)
   MnF+            7.039e-10   6.314e-10    -9.152    -9.200    -0.047     (0)
   HF              4.949e-10   4.949e-10    -9.306    -9.306     0.000     (0)
   NaF             3.241e-10   3.241e-10    -9.489    -9.489     0.000     (0)
   AlF2+           6.958e-11   6.249e-11   -10.158   -10.204    -0.047     (0)
   CuF+            3.714e-11   3.267e-11   -10.430   -10.486    -0.056     (0)
   AlF+2           1.811e-11   1.178e-11   -10.742   -10.929    -0.187     (0)
   AlF3            1.048e-11   1.048e-11   -10.980   -10.980     0.000     (0)
   CoF+            7.852e-12   6.907e-12   -11.105   -11.161    -0.056     (0)
   NiF+            3.255e-12   2.863e-12   -11.487   -11.543    -0.056     (0)
   UO2F+           1.122e-13   9.871e-14   -12.950   -13.006    -0.056     (0)
   AlF4-           7.812e-14   6.995e-14   -13.107   -13.155    -0.048     (0)
   HF2-            2.808e-14   2.506e-14   -13.552   -13.601    -0.049     (0)
   UO2F2           3.792e-15   3.792e-15   -14.421   -14.421     0.000     (0)
   FeF+2           4.333e-16   2.804e-16   -15.363   -15.552    -0.189     (0)
   FeF2+           1.114e-16   9.996e-17   -15.953   -16.000    -0.047     (0)
   UO2F3-          1.442e-17   1.269e-17   -16.841   -16.897    -0.056     (0)
   FeF3            1.879e-18   1.879e-18   -17.726   -17.726     0.000     (0)
   H2F2            6.561e-19   6.561e-19   -18.183   -18.183     0.000     (0)
   UO2F4-2         2.242e-21   1.342e-21   -20.649   -20.872    -0.223     (0)
   UF3+            3.760e-36   3.307e-36   -35.425   -35.481    -0.056     (0)
   UF2+2           2.617e-36   1.567e-36   -35.582   -35.805    -0.223     (0)
   UF+3            2.964e-38   9.342e-39   -37.528   -38.030    -0.501     (0)
   UF4             4.830e-39   4.830e-39   -38.316   -38.316     0.000     (0)
   UF5-            0.000e+00   0.000e+00   -41.538   -41.594    -0.056     (0)
   UF6-2           0.000e+00   0.000e+00   -43.766   -43.989    -0.223     (0)
Fe(2)           4.379e-08
   Fe+2            3.453e-08   2.067e-08    -7.462    -7.685    -0.223     (0)
   FeSO4           8.785e-09   8.785e-09    -8.056    -8.056     0.000     (0)
   FeOH+           3.677e-10   3.298e-10    -9.434    -9.482    -0.047     (0)
   FeHCO3+         1.083e-10   9.748e-11    -9.965   -10.011    -0.046     (0)
   Fe(OH)2         1.050e-13   1.050e-13   -12.979   -12.979     0.000     (0)
   Fe(OH)3-        1.484e-14   1.331e-14   -13.829   -13.876    -0.047     (0)
Fe(3)           1.210e-06
   Fe(OH)2+        8.628e-07   7.749e-07    -6.064    -6.111    -0.047     (0)
   Fe(OH)3         3.336e-07   3.336e-07    -6.477    -6.477     0.000     (0)
   Fe(OH)4-        1.386e-08   1.245e-08    -7.858    -7.905    -0.047     (0)
   FeOH+2          7.678e-12   4.969e-12   -11.115   -11.304    -0.189     (0)
   FeF+2           4.333e-16   2.804e-16   -15.363   -15.552    -0.189     (0)
   FeSO4+          4.159e-16   3.730e-16   -15.381   -15.428    -0.047     (0)
   FeF2+           1.114e-16   9.996e-17   -15.953   -16.000    -0.047     (0)
   Fe+3            5.236e-17   1.920e-17   -16.281   -16.717    -0.436     (0)
   Fe(SO4)2-       1.570e-17   1.381e-17   -16.804   -16.860    -0.056     (0)
   FeF3            1.879e-18   1.879e-18   -17.726   -17.726     0.000     (0)
   Fe2(OH)2+4      6.368e-21   8.178e-22   -20.196   -21.087    -0.891     (0)
   Fe3(OH)4+5      2.263e-25   9.160e-27   -24.645   -26.038    -1.393     (0)
H(0)            8.909e-27
   H2              4.455e-27   4.467e-27   -26.351   -26.350     0.001     (0)
K               4.094e-04
   K+              4.045e-04   3.618e-04    -3.393    -3.441    -0.048     (0)
   KSO4-           4.938e-06   4.435e-06    -5.306    -5.353    -0.047     (0)
Mg              7.410e-04
   Mg+2            6.144e-04   3.934e-04    -3.212    -3.405    -0.194     (0)
   MgSO4           1.239e-04   1.239e-04    -3.907    -3.907     0.000     (0)
   MgHCO3+         1.687e-06   1.508e-06    -5.773    -5.822    -0.049     (0)
   MgF+            6.566e-07   5.879e-07    -6.183    -6.231    -0.048     (0)
   MgCO3           2.288e-07   2.288e-07    -6.641    -6.641     0.000     (0)
   MgOH+           6.966e-08   6.278e-08    -7.157    -7.202    -0.045     (0)
Mn(2)           2.368e-06
   Mn+2            1.989e-06   1.191e-06    -5.701    -5.924    -0.223     (0)
   MnSO4           3.666e-07   3.666e-07    -6.436    -6.436     0.000     (0)
   MnHCO3+         9.921e-09   8.899e-09    -8.003    -8.051    -0.047     (0)
   MnOH+           1.337e-09   1.199e-09    -8.874    -8.921    -0.047     (0)
   MnF+            7.039e-10   6.314e-10    -9.152    -9.200    -0.047     (0)
   Mn(OH)3-        1.327e-18   1.190e-18   -17.877   -17.924    -0.047     (0)
   Mn(OH)4-2       2.380e-24   1.540e-24   -23.623   -23.812    -0.189     (0)
Mn(3)           1.450e-27
   Mn+3            1.450e-27   5.318e-28   -26.839   -27.274    -0.436     (0)
Mn(6)           0.000e+00
   MnO4-2          0.000e+00   0.000e+00   -47.357   -47.546    -0.189     (0)
Mn(7)           0.000e+00
   MnO4-           0.000e+00   0.000e+00   -52.868   -52.918    -0.050     (0)
Mo              5.214e-08
   MoO4-2          5.212e-08   3.338e-08    -7.283    -7.477    -0.194     (0)
   HMoO4-          1.896e-11   1.668e-11   -10.722   -10.778    -0.056     (0)
   H2MoO4          3.069e-15   3.069e-15   -14.513   -14.513     0.000     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -48.018   -48.520    -0.501     (0)
   Mo7O24-6        0.000e+00   0.000e+00   -58.140   -60.146    -2.006     (0)
   HMo7O24-5       0.000e+00   0.000e+00   -59.966   -61.359    -1.393     (0)
   H2Mo7O24-4      0.000e+00   0.000e+00   -63.285   -64.177    -0.891     (0)
   H3Mo7O24-3      0.000e+00   0.000e+00   -68.029   -68.531    -0.501     (0)
Na              4.352e-05
   Na+             4.311e-05   3.857e-05    -4.365    -4.414    -0.048     (0)
   NaSO4-          3.992e-07   3.586e-07    -6.399    -6.445    -0.047     (0)
   NaHCO3          8.124e-09   8.124e-09    -8.090    -8.090     0.000     (0)
   NaCO3-          5.590e-10   5.020e-10    -9.253    -9.299    -0.047     (0)
   NaF             3.241e-10   3.241e-10    -9.489    -9.489     0.000     (0)
Ni              1.705e-08
   Ni+2            1.336e-08   8.558e-09    -7.874    -8.068    -0.194     (0)
   NiSO4           2.956e-09   2.956e-09    -8.529    -8.529     0.000     (0)
   NiHCO3+         4.493e-10   3.952e-10    -9.347    -9.403    -0.056     (0)
   NiCO3           2.232e-10   2.232e-10    -9.651    -9.651     0.000     (0)
   NiOH+           4.909e-11   4.318e-11   -10.309   -10.365    -0.056     (0)
   NiF+            3.255e-12   2.863e-12   -11.487   -11.543    -0.056     (0)
   Ni(OH)2         1.375e-12   1.375e-12   -11.862   -11.862     0.000     (0)
   Ni(SO4)2-2      2.831e-13   1.695e-13   -12.548   -12.771    -0.223     (0)
   Ni(OH)3-        6.265e-16   5.511e-16   -15.203   -15.259    -0.056     (0)
O(0)            5.066e-40
   O2              2.533e-40   2.540e-40   -39.596   -39.595     0.001     (0)
S(6)            3.447e-03
   SO4-2           2.704e-03   1.731e-03    -2.568    -2.762    -0.194     (0)
   CaSO4           6.140e-04   6.140e-04    -3.212    -3.212     0.000     (0)
   MgSO4           1.239e-04   1.239e-04    -3.907    -3.907     0.000     (0)
   KSO4-           4.938e-06   4.435e-06    -5.306    -5.353    -0.047     (0)
   NaSO4-          3.992e-07   3.586e-07    -6.399    -6.445    -0.047     (0)
   MnSO4           3.666e-07   3.666e-07    -6.436    -6.436     0.000     (0)
   CuSO4           1.542e-08   1.542e-08    -7.812    -7.812     0.000     (0)
   FeSO4           8.785e-09   8.785e-09    -8.056    -8.056     0.000     (0)
   CoSO4           5.664e-09   5.664e-09    -8.247    -8.247     0.000     (0)
   HSO4-           4.746e-09   4.250e-09    -8.324    -8.372    -0.048     (0)
   NiSO4           2.956e-09   2.956e-09    -8.529    -8.529     0.000     (0)
   AlSO4+          1.328e-12   1.189e-12   -11.877   -11.925    -0.048     (0)
   Ni(SO4)2-2      2.831e-13   1.695e-13   -12.548   -12.771    -0.223     (0)
   UO2SO4          1.407e-13   1.407e-13   -12.852   -12.852     0.000     (0)
   Al(SO4)2-       2.463e-14   2.206e-14   -13.608   -13.656    -0.048     (0)
   UO2(SO4)2-2     5.363e-15   3.210e-15   -14.271   -14.493    -0.223     (0)
   FeSO4+          4.159e-16   3.730e-16   -15.381   -15.428    -0.047     (0)
   Fe(SO4)2-       1.570e-17   1.381e-17   -16.804   -16.860    -0.056     (0)
   U(SO4)2         3.332e-38   3.332e-38   -37.477   -37.477     0.000     (0)
   USO4+2          4.047e-39   2.423e-39   -38.393   -38.616    -0.223     (0)
U(3)            0.000e+00
   U+3             0.000e+00   0.000e+00   -54.749   -55.250    -0.501     (0)
U(4)            3.033e-18
   U(OH)5-         3.030e-18   2.665e-18   -17.519   -17.574    -0.056     (0)
   U(OH)4          2.804e-21   2.804e-21   -20.552   -20.552     0.000     (0)
   U(OH)3+         2.928e-25   2.575e-25   -24.533   -24.589    -0.056     (0)
   U(OH)2+2        4.997e-30   2.991e-30   -29.301   -29.524    -0.223     (0)
   UOH+3           1.123e-35   3.539e-36   -34.950   -35.451    -0.501     (0)
   UF3+            3.760e-36   3.307e-36   -35.425   -35.481    -0.056     (0)
   UF2+2           2.617e-36   1.567e-36   -35.582   -35.805    -0.223     (0)
   U(SO4)2         3.332e-38   3.332e-38   -37.477   -37.477     0.000     (0)
   UF+3            2.964e-38   9.342e-39   -37.528   -38.030    -0.501     (0)
   UF4             4.830e-39   4.830e-39   -38.316   -38.316     0.000     (0)
   USO4+2          4.047e-39   2.423e-39   -38.393   -38.616    -0.223     (0)
   UF5-            0.000e+00   0.000e+00   -41.538   -41.594    -0.056     (0)
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   U+4             0.000e+00   0.000e+00   -41.563   -42.454    -0.891     (0)
   UF6-2           0.000e+00   0.000e+00   -43.766   -43.989    -0.223     (0)
   U6(OH)15+9      0.000e+00   0.000e+00  -153.367  -157.880    -4.513     (0)
U(5)          3.720e-15
   UO2+            3.720e-15   3.272e-15   -14.429   -14.485    -0.056     (0)
U(6)          4.203e-09
   UO2(CO3)2-2     3.482e-09   2.084e-09    -8.458    -8.681    -0.223     (0)
   UO2(CO3)3-4     5.687e-10   7.303e-11    -9.245   -10.136    -0.891     (0)
   UO2CO3          1.494e-10   1.494e-10    -9.826    -9.826     0.000     (0)
   UO2OH+          3.080e-12   2.709e-12   -11.511   -11.567    -0.056     (0)
   UO2SO4          1.407e-13   1.407e-13   -12.852   -12.852     0.000     (0)
   UO2F+           1.122e-13   9.871e-14   -12.950   -13.006    -0.056     (0)
   UO2+2           8.384e-14   5.369e-14   -13.077   -13.270    -0.194     (0)
   UO2(SO4)2-2     5.363e-15   3.210e-15   -14.271   -14.493    -0.223     (0)
   UO2F2           3.792e-15   3.792e-15   -14.421   -14.421     0.000     (0)
   (UO2)2(OH)2+2   2.034e-17   1.218e-17   -16.692   -16.914    -0.223     (0)
   UO2F3-          1.442e-17   1.269e-17   -16.841   -16.897    -0.056     (0)
   (UO2)3(OH)5+    4.571e-18   4.021e-18   -17.340   -17.396    -0.056     (0)
   UO2F4-2         2.242e-21   1.342e-21   -20.649   -20.872    -0.223     (0)

----------------------------Saturation indices----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.05      9.75   10.80  Al(OH)3
  Al2(MoO4)3      -50.90    -48.54    2.37  Al2(MoO4)3
  Al2O3            -0.16     19.49   19.65  Al2O3
  Al4(OH)10SO4     -1.67     21.03   22.70  Al4(OH)10SO4
  AlAsO4:2H2O      -7.75     -2.95    4.80  AlAsO4:2H2O
  AlOHSO4          -4.98     -8.21   -3.23  AlOHSO4
  Alunite          -1.12     -2.52   -1.40  KAl3(SO4)2(OH)6
  Anhydrite        -1.21     -5.57   -4.36  CaSO4
  Antlerite        -3.38      5.41    8.79  Cu3(OH)4SO4
  Aragonite        -0.67     -8.97   -8.30  CaCO3
  Arsenolite      -65.24    -68.00   -2.76  As4O6
  Artinite         -7.37      2.23    9.60  MgCO3:Mg(OH)2:3H2O
  As2O5           -32.10    -25.40    6.71  As2O5
  Azurite          -2.44    -19.34  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -16.23      8.17   24.39  Ba(OH)2:8H2O
  Ba3(AsO4)2        8.02     -0.89   -8.91  Ba3(AsO4)2
  BaF2            -10.96    -16.78   -5.82  BaF2
  BaMoO4           -7.55    -14.51   -6.96  BaMoO4
  Barite            0.19     -9.79   -9.98  BaSO4
  Birnessite      -10.97      7.13   18.09  MnO2
  Bixbyite         -8.30     -8.95   -0.64  Mn2O3
  Boehmite          1.17      9.75    8.58  AlOOH
  Brochantite      -2.03     13.20   15.22  Cu4(OH)6SO4
  Brucite          -5.05     11.79   16.84  Mg(OH)2
  Bunsenite        -5.31      7.13   12.45  NiO
  Ca3(AsO4)2:4H2O -10.53     11.77   22.30  Ca3(AsO4)2:4H2O
  Calcite          -0.49     -8.97   -8.48  CaCO3
  CaMoO4           -2.34    -10.29   -7.95  CaMoO4
  CH4(g)          -73.11   -114.16  -41.05  CH4
  Chalcanthite     -7.53    -10.17   -2.64  CuSO4:5H2O
  Claudetite      -64.93    -68.00   -3.06  As4O6
  Co(OH)2          -5.68      7.41   13.09  Co(OH)2
  Co(OH)3         -11.08    -13.39   -2.31  Co(OH)3
  CO2(g)           -3.21    -21.36  -18.15  CO2
  Co3(AsO4)2      -16.19     -3.15   13.03  Co3(AsO4)2
  Co3O4            -8.86    -19.36  -10.50  Co3O4
  CoCO3            -3.96    -13.94   -9.98  CoCO3
  CoF2            -15.94    -17.54   -1.60  CoF2
  CoF3            -49.35    -50.81   -1.46  CoF3
  CoFe2O4          23.11     19.58   -3.53  CoFe2O4
  CoMoO4           -7.50    -15.26   -7.76  CoMoO4
  CoO              -6.17      7.41   13.59  CoO
  CoSO4           -13.35    -10.55    2.80  CoSO4
  CoSO4:6H2O       -8.07    -10.55   -2.47  CoSO4:6H2O
  Cryolite        -21.71    -55.55  -33.84  Na3AlF6
  Cu(OH)2          -0.88      7.79    8.67  Cu(OH)2
  Cu2SO4          -18.25    -20.20   -1.95  Cu2SO4
  Cu3(AsO4)2:2H2O  -8.13     -2.03    6.10  Cu3(AsO4)2:2H2O
  CuCO3            -2.07    -13.57  -11.50  CuCO3
  CuF              -8.69    -13.60   -4.91  CuF
  CuF2            -18.28    -17.16    1.12  CuF2
  CuF2:2H2O       -12.61    -17.16   -4.55  CuF2:2H2O
  Cumetal          -3.96    -12.72   -8.76  Cu
  CuMoO4           -1.81    -14.89  -13.08  CuMoO4
  CuOCuSO4        -12.69     -2.38   10.30  CuOCuSO4
  Cupricferrite    13.97     19.96    5.99  CuFe2O4
  Cuprite          -0.83     -2.24   -1.41  Cu2O
  Cuprousferrite   13.88      4.96   -8.92  CuFeO2
  CuSO4           -13.11    -10.17    2.94  CuSO4
  Diaspore          2.87      9.75    6.87  AlOOH
  Dolomite(disordered)  -1.99    -18.53  -16.54  CaMg(CO3)2
  Dolomite(ordered)  -1.44    -18.53  -17.09  CaMg(CO3)2
  Epsomite         -4.04     -6.17   -2.13  MgSO4:7H2O
  Fe(OH)2          -6.05      7.52   13.56  Fe(OH)2
  Fe2(SO4)3       -37.98    -41.72   -3.73  Fe2(SO4)3
  Fe3(OH)8         -0.54     19.68   20.22  Fe3(OH)8
  FeAsO4:2H2O      -7.01     -6.61    0.40  FeAsO4:2H2O
  FeMoO4           -5.07    -15.16  -10.09  FeMoO4
  Ferrihydrite      2.89      6.08    3.19  Fe(OH)3
  Fluorite         -2.06    -12.56  -10.50  CaF2
  Gibbsite          1.46      9.75    8.29  Al(OH)3
  Goethite          5.59      6.08    0.49  FeOOH
  Gummite          -5.74      1.93    7.67  UO3
  Gypsum           -0.96     -5.57   -4.61  CaSO4:2H2O
  H-Jarosite       -5.57    -17.67  -12.10  (H3O)Fe3(SO4)2(OH)6
  H2MoO4           -9.80    -22.68  -12.88  H2MoO4
  Hausmannite     -10.00     51.03   61.03  Mn3O4
  Hematite         13.58     12.17   -1.42  Fe2O3
  Hercynite         4.12     27.01   22.89  FeAl2O4
  Huntite          -7.68    -37.65  -29.97  CaMg3(CO3)4
  Hydromagnesite  -17.68    -26.45   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum          -16.85    -22.02   -5.17  KAl(SO4)2:12H2O
  K-Jarosite        1.28    -13.52  -14.80  KFe3(SO4)2(OH)6
  K2MoO4          -17.62    -14.36    3.26  K2MoO4
  Langite          -4.29     13.20   17.49  Cu4(OH)6SO4:H2O
  Lepidocrocite     4.71      6.08    1.37  FeOOH
  Lime            -20.31     12.39   32.70  CaO
  Maghemite         5.78     12.17    6.39  Fe2O3
  Magnesioferrite   7.10     23.96   16.86  Fe2MgO4
  Magnesite        -2.10     -9.56   -7.46  MgCO3
  Magnetite        16.28     19.68    3.40  Fe3O4
  Malachite        -0.47     -5.78   -5.31  Cu2(OH)2CO3
  Manganite        -4.46     20.88   25.34  MnOOH
  Melanterite      -8.24    -10.45   -2.21  FeSO4:7H2O
  Mg(OH)2(active)  -7.00     11.79   18.79  Mg(OH)2
  MgF2             -5.03    -13.16   -8.13  MgF2
  MgMoO4           -9.03    -10.88   -1.85  MgMoO4
  Mirabilite      -10.48    -11.59   -1.11  Na2SO4:10H2O
  Mn2(SO4)3       -57.12    -62.83   -5.71  Mn2(SO4)3
  Mn3(AsO4)2:8H2O -10.07      2.43   12.50  Mn3(AsO4)2:8H2O
  MnSO4           -11.27     -8.69    2.58  MnSO4
  MoO3            -14.68    -22.68   -8.00  MoO3
  Morenosite       -8.68    -10.83   -2.14  NiSO4:7H2O
  Na-Jarosite      -3.29    -14.49  -11.20  NaFe3(SO4)2(OH)6
  Na2Mo2O7        -22.38    -38.98  -16.60  Na2Mo2O7
  Na2MoO4         -17.79    -16.30    1.49  Na2MoO4
  Na2MoO4:2H2O    -17.53    -16.30    1.22  Na2MoO4:2H2O
  Natron          -13.67    -14.98   -1.31  Na2CO3:10H2O
  Nesquehonite     -4.89     -9.56   -4.67  MgCO3:3H2O
  Ni(OH)2          -5.66      7.13   12.79  Ni(OH)2
  Ni3(AsO4)2:8H2O -19.70     -4.00   15.70  Ni3(AsO4)2:8H2O
  Ni4(OH)6SO4     -21.43     10.57   32.00  Ni4(OH)6SO4
  NiCO3            -7.35    -14.22   -6.87  NiCO3
  NiMoO4           -4.40    -15.54  -11.14  NiMoO4
  Nsutite         -10.38      7.13   17.50  MnO2
  O2(g)           -36.69     46.40   83.09  O2
  Periclase        -9.79     11.79   21.58  MgO
  Portlandite     -10.41     12.39   22.80  Ca(OH)2
  Pyrochroite      -5.92      9.28   15.19  Mn(OH)2
  Pyrolusite       -8.90     32.48   41.38  MnO2
  Retgersite       -8.79    -10.83   -2.04  NiSO4:6H2O
  Rhodochrosite    -1.50    -12.08  -10.58  MnCO3
  Rutherfordine    -4.93    -19.43  -14.50  UO2CO3
  Schoepite        -4.06      1.93    5.99  UO2(OH)2:H2O
  Siderite         -3.60    -13.84  -10.24  FeCO3
  Spinel           -5.56     31.29   36.85  MgAl2O4
  Tenorite          0.15      7.79    7.64  CuO
  Thenardite      -11.91    -11.59    0.32  Na2SO4
  Thermonatrite   -15.62    -14.98    0.64  Na2CO3:H2O
  U3O8            -10.85     10.24   21.08  U3O8
  U4O9            -22.00    -25.02   -3.02  U4O9
  UF4             -32.42    -61.96  -29.54  UF4
  UF4:2.5H2O      -29.24    -61.96  -32.72  UF4:2.5H2O
  UO2(am)         -12.99    -12.05    0.93  UO2
  UO2(OH)2(beta)   -3.68      1.93    5.61  UO2(OH)2
  UO3              -5.77      1.93    7.70  UO3
  Uraninite        -7.38    -12.05   -4.67  UO2
  Witherite        -4.62    -13.19   -8.57  BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 4.     Make-up Material

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                7.415e-07   7.415e-07
      Alkalinity        3.607e-04   3.607e-04
      Ba                1.457e-07   1.457e-07
      Ca                1.672e-03   1.672e-03
      Co                1.188e-07   1.188e-07
      Cu                4.408e-07   4.408e-07
      F                 1.580e-05   1.580e-05
      K                 3.326e-04   3.326e-04
      Mg                3.293e-04   3.293e-04
      Mn                7.283e-07   7.283e-07
      Mo                3.128e-08   3.128e-08
      Na                4.351e-05   4.351e-05
      Ni                6.818e-08   6.818e-08
      S(6)              2.051e-03   2.051e-03

----------------------------Description of solution----------------------------

                                     pH  =   7.700
                                     pe  =   4.000
                     Activity of water  =   1.000
                 Ionic strength (mol/kgw)  =   7.199e-03
                    Mass of water (kg)  =   1.000e+00
                Total carbon (mol/kg)  =   3.686e-04
                   Total CO2 (mol/kg)  =   3.686e-04
                      Temperature (°C)  =  25.00
             Electrical balance (eq)  =  -9.478e-05

 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  -1.25
                                  Iterations  =  12 (46 overall)
                                     Total H  = 1.110140e+02
                                     Total O  = 5.551615e+01

----------------------------Distribution of species----------------------------

                                                  Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma   cm³/mol

   OH-             5.526e-07   5.046e-07    -6.258    -6.297    -0.039     (0)
   H+              2.182e-08   1.995e-08    -7.661    -7.700    -0.039      0.00
   H2O             5.551e+01   9.999e-01     1.744    -0.000     0.000     18.07
Al            7.415e-07
   Al(OH)4-        7.298e-07   6.680e-07    -6.137    -6.175    -0.038     (0)
   Al(OH)3         1.051e-08   1.051e-08    -7.978    -7.978     0.000     (0)
   Al(OH)2+        1.139e-09   1.044e-09    -8.944    -8.981    -0.038     (0)
   AlF2+           4.383e-12   4.020e-12   -11.358   -11.396    -0.038     (0)
   AlOH+2          3.684e-12   2.605e-12   -11.434   -11.584    -0.150     (0)
   AlF+2           1.021e-12   7.220e-13   -11.991   -12.141    -0.150     (0)
   AlF3            7.077e-13   7.077e-13   -12.150   -12.150     0.000     (0)
   AlSO4+          5.310e-14   4.860e-14   -13.275   -13.313    -0.038     (0)
   Al+3            1.153e-14   5.163e-15   -13.938   -14.287    -0.349     (0)
   AlF4-           5.420e-15   4.960e-15   -14.266   -14.304    -0.038     (0)
   Al(SO4)2-       6.899e-16   6.315e-16   -15.161   -15.200    -0.038     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -51.065   -51.455    -0.389     (0)
Ba            1.457e-07
   Ba+2            1.453e-07   1.017e-07    -6.838    -6.993    -0.155     (0)
   BaHCO3+         3.344e-10   3.070e-10    -9.476    -9.513    -0.037     (0)
   BaCO3           3.874e-11   3.874e-11   -10.412   -10.412     0.000     (0)
   BaOH+           2.444e-13   2.239e-13   -12.612   -12.650    -0.038     (0)
C(4)          3.686e-04
   HCO3-           3.449e-04   3.163e-04    -3.462    -3.500    -0.038     (0)
   H2CO3           1.419e-05   1.419e-05    -4.848    -4.848     0.000     (0)
   CaHCO3+         6.254e-06   5.742e-06    -5.204    -5.241    -0.037     (0)
   CaCO3           1.148e-06   1.148e-06    -5.940    -5.940     0.000     (0)
   CO3-2           1.062e-06   7.431e-07    -5.974    -6.129    -0.155     (0)
   MgHCO3+         7.037e-07   6.434e-07    -6.153    -6.192    -0.039     (0)
   CuCO3           2.384e-07   2.384e-07    -6.623    -6.623     0.000     (0)
   MgCO3           1.229e-07   1.229e-07    -6.911    -6.911     0.000     (0)
   NaHCO3          7.030e-09   7.030e-09    -8.153    -8.153     0.000     (0)
   MnHCO3+         2.926e-09   2.681e-09    -8.534    -8.572    -0.038     (0)
   CoHCO3+         1.811e-09   1.639e-09    -8.742    -8.785    -0.043     (0)
   NiHCO3+         1.678e-09   1.519e-09    -8.775    -8.818    -0.043     (0)
   CuHCO3+         1.201e-09   1.087e-09    -8.920    -8.964    -0.043     (0)
   NiCO3           1.080e-09   1.080e-09    -8.967    -8.967     0.000     (0)
   CoCO3           8.369e-10   8.369e-10    -9.077    -9.077     0.000     (0)
   Cu(CO3)2-2      7.104e-10   4.768e-10    -9.149    -9.322    -0.173     (0)
   NaCO3-          5.965e-10   5.470e-10    -9.224    -9.262    -0.038     (0)
   BaHCO3+         3.344e-10   3.070e-10    -9.476    -9.513    -0.037     (0)
   BaCO3           3.874e-11   3.874e-11   -10.412   -10.412     0.000     (0)
Ca            1.672e-03
   Ca+2            1.394e-03   9.751e-04    -2.856    -3.011    -0.155     (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000     (0)
   CaHCO3+         6.254e-06   5.742e-06    -5.204    -5.241    -0.037     (0)
   CaCO3           1.148e-06   1.148e-06    -5.940    -5.940     0.000     (0)
   CaF+            1.624e-07   1.488e-07    -6.789    -6.827    -0.038     (0)
   CaOH+           1.069e-08   9.818e-09    -7.971    -8.008    -0.037     (0)
Co(2)         1.188e-07
   Co+2            9.925e-08   6.662e-08    -7.003    -7.176    -0.173     (0)
   CoSO4           1.612e-08   1.612e-08    -7.793    -7.793     0.000     (0)
   CoHCO3+         1.811e-09   1.639e-09    -8.742    -8.785    -0.043     (0)
   CoCO3           8.369e-10   8.369e-10    -9.077    -9.077     0.000     (0)
   CoOH+           7.411e-10   6.708e-10    -9.130    -9.173    -0.043     (0)
   CoF+            3.255e-11   2.946e-11   -10.487   -10.531    -0.043     (0)
   Co(OH)2         2.689e-11   2.689e-11   -10.570   -10.570     0.000     (0)
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   Co(OH)3-        2.991e-16   2.707e-16   -15.524   -15.567    -0.043     (0)
   CoOOH-          7.505e-17   6.793e-17   -16.125   -16.168    -0.043     (0)
   Co2OH+3         5.491e-18   2.240e-18   -17.260   -17.650    -0.389     (0)
   Co(OH)4-2       3.225e-23   2.165e-23   -22.491   -22.665    -0.173     (0)
   Co4(OH)4+4      1.990e-28   4.040e-29   -27.701   -28.394    -0.692     (0)
Co(3)          1.013e-29
   COOH+2          1.013e-29   6.801e-30   -28.994   -29.167    -0.173     (0)
   Co+3            5.925e-36   2.652e-36   -35.227   -35.576    -0.349     (0)
Cu(1)          2.948e-09
   Cu+             2.948e-09   2.668e-09    -8.530    -8.574    -0.043     (0)
Cu(2)          4.378e-07
   CuCO3           2.384e-07   2.384e-07    -6.623    -6.623     0.000     (0)
   CuOH+           9.510e-08   8.694e-08    -7.022    -7.061    -0.039     (0)
   Cu+2            7.788e-08   5.448e-08    -7.109    -7.264    -0.155     (0)
   CuSO4           1.514e-08   1.514e-08    -7.820    -7.820     0.000     (0)
   Cu(OH)2         8.754e-09   8.754e-09    -8.058    -8.058     0.000     (0)
   CuHCO3+         1.201e-09   1.087e-09    -8.920    -8.964    -0.043     (0)
   Cu(CO3)2-2      7.104e-10   4.768e-10    -9.149    -9.322    -0.173     (0)
   Cu2(OH)2+2      2.829e-10   1.899e-10    -9.548    -9.722    -0.173     (0)
   CuF+            5.311e-11   4.808e-11   -10.275   -10.318    -0.043     (0)
   Cu(OH)3-        1.001e-11   9.061e-12   -11.000   -11.043    -0.043     (0)
   Cu(OH)4-2       5.361e-17   3.599e-17   -16.271   -16.444    -0.173     (0)
F              1.580e-05
   F-              1.529e-05   1.398e-05    -4.816    -4.854    -0.039     (0)
   MgF+            3.408e-07   3.119e-07    -6.467    -6.506    -0.038     (0)
   CaF+            1.624e-07   1.488e-07    -6.789    -6.827    -0.038     (0)
   HF              4.127e-10   4.127e-10    -9.384    -9.384     0.000     (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000     (0)
   MnF+            2.582e-10   2.365e-10    -9.588    -9.626    -0.038     (0)
   CuF+            5.311e-11   4.808e-11   -10.275   -10.318    -0.043     (0)
   CoF+            3.255e-11   2.946e-11   -10.487   -10.531    -0.043     (0)
   NiF+            1.512e-11   1.369e-11   -10.820   -10.864    -0.043     (0)
   AlF2+           4.383e-12   4.020e-12   -11.358   -11.396    -0.038     (0)
   AlF+2           1.021e-12   7.220e-13   -11.991   -12.141    -0.150     (0)
   AlF3            7.077e-13   7.077e-13   -12.150   -12.150     0.000     (0)
   HF2-            2.403e-14   2.194e-14   -13.619   -13.659    -0.039     (0)
   AlF4-           5.420e-15   4.960e-15   -14.266   -14.304    -0.038     (0)
   H2F2            4.564e-19   4.564e-19   -18.341   -18.341     0.000     (0)
H(0)           5.627e-27
   H2              2.814e-27   2.818e-27   -26.551   -26.550     0.001     (0)
K              3.326e-04
   K+              3.298e-04   3.016e-04    -3.482    -3.521    -0.039     (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038     (0)
Mg             3.293e-04
   Mg+2            2.842e-04   1.988e-04    -3.546    -3.702    -0.155     (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000     (0)
   MgHCO3+         7.037e-07   6.434e-07    -6.153    -6.192    -0.039     (0)
   MgF+            3.408e-07   3.119e-07    -6.467    -6.506    -0.038     (0)
   MgCO3           1.229e-07   1.229e-07    -6.911    -6.911     0.000     (0)
   MgOH+           4.345e-08   3.994e-08    -7.362    -7.399    -0.037     (0)
Mn(2)          7.283e-07
   Mn+2            6.329e-07   4.249e-07    -6.199    -6.372    -0.173     (0)
   MnSO4           9.162e-08   9.162e-08    -7.038    -7.038     0.000     (0)
   MnHCO3+         2.926e-09   2.681e-09    -8.534    -8.572    -0.038     (0)
   MnOH+           5.878e-10   5.385e-10    -9.231    -9.269    -0.038     (0)
   MnF+            2.582e-10   2.365e-10    -9.588    -9.626    -0.038     (0)
   Mn(OH)3-        9.250e-19   8.475e-19   -18.034   -18.072    -0.038     (0)
   Mn(OH)4-2       1.959e-24   1.381e-24   -23.708   -23.860    -0.152     (0)
Mn(3)          4.240e-28
   Mn+3            4.240e-28   1.898e-28   -27.373   -27.722    -0.349     (0)
Mn(6)          0.000e+00
   MnO4-2          0.000e+00   0.000e+00   -47.042   -47.194    -0.152     (0)
Mn(7)          0.000e+00
   MnO4-           0.000e+00   0.000e+00   -52.526   -52.566    -0.040     (0)
Mo             3.128e-08
   MoO4-2          3.127e-08   2.188e-08    -7.505    -7.660    -0.155     (0)
   HMoO4-          9.595e-12   8.685e-12   -11.018   -11.061    -0.043     (0)
   H2MoO4          1.269e-15   1.269e-15   -14.896   -14.896     0.000     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -51.065   -51.455    -0.389     (0)
   Mo7O24-6        0.000e+00   0.000e+00   -60.672   -62.230    -1.558     (0)
   HMo7O24-5       0.000e+00   0.000e+00   -62.461   -63.543    -1.082     (0)
   H2Mo7O24-4      0.000e+00   0.000e+00   -65.769   -66.461    -0.692     (0)
   H3Mo7O24-3      0.000e+00   0.000e+00   -70.526   -70.915    -0.389     (0)
Na             4.351e-05
   Na+             4.322e-05   3.953e-05    -4.364    -4.403    -0.039     (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   NaHCO3          7.030e-09   7.030e-09    -8.153    -8.153     0.000     (0)
   NaCO3-          5.965e-10   5.470e-10    -9.224    -9.262    -0.038     (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000     (0)
Ni             6.818e-08
   Ni+2            5.569e-08   3.896e-08    -7.254    -7.409    -0.155     (0)
   NiSO4           9.427e-09   9.427e-09    -8.026    -8.026     0.000     (0)
   NiHCO3+         1.678e-09   1.519e-09    -8.775    -8.818    -0.043     (0)
   NiCO3           1.080e-09   1.080e-09    -8.967    -8.967     0.000     (0)
   NiOH+           2.734e-10   2.475e-10    -9.563    -9.606    -0.043     (0)
   NiF+            1.512e-11   1.369e-11   -10.820   -10.864    -0.043     (0)
   Ni(OH)2         9.921e-12   9.921e-12   -11.003   -11.003     0.000     (0)
   Ni(SO4)2-2      5.639e-13   3.785e-13   -12.249   -12.422    -0.173     (0)
   Ni(OH)3-        5.531e-15   5.006e-15   -14.257   -14.300    -0.043     (0)
O(0)           1.274e-39
   O2              6.370e-40   6.381e-40   -39.196   -39.195     0.001     (0)
S(6)           2.051e-03
   SO4-2           1.733e-03   1.213e-03    -2.761    -2.916    -0.155     (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000     (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000     (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038     (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   MnSO4           9.162e-08   9.162e-08    -7.038    -7.038     0.000     (0)
   CoSO4           1.612e-08   1.612e-08    -7.793    -7.793     0.000     (0)
   CuSO4           1.514e-08   1.514e-08    -7.820    -7.820     0.000     (0)
   NiSO4           9.427e-09   9.427e-09    -8.026    -8.026     0.000     (0)
   HSO4-           2.583e-09   2.364e-09    -8.588    -8.626    -0.038     (0)
   Ni(SO4)2-2      5.639e-13   3.785e-13   -12.249   -12.422    -0.173     (0)
   AlSO4+          5.310e-14   4.860e-14   -13.275   -13.313    -0.038     (0)
   Al(SO4)2-       6.899e-16   6.315e-16   -15.161   -15.200    -0.038     (0)

-----------------------------Saturation indices-----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.99      8.81   10.80  Al(OH)3
  Al2(MoO4)3      -53.92    -51.55    2.37  Al2(MoO4)3
  Al2O3            -2.03     17.63   19.65  Al2O3
  Al4(OH)10SO4     -5.77     16.93   22.70  Al4(OH)10SO4
  AlOHSO4          -6.27     -9.50   -3.23  AlOHSO4
  Alunite          -4.61     -6.01   -1.40  KAl3(SO4)2(OH)6
  Anhydrite        -1.57     -5.93   -4.36  CaSO4
  Antlerite        -2.70      6.09    8.79  Cu3(OH)4SO4
  Aragonite        -0.84     -9.14   -8.30  CaCO3
  Artinite         -7.73      1.87    9.60  MgCO3:Mg(OH)2:3H2O
  Azurite          -1.74    -18.65  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -15.99      8.41   24.39  Ba(OH)2:8H2O
  BaF2            -10.88    -16.70   -5.82  BaF2
  BaMoO4           -7.69    -14.65   -6.96  BaMoO4
  Barite            0.07     -9.91   -9.98  BaSO4
  Birnessite      -11.01      7.08   18.09  MnO2
  Bixbyite         -8.60     -9.24   -0.64  Mn2O3
  Boehmite          0.23      8.81    8.58  AlOOH
  Brochantite      -0.99     14.23   15.22  Cu4(OH)6SO4
  Brucite          -5.15     11.70   16.84  Mg(OH)2
  Bunsenite        -4.45      7.99   12.45  NiO
  Calcite          -0.66     -9.14   -8.48  CaCO3
  CaMoO4           -2.72    -10.67   -7.95  CaMoO4
  CH4(g)          -74.08   -115.13  -41.05  CH4
  Chalcanthite     -7.54    -10.18   -2.64  CuSO4:5H2O
  Co(OH)2          -4.87      8.22   13.09  Co(OH)2
  Co(OH)3         -10.17    -12.48   -2.31  Co(OH)3
  CO2(g)           -3.38    -21.53  -18.15  CO2
  Co3O4            -6.23    -16.73  -10.50  Co3O4
  CoCO3            -3.33    -13.31   -9.98  CoCO3
  CoF2            -15.29    -16.89   -1.60  CoF2
  CoF3            -48.68    -50.14   -1.46  CoF3
  CoMoO4           -7.08    -14.84   -7.76  CoMoO4
  CoO              -5.36      8.22   13.59  CoO
  CoSO4           -12.90    -10.09    2.80  CoSO4
  CoSO4:6H2O       -7.62    -10.09   -2.47  CoSO4:6H2O
  Cryolite        -22.78    -56.62  -33.84  Na3AlF6
  Cu(OH)2          -0.54      8.14    8.67  Cu(OH)2
  Cu2SO4          -18.11    -20.06   -1.95  Cu2SO4
  CuCO3            -1.89    -13.39  -11.50  CuCO3
  CuF              -8.52    -13.43   -4.91  CuF
  CuF2            -18.09    -16.97    1.12  CuF2
  CuF2:2H2O       -12.42    -16.97   -4.55  CuF2:2H2O
  Cumetal          -3.82    -12.57   -8.76  Cu
  CuMoO4           -1.85    -14.92  -13.08  CuMoO4
  CuOCuSO4        -12.35     -2.04   10.30  CuOCuSO4
  Cuprite          -0.34     -1.75   -1.41  Cu2O
  CuSO4           -13.12    -10.18    2.94  CuSO4
  Diaspore          1.94      8.81    6.87  AlOOH
  Dolomite(disordered)  -2.43    -18.97  -16.54  CaMg(CO3)2
  Dolomite(ordered)     -1.88    -18.97  -17.09  CaMg(CO3)2
  Epsomite         -4.49     -6.62   -2.13  MgSO4:7H2O
  Fluorite         -2.22    -12.72  -10.50  CaF2
  Gibbsite          0.52      8.81    8.29  Al(OH)3
  Gypsum           -1.32     -5.93   -4.61  CaSO4:2H2O
  H2MoO4          -10.18    -23.06  -12.88  H2MoO4
  Hausmannite     -10.55     50.48   61.03  Mn3O4
  Huntite          -8.66    -38.63  -29.97  CaMg3(CO3)4
  Hydromagnesite  -18.86    -27.62   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum          -18.47    -23.64   -5.17  KAl(SO4)2:12H2O
  K2MoO4          -17.96    -14.70    3.26  K2MoO4
  Langite          -3.26     14.23   17.49  Cu4(OH)6SO4:H2O
  Lime            -20.31     12.39   32.70  CaO
  Magnesite        -2.37     -9.83   -7.46  MgCO3
  Malachite         0.05     -5.26   -5.31  Cu2(OH)2CO3
  Manganite        -4.61     20.73   25.34  MnOOH
  Mg(OH)2(active)  -7.10     11.70   18.79  Mg(OH)2
  MgF2             -5.28    -13.41   -8.13  MgF2
  MgMoO4           -9.51    -11.36   -1.85  MgMoO4
  Mirabilite      -10.61    -11.72   -1.11  Na2SO4:10H2O
  Mn2(SO4)3       -58.48    -64.19   -5.71  Mn2(SO4)3
  MnSO4           -11.87     -9.29    2.58  MnSO4
  MoO3            -15.06    -23.06   -8.00  MoO3
  Morenosite       -8.18    -10.33   -2.14  NiSO4:7H2O
  Na2Mo2O7        -22.93    -39.53  -16.60  Na2Mo2O7
  Na2MoO4         -17.96    -16.47    1.49  Na2MoO4
  Na2MoO4:2H2O    -17.69    -16.47    1.22  Na2MoO4:2H2O
  Natron          -13.62    -14.94   -1.31  Na2CO3:10H2O
  Nesquehonite     -5.16     -9.83   -4.67  MgCO3:3H2O
  Ni(OH)2          -4.80      7.99   12.79  Ni(OH)2
  Ni4(OH)6SO4     -18.35     13.65   32.00  Ni4(OH)6SO4
  NiCO3            -6.67    -13.54   -6.87  NiCO3
  NiMoO4           -3.93    -15.07  -11.14  NiMoO4
  Nsutite         -10.43      7.08   17.50  MnO2
  O2(g)           -36.29     46.80   83.09  O2
  Periclase        -9.89     11.70   21.58  MgO
  Portlandite     -10.42     12.39   22.80  Ca(OH)2
  Pyrochroite      -6.17      9.03   15.19  Mn(OH)2
  Pyrolusite       -8.95     32.43   41.38  MnO2
  Retgersite       -8.29    -10.33   -2.04  NiSO4:6H2O
  Rhodochrosite    -1.92    -12.50  -10.58  MnCO3
  Spinel           -7.52     29.32   36.85  MgAl2O4
  Tenorite          0.49      8.14    7.64  CuO
  Thenardite      -12.04    -11.72    0.32  Na2SO4
  Thermonatrite   -15.57    -14.94    0.64  Na2CO3:H2O
  Witherite        -4.55    -13.12   -8.57  BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

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Beginning of batch-reaction calculations.
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Reaction step 1.

Using mix 1.      Mix within UG Works

Mixture 1.  Mix within UG Works

        3.420e-01 Solution 1  UG Water P05
        1.050e-01 Solution 2  PAF Material
        3.800e-01 Solution 3  NAF Material
        1.730e-01 Solution 4  Make-up Material

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                3.180e-06   3.180e-06
      As                1.590e-07   1.590e-07
      B                 4.060e-06   4.060e-06
      Ba                5.439e-07   5.439e-07
      C                 2.962e-03   2.962e-03
      Ca                2.383e-03   2.383e-03
      Cd                2.132e-08   2.132e-08
      Cl                4.877e-04   4.877e-04
      Co                6.801e-08   6.801e-08
      Cr                5.004e-08   5.004e-08
      Cu                6.015e-07   6.015e-07
      F                 2.747e-05   2.747e-05
      Fe                1.566e-06   1.566e-06
      K                 5.694e-04   5.694e-04
      Mg                9.788e-04   9.788e-04
      Mn                1.614e-06   1.614e-06
      Mo                5.599e-08   5.599e-08
      Na                2.773e-03   2.773e-03
      Ni                5.751e-08   5.751e-08
      Pb                7.188e-08   7.188e-08
      S                 2.471e-03   2.471e-03
      Se                3.729e-08   3.729e-08
      U                 1.267e-08   1.267e-08
      V                 1.680e-08   1.680e-08
      Zn                9.927e-07   9.927e-07

---------------------------Description of solution---------------------------

                                       pH  =   8.070      Charge balance
                                       pe  =   3.331      Adjusted to redox equilibrium
                          Activity of water  =   1.000
                     Ionic strength (mol/kgw)  =   1.292e-02
                          Mass of water (kg)  =   1.000e+00
                    Total alkalinity (eq/kg)  =   2.986e-03
                          Total CO2 (mol/kg)  =   2.962e-03
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                    Temperature (°C)  =  25.00
              Electrical balance (eq)  =   1.641e-03
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  10.08
                           Iterations  =  12
                              Total H  = 1.110166e+02
                              Total O  = 5.552563e+01

----------------------------Distribution of species----------------------------

                                                  Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             1.331e-06   1.183e-06    -5.876    -5.927    -0.051     (0)
   H+              9.554e-09   8.513e-09    -8.020    -8.070    -0.050      0.00
   H2O             5.551e+01   9.998e-01     1.744     -0.000     0.000     18.07
Al             3.180e-06
   Al(OH)4-        3.160e-06   2.819e-06    -5.500    -5.550    -0.050     (0)
   Al(OH)3         1.894e-08   1.894e-08    -7.723    -7.723     0.000     (0)
   Al(OH)2+        8.968e-10   8.025e-10    -9.047    -9.096    -0.048     (0)
   AlF2+           1.670e-12   1.495e-12   -11.777   -11.825    -0.048     (0)
   AlOH+2          1.332e-12   8.544e-13   -11.875   -12.068    -0.193     (0)
   AlF3            4.290e-13   4.290e-13   -12.368   -12.368     0.000     (0)
   AlF+2           2.569e-13   1.647e-13   -12.590   -12.783    -0.193     (0)
   AlSO4+          7.841e-15   6.994e-15   -14.106   -14.155    -0.050     (0)
   AlF4-           5.495e-15   4.902e-15   -14.260   -14.310    -0.050     (0)
   Al+3            2.040e-15   7.225e-16   -14.690   -15.141    -0.451     (0)
   Al(SO4)2-       1.048e-16   9.347e-17   -15.980   -16.029    -0.050     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -52.760   -53.281    -0.522     (0)
As(3)          1.360e-18
   H3AsO3          1.272e-18   1.272e-18   -17.895   -17.895     0.000     (0)
   H2AsO3-         8.758e-20   7.664e-20   -19.058   -19.116    -0.058     (0)
   HAsO3-2         1.400e-23   8.210e-24   -22.854   -23.086    -0.232     (0)
   H4AsO3+         6.132e-27   5.366e-27   -26.212   -26.270    -0.058     (0)
   AsO3-3          1.236e-28   3.717e-29   -27.908   -28.430    -0.522     (0)
As(5)          1.590e-07
   HAsO4-2         1.511e-07   8.857e-08    -6.821    -7.053    -0.232     (0)
   H2AsO4-         7.859e-09   6.877e-09    -8.105    -8.163    -0.058     (0)
   AsO4-3          1.094e-10   3.290e-11    -9.961   -10.483    -0.522     (0)
   H3AsO4          1.014e-14   1.017e-14   -13.994   -13.992     0.001     (0)
B              4.060e-06
   H3BO3           3.744e-06   3.755e-06    -5.427    -5.425     0.001     (0)
   H2BO3-          2.894e-07   2.562e-07    -6.538    -6.591    -0.053     (0)
   CaH2BO3+        2.040e-08   1.805e-08    -7.690    -7.743    -0.053     (0)
   MgH2BO3+        5.292e-09   4.683e-09    -8.276    -8.329    -0.053     (0)
   NaH2BO3         9.952e-10   9.952e-10    -9.002    -9.002     0.000     (0)
   BF(OH)3-        3.859e-11   3.416e-11   -10.413   -10.466    -0.053     (0)
   BaH2BO3+        3.004e-12   2.658e-12   -11.522   -11.575    -0.053     (0)
   H5(BO3)2-       9.251e-13   8.188e-13   -12.034   -12.087    -0.053     (0)
   BF2(OH)2-       8.009e-16   7.089e-16   -15.096   -15.149    -0.053     (0)
   H8(BO3)3-       3.474e-16   3.075e-16   -15.459   -15.512    -0.053     (0)
   BF3OH-          6.049e-23   5.354e-23   -22.218   -22.271    -0.053     (0)
   BF4-            5.777e-29   5.113e-29   -28.238   -28.291    -0.053     (0)
Ba             5.439e-07
   Ba+2            5.326e-07   3.358e-07    -6.274    -6.474    -0.200     (0)
   BaHCO3+         8.885e-09   7.967e-09    -8.051    -8.099    -0.047     (0)
   BaCO3           2.356e-09   2.356e-09    -8.628    -8.628     0.000     (0)
   BaH2BO3+        3.004e-12   2.658e-12   -11.522   -11.575    -0.053     (0)
   BaOH+           1.940e-12   1.733e-12   -11.712   -11.761    -0.049     (0)
C(4)           2.962e-03
   HCO3-           2.776e-03   2.484e-03    -2.557    -2.605    -0.048     (0)
   CaHCO3+         6.319e-05   5.666e-05    -4.199    -4.247    -0.047     (0)
   H2CO3           4.757e-05   4.757e-05    -4.323    -4.323     0.000     (0)
   CaCO3           2.656e-05   2.656e-05    -4.576    -4.576     0.000     (0)
   CO3-2           2.170e-05   1.368e-05    -4.664    -4.864    -0.200     (0)
   MgHCO3+         1.506e-05   1.340e-05    -4.822    -4.873    -0.050     (0)
   MgCO3           6.000e-06   6.000e-06    -5.222    -5.222     0.000     (0)
   NaHCO3          3.424e-06   3.424e-06    -5.465    -5.465     0.000     (0)
   NaCO3-          6.978e-07   6.244e-07    -6.156    -6.205    -0.048     (0)
   CuCO3           5.201e-07   5.201e-07    -6.284    -6.284     0.000     (0)
   ZnCO3           2.693e-07   2.693e-07    -6.570    -6.570     0.000     (0)
   PbCO3           5.714e-08   5.714e-08    -7.243    -7.243     0.000     (0)
   MnHCO3+         4.505e-08   4.026e-08    -7.346    -7.395    -0.049     (0)
   Cu(CO3)2-2      3.267e-08   1.915e-08    -7.486    -7.718    -0.232     (0)
   ZnHCO3+         3.071e-08   2.688e-08    -7.513    -7.571    -0.058     (0)
   NiCO3           1.081e-08   1.081e-08    -7.966    -7.966     0.000     (0)
   UO2(CO3)3-4     9.789e-09   1.157e-09    -8.009    -8.937    -0.928     (0)
   BaHCO3+         8.885e-09   7.967e-09    -8.051    -8.099    -0.047     (0)
   NiHCO3+         7.413e-09   6.487e-09    -8.130    -8.188    -0.058     (0)
   CoCO3           6.450e-09   6.450e-09    -8.190    -8.190     0.000     (0)
   CoHCO3+         6.160e-09   5.390e-09    -8.210    -8.268    -0.058     (0)
   Pb(CO3)2-2      3.845e-09   2.254e-09    -8.415    -8.647    -0.232     (0)
   PbHCO3+         2.931e-09   2.565e-09    -8.533    -8.591    -0.058     (0)
   CdCO3           2.927e-09   2.927e-09    -8.534    -8.534     0.000     (0)
   UO2(CO3)2-2     2.877e-09   1.687e-09    -8.541    -8.773    -0.232     (0)
   BaCO3           2.356e-09   2.356e-09    -8.628    -8.628     0.000     (0)
   CuHCO3+         1.157e-09   1.012e-09    -8.937    -8.995    -0.058     (0)
   FeHCO3+         3.038e-10   2.724e-10    -9.517    -9.565    -0.047     (0)
   CdHCO3+         6.068e-11   5.309e-11   -10.217   -10.275    -0.058     (0)
   Cd(CO3)2-2      5.063e-11   2.969e-11   -10.296   -10.527    -0.232     (0)
   UO2CO3          6.179e-12   6.179e-12   -11.209   -11.209     0.000     (0)
Ca             2.383e-03
   Ca+2            1.942e-03   1.225e-03    -2.712    -2.912    -0.200     (0)
   CaSO4           3.499e-04   3.499e-04    -3.456    -3.456     0.000     (0)
   CaHCO3+         6.319e-05   5.666e-05    -4.199    -4.247    -0.047     (0)
   CaCO3           2.656e-05   2.656e-05    -4.576    -4.576     0.000     (0)
   CaF+            3.410e-07   3.047e-07    -6.467    -6.516    -0.049     (0)
   CaOH+           3.223e-08   2.890e-08    -7.492    -7.539    -0.047     (0)
   CaH2BO3+        2.040e-08   1.805e-08    -7.690    -7.743    -0.053     (0)
Cd             2.132e-08
   Cd+2            1.489e-08   9.387e-09    -7.827    -8.027    -0.200     (0)
   CdCO3           2.927e-09   2.927e-09    -8.534    -8.534     0.000     (0)
   CdSO4           2.744e-09   2.744e-09    -8.562    -8.562     0.000     (0)
   CdCl+           4.452e-10   3.895e-10    -9.351    -9.409    -0.058     (0)
   CdOH+           1.008e-10   8.817e-11    -9.997   -10.055    -0.058     (0)
   Cd(SO4)2-2      7.874e-11   4.617e-11   -10.104   -10.336    -0.232     (0)
   CdHCO3+         6.068e-11   5.309e-11   -10.217   -10.275    -0.058     (0)
   Cd(CO3)2-2      5.063e-11   2.969e-11   -10.296   -10.527    -0.232     (0)
   CdOHCl          1.890e-11   1.890e-11   -10.724   -10.724     0.000     (0)
   CdF+            3.876e-12   3.392e-12   -11.412   -11.470    -0.058     (0)
   CdCl2           7.057e-13   7.057e-13   -12.151   -12.151     0.000     (0)
   Cd(OH)2         6.579e-13   6.579e-13   -12.182   -12.182     0.000     (0)
   CdCl3-          2.211e-16   1.935e-16   -15.655   -15.713    -0.058     (0)
   CdF2            1.543e-16   1.543e-16   -15.812   -15.812     0.000     (0)
   Cd(OH)3-        5.431e-17   4.753e-17   -16.265   -16.323    -0.058     (0)
   Cd2OH+3         1.379e-17   4.148e-18   -16.860   -17.382    -0.522     (0)
   Cd(SeO3)2-2     1.066e-18   6.247e-19   -17.972   -18.204    -0.232     (0)
   CdSeO4          1.228e-19   1.228e-19   -18.911   -18.911     0.000     (0)
   Cd(OH)4-2       1.569e-23   9.199e-24   -22.804   -23.036    -0.232     (0)
   CdHS+           0.000e+00   0.000e+00   -68.479   -68.537    -0.058     (0)
   Cd(HS)2         0.000e+00   0.000e+00  -129.851  -129.851     0.000     (0)
   Cd(HS)3-        0.000e+00   0.000e+00  -196.411  -196.469    -0.058     (0)
   Cd(HS)4-2       0.000e+00   0.000e+00  -262.559  -262.791    -0.232     (0)
Cl             4.877e-04
   Cl-             4.877e-04   4.346e-04    -3.312    -3.362    -0.050     (0)
   CuCl            8.079e-10   8.079e-10    -9.093    -9.093     0.000     (0)
   ZnOHCl          5.781e-10   5.781e-10    -9.238    -9.238     0.000     (0)
   MnCl+           4.972e-10   4.443e-10    -9.303    -9.352    -0.049     (0)
   CdCl+           4.452e-10   3.895e-10    -9.351    -9.409    -0.058     (0)
   ZnCl+           4.194e-10   3.734e-10    -9.377    -9.428    -0.050     (0)
   CuCl2-          8.239e-11   7.335e-11   -10.084   -10.135    -0.050     (0)
   CoCl+           4.792e-11   4.193e-11   -10.320   -10.377    -0.058     (0)
   NiCl+           2.691e-11   2.355e-11   -10.570   -10.628    -0.058     (0)
   PbCl+           2.448e-11   2.142e-11   -10.611   -10.669    -0.058     (0)
   CdOHCl          1.890e-11   1.890e-11   -10.724   -10.724     0.000     (0)
   CuCl+           4.994e-12   4.447e-12   -11.302   -11.352    -0.050     (0)
   CdCl2           7.057e-13   7.057e-13   -12.151   -12.151     0.000     (0)
   MnCl2           2.727e-13   2.727e-13   -12.564   -12.564     0.000     (0)
   ZnCl2           2.572e-13   2.572e-13   -12.590   -12.590     0.000     (0)
   PbCl2           4.158e-14   4.158e-14   -13.381   -13.381     0.000     (0)
   CuCl3-2         1.069e-14   6.815e-15   -13.971   -14.167    -0.195     (0)
   CuCl2           6.700e-16   6.700e-16   -15.174   -15.174     0.000     (0)
   CdCl3-          2.211e-16   1.935e-16   -15.655   -15.713    -0.058     (0)
   ZnCl3-          9.970e-17   8.877e-17   -16.001   -16.052    -0.050     (0)
   NiCl2           5.152e-17   5.152e-17   -16.288   -16.288     0.000     (0)
   MnCl3-          3.653e-17   3.264e-17   -16.437   -16.486    -0.049     (0)
   PbCl3-          8.221e-18   7.193e-18   -17.085   -17.143    -0.058     (0)
   CrCl+2          7.801e-18   4.573e-18   -17.108   -17.340    -0.232     (0)
   UO2Cl+          9.138e-20   7.996e-20   -19.039   -19.097    -0.058     (0)
   CrOHCl2         4.467e-20   4.467e-20   -19.350   -19.350     0.000     (0)
   FeCl+2          3.565e-20   2.273e-20   -19.448   -19.643    -0.195     (0)
   ZnCl4-2         3.025e-20   1.929e-20   -19.519   -19.715    -0.195     (0)
   CuCl3-          3.052e-21   2.717e-21   -20.515   -20.566    -0.050     (0)
   PbCl4-2         2.437e-21   1.429e-21   -20.613   -20.845    -0.232     (0)
   CrCl2+          2.155e-22   1.886e-22   -21.667   -21.725    -0.058     (0)
   VOCl+           5.571e-23   4.875e-23   -22.254   -22.312    -0.058     (0)
   FeCl2+          4.937e-23   4.412e-23   -22.306   -22.355    -0.049     (0)
   CuCl4-2         9.280e-27   5.918e-27   -26.032   -26.228    -0.195     (0)
   FeCl3           1.917e-27   1.917e-27   -26.717   -26.717     0.000     (0)
   CrO3Cl-         2.405e-29   2.104e-29   -28.619   -28.677    -0.058     (0)
   CoCl+2          3.585e-38   2.102e-38   -37.445   -37.677    -0.232     (0)
   UCl+3           0.000e+00   0.000e+00   -46.810   -47.332    -0.522     (0)
Co(2)          6.801e-08
   Co+2            4.757e-08   2.789e-08    -7.323    -7.555    -0.232     (0)
   CoSO4           6.940e-09   6.940e-09    -8.159    -8.159     0.000     (0)
   CoCO3           6.450e-09   6.450e-09    -8.190    -8.190     0.000     (0)
   CoHCO3+         6.160e-09   5.390e-09    -8.210    -8.268    -0.058     (0)
   CoOH+           7.521e-10   6.581e-10    -9.124    -9.182    -0.058     (0)
   Co(OH)2         6.181e-11   6.181e-11   -10.209   -10.209     0.000     (0)
   CoCl+           4.792e-11   4.193e-11   -10.320   -10.377    -0.058     (0)
   CoF+            2.298e-11   2.011e-11   -10.639   -10.697    -0.058     (0)
   Co(OH)3-        1.667e-15   1.458e-15   -14.778   -14.836    -0.058     (0)
   CoOOH-          4.183e-16   3.660e-16   -15.379   -15.437    -0.058     (0)
   Co2OH+3         3.058e-18   9.199e-19   -17.514   -18.036    -0.522     (0)
   CoSeO4          9.818e-19   9.818e-19   -18.008   -18.008     0.000     (0)
   Co(OH)4-2       4.662e-22   2.733e-22   -21.331   -21.563    -0.232     (0)
   Co4(OH)4+4      3.167e-28   3.742e-29   -27.499   -28.427    -0.928     (0)
Co(3)          2.437e-30
   CoOH+2          2.437e-30   1.429e-30   -29.613   -29.845    -0.232     (0)
   Co+3            6.711e-37   2.377e-37   -36.173   -36.624    -0.451     (0)
   CoCl+2          3.585e-38   2.102e-38   -37.445   -37.677    -0.232     (0)
Cr(2)          1.548e-24
   Cr+2            1.548e-24   9.073e-25   -23.810   -24.042    -0.232     (0)
Cr(3)          5.004e-08
   Cr(OH)2+        3.459e-08   3.027e-08    -7.461    -7.519    -0.058     (0)
   Cr(OH)3         1.345e-08   1.345e-08    -7.871    -7.871     0.000     (0)
   CrO2-           8.574e-10   7.502e-10    -9.067    -9.125    -0.058     (0)
   Cr(OH)4-        7.234e-10   6.330e-10    -9.141    -9.199    -0.058     (0)
   Cr(OH)+2        3.588e-10   2.104e-10    -9.445    -9.677    -0.232     (0)
   CrOHSO4         6.226e-11   6.226e-11   -10.206   -10.206     0.000     (0)
   CrF+2           5.011e-14   2.938e-14   -13.300   -13.532    -0.232     (0)
   CrSO4+          2.706e-14   2.368e-14   -13.568   -13.626    -0.058     (0)
   Cr+3            2.704e-14   8.132e-15   -13.568   -14.090    -0.522     (0)
   CrCl+2          7.801e-18   4.573e-18   -17.108   -17.340    -0.232     (0)
   Cr2(OH)2SO4+2   2.019e-18   1.184e-18   -17.695   -17.927    -0.232     (0)
   Cr2(OH)2(SO4)2   8.770e-20   8.770e-20   -19.057   -19.057     0.000     (0)
   CrOHCl2         4.467e-20   4.467e-20   -19.350   -19.350     0.000     (0)
   CrCl2+          2.155e-22   1.886e-22   -21.667   -21.725    -0.058     (0)
Cr(6)          5.361e-17
   CrO4-2          5.205e-17   3.282e-17   -16.284   -16.484    -0.200     (0)
   HCrO4-          1.033e-18   9.041e-19   -17.986   -18.044    -0.058     (0)
   NaCrO4-         4.568e-19   3.997e-19   -18.340   -18.398    -0.058     (0)
   KCrO4-          7.009e-20   6.133e-20   -19.154   -19.212    -0.058     (0)
   H2CrO4          6.239e-27   6.239e-27   -26.205   -26.205     0.000     (0)
   CrO3SO4-2       4.988e-27   2.924e-27   -26.302   -26.534    -0.232     (0)
   CrO3Cl-         2.405e-29   2.104e-29   -28.619   -28.677    -0.058     (0)
   Cr2O7-2         4.835e-35   2.835e-35   -34.316   -34.547    -0.232     (0)
Cu(1)          2.578e-09
   Cu+             1.688e-09   1.477e-09    -8.773    -8.831    -0.058     (0)
   CuCl            8.079e-10   8.079e-10    -9.093    -9.093     0.000     (0)
   CuCl2-          8.239e-11   7.335e-11   -10.084   -10.135    -0.050     (0)
   CuCl3-2         1.069e-14   6.815e-15   -13.971   -14.167    -0.195     (0)
   Cu(S4)2-3       0.000e+00   0.000e+00  -126.056  -126.337    -0.281     (0)
   CuS4S5-3        0.000e+00   0.000e+00  -126.797  -127.067    -0.270     (0)
Cu(2)          5.989e-07
   CuCO3           5.201e-07   5.201e-07    -6.284    -6.284     0.000     (0)
   Cu(CO3)2-2      3.267e-08   1.915e-08    -7.486    -7.718    -0.232     (0)
   CuOH+           2.712e-08   2.414e-08    -7.567    -7.617    -0.050     (0)
   Cu+2            1.024e-08   6.456e-09    -7.990    -8.190    -0.200     (0)
   Cu(OH)2         5.696e-09   5.696e-09    -8.244    -8.244     0.000     (0)
   CuSO4           1.845e-09   1.845e-09    -8.734    -8.734     0.000     (0)
   CuHCO3+         1.157e-09   1.012e-09    -8.937    -8.995    -0.058     (0)
   Cu2(OH)2+2      2.497e-11   1.464e-11   -10.603   -10.834    -0.232     (0)
   Cu(OH)3-        1.579e-11   1.382e-11   -10.802   -10.860    -0.058     (0)
   CuF+            1.061e-11   9.287e-12   -10.974   -11.032    -0.058     (0)
   CuCl+           4.994e-12   4.447e-12   -11.302   -11.352    -0.050     (0)
   CuCl2           6.700e-16   6.700e-16   -15.174   -15.174     0.000     (0)
   Cu(OH)4-2       2.193e-16   1.286e-16   -15.659   -15.891    -0.232     (0)
   CuCl3-          3.052e-21   2.717e-21   -20.515   -20.566    -0.050     (0)
   CuCl4-2         9.280e-27   5.918e-27   -26.032   -26.228    -0.195     (0)
   Cu(HS)3-        0.000e+00   0.000e+00  -187.787  -187.845    -0.058     (0)
F              2.747e-05
   F-              2.558e-05   2.280e-05    -4.592    -4.642    -0.050     (0)
   MgF+            1.512e-06   1.349e-06    -5.820    -5.870    -0.050     (0)
   CaF+            3.410e-07   3.047e-07    -6.467    -6.516    -0.049     (0)
   NaF             3.526e-08   3.526e-08    -7.453    -7.453     0.000     (0)
   MnF+            8.248e-10   7.371e-10    -9.084    -9.133    -0.049     (0)
   HF              2.871e-10   2.871e-10    -9.542    -9.542     0.000     (0)
   ZnF+            1.778e-10   1.556e-10    -9.750    -9.808    -0.058     (0)
   BF(OH)3-        3.859e-11   3.416e-11   -10.413   -10.466    -0.053     (0)
   CoF+            2.298e-11   2.011e-11   -10.639   -10.697    -0.058     (0)
   NiF+            1.386e-11   1.213e-11   -10.858   -10.916    -0.058     (0)
   CuF+            1.061e-11   9.287e-12   -10.974   -11.032    -0.058     (0)
   CdF+            3.876e-12   3.392e-12   -11.412   -11.470    -0.058     (0)
   PbF+            2.551e-12   2.232e-12   -11.593   -11.651    -0.058     (0)
   AlF2+           1.670e-12   1.495e-12   -11.777   -11.825    -0.048     (0)
   AlF3            4.290e-13   4.290e-13   -12.368   -12.368     0.000     (0)
   AlF+2           2.569e-13   1.647e-13   -12.590   -12.783    -0.193     (0)
   CrF+2           5.011e-14   2.938e-14   -13.300   -13.532    -0.232     (0)
   HF2-            2.800e-14   2.488e-14   -13.553   -13.604    -0.051     (0)
   AlF4-           5.495e-15   4.902e-15   -14.260   -14.310    -0.050     (0)
   PbF2            1.001e-15   1.001e-15   -14.999   -14.999     0.000     (0)
   BF2(OH)2-       8.009e-16   7.089e-16   -15.096   -15.149    -0.053     (0)
   UO2F+           4.080e-16   3.570e-16   -15.389   -15.447    -0.058     (0)
   CdF2            1.543e-16   1.543e-16   -15.812   -15.812     0.000     (0)
   FeF+2           6.790e-17   4.330e-17   -16.168   -16.364    -0.195     (0)
   FeF2+           2.956e-17   2.641e-17   -16.529   -16.578    -0.049     (0)
   UO2F2           2.347e-17   2.347e-17   -16.629   -16.629     0.000     (0)
   FeF3            8.496e-19   8.496e-19   -18.071   -18.071     0.000     (0)
   VO2F            5.904e-19   5.904e-19   -18.229   -18.229     0.000     (0)
   H2F2            2.208e-19   2.208e-19   -18.656   -18.656     0.000     (0)
   UO2F3-          1.536e-19   1.344e-19   -18.814   -18.872    -0.058     (0)
   PbF3-           4.948e-20   4.330e-20   -19.306   -19.364    -0.058     (0)
   VOF+            6.248e-21   5.467e-21   -20.204   -20.262    -0.058     (0)
   VO2F2-          5.584e-21   4.887e-21   -20.253   -20.311    -0.058     (0)
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BF3OH-	6.049e-23	5.354e-23	-22.218	-22.271	-0.053	(0)
VOF2	4.674e-23	4.674e-23	-22.330	-22.330	0.000	(0)
UO2F4-2	4.152e-23	2.434e-23	-22.382	-22.614	-0.232	(0)
VO2F3-2	2.370e-24	1.390e-24	-23.625	-23.857	-0.232	(0)
PbF4-2	8.058e-25	4.724e-25	-24.094	-24.326	-0.232	(0)
VOF3-	4.320e-26	3.780e-26	-25.364	-25.422	-0.058	(0)
BF4-	5.777e-29	5.113e-29	-28.238	-28.291	-0.053	(0)
VO2F4-3	5.182e-29	1.559e-29	-28.285	-28.807	-0.522	(0)
VOF4-2	5.933e-30	3.479e-30	-29.227	-29.459	-0.232	(0)
UF3+	1.153e-38	1.009e-38	-37.938	-37.996	-0.058	(0)
UF2+2	4.762e-39	2.792e-39	-38.322	-38.554	-0.232	(0)
UF+3	0.000e+00	0.000e+00	-40.490	-41.012	-0.522	(0)
UF4	0.000e+00	0.000e+00	-40.598	-40.598	0.000	(0)
UF5-	0.000e+00	0.000e+00	-43.585	-43.642	-0.058	(0)
UF6-2	0.000e+00	0.000e+00	-45.573	-45.805	-0.232	(0)
Fe(2)	1.828e-08					
Fe+2	1.485e-08	8.708e-09	-7.828	-8.060	-0.232	(0)
FeSO4	2.666e-09	2.666e-09	-8.574	-8.574	0.000	(0)
FeOH+	4.588e-10	4.100e-10	-9.338	-9.387	-0.049	(0)
FeHCO3+	3.038e-10	2.724e-10	-9.517	-9.565	-0.047	(0)
Fe(OH)2	3.851e-13	3.851e-13	-12.414	-12.414	0.000	(0)
Fe(OH)3-	1.611e-13	1.440e-13	-12.793	-12.842	-0.049	(0)
Fe(HS)2	0.000e+00	0.000e+00	-136.146	-136.146	0.000	(0)
Fe(HS)3-	0.000e+00	0.000e+00	-202.569	-202.627	-0.058	(0)
Fe(3)	1.548e-06					
Fe(OH)3	7.727e-07	7.727e-07	-6.112	-6.112	0.000	(0)
Fe(OH)2+	6.799e-07	6.084e-07	-6.168	-6.216	-0.048	(0)
Fe(OH)4-	9.507e-08	8.508e-08	-7.022	-7.070	-0.048	(0)
FeOH+2	2.074e-12	1.322e-12	-11.683	-11.879	-0.195	(0)
FeF+2	6.790e-17	4.330e-17	-16.168	-16.364	-0.195	(0)
FeF2+	2.956e-17	2.641e-17	-16.529	-16.578	-0.049	(0)
FeSO4+	2.712e-17	2.424e-17	-16.567	-16.616	-0.049	(0)
Fe+3	4.890e-18	1.732e-18	-17.311	-17.761	-0.451	(0)
FeF3	8.496e-19	8.496e-19	-18.071	-18.071	0.000	(0)
Fe(SO4)2-	7.385e-19	6.462e-19	-18.132	-18.190	-0.058	(0)
FeCl+2	3.565e-20	2.273e-20	-19.448	-19.643	-0.195	(0)
Fe2(OH)2+4	4.901e-22	5.791e-23	-21.310	-22.237	-0.928	(0)
FeHSeO3+2	1.500e-22	8.795e-23	-21.824	-22.056	-0.232	(0)
FeCl2+	4.937e-23	4.412e-23	-22.306	-22.355	-0.049	(0)
Fe3(OH)4+5	1.433e-26	5.093e-28	-25.844	-27.293	-1.449	(0)
FeCl3	1.917e-27	1.917e-27	-26.717	-26.717	0.000	(0)
H(0)	2.232e-26					
H2	1.116e-26	1.119e-26	-25.952	-25.951	0.001	(0)
K	5.694e-04					
K+	5.644e-04	5.030e-04	-3.248	-3.298	-0.050	(0)
KSO4-	4.962e-06	4.441e-06	-5.304	-5.353	-0.048	(0)
KCrO4-	7.009e-20	6.133e-20	-19.154	-19.212	-0.058	(0)
Mg	9.788e-04					
Mg+2	8.363e-04	5.273e-04	-3.078	-3.278	-0.200	(0)
MgSO4	1.197e-04	1.197e-04	-3.922	-3.922	0.000	(0)
MgHCO3+	1.506e-05	1.340e-05	-4.822	-4.873	-0.050	(0)
MgCO3	6.000e-06	6.000e-06	-5.222	-5.222	0.000	(0)
MgF+	1.512e-06	1.349e-06	-5.820	-5.870	-0.050	(0)
MgOH+	2.764e-07	2.482e-07	-6.558	-6.605	-0.047	(0)
MgH2BO3+	5.292e-09	4.683e-09	-8.276	-8.329	-0.053	(0)
Mn(2)	1.614e-06					
Mn+2	1.385e-06	8.121e-07	-5.858	-6.090	-0.232	(0)
MnSO4	1.801e-07	1.801e-07	-6.744	-6.744	0.000	(0)
MnHCO3+	4.505e-08	4.026e-08	-7.346	-7.395	-0.049	(0)
MnOH+	2.700e-09	2.412e-09	-8.569	-8.618	-0.049	(0)
MnF+	8.248e-10	7.371e-10	-9.084	-9.133	-0.049	(0)
MnCl+	4.972e-10	4.443e-10	-9.303	-9.352	-0.049	(0)
MnCl2	2.727e-13	2.727e-13	-12.564	-12.564	0.000	(0)
MnCl3-	3.653e-17	3.264e-17	-16.437	-16.486	-0.049	(0)
Mn(OH)3-	2.333e-17	2.085e-17	-16.632	-16.681	-0.049	(0)
MnSeO4	1.535e-17	1.535e-17	-16.814	-16.814	0.000	(0)
Mn(OH)4-2	1.248e-22	7.959e-23	-21.904	-22.099	-0.195	(0)
MnSe	2.164e-35	2.164e-35	-34.665	-34.665	0.000	(0)
Mn(3)	2.193e-28					
Mn+3	2.193e-28	7.767e-29	-27.659	-28.110	-0.451	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-46.436	-46.631	-0.195	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-52.620	-52.672	-0.052	(0)
Mo	5.599e-08					
MoO4-2	5.598e-08	3.530e-08	-7.252	-7.452	-0.200	(0)
HMoO4-	6.833e-12	5.979e-12	-11.165	-11.223	-0.058	(0)
H2MoO4	3.728e-16	3.728e-16	-15.428	-15.428	0.000	(0)
AlMo6O21-3	0.000e+00	0.000e+00	-52.760	-53.281	-0.522	(0)
Mo7O24-6	0.000e+00	0.000e+00	-61.648	-63.735	-2.087	(0)
HMo7O24-5	0.000e+00	0.000e+00	-63.969	-65.418	-1.449	(0)
H2Mo7O24-4	0.000e+00	0.000e+00	-67.778	-68.706	-0.928	(0)
H3Mo7O24-3	0.000e+00	0.000e+00	-73.008	-73.529	-0.522	(0)
Na	2.773e-03					
Na+	2.751e-03	2.451e-03	-2.561	-2.611	-0.050	(0)
NaSO4-	1.834e-05	1.642e-05	-4.736	-4.785	-0.048	(0)
NaHCO3	3.424e-06	3.424e-06	-5.465	-5.465	0.000	(0)
NaCO3-	6.978e-07	6.244e-07	-6.156	-6.205	-0.048	(0)
NaF	3.526e-08	3.526e-08	-7.453	-7.453	0.000	(0)
NaH2BO3	9.952e-10	9.952e-10	-9.002	-9.002	0.000	(0)
NaCrO4-	4.568e-19	3.997e-19	-18.340	-18.398	-0.058	(0)
Ni	5.751e-08					
Ni+2	3.359e-08	2.118e-08	-7.474	-7.674	-0.200	(0)
NiCO3	1.081e-08	1.081e-08	-7.966	-7.966	0.000	(0)
NiHCO3+	7.413e-09	6.487e-09	-8.130	-8.188	-0.058	(0)
NiSO4	5.270e-09	5.270e-09	-8.278	-8.278	0.000	(0)
NiOH+	3.603e-10	3.153e-10	-9.443	-9.501	-0.058	(0)
Ni(OH)2	2.962e-11	2.962e-11	-10.528	-10.528	0.000	(0)
NiCl+	2.691e-11	2.355e-11	-10.570	-10.628	-0.058	(0)
NiF+	1.386e-11	1.213e-11	-10.858	-10.916	-0.058	(0)
Ni(SO4)2-2	3.712e-13	2.176e-13	-12.430	-12.662	-0.232	(0)
Ni(OH)3-	4.002e-14	3.502e-14	-13.398	-13.456	-0.058	(0)
NiCl2	5.152e-17	5.152e-17	-16.288	-16.288	0.000	(0)
NiSeO4	6.958e-19	6.958e-19	-18.158	-18.158	0.000	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-40.394	-40.393	0.001	(0)
Pb	7.188e-08					
PbCO3	5.714e-08	5.714e-08	-7.243	-7.243	0.000	(0)
PbOH+	4.716e-09	4.127e-09	-8.326	-8.384	-0.058	(0)
Pb(CO3)2-2	3.845e-09	2.254e-09	-8.415	-8.647	-0.232	(0)
PbHCO3+	2.931e-09	2.565e-09	-8.533	-8.591	-0.058	(0)
Pb+2	2.204e-09	1.389e-09	-8.657	-8.857	-0.200	(0)
PbSO4	8.486e-10	8.486e-10	-9.071	-9.071	0.000	(0)
Pb(OH)2	1.543e-10	1.543e-10	-9.812	-9.812	0.000	(0)
PbCl+	2.448e-11	2.142e-11	-10.611	-10.669	-0.058	(0)
Pb(SO4)2-2	1.088e-11	6.377e-12	-10.963	-11.195	-0.232	(0)
PbF+	2.551e-12	2.232e-12	-11.593	-11.651	-0.058	(0)
Pb(OH)3-	2.085e-13	1.825e-13	-12.681	-12.739	-0.058	(0)
PbCl2	4.158e-14	4.158e-14	-13.381	-13.381	0.000	(0)
PbF2	1.001e-15	1.001e-15	-14.999	-14.999	0.000	(0)
Pb2OH+3	3.021e-16	9.087e-17	-15.520	-16.042	-0.522	(0)
Pb(OH)4-2	9.014e-17	5.285e-17	-16.045	-16.277	-0.232	(0)
PbCl3-	8.221e-18	7.193e-18	-17.085	-17.143	-0.058	(0)
Pb3(OH)4+2	1.126e-18	6.602e-19	-17.948	-18.180	-0.232	(0)
PbF3-	4.948e-20	4.330e-20	-19.306	-19.364	-0.058	(0)
PbCl4-2	2.437e-21	1.429e-21	-20.613	-20.845	-0.232	(0)
Pb4(OH)4+4	6.167e-23	7.286e-24	-22.210	-23.138	-0.928	(0)
PbF4-2	8.058e-25	4.724e-25	-24.094	-24.326	-0.232	(0)
Pb(HS)2	0.000e+00	0.000e+00	-130.623	-130.623	0.000	(0)
Pb(HS)3-	0.000e+00	0.000e+00	-197.783	-197.841	-0.058	(0)
S(-2)	0.000e+00					
HS-	0.000e+00	0.000e+00	-68.460	-68.518	-0.058	(0)
CdHS+	0.000e+00	0.000e+00	-68.479	-68.537	-0.058	(0)
H2S	0.000e+00	0.000e+00	-69.568	-69.568	0.000	(0)
S5-2	0.000e+00	0.000e+00	-69.581	-69.813	-0.232	(0)
S6-2	0.000e+00	0.000e+00	-70.097	-70.329	-0.232	(0)
S4-2	0.000e+00	0.000e+00	-70.177	-70.409	-0.232	(0)
S3-2	0.000e+00	0.000e+00	-70.983	-71.215	-0.232	(0)
S2-2	0.000e+00	0.000e+00	-71.999	-72.231	-0.232	(0)
S-2	0.000e+00	0.000e+00	-77.553	-77.748	-0.195	(0)
Cu(S4)2-3	0.000e+00	0.000e+00	-126.056	-126.337	-0.281	(0)
CuS4S5-3	0.000e+00	0.000e+00	-126.797	-127.067	-0.270	(0)
ZnS(HS)-	0.000e+00	0.000e+00	-128.564	-128.622	-0.058	(0)
Cd(HS)2	0.000e+00	0.000e+00	-129.851	-129.851	0.000	(0)
Pb(HS)2	0.000e+00	0.000e+00	-130.623	-130.623	0.000	(0)
Zn(HS)2	0.000e+00	0.000e+00	-130.682	-130.682	0.000	(0)
Fe(HS)2	0.000e+00	0.000e+00	-136.146	-136.146	0.000	(0)
Cu(HS)3-	0.000e+00	0.000e+00	-187.787	-187.845	-0.058	(0)
Zn(HS)3-	0.000e+00	0.000e+00	-195.862	-195.920	-0.058	(0)
Cd(HS)3-	0.000e+00	0.000e+00	-196.411	-196.469	-0.058	(0)
ZnS(HS)2-2	0.000e+00	0.000e+00	-197.598	-197.830	-0.232	(0)
Pb(HS)3-	0.000e+00	0.000e+00	-197.783	-197.841	-0.058	(0)
Fe(HS)3-	0.000e+00	0.000e+00	-202.569	-202.627	-0.058	(0)
Cd(HS)4-2	0.000e+00	0.000e+00	-262.559	-262.791	-0.232	(0)
Zn(HS)4-2	0.000e+00	0.000e+00	-265.666	-265.897	-0.232	(0)
S(6)	2.471e-03					
SO4-2	1.978e-03	1.247e-03	-2.704	-2.904	-0.200	(0)
CaSO4	3.499e-04	3.499e-04	-3.456	-3.456	0.000	(0)
MgSO4	1.197e-04	1.197e-04	-3.922	-3.922	0.000	(0)
NaSO4-	1.834e-05	1.642e-05	-4.736	-4.785	-0.048	(0)
KSO4-	4.962e-06	4.441e-06	-5.304	-5.353	-0.048	(0)
MnSO4	1.801e-07	1.801e-07	-6.744	-6.744	0.000	(0)
ZnSO4	9.333e-08	9.333e-08	-7.030	-7.030	0.000	(0)
CoSO4	6.940e-09	6.940e-09	-8.159	-8.159	0.000	(0)
NiSO4	5.270e-09	5.270e-09	-8.278	-8.278	0.000	(0)
CdSO4	2.744e-09	2.744e-09	-8.562	-8.562	0.000	(0)
FeSO4	2.666e-09	2.666e-09	-8.574	-8.574	0.000	(0)
CuSO4	1.845e-09	1.845e-09	-8.734	-8.734	0.000	(0)
Zn(SO4)2-2	1.729e-09	1.014e-09	-8.762	-8.994	-0.232	(0)
HSO4-	1.163e-09	1.038e-09	-8.934	-8.984	-0.050	(0)
PbSO4	8.486e-10	8.486e-10	-9.071	-9.071	0.000	(0)
Cd(SO4)2-2	7.874e-11	4.617e-11	-10.104	-10.336	-0.232	(0)
CrOHSO4	6.226e-11	6.226e-11	-10.206	-10.206	0.000	(0)
Pb(SO4)2-2	1.088e-11	6.377e-12	-10.963	-11.195	-0.232	(0)
Ni(SO4)2-2	3.712e-13	2.176e-13	-12.430	-12.662	-0.232	(0)
CrSO4+	2.706e-14	2.368e-14	-13.568	-13.626	-0.058	(0)
AlSO4+	7.841e-15	6.994e-15	-14.106	-14.155	-0.050	(0)
UO2SO4	2.142e-16	2.142e-16	-15.669	-15.669	0.000	(0)
Al(SO4)2-	1.048e-16	9.347e-17	-15.980	-16.029	-0.050	(0)
FeSO4+	2.712e-17	2.424e-17	-16.567	-16.616	-0.049	(0)
UO2(SO4)2-2	6.005e-18	3.521e-18	-17.221	-17.453	-0.232	(0)
Cr2(OH)2SO4+2	2.019e-18	1.184e-18	-17.695	-17.927	-0.232	(0)
Fe(SO4)2-	7.385e-19	6.462e-19	-18.132	-18.190	-0.058	(0)
VO2SO4-	5.025e-19	4.397e-19	-18.299	-18.357	-0.058	(0)
Cr2(OH)2(SO4)2	8.770e-20	8.770e-20	-19.057	-19.057	0.000	(0)
VOSO4	1.373e-20	1.373e-20	-19.862	-19.862	0.000	(0)
CrO3SO4-2	4.988e-27	2.924e-27	-26.302	-26.534	-0.232	(0)
VSO4+	4.523e-34	3.958e-34	-33.345	-33.403	-0.058	(0)
U(SO4)2	0.000e+00	0.000e+00	-40.978	-40.978	0.000	(0)
USO4+2	0.000e+00	0.000e+00	-41.742	-41.974	-0.232	(0)
Se(-2)	6.294e-32					
HSe-	6.291e-32	5.505e-32	-31.201	-31.259	-0.058	(0)
MnSe	2.164e-35	2.164e-35	-34.665	-34.665	0.000	(0)
H2Se	3.638e-36	3.638e-36	-35.439	-35.439	0.000	(0)
Se-2	1.103e-38	6.466e-39	-37.957	-38.189	-0.232	(0)
Se(4)	3.729e-08					
HSeO3-	2.196e-08	1.922e-08	-7.658	-7.716	-0.058	(0)
SeO3-2	1.533e-08	8.986e-09	-7.815	-8.046	-0.232	(0)
H2SeO3	6.979e-14	6.979e-14	-13.156	-13.156	0.000	(0)
Cd(SeO3)2-2	1.066e-18	6.247e-19	-17.972	-18.204	-0.232	(0)
FeHSeO3+2	1.500e-22	8.795e-23	-21.824	-22.056	-0.232	(0)
Se(6)	1.114e-13					
SeO4-2	1.114e-13	7.023e-14	-12.953	-13.153	-0.200	(0)
MnSeO4	1.535e-17	1.535e-17	-16.814	-16.814	0.000	(0)
ZnSeO4	3.721e-18	3.721e-18	-17.429	-17.429	0.000	(0)
CoSeO4	9.818e-19	9.818e-19	-18.008	-18.008	0.000	(0)
NiSeO4	6.958e-19	6.958e-19	-18.158	-18.158	0.000	(0)
CdSeO4	1.228e-19	1.228e-19	-18.911	-18.911	0.000	(0)
HSeO4-	3.425e-20	2.997e-20	-19.465	-19.523	-0.058	(0)
Zn(SeO4)2-2	4.520e-31	2.650e-31	-30.345	-30.577	-0.232	(0)
U(3)	0.000e+00					
U+3	0.000e+00	0.000e+00	-57.275	-57.796	-0.522	(0)
U(4)	4.143e-19					
U(OH)5-	4.141e-19	3.624e-19	-18.383	-18.441	-0.058	(0)
U(OH)4	1.292e-22	1.292e-22	-21.889	-21.889	0.000	(0)
U(OH)3+	4.598e-27	4.023e-27	-26.337	-26.395	-0.058	(0)
U(OH)2+2	2.702e-32	1.584e-32	-31.568	-31.800	-0.232	(0)
UOH+3	2.112e-38	6.353e-39	-37.675	-38.197	-0.522	(0)
UF3+	1.153e-38	1.009e-38	-37.938	-37.996	-0.058	(0)
UF2+2	4.762e-39	2.792e-39	-38.322	-38.554	-0.232	(0)
UF+3	0.000e+00	0.000e+00	-40.490	-41.012	-0.522	(0)
UF4	0.000e+00	0.000e+00	-40.598	-40.598	0.000	(0)
U(SO4)2	0.000e+00	0.000e+00	-40.978	-40.978	0.000	(0)
USO4+2	0.000e+00	0.000e+00	-41.742	-41.974	-0.232	(0)
UF5-	0.000e+00	0.000e+00	-43.585	-43.642	-0.058	(0)
U+4	0.000e+00	0.000e+00	-44.742	-45.670	-0.928	(0)
UF6-2	0.000e+00	0.000e+00	-45.573	-45.805	-0.232	(0)
UCl+3	0.000e+00	0.000e+00	-46.810	-47.332	-0.522	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-165.431	-170.127	-4.696	(0)
U(5)	3.691e-17					
UO2+	3.691e-17	3.230e-17	-16.433	-16.491	-0.058	(0)
U(6)	1.267e-08					
UO2(CO3)3-4	9.789e-09	1.157e-09	-8.009	-8.937	-0.928	(0)
UO2(CO3)2-2	2.877e-09	1.687e-09	-8.541	-8.773	-0.232	(0)
UO2CO3	6.179e-12	6.179e-12	-11.209	-11.209	0.000	(0)
UO2OH+	1.930e-14	1.689e-14	-13.714	-13.772	-0.058	(0)
UO2F+	4.080e-16	3.570e-16	-15.389	-15.447	-0.058	(0)
UO2SO4	2.142e-16	2.142e-16	-15.669	-15.669	0.000	(0)
UO2+2	1.799e-16	1.135e-16	-15.745	-15.945	-0.200	(0)
UO2F2	2.347e-17	2.347e-17	-16.629	-16.629	0.000	(0)
UO2(SO4)2-2	6.005e-18	3.521e-18	-17.221	-17.453	-0.232	(0)
UO2F3-	1.536e-19	1.344e-19	-18.814	-18.872	-0.058	(0)
UO2Cl+	9.138e-20	7.996e-20	-19.039	-19.097	-0.058	(0)
(UO2)2(OH)2+2	8.075e-22	4.734e-22	-21.093	-21.325	-0.232	(0)
UO2F4-2	4.152e-23	2.434e-23	-22.382	-22.614	-0.232	(0)
(UO2)3(OH)5+	9.694e-24	8.482e-24	-23.014	-23.071	-0.058	(0)
V(2)	6.725e-40					
VOH+	6.725e-40	5.885e-40	-39.172	-39.230	-0.058	(0)
V+2	0.000e+00	0.000e+00	-40.581	-40.813	-0.232	(0)
V(3)	8.968e-13					
V(OH)3	8.968e-13	8.968e-13	-12.047	-12.047	0.000	(0)
V(OH)2+	5.638e-24	4.934e-24	-23.249	-23.307	-0.058	(0)
VOH+2	6.796e-28	3.985e-28	-27.168	-27.400	-0.232	(0)
V+3	2.235e-33	6.723e-34	-32.651	-33.172	-0.522	(0)
VSO4+	4.523e-34	3.958e-34	-33.345	-33.403	-0.058	(0)
V2(OH)3+3	0.000e+00	0.000e+00	-51.733	-52.255	-0.522	(0)
V2(OH)2+4	0.000e+00	0.000e+00	-53.072	-53.999	-0.928	(0)
V(4)	1.087e-17					
V(OH)3+	1.078e-17	9.433e-18	-16.967	-17.025	-0.058	(0)
VO+2	6.820e-20	3.999e-20	-19.166	-19.398	-0.232	(0)
VOSO4	1.373e-20	1.373e-20	-19.862	-19.862	0.000	(0)
VOF+	6.248e-21	5.467e-21	-20.204	-20.262	-0.058	(0)
VOCl+	5.571e-23	4.875e-23	-22.254	-22.312	-0.058	(0)
VOF2	4.674e-23	4.674e-23	-22.330	-22.330	0.000	(0)

VOF3-	4.320e-26	3.780e-26	-25.364	-25.422	-0.058	(0)
H2V2O4+2	7.609e-30	4.461e-30	-29.119	-29.351	-0.232	(0)
VOF4-2	5.933e-30	3.479e-30	-29.227	-29.459	-0.232	(0)
V(5)	1.680e-08					
H2VO4-	1.166e-08	1.021e-08	-7.933	-7.991	-0.058	(0)
HVO4-2	5.136e-09	3.011e-09	-8.289	-8.521	-0.232	(0)
H3VO4	8.689e-13	8.689e-13	-12.061	-12.061	0.000	(0)
H3V2O7-	6.545e-14	5.727e-14	-13.184	-13.242	-0.058	(0)
HV2O7-3	3.463e-14	1.042e-14	-13.461	-13.982	-0.522	(0)
VO4-3	5.894e-15	1.773e-15	-14.230	-14.751	-0.522	(0)
V2O7-4	2.787e-16	3.293e-17	-15.555	-16.482	-0.928	(0)
VO2+	1.657e-17	1.477e-17	-16.781	-16.831	-0.050	(0)
V3O9-3	3.704e-18	1.114e-18	-17.431	-17.953	-0.522	(0)
VO2F	5.904e-19	5.904e-19	-18.229	-18.229	0.000	(0)
VO2SO4-	5.025e-19	4.397e-19	-18.299	-18.357	-0.058	(0)
VO2F2-	5.584e-21	4.887e-21	-20.253	-20.311	-0.058	(0)
V4O12-4	4.012e-23	4.741e-24	-22.397	-23.324	-0.928	(0)
VO2F3-2	2.370e-24	1.390e-24	-23.625	-23.857	-0.232	(0)
VO2F4-3	5.182e-29	1.559e-29	-28.285	-28.807	-0.522	(0)
V10O28-6	0.000e+00	0.000e+00	-61.197	-63.284	-2.087	(0)
HV10O28-5	0.000e+00	0.000e+00	-61.718	-63.167	-1.449	(0)
H2V10O28-4	0.000e+00	0.000e+00	-65.102	-66.030	-0.928	(0)
Zn	9.927e-07					
Zn+2	5.426e-07	3.421e-07	-6.266	-6.466	-0.200	(0)
ZnCO3	2.693e-07	2.693e-07	-6.570	-6.570	0.000	(0)
ZnSO4	9.333e-08	9.333e-08	-7.030	-7.030	0.000	(0)
ZnOH+	4.623e-08	4.045e-08	-7.335	-7.393	-0.058	(0)
ZnHCO3+	3.071e-08	2.688e-08	-7.513	-7.571	-0.058	(0)
Zn(OH)2	7.581e-09	7.581e-09	-8.120	-8.120	0.000	(0)
Zn(SO4)2-2	1.729e-09	1.014e-09	-8.762	-8.994	-0.232	(0)
ZnOHCl	5.781e-10	5.781e-10	-9.238	-9.238	0.000	(0)
ZnCl+	4.194e-10	3.734e-10	-9.377	-9.428	-0.050	(0)
ZnF+	1.778e-10	1.556e-10	-9.750	-9.808	-0.058	(0)
Zn(OH)3-	5.135e-11	4.493e-11	-10.289	-10.347	-0.058	(0)
ZnCl2	2.572e-13	2.572e-13	-12.590	-12.590	0.000	(0)
Zn(OH)4-2	3.608e-15	2.115e-15	-14.443	-14.675	-0.232	(0)
ZnCl3-	9.970e-17	8.877e-17	-16.001	-16.052	-0.050	(0)
ZnSeO4	3.721e-18	3.721e-18	-17.429	-17.429	0.000	(0)
ZnCl4-2	3.025e-20	1.929e-20	-19.519	-19.715	-0.195	(0)
Zn(SeO4)2-2	4.520e-31	2.650e-31	-30.345	-30.577	-0.232	(0)
ZnS(HS)-	0.000e+00	0.000e+00	-128.564	-128.622	-0.058	(0)
Zn(HS)2	0.000e+00	0.000e+00	-130.682	-130.682	0.000	(0)
Zn(HS)3-	0.000e+00	0.000e+00	-195.862	-195.920	-0.058	(0)
ZnS(HS)2-2	0.000e+00	0.000e+00	-197.598	-197.830	-0.232	(0)
Zn(HS)4-2	0.000e+00	0.000e+00	-265.666	-265.897	-0.232	(0)

----------Saturation indices----------

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(am)	-1.73	9.07	10.80	Al(OH)3
Al2(MoO4)3	-55.01	-52.64	2.37	Al2(MoO4)3
Al2O3	-1.52	18.14	19.65	Al2O3
Al4(OH)10SO4	-5.47	17.23	22.70	Al4(OH)10SO4
AlAsO4:2H2O	-9.72	-4.92	4.80	AlAsO4:2H2O
AlOHSO4	-6.75	-9.98	-3.23	AlOHSO4
Alunite	-4.71	-6.11	-1.40	KAl3(SO4)2(OH)6
Anglesite	-3.97	-11.76	-7.79	PbSO4
Anhydrite	-1.46	-5.82	-4.36	CaSO4
Anilite	-43.86	-75.74	-31.88	Cu0.25Cu1.5S
Antlerite	-3.98	4.81	8.79	Cu3(OH)4SO4
Aragonite	0.52	-7.78	-8.30	CaCO3
Arsenolite	-68.82	-71.58	-2.76	As4O6
Artinite	-4.88	4.72	9.60	MgCO3:Mg(OH)2:3H2O
As2O5	-34.69	-27.98	6.71	As2O5
Atacamite	-2.92	4.47	7.39	Cu2(OH)3Cl
Azurite	-1.25	-18.16	-16.91	Cu3(OH)2(CO3)2
Ba(OH)2:8H2O	-14.73	9.66	24.39	Ba(OH)2:8H2O
Ba2V2O7:2H2O	-14.06	1.81	15.87	Ba2V2O7:2H2O
Ba3(AsO4)2	9.92	1.01	-8.91	Ba3(AsO4)2
Ba3(VO4)2:4H2O	-21.46	11.48	32.94	Ba3(VO4)2:4H2O
BaCrO4	-13.29	-22.96	-9.67	BaCrO4
BaF2	-9.94	-15.76	-5.82	BaF2
BaMoO4	-6.97	-13.93	-6.96	BaMoO4
Barite	0.60	-9.38	-9.98	BaSO4
BaS	-83.10	-66.92	16.18	BaS
BaSeO3	-7.95	-6.12	1.83	BaSeO3
BaSeO4	-12.17	-19.63	-7.46	BaSeO4
Bianchite	-7.61	-9.37	-1.76	ZnSO4:6H2O
Birnessite	-10.59	7.50	18.09	MnO2
Bixbyite	-7.16	-7.80	-0.64	Mn2O3
BlaubleiI	-45.42	-69.59	-24.16	Cu0.9Cu0.2S
BlaubleiII	-45.15	-72.43	-27.28	Cu0.6Cu0.8S
Boehmite	0.49	9.07	8.58	AlOOH
Brochantite	-2.47	12.75	15.22	Cu4(OH)6SO4
Brucite	-3.98	12.86	16.84	Mg(OH)2
Bunsenite	-3.98	8.47	12.45	NiO
Ca(VO3)2	-9.95	-4.29	5.66	Ca(VO3)2
Ca2V2O7	-8.57	8.93	17.50	Ca2V2O7
Ca2V2O7:2H2O	-12.62	8.93	21.55	Ca2V2O7:2H2O
Ca3(AsO4)2:4H2O	-10.60	11.70	22.30	Ca3(AsO4)2:4H2O
Ca3(VO4)2	-16.80	22.16	38.96	Ca3(VO4)2
Ca3(VO4)2:4H2O	-17.70	22.16	39.86	Ca3(VO4)2:4H2O
CaCrO4	-17.13	-19.40	-2.27	CaCrO4
Calcite	0.70	-7.78	-8.48	CaCO3
CaMoO4	-2.41	-10.36	-7.95	CaMoO4
Carnotite	-4.02	-3.79	0.23	KUO2VO4
CaSeO3:2H2O	-5.37	-2.56	2.81	CaSeO3:2H2O
CaSeO4:2H2O	-13.05	-16.07	-3.02	CaSeO4:2H2O
Cd(BO2)2	-12.58	-2.74	9.84	Cd(BO2)2
Cd(OH)2	-5.53	8.11	13.64	Cd(OH)2
Cd(OH)2(am)	-5.62	8.11	13.73	Cd(OH)2
Cd3(OH)2(SO4)2	-20.46	-13.75	6.71	Cd3(OH)2(SO4)2
Cd3(OH)4SO4	-17.27	5.29	22.56	Cd3(OH)4SO4
Cd4(OH)6SO4	-15.00	13.40	28.40	Cd4(OH)6SO4
CdCl2	-14.09	-14.75	-0.66	CdCl2
CdCl2:1H2O	-13.06	-14.75	-1.69	CdCl2:1H2O
CdCl2:2.5H2O	-12.84	-14.75	-1.91	CdCl2:2.5H2O
CdF2	-16.10	-17.31	-1.21	CdF2
Cdmetal(alpha)	-28.20	-14.69	13.51	Cd
Cdmetal(gamma)	-28.31	-14.69	13.62	Cd
CdMoO4	-1.33	-15.48	-14.15	CdMoO4
CdOHCl	-6.86	-3.32	3.54	CdOHCl
CdSe	-11.02	-31.22	-20.20	CdSe
CdSeO4:2H2O	-19.33	-21.18	-1.85	CdSeO4:2H2O
CdSO4	-10.76	-10.93	-0.17	CdSO4
CdSO4:1H2O	-9.21	-10.93	-1.73	CdSO4:1H2O
CdSO4:2.67H2O	-9.06	-10.93	-1.87	CdSO4:2.67H2O
Cerussite	-0.59	-13.72	-13.13	PbCO3
CH4(g)	-71.16	-112.21	-41.05	CH4
Chalcanthite	-8.45	-11.09	-2.64	CuSO4:5H2O
Chalcocite	-43.19	-78.11	-34.92	Cu2S
Chalcopyrite	-101.88	-137.15	-35.27	CuFeS2
Claudetite	-68.52	-71.58	-3.06	As4O6
Clausthalite	-4.95	-32.05	-27.10	PbSe
Co(BO2)2	-29.34	-2.27	27.07	Co(BO2)2
Co(OH)2	-4.51	8.59	13.09	Co(OH)2
Co(OH)3	-10.11	-12.41	-2.31	Co(OH)3
CO2(g)	-2.86	-21.00	-18.15	CO2
Co3(AsO4)2	-15.26	-2.23	13.03	Co3(AsO4)2
Co3O4	-5.75	-16.24	-10.50	Co3O4
CoCl2	-22.55	-14.28	8.27	CoCl2
CoCl2:6H2O	-16.82	-14.28	2.54	CoCl2:6H2O
CoCO3	-2.44	-12.42	-9.98	CoCO3
CoF2	-15.24	-16.84	-1.60	CoF2
CoF3	-49.09	-50.55	-1.46	CoF3
CoFe2O4	25.01	21.48	-3.53	CoFe2O4
CoMoO4	-7.25	-15.01	-7.76	CoMoO4
CoO	-5.00	8.59	13.59	CoO
CoS(alpha)	-60.56	-68.00	-7.44	CoS
CoS(beta)	-56.93	-68.00	-11.07	CoS
CoSe	-14.54	-30.74	-16.20	CoSe
CoSeO3	-8.52	-7.20	1.32	CoSeO3
CoSeO4:6H2O	-19.18	-20.71	-1.53	CoSeO4:6H2O
CoSO4	-13.26	-10.46	2.80	CoSO4
CoSO4:6H2O	-7.99	-10.46	-2.47	CoSO4:6H2O
Cotunnite	-10.80	-15.58	-4.78	PbCl2
Covellite	-46.34	-68.64	-22.30	CuS
Cr(OH)2	-18.72	-7.90	10.82	Cr(OH)2
Cr(OH)3	-0.78	0.55	1.34	Cr(OH)3
Cr(OH)3(am)	1.30	0.55	-0.75	Cr(OH)3
Cr2O3	3.46	1.10	-2.36	Cr2O3
CrCl2	-44.86	-30.77	14.09	CrCl2
CrCl3	-48.86	-33.74	15.11	CrCl3
CrF3	-26.25	-37.58	-11.34	CrF3
Crmetal	-61.19	-30.70	30.48	Cr
CrO3	-29.41	-32.62	-3.21	CrO3
Cryolite	-16.99	-50.83	-33.84	Na3AlF6
Cu(OH)2	-0.72	7.95	8.67	Cu(OH)2
Cu2Se(alpha)	4.95	-40.85	-45.80	Cu2Se
Cu2SO4	-18.62	-20.57	-1.95	Cu2SO4
Cu3(AsO4)2:2H2O	-10.24	-4.14	6.10	Cu3(AsO4)2:2H2O
Cu3Se2	-8.74	-72.23	-63.49	Cu3Se2
CuCO3	-1.55	-13.05	-11.50	CuCO3
CuCrO4	-19.23	-24.67	-5.44	CuCrO4
CuF	-8.57	-13.47	-4.91	CuF
CuF2	-18.59	-17.47	1.12	CuF2
CuF2:2H2O	-12.92	-17.47	-4.55	CuF2:2H2O
Cumetal	-3.41	-12.16	-8.76	Cu
CuMoO4	-2.57	-15.64	-13.08	CuMoO4
CuOCuSO4	-13.45	-3.14	10.30	CuOCuSO4
Cupricferrite	14.86	20.85	5.99	CuFe2O4
Cuprite	-0.12	-1.52	-1.41	Cu2O
Cuprousferrite	14.60	5.69	-8.92	CuFeO2
CuSe	1.72	-31.38	-33.10	CuSe
CuSe2	-14.54	-47.91	-33.37	CuSe2
CuSeO3:2H2O	-8.35	-7.84	0.51	CuSeO3:2H2O
CuSeO4:5H2O	-18.90	-21.34	-2.44	CuSeO4:5H2O
CuSO4	-14.03	-11.09	2.94	CuSO4
Diaspore	2.20	9.07	6.87	AlOOH
Djurleite	-43.56	-77.48	-33.92	Cu0.066Cu1.868S
Dolomite(disordered)	0.62	-15.92	-16.54	CaMg(CO3)2
Dolomite(ordered)	1.17	-15.92	-17.09	CaMg(CO3)2
Epsomite	-4.06	-6.18	-2.13	MgSO4:7H2O
Fe(OH)2	-5.48	8.08	13.56	Fe(OH)2
Fe(OH)2.7Cl.3	6.06	3.02	-3.04	Fe(OH)2.7Cl.3
Fe(VO3)2	-5.72	-9.44	-3.72	Fe(VO3)2
Fe2(OH)4SeO3	-4.44	-2.89	1.55	Fe2(OH)4SeO3
Fe2(SeO3)3:2H2O	-13.84	-34.46	-20.63	Fe2(SeO3)3:2H2O
Fe2(SO4)3	-40.50	-44.24	-3.73	Fe2(SO4)3
Fe3(OH)8	0.75	20.98	20.22	Fe3(OH)8
FeAsO4:2H2O	-7.94	-7.54	0.40	FeAsO4:2H2O
FeCr2O4	1.98	9.18	7.20	FeCr2O4
FeMoO4	-5.42	-15.51	-10.09	FeMoO4
Ferrihydrite	3.26	6.45	3.19	Fe(OH)3
Ferroselite	-29.18	-47.78	-18.60	FeSe2
FeS(ppt)	-65.56	-68.51	-2.95	FeS
FeSe	-20.25	-31.25	-11.00	FeSe
Fluorite	-1.70	-12.20	-10.50	CaF2
Galena	-55.34	-69.31	-13.97	PbS
Gibbsite	0.78	9.07	8.29	Al(OH)3
Goethite	5.96	6.45	0.49	FeOOH
Goslarite	-7.36	-9.37	-2.01	ZnSO4:7H2O
Greenockite	-54.12	-68.48	-14.36	CdS
Greigite	-240.34	-285.37	-45.03	Fe3S4
Gummite	-7.48	0.19	7.67	UO3
Gypsum	-1.21	-5.82	-4.61	CaSO4:2H2O
H-Jarosite	-6.64	-18.74	-12.10	(H3O)Fe3(SO4)2(OH)6
H2MoO4	-10.72	-23.59	-12.88	H2MoO4
H2S(g)	-68.58	-76.59	-8.01	H2S
H2Se(g)	-34.37	-39.33	-4.96	H2Se
Halite	-7.58	-5.97	1.60	NaCl
Hausmannite	-8.08	52.95	61.03	Mn3O4
Hematite	14.31	12.90	-1.42	Fe2O3
Hercynite	3.32	26.22	22.89	FeAl2O4
Huntite	-2.23	-32.20	-29.97	CaMg3(CO3)4
Hydrocerussite	-1.39	-20.16	-18.77	Pb3(OH)2(CO3)2
Hydromagnesite	-10.94	-19.71	-8.77	Mg5(CO3)4(OH)2:4H2O
K-Alum	-19.08	-24.25	-5.17	KAl(SO4)2:12H2O
K-Jarosite	0.83	-13.97	-14.80	KFe3(SO4)2(OH)6
K2Cr2O7	-38.46	-55.70	-17.24	K2Cr2O7
K2CrO4	-22.57	-23.08	-0.51	K2CrO4
K2MoO4	-17.31	-14.05	3.26	K2MoO4
K2SeO4	-19.02	-19.75	-0.73	K2SeO4
Langite	-4.73	12.75	17.49	Cu4(OH)6SO4:H2O
Larnakite	-4.04	-4.48	-0.43	PbO:PbSO4
Laurionite	-4.77	-4.15	0.62	PbOHCl
Lepidocrocite	5.08	6.45	1.37	FeOOH
Lime	-19.47	13.23	32.70	CaO
Litharge	-5.41	7.28	12.69	PbO
Mackinawite	-64.91	-68.51	-3.60	FeS
Maghemite	6.51	12.90	6.39	Fe2O3
Magnesioferrite	8.90	25.76	16.86	Fe2MgO4
Magnesite	-0.68	-8.14	-7.46	MgCO3
Magnetite	17.57	20.98	3.40	Fe3O4
Malachite	0.20	-5.10	-5.31	Cu2(OH)2CO3
Manganite	-3.89	21.45	25.34	MnOOH
Massicot	-5.61	7.28	12.89	PbO
Matlockite	-7.89	-16.86	-8.97	PbClF
Melanothallite	-21.17	-14.91	6.26	CuCl2
Melanterite	-8.76	-10.96	-2.21	FeSO4:7H2O
Mg(OH)2(active)	-5.93	12.86	18.79	Mg(OH)2
Mg(VO3)2	-15.94	-4.66	11.28	Mg(VO3)2
Mg2V2O7	-18.16	8.20	26.36	Mg2V2O7
MgCr2O4	-2.24	13.96	16.20	MgCr2O4
MgCrO4	-25.14	-19.76	5.38	MgCrO4
MgF2	-4.43	-12.56	-8.13	MgF2
MgMoO4	-8.88	-10.73	-1.85	MgMoO4
MgSeO3:6H2O	-5.98	-2.92	3.06	MgSeO3:6H2O
MgSeO4:6H2O	-15.23	-16.43	-1.20	MgSeO4:6H2O
Minium	-28.87	44.65	73.52	Pb3O4
Mirabilite	-7.01	-8.13	-1.11	Na2SO4:10H2O
Mn(VO3)2	-12.37	-7.47	4.90	Mn(VO3)2
Mn2(SO4)3	-59.22	-64.93	-5.71	Mn2(SO4)3
Mn3(AsO4)2:8H2O	-10.34	2.16	12.50	Mn3(AsO4)2:8H2O
MnCl2:4H2O	-15.53	-12.81	2.72	MnCl2:4H2O
MnS(grn)	-66.71	-66.54	0.17	MnS
MnS(pnk)	-69.88	-66.54	3.34	MnS
MnSe	-32.78	-29.28	3.50	MnSe
MnSeO3	-6.87	-5.74	1.13	MnSeO3
MnSeO3:2H2O	-6.72	-5.74	0.98	MnSeO3:2H2O
MnSeO4:5H2O	-17.19	-19.24	-2.05	MnSeO4:5H2O
MnSO4	-11.58	-8.99	2.58	MnSO4
Monteponite	-6.99	8.11	15.10	CdO

```
  MoO3             -15.59    -23.59   -8.00  MoO3
  Morenosite        -8.43    -10.58   -2.14  NiSO4:7H2O
  MoS2           -129.31   -199.57  -70.26  MoS2
  Na-Jarosite       -2.08    -13.28  -11.20  NaFe3(SO4)2(OH)6
  Na2Cr2O7         -44.43    -54.33   -9.90  Na2Cr2O7
  Na2CrO4          -24.64    -21.71    2.93  Na2CrO4
  Na2Mo2O7         -19.67    -36.27  -16.60  Na2Mo2O7
  Na2MoO4          -14.16    -12.67    1.49  Na2MoO4
  Na2MoO4:2H2O     -13.90    -12.67    1.22  Na2MoO4:2H2O
  Na2SeO3:5H2O     -15.17     -4.87   10.30  Na2SeO3:5H2O
  Na2SeO4          -19.65    -18.37    1.28  Na2SeO4
  Na3VO4           -29.06      7.62   36.68  Na3VO4
  Na4V2O7          -33.08      4.32   37.40  Na4V2O7
  Nantokite         -5.46    -12.19   -6.73  CuCl
  Natron            -8.78    -10.09   -1.31  Na2CO3:10H2O
  NaVO3             -7.16     -3.30    3.86  NaVO3
  Nesquehonite      -3.47     -8.14   -4.67  MgCO3:3H2O
  Ni(OH)2           -4.33      8.47   12.79  Ni(OH)2
  Ni3(AsO4)2:8H2O  -18.29     -2.59   15.70  Ni3(AsO4)2:8H2O
  Ni4(OH)6SO4      -17.18     14.82   32.00  Ni4(OH)6SO4
  NiCO3             -5.67    -12.54   -6.87  NiCO3
  NiMoO4            -3.98    -15.13  -11.14  NiMoO4
  NiS(alpha)       -62.52    -68.12   -5.60  NiS
  NiS(beta)        -57.02    -68.12  -11.10  NiS
  NiS(gamma)       -55.32    -68.12  -12.80  NiS
  NiSe             -13.16    -30.86  -17.70  NiSe
  NiSeO3:2H2O      -10.14     -7.32    2.81  NiSeO3:2H2O
  NiSeO4:6H2O      -19.31    -20.83   -1.52  NiSeO4:6H2O
  Nsutite          -10.00      7.50   17.50  MnO2
  O2(g)            -37.49     45.60   83.09  O2
  Orpiment        -204.49   -265.55  -61.07  As2S3
  Otavite           -0.89    -12.89  -12.00  CdCO3
  Pb(BO2)2         -10.09     -3.57    6.52  Pb(BO2)2
  Pb(OH)2           -0.87      7.28    8.15  Pb(OH)2
  Pb10(OH)6O(CO3)6 -44.44    -53.20   -8.76  Pb10(OH)6O(CO3)6
  Pb2(OH)3Cl        -5.66      3.13    8.79  Pb2(OH)3Cl
  Pb2O(OH)2        -11.62     14.56   26.19  Pb2O(OH)2
  Pb2O3            -23.67     37.37   61.04  Pb2O3
  Pb2OCO3           -5.88     -6.44   -0.56  Pb2OCO3
  Pb2V2O7           -1.06     -2.96   -1.90  Pb2V2O7
  Pb3(AsO4)2       -11.94     -6.14    5.80  Pb3(AsO4)2
  Pb3(VO4)2         -1.81      4.33    6.14  Pb3(VO4)2
  Pb3O2CO3         -10.18      0.84   11.02  Pb3O2CO3
  Pb3O2SO4          -7.88      2.80   10.69  Pb3O2SO4
  Pb4(OH)6SO4      -11.01     10.09   21.10  Pb4(OH)6SO4
  Pb4O3SO4         -11.79     10.09   21.88  Pb4O3SO4
  PbCrO4           -12.74    -25.34  -12.60  PbCrO4
  PbF2             -10.70    -18.14   -7.44  PbF2
  Pbmetal          -19.76    -15.52    4.25  Pb
  PbMoO4            -0.69    -16.31  -15.62  PbMoO4
  PbO:0.3H2O        -5.70      7.28   12.98  PbO:0.33H2O
  PbSeO4           -15.17    -22.01   -6.84  PbSeO4
  Periclase         -8.72     12.86   21.58  MgO
  Phosgenite        -9.49    -29.30  -19.81  PbCl2:PbCO3
  Plattnerite      -19.52     30.08   49.60  PbO2
  Portlandite       -9.58     13.23   22.80  Ca(OH)2
  Pyrite          -103.79   -122.29  -18.51  FeS2
  Pyrochroite       -5.14     10.05   15.19  Mn(OH)2
  Pyrolusite        -8.53     32.85   41.38  MnO2
  Realgar          -86.14   -105.88  -19.75  AsS
  Retgersite        -8.54    -10.58   -2.04  NiSO4:6H2O
  Rhodochrosite     -0.37    -10.95  -10.58  MnCO3
  Rutherfordine     -6.31    -20.81  -14.50  UO2CO3
  Schoepite         -5.80      0.19    5.99  UO2(OH)2:H2O
  Semetal(am)       -9.42    -16.53   -7.11  Se
  Semetal(hex       -8.82    -16.53   -7.71  Se
```

```
  SeO2             -15.91    -15.79    0.12  SeO2
  SeO3             -50.34    -29.29   21.04  SeO3
  Siderite          -2.68    -12.92  -10.24  FeCO3
  Smithsonite       -1.33    -11.33  -10.00  ZnCO3
  Sphalerite       -55.46    -66.91  -11.45  ZnS
  Spinel            -5.85     31.00   36.85  MgAl2O4
  Sulfur           -51.64    -53.79   -2.14  S
  Tenorite           0.31      7.95    7.64  CuO
  Thenardite        -8.45     -8.13    0.32  Na2SO4
  Thermonatrite    -10.72    -10.09    0.64  Na2CO3:H2O
  Tyuyamunite       -7.98     -3.90    4.08  Ca(UO2)2(VO4)2
  U3O8             -15.65      5.43   21.08  U3O8
  U4O9             -27.74    -30.76   -3.02  U4O9
  UF4              -34.70    -64.24  -29.54  UF4
  UF4:2.5H2O       -31.52    -64.24  -32.72  UF4:2.5H2O
  UO2(am)          -14.32    -13.39    0.93  UO2
  UO2(OH)2(beta)    -5.42      0.19    5.61  UO2(OH)2
  UO2SeO4:4H2O     -26.85    -29.10   -2.25  UO2SeO4:4H2O
  UO3               -7.51      0.19    7.70  UO3
  Uraninite         -8.72    -13.39   -4.67  UO2
  V(OH)3           -16.55     -8.96    7.59  V(OH)3
  V2O5             -16.16    -17.52   -1.36  V2O5
  V3O5             -34.41    -32.58    1.84  V3O5
  V4O7             -43.02    -35.83    7.19  V4O7
  V6O13            -37.31    -98.17  -60.86  V6O13
  VCl2             -62.10    -43.23   18.87  VCl2
  VCl3             -66.69    -43.26   23.43  VCl3
  VF4              -69.04    -54.11   14.93  VF4
  Vmetal           -87.19    -43.16   44.03  V
  VO               -35.12    -20.36   14.76  VO
  VO(OH)2           -8.41     -3.26    5.15  VO(OH)2
  VO2Cl            -23.03    -20.19    2.84  VO2Cl
  VOCl             -31.55    -20.39   11.15  VOCl
  VOCl2            -38.88    -26.12   12.76  VOCl2
  VOSO4            -25.91    -22.30    3.61  VOSO4
  Witherite         -2.77    -11.34   -8.57  BaCO3
  Wurtzite         -57.96    -66.91   -8.95  ZnS
  Zincite           -1.66      9.67   11.33  ZnO
  Zincosite        -13.30     -9.37    3.93  ZnSO4
  Zn(BO2)2          -9.47     -1.18    8.29  Zn(BO2)2
  Zn(OH)2           -2.53      9.67   12.20  Zn(OH)2
  Zn(OH)2(am)       -2.80      9.67   12.47  Zn(OH)2
  Zn(OH)2(beta)     -2.08      9.67   11.75  Zn(OH)2
  Zn(OH)2(epsilon)  -1.86      9.67   11.53  Zn(OH)2
  Zn(OH)2(gamma)    -2.06      9.67   11.73  Zn(OH)2
  Zn2(OH)2SO4       -7.20      0.30    7.50  Zn2(OH)2SO4
  Zn2(OH)3Cl        -7.28      7.92   15.19  Zn2(OH)3Cl
  Zn3(AsO4)2:2.5H2O -12.61      1.04   13.65  Zn3(AsO4)2:2.5H2O
  Zn3O(SO4)2       -27.98     -9.07   18.91  Zn3O(SO4)2
  Zn4(OH)6SO4       -8.75     19.65   28.40  Zn4(OH)6SO4
  Zn5(OH)8Cl2      -12.99     25.51   38.50  Zn5(OH)8Cl2
  ZnCl2            -20.24    -13.19    7.05  ZnCl2
  ZnCO3:1H2O        -1.07    -11.33  -10.26  ZnCO3:1H2O
  ZnF2             -15.22    -15.75   -0.53  ZnF2
  Znmetal          -38.92    -13.13   25.79  Zn
  ZnMoO4            -3.79    -13.92  -10.13  ZnMoO4
  ZnO(active)       -1.51      9.67   11.19  ZnO
  ZnS(am)          -57.86    -66.91   -9.05  ZnS
  ZnSe             -15.26    -29.66  -14.40  ZnSe
  ZnSeO4:6H2O      -18.10    -19.62   -1.52  ZnSeO4:6H2O
  ZnSO4:1H2O        -8.73     -9.37   -0.64  ZnSO4:1H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

------------------
```

```
End of simulation.
------------------

------------------------------------
Reading input data for simulation 2.
------------------------------------

------------------------------
End of Run after 0.688 Seconds.
------------------------------
```

```
# P25 Scenario

SOLUTION 1 UG Water P25
    temp      25
    pH        8.112
    units     mg/L
    density   1
Al    0.0776
As    0.0027
Ba    0.1797
B     0.1302
Ca    101.7
Cl    53.6
Mg    52.5
Na    206.2
K     37.9
F     0.9956
S(6)  246.5
Cd    0.0077
Cr    0.0078
Co    0.0039
Cu    0.0722
Fe    0.1879
Pb    0.0477
Mn    0.0895
Mo    0.0110
Ni    0.0056
Se    0.0150
U     0.0082
V     0.0024
Zn    0.2006
      Alkalinity 553.3 as HCO3
    -water    1 # kg

SOLUTION 2 PAF Material
    temp      25
    pH        7.5
    units     mg/L
    density   1
      Al    0.020
      As    0
      Ba    0.020
      B     0
      Ca    67.0
      Cl    0
      Mg    8.0
      Na    1.0
      K     13.0
      F     0.300
      S(6)  197.0
      Cd    0.000
      Cr    0
      Co    0.007
      Cu    0.028
      Fe    0
      Pb    0
      Mn    0.040
      Mo    0.003
      Ni    0.004
      Se    0
      U     0
      V     0
      Zn    0
      Alkalinity 22 as HCO3
    -water    1 # kg
```

```
SOLUTION 3 NAF Material
    temp      25
    pH        7.6
    units     mg/L
    density   1
      Al    0.140
      As    0.029
      Ba    0.020
      B     0
      Ca    122.0
      Cl    0
      Mg    18.0
      Na    1.0
      K     16.0
      F     0.300
      S(6)  331.0
      Cd    0.000
      Cr    0
      Co    0.002
      Cu    0.019
      Fe    0.070
      Pb    0
      Mn    0.130
      Mo    0.005
      Ni    0.001
      Se    0
      U     0.001
      V     0
      Zn    0
      Alkalinity 28 as HCO3
    -water    1 # kg


SOLUTION 4 Make-up Material
    temp      25
    pH        7.7
    units     mg/L
    density   1
      Al    0.020
      As    0
      Ba    0.020
      B     0
      Ca    67.0
      Cl    0
      Mg    8.0
      Na    1.0
      K     13.0
      F     0.300
      S(6)  197.0
      Cd    0.000
      Cr    0
      Co    0.007
      Cu    0.028
      Fe    0
      Pb    0
      Mn    0.040
      Mo    0.003
      Ni    0.004
      Se    0
      U     0
      V     0
      Zn    0
      Alkalinity 22 as HCO3
    -water    1 # kg

# Mix the three solutions together
```

```
MIX 1 Mix within UG Works
    1    0.312
    2    0.109
    3    0.398
    4    0.181

SAVE Solution 5

SELECTED_OUTPUT 2
    -file                D:\selected_output_3.txt
    -high_precision      true
    -reset               true
    -distance            false
    -time                false
    -temperature         false
    -ionic_strength      false
    -water               false
    -totals              pH Al As Ba B Ca Cl Mg
                         Na K  F  S(6) Cd Cr Co
                         Cu Fe Pb Mn Mo  Ni Se
                         U V Zn Alkalinity
END
```

```
   Input file: P:\J23011 - BCP Underground EA (Aeris)\2. Tech Work Area\2.08 Water Quality
Model\2.08.02 PAF Assessment\BPC_UG_PAF_Disposal_P25.pqi
  Output file: P:\J23011 - BCP Underground EA (Aeris)\2. Tech Work Area\2.08 Water Quality
Model\2.08.02 PAF Assessment\BPC_UG_PAF_Disposal_P25.pqo
Database file: c:\phreeqc\database\minteq.v4.dat

------------------
Reading data base.
------------------

      SOLUTION_MASTER_SPECIES
      SOLUTION_SPECIES
      SOLUTION_SPECIES
      PHASES
      PHASES
      SURFACE_MASTER_SPECIES
      SURFACE_SPECIES
      END
------------------------------------
Reading input data for simulation 1.
------------------------------------

      DATABASE c:\phreeqc\database\minteq.v4.dat
      SOLUTION 1 UG Water P25
          temp      25
          pH        8.112
          units     mg/L
          density   1
      Al    0.0776
      As    0.0027
      Ba    0.1797
      B     0.1302
      Ca    101.7
      Cl    53.6
      Mg    52.5
      Na    206.2
      K     37.9
      F     0.9956
      S(6)  246.5
      Cd    0.0077
      Cr    0.0078
      Co    0.0039
      Cu    0.0722
      Fe    0.1879
      Pb    0.0477
      Mn    0.0895
      Mo    0.0110
      Ni    0.0056
      Se    0.0150
      U     0.0082
      V     0.0024
      Zn    0.2006
            Alkalinity 553.3 as HCO3
          water    1 # kg
      SOLUTION 2 PAF Material
          temp      25
          pH        7.5
          units     mg/L
          density   1
            Al    0.020
            As    0
            Ba    0.020
            B     0
            Ca    67.0
            Cl    0
            Mg    8.0
```

```
            Na    1.0
            K     13.0
            F     0.300
            S(6)  197.0
            Cd    0.000
            Cr    0
            Co    0.007
            Cu    0.028
            Fe    0
            Pb    0
            Mn    0.040
            Mo    0.003
            Ni    0.004
            Se    0
            U     0
            V     0
            Zn    0
            Alkalinity 22 as HCO3
          water    1 # kg
      SOLUTION 3 NAF Material
          temp      25
          pH        7.6
          units     mg/L
          density   1
            Al    0.140
            As    0.029
            Ba    0.020
            B     0
            Ca    122.0
            Cl    0
            Mg    18.0
            Na    1.0
            K     16.0
            F     0.300
            S(6)  331.0
            Cd    0.000
            Cr    0
            Co    0.002
            Cu    0.019
            Fe    0.070
            Pb    0
            Mn    0.130
            Mo    0.005
            Ni    0.001
            Se    0
            U     0.001
            V     0
            Zn    0
            Alkalinity 28 as HCO3
          water    1 # kg
      SOLUTION 4 Make-up Material
          temp      25
          pH        7.7
          units     mg/L
          density   1
            Al    0.020
            As    0
            Ba    0.020
            B     0
            Ca    67.0
            Cl    0
            Mg    8.0
            Na    1.0
            K     13.0
            F     0.300
            S(6)  197.0
```

```
            Cd    0.000
            Cr    0
            Co    0.007
            Cu    0.028
            Fe    0
            Pb    0
            Mn    0.040
            Mo    0.003
            Ni    0.004
            Se    0
            U     0
            V     0
            Zn    0
            Alkalinity 22 as HCO3
        water    1 # kg
    MIX 1 Mix within UG Works
        1    0.312
        2    0.109
        3    0.398
        4    0.181
    SAVE Solution 5
    SELECTED_OUTPUT 2
        file                 D:\selected_output_3.txt
        high_precision       true
        reset                true
        distance             false
        time                 false
        temperature          false
        ionic_strength       false
        water                false
        totals               pH Al As Ba B Ca Cl Mg
WARNING: Expected element name to begin with upper case letter.
                              Na K  F  S(6) Cd Cr Co
                              Cu Fe Pb Mn Mo  Ni Se
                              U V Zn Alkalinity
    END
------------------------------------------
Beginning of initial solution calculations.
------------------------------------------

Initial solution 1.     UG Water P25

-----------------------------Solution composition-----------------------------

      Elements           Molality       Moles

      Al                 2.880e-06   2.880e-06
      Alkalinity         9.079e-03   9.079e-03
      As                 3.608e-08   3.608e-08
      B                  1.206e-05   1.206e-05
      Ba                 1.310e-06   1.310e-06
      Ca                 2.541e-03   2.541e-03
      Cd                 6.859e-08   6.859e-08
      Cl                 1.514e-03   1.514e-03
      Co                 6.626e-08   6.626e-08
      Cr                 1.502e-07   1.502e-07
      Cu                 1.138e-06   1.138e-06
      F                  5.247e-05   5.247e-05
      Fe                 3.369e-06   3.369e-06
      K                  9.706e-04   9.706e-04
      Mg                 2.163e-03   2.163e-03
      Mn                 1.631e-06   1.631e-06
      Mo                 1.148e-07   1.148e-07
      Na                 8.980e-03   8.980e-03
      Ni                 9.554e-08   9.554e-08
      Pb                 2.305e-07   2.305e-07
      S(6)               2.569e-03   2.569e-03
      Se                 1.902e-07   1.902e-07
      U                  3.449e-08   3.449e-08
      V                  4.717e-08   4.717e-08
      Zn                 3.072e-06   3.072e-06

----------------------------Description of solution----------------------------

                                       pH  =   8.112
                                       pe  =   4.000
                                 Activity of water  =   1.000
                       Ionic strength (mol/kgw)  =   2.187e-02
                            Mass of water (kg)  =   1.000e+00
                          Total carbon (mol/kg)  =   8.983e-03
                             Total CO2 (mol/kg)  =   8.983e-03
                               Temperature (°C)  =  25.00
                         Electrical balance (eq)  =   3.601e-03
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  11.28
                                    Iterations  =  10
                                       Total H  = 1.110226e+02
                                       Total O  = 5.554412e+01

----------------------------Distribution of species----------------------------

                                                  Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             1.511e-06   1.303e-06    -5.821    -5.885    -0.064     (0)
   H+              8.920e-09   7.727e-09    -8.050    -8.112    -0.062      0.00
   H2O             5.551e+01   9.995e-01     1.744    -0.000     0.000     18.07
Al            2.880e-06
   Al(OH)4-        2.864e-06   2.483e-06    -5.543    -5.605    -0.062     (0)
   Al(OH)3         1.514e-08   1.514e-08    -7.820    -7.820     0.000     (0)
   Al(OH)2+        6.687e-10   5.827e-10    -9.175    -9.235    -0.060     (0)
   AlF2+           3.188e-12   2.778e-12   -11.496   -11.556    -0.060     (0)
   AlF3            1.405e-12   1.405e-12   -11.852   -11.852     0.000     (0)
   AlOH+2          9.764e-13   5.632e-13   -12.010   -12.249    -0.239     (0)
   AlF+2           3.012e-13   1.737e-13   -12.521   -12.760    -0.239     (0)
   AlF4-           3.263e-14   2.829e-14   -13.486   -13.548    -0.062     (0)
   AlSO4+          4.372e-15   3.791e-15   -14.359   -14.421    -0.062     (0)
   Al+3            1.574e-15   4.324e-16   -14.803   -15.364    -0.561     (0)
   Al(SO4)2-       5.291e-17   4.589e-17   -16.276   -16.338    -0.062     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -51.502   -52.180    -0.679     (0)
As(3)         8.330e-21
   H3AsO3          7.720e-21   7.720e-21   -20.112   -20.112     0.000     (0)
   H2AsO3-         6.096e-22   5.124e-22   -21.215   -21.290    -0.075     (0)
   HAsO3-2         1.211e-25   6.048e-26   -24.917   -25.218    -0.302     (0)
   H4AsO3+         3.516e-29   2.955e-29   -28.454   -28.529    -0.075     (0)
   AsO3-3          1.440e-30   3.017e-31   -29.842   -30.520    -0.679     (0)
As(5)         3.608e-08
   HAsO4-2         3.460e-08   1.727e-08    -7.461    -7.763    -0.302     (0)
   H2AsO4-         1.448e-09   1.217e-09    -8.839    -8.915    -0.075     (0)
   AsO4-3          3.374e-11   7.070e-12   -10.472   -11.151    -0.679     (0)
   H3AsO4          1.626e-15   1.635e-15   -14.789   -14.787     0.002     (0)
B             1.206e-05
   H3BO3           1.098e-05   1.104e-05    -4.959    -4.957     0.002     (0)
   H2BO3-          9.687e-07   8.297e-07    -6.014    -6.081    -0.067     (0)
   CaH2BO3+        6.265e-08   5.366e-08    -7.203    -7.270    -0.067     (0)
   MgH2BO3+        3.442e-08   2.948e-08    -7.463    -7.530    -0.067     (0)
   NaH2BO3         1.012e-08   1.012e-08    -7.995    -7.995     0.000     (0)
   BF(OH)3-        2.066e-10   1.770e-10    -9.685    -9.752    -0.067     (0)
   BaH2BO3+        2.088e-11   1.789e-11   -10.680   -10.747    -0.067     (0)
   H5(BO3)2-       9.101e-12   7.796e-12   -11.041   -11.108    -0.067     (0)
   H8(BO3)3-       1.005e-14   8.605e-15   -13.998   -14.065    -0.067     (0)
   BF2(OH)2-       6.859e-15   5.875e-15   -14.164   -14.231    -0.067     (0)
   BF3OH-          8.288e-22   7.099e-22   -21.082   -21.149    -0.067     (0)
   BF4-            1.266e-27   1.085e-27   -26.897   -26.965    -0.067     (0)
Ba            1.310e-06
   Ba+2            1.239e-06   6.976e-07    -5.907    -6.156    -0.249     (0)
   BaHCO3+         5.549e-08   4.851e-08    -7.256    -7.314    -0.058     (0)
   BaCO3           1.581e-08   1.581e-08    -7.801    -7.801     0.000     (0)
   BaH2BO3+        2.088e-11   1.789e-11   -10.680   -10.747    -0.067     (0)
   BaOH+           4.561e-12   3.966e-12   -11.341   -11.402    -0.061     (0)
C(4)          8.983e-03
   HCO3-           8.356e-03   7.282e-03    -2.078    -2.138    -0.060     (0)
   CaHCO3+         1.744e-04   1.524e-04    -3.759    -3.817    -0.058     (0)
   H2CO3           1.266e-04   1.266e-04    -3.898    -3.898     0.000     (0)
   MgHCO3+         8.833e-05   7.637e-05    -4.054    -4.117    -0.063     (0)
   CaCO3           7.871e-05   7.871e-05    -4.104    -4.104     0.000     (0)
   CO3-2           7.847e-05   4.418e-05    -4.105    -4.355    -0.249     (0)
   MgCO3           3.767e-05   3.767e-05    -4.424    -4.424     0.000     (0)
   NaHCO3          3.153e-05   3.153e-05    -4.501    -4.501     0.000     (0)
   NaCO3-          7.269e-06   6.334e-06    -5.139    -5.198    -0.060     (0)
   ZnCO3           1.550e-06   1.550e-06    -5.810    -5.810     0.000     (0)
   CuCO3           8.949e-07   8.949e-07    -6.048    -6.048     0.000     (0)
   Cu(CO3)2-2      2.132e-07   1.064e-07    -6.671    -6.973    -0.302     (0)
   PbCO3           1.705e-07   1.705e-07    -6.768    -6.768     0.000     (0)
   ZnHCO3+         1.671e-07   1.404e-07    -6.777    -6.853    -0.075     (0)
   MnHCO3+         1.146e-07   9.965e-08    -6.941    -7.002    -0.061     (0)
   BaHCO3+         5.549e-08   4.851e-08    -7.256    -7.314    -0.058     (0)
   Pb(CO3)2-2      4.351e-08   2.172e-08    -7.361    -7.663    -0.302     (0)
   NiCO3           3.319e-08   3.319e-08    -7.479    -7.479     0.000     (0)
   UO2(CO3)3-4     3.266e-08   2.029e-09    -7.486    -8.693    -1.207     (0)
   NiHCO3+         2.151e-08   1.808e-08    -7.667    -7.743    -0.075     (0)
   CdCO3           2.086e-08   2.086e-08    -7.681    -7.681     0.000     (0)
   BaCO3           1.581e-08   1.581e-08    -7.801    -7.801     0.000     (0)
   CoCO3           1.341e-08   1.341e-08    -7.872    -7.872     0.000     (0)
   CoHCO3+         1.210e-08   1.017e-08    -7.917    -7.993    -0.075     (0)
   PbHCO3+         8.262e-09   6.945e-09    -8.083    -8.158    -0.075     (0)
   CuHCO3+         1.880e-09   1.580e-09    -8.726    -8.801    -0.075     (0)
   UO2(CO3)2-2     1.835e-09   9.162e-10    -8.736    -9.038    -0.302     (0)
   Cd(CO3)2-2      1.369e-09   6.832e-10    -8.864    -9.165    -0.302     (0)
   CdHCO3+         4.085e-10   3.434e-10    -9.389    -9.464    -0.075     (0)
   FeHCO3+         3.248e-10   2.839e-10    -9.488    -9.547    -0.058     (0)
   UO2CO3          1.039e-12   1.039e-12   -11.983   -11.983     0.000     (0)
Ca            2.541e-03
   Ca+2            1.996e-03   1.124e-03    -2.700    -2.949    -0.249     (0)
   CaSO4           2.909e-04   2.909e-04    -3.536    -3.536     0.000     (0)
   CaHCO3+         1.744e-04   1.524e-04    -3.759    -3.817    -0.058     (0)
   CaCO3           7.871e-05   7.871e-05    -4.104    -4.104     0.000     (0)
   CaF+            5.668e-07   4.929e-07    -6.247    -6.307    -0.061     (0)
   CaH2BO3+        6.265e-08   5.366e-08    -7.203    -7.270    -0.067     (0)
   CaOH+           3.342e-08   2.921e-08    -7.476    -7.534    -0.058     (0)
Cd            6.859e-08
   Cd+2            3.679e-08   2.071e-08    -7.434    -7.684    -0.249     (0)
   CdCO3           2.086e-08   2.086e-08    -7.681    -7.681     0.000     (0)
   CdSO4           5.485e-09   5.485e-09    -8.261    -8.261     0.000     (0)
   CdCl+           3.086e-09   2.594e-09    -8.511    -8.586    -0.075     (0)
   Cd(CO3)2-2      1.369e-09   6.832e-10    -8.864    -9.165    -0.302     (0)
   CdHCO3+         4.085e-10   3.434e-10    -9.389    -9.464    -0.075     (0)
   CdOH+           2.550e-10   2.143e-10    -9.594    -9.669    -0.075     (0)
   Cd(SO4)2-2      1.674e-10   8.357e-11    -9.776   -10.078    -0.302     (0)
   CdOHCl          1.386e-10   1.386e-10    -9.858    -9.858     0.000     (0)
   CdF+            1.569e-11   1.319e-11   -10.804   -10.880    -0.075     (0)
   CdCl2           1.418e-11   1.418e-11   -10.848   -10.848     0.000     (0)
   Cd(OH)2         1.761e-12   1.761e-12   -11.754   -11.754     0.000     (0)
   CdCl3-          1.396e-14   1.173e-14   -13.855   -13.931    -0.075     (0)
   CdF2            1.057e-15   1.057e-15   -14.976   -14.976     0.000     (0)
   Cd(OH)3-        1.668e-16   1.402e-16   -15.778   -15.853    -0.075     (0)
   Cd2OH+3         1.062e-16   2.225e-17   -15.974   -16.653    -0.679     (0)
   Cd(SeO3)2-2     6.652e-17   3.321e-17   -16.177   -16.479    -0.302     (0)
   CdSeO4          3.520e-17   3.520e-17   -16.453   -16.453     0.000     (0)
   Cd(OH)4-2       5.986e-23   2.988e-23   -22.223   -22.525    -0.302     (0)
Cl            1.514e-03
   Cl-             1.514e-03   1.311e-03    -2.820    -2.882    -0.062     (0)
   ZnOHCl          3.425e-09   3.425e-09    -8.465    -8.465     0.000     (0)
   CdCl+           3.086e-09   2.594e-09    -8.511    -8.586    -0.075     (0)
   ZnCl+           2.323e-09   2.009e-09    -8.634    -8.697    -0.063     (0)
   MnCl+           1.302e-09   1.132e-09    -8.885    -8.946    -0.061     (0)
   CuCl            2.781e-10   2.781e-10    -9.556    -9.556     0.000     (0)
   CdOHCl          1.386e-10   1.386e-10    -9.858    -9.858     0.000     (0)
   CoCl+           9.691e-11   8.146e-11   -10.014   -10.089    -0.075     (0)
   CuCl2-          8.811e-11   7.619e-11   -10.055   -10.118    -0.063     (0)
   NiCl+           8.037e-11   6.756e-11   -10.095   -10.170    -0.075     (0)
   PbCl+           7.104e-11   5.972e-11   -10.148   -10.224    -0.075     (0)
   CdCl2           1.418e-11   1.418e-11   -10.848   -10.848     0.000     (0)
   CuCl+           8.267e-12   7.148e-12   -11.083   -11.146    -0.063     (0)
   ZnCl2           4.174e-12   4.174e-12   -11.379   -11.379     0.000     (0)
   MnCl2           2.097e-12   2.097e-12   -11.678   -11.678     0.000     (0)
   PbCl2           3.498e-13   3.498e-13   -12.456   -12.456     0.000     (0)
   CuCl3-2         3.735e-14   2.136e-14   -13.428   -13.670    -0.243     (0)
   CdCl3-          1.396e-14   1.173e-14   -13.855   -13.931    -0.075     (0)
   ZnCl3-          5.028e-15   4.348e-15   -14.299   -14.362    -0.063     (0)
   CuCl2           3.250e-15   3.250e-15   -14.488   -14.488     0.000     (0)
   MnCl3-          8.709e-16   7.573e-16   -15.060   -15.121    -0.061     (0)
   NiCl2           4.461e-16   4.461e-16   -15.351   -15.351     0.000     (0)
   PbCl3-          2.172e-16   1.826e-16   -15.663   -15.739    -0.075     (0)
   CrCl+2          6.425e-17   3.208e-17   -16.192   -16.494    -0.302     (0)
   ZnCl4-2         4.986e-18   2.851e-18   -17.302   -17.545    -0.243     (0)
   CrOHCl2         1.041e-18   1.041e-18   -17.982   -17.982     0.000     (0)
   PbCl4-2         2.192e-19   1.094e-19   -18.659   -18.961    -0.302     (0)
   FeCl+2          1.992e-19   1.139e-19   -18.701   -18.943    -0.243     (0)
   CuCl3-          4.600e-20   3.977e-20   -19.337   -19.400    -0.063     (0)
   UO2Cl+          1.495e-20   1.256e-20   -19.825   -19.901    -0.075     (0)
   CrCl2+          4.748e-21   3.991e-21   -20.323   -20.399    -0.075     (0)
   FeCl2+          7.674e-22   6.673e-22   -21.115   -21.176    -0.061     (0)
   VOCl+           6.388e-23   5.370e-23   -22.195   -22.270    -0.075     (0)
   CuCl4-2         4.571e-25   2.614e-25   -24.340   -24.583    -0.243     (0)
   FeCl3           8.751e-26   8.751e-26   -25.058   -25.058     0.000     (0)
   CrO3Cl-         3.198e-26   2.688e-26   -25.495   -25.571    -0.075     (0)
   CoCl+2          3.821e-37   1.907e-37   -36.418   -36.720    -0.302     (0)
   UCl+3           0.000e+00   0.000e+00   -48.964   -49.642    -0.679     (0)
Co(2)         6.626e-08
   Co+2            3.597e-08   1.796e-08    -7.444    -7.746    -0.302     (0)
   CoCO3           1.341e-08   1.341e-08    -7.872    -7.872     0.000     (0)
   CoHCO3+         1.210e-08   1.017e-08    -7.917    -7.993    -0.075     (0)
   CoSO4           4.047e-09   4.047e-09    -8.393    -8.393     0.000     (0)
   CoOH+           5.552e-10   4.667e-10    -9.256    -9.331    -0.075     (0)
   CoCl+           9.691e-11   8.146e-11   -10.014   -10.089    -0.075     (0)
   Co(OH)2         4.829e-11   4.829e-11   -10.316   -10.316     0.000     (0)
   CoF+            2.714e-11   2.281e-11   -10.566   -10.642    -0.075     (0)
   Co(OH)3-        1.493e-15   1.255e-15   -14.826   -14.901    -0.075     (0)
   CoOOH-          3.748e-16   3.150e-16   -15.426   -15.502    -0.075     (0)
   CoSeO4          8.214e-17   8.214e-17   -16.085   -16.085     0.000     (0)
   Co2OH+3         2.005e-18   4.201e-19   -17.698   -18.377    -0.679     (0)
   Co(OH)4-2       5.190e-22   2.591e-22   -21.285   -21.587    -0.302     (0)
   Co4(OH)4+4      1.524e-28   9.468e-30   -27.817   -29.024    -1.207     (0)
Co(3)         9.479e-30
   CoOH+2          9.479e-30   4.732e-30   -29.023   -29.325    -0.302     (0)
   Co+3            2.603e-36   7.149e-37   -35.585   -36.146    -0.561     (0)
   CoCl+2          3.821e-37   1.907e-37   -36.418   -36.720    -0.302     (0)
Cr(2)         9.045e-25
   Cr+2            9.045e-25   4.516e-25   -24.044   -24.345    -0.302     (0)
Cr(3)         1.502e-07
   Cr(OH)2+        1.016e-07   8.537e-08    -6.993    -7.069    -0.075     (0)
   Cr(OH)3         4.178e-08   4.178e-08    -7.379    -7.379     0.000     (0)
   CrO2-           3.056e-09   2.569e-09    -8.515    -8.590    -0.075     (0)
   Cr(OH)4-        2.577e-09   2.166e-09    -8.589    -8.664    -0.075     (0)
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Cr(OH)+2	1.079e-09	5.387e-10	-8.967	-9.269	-0.302	(0)
CrOHSO4	1.444e-10	1.444e-10	-9.840	-9.840	0.000	(0)
CrF+2	2.411e-13	1.204e-13	-12.618	-12.920	-0.302	(0)
Cr+3	9.022e-14	1.890e-14	-13.045	-13.723	-0.679	(0)
CrSO4+	5.931e-14	4.986e-14	-13.227	-13.302	-0.075	(0)
CrCl+2	6.425e-17	3.208e-17	-16.192	-16.494	-0.302	(0)
Cr2(OH)2SO4+2	1.408e-17	7.030e-18	-16.851	-17.153	-0.302	(0)
CrOHCl2	1.041e-18	1.041e-18	-17.982	-17.982	0.000	(0)
Cr2(OH)2(SO4)2	4.717e-19	4.717e-19	-18.326	-18.326	0.000	(0)
CrCl2+	4.748e-21	3.991e-21	-20.323	-20.399	-0.075	(0)
Cr(6)	3.128e-14					
CrO4-2	2.995e-14	1.686e-14	-13.524	-13.773	-0.249	(0)
NaCrO4-	7.675e-16	6.452e-16	-15.115	-15.190	-0.075	(0)
HCrO4-	5.016e-16	4.216e-16	-15.300	-15.375	-0.075	(0)
KCrO4-	6.217e-17	5.226e-17	-16.206	-16.282	-0.075	(0)
H2CrO4	2.641e-24	2.641e-24	-23.578	-23.578	0.000	(0)
CrO3SO4-2	2.246e-24	1.121e-24	-23.649	-23.950	-0.302	(0)
CrO3Cl-	3.198e-26	2.688e-26	-25.495	-25.571	-0.075	(0)
Cr2O7-2	1.235e-29	6.167e-30	-28.908	-29.210	-0.302	(0)
Cu(1)	5.667e-10					
CuCl	2.781e-10	2.781e-10	-9.556	-9.556	0.000	(0)
Cu+	2.004e-10	1.685e-10	-9.698	-9.774	-0.075	(0)
CuCl2-	8.811e-11	7.619e-11	-10.055	-10.118	-0.063	(0)
CuCl3-2	3.735e-14	2.136e-14	-13.428	-13.670	-0.243	(0)
Cu(2)	1.137e-06					
CuCO3	8.949e-07	8.949e-07	-6.048	-6.048	0.000	(0)
Cu(CO3)2-2	2.132e-07	1.064e-07	-6.671	-6.973	-0.302	(0)
CuOH+	1.639e-08	1.417e-08	-7.786	-7.849	-0.063	(0)
Cu+2	6.108e-09	3.440e-09	-8.214	-8.464	-0.249	(0)
Cu(OH)2	3.682e-09	3.682e-09	-8.434	-8.434	0.000	(0)
CuHCO3+	1.880e-09	1.580e-09	-8.726	-8.801	-0.075	(0)
CuSO4	8.901e-10	8.901e-10	-9.051	-9.051	0.000	(0)
Cu(OH)3-	1.170e-11	9.838e-12	-10.932	-11.007	-0.075	(0)
CuF+	1.037e-11	8.719e-12	-10.984	-11.060	-0.075	(0)
Cu2(OH)2+2	1.010e-11	5.042e-12	-10.996	-11.297	-0.302	(0)
CuCl+	8.267e-12	7.148e-12	-11.083	-11.146	-0.063	(0)
CuCl2	3.250e-15	3.250e-15	-14.488	-14.488	0.000	(0)
Cu(OH)4-2	2.020e-16	1.009e-16	-15.695	-15.996	-0.302	(0)
CuCl3-	4.600e-20	3.977e-20	-19.337	-19.400	-0.063	(0)
CuCl4-2	4.571e-25	2.614e-25	-24.340	-24.583	-0.243	(0)
F	5.247e-05					
F-	4.638e-05	4.018e-05	-4.334	-4.396	-0.062	(0)
MgF+	5.327e-06	4.620e-06	-5.273	-5.335	-0.062	(0)
CaF+	5.668e-07	4.929e-07	-6.247	-6.307	-0.061	(0)
NaF	1.952e-07	1.952e-07	-6.710	-6.710	0.000	(0)
MnF+	1.261e-09	1.097e-09	-8.899	-8.960	-0.061	(0)
ZnF+	5.815e-10	4.888e-10	-9.235	-9.311	-0.075	(0)
HF	4.592e-10	4.592e-10	-9.338	-9.338	0.000	(0)
BF(OH)3-	2.066e-10	1.770e-10	-9.685	-9.752	-0.067	(0)
CoF+	2.714e-11	2.281e-11	-10.566	-10.642	-0.075	(0)
NiF+	2.418e-11	2.032e-11	-10.617	-10.692	-0.075	(0)
CdF+	1.569e-11	1.319e-11	-10.804	-10.880	-0.075	(0)
CuF+	1.037e-11	8.719e-12	-10.984	-11.060	-0.075	(0)
PbF+	4.323e-12	3.634e-12	-11.364	-11.440	-0.075	(0)
AlF2+	3.188e-12	2.778e-12	-11.496	-11.556	-0.060	(0)
AlF3	1.405e-12	1.405e-12	-11.852	-11.852	0.000	(0)
AlF+2	3.012e-13	1.737e-13	-12.521	-12.760	-0.239	(0)
CrF+2	2.411e-13	1.204e-13	-12.618	-12.920	-0.302	(0)
HF2-	8.135e-14	7.013e-14	-13.090	-13.154	-0.064	(0)
AlF4-	3.263e-14	2.829e-14	-13.486	-13.548	-0.062	(0)
BF2(OH)2-	6.859e-15	5.875e-15	-14.164	-14.231	-0.067	(0)
PbF2	2.873e-15	2.873e-15	-14.542	-14.542	0.000	(0)
CdF2	1.057e-15	1.057e-15	-14.976	-14.976	0.000	(0)
FeF+2	2.216e-16	1.267e-16	-15.654	-15.897	-0.243	(0)
FeF2+	1.567e-16	1.363e-16	-15.805	-15.866	-0.061	(0)
UO2F+	3.898e-17	3.276e-17	-16.409	-16.485	-0.075	(0)
FeF3	7.724e-18	7.724e-18	-17.112	-17.112	0.000	(0)
UO2F2	3.796e-18	3.796e-18	-17.421	-17.421	0.000	(0)
VO2F	2.153e-18	2.153e-18	-17.667	-17.667	0.000	(0)
H2F2	5.648e-19	5.648e-19	-18.248	-18.248	0.000	(0)
PbF3-	2.604e-19	2.189e-19	-18.584	-18.660	-0.075	(0)
UO2F3-	4.558e-20	3.831e-20	-19.341	-19.417	-0.075	(0)
VO2F2-	3.736e-20	3.140e-20	-19.428	-19.503	-0.075	(0)
VOF+	4.184e-21	3.517e-21	-20.378	-20.454	-0.075	(0)
BF3OH-	8.288e-22	7.099e-22	-21.082	-21.149	-0.067	(0)
VOF2	5.299e-23	5.299e-23	-22.276	-22.276	0.000	(0)
VO2F3-2	3.152e-23	1.574e-23	-22.501	-22.803	-0.302	(0)
UO2F4-2	2.449e-23	1.223e-23	-22.611	-22.913	-0.302	(0)
PbF4-2	8.432e-24	4.210e-24	-23.074	-23.376	-0.302	(0)
VOF3-	8.985e-26	7.553e-26	-25.046	-25.122	-0.075	(0)
VO2F4-3	1.485e-27	3.111e-28	-26.828	-27.507	-0.679	(0)
BF4-	1.266e-27	1.085e-27	-26.897	-26.965	-0.067	(0)
VOF4-2	2.453e-29	1.225e-29	-28.610	-28.912	-0.302	(0)
UF3+	1.064e-40	0.000e+00	-39.973	-40.048	-0.075	(0)
UF2+2	0.000e+00	0.000e+00	-40.551	-40.852	-0.302	(0)
UF4	0.000e+00	0.000e+00	-42.404	-42.404	0.000	(0)
UF+3	0.000e+00	0.000e+00	-42.877	-43.556	-0.679	(0)
UF5-	0.000e+00	0.000e+00	-45.127	-45.202	-0.075	(0)
UF6-2	0.000e+00	0.000e+00	-46.817	-47.118	-0.302	(0)
Fe(2)	7.572e-09					
Fe+2	6.204e-09	3.097e-09	-8.207	-8.509	-0.302	(0)
FeSO4	8.588e-10	8.588e-10	-9.066	-9.066	0.000	(0)
FeHCO3+	3.248e-10	2.839e-10	-9.488	-9.547	-0.058	(0)
FeOH+	1.847e-10	1.606e-10	-9.734	-9.794	-0.061	(0)
Fe(OH)2	1.662e-13	1.662e-13	-12.779	-12.779	0.000	(0)
Fe(OH)3-	7.871e-14	6.845e-14	-13.104	-13.165	-0.061	(0)
Fe(3)	3.361e-06					
Fe(OH)3	1.715e-06	1.715e-06	-5.766	-5.766	0.000	(0)
Fe(OH)2+	1.407e-06	1.226e-06	-5.852	-5.911	-0.060	(0)
Fe(OH)4-	2.387e-07	2.081e-07	-6.622	-6.682	-0.060	(0)
FeOH+2	4.231e-12	2.420e-12	-11.374	-11.616	-0.243	(0)
FeF+2	2.216e-16	1.267e-16	-15.654	-15.897	-0.243	(0)
FeF2+	1.567e-16	1.363e-16	-15.805	-15.866	-0.061	(0)
FeSO4+	4.193e-17	3.647e-17	-16.377	-16.438	-0.061	(0)
Fe+3	1.048e-17	2.877e-18	-16.980	-17.541	-0.561	(0)
FeF3	7.724e-18	7.724e-18	-17.112	-17.112	0.000	(0)
Fe(SO4)2-	1.048e-18	8.806e-19	-17.980	-18.055	-0.075	(0)
FeCl+2	1.992e-19	1.139e-19	-18.701	-18.943	-0.243	(0)
Fe2(OH)2+4	3.121e-21	1.939e-22	-20.506	-21.712	-1.207	(0)
FeHSeO3+2	1.304e-21	6.508e-22	-20.885	-21.187	-0.302	(0)
FeCl2+	7.674e-22	6.673e-22	-21.115	-21.176	-0.061	(0)
Fe3(OH)4+5	2.640e-25	3.436e-27	-24.578	-26.464	-1.885	(0)
FeCl3	8.751e-26	8.751e-26	-25.058	-25.058	0.000	(0)
H(0)	8.411e-28					
H2	4.205e-28	4.227e-28	-27.376	-27.374	0.002	(0)
K	9.706e-04					
K+	9.629e-04	8.341e-04	-3.016	-3.079	-0.062	(0)
KSO4-	7.654e-06	6.670e-06	-5.116	-5.176	-0.060	(0)
KCrO4-	6.217e-17	5.226e-17	-16.206	-16.282	-0.075	(0)
Mg	2.163e-03					
Mg+2	1.820e-03	1.025e-03	-2.740	-2.989	-0.249	(0)
MgSO4	2.107e-04	2.107e-04	-3.676	-3.676	0.000	(0)
MgHCO3+	8.833e-05	7.637e-05	-4.054	-4.117	-0.063	(0)
MgCO3	3.767e-05	3.767e-05	-4.424	-4.424	0.000	(0)
MgF+	5.327e-06	4.620e-06	-5.273	-5.335	-0.062	(0)
MgOH+	6.064e-07	5.315e-07	-6.217	-6.275	-0.057	(0)
MgH2BO3+	3.442e-08	2.948e-08	-7.463	-7.530	-0.067	(0)
Mn(2)	1.631e-06					
Mn+2	1.374e-06	6.858e-07	-5.862	-6.164	-0.302	(0)
MnSO4	1.378e-07	1.378e-07	-6.861	-6.861	0.000	(0)
MnHCO3+	1.146e-07	9.965e-08	-6.941	-7.002	-0.061	(0)
MnOH+	2.580e-09	2.244e-09	-8.588	-8.649	-0.061	(0)
MnCl+	1.302e-09	1.132e-09	-8.885	-8.946	-0.061	(0)
MnF+	1.261e-09	1.097e-09	-8.899	-8.960	-0.061	(0)
MnCl2	2.097e-12	2.097e-12	-11.678	-11.678	0.000	(0)
MnSeO4	1.685e-15	1.685e-15	-14.773	-14.773	0.000	(0)
MnCl3-	8.709e-16	7.573e-16	-15.060	-15.121	-0.061	(0)
Mn(OH)3-	2.706e-17	2.353e-17	-16.568	-16.628	-0.061	(0)
Mn(OH)4-2	1.730e-22	9.895e-23	-21.762	-22.005	-0.243	(0)
MnSe	4.834e-39	4.834e-39	-38.316	-38.316	0.000	(0)
Mn(3)	1.115e-27					
Mn+3	1.115e-27	3.063e-28	-26.953	-27.514	-0.561	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-43.448	-43.691	-0.243	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-48.997	-49.063	-0.066	(0)
Mo	1.148e-07					
MoO4-2	1.148e-07	6.463e-08	-6.940	-7.190	-0.249	(0)
HMoO4-	1.182e-11	9.937e-12	-10.927	-11.003	-0.075	(0)
H2MoO4	5.624e-16	5.624e-16	-15.250	-15.250	0.000	(0)
AlMo6O21-3	0.000e+00	0.000e+00	-51.502	-52.180	-0.679	(0)
Mo7O24-6	0.000e+00	0.000e+00	-59.517	-62.232	-2.715	(0)
HMo7O24-5	0.000e+00	0.000e+00	-62.072	-63.957	-1.885	(0)
H2Mo7O24-4	0.000e+00	0.000e+00	-66.080	-67.287	-1.207	(0)
H3Mo7O24-3	0.000e+00	0.000e+00	-71.474	-72.153	-0.679	(0)
Na	8.980e-03					
Na+	8.888e-03	7.699e-03	-2.051	-2.114	-0.062	(0)
NaSO4-	5.359e-05	4.670e-05	-4.271	-4.331	-0.060	(0)
NaHCO3	3.153e-05	3.153e-05	-4.501	-4.501	0.000	(0)
NaCO3-	7.269e-06	6.334e-06	-5.139	-5.198	-0.060	(0)
NaF	1.952e-07	1.952e-07	-6.710	-6.710	0.000	(0)
NaH2BO3	1.012e-08	1.012e-08	-7.995	-7.995	0.000	(0)
NaCrO4-	7.675e-16	6.452e-16	-15.115	-15.190	-0.075	(0)
Ni	9.554e-08					
Ni+2	3.576e-08	2.014e-08	-7.447	-7.696	-0.249	(0)
NiCO3	3.319e-08	3.319e-08	-7.479	-7.479	0.000	(0)
NiHCO3+	2.151e-08	1.808e-08	-7.667	-7.743	-0.075	(0)
NiSO4	4.539e-09	4.539e-09	-8.343	-8.343	0.000	(0)
NiOH+	3.928e-10	3.302e-10	-9.406	-9.481	-0.075	(0)
NiCl+	8.037e-11	6.756e-11	-10.095	-10.170	-0.075	(0)
Ni(OH)2	3.417e-11	3.417e-11	-10.466	-10.466	0.000	(0)
NiF+	2.418e-11	2.032e-11	-10.617	-10.692	-0.075	(0)
Ni(SO4)2-2	3.400e-13	1.698e-13	-12.468	-12.770	-0.302	(0)
Ni(OH)3-	5.295e-14	4.451e-14	-13.276	-13.352	-0.075	(0)
NiCl2	4.461e-16	4.461e-16	-15.351	-15.351	0.000	(0)
NiSeO4	8.596e-17	8.596e-17	-16.066	-16.066	0.000	(0)
O(0)	5.641e-38					
O2	2.821e-38	2.835e-38	-37.550	-37.547	0.002	(0)
Pb	2.305e-07					
PbCO3	1.705e-07	1.705e-07	-6.768	-6.768	0.000	(0)
Pb(CO3)2-2	4.351e-08	2.172e-08	-7.361	-7.663	-0.302	(0)
PbHCO3+	8.262e-09	6.945e-09	-8.083	-8.158	-0.075	(0)
PbOH+	4.996e-09	4.200e-09	-8.301	-8.377	-0.075	(0)
Pb+2	2.280e-09	1.284e-09	-8.642	-8.892	-0.249	(0)
PbSO4	7.101e-10	7.101e-10	-9.149	-9.149	0.000	(0)
Pb(OH)2	1.730e-10	1.730e-10	-9.762	-9.762	0.000	(0)
PbCl+	7.104e-11	5.972e-11	-10.148	-10.224	-0.075	(0)
Pb(SO4)2-2	9.681e-12	4.833e-12	-11.014	-11.316	-0.302	(0)
PbF+	4.323e-12	3.634e-12	-11.364	-11.440	-0.075	(0)
PbCl2	3.498e-13	3.498e-13	-12.456	-12.456	0.000	(0)
Pb(OH)3-	2.681e-13	2.253e-13	-12.572	-12.647	-0.075	(0)
PbF2	2.873e-15	2.873e-15	-14.542	-14.542	0.000	(0)
Pb2OH+3	4.078e-16	8.543e-17	-15.390	-16.068	-0.679	(0)
PbCl3-	2.172e-16	1.826e-16	-15.663	-15.739	-0.075	(0)
Pb(OH)4-2	1.440e-16	7.188e-17	-15.842	-16.143	-0.302	(0)
Pb3(OH)4+2	1.535e-18	7.664e-19	-17.814	-18.116	-0.302	(0)
PbF3-	2.604e-19	2.189e-19	-18.584	-18.660	-0.075	(0)
PbCl4-2	2.192e-19	1.094e-19	-18.659	-18.961	-0.302	(0)
Pb4(OH)4+4	1.258e-22	7.813e-24	-21.900	-23.107	-1.207	(0)
PbF4-2	8.432e-24	4.210e-24	-23.074	-23.376	-0.302	(0)
S(6)	2.569e-03					
SO4-2	2.006e-03	1.130e-03	-2.698	-2.947	-0.249	(0)
CaSO4	2.909e-04	2.909e-04	-3.536	-3.536	0.000	(0)
MgSO4	2.107e-04	2.107e-04	-3.676	-3.676	0.000	(0)
NaSO4-	5.359e-05	4.670e-05	-4.271	-4.331	-0.060	(0)
KSO4-	7.654e-06	6.670e-06	-5.116	-5.176	-0.060	(0)
ZnSO4	1.507e-07	1.507e-07	-6.822	-6.822	0.000	(0)
MnSO4	1.378e-07	1.378e-07	-6.861	-6.861	0.000	(0)
CdSO4	5.485e-09	5.485e-09	-8.261	-8.261	0.000	(0)
NiSO4	4.539e-09	4.539e-09	-8.343	-8.343	0.000	(0)
CoSO4	4.047e-09	4.047e-09	-8.393	-8.393	0.000	(0)
Zn(SO4)2-2	2.970e-09	1.483e-09	-8.527	-8.829	-0.302	(0)
HSO4-	9.836e-10	8.529e-10	-9.007	-9.069	-0.062	(0)
CuSO4	8.901e-10	8.901e-10	-9.051	-9.051	0.000	(0)
FeSO4	8.588e-10	8.588e-10	-9.066	-9.066	0.000	(0)
PbSO4	7.101e-10	7.101e-10	-9.149	-9.149	0.000	(0)
Cd(SO4)2-2	1.674e-10	8.357e-11	-9.776	-10.078	-0.302	(0)
CrOHSO4	1.444e-10	1.444e-10	-9.840	-9.840	0.000	(0)
Pb(SO4)2-2	9.681e-12	4.833e-12	-11.014	-11.316	-0.302	(0)
Ni(SO4)2-2	3.400e-13	1.698e-13	-12.468	-12.770	-0.302	(0)
CrSO4+	5.931e-14	4.986e-14	-13.227	-13.302	-0.075	(0)
AlSO4+	4.372e-15	3.791e-15	-14.359	-14.421	-0.062	(0)
Al(SO4)2-	5.291e-17	4.589e-17	-16.276	-16.338	-0.062	(0)
FeSO4+	4.193e-17	3.647e-17	-16.377	-16.438	-0.061	(0)
Cr2(OH)2SO4+2	1.408e-17	7.030e-18	-16.851	-17.153	-0.302	(0)
UO2SO4	1.010e-17	1.010e-17	-16.996	-16.996	0.000	(0)
Fe(SO4)2-	1.048e-18	8.806e-19	-17.980	-18.055	-0.075	(0)
VO2SO4-	9.804e-19	8.241e-19	-18.009	-18.084	-0.075	(0)
Cr2(OH)2(SO4)2	4.717e-19	4.717e-19	-18.326	-18.326	0.000	(0)
UO2(SO4)2-2	3.013e-19	1.504e-19	-18.521	-18.823	-0.302	(0)
VOSO4	4.541e-21	4.541e-21	-20.343	-20.343	0.000	(0)
CrO3SO4-2	2.246e-24	1.121e-24	-23.649	-23.950	-0.302	(0)
VSO4+	2.747e-35	2.309e-35	-34.561	-34.637	-0.075	(0)
U(SO4)2	0.000e+00	0.000e+00	-43.854	-43.854	0.000	(0)
USO4+2	0.000e+00	0.000e+00	-44.506	-44.807	-0.302	(0)
Se(-2)	1.573e-35					
HSe-	1.572e-35	1.322e-35	-34.803	-34.879	-0.075	(0)
MnSe	4.834e-39	4.834e-39	-38.316	-38.316	0.000	(0)
H2Se	7.927e-40	7.927e-40	-39.101	-39.101	0.000	(0)
Se-2	0.000e+00	0.000e+00	-41.465	-41.767	-0.302	(0)
Se(4)	1.902e-07					
HSeO3-	1.018e-07	8.561e-08	-6.992	-7.067	-0.075	(0)
SeO3-2	8.835e-08	4.411e-08	-7.054	-7.355	-0.302	(0)
H2SeO3	2.822e-13	2.822e-13	-12.549	-12.549	0.000	(0)
Cd(SeO3)2-2	6.652e-17	3.321e-17	-16.177	-16.479	-0.302	(0)
FeHSeO3+2	1.304e-21	6.508e-22	-20.885	-21.187	-0.302	(0)
Se(6)	1.621e-11					
SeO4-2	1.621e-11	9.127e-12	-10.790	-11.040	-0.249	(0)
MnSeO4	1.685e-15	1.685e-15	-14.773	-14.773	0.000	(0)
ZnSeO4	8.620e-16	8.620e-16	-15.064	-15.064	0.000	(0)
NiSeO4	8.596e-17	8.596e-17	-16.066	-16.066	0.000	(0)
CoSeO4	8.214e-17	8.214e-17	-16.085	-16.085	0.000	(0)
CdSeO4	3.520e-17	3.520e-17	-16.453	-16.453	0.000	(0)
HSeO4-	4.205e-18	3.534e-18	-17.376	-17.452	-0.075	(0)
Zn(SeO4)2-2	1.598e-26	7.977e-27	-25.796	-26.098	-0.302	(0)
U(3)	0.000e+00					
U+3	0.000e+00	0.000e+00	-60.577	-61.256	-0.679	(0)
U(4)	1.133e-21					
U(OH)5-	1.133e-21	9.525e-22	-20.946	-21.021	-0.075	(0)
U(OH)4	3.084e-25	3.084e-25	-24.511	-24.511	0.000	(0)
U(OH)3+	1.037e-29	8.715e-30	-28.984	-29.060	-0.075	(0)
U(OH)2+2	6.239e-35	3.115e-35	-34.205	-34.507	-0.302	(0)
UF3+	1.064e-40	0.000e+00	-39.973	-40.048	-0.075	(0)
UOH+3	0.000e+00	0.000e+00	-40.267	-40.945	-0.679	(0)

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   UF2+2           0.000e+00   0.000e+00   -40.551   -40.852    -0.302     (0)
   UF4             0.000e+00   0.000e+00   -42.404   -42.404     0.000     (0)
   UF+3            0.000e+00   0.000e+00   -42.877   -43.556    -0.679     (0)
   U(SO4)2         0.000e+00   0.000e+00   -43.854   -43.854     0.000     (0)
   USO4+2          0.000e+00   0.000e+00   -44.506   -44.807    -0.302     (0)
   UF5-            0.000e+00   0.000e+00   -45.127   -45.202    -0.075     (0)
   UF6-2           0.000e+00   0.000e+00   -46.817   -47.118    -0.302     (0)
   U+4             0.000e+00   0.000e+00   -47.253   -48.460    -1.207     (0)
   UCl+3           0.000e+00   0.000e+00   -48.964   -49.642    -0.679     (0)
   U6(OH)15+9      0.000e+00   0.000e+00  -180.130  -186.239    -6.109     (0)
U(5)          4.284e-19
   UO2+            4.284e-19   3.601e-19   -18.368   -18.444    -0.075     (0)
U(6)          3.449e-08
   UO2(CO3)3-4     3.266e-08   2.029e-09    -7.486    -8.693    -1.207     (0)
   UO2(CO3)2-2     1.835e-09   9.162e-10    -8.736    -9.038    -0.302     (0)
   UO2CO3          1.039e-12   1.039e-12   -11.983   -11.983     0.000     (0)
   UO2OH+          1.153e-15   9.688e-16   -14.938   -15.014    -0.075     (0)
   UO2F+           3.898e-17   3.276e-17   -16.409   -16.485    -0.075     (0)
   UO2+2           1.049e-17   5.908e-18   -16.979   -17.229    -0.249     (0)
   UO2SO4          1.010e-17   1.010e-17   -16.996   -16.996     0.000     (0)
   UO2F2           3.796e-18   3.796e-18   -17.421   -17.421     0.000     (0)
   UO2(SO4)2-2     3.013e-19   1.504e-19   -18.521   -18.823    -0.302     (0)
   UO2F3-          4.558e-20   3.831e-20   -19.341   -19.417    -0.075     (0)
   UO2Cl+          1.495e-20   1.256e-20   -19.825   -19.901    -0.075     (0)
   UO2F4-2         2.449e-23   1.223e-23   -22.611   -22.913    -0.302     (0)
   (UO2)2(OH)2+2   3.120e-24   1.558e-24   -23.506   -23.807    -0.302     (0)
   (UO2)3(OH)5+    2.311e-27   1.942e-27   -26.636   -26.712    -0.075     (0)
V(2)          0.000e+00
   VOH+            0.000e+00   0.000e+00   -40.973   -41.049    -0.075     (0)
   V+2             0.000e+00   0.000e+00   -42.372   -42.674    -0.302     (0)
V(3)          7.719e-14
   V(OH)3          7.719e-14   7.719e-14   -13.112   -13.112     0.000     (0)
   V(OH)2+         4.586e-25   3.855e-25   -24.339   -24.414    -0.075     (0)
   VOH+2           5.661e-29   2.827e-29   -28.247   -28.549    -0.302     (0)
   V+3             2.066e-34   4.330e-35   -33.685   -34.364    -0.679     (0)
   VSO4+           2.747e-35   2.309e-35   -34.561   -34.637    -0.075     (0)
   V2(OH)3+3       0.000e+00   0.000e+00   -53.832   -54.511    -0.679     (0)
   V2(OH)2+4       0.000e+00   0.000e+00   -55.091   -56.297    -1.207     (0)
V(4)          4.549e-18
   V(OH)3+         4.511e-18   3.792e-18   -17.346   -17.421    -0.075     (0)
   VO+2            2.924e-20   1.460e-20   -19.534   -19.836    -0.302     (0)
   VOSO4           4.541e-21   4.541e-21   -20.343   -20.343     0.000     (0)
   VOF+            4.184e-21   3.517e-21   -20.378   -20.454    -0.075     (0)
   VOCl+           6.388e-23   5.370e-23   -22.195   -22.270    -0.075     (0)
   VOF2            5.299e-23   5.299e-23   -22.276   -22.276     0.000     (0)
   VOF3-           8.985e-26   7.553e-26   -25.046   -25.122    -0.075     (0)
   VOF4-2          2.453e-29   1.225e-29   -28.610   -28.912    -0.302     (0)
   H2V2O4+2        1.445e-30   7.213e-31   -29.840   -30.142    -0.302     (0)
V(5)          4.717e-08
   H2VO4-          3.048e-08   2.562e-08    -7.516    -7.591    -0.075     (0)
   HVO4-2          1.669e-08   8.330e-09    -7.778    -8.079    -0.302     (0)
   H3VO4           1.980e-12   1.980e-12   -11.703   -11.703     0.000     (0)
   H3V2O7-         3.899e-13   3.277e-13   -12.409   -12.484    -0.075     (0)
   HV2O7-3         3.454e-13   7.236e-14   -12.462   -13.140    -0.679     (0)
   VO4-3           2.579e-14   5.403e-15   -13.589   -14.267    -0.679     (0)
   V2O7-4          4.057e-15   2.521e-16   -14.392   -15.598    -1.207     (0)
   V3O9-3          8.421e-17   1.764e-17   -16.075   -16.753    -0.679     (0)
   VO2+            3.527e-17   3.055e-17   -16.453   -16.515    -0.062     (0)
   VO2F            2.153e-18   2.153e-18   -17.667   -17.667     0.000     (0)
   VO2SO4-         9.804e-19   8.241e-19   -18.009   -18.084    -0.075     (0)
   VO2F2-          3.736e-20   3.140e-20   -19.428   -19.503    -0.075     (0)
   V4O12-4         3.035e-21   1.885e-22   -20.518   -21.725    -1.207     (0)
   VO2F3-2         3.152e-23   1.574e-23   -22.501   -22.803    -0.302     (0)
   VO2F4-3         1.485e-27   3.111e-28   -26.828   -27.507    -0.679     (0)
   V10O28-6        0.000e+00   0.000e+00   -56.738   -59.453    -2.715     (0)
   HV10O28-5       0.000e+00   0.000e+00   -57.493   -59.379    -1.885     (0)
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   H2V10O28-4      0.000e+00   0.000e+00   -61.076   -62.283    -1.207     (0)
Zn            3.072e-06
   ZnCO3           1.550e-06   1.550e-06    -5.810    -5.810     0.000     (0)
   Zn+2            1.083e-06   6.098e-07    -5.965    -6.215    -0.249     (0)
   ZnHCO3+         1.671e-07   1.404e-07    -6.777    -6.853    -0.075     (0)
   ZnSO4           1.507e-07   1.507e-07    -6.822    -6.822     0.000     (0)
   ZnOH+           9.450e-08   7.943e-08    -7.025    -7.100    -0.075     (0)
   Zn(OH)2         1.640e-08   1.640e-08    -7.785    -7.785     0.000     (0)
   ZnOHCl          3.425e-09   3.425e-09    -8.465    -8.465     0.000     (0)
   Zn(SO4)2-2      2.970e-09   1.483e-09    -8.527    -8.829    -0.302     (0)
   ZnCl+           2.323e-09   2.009e-09    -8.634    -8.697    -0.063     (0)
   ZnF+            5.815e-10   4.888e-10    -9.235    -9.311    -0.075     (0)
   Zn(OH)3-        1.274e-10   1.071e-10    -9.895    -9.970    -0.075     (0)
   ZnCl2           4.174e-12   4.174e-12   -11.379   -11.379     0.000     (0)
   Zn(OH)4-2       1.112e-14   5.551e-15   -13.954   -14.256    -0.302     (0)
   ZnCl3-          5.028e-15   4.348e-15   -14.299   -14.362    -0.063     (0)
   ZnSeO4          8.620e-16   8.620e-16   -15.064   -15.064     0.000     (0)
   ZnCl4-2         4.986e-18   2.851e-18   -17.302   -17.545    -0.243     (0)
   Zn(SeO4)2-2     1.598e-26   7.977e-27   -25.796   -26.098    -0.302     (0)

----------------------------Saturation indices----------------------------

   Phase               SI** log IAP   log K(298 K,   1 atm)

   Al(OH)3(am)      -1.83      8.97   10.80  Al(OH)3
   Al2(MoO4)3      -54.66    -52.30    2.37  Al2(MoO4)3
   Al2O3            -1.71     17.94   19.65  Al2O3
   Al4(OH)10SO4     -5.99     16.71   22.70  Al4(OH)10SO4
   AlAsO4:2H2O     -10.62     -5.82    4.80  AlAsO4:2H2O
   AlOHSO4          -6.97    -10.20   -3.23  AlOHSO4
   Alunite          -4.99     -6.39   -1.40  KAl3(SO4)2(OH)6
   Anglesite        -4.05    -11.84   -7.79  PbSO4
   Anhydrite        -1.54     -5.90   -4.36  CaSO4
   Antlerite        -4.68      4.11    8.79  Cu3(OH)4SO4
   Aragonite         1.00     -7.30   -8.30  CaCO3
   Arsenolite      -77.69    -80.45   -2.76  As4O6
   Artinite         -3.71      5.89    9.60  MgCO3:Mg(OH)2:3H2O
   As2O5           -36.28    -29.57    6.71  As2O5
   Atacamite        -2.86      4.53    7.39  Cu2(OH)3Cl
   Azurite          -0.97    -17.88  -16.91  Cu3(OH)2(CO3)2
   Ba(OH)2:8H2O    -14.33     10.07   24.39  Ba(OH)2:8H2O
   Ba2V2O7:2H2O    -12.54      3.33   15.87  Ba2V2O7:2H2O
   Ba3(AsO4)2        9.54      0.63   -8.91  Ba3(AsO4)2
   Ba3(VO4)2:4H2O  -19.54     13.40   32.94  Ba3(VO4)2:4H2O
   BaCrO4          -10.26    -19.93   -9.67  BaCrO4
   BaF2             -9.13    -14.95   -5.82  BaF2
   BaMoO4           -6.39    -13.35   -6.96  BaMoO4
   Barite            0.88     -9.10   -9.98  BaSO4
   BaSeO3           -6.94     -5.11    1.83  BaSeO3
   BaSeO4           -9.74    -17.20   -7.46  BaSeO4
   Bianchite        -7.40     -9.16   -1.76  ZnSO4:6H2O
   Birnessite       -9.16      8.93   18.09  MnO2
   Bixbyite         -5.71     -6.36   -0.64  Mn2O3
   Boehmite          0.39      8.97    8.58  AlOOH
   Brochantite      -3.35     11.87   15.22  Cu4(OH)6SO4
   Brucite          -3.61     13.23   16.84  Mg(OH)2
   Bunsenite        -3.92      8.53   12.45  NiO
   Ca(VO3)2         -9.19     -3.53    5.66  Ca(VO3)2
   Ca2V2O7          -7.76      9.74   17.50  Ca2V2O7
   Ca2V2O7:2H2O    -11.81      9.74   21.55  Ca2V2O7:2H2O
   Ca3(AsO4)2:4H2O -12.05     10.25   22.30  Ca3(AsO4)2:4H2O
   Ca3(VO4)2       -15.94     23.02   38.96  Ca3(VO4)2
   Ca3(VO4)2:4H2O  -16.84     23.02   39.86  Ca3(VO4)2:4H2O
   CaCrO4          -14.46    -16.72   -2.27  CaCrO4
   Calcite           1.18     -7.30   -8.48  CaCO3
   CaMoO4           -2.19    -10.14   -7.95  CaMoO4
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   Carnotite        -4.60     -4.37    0.23  KUO2VO4
   CaSeO3:2H2O      -4.72     -1.91    2.81  CaSeO3:2H2O
   CaSeO4:2H2O     -10.97    -13.99   -3.02  CaSeO4:2H2O
   Cd(BO2)2        -11.21     -1.37    9.84  Cd(BO2)2
   Cd(OH)2          -5.10      8.54   13.64  Cd(OH)2
   Cd(OH)2(am)      -5.19      8.54   13.73  Cd(OH)2
   Cd3(OH)2(SO4)2  -19.43    -12.72    6.71  Cd3(OH)2(SO4)2
   Cd3(OH)4SO4     -16.11      6.45   22.56  Cd3(OH)4SO4
   Cd4(OH)6SO4     -13.41     14.99   28.40  Cd4(OH)6SO4
   CdCl2           -12.79    -13.45   -0.66  CdCl2
   CdCl2:1H2O      -11.76    -13.45   -1.69  CdCl2:1H2O
   CdCl2:2.5H2O    -11.54    -13.45   -1.91  CdCl2:2.5H2O
   CdF2            -15.26    -16.48   -1.21  CdF2
   Cdmetal(alpha)  -29.20    -15.68   13.51  Cd
   Cdmetal(gamma)  -29.30    -15.68   13.62  Cd
   CdMoO4           -0.72    -14.87  -14.15  CdMoO4
   CdOHCl           -5.99     -2.45    3.54  CdOHCl
   CdSe            -14.25    -34.45  -20.20  CdSe
   CdSeO4:2H2O     -16.87    -18.72   -1.85  CdSeO4:2H2O
   CdSO4           -10.46    -10.63   -0.17  CdSO4
   CdSO4:1H2O       -8.90    -10.63   -1.73  CdSO4:1H2O
   CdSO4:2.67H2O    -8.76    -10.63   -1.87  CdSO4:2.67H2O
   Cerussite        -0.12    -13.25  -13.13  PbCO3
   CH4(g)          -76.43   -117.47  -41.05  CH4
   Chalcanthite     -8.77    -11.41   -2.64  CuSO4:5H2O
   Claudetite      -77.38    -80.45   -3.06  As4O6
   Clausthalite     -8.56    -35.66  -27.10  PbSe
   Co(BO2)2        -28.51     -1.44   27.07  Co(BO2)2
   Co(OH)2          -4.62      8.48   13.09  Co(OH)2
   Co(OH)3          -9.50    -11.81   -2.31  Co(OH)3
   CO2(g)           -2.43    -20.58  -18.15  CO2
   Co3(AsO4)2      -17.17     -4.14   13.03  Co3(AsO4)2
   Co3O4            -4.65    -15.14  -10.50  Co3O4
   CoCl2           -21.78    -13.51    8.27  CoCl2
   CoCl2:6H2O      -16.05    -13.51    2.54  CoCl2:6H2O
   CoCO3            -2.12    -12.10   -9.98  CoCO3
   CoF2            -14.94    -16.54   -1.60  CoF2
   CoF3            -47.88    -49.33   -1.46  CoF3
   CoFe2O4          25.60     22.07   -3.53  CoFe2O4
   CoMoO4           -7.17    -14.94   -7.76  CoMoO4
   CoO              -5.11      8.48   13.59  CoO
   CoSe            -18.31    -34.51  -16.20  CoSe
   CoSeO3           -8.02     -6.70    1.32  CoSeO3
   CoSeO4:6H2O     -17.26    -18.79   -1.53  CoSeO4:6H2O
   CoSO4           -13.50    -10.69    2.80  CoSO4
   CoSO4:6H2O       -8.22    -10.69   -2.47  CoSO4:6H2O
   Cotunnite        -9.88    -14.66   -4.78  PbCl2
   Cr(OH)2         -18.94     -8.12   10.82  Cr(OH)2
   Cr(OH)3          -0.29      1.04    1.34  Cr(OH)3
   Cr(OH)3(am)       1.79      1.04   -0.75  Cr(OH)3
   Cr2O3             4.44      2.09   -2.36  Cr2O3
   CrCl2           -44.20    -30.11   14.09  CrCl2
   CrCl3           -47.05    -31.94   15.11  CrCl3
   CrF3            -25.14    -36.48  -11.34  CrF3
   Crmetal         -62.83    -32.35   30.48  Cr
   CrO3            -26.79    -30.00   -3.21  CrO3
   Cryolite        -14.24    -48.08  -33.84  Na3AlF6
   Cu(OH)2          -0.91      7.76    8.67  Cu(OH)2
   Cu2Se(alpha)     -0.51    -46.31  -45.80  Cu2Se
   Cu2SO4          -20.54    -22.49   -1.95  Cu2SO4
   Cu3(AsO4)2:2H2O -12.39     -6.29    6.10  Cu3(AsO4)2:2H2O
   Cu3Se2          -18.05    -81.54  -63.49  Cu3Se2
   CuCO3            -1.32    -12.82  -11.50  CuCO3
   CuCrO4          -16.80    -22.24   -5.44  CuCrO4
   CuF              -9.26    -14.17   -4.91  CuF
   CuF2            -18.37    -17.26    1.12  CuF2
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   CuF2:2H2O       -12.71    -17.26   -4.55  CuF2:2H2O
   Cumetal          -5.02    -13.77   -8.76  Cu
   CuMoO4           -2.58    -15.65  -13.08  CuMoO4
   CuOCuSO4        -13.95     -3.65   10.30  CuOCuSO4
   Cupricferrite    15.36     21.35    5.99  CuFe2O4
   Cuprite          -1.92     -3.32   -1.41  Cu2O
   Cuprousferrite   14.05      5.13   -8.92  CuFeO2
   CuSe             -2.13    -35.23  -33.10  CuSe
   CuSe2           -20.63    -54.00  -33.37  CuSe2
   CuSeO3:2H2O      -7.93     -7.42    0.51  CuSeO3:2H2O
   CuSeO4:5H2O     -17.06    -19.50   -2.44  CuSeO4:5H2O
   CuSO4           -14.35    -11.41    2.94  CuSO4
   Diaspore          2.10      8.97    6.87  AlOOH
   Dolomite(disordered)   1.89    -14.65  -16.54  CaMg(CO3)2
   Dolomite(ordered)   2.44    -14.65  -17.09  CaMg(CO3)2
   Epsomite         -3.81     -5.94   -2.13  MgSO4:7H2O
   Fe(OH)2          -5.85      7.71   13.56  Fe(OH)2
   Fe(OH)2.7Cl.3     6.54      3.50   -3.04  Fe(OH)2.7Cl.3
   Fe(VO3)2         -5.37     -9.09   -3.72  Fe(VO3)2
   Fe2(OH)4SeO3     -3.14     -1.59    1.55  Fe2(OH)4SeO3
   Fe2(SeO3)3:2H2O -11.32    -31.95  -20.63  Fe2(SeO3)3:2H2O
   Fe2(SO4)3       -40.19    -43.92   -3.73  Fe2(SO4)3
   Fe3(OH)8          1.08     21.30   20.22  Fe3(OH)8
   FeAsO4:2H2O      -8.39     -7.99    0.40  FeAsO4:2H2O
   FeCr2O4           2.60      9.80    7.20  FeCr2O4
   FeMoO4           -5.61    -15.70  -10.09  FeMoO4
   Ferrihydrite      3.60      6.79    3.19  Fe(OH)3
   Ferroselite     -35.45    -54.04  -18.60  FeSe2
   FeSe            -24.28    -35.28  -11.00  FeSe
   Fluorite         -1.24    -11.74  -10.50  CaF2
   Gibbsite          0.68      8.97    8.29  Al(OH)3
   Goethite          6.30      6.79    0.49  FeOOH
   Goslarite        -7.15     -9.16   -2.01  ZnSO4:7H2O
   Gummite          -8.68     -1.00    7.67  UO3
   Gypsum           -1.29     -5.90   -4.61  CaSO4:2H2O
   H-Jarosite       -5.86    -17.96  -12.10  (H3O)Fe3(SO4)2(OH)6
   H2MoO4          -10.54    -23.41  -12.88  H2MoO4
   H2Se(g)         -38.03    -42.99   -4.96  H2Se
   Halite           -6.60     -5.00    1.60  NaCl
   Hausmannite      -6.63     54.40   61.03  Mn3O4
   Hematite         15.01     13.59   -1.42  Fe2O3
   Hercynite         2.76     25.66   22.89  FeAl2O4
   Huntite           0.63    -29.34  -29.97  CaMg3(CO3)4
   Hydrocerussite   -0.39    -19.16  -18.77  Pb3(OH)2(CO3)2
   Hydromagnesite   -7.38    -16.14   -8.77  Mg5(CO3)4(OH)2:4H2O
   K-Alum          -19.17    -24.34   -5.17  KAl(SO4)2:12H2O
   K-Jarosite        1.87    -12.93  -14.80  KFe3(SO4)2(OH)6
   K2Cr2O7         -32.69    -49.93  -17.24  K2Cr2O7
   K2CrO4          -19.42    -19.93   -0.51  K2CrO4
   K2MoO4          -16.61    -13.35    3.26  K2MoO4
   K2SeO4          -16.47    -17.20   -0.73  K2SeO4
   Langite          -5.62     11.87   17.49  Cu4(OH)6SO4:H2O
   Larnakite        -4.07     -4.51   -0.43  PbO:PbSO4
   Laurionite       -4.29     -3.66    0.62  PbOHCl
   Lepidocrocite     5.42      6.79    1.37  FeOOH
   Lime            -19.42     13.27   32.70  CaO
   Litharge         -5.36      7.33   12.69  PbO
   Maghemite         7.20     13.59    6.39  Fe2O3
   Magnesioferrite   9.96     26.82   16.86  Fe2MgO4
   Magnesite         0.12     -7.34   -7.46  MgCO3
   Magnetite        17.90     21.30    3.40  Fe3O4
   Malachite         0.25     -5.06   -5.31  Cu2(OH)2CO3
   Manganite        -3.17     22.17   25.34  MnOOH
   Massicot         -5.56      7.33   12.89  PbO
   Matlockite       -7.20    -16.17   -8.97  PbClF
   Melanothallite  -20.49    -14.23    6.26  CuCl2
```

Melanterite	-9.25	-11.46	-2.21	FeSO4:7H2O
Mg(OH)2(active)	-5.56	13.23	18.79	Mg(OH)2
Mg(VO3)2	-14.85	-3.57	11.28	Mg(VO3)2
Mg2V2O7	-16.70	9.66	26.36	Mg2V2O7
MgCr2O4	-0.88	15.32	16.20	MgCr2O4
MgCrO4	-22.14	-16.76	5.38	MgCrO4
MgF2	-3.65	-11.78	-8.13	MgF2
MgMoO4	-8.33	-10.18	-1.85	MgMoO4
MgSeO3:6H2O	-5.00	-1.95	3.06	MgSeO3:6H2O
MgSeO4:6H2O	-12.83	-14.03	-1.20	MgSeO4:6H2O
Minium	-27.30	46.22	73.52	Pb3O4
Mirabilite	-6.06	-7.18	-1.11	Na2SO4:10H2O
Mn(VO3)2	-11.65	-6.75	4.90	Mn(VO3)2
Mn2(SO4)3	-58.16	-63.87	-5.71	Mn2(SO4)3
Mn3(AsO4)2:8H2O	-11.89	0.61	12.50	Mn3(AsO4)2:8H2O
MnCl2:4H2O	-14.64	-11.93	2.72	MnCl2:4H2O
MnSe	-36.43	-32.93	3.50	MnSe
MnSeO3	-6.25	-5.12	1.13	MnSeO3
MnSeO3:2H2O	-6.10	-5.12	0.98	MnSeO3:2H2O
MnSeO4:5H2O	-15.15	-17.20	-2.05	MnSeO4:5H2O
MnSO4	-11.69	-9.11	2.58	MnSO4
Monteponite	-6.56	8.54	15.10	CdO
MoO3	-15.41	-23.41	-8.00	MoO3
Morenosite	-8.50	-10.64	-2.14	NiSO4:7H2O
Na-Jarosite	-0.76	-11.96	-11.20	NaFe3(SO4)2(OH)6
Na2Cr2O7	-38.10	-48.00	-9.90	Na2Cr2O7
Na2CrO4	-20.93	-18.00	2.93	Na2CrO4
Na2Mo2O7	-18.23	-34.83	-16.60	Na2Mo2O7
Na2MoO4	-12.91	-11.42	1.49	Na2MoO4
Na2MoO4:2H2O	-12.64	-11.42	1.22	Na2MoO4:2H2O
Na2SeO3:5H2O	-13.48	-3.18	10.30	Na2SeO3:5H2O
Na2SeO4	-16.55	-15.27	1.28	Na2SeO4
Na3VO4	-27.09	9.59	36.68	Na3VO4
Na4V2O7	-30.21	7.19	37.40	Na4V2O7
Nantokite	-5.93	-12.66	-6.73	CuCl
Natron	-7.27	-8.58	-1.31	Na2CO3:10H2O
NaVO3	-6.26	-2.40	3.86	NaVO3
Nesquehonite	-2.67	-7.34	-4.67	MgCO3:3H2O
Ni(OH)2	-4.27	8.53	12.79	Ni(OH)2
Ni3(AsO4)2:8H2O	-19.69	-3.99	15.70	Ni3(AsO4)2:8H2O
Ni4(OH)6SO4	-17.06	14.94	32.00	Ni4(OH)6SO4
NiCO3	-5.18	-12.05	-6.87	NiCO3
NiMoO4	-3.74	-14.89	-11.14	NiMoO4
NiSe	-16.76	-34.46	-17.70	NiSe
NiSeO3:2H2O	-9.47	-6.65	2.81	NiSeO3:2H2O
NiSeO4:6H2O	-17.22	-18.74	-1.52	NiSeO4:6H2O
Nsutite	-8.57	8.93	17.50	MnO2
O2(g)	-34.64	48.45	83.09	O2
Otavite	-0.04	-12.04	-12.00	CdCO3
Pb(BO2)2	-9.10	-2.58	6.52	Pb(BO2)2
Pb(OH)2	-0.82	7.33	8.15	Pb(OH)2
Pb10(OH)6O(CO3)6	-41.39	-50.15	-8.76	Pb10(OH)6O(CO3)6
Pb2(OH)3Cl	-5.12	3.67	8.79	Pb2(OH)3Cl
Pb2O(OH)2	-11.52	14.66	26.19	Pb2O(OH)2
Pb2O3	-22.15	38.89	61.04	Pb2O3
Pb2OCO3	-5.36	-5.91	-0.56	Pb2OCO3
Pb2V2O7	-0.24	-2.14	-1.90	Pb2V2O7
Pb3(AsO4)2	-13.38	-7.58	5.80	Pb3(AsO4)2
Pb3(VO4)2	-0.95	5.19	6.14	Pb3(VO4)2
Pb3O2CO3	-9.60	1.42	11.02	Pb3O2CO3
Pb3O2SO4	-7.86	2.83	10.69	Pb3O2SO4
Pb4(OH)6SO4	-10.94	10.16	21.10	Pb4(OH)6SO4
Pb4O3SO4	-11.72	10.16	21.88	Pb4O3SO4
PbCrO4	-10.06	-22.66	-12.60	PbCrO4
PbF2	-10.24	-17.68	-7.44	PbF2
Pbmetal	-21.14	-16.89	4.25	Pb
PbMoO4	-0.46	-16.08	-15.62	PbMoO4
PbO:0.3H2O	-5.65	7.33	12.98	PbO:0.33H2O
PbSeO4	-13.09	-19.93	-6.84	PbSeO4
Periclase	-8.35	13.23	21.58	MgO
Phosgenite	-8.09	-27.90	-19.81	PbCl2:PbCO3
Plattnerite	-18.04	31.56	49.60	PbO2
Portlandite	-9.53	13.27	22.80	Ca(OH)2
Pyrochroite	-5.13	10.06	15.19	Mn(OH)2
Pyrolusite	-7.10	34.28	41.38	MnO2
Retgersite	-8.60	-10.64	-2.04	NiSO4:6H2O
Rhodochrosite	0.06	-10.52	-10.58	MnCO3
Rutherfordine	-7.08	-21.58	-14.50	UO2CO3
Schoepite	-7.00	-1.01	5.99	UO2(OH)2:H2O
Semetal(am)	-11.66	-18.77	-7.11	Se
Semetal(hex	-11.06	-18.77	-7.71	Se
SeO2	-15.30	-15.18	0.12	SeO2
SeO3	-48.31	-27.26	21.04	SeO3
Siderite	-2.62	-12.86	-10.24	FeCO3
Smithsonite	-0.57	-10.57	-10.00	ZnCO3
Spinel	-5.67	31.18	36.85	MgAl2O4
Tenorite	0.12	7.76	7.64	CuO
Thenardite	-7.50	-7.17	0.32	Na2SO4
Thermonatrite	-9.22	-8.58	0.64	Na2CO3:H2O
Tyuyamunite	-9.62	-5.54	4.08	Ca(UO2)2(VO4)2
U3O8	-20.67	0.41	21.08	U3O8
U4O9	-36.81	-39.83	-3.02	U4O9
UF4	-36.51	-66.04	-29.54	UF4
UF4:2.5H2O	-33.33	-66.04	-32.72	UF4:2.5H2O
UO2(am)	-16.95	-16.01	0.93	UO2
UO2(OH)2(beta)	-6.62	-1.00	5.61	UO2(OH)2
UO2SeO4:4H2O	-26.02	-28.27	-2.25	UO2SeO4:4H2O
UO3	-8.70	-1.00	7.70	UO3
Uraninite	-11.34	-16.01	-4.67	UO2
V(OH)3	-17.62	-10.03	7.59	V(OH)3
V2O5	-15.45	-16.81	-1.36	V2O5
V3O5	-36.90	-35.06	1.84	V3O5
V4O7	-45.86	-38.67	7.19	V4O7
V6O13	-38.01	-98.87	-60.86	V6O13
VCl2	-63.00	-44.13	18.87	VCl2
VCl3	-66.44	-43.01	23.43	VCl3
VF4	-68.57	-53.64	14.93	VF4
Vmetal	-90.39	-46.36	44.03	V
VO	-36.90	-22.14	14.76	VO
VO(OH)2	-8.76	-3.61	5.15	VO(OH)2
VO2Cl	-22.24	-19.40	2.84	VO2Cl
VOCl	-32.17	-21.02	11.15	VOCl
VOCl2	-38.36	-25.60	12.76	VOCl2
VOSO4	-26.39	-22.78	3.61	VOSO4
Witherite	-1.94	-10.51	-8.57	BaCO3
Zincite	-1.32	10.01	11.33	ZnO
Zincosite	-13.09	-9.16	3.93	ZnSO4
Zn(BO2)2	-8.19	0.10	8.29	Zn(BO2)2
Zn(OH)2	-2.19	10.01	12.20	Zn(OH)2
Zn(OH)2(am)	-2.47	10.01	12.47	Zn(OH)2
Zn(OH)2(beta)	-1.75	10.01	11.75	Zn(OH)2
Zn(OH)2(epsilon)	-1.53	10.01	11.53	Zn(OH)2
Zn(OH)2(gamma)	-1.73	10.01	11.73	Zn(OH)2
Zn2(OH)2SO4	-6.65	0.85	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-6.17	9.02	15.19	Zn2(OH)3Cl
Zn3(AsO4)2:2.5H2O	-13.20	0.45	13.65	Zn3(AsO4)2:2.5H2O
Zn3O(SO4)2	-27.23	-8.31	18.91	Zn3O(SO4)2
Zn4(OH)6SO4	-7.54	20.86	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-10.44	28.06	38.50	Zn5(OH)8Cl2
ZnCl2	-19.03	-11.98	7.05	ZnCl2
ZnCO3:1H2O	-0.31	-10.57	-10.26	ZnCO3:1H2O
ZnF2	-14.47	-15.01	-0.53	ZnF2
Znmetal	-40.00	-14.21	25.79	Zn
ZnMoO4	-3.28	-13.40	-10.13	ZnMoO4
ZnO(active)	-1.18	10.01	11.19	ZnO
ZnSe	-18.58	-32.98	-14.40	ZnSe
ZnSeO4:6H2O	-15.74	-17.26	-1.52	ZnSeO4:6H2O
ZnSO4:1H2O	-8.52	-9.16	-0.64	ZnSO4:1H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

Initial solution 2. PAF Material

----------Solution composition----------

Elements	Molality	Moles
Al	7.415e-07	7.415e-07
Alkalinity	3.607e-04	3.607e-04
Ba	1.457e-07	1.457e-07
Ca	1.672e-03	1.672e-03
Co	1.188e-07	1.188e-07
Cu	4.408e-07	4.408e-07
F	1.580e-05	1.580e-05
K	3.326e-04	3.326e-04
Mg	3.293e-04	3.293e-04
Mn	7.283e-07	7.283e-07
Mo	3.128e-08	3.128e-08
Na	4.351e-05	4.351e-05
Ni	6.818e-08	6.818e-08
S(6)	2.051e-03	2.051e-03

----------Description of solution----------

```
                                    pH  =   7.500
                                    pe  =   4.000
                     Activity of water  =   1.000
                Ionic strength (mol/kgw)  =   7.200e-03
                     Mass of water (kg)  =   1.000e+00
                 Total carbon (mol/kg)  =   3.782e-04
                    Total CO2 (mol/kg)  =   3.782e-04
                      Temperature (°C)  =  25.00
                Electrical balance (eq)  =  -9.478e-05
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  -1.25
                            Iterations  =  13 (23 overall)
                               Total H  = 1.110141e+02
                               Total O  = 5.551618e+01
```

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
OH-	3.487e-07	3.184e-07	-6.458	-6.497	-0.039	(0)
H+	3.458e-08	3.162e-08	-7.461	-7.500	-0.039	0.00
H2O	5.551e+01	9.999e-01	1.744	-0.000	0.000	18.07
Al	7.415e-07					
Al(OH)4-	7.221e-07	6.609e-07	-6.141	-6.180	-0.038	(0)
Al(OH)3	1.649e-08	1.649e-08	-7.783	-7.783	0.000	(0)
Al(OH)2+	2.830e-09	2.595e-09	-8.548	-8.586	-0.038	(0)
AlF2+	2.736e-11	2.509e-11	-10.563	-10.600	-0.038	(0)
AlOH+2	1.451e-11	1.026e-11	-10.838	-10.989	-0.150	(0)
AlF+2	6.374e-12	4.507e-12	-11.196	-11.346	-0.150	(0)
AlF3	4.418e-12	4.418e-12	-11.355	-11.355	0.000	(0)
AlSO4+	3.315e-13	3.034e-13	-12.480	-12.518	-0.038	(0)
Al+3	7.201e-14	3.223e-14	-13.143	-13.492	-0.349	(0)
AlF4-	3.383e-14	3.096e-14	-13.471	-13.509	-0.038	(0)
Al(SO4)2-	4.307e-15	3.942e-15	-14.366	-14.404	-0.038	(0)
AlMo6O21-3	0.000e+00	0.000e+00	-49.070	-49.460	-0.390	(0)
Ba	1.457e-07					
Ba+2	1.453e-07	1.017e-07	-6.838	-6.993	-0.155	(0)
BaHCO3+	3.363e-10	3.088e-10	-9.473	-9.510	-0.037	(0)
BaCO3	2.459e-11	2.459e-11	-10.609	-10.609	0.000	(0)
BaOH+	1.542e-13	1.413e-13	-12.812	-12.850	-0.038	(0)
C(4)	3.782e-04					
HCO3-	3.469e-04	3.181e-04	-3.460	-3.497	-0.038	(0)
H2CO3	2.262e-05	2.262e-05	-4.645	-4.645	0.000	(0)
CaHCO3+	6.292e-06	5.777e-06	-5.201	-5.238	-0.037	(0)
CaCO3	7.289e-07	7.289e-07	-6.137	-6.137	0.000	(0)
MgHCO3+	7.079e-07	6.472e-07	-6.150	-6.189	-0.039	(0)
CO3-2	6.741e-07	4.716e-07	-6.171	-6.326	-0.155	(0)
CuCO3	2.133e-07	2.133e-07	-6.671	-6.671	0.000	(0)
MgCO3	7.799e-08	7.799e-08	-7.108	-7.108	0.000	(0)
NaHCO3	7.071e-09	7.071e-09	-8.151	-8.151	0.000	(0)
MnHCO3+	2.944e-09	2.697e-09	-8.531	-8.569	-0.038	(0)
CoHCO3+	1.830e-09	1.657e-09	-8.738	-8.781	-0.043	(0)
CuHCO3+	1.703e-09	1.542e-09	-8.769	-8.812	-0.043	(0)
NiHCO3+	1.700e-09	1.539e-09	-8.770	-8.813	-0.043	(0)
NiCO3	6.904e-10	6.904e-10	-9.161	-9.161	0.000	(0)
CoCO3	5.337e-10	5.337e-10	-9.273	-9.273	0.000	(0)
Cu(CO3)2-2	4.033e-10	2.707e-10	-9.394	-9.567	-0.173	(0)
NaCO3-	3.785e-10	3.471e-10	-9.422	-9.460	-0.038	(0)
BaHCO3+	3.363e-10	3.088e-10	-9.473	-9.510	-0.037	(0)
BaCO3	2.459e-11	2.459e-11	-10.609	-10.609	0.000	(0)
Ca	1.672e-03					
Ca+2	1.394e-03	9.753e-04	-2.856	-3.011	-0.155	(0)
CaSO4	2.709e-04	2.709e-04	-3.567	-3.567	0.000	(0)
CaHCO3+	6.292e-06	5.777e-06	-5.201	-5.238	-0.037	(0)
CaCO3	7.289e-07	7.289e-07	-6.137	-6.137	0.000	(0)
CaF+	1.625e-07	1.489e-07	-6.789	-6.827	-0.038	(0)
CaOH+	6.748e-09	6.196e-09	-8.171	-8.208	-0.037	(0)
Co(2)	1.188e-07					
Co+2	9.974e-08	6.695e-08	-7.001	-7.174	-0.173	(0)
CoSO4	1.620e-08	1.620e-08	-7.791	-7.791	0.000	(0)
CoHCO3+	1.830e-09	1.657e-09	-8.738	-8.781	-0.043	(0)
CoCO3	5.337e-10	5.337e-10	-9.273	-9.273	0.000	(0)
CoOH+	4.699e-10	4.253e-10	-9.328	-9.371	-0.043	(0)
CoF+	3.271e-11	2.961e-11	-10.485	-10.529	-0.043	(0)
Co(OH)2	1.076e-11	1.076e-11	-10.968	-10.968	0.000	(0)
Co(OH)3-	7.550e-17	6.834e-17	-16.122	-16.165	-0.043	(0)
CoOOH-	1.894e-17	1.715e-17	-16.723	-16.766	-0.043	(0)
Co2OH+3	3.499e-18	1.427e-18	-17.456	-17.846	-0.390	(0)
Co(OH)4-2	5.137e-24	3.448e-24	-23.289	-23.462	-0.173	(0)
Co4(OH)4+4	3.216e-29	6.530e-30	-28.493	-29.185	-0.692	(0)
Co(3)	6.424e-30					
CoOH+2	6.424e-30	4.312e-30	-29.192	-29.365	-0.173	(0)
Co+3	5.955e-36	2.665e-36	-35.225	-35.574	-0.349	(0)
Cu(1)	4.157e-09					
Cu+	4.157e-09	3.762e-09	-8.381	-8.425	-0.043	(0)
Cu(2)	4.366e-07					
CuCO3	2.133e-07	2.133e-07	-6.671	-6.671	0.000	(0)
Cu+2	1.098e-07	7.682e-08	-6.959	-7.115	-0.155	(0)
CuOH+	8.460e-08	7.735e-08	-7.073	-7.112	-0.039	(0)
CuSO4	2.134e-08	2.134e-08	-7.671	-7.671	0.000	(0)
Cu(OH)2	4.914e-09	4.914e-09	-8.309	-8.309	0.000	(0)
CuHCO3+	1.703e-09	1.542e-09	-8.769	-8.812	-0.043	(0)
Cu(CO3)2-2	4.033e-10	2.707e-10	-9.394	-9.567	-0.173	(0)
Cu2(OH)2+2	2.239e-10	1.503e-10	-9.650	-9.823	-0.173	(0)
CuF+	7.488e-11	6.778e-11	-10.126	-10.169	-0.043	(0)
Cu(OH)3-	3.545e-12	3.209e-12	-11.450	-11.494	-0.043	(0)
Cu(OH)4-2	1.198e-17	8.042e-18	-16.922	-17.095	-0.173	(0)
F	1.580e-05					
F-	1.529e-05	1.398e-05	-4.816	-4.854	-0.039	(0)

```
   MgF+           3.409e-07   3.120e-07    -6.467    -6.506    -0.038     (0)
   CaF+           1.625e-07   1.489e-07    -6.789    -6.827    -0.038     (0)
   HF             6.541e-10   6.541e-10    -9.184    -9.184     0.000     (0)
   NaF            3.488e-10   3.488e-10    -9.457    -9.457     0.000     (0)
   MnF+           2.582e-10   2.366e-10    -9.588    -9.626    -0.038     (0)
   CuF+           7.488e-11   6.778e-11   -10.126   -10.169    -0.043     (0)
   CoF+           3.271e-11   2.961e-11   -10.485   -10.529    -0.043     (0)
   AlF2+          2.736e-11   2.509e-11   -10.563   -10.600    -0.038     (0)
   NiF+           1.523e-11   1.379e-11   -10.817   -10.861    -0.043     (0)
   AlF+2          6.374e-12   4.507e-12   -11.196   -11.346    -0.150     (0)
   AlF3           4.418e-12   4.418e-12   -11.355   -11.355     0.000     (0)
   HF2-           3.808e-14   3.478e-14   -13.419   -13.459    -0.039     (0)
   AlF4-          3.383e-14   3.096e-14   -13.471   -13.509    -0.038     (0)
   H2F2           1.146e-18   1.146e-18   -17.941   -17.941     0.000     (0)
H(0)          1.414e-26
   H2             7.068e-27   7.079e-27   -26.151   -26.150     0.001     (0)
K             3.326e-04
   K+             3.298e-04   3.016e-04    -3.482    -3.521    -0.039     (0)
   KSO4-          2.823e-06   2.589e-06    -5.549    -5.587    -0.038     (0)
Mg            3.293e-04
   Mg+2           2.842e-04   1.988e-04    -3.546    -3.702    -0.155     (0)
   MgSO4          4.387e-05   4.387e-05    -4.358    -4.358     0.000     (0)
   MgHCO3+        7.079e-07   6.472e-07    -6.150    -6.189    -0.039     (0)
   MgF+           3.409e-07   3.120e-07    -6.467    -6.506    -0.038     (0)
   MgCO3          7.799e-08   7.799e-08    -7.108    -7.108     0.000     (0)
   MgOH+          2.742e-08   2.520e-08    -7.562    -7.599    -0.037     (0)
Mn(2)         7.283e-07
   Mn+2           6.331e-07   4.250e-07    -6.199    -6.372    -0.173     (0)
   MnSO4          9.164e-08   9.164e-08    -7.038    -7.038     0.000     (0)
   MnHCO3+        2.944e-09   2.697e-09    -8.531    -8.569    -0.038     (0)
   MnOH+          3.710e-10   3.399e-10    -9.431    -9.469    -0.038     (0)
   MnF+           2.582e-10   2.366e-10    -9.588    -9.626    -0.038     (0)
   Mn(OH)3-       2.324e-19   2.129e-19   -18.634   -18.672    -0.038     (0)
   Mn(OH)4-2      3.106e-25   2.189e-25   -24.508   -24.660    -0.152     (0)
Mn(3)         4.241e-28
   Mn+3           4.241e-28   1.898e-28   -27.373   -27.722    -0.349     (0)
Mn(6)         0.000e+00
   MnO4-2         0.000e+00   0.000e+00   -48.642   -48.794    -0.152     (0)
Mn(7)         0.000e+00
   MnO4-          0.000e+00   0.000e+00   -54.126   -54.166    -0.040     (0)
Mo            3.128e-08
   MoO4-2         3.126e-08   2.187e-08    -7.505    -7.660    -0.155     (0)
   HMoO4-         1.520e-11   1.376e-11   -10.818   -10.861    -0.043     (0)
   H2MoO4         3.188e-15   3.188e-15   -14.497   -14.497     0.000     (0)
   AlMo6O21-3     0.000e+00   0.000e+00   -49.070   -49.460    -0.390     (0)
   Mo7O24-6       0.000e+00   0.000e+00   -59.073   -60.631    -1.558     (0)
   HMo7O24-5      0.000e+00   0.000e+00   -60.662   -61.744    -1.082     (0)
   H2Mo7O24-4     0.000e+00   0.000e+00   -63.769   -64.462    -0.692     (0)
   H3Mo7O24-3     0.000e+00   0.000e+00   -68.326   -68.716    -0.390     (0)
Na            4.351e-05
   Na+            4.322e-05   3.953e-05    -4.364    -4.403    -0.039     (0)
   NaSO4-         2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   NaHCO3         7.071e-09   7.071e-09    -8.151    -8.151     0.000     (0)
   NaCO3-         3.785e-10   3.471e-10    -9.422    -9.460    -0.038     (0)
   NaF            3.488e-10   3.488e-10    -9.457    -9.457     0.000     (0)
Ni            6.818e-08
   Ni+2           5.610e-08   3.924e-08    -7.251    -7.406    -0.155     (0)
   NiSO4          9.495e-09   9.495e-09    -8.023    -8.023     0.000     (0)
   NiHCO3+        1.700e-09   1.539e-09    -8.770    -8.813    -0.043     (0)
   NiCO3          6.904e-10   6.904e-10    -9.161    -9.161     0.000     (0)
   NiOH+          1.738e-10   1.573e-10    -9.760    -9.803    -0.043     (0)
   NiF+           1.523e-11   1.379e-11   -10.817   -10.861    -0.043     (0)
   Ni(OH)2        3.978e-12   3.978e-12   -11.400   -11.400     0.000     (0)
   Ni(SO4)2-2     5.679e-13   3.812e-13   -12.246   -12.419    -0.173     (0)
   Ni(OH)3-       1.399e-15   1.267e-15   -14.854   -14.897    -0.043     (0)
O(0)          2.019e-40
   O2             1.010e-40   1.011e-40   -39.996   -39.995     0.001     (0)
S(6)          2.051e-03
   SO4-2          1.733e-03   1.213e-03    -2.761    -2.916    -0.155     (0)
   CaSO4          2.709e-04   2.709e-04    -3.567    -3.567     0.000     (0)
   MgSO4          4.387e-05   4.387e-05    -4.358    -4.358     0.000     (0)
   KSO4-          2.823e-06   2.589e-06    -5.549    -5.587    -0.038     (0)
   NaSO4-         2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   MnSO4          9.164e-08   9.164e-08    -7.038    -7.038     0.000     (0)
   CuSO4          2.134e-08   2.134e-08    -7.671    -7.671     0.000     (0)
   CoSO4          1.620e-08   1.620e-08    -7.791    -7.791     0.000     (0)
   NiSO4          9.495e-09   9.495e-09    -8.023    -8.023     0.000     (0)
   HSO4-          4.094e-09   3.747e-09    -8.388    -8.426    -0.038     (0)
   Ni(SO4)2-2     5.679e-13   3.812e-13   -12.246   -12.419    -0.173     (0)
   AlSO4+         3.315e-13   3.034e-13   -12.480   -12.518    -0.038     (0)
   Al(SO4)2-      4.307e-15   3.942e-15   -14.366   -14.404    -0.038     (0)

----------------------------Saturation indices----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.79      9.01   10.80  Al(OH)3
  Al2(MoO4)3      -52.33    -49.96    2.37  Al2(MoO4)3
  Al2O3            -1.64     18.02   19.65  Al2O3
  Al4(OH)10SO4     -4.58     18.12   22.70  Al4(OH)10SO4
  AlOHSO4          -5.68     -8.91   -3.23  AlOHSO4
  Alunite          -3.43     -4.83   -1.40  KAl3(SO4)2(OH)6
  Anhydrite        -1.57     -5.93   -4.36  CaSO4
  Antlerite        -3.05      5.74    8.79  Cu3(OH)4SO4
  Aragonite        -1.04     -9.34   -8.30  CaCO3
  Artinite         -8.33      1.27    9.60  MgCO3:Mg(OH)2:3H2O
  Azurite          -2.09    -19.00  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -16.39      8.01   24.39  Ba(OH)2:8H2O
  BaF2            -10.88    -16.70   -5.82  BaF2
  BaMoO4           -7.69    -14.65   -6.96  BaMoO4
  Barite            0.07     -9.91   -9.98  BaSO4
  Birnessite      -11.81      6.28   18.09  MnO2
  Bixbyite         -9.80    -10.44   -0.64  Mn2O3
  Boehmite         0.43      9.01    8.58  AlOOH
  Brochantite      -1.60     13.63   15.22  Cu4(OH)6SO4
  Brucite          -5.55     11.30   16.84  Mg(OH)2
  Bunsenite        -4.85      7.59   12.45  NiO
  Calcite          -0.86     -9.34   -8.48  CaCO3
  CaMoO4           -2.72    -10.67   -7.95  CaMoO4
  CH4(g)          -72.28   -113.33  -41.05  CH4
  Chalcanthite     -7.39    -10.03   -2.64  CuSO4:5H2O
  Co(OH)2          -5.27      7.83   13.09  Co(OH)2
  Co(OH)3         -10.77    -13.07   -2.31  Co(OH)3
  CO2(g)           -3.18    -21.33  -18.15  CO2
  Co3O4            -7.83    -18.32  -10.50  Co3O4
  CoCO3            -3.52    -13.50   -9.98  CoCO3
  CoF2            -15.29    -16.88   -1.60  CoF2
  CoF3            -48.68    -50.14   -1.46  CoF3
  CoMoO4           -7.07    -14.83   -7.76  CoMoO4
  CoO              -5.76      7.83   13.59  CoO
  CoSO4           -12.89    -10.09    2.80  CoSO4
  CoSO4:6H2O       -7.62    -10.09   -2.47  CoSO4:6H2O
  Cryolite        -21.99    -55.83  -33.84  Na3AlF6
  Cu(OH)2          -0.79      7.88    8.67  Cu(OH)2
  Cu2SO4          -17.82    -19.77   -1.95  Cu2SO4
  CuCO3            -1.94    -13.44  -11.50  CuCO3
  CuF              -8.37    -13.28   -4.91  CuF
  CuF2            -17.94    -16.82    1.12  CuF2
  CuF2:2H2O       -12.27    -16.82   -4.55  CuF2:2H2O
  Cumetal          -3.67    -12.42   -8.76  Cu
  CuMoO4           -1.70    -14.77  -13.08  CuMoO4
  CuOCuSO4        -12.45     -2.15   10.30  CuOCuSO4
  Cuprite          -0.44     -1.85   -1.41  Cu2O
  CuSO4           -12.97    -10.03    2.94  CuSO4
  Diaspore          2.14      9.01    6.87  AlOOH
  Dolomite(disordered)  -2.83    -19.37  -16.54  CaMg(CO3)2
  Dolomite(ordered)  -2.28    -19.37  -17.09  CaMg(CO3)2
  Epsomite         -4.49     -6.62   -2.13  MgSO4:7H2O
  Fluorite         -2.22    -12.72  -10.50  CaF2
  Gibbsite          0.72      9.01    8.29  Al(OH)3
  Gypsum           -1.32     -5.93   -4.61  CaSO4:2H2O
  H2MoO4           -9.78    -22.66  -12.88  H2MoO4
  Hausmannite     -12.15     48.88   61.03  Mn3O4
  Huntite          -9.45    -39.42  -29.97  CaMg3(CO3)4
  Hydromagnesite  -20.05    -28.81   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum          -17.68    -22.85   -5.17  KAl(SO4)2:12H2O
  K2MoO4          -17.96    -14.70    3.26  K2MoO4
  Langite          -3.86     13.63   17.49  Cu4(OH)6SO4:H2O
  Lime            -20.71     11.99   32.70  CaO
  Magnesite        -2.57    -10.03   -7.46  MgCO3
  Malachite        -0.25     -5.56   -5.31  Cu2(OH)2CO3
  Manganite        -5.21     20.13   25.34  MnOOH
  Mg(OH)2(active)  -7.50     11.30   18.79  Mg(OH)2
  MgF2             -5.28    -13.41   -8.13  MgF2
  MgMoO4           -9.51    -11.36   -1.85  MgMoO4
  Mirabilite      -10.61    -11.72   -1.11  Na2SO4:10H2O
  Mn2(SO4)3       -58.48    -64.19   -5.71  Mn2(SO4)3
  MnSO4           -11.87     -9.29    2.58  MnSO4
  MoO3            -14.66    -22.66   -8.00  MoO3
  Morenosite       -8.18    -10.32   -2.14  NiSO4:7H2O
  Na2Mo2O7        -22.53    -39.13  -16.60  Na2Mo2O7
  Na2MoO4         -17.96    -16.47    1.49  Na2MoO4
  Na2MoO4:2H2O    -17.69    -16.47    1.22  Na2MoO4:2H2O
  Natron          -13.82    -15.13   -1.31  Na2CO3:10H2O
  Nesquehonite     -5.36    -10.03   -4.67  MgCO3:3H2O
  Ni(OH)2          -5.20      7.59   12.79  Ni(OH)2
  Ni4(OH)6SO4     -19.54     12.46   32.00  Ni4(OH)6SO4
  NiCO3            -6.86    -13.73   -6.87  NiCO3
  NiMoO4           -3.92    -15.07  -11.14  NiMoO4
  Nsutite         -11.23      6.28   17.50  MnO2
  O2(g)           -37.09     46.00   83.09  O2
  Periclase       -10.29     11.30   21.58  MgO
  Portlandite     -10.81     11.99   22.80  Ca(OH)2
  Pyrochroite      -6.57      8.63   15.19  Mn(OH)2
  Pyrolusite       -9.75     31.63   41.38  MnO2
  Retgersite       -8.28    -10.32   -2.04  NiSO4:6H2O
  Rhodochrosite    -2.12    -12.70  -10.58  MnCO3
  Spinel           -7.53     29.31   36.85  MgAl2O4
  Tenorite          0.24      7.89    7.64  CuO
  Thenardite      -12.04    -11.72    0.32  Na2SO4
  Thermonatrite   -15.77    -15.13    0.64  Na2CO3:H2O
  Witherite        -4.75    -13.32   -8.57  BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 3.     NAF Material

----------------------------Solution composition----------------------------

      Elements            Molality        Moles

      Al                 5.191e-06   5.191e-06
      Alkalinity         4.591e-04   4.591e-04
      As                 3.873e-07   3.873e-07
      Ba                 1.457e-07   1.457e-07
      Ca                 3.046e-03   3.046e-03
      Co                 3.395e-08   3.395e-08
      Cu                 2.992e-07   2.992e-07
      F                  1.580e-05   1.580e-05
      Fe                 1.254e-06   1.254e-06
      K                  4.094e-04   4.094e-04
      Mg                 7.410e-04   7.410e-04
      Mn                 2.368e-06   2.368e-06
      Mo                 5.214e-08   5.214e-08
      Na                 4.352e-05   4.352e-05
      Ni                 1.705e-08   1.705e-08
      S(6)               3.447e-03   3.447e-03
      U                  4.203e-09   4.203e-09

----------------------------Description of solution----------------------------

                                     pH  =   7.600
                                     pe  =   4.000
                            Activity of water  =   1.000
                     Ionic strength (mol/kgw)  =   1.193e-02
                          Mass of water (kg)  =   1.000e+00
                      Total carbon (mol/kg)  =   4.552e-04
                         Total CO2 (mol/kg)  =   4.552e-04
                           Temperature (°C)  =  25.00
                     Electrical balance (eq)  =   6.787e-04
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =   5.48
                                 Iterations  =  11 (34 overall)
                                    Total H  = 1.110142e+02
                                    Total O  = 5.552201e+01

----------------------------Distribution of species----------------------------

                                                  Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             4.492e-07   4.008e-07    -6.348    -6.397    -0.049     (0)
   H+              2.808e-08   2.512e-08    -7.552    -7.600    -0.048      0.00
   H2O             5.551e+01   9.999e-01     1.744    -0.000     0.000     18.07
Al            5.191e-06
   Al(OH)4-        5.088e-06   4.556e-06    -5.293    -5.341    -0.048     (0)
   Al(OH)3         9.030e-08   9.030e-08    -7.044    -7.044     0.000     (0)
   Al(OH)2+        1.257e-08   1.129e-08    -7.901    -7.947    -0.047     (0)
   AlF2+           6.958e-11   6.249e-11   -10.158   -10.204    -0.047     (0)
   AlOH+           5.451e-11   3.546e-11   -10.264   -10.450    -0.187     (0)
   AlF+2           1.811e-11   1.178e-11   -10.742   -10.929    -0.187     (0)
   AlF3            1.048e-11   1.048e-11   -10.980   -10.980     0.000     (0)
   AlSO4+          1.328e-12   1.189e-12   -11.877   -11.925    -0.048     (0)
   Al+3            2.412e-13   8.848e-14   -12.618   -13.053    -0.436     (0)
   AlF4-           7.812e-14   6.995e-14   -13.107   -13.155    -0.048     (0)
   Al(SO4)2-       2.463e-14   2.206e-14   -13.608   -13.656    -0.048     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -48.018   -48.520    -0.501     (0)
As(3)         1.024e-17
   H3AsO3          1.000e-17   1.000e-17   -17.000   -17.000     0.000     (0)
   H2AsO3-         2.322e-19   2.043e-19   -18.634   -18.690    -0.056     (0)
   HAsO3-2         1.239e-23   7.417e-24   -22.907   -23.130    -0.223     (0)
   H4AsO3+         1.416e-25   1.245e-25   -24.849   -24.905    -0.056     (0)
   AsO3-3          3.611e-29   1.138e-29   -28.442   -28.944    -0.501     (0)
As(5)         3.873e-07
   HAsO4-2         3.350e-07   2.005e-07    -6.475    -6.698    -0.223     (0)
   H2AsO4-         5.222e-08   4.594e-08    -7.282    -7.338    -0.056     (0)
   AsO4-3          8.009e-11   2.524e-11   -10.096   -10.598    -0.501     (0)
   H3AsO4          2.000e-13   2.005e-13   -12.699   -12.698     0.001     (0)
Ba            1.457e-07
   Ba+2            1.453e-07   9.304e-08    -6.838    -7.031    -0.194     (0)
   BaHCO3+         3.699e-10   3.328e-10    -9.432    -9.478    -0.046     (0)
   BaCO3           3.336e-11   3.336e-11   -10.477   -10.477     0.000     (0)
   BaOH+           1.815e-13   1.628e-13   -12.741   -12.788    -0.047     (0)
C(4)          4.552e-04
```

HCO3-	4.171e-04	3.746e-04	-3.380	-3.426	-0.047	(0)
H2CO3	2.116e-05	2.116e-05	-4.674	-4.674	0.000	(0)
CaHCO3+	1.200e-05	1.080e-05	-4.921	-4.967	-0.046	(0)
CaCO3	1.715e-06	1.715e-06	-5.766	-5.766	0.000	(0)
MgHCO3+	1.687e-06	1.508e-06	-5.773	-5.822	-0.049	(0)
CO3-2	1.092e-06	6.991e-07	-5.962	-6.155	-0.194	(0)
MgCO3	2.288e-07	2.288e-07	-6.641	-6.641	0.000	(0)
CuCO3	1.600e-07	1.600e-07	-6.796	-6.796	0.000	(0)
MnHCO3+	9.921e-09	8.899e-09	-8.003	-8.051	-0.047	(0)
NaHCO3	8.124e-09	8.124e-09	-8.090	-8.090	0.000	(0)
UO2(CO3)2-2	3.482e-09	2.084e-09	-8.458	-8.681	-0.223	(0)
CuHCO3+	1.044e-09	9.187e-10	-8.981	-9.037	-0.056	(0)
UO2(CO3)3-4	5.687e-10	7.303e-11	-9.245	-10.136	-0.891	(0)
NaCO3-	5.590e-10	5.020e-10	-9.253	-9.299	-0.047	(0)
CoHCO3+	5.432e-10	4.778e-10	-9.265	-9.321	-0.056	(0)
Cu(CO3)2-2	5.030e-10	3.011e-10	-9.298	-9.521	-0.223	(0)
NiHCO3+	4.493e-10	3.952e-10	-9.347	-9.403	-0.056	(0)
BaHCO3+	3.699e-10	3.328e-10	-9.432	-9.478	-0.046	(0)
NiCO3	2.232e-10	2.232e-10	-9.651	-9.651	0.000	(0)
CoCO3	1.938e-10	1.938e-10	-9.713	-9.713	0.000	(0)
UO2CO3	1.494e-10	1.494e-10	-9.826	-9.826	0.000	(0)
FeHCO3+	1.083e-10	9.748e-11	-9.965	-10.011	-0.046	(0)
BaCO3	3.336e-11	3.336e-11	-10.477	-10.477	0.000	(0)
Ca 3.046e-03						
Ca+2	2.418e-03	1.548e-03	-2.617	-2.810	-0.194	(0)
CaSO4	6.140e-04	6.140e-04	-3.212	-3.212	0.000	(0)
CaHCO3+	1.200e-05	1.080e-05	-4.921	-4.967	-0.046	(0)
CaCO3	1.715e-06	1.715e-06	-5.766	-5.766	0.000	(0)
CaF+	2.509e-07	2.251e-07	-6.600	-6.648	-0.047	(0)
CaOH+	1.376e-08	1.238e-08	-7.861	-7.907	-0.046	(0)
Co(2) 3.395e-08						
Co+2	2.739e-08	1.640e-08	-7.562	-7.785	-0.223	(0)
CoSO4	5.664e-09	5.664e-09	-8.247	-8.247	0.000	(0)
CoHCO3+	5.432e-10	4.778e-10	-9.265	-9.321	-0.056	(0)
CoCO3	1.938e-10	1.938e-10	-9.713	-9.713	0.000	(0)
CoOH+	1.491e-10	1.311e-10	-9.827	-9.882	-0.056	(0)
CoF+	7.852e-12	6.907e-12	-11.105	-11.161	-0.056	(0)
Co(OH)2	4.175e-12	4.175e-12	-11.379	-11.379	0.000	(0)
Co(OH)3-	3.796e-17	3.339e-17	-16.421	-16.476	-0.056	(0)
CoOOH-	9.525e-18	8.379e-18	-17.021	-17.077	-0.056	(0)
Co2OH+3	3.419e-19	1.078e-19	-18.466	-18.968	-0.501	(0)
Co(OH)4-2	3.543e-24	2.121e-24	-23.451	-23.673	-0.223	(0)
Co4(OH)4+4	4.595e-31	5.900e-32	-30.338	-31.229	-0.891	(0)
Co(3) 2.221e-30						
COOH+2	2.221e-30	1.330e-30	-29.653	-29.876	-0.223	(0)
Co+3	1.780e-36	6.528e-37	-35.750	-36.185	-0.436	(0)
Cu(1) 2.164e-09						
Cu+	2.164e-09	1.904e-09	-8.665	-8.720	-0.056	(0)
Cu(2) 2.970e-07						
CuCO3	1.600e-07	1.600e-07	-6.796	-6.796	0.000	(0)
Cu+2	6.070e-08	3.887e-08	-7.217	-7.410	-0.194	(0)
CuOH+	5.512e-08	4.927e-08	-7.259	-7.307	-0.049	(0)
CuSO4	1.542e-08	1.542e-08	-7.812	-7.812	0.000	(0)
Cu(OH)2	3.940e-09	3.940e-09	-8.404	-8.404	0.000	(0)
CuHCO3+	1.044e-09	9.187e-10	-8.981	-9.037	-0.056	(0)
Cu(CO3)2-2	5.030e-10	3.011e-10	-9.298	-9.521	-0.223	(0)
Cu2(OH)2+2	1.019e-10	6.097e-11	-9.992	-10.215	-0.223	(0)
CuF+	3.714e-11	3.267e-11	-10.430	-10.486	-0.056	(0)
Cu(OH)3-	3.683e-12	3.239e-12	-11.434	-11.490	-0.056	(0)
Cu(OH)4-2	1.707e-17	1.022e-17	-16.768	-16.991	-0.223	(0)
F 1.580e-05						
F-	1.489e-05	1.332e-05	-4.827	-4.876	-0.048	(0)
MgF+	6.566e-07	5.879e-07	-6.183	-6.231	-0.048	(0)
CaF+	2.509e-07	2.251e-07	-6.600	-6.648	-0.047	(0)
MnF+	7.039e-10	6.314e-10	-9.152	-9.200	-0.047	(0)
HF	4.949e-10	4.949e-10	-9.306	-9.306	0.000	(0)
NaF	3.241e-10	3.241e-10	-9.489	-9.489	0.000	(0)
AlF2+	6.958e-11	6.249e-11	-10.158	-10.204	-0.047	(0)
CuF+	3.714e-11	3.267e-11	-10.430	-10.486	-0.056	(0)
AlF+2	1.811e-11	1.178e-11	-10.742	-10.929	-0.187	(0)
AlF3	1.048e-11	1.048e-11	-10.980	-10.980	0.000	(0)
CoF+	7.852e-12	6.907e-12	-11.105	-11.161	-0.056	(0)
NiF+	3.255e-12	2.863e-12	-11.487	-11.543	-0.056	(0)
UO2F+	1.122e-13	9.871e-14	-12.950	-13.006	-0.056	(0)
AlF4-	7.812e-14	6.995e-14	-13.107	-13.155	-0.048	(0)
HF2-	2.808e-14	2.506e-14	-13.552	-13.601	-0.049	(0)
UO2F2	3.792e-15	3.792e-15	-14.421	-14.421	0.000	(0)
FeF+2	4.333e-16	2.804e-16	-15.363	-15.552	-0.189	(0)
FeF2+	1.114e-16	9.996e-17	-15.953	-16.000	-0.047	(0)
UO2F3-	1.442e-17	1.269e-17	-16.841	-16.897	-0.056	(0)
FeF3	1.879e-18	1.879e-18	-17.726	-17.726	0.000	(0)
H2F2	6.561e-19	6.561e-19	-18.183	-18.183	0.000	(0)
UO2F4-2	2.242e-21	1.342e-21	-20.649	-20.872	-0.223	(0)
UF3+	3.760e-36	3.307e-36	-35.425	-35.481	-0.056	(0)
UF2+2	2.617e-36	1.567e-36	-35.582	-35.805	-0.223	(0)
UF+3	2.964e-38	9.342e-39	-37.528	-38.030	-0.501	(0)
UF4	4.830e-39	4.830e-39	-38.316	-38.316	0.000	(0)
UF5-	0.000e+00	0.000e+00	-41.538	-41.594	-0.056	(0)
UF6-2	0.000e+00	0.000e+00	-43.766	-43.989	-0.223	(0)
Fe(2) 4.379e-08						
Fe+2	3.453e-08	2.067e-08	-7.462	-7.685	-0.223	(0)
FeSO4	8.785e-09	8.785e-09	-8.056	-8.056	0.000	(0)
FeOH+	3.677e-10	3.298e-10	-9.434	-9.482	-0.047	(0)
FeHCO3+	1.083e-10	9.748e-11	-9.965	-10.011	-0.046	(0)
Fe(OH)2	1.050e-13	1.050e-13	-12.979	-12.979	0.000	(0)
Fe(OH)3-	1.484e-14	1.331e-14	-13.829	-13.876	-0.047	(0)
Fe(3) 1.210e-06						
Fe(OH)2+	8.628e-07	7.749e-07	-6.064	-6.111	-0.047	(0)
Fe(OH)3	3.336e-07	3.336e-07	-6.477	-6.477	0.000	(0)
Fe(OH)4-	1.386e-08	1.245e-08	-7.858	-7.905	-0.047	(0)
FeOH+2	7.678e-12	4.969e-12	-11.115	-11.304	-0.189	(0)
FeF+2	4.333e-16	2.804e-16	-15.363	-15.552	-0.189	(0)
FeSO4+	4.159e-16	3.730e-16	-15.381	-15.428	-0.047	(0)
FeF2+	1.114e-16	9.996e-17	-15.953	-16.000	-0.047	(0)
Fe+3	5.236e-17	1.920e-17	-16.281	-16.717	-0.436	(0)
Fe(SO4)2-	1.570e-17	1.381e-17	-16.804	-16.860	-0.056	(0)
FeF3	1.879e-18	1.879e-18	-17.726	-17.726	0.000	(0)
Fe2(OH)2+4	6.368e-21	8.178e-22	-20.196	-21.087	-0.891	(0)
Fe3(OH)4+5	2.263e-25	9.160e-27	-24.645	-26.038	-1.393	(0)
H(0) 8.909e-27						
H2	4.455e-27	4.467e-27	-26.351	-26.350	0.001	(0)
K 4.094e-04						
K+	4.045e-04	3.618e-04	-3.393	-3.441	-0.048	(0)
KSO4-	4.938e-06	4.435e-06	-5.306	-5.353	-0.047	(0)
Mg 7.410e-04						
Mg+2	6.144e-04	3.934e-04	-3.212	-3.405	-0.194	(0)
MgSO4	1.239e-04	1.239e-04	-3.907	-3.907	0.000	(0)
MgHCO3+	1.687e-06	1.508e-06	-5.773	-5.822	-0.049	(0)
MgF+	6.566e-07	5.879e-07	-6.183	-6.231	-0.048	(0)
MgCO3	2.288e-07	2.288e-07	-6.641	-6.641	0.000	(0)
MgOH+	6.966e-08	6.278e-08	-7.157	-7.202	-0.045	(0)
Mn(2) 2.368e-06						
Mn+2	1.989e-06	1.191e-06	-5.701	-5.924	-0.223	(0)
MnSO4	3.666e-07	3.666e-07	-6.436	-6.436	0.000	(0)
MnHCO3+	9.921e-09	8.899e-09	-8.003	-8.051	-0.047	(0)
MnOH+	1.337e-09	1.199e-09	-8.874	-8.921	-0.047	(0)
MnF+	7.039e-10	6.314e-10	-9.152	-9.200	-0.047	(0)
Mn(OH)3-	1.327e-18	1.190e-18	-17.877	-17.924	-0.047	(0)
Mn(OH)4-2	2.380e-24	1.540e-24	-23.623	-23.812	-0.189	(0)
Mn(3) 1.450e-27						
Mn+3	1.450e-27	5.318e-28	-26.839	-27.274	-0.436	(0)
Mn(6) 0.000e+00						
MnO4-2	0.000e+00	0.000e+00	-47.357	-47.546	-0.189	(0)
Mn(7) 0.000e+00						
MnO4-	0.000e+00	0.000e+00	-52.868	-52.918	-0.050	(0)
Mo 5.214e-08						
MoO4-2	5.212e-08	3.338e-08	-7.283	-7.477	-0.194	(0)
HMoO4-	1.896e-11	1.668e-11	-10.722	-10.778	-0.056	(0)
H2MoO4	3.069e-15	3.069e-15	-14.513	-14.513	0.000	(0)
AlMo6O21-3	0.000e+00	0.000e+00	-48.018	-48.520	-0.501	(0)
Mo7O24-6	0.000e+00	0.000e+00	-58.140	-60.146	-2.006	(0)
HMo7O24-5	0.000e+00	0.000e+00	-59.966	-61.359	-1.393	(0)
H2Mo7O24-4	0.000e+00	0.000e+00	-63.285	-64.177	-0.891	(0)
H3Mo7O24-3	0.000e+00	0.000e+00	-68.029	-68.531	-0.501	(0)
Na 4.352e-05						
Na+	4.311e-05	3.857e-05	-4.365	-4.414	-0.048	(0)
NaSO4-	3.992e-07	3.586e-07	-6.399	-6.445	-0.047	(0)
NaHCO3	8.124e-09	8.124e-09	-8.090	-8.090	0.000	(0)
NaCO3-	5.590e-10	5.020e-10	-9.253	-9.299	-0.047	(0)
NaF	3.241e-10	3.241e-10	-9.489	-9.489	0.000	(0)
Ni 1.705e-08						
Ni+2	1.336e-08	8.558e-09	-7.874	-8.068	-0.194	(0)
NiSO4	2.956e-09	2.956e-09	-8.529	-8.529	0.000	(0)
NiHCO3+	4.493e-10	3.952e-10	-9.347	-9.403	-0.056	(0)
NiCO3	2.232e-10	2.232e-10	-9.651	-9.651	0.000	(0)
NiOH+	4.909e-11	4.318e-11	-10.309	-10.365	-0.056	(0)
NiF+	3.255e-12	2.863e-12	-11.487	-11.543	-0.056	(0)
Ni(OH)2	1.375e-12	1.375e-12	-11.862	-11.862	0.000	(0)
Ni(SO4)2-2	2.831e-13	1.695e-13	-12.548	-12.771	-0.223	(0)
Ni(OH)3-	6.265e-16	5.511e-16	-15.203	-15.259	-0.056	(0)
O(0) 5.066e-40						
O2	2.533e-40	2.540e-40	-39.596	-39.595	0.001	(0)
S(6) 3.447e-03						
SO4-2	2.704e-03	1.731e-03	-2.568	-2.762	-0.194	(0)
CaSO4	6.140e-04	6.140e-04	-3.212	-3.212	0.000	(0)
MgSO4	1.239e-04	1.239e-04	-3.907	-3.907	0.000	(0)
KSO4-	4.938e-06	4.435e-06	-5.306	-5.353	-0.047	(0)
NaSO4-	3.992e-07	3.586e-07	-6.399	-6.445	-0.047	(0)
MnSO4	3.666e-07	3.666e-07	-6.436	-6.436	0.000	(0)
CuSO4	1.542e-08	1.542e-08	-7.812	-7.812	0.000	(0)
FeSO4	8.785e-09	8.785e-09	-8.056	-8.056	0.000	(0)
CoSO4	5.664e-09	5.664e-09	-8.247	-8.247	0.000	(0)
HSO4-	4.746e-09	4.250e-09	-8.324	-8.372	-0.048	(0)
NiSO4	2.956e-09	2.956e-09	-8.529	-8.529	0.000	(0)
AlSO4+	1.328e-12	1.189e-12	-11.877	-11.925	-0.048	(0)
Ni(SO4)2-2	2.831e-13	1.695e-13	-12.548	-12.771	-0.223	(0)
UO2SO4	1.407e-13	1.407e-13	-12.852	-12.852	0.000	(0)
Al(SO4)2-	2.463e-14	2.206e-14	-13.608	-13.656	-0.048	(0)
UO2(SO4)2-2	5.363e-15	3.210e-15	-14.271	-14.493	-0.223	(0)
FeSO4+	4.159e-16	3.730e-16	-15.381	-15.428	-0.047	(0)
Fe(SO4)2-	1.570e-17	1.381e-17	-16.804	-16.860	-0.056	(0)
U(SO4)2	3.332e-38	3.332e-38	-37.477	-37.477	0.000	(0)
USO4+2	4.047e-39	2.423e-39	-38.393	-38.616	-0.223	(0)
U(3) 0.000e+00						
U+3	0.000e+00	0.000e+00	-54.749	-55.250	-0.501	(0)
U(4) 3.033e-18						
U(OH)5-	3.030e-18	2.665e-18	-17.519	-17.574	-0.056	(0)
U(OH)4	2.804e-21	2.804e-21	-20.552	-20.552	0.000	(0)
U(OH)3+	2.928e-25	2.575e-25	-24.533	-24.589	-0.056	(0)
U(OH)2+2	4.997e-30	2.991e-30	-29.301	-29.524	-0.223	(0)
UOH+3	1.123e-35	3.539e-36	-34.950	-35.451	-0.501	(0)
UF3+	3.760e-36	3.307e-36	-35.425	-35.481	-0.056	(0)
UF2+2	2.617e-36	1.567e-36	-35.582	-35.805	-0.223	(0)
U(SO4)2	3.332e-38	3.332e-38	-37.477	-37.477	0.000	(0)
UF+3	2.964e-38	9.342e-39	-37.528	-38.030	-0.501	(0)
UF4	4.830e-39	4.830e-39	-38.316	-38.316	0.000	(0)
USO4+2	4.047e-39	2.423e-39	-38.393	-38.616	-0.223	(0)
UF5-	0.000e+00	0.000e+00	-41.538	-41.594	-0.056	(0)
U+4	0.000e+00	0.000e+00	-41.563	-42.454	-0.891	(0)
UF6-2	0.000e+00	0.000e+00	-43.766	-43.989	-0.223	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-153.367	-157.880	-4.513	(0)
U(5) 3.720e-15						
UO2+	3.720e-15	3.272e-15	-14.429	-14.485	-0.056	(0)
U(6) 4.203e-09						
UO2(CO3)2-2	3.482e-09	2.084e-09	-8.458	-8.681	-0.223	(0)
UO2(CO3)3-4	5.687e-10	7.303e-11	-9.245	-10.136	-0.891	(0)
UO2CO3	1.494e-10	1.494e-10	-9.826	-9.826	0.000	(0)
UO2OH+	3.080e-12	2.709e-12	-11.511	-11.567	-0.056	(0)
UO2SO4	1.407e-13	1.407e-13	-12.852	-12.852	0.000	(0)
UO2F+	1.122e-13	9.871e-14	-12.950	-13.006	-0.056	(0)
UO2+2	8.384e-14	5.369e-14	-13.077	-13.270	-0.194	(0)
UO2(SO4)2-2	5.363e-15	3.210e-15	-14.271	-14.493	-0.223	(0)
UO2F2	3.792e-15	3.792e-15	-14.421	-14.421	0.000	(0)
(UO2)2(OH)2+2	2.034e-17	1.218e-17	-16.692	-16.914	-0.223	(0)
UO2F3-	1.442e-17	1.269e-17	-16.841	-16.897	-0.056	(0)
(UO2)3(OH)5+	4.571e-18	4.021e-18	-17.340	-17.396	-0.056	(0)
UO2F4-2	2.242e-21	1.342e-21	-20.649	-20.872	-0.223	(0)

----------Saturation indices----------

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(am)	-1.05	9.75	10.80	Al(OH)3
Al2(MoO4)3	-50.90	-48.54	2.37	Al2(MoO4)3
Al2O3	-0.16	19.49	19.65	Al2O3
Al4(OH)10SO4	-1.67	21.03	22.70	Al4(OH)10SO4
AlAsO4:2H2O	-7.75	-2.95	4.80	AlAsO4:2H2O
AlOHSO4	-4.98	-8.21	-3.23	AlOHSO4
Alunite	-1.12	-2.52	-1.40	KAl3(SO4)2(OH)6
Anhydrite	-1.21	-5.57	-4.36	CaSO4
Antlerite	-3.38	5.41	8.79	Cu3(OH)4SO4
Aragonite	-0.67	-8.97	-8.30	CaCO3
Arsenolite	-65.24	-68.00	-2.76	As4O6
Artinite	-7.37	2.23	9.60	MgCO3:Mg(OH)2:3H2O
As2O5	-32.10	-25.40	6.71	As2O5
Azurite	-2.44	-19.34	-16.91	Cu3(OH)2(CO3)2
Ba(OH)2:8H2O	-16.23	8.17	24.39	Ba(OH)2:8H2O
Ba3(AsO4)2	8.02	-0.89	-8.91	Ba3(AsO4)2
BaF2	-10.96	-16.78	-5.82	BaF2
BaMoO4	-7.55	-14.51	-6.96	BaMoO4
Barite	0.19	-9.79	-9.98	BaSO4
Birnessite	-10.97	7.13	18.09	MnO2
Bixbyite	-8.30	-8.95	-0.64	Mn2O3
Boehmite	1.17	9.75	8.58	AlOOH
Brochantite	-2.03	13.20	15.22	Cu4(OH)6SO4
Brucite	-5.05	11.79	16.84	Mg(OH)2
Bunsenite	-5.31	7.13	12.45	NiO
Ca3(AsO4)2:4H2O	-10.53	11.77	22.30	Ca3(AsO4)2:4H2O
Calcite	-0.49	-8.97	-8.48	CaCO3
CaMoO4	-2.34	-10.29	-7.95	CaMoO4
CH4(g)	-73.11	-114.16	-41.05	CH4
Chalcanthite	-7.53	-10.17	-2.64	CuSO4:5H2O
Claudetite	-64.93	-68.00	-3.06	As4O6
Co(OH)2	-5.68	7.41	13.09	Co(OH)2
Co(OH)3	-11.08	-13.39	-2.31	Co(OH)3
CO2(g)	-3.21	-21.36	-18.15	CO2
Co3(AsO4)2	-16.19	-3.15	13.03	Co3(AsO4)2
Co3O4	-8.86	-19.36	-10.50	Co3O4
CoCO3	-3.96	-13.94	-9.98	CoCO3
CoF2	-15.94	-17.54	-1.60	CoF2
CoF3	-49.35	-50.81	-1.46	CoF3
CoFe2O4	23.11	19.58	-3.53	CoFe2O4
CoMoO4	-7.50	-15.26	-7.76	CoMoO4
CoO	-6.17	7.41	13.59	CoO

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  CoSO4           -13.35    -10.55    2.80  CoSO4
  CoSO4:6H2O       -8.07    -10.55   -2.47  CoSO4:6H2O
  Cryolite        -21.71    -55.55  -33.84  Na3AlF6
  Cu(OH)2          -0.88      7.79    8.67  Cu(OH)2
  Cu2SO4          -18.25    -20.20   -1.95  Cu2SO4
  Cu3(AsO4)2:2H2O  -8.13     -2.03    6.10  Cu3(AsO4)2:2H2O
  CuCO3            -2.07    -13.57  -11.50  CuCO3
  CuF              -8.69    -13.60   -4.91  CuF
  CuF2            -18.28    -17.16    1.12  CuF2
  CuF2:2H2O       -12.61    -17.16   -4.55  CuF2:2H2O
  Cumetal          -3.96    -12.72   -8.76  Cu
  CuMoO4           -1.81    -14.89  -13.08  CuMoO4
  CuOCuSO4        -12.69     -2.38   10.30  CuOCuSO4
  Cupricferrite    13.97     19.96    5.99  CuFe2O4
  Cuprite          -0.83     -2.24   -1.41  Cu2O
  Cuprousferrite   13.88      4.96   -8.92  CuFeO2
  CuSO4           -13.11    -10.17    2.94  CuSO4
  Diaspore          2.87      9.75    6.87  AlOOH
  Dolomite(disordered)  -1.99    -18.53  -16.54  CaMg(CO3)2
  Dolomite(ordered)  -1.44    -18.53  -17.09  CaMg(CO3)2
  Epsomite         -4.04     -6.17   -2.13  MgSO4:7H2O
  Fe(OH)2          -6.05      7.52   13.56  Fe(OH)2
  Fe2(SO4)3       -37.98    -41.72   -3.73  Fe2(SO4)3
  Fe3(OH)8         -0.54     19.68   20.22  Fe3(OH)8
  FeAsO4:2H2O      -7.01     -6.61    0.40  FeAsO4:2H2O
  FeMoO4           -5.07    -15.16  -10.09  FeMoO4
  Ferrihydrite      2.89      6.08    3.19  Fe(OH)3
  Fluorite         -2.06    -12.56  -10.50  CaF2
  Gibbsite          1.46      9.75    8.29  Al(OH)3
  Goethite          5.59      6.08    0.49  FeOOH
  Gummite          -5.74      1.93    7.67  UO3
  Gypsum           -0.96     -5.57   -4.61  CaSO4:2H2O
  H-Jarosite       -5.57    -17.67  -12.10  (H3O)Fe3(SO4)2(OH)6
  H2MoO4           -9.80    -22.68  -12.88  H2MoO4
  Hausmannite     -10.00     51.03   61.03  Mn3O4
  Hematite         13.58     12.17   -1.42  Fe2O3
  Hercynite         4.12     27.01   22.89  FeAl2O4
  Huntite          -7.68    -37.65  -29.97  CaMg3(CO3)4
  Hydromagnesite  -17.68    -26.45   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum          -16.85    -22.02   -5.17  KAl(SO4)2:12H2O
  K-Jarosite        1.28    -13.52  -14.80  KFe3(SO4)2(OH)6
  K2MoO4          -17.62    -14.36    3.26  K2MoO4
  Langite          -4.29     13.20   17.49  Cu4(OH)6SO4:H2O
  Lepidocrocite     4.71      6.08    1.37  FeOOH
  Lime            -20.31     12.39   32.70  CaO
  Maghemite         5.78     12.17    6.39  Fe2O3
  Magnesioferrite   7.10     23.96   16.86  Fe2MgO4
  Magnesite        -2.10     -9.56   -7.46  MgCO3
  Magnetite        16.28     19.68    3.40  Fe3O4
  Malachite        -0.47     -5.78   -5.31  Cu2(OH)2CO3
  Manganite        -4.46     20.88   25.34  MnOOH
  Melanterite      -8.24    -10.45   -2.21  FeSO4:7H2O
  Mg(OH)2(active)  -7.00     11.79   18.79  Mg(OH)2
  MgF2             -5.03    -13.16   -8.13  MgF2
  MgMoO4           -9.03    -10.88   -1.85  MgMoO4
  Mirabilite      -10.48    -11.59   -1.11  Na2SO4:10H2O
  Mn2(SO4)3       -57.12    -62.83   -5.71  Mn2(SO4)3
  Mn3(AsO4)2:8H2O -10.07      2.43   12.50  Mn3(AsO4)2:8H2O
  MnSO4           -11.27     -8.69    2.58  MnSO4
  MoO3            -14.68    -22.68   -8.00  MoO3
  Morenosite       -8.68    -10.83   -2.14  NiSO4:7H2O
  Na-Jarosite      -3.29    -14.49  -11.20  NaFe3(SO4)2(OH)6
  Na2Mo2O7        -22.38    -38.98  -16.60  Na2Mo2O7
  Na2MoO4         -17.79    -16.30    1.49  Na2MoO4
  Na2MoO4:2H2O    -17.53    -16.30    1.22  Na2MoO4:2H2O
  Natron          -13.67    -14.98   -1.31  Na2CO3:10H2O
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  Nesquehonite     -4.89     -9.56   -4.67  MgCO3:3H2O
  Ni(OH)2          -5.66      7.13   12.79  Ni(OH)2
  Ni3(AsO4)2:8H2O -19.70     -4.00   15.70  Ni3(AsO4)2:8H2O
  Ni4(OH)6SO4     -21.43     10.57   32.00  Ni4(OH)6SO4
  NiCO3            -7.35    -14.22   -6.87  NiCO3
  NiMoO4           -4.40    -15.54  -11.14  NiMoO4
  Nsutite         -10.38      7.13   17.50  MnO2
  O2(g)           -36.69     46.40   83.09  O2
  Periclase        -9.79     11.79   21.58  MgO
  Portlandite     -10.41     12.39   22.80  Ca(OH)2
  Pyrochroite      -5.92      9.28   15.19  Mn(OH)2
  Pyrolusite       -8.90     32.48   41.38  MnO2
  Retgersite       -8.79    -10.83   -2.04  NiSO4:6H2O
  Rhodochrosite    -1.50    -12.08  -10.58  MnCO3
  Rutherfordine    -4.93    -19.43  -14.50  UO2CO3
  Schoepite        -4.06      1.93    5.99  UO2(OH)2:H2O
  Siderite         -3.60    -13.84  -10.24  FeCO3
  Spinel           -5.56     31.29   36.85  MgAl2O4
  Tenorite          0.15      7.79    7.64  CuO
  Thenardite      -11.91    -11.59    0.32  Na2SO4
  Thermonatrite   -15.62    -14.98    0.64  Na2CO3:H2O
  U3O8            -10.85     10.24   21.08  U3O8
  U4O9            -22.00    -25.02   -3.02  U4O9
  UF4             -32.42    -61.96  -29.54  UF4
  UF4:2.5H2O      -29.24    -61.96  -32.72  UF4:2.5H2O
  UO2(am)         -12.99    -12.05    0.93  UO2
  UO2(OH)2(beta)   -3.68      1.93    5.61  UO2(OH)2
  UO3              -5.77      1.93    7.70  UO3
  Uraninite        -7.38    -12.05   -4.67  UO2
  Witherite        -4.62    -13.19   -8.57  BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 4.     Make-up Material

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                7.415e-07   7.415e-07
      Alkalinity        3.607e-04   3.607e-04
      Ba                1.457e-07   1.457e-07
      Ca                1.672e-03   1.672e-03
      Co                1.188e-07   1.188e-07
      Cu                4.408e-07   4.408e-07
      F                 1.580e-05   1.580e-05
      K                 3.326e-04   3.326e-04
      Mg                3.293e-04   3.293e-04
      Mn                7.283e-07   7.283e-07
      Mo                3.128e-08   3.128e-08
      Na                4.351e-05   4.351e-05
      Ni                6.818e-08   6.818e-08
      S(6)              2.051e-03   2.051e-03

----------------------------Description of solution----------------------------

                                       pH  =   7.700
                                       pe  =   4.000
                              Activity of water  =   1.000
                       Ionic strength (mol/kgw)  =   7.199e-03
                            Mass of water (kg)  =   1.000e+00
                         Total carbon (mol/kg)  =   3.686e-04
                            Total CO2 (mol/kg)  =   3.686e-04
                              Temperature (°C)  =  25.00
                     Electrical balance (eq)  =  -9.478e-05
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 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  -1.25
                                Iterations  =  12 (46 overall)
                                   Total H  = 1.110140e+02
                                   Total O  = 5.551615e+01

----------------------------Distribution of species----------------------------

                                                  Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             5.526e-07   5.046e-07    -6.258    -6.297    -0.039      (0)
   H+              2.182e-08   1.995e-08    -7.661    -7.700    -0.039      0.00
   H2O             5.551e+01   9.999e-01     1.744    -0.000     0.000     18.07
Al            7.415e-07
   Al(OH)4-        7.298e-07   6.680e-07    -6.137    -6.175    -0.038      (0)
   Al(OH)3         1.051e-08   1.051e-08    -7.978    -7.978     0.000      (0)
   Al(OH)2+        1.139e-09   1.044e-09    -8.944    -8.981    -0.038      (0)
   AlF2+           4.383e-12   4.020e-12   -11.358   -11.396    -0.038      (0)
   AlOH+2          3.684e-12   2.605e-12   -11.434   -11.584    -0.150      (0)
   AlF+2           1.021e-12   7.220e-13   -11.991   -12.141    -0.150      (0)
   AlF3            7.077e-13   7.077e-13   -12.150   -12.150     0.000      (0)
   AlSO4+          5.310e-14   4.860e-14   -13.275   -13.313    -0.038      (0)
   Al+3            1.153e-14   5.163e-15   -13.938   -14.287    -0.349      (0)
   AlF4-           5.420e-15   4.960e-15   -14.266   -14.304    -0.038      (0)
   Al(SO4)2-       6.899e-16   6.315e-16   -15.161   -15.200    -0.038      (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -51.065   -51.455    -0.389      (0)
Ba            1.457e-07
   Ba+2            1.453e-07   1.017e-07    -6.838    -6.993    -0.155      (0)
   BaHCO3+         3.344e-10   3.070e-10    -9.476    -9.513    -0.037      (0)
   BaCO3           3.874e-11   3.874e-11   -10.412   -10.412     0.000      (0)
   BaOH+           2.444e-13   2.239e-13   -12.612   -12.650    -0.038      (0)
C(4)          3.686e-04
   HCO3-           3.449e-04   3.163e-04    -3.462    -3.500    -0.038      (0)
   H2CO3           1.419e-05   1.419e-05    -4.848    -4.848     0.000      (0)
   CaHCO3+         6.254e-06   5.742e-06    -5.204    -5.241    -0.037      (0)
   CaCO3           1.148e-06   1.148e-06    -5.940    -5.940     0.000      (0)
   CO3-2           1.062e-06   7.431e-07    -5.974    -6.129    -0.155      (0)
   MgHCO3+         7.037e-07   6.434e-07    -6.153    -6.192    -0.039      (0)
   CuCO3           2.384e-07   2.384e-07    -6.623    -6.623     0.000      (0)
   MgCO3           1.229e-07   1.229e-07    -6.911    -6.911     0.000      (0)
   NaHCO3          7.030e-09   7.030e-09    -8.153    -8.153     0.000      (0)
   MnHCO3+         2.926e-09   2.681e-09    -8.534    -8.572    -0.038      (0)
   CoHCO3+         1.811e-09   1.639e-09    -8.742    -8.785    -0.043      (0)
   NiHCO3+         1.678e-09   1.519e-09    -8.775    -8.818    -0.043      (0)
   CuHCO3+         1.201e-09   1.087e-09    -8.920    -8.964    -0.043      (0)
   NiCO3           1.080e-09   1.080e-09    -8.967    -8.967     0.000      (0)
   CoCO3           8.369e-10   8.369e-10    -9.077    -9.077     0.000      (0)
   Cu(CO3)2-2      7.104e-10   4.768e-10    -9.149    -9.322    -0.173      (0)
   NaCO3-          5.965e-10   5.470e-10    -9.224    -9.262    -0.038      (0)
   BaHCO3+         3.344e-10   3.070e-10    -9.476    -9.513    -0.037      (0)
   BaCO3           3.874e-11   3.874e-11   -10.412   -10.412     0.000      (0)
Ca            1.672e-03
   Ca+2            1.394e-03   9.751e-04    -2.856    -3.011    -0.155      (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000      (0)
   CaHCO3+         6.254e-06   5.742e-06    -5.204    -5.241    -0.037      (0)
   CaCO3           1.148e-06   1.148e-06    -5.940    -5.940     0.000      (0)
   CaF+            1.624e-07   1.488e-07    -6.789    -6.827    -0.038      (0)
   CaOH+           1.069e-08   9.818e-09    -7.971    -8.008    -0.037      (0)
Co(2)         1.188e-07
   Co+2            9.925e-08   6.662e-08    -7.003    -7.176    -0.173      (0)
   CoSO4           1.612e-08   1.612e-08    -7.793    -7.793     0.000      (0)
   CoHCO3+         1.811e-09   1.639e-09    -8.742    -8.785    -0.043      (0)
   CoCO3           8.369e-10   8.369e-10    -9.077    -9.077     0.000      (0)
   CoOH+           7.411e-10   6.708e-10    -9.130    -9.173    -0.043      (0)
   CoF+            3.255e-11   2.946e-11   -10.487   -10.531    -0.043      (0)
   Co(OH)2         2.689e-11   2.689e-11   -10.570   -10.570     0.000      (0)
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   Co(OH)3-        2.991e-16   2.707e-16   -15.524   -15.567    -0.043      (0)
   CoOOH-          7.505e-17   6.793e-17   -16.125   -16.168    -0.043      (0)
   Co2OH+3         5.491e-18   2.240e-18   -17.260   -17.650    -0.389      (0)
   Co(OH)4-2       3.225e-23   2.165e-23   -22.491   -22.665    -0.173      (0)
   Co4(OH)4+4      1.990e-28   4.040e-29   -27.701   -28.394    -0.692      (0)
Co(3)         1.013e-29
   CoOH+2          1.013e-29   6.801e-30   -28.994   -29.167    -0.173      (0)
   Co+3            5.925e-36   2.652e-36   -35.227   -35.576    -0.349      (0)
Cu(1)         2.948e-09
   Cu+             2.948e-09   2.668e-09    -8.530    -8.574    -0.043      (0)
Cu(2)         4.378e-07
   CuCO3           2.384e-07   2.384e-07    -6.623    -6.623     0.000      (0)
   CuOH+           9.510e-08   8.694e-08    -7.022    -7.061    -0.039      (0)
   Cu+2            7.788e-08   5.448e-08    -7.109    -7.264    -0.155      (0)
   CuSO4           1.514e-08   1.514e-08    -7.820    -7.820     0.000      (0)
   Cu(OH)2         8.754e-09   8.754e-09    -8.058    -8.058     0.000      (0)
   CuHCO3+         1.201e-09   1.087e-09    -8.920    -8.964    -0.043      (0)
   Cu(CO3)2-2      7.104e-10   4.768e-10    -9.149    -9.322    -0.173      (0)
   Cu2(OH)2+2      2.829e-10   1.899e-10    -9.548    -9.722    -0.173      (0)
   CuF+            5.311e-11   4.808e-11   -10.275   -10.318    -0.043      (0)
   Cu(OH)3-        1.001e-11   9.061e-12   -11.000   -11.043    -0.043      (0)
   Cu(OH)4-2       5.361e-17   3.599e-17   -16.271   -16.444    -0.173      (0)
F             1.580e-05
   F-              1.529e-05   1.398e-05    -4.816    -4.854    -0.039      (0)
   MgF+            3.408e-07   3.119e-07    -6.467    -6.506    -0.038      (0)
   CaF+            1.624e-07   1.488e-07    -6.789    -6.827    -0.038      (0)
   HF              4.127e-10   4.127e-10    -9.384    -9.384     0.000      (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000      (0)
   MnF+            2.582e-10   2.365e-10    -9.588    -9.626    -0.038      (0)
   CuF+            5.311e-11   4.808e-11   -10.275   -10.318    -0.043      (0)
   CoF+            3.255e-11   2.946e-11   -10.487   -10.531    -0.043      (0)
   NiF+            1.512e-11   1.369e-11   -10.820   -10.864    -0.043      (0)
   AlF2+           4.383e-12   4.020e-12   -11.358   -11.396    -0.038      (0)
   AlF+2           1.021e-12   7.220e-13   -11.991   -12.141    -0.150      (0)
   AlF3            7.077e-13   7.077e-13   -12.150   -12.150     0.000      (0)
   HF2-            2.403e-14   2.194e-14   -13.619   -13.659    -0.039      (0)
   AlF4-           5.420e-15   4.960e-15   -14.266   -14.304    -0.038      (0)
   H2F2            4.564e-19   4.564e-19   -18.341   -18.341     0.000      (0)
H(0)          5.627e-27
   H2              2.814e-27   2.818e-27   -26.551   -26.550     0.001      (0)
K             3.326e-04
   K+              3.298e-04   3.016e-04    -3.482    -3.521    -0.039      (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038      (0)
Mg            3.293e-04
   Mg+2            2.842e-04   1.988e-04    -3.546    -3.702    -0.155      (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000      (0)
   MgHCO3+         7.037e-07   6.434e-07    -6.153    -6.192    -0.039      (0)
   MgF+            3.408e-07   3.119e-07    -6.467    -6.506    -0.038      (0)
   MgCO3           1.229e-07   1.229e-07    -6.911    -6.911     0.000      (0)
   MgOH+           4.345e-08   3.994e-08    -7.362    -7.399    -0.037      (0)
Mn(2)         7.283e-07
   Mn+2            6.329e-07   4.249e-07    -6.199    -6.372    -0.173      (0)
   MnSO4           9.162e-08   9.162e-08    -7.038    -7.038     0.000      (0)
   MnHCO3+         2.926e-09   2.681e-09    -8.534    -8.572    -0.038      (0)
   MnOH+           5.878e-10   5.385e-10    -9.231    -9.269    -0.038      (0)
   MnF+            2.582e-10   2.365e-10    -9.588    -9.626    -0.038      (0)
   Mn(OH)3-        9.250e-19   8.475e-19   -18.034   -18.072    -0.038      (0)
   Mn(OH)4-2       1.959e-24   1.381e-24   -23.708   -23.860    -0.152      (0)
Mn(3)         4.240e-28
   Mn+3            4.240e-28   1.898e-28   -27.373   -27.722    -0.349      (0)
Mn(6)         0.000e+00
   MnO4-2          0.000e+00   0.000e+00   -47.042   -47.194    -0.152      (0)
Mn(7)         0.000e+00
   MnO4-           0.000e+00   0.000e+00   -52.526   -52.566    -0.040      (0)
Mo            3.128e-08
   MoO4-2          3.127e-08   2.188e-08    -7.505    -7.660    -0.155      (0)
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```
   HMoO4-          9.595e-12   8.685e-12   -11.018   -11.061    -0.043     (0)
   H2MoO4          1.269e-15   1.269e-15   -14.896   -14.896     0.000     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -51.065   -51.455    -0.389     (0)
   Mo7O24-6        0.000e+00   0.000e+00   -60.672   -62.230    -1.558     (0)
   HMo7O24-5       0.000e+00   0.000e+00   -62.461   -63.543    -1.082     (0)
   H2Mo7O24-4      0.000e+00   0.000e+00   -65.769   -66.461    -0.692     (0)
   H3Mo7O24-3      0.000e+00   0.000e+00   -70.526   -70.915    -0.389     (0)
Na            4.351e-05
   Na+             4.322e-05   3.953e-05    -4.364    -4.403    -0.039     (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   NaHCO3          7.030e-09   7.030e-09    -8.153    -8.153     0.000     (0)
   NaCO3-          5.965e-10   5.470e-10    -9.224    -9.262    -0.038     (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000     (0)
Ni            6.818e-08
   Ni+2            5.569e-08   3.896e-08    -7.254    -7.409    -0.155     (0)
   NiSO4           9.427e-09   9.427e-09    -8.026    -8.026     0.000     (0)
   NiHCO3+         1.678e-09   1.519e-09    -8.775    -8.818    -0.043     (0)
   NiCO3           1.080e-09   1.080e-09    -8.967    -8.967     0.000     (0)
   NiOH+           2.734e-10   2.475e-10    -9.563    -9.606    -0.043     (0)
   NiF+            1.512e-11   1.369e-11   -10.820   -10.864    -0.043     (0)
   Ni(OH)2         9.921e-12   9.921e-12   -11.003   -11.003     0.000     (0)
   Ni(SO4)2-2      5.639e-13   3.785e-13   -12.249   -12.422    -0.173     (0)
   Ni(OH)3-        5.531e-15   5.006e-15   -14.257   -14.300    -0.043     (0)
O(0)          1.274e-39
   O2              6.370e-40   6.381e-40   -39.196   -39.195     0.001     (0)
S(6)          2.051e-03
   SO4-2           1.733e-03   1.213e-03    -2.761    -2.916    -0.155     (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000     (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000     (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038     (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   MnSO4           9.162e-08   9.162e-08    -7.038    -7.038     0.000     (0)
   CoSO4           1.612e-08   1.612e-08    -7.793    -7.793     0.000     (0)
   CuSO4           1.514e-08   1.514e-08    -7.820    -7.820     0.000     (0)
   NiSO4           9.427e-09   9.427e-09    -8.026    -8.026     0.000     (0)
   HSO4-           2.583e-09   2.364e-09    -8.588    -8.626    -0.038     (0)
   Ni(SO4)2-2      5.639e-13   3.785e-13   -12.249   -12.422    -0.173     (0)
   AlSO4+          5.310e-14   4.860e-14   -13.275   -13.313    -0.038     (0)
   Al(SO4)2-       6.899e-16   6.315e-16   -15.161   -15.200    -0.038     (0)

-----------------------------Saturation indices-----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.99      8.81   10.80  Al(OH)3
  Al2(MoO4)3      -53.92    -51.55    2.37  Al2(MoO4)3
  Al2O3            -2.03     17.63   19.65  Al2O3
  Al4(OH)10SO4     -5.77     16.93   22.70  Al4(OH)10SO4
  AlOHSO4          -6.27     -9.50   -3.23  AlOHSO4
  Alunite          -4.61     -6.01   -1.40  KAl3(SO4)2(OH)6
  Anhydrite        -1.57     -5.93   -4.36  CaSO4
  Antlerite        -2.70      6.09    8.79  Cu3(OH)4SO4
  Aragonite        -0.84     -9.14   -8.30  CaCO3
  Artinite         -7.73      1.87    9.60  MgCO3:Mg(OH)2:3H2O
  Azurite          -1.74    -18.65  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -15.99      8.41   24.39  Ba(OH)2:8H2O
  BaF2            -10.88    -16.70   -5.82  BaF2
  BaMoO4           -7.69    -14.65   -6.96  BaMoO4
  Barite            0.07     -9.91   -9.98  BaSO4
  Birnessite      -11.01      7.08   18.09  MnO2
  Bixbyite         -8.60     -9.24   -0.64  Mn2O3
  Boehmite          0.23      8.81    8.58  AlOOH
  Brochantite      -0.99     14.23   15.22  Cu4(OH)6SO4
  Brucite          -5.15     11.70   16.84  Mg(OH)2
  Bunsenite        -4.45      7.99   12.45  NiO
  Calcite          -0.66     -9.14   -8.48  CaCO3
  CaMoO4           -2.72    -10.67   -7.95  CaMoO4
  CH4(g)          -74.08   -115.13  -41.05  CH4
  Chalcanthite     -7.54    -10.18   -2.64  CuSO4:5H2O
  Co(OH)2          -4.87      8.22   13.09  Co(OH)2
  Co(OH)3         -10.17    -12.48   -2.31  Co(OH)3
  CO2(g)           -3.38    -21.53  -18.15  CO2
  Co3O4            -6.23    -16.73  -10.50  Co3O4
  CoCO3            -3.33    -13.31   -9.98  CoCO3
  CoF2            -15.29    -16.89   -1.60  CoF2
  CoF3            -48.68    -50.14   -1.46  CoF3
  CoMoO4           -7.08    -14.84   -7.76  CoMoO4
  CoO              -5.36      8.22   13.59  CoO
  CoSO4           -12.90    -10.09    2.80  CoSO4
  CoSO4:6H2O       -7.62    -10.09   -2.47  CoSO4:6H2O
  Cryolite        -22.78    -56.62  -33.84  Na3AlF6
  Cu(OH)2          -0.54      8.14    8.67  Cu(OH)2
  Cu2SO4          -18.11    -20.06   -1.95  Cu2SO4
  CuCO3            -1.89    -13.39  -11.50  CuCO3
  CuF              -8.52    -13.43   -4.91  CuF
  CuF2            -18.09    -16.97    1.12  CuF2
  CuF2:2H2O       -12.42    -16.97   -4.55  CuF2:2H2O
  Cumetal          -3.82    -12.57   -8.76  Cu
  CuMoO4           -1.85    -14.92  -13.08  CuMoO4
  CuOCuSO4        -12.35     -2.04   10.30  CuOCuSO4
  Cuprite          -0.34     -1.75   -1.41  Cu2O
  CuSO4           -13.12    -10.18    2.94  CuSO4
  Diaspore          1.94      8.81    6.87  AlOOH
  Dolomite(disordered)  -2.43    -18.97  -16.54  CaMg(CO3)2
  Dolomite(ordered)  -1.88    -18.97  -17.09  CaMg(CO3)2
  Epsomite         -4.49     -6.62   -2.13  MgSO4:7H2O
  Fluorite         -2.22    -12.72  -10.50  CaF2
  Gibbsite          0.52      8.81    8.29  Al(OH)3
  Gypsum           -1.32     -5.93   -4.61  CaSO4:2H2O
  H2MoO4          -10.18    -23.06  -12.88  H2MoO4
  Hausmannite     -10.55     50.48   61.03  Mn3O4
  Huntite          -8.66    -38.63  -29.97  CaMg3(CO3)4
  Hydromagnesite  -18.86    -27.62   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum          -18.47    -23.64   -5.17  KAl(SO4)2:12H2O
  K2MoO4          -17.96    -14.70    3.26  K2MoO4
  Langite          -3.26     14.23   17.49  Cu4(OH)6SO4:H2O
  Lime            -20.31     12.39   32.70  CaO
  Magnesite        -2.37     -9.83   -7.46  MgCO3
  Malachite         0.05     -5.26   -5.31  Cu2(OH)2CO3
  Manganite        -4.61     20.73   25.34  MnOOH
  Mg(OH)2(active)  -7.10     11.70   18.79  Mg(OH)2
  MgF2             -5.28    -13.41   -8.13  MgF2
  MgMoO4           -9.51    -11.36   -1.85  MgMoO4
  Mirabilite      -10.61    -11.72   -1.11  Na2SO4:10H2O
  Mn2(SO4)3       -58.48    -64.19   -5.71  Mn2(SO4)3
  MnSO4           -11.87     -9.29    2.58  MnSO4
  MoO3            -15.06    -23.06   -8.00  MoO3
  Morenosite       -8.18    -10.33   -2.14  NiSO4:7H2O
  Na2Mo2O7        -22.93    -39.53  -16.60  Na2Mo2O7
  Na2MoO4         -17.96    -16.47    1.49  Na2MoO4
  Na2MoO4:2H2O    -17.69    -16.47    1.22  Na2MoO4:2H2O
  Natron          -13.62    -14.94   -1.31  Na2CO3:10H2O
  Nesquehonite     -5.16     -9.83   -4.67  MgCO3:3H2O
  Ni(OH)2          -4.80      7.99   12.79  Ni(OH)2
  Ni4(OH)6SO4     -18.35     13.65   32.00  Ni4(OH)6SO4
  NiCO3            -6.67    -13.54   -6.87  NiCO3
  NiMoO4           -3.93    -15.07  -11.14  NiMoO4
  Nsutite         -10.43      7.08   17.50  MnO2
  O2(g)           -36.29     46.80   83.09  O2
  Periclase        -9.89     11.70   21.58  MgO
  Portlandite     -10.42     12.39   22.80  Ca(OH)2
  Pyrochroite      -6.17      9.03   15.19  Mn(OH)2
  Pyrolusite       -8.95     32.43   41.38  MnO2
  Retgersite       -8.29    -10.33   -2.04  NiSO4:6H2O
  Rhodochrosite    -1.92    -12.50  -10.58  MnCO3
  Spinel           -7.52     29.32   36.85  MgAl2O4
  Tenorite          0.49      8.14    7.64  CuO
  Thenardite      -12.04    -11.72    0.32  Na2SO4
  Thermonatrite   -15.57    -14.94    0.64  Na2CO3:H2O
  Witherite        -4.55    -13.12   -8.57  BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

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Beginning of batch-reaction calculations.
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Reaction step 1.

Using mix 1.      Mix within UG Works

Mixture 1.  Mix within UG Works

        3.120e-01 Solution 1  UG Water P25
        1.090e-01 Solution 2  PAF Material
        3.980e-01 Solution 3  NAF Material
        1.810e-01 Solution 4  Make-up Material

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                3.180e-06   3.180e-06
      As                1.654e-07   1.654e-07
      B                 3.763e-06   3.763e-06
      Ba                5.090e-07   5.090e-07
      C                 3.092e-03   3.092e-03
      Ca                2.490e-03   2.490e-03
      Cd                2.140e-08   2.140e-08
      Cl                4.723e-04   4.723e-04
      Co                6.864e-08   6.864e-08
      Cr                4.686e-08   4.686e-08
      Cu                6.018e-07   6.018e-07
      F                 2.724e-05   2.724e-05
      Fe                1.550e-06   1.550e-06
      K                 5.622e-04   5.622e-04
      Mg                1.065e-03   1.065e-03
      Mn                1.662e-06   1.662e-06
      Mo                6.564e-08   6.564e-08
      Na                2.832e-03   2.832e-03
      Ni                5.636e-08   5.636e-08
      Pb                7.192e-08   7.192e-08
      S                 2.768e-03   2.768e-03
      Se                5.934e-08   5.934e-08
      U                 1.243e-08   1.243e-08
      V                 1.472e-08   1.472e-08
      Zn                9.583e-07   9.583e-07

---------------------------Description of solution---------------------------

                                       pH  =   8.080      Charge balance
                                       pe  =   3.291      Adjusted to redox equilibrium
                             Activity of water  =   1.000
                       Ionic strength (mol/kgw)  =   1.371e-02
                             Mass of water (kg)  =   1.000e+00
                       Total alkalinity (eq/kg)  =   3.120e-03
                             Total CO2 (mol/kg)  =   3.092e-03
                                Temperature (°C)  =  25.00
                         Electrical balance (eq)  =   1.366e-03
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =   7.97
                                     Iterations  =  10
                                        Total H  = 1.110168e+02
                                        Total O  = 5.552721e+01

----------------------------Distribution of species-------------------------

                                                Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             1.365e-06   1.209e-06    -5.865    -5.917    -0.053     (0)
   H+              9.369e-09   8.324e-09    -8.028    -8.080    -0.051      0.00
   H2O             5.551e+01   9.998e-01     1.744    -0.000     0.000     18.07
Al            3.180e-06
   Al(OH)4-        3.160e-06   2.811e-06    -5.500    -5.551    -0.051     (0)
   Al(OH)3         1.846e-08   1.846e-08    -7.734    -7.734     0.000     (0)
   Al(OH)2+        8.573e-10   7.650e-10    -9.067    -9.116    -0.049     (0)
   AlF2+           1.481e-12   1.322e-12   -11.829   -11.879    -0.049     (0)
   AlOH+2          1.256e-12   7.963e-13   -11.901   -12.099    -0.198     (0)
   AlF3            3.736e-13   3.736e-13   -12.428   -12.428     0.000     (0)
   AlF+2           2.331e-13   1.478e-13   -12.632   -12.830    -0.198     (0)
   AlSO4+          7.909e-15   7.034e-15   -14.102   -14.153    -0.051     (0)
   AlF4-           4.727e-15   4.204e-15   -14.325   -14.376    -0.051     (0)
   Al+3            1.909e-15   6.584e-16   -14.719   -15.181    -0.462     (0)
   Al(SO4)2-       1.166e-16   1.037e-16   -15.933   -15.984    -0.051     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -52.459   -52.997    -0.537     (0)
As(3)         1.528e-18
   H3AsO3          1.427e-18   1.427e-18   -17.845   -17.845     0.000     (0)
   H2AsO3-         1.009e-19   8.795e-20   -18.996   -19.056    -0.060     (0)
   HAsO3-2         1.670e-23   9.636e-24   -22.777   -23.016    -0.239     (0)
   H4AsO3+         6.754e-27   5.887e-27   -26.170   -26.230    -0.060     (0)
   AsO3-3          1.538e-28   4.462e-29   -27.813   -28.350    -0.537     (0)
As(5)         1.654e-07
   HAsO4-2         1.574e-07   9.079e-08    -6.803    -7.042    -0.239     (0)
   H2AsO4-         7.908e-09   6.893e-09    -8.102    -8.162    -0.060     (0)
   AsO4-3          1.189e-10   3.449e-11    -9.925   -10.462    -0.537     (0)
   H3AsO4          9.939e-15   9.970e-15   -14.003   -14.001     0.001     (0)
B             3.763e-06
   H3BO3           3.462e-06   3.473e-06    -5.461    -5.459     0.001     (0)
   H2BO3-          2.747e-07   2.423e-07    -6.561    -6.616    -0.054     (0)
   CaH2BO3+        1.970e-08   1.738e-08    -7.705    -7.760    -0.054     (0)
   MgH2BO3+        5.338e-09   4.709e-09    -8.273    -8.327    -0.054     (0)
   NaH2BO3         9.576e-10   9.576e-10    -9.019    -9.019     0.000     (0)
   BF(OH)3-        3.527e-11   3.111e-11   -10.453   -10.507    -0.054     (0)
   BaH2BO3+        2.635e-12   2.324e-12   -11.579   -11.634    -0.054     (0)
   H5(BO3)2-       8.119e-13   7.162e-13   -12.090   -12.145    -0.054     (0)
   BF2(OH)2-       7.049e-16   6.218e-16   -15.152   -15.206    -0.054     (0)
   H8(BO3)3-       2.820e-16   2.487e-16   -15.550   -15.604    -0.054     (0)
   BF3OH-          5.127e-23   4.523e-23   -22.290   -22.345    -0.054     (0)
   BF4-            4.716e-29   4.160e-29   -28.326   -28.381    -0.054     (0)
Ba            5.090e-07
   Ba+2            4.981e-07   3.104e-07    -6.303    -6.508    -0.205     (0)
   BaHCO3+         8.564e-09   7.659e-09    -8.067    -8.116    -0.049     (0)
   BaCO3           2.316e-09   2.316e-09    -8.635    -8.635     0.000     (0)
   BaH2BO3+        2.635e-12   2.324e-12   -11.579   -11.634    -0.054     (0)
   BaOH+           1.839e-12   1.639e-12   -11.735   -11.786    -0.050     (0)
C(4)          3.092e-03
   HCO3-           2.895e-03   2.584e-03    -2.538    -2.588    -0.049     (0)
   CaHCO3+         6.706e-05   5.998e-05    -4.174    -4.222    -0.049     (0)
   H2CO3           4.837e-05   4.837e-05    -4.315    -4.315     0.000     (0)
   CaCO3           2.875e-05   2.875e-05    -4.541    -4.541     0.000     (0)
   CO3-2           2.335e-05   1.455e-05    -4.632    -4.837    -0.205     (0)
   MgHCO3+         1.669e-05   1.482e-05    -4.777    -4.829    -0.052     (0)
   MgCO3           6.784e-06   6.784e-06    -5.169    -5.169     0.000     (0)
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NaHCO3	3.623e-06	3.623e-06	-5.441	-5.441	0.000	(0)
NaCO3-	7.572e-07	6.757e-07	-6.121	-6.170	-0.049	(0)
CuCO3	5.194e-07	5.194e-07	-6.285	-6.285	0.000	(0)
ZnCO3	2.667e-07	2.667e-07	-6.574	-6.574	0.000	(0)
PbCO3	5.716e-08	5.716e-08	-7.243	-7.243	0.000	(0)
MnHCO3+	4.713e-08	4.199e-08	-7.327	-7.377	-0.050	(0)
Cu(CO3)2-2	3.526e-08	2.034e-08	-7.453	-7.692	-0.239	(0)
ZnHCO3+	2.986e-08	2.602e-08	-7.525	-7.585	-0.060	(0)
NiCO3	1.089e-08	1.089e-08	-7.963	-7.963	0.000	(0)
UO2(CO3)3-4	9.839e-09	1.090e-09	-8.007	-8.962	-0.955	(0)
BaHCO3+	8.564e-09	7.659e-09	-8.067	-8.116	-0.049	(0)
NiHCO3+	7.334e-09	6.392e-09	-8.135	-8.194	-0.060	(0)
CoCO3	6.709e-09	6.709e-09	-8.173	-8.173	0.000	(0)
CoHCO3+	6.289e-09	5.481e-09	-8.201	-8.261	-0.060	(0)
Pb(CO3)2-2	4.158e-09	2.399e-09	-8.381	-8.620	-0.239	(0)
CdCO3	3.031e-09	3.031e-09	-8.518	-8.518	0.000	(0)
PbHCO3+	2.878e-09	2.508e-09	-8.541	-8.601	-0.060	(0)
UO2(CO3)2-2	2.591e-09	1.495e-09	-8.587	-8.825	-0.239	(0)
BaCO3	2.316e-09	2.316e-09	-8.635	-8.635	0.000	(0)
CuHCO3+	1.134e-09	9.881e-10	-8.945	-9.005	-0.060	(0)
FeHCO3+	3.228e-10	2.887e-10	-9.491	-9.540	-0.049	(0)
CdHCO3+	6.167e-11	5.375e-11	-10.210	-10.270	-0.060	(0)
Cd(CO3)2-2	5.666e-11	3.269e-11	-10.247	-10.486	-0.239	(0)
UO2CO3	5.149e-12	5.149e-12	-11.288	-11.288	0.000	(0)
Ca 2.490e-03						
Ca+2	2.001e-03	1.247e-03	-2.699	-2.904	-0.205	(0)
CaSO4	3.930e-04	3.930e-04	-3.406	-3.406	0.000	(0)
CaHCO3+	6.706e-05	5.998e-05	-4.174	-4.222	-0.049	(0)
CaCO3	2.875e-05	2.875e-05	-4.541	-4.541	0.000	(0)
CaF+	3.428e-07	3.055e-07	-6.465	-6.515	-0.050	(0)
CaOH+	3.364e-08	3.008e-08	-7.473	-7.522	-0.049	(0)
CaH2BO3+	1.970e-08	1.738e-08	-7.705	-7.760	-0.054	(0)
Cd 2.140e-08						
Cd+2	1.466e-08	9.137e-09	-7.834	-8.039	-0.205	(0)
CdCO3	3.031e-09	3.031e-09	-8.518	-8.518	0.000	(0)
CdSO4	2.948e-09	2.948e-09	-8.530	-8.530	0.000	(0)
CdCl+	4.201e-10	3.661e-10	-9.377	-9.436	-0.060	(0)
CdOH+	1.007e-10	8.778e-11	-9.997	-10.057	-0.060	(0)
Cd(SO4)2-2	9.486e-11	5.473e-11	-10.023	-10.262	-0.239	(0)
CdHCO3+	6.167e-11	5.375e-11	-10.210	-10.270	-0.060	(0)
Cd(CO3)2-2	5.666e-11	3.269e-11	-10.247	-10.486	-0.239	(0)
CdOHCl	1.816e-11	1.816e-11	-10.741	-10.741	0.000	(0)
CdF+	3.731e-12	3.251e-12	-11.428	-11.488	-0.060	(0)
Cd(OH)2	6.698e-13	6.698e-13	-12.174	-12.174	0.000	(0)
CdCl2	6.405e-13	6.405e-13	-12.194	-12.194	0.000	(0)
CdCl3-	1.946e-16	1.696e-16	-15.711	-15.771	-0.060	(0)
CdF2	1.457e-16	1.457e-16	-15.837	-15.837	0.000	(0)
Cd(OH)3-	5.679e-17	4.949e-17	-16.246	-16.305	-0.060	(0)
Cd2OH+3	1.385e-17	4.019e-18	-16.858	-17.396	-0.537	(0)
Cd(SeO3)2-2	2.692e-18	1.553e-18	-17.570	-17.809	-0.239	(0)
CdSeO4	1.668e-19	1.668e-19	-18.778	-18.778	0.000	(0)
Cd(OH)4-2	1.698e-23	9.798e-24	-22.770	-23.009	-0.239	(0)
CdHS+	0.000e+00	0.000e+00	-68.221	-68.281	-0.060	(0)
Cd(HS)2	0.000e+00	0.000e+00	-129.326	-129.326	0.000	(0)
Cd(HS)3-	0.000e+00	0.000e+00	-195.616	-195.676	-0.060	(0)
Cd(HS)4-2	0.000e+00	0.000e+00	-261.491	-261.730	-0.239	(0)
Cl 4.723e-04						
Cl-	4.723e-04	4.196e-04	-3.326	-3.377	-0.051	(0)
CuCl	8.016e-10	8.016e-10	-9.096	-9.096	0.000	(0)
ZnOHCl	5.316e-10	5.316e-10	-9.274	-9.274	0.000	(0)
MnCl+	4.829e-10	4.303e-10	-9.316	-9.366	-0.050	(0)
CdCl+	4.201e-10	3.661e-10	-9.377	-9.436	-0.060	(0)
ZnCl+	3.782e-10	3.357e-10	-9.422	-9.474	-0.052	(0)
CuCl2-	7.917e-11	7.028e-11	-10.101	-10.153	-0.052	(0)
CoCl+	4.543e-11	3.959e-11	-10.343	-10.402	-0.060	(0)
NiCl+	2.472e-11	2.155e-11	-10.607	-10.667	-0.060	(0)
PbCl+	2.232e-11	1.945e-11	-10.651	-10.711	-0.060	(0)
CdOHCl	1.816e-11	1.816e-11	-10.741	-10.741	0.000	(0)
CuCl+	4.541e-12	4.031e-12	-11.343	-11.395	-0.052	(0)
CdCl2	6.405e-13	6.405e-13	-12.194	-12.194	0.000	(0)
MnCl2	2.551e-13	2.551e-13	-12.593	-12.593	0.000	(0)
ZnCl2	2.233e-13	2.233e-13	-12.651	-12.651	0.000	(0)
PbCl2	3.646e-14	3.646e-14	-13.438	-13.438	0.000	(0)
CuCl3-2	1.000e-14	6.305e-15	-14.000	-14.200	-0.200	(0)
CuCl2	5.865e-16	5.865e-16	-15.232	-15.232	0.000	(0)
CdCl3-	1.946e-16	1.696e-16	-15.711	-15.771	-0.060	(0)
ZnCl3-	8.384e-17	7.442e-17	-16.077	-16.128	-0.052	(0)
NiCl2	4.552e-17	4.552e-17	-16.342	-16.342	0.000	(0)
MnCl3-	3.308e-17	2.948e-17	-16.480	-16.531	-0.050	(0)
PbCl3-	6.989e-18	6.091e-18	-17.156	-17.215	-0.060	(0)
CrCl+2	6.781e-18	3.912e-18	-17.169	-17.408	-0.239	(0)
UO2Cl+	6.939e-20	6.048e-20	-19.159	-19.218	-0.060	(0)
CrOHCl2	3.774e-20	3.774e-20	-19.423	-19.423	0.000	(0)
FeCl+2	3.242e-20	2.044e-20	-19.489	-19.690	-0.200	(0)
ZnCl4-2	2.477e-20	1.561e-20	-19.606	-19.806	-0.200	(0)
CuCl3-	2.587e-21	2.297e-21	-20.587	-20.639	-0.052	(0)
PbCl4-2	2.025e-21	1.168e-21	-20.694	-20.932	-0.239	(0)
CrCl2+	1.787e-22	1.558e-22	-21.748	-21.808	-0.060	(0)
VOCl+	4.663e-23	4.064e-23	-22.331	-22.391	-0.060	(0)
FeCl2+	4.299e-23	3.831e-23	-22.367	-22.417	-0.050	(0)
CuCl4-2	7.661e-27	4.830e-27	-26.116	-26.316	-0.200	(0)
FeCl3	1.608e-27	1.608e-27	-26.794	-26.794	0.000	(0)
CrO3Cl-	1.803e-29	1.572e-29	-28.744	-28.804	-0.060	(0)
CoCl+2	3.143e-38	1.814e-38	-37.503	-37.741	-0.239	(0)
UCl+3	0.000e+00	0.000e+00	-46.876	-47.414	-0.537	(0)
Co(2) 6.864e-08						
Co+2	4.727e-08	2.727e-08	-7.325	-7.564	-0.239	(0)
CoSO4	7.489e-09	7.489e-09	-8.126	-8.126	0.000	(0)
CoCO3	6.709e-09	6.709e-09	-8.173	-8.173	0.000	(0)
CoHCO3+	6.289e-09	5.481e-09	-8.201	-8.261	-0.060	(0)
CoOH+	7.551e-10	6.581e-10	-9.122	-9.182	-0.060	(0)
Co(OH)2	6.323e-11	6.323e-11	-10.199	-10.199	0.000	(0)
CoCl+	4.543e-11	3.959e-11	-10.343	-10.402	-0.060	(0)
CoF+	2.222e-11	1.937e-11	-10.653	-10.713	-0.060	(0)
Co(OH)3-	1.751e-15	1.526e-15	-14.757	-14.817	-0.060	(0)
CoOOH-	4.393e-16	3.829e-16	-15.357	-15.417	-0.060	(0)
Co2OH+3	3.101e-18	8.996e-19	-17.509	-18.046	-0.537	(0)
CoSeO4	1.340e-18	1.340e-18	-17.873	-17.873	0.000	(0)
Co(OH)4-2	5.069e-22	2.925e-22	-21.295	-21.534	-0.239	(0)
Co4(OH)4+4	3.378e-28	3.743e-29	-27.471	-28.427	-0.955	(0)
Co(3) 2.263e-30						
CoOH+2	2.263e-30	1.305e-30	-29.645	-29.884	-0.239	(0)
Co+3	6.158e-37	2.124e-37	-36.211	-36.673	-0.462	(0)
CoCl+2	3.143e-38	1.814e-38	-37.503	-37.741	-0.239	(0)
Cr(2) 1.525e-24						
Cr+2	1.525e-24	8.797e-25	-23.817	-24.056	-0.239	(0)
Cr(3) 4.686e-08						
Cr(OH)2+	3.219e-08	2.805e-08	-7.492	-7.552	-0.060	(0)
Cr(OH)3	1.274e-08	1.274e-08	-7.895	-7.895	0.000	(0)
CrO2-	8.345e-10	7.273e-10	-9.079	-9.138	-0.060	(0)
Cr(OH)4-	7.041e-10	6.136e-10	-9.152	-9.212	-0.060	(0)
Cr(OH)+2	3.304e-10	1.906e-10	-9.481	-9.720	-0.239	(0)
CrOHSO4	6.226e-11	6.226e-11	-10.206	-10.206	0.000	(0)
CrF+2	4.444e-14	2.564e-14	-13.352	-13.591	-0.239	(0)
CrSO4+	2.657e-14	2.315e-14	-13.576	-13.635	-0.060	(0)
Cr+3	2.483e-14	7.204e-15	-13.605	-14.142	-0.537	(0)
CrCl+2	6.781e-18	3.912e-18	-17.169	-17.408	-0.239	(0)
Cr2(OH)2SO4+2	1.859e-18	1.073e-18	-17.731	-17.970	-0.239	(0)
Cr2(OH)2(SO4)2	8.769e-20	8.769e-20	-19.057	-19.057	0.000	(0)
CrOHCl2	3.774e-20	3.774e-20	-19.423	-19.423	0.000	(0)
CrCl2+	1.787e-22	1.558e-22	-21.748	-21.808	-0.060	(0)
Cr(6) 4.387e-17						
CrO4-2	4.262e-17	2.656e-17	-16.370	-16.576	-0.205	(0)
HCrO4-	8.208e-19	7.153e-19	-18.086	-18.145	-0.060	(0)
NaCrO4-	3.776e-19	3.291e-19	-18.423	-18.483	-0.060	(0)
KCrO4-	5.601e-20	4.881e-20	-19.252	-19.311	-0.060	(0)
H2CrO4	4.827e-27	4.827e-27	-26.316	-26.316	0.000	(0)
CrO3SO4-2	4.327e-27	2.497e-27	-26.364	-26.603	-0.239	(0)
CrO3Cl-	1.803e-29	1.572e-29	-28.744	-28.804	-0.060	(0)
Cr2O7-2	3.076e-35	1.775e-35	-34.512	-34.751	-0.239	(0)
Cu(1) 2.622e-09						
Cu+	1.741e-09	1.517e-09	-8.759	-8.819	-0.060	(0)
CuCl	8.016e-10	8.016e-10	-9.096	-9.096	0.000	(0)
CuCl2-	7.917e-11	7.028e-11	-10.101	-10.153	-0.052	(0)
CuCl3-2	1.000e-14	6.305e-15	-14.000	-14.200	-0.200	(0)
Cu(S4)2-3	0.000e+00	0.000e+00	-125.484	-125.769	-0.285	(0)
CuS4S5-3	0.000e+00	0.000e+00	-126.225	-126.499	-0.274	(0)
Cu(2) 5.992e-07						
CuCO3	5.194e-07	5.194e-07	-6.285	-6.285	0.000	(0)
Cu(CO3)2-2	3.526e-08	2.034e-08	-7.453	-7.692	-0.239	(0)
CuOH+	2.612e-08	2.318e-08	-7.583	-7.635	-0.052	(0)
Cu+2	9.727e-09	6.061e-09	-8.012	-8.217	-0.205	(0)
Cu(OH)2	5.594e-09	5.594e-09	-8.252	-8.252	0.000	(0)
CuSO4	1.911e-09	1.911e-09	-8.719	-8.719	0.000	(0)
CuHCO3+	1.134e-09	9.881e-10	-8.945	-9.005	-0.060	(0)
Cu2(OH)2+2	2.340e-11	1.350e-11	-10.631	-10.870	-0.239	(0)
Cu(OH)3-	1.592e-11	1.388e-11	-10.798	-10.858	-0.060	(0)
CuF+	9.853e-12	8.587e-12	-11.006	-11.066	-0.060	(0)
CuCl+	4.541e-12	4.031e-12	-11.343	-11.395	-0.052	(0)
CuCl2	5.865e-16	5.865e-16	-15.232	-15.232	0.000	(0)
Cu(OH)4-2	2.289e-16	1.321e-16	-15.640	-15.879	-0.239	(0)
CuCl3-	2.587e-21	2.297e-21	-20.587	-20.639	-0.052	(0)
CuCl4-2	7.661e-27	4.830e-27	-26.116	-26.316	-0.200	(0)
Cu(HS)3-	0.000e+00	0.000e+00	-187.008	-187.067	-0.060	(0)
F 2.724e-05						
F-	2.527e-05	2.245e-05	-4.597	-4.649	-0.051	(0)
MgF+	1.588e-06	1.412e-06	-5.799	-5.850	-0.051	(0)
CaF+	3.428e-07	3.055e-07	-6.465	-6.515	-0.050	(0)
NaF	3.533e-08	3.533e-08	-7.452	-7.452	0.000	(0)
MnF+	8.172e-10	7.282e-10	-9.088	-9.138	-0.050	(0)
HF	2.764e-10	2.764e-10	-9.558	-9.558	0.000	(0)
ZnF+	1.637e-10	1.427e-10	-9.786	-9.846	-0.060	(0)
BF(OH)3-	3.527e-11	3.111e-11	-10.453	-10.507	-0.054	(0)
CoF+	2.222e-11	1.937e-11	-10.653	-10.713	-0.060	(0)
NiF+	1.299e-11	1.132e-11	-10.887	-10.946	-0.060	(0)
CuF+	9.853e-12	8.587e-12	-11.006	-11.066	-0.060	(0)
CdF+	3.731e-12	3.251e-12	-11.428	-11.488	-0.060	(0)
PbF+	2.372e-12	2.068e-12	-11.625	-11.685	-0.060	(0)
AlF2+	1.481e-12	1.322e-12	-11.829	-11.879	-0.049	(0)
AlF3	3.736e-13	3.736e-13	-12.428	-12.428	0.000	(0)
AlF+2	2.331e-13	1.478e-13	-12.632	-12.830	-0.198	(0)
CrF+2	4.444e-14	2.564e-14	-13.352	-13.591	-0.239	(0)
HF2-	2.664e-14	2.360e-14	-13.574	-13.627	-0.053	(0)
AlF4-	4.727e-15	4.204e-15	-14.325	-14.376	-0.051	(0)
PbF2	9.136e-16	9.136e-16	-15.039	-15.039	0.000	(0)
BF2(OH)2-	7.049e-16	6.218e-16	-15.152	-15.206	-0.054	(0)
UO2F+	3.161e-16	2.755e-16	-15.500	-15.560	-0.060	(0)
CdF2	1.457e-16	1.457e-16	-15.837	-15.837	0.000	(0)
FeF+2	6.298e-17	3.971e-17	-16.201	-16.401	-0.200	(0)
FeF2+	2.678e-17	2.386e-17	-16.572	-16.622	-0.050	(0)
UO2F2	1.784e-17	1.784e-17	-16.749	-16.749	0.000	(0)
FeF3	7.559e-19	7.559e-19	-18.122	-18.122	0.000	(0)
VO2F	4.798e-19	4.798e-19	-18.319	-18.319	0.000	(0)
H2F2	2.048e-19	2.048e-19	-18.689	-18.689	0.000	(0)
UO2F3-	1.154e-19	1.006e-19	-18.938	-18.997	-0.060	(0)
PbF3-	4.464e-20	3.891e-20	-19.350	-19.410	-0.060	(0)
VOF+	5.335e-21	4.649e-21	-20.273	-20.333	-0.060	(0)
VO2F2-	4.488e-21	3.912e-21	-20.348	-20.408	-0.060	(0)
BF3OH-	5.127e-23	4.523e-23	-22.290	-22.345	-0.054	(0)
VOF2	3.915e-23	3.915e-23	-22.407	-22.407	0.000	(0)
UO2F4-2	3.110e-23	1.794e-23	-22.507	-22.746	-0.239	(0)
VO2F3-2	1.899e-24	1.096e-24	-23.721	-23.960	-0.239	(0)
PbF4-2	7.247e-25	4.181e-25	-24.140	-24.379	-0.239	(0)
VOF3-	3.578e-26	3.119e-26	-25.446	-25.506	-0.060	(0)
BF4-	4.716e-29	4.160e-29	-28.326	-28.381	-0.054	(0)
VO2F4-3	4.172e-29	1.210e-29	-28.380	-28.917	-0.537	(0)
VOF4-2	4.899e-30	2.827e-30	-29.310	-29.549	-0.239	(0)
UF3+	9.482e-39	8.264e-39	-38.023	-38.083	-0.060	(0)
UF2+2	4.025e-39	2.322e-39	-38.395	-38.634	-0.239	(0)
UF+3	0.000e+00	0.000e+00	-40.548	-41.085	-0.537	(0)
UF4	0.000e+00	0.000e+00	-40.692	-40.692	0.000	(0)
UF5-	0.000e+00	0.000e+00	-43.683	-43.742	-0.060	(0)
UF6-2	0.000e+00	0.000e+00	-45.672	-45.911	-0.239	(0)
Fe(2) 1.918e-08						
Fe+2	1.538e-08	8.875e-09	-7.813	-8.052	-0.239	(0)
FeSO4	2.998e-09	2.998e-09	-8.523	-8.523	0.000	(0)
FeOH+	4.795e-10	4.273e-10	-9.319	-9.369	-0.050	(0)
FeHCO3+	3.228e-10	2.887e-10	-9.491	-9.540	-0.049	(0)
Fe(OH)2	4.105e-13	4.105e-13	-12.387	-12.387	0.000	(0)
Fe(OH)3-	1.762e-13	1.570e-13	-12.754	-12.804	-0.050	(0)
Fe(HS)2	0.000e+00	0.000e+00	-135.601	-135.601	0.000	(0)
Fe(HS)3-	0.000e+00	0.000e+00	-201.754	-201.814	-0.060	(0)
Fe(3) 1.531e-06						
Fe(OH)3	7.698e-07	7.698e-07	-6.114	-6.114	0.000	(0)
Fe(OH)2+	6.641e-07	5.926e-07	-6.178	-6.227	-0.049	(0)
Fe(OH)4-	9.714e-08	8.668e-08	-7.013	-7.062	-0.049	(0)
FeOH+2	1.998e-12	1.260e-12	-11.699	-11.900	-0.200	(0)
FeF+2	6.298e-17	3.971e-17	-16.201	-16.401	-0.200	(0)
FeSO4+	2.795e-17	2.491e-17	-16.554	-16.604	-0.050	(0)
FeF2+	2.678e-17	2.386e-17	-16.572	-16.622	-0.050	(0)
Fe+3	4.676e-18	1.613e-18	-17.330	-17.792	-0.462	(0)
Fe(SO4)2-	8.409e-19	7.329e-19	-18.075	-18.135	-0.060	(0)
FeF3	7.559e-19	7.559e-19	-18.122	-18.122	0.000	(0)
FeCl+2	3.242e-20	2.044e-20	-19.489	-19.690	-0.200	(0)
Fe2(OH)2+4	4.740e-22	5.253e-23	-21.324	-22.280	-0.955	(0)
FeHSeO3+2	2.218e-22	1.280e-22	-21.654	-21.893	-0.239	(0)
FeCl2+	4.299e-23	3.831e-23	-22.367	-22.417	-0.050	(0)
Fe3(OH)4+5	1.400e-26	4.500e-28	-25.854	-27.347	-1.493	(0)
FeCl3	1.608e-27	1.608e-27	-26.794	-26.794	0.000	(0)
H(0) 2.555e-26						
H2	1.278e-26	1.282e-26	-25.894	-25.892	0.001	(0)
K 5.622e-04						
K+	5.568e-04	4.947e-04	-3.254	-3.306	-0.051	(0)
KSO4-	5.402e-06	4.820e-06	-5.267	-5.317	-0.049	(0)
KCrO4-	5.601e-20	4.881e-20	-19.252	-19.311	-0.060	(0)
Mg 1.065e-03						
Mg+2	8.994e-04	5.605e-04	-3.046	-3.251	-0.205	(0)
MgSO4	1.404e-04	1.404e-04	-3.853	-3.853	0.000	(0)
MgHCO3+	1.669e-05	1.482e-05	-4.777	-4.829	-0.052	(0)
MgCO3	6.784e-06	6.784e-06	-5.169	-5.169	0.000	(0)
MgF+	1.588e-06	1.412e-06	-5.799	-5.850	-0.051	(0)
MgOH+	3.012e-07	2.698e-07	-6.521	-6.569	-0.048	(0)
MgH2BO3+	5.338e-09	4.709e-09	-8.273	-8.327	-0.054	(0)
Mn(2) 1.662e-06						
Mn+2	1.412e-06	8.146e-07	-5.850	-6.089	-0.239	(0)
MnSO4	1.994e-07	1.994e-07	-6.700	-6.700	0.000	(0)
MnHCO3+	4.713e-08	4.199e-08	-7.327	-7.377	-0.050	(0)
MnOH+	2.777e-09	2.475e-09	-8.556	-8.606	-0.050	(0)
MnF+	8.172e-10	7.282e-10	-9.088	-9.138	-0.050	(0)
MnCl+	4.829e-10	4.303e-10	-9.316	-9.366	-0.050	(0)
MnCl2	2.551e-13	2.551e-13	-12.593	-12.593	0.000	(0)
MnCl3-	3.308e-17	2.948e-17	-16.480	-16.531	-0.050	(0)
Mn(OH)3-	2.510e-17	2.237e-17	-16.600	-16.650	-0.050	(0)
MnSeO4	2.149e-17	2.149e-17	-16.668	-16.668	0.000	(0)

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   Mn(OH)4-2        1.385e-22   8.735e-23   -21.858   -22.059    -0.200      (0)
   MnSe             5.207e-35   5.207e-35   -34.283   -34.283     0.000      (0)
Mn(3)          2.064e-28
   Mn+3             2.064e-28   7.119e-29   -27.685   -28.148    -0.462      (0)
Mn(6)          0.000e+00
   MnO4-2           0.000e+00   0.000e+00   -46.508   -46.708    -0.200      (0)
Mn(7)          0.000e+00
   MnO4-            0.000e+00   0.000e+00   -52.735   -52.789    -0.054      (0)
Mo             6.564e-08
   MoO4-2           6.563e-08   4.090e-08    -7.183    -7.388    -0.205      (0)
   HMoO4-           7.772e-12   6.774e-12   -11.109   -11.169    -0.060      (0)
   H2MoO4           4.130e-16   4.130e-16   -15.384   -15.384     0.000      (0)
   AlMo6O21-3       0.000e+00   0.000e+00   -52.459   -52.997    -0.537      (0)
   Mo7O24-6         0.000e+00   0.000e+00   -61.215   -63.365    -2.150      (0)
   HMo7O24-5        0.000e+00   0.000e+00   -63.565   -65.058    -1.493      (0)
   H2Mo7O24-4       0.000e+00   0.000e+00   -67.400   -68.356    -0.955      (0)
   H3Mo7O24-3       0.000e+00   0.000e+00   -72.652   -73.189    -0.537      (0)
Na             2.832e-03
   Na+              2.807e-03   2.494e-03    -2.552    -2.603    -0.051      (0)
   NaSO4-           2.065e-05   1.843e-05    -4.685    -4.734    -0.049      (0)
   NaHCO3           3.623e-06   3.623e-06    -5.441    -5.441     0.000      (0)
   NaCO3-           7.572e-07   6.757e-07    -6.121    -6.170    -0.049      (0)
   NaF              3.533e-08   3.533e-08    -7.452    -7.452     0.000      (0)
   NaH2BO3          9.576e-10   9.576e-10    -9.019    -9.019     0.000      (0)
   NaCrO4-          3.776e-19   3.291e-19   -18.423   -18.483    -0.060      (0)
Ni             5.636e-08
   Ni+2             3.221e-08   2.007e-08    -7.492    -7.698    -0.205      (0)
   NiCO3            1.089e-08   1.089e-08    -7.963    -7.963     0.000      (0)
   NiHCO3+          7.334e-09   6.392e-09    -8.135    -8.194    -0.060      (0)
   NiSO4            5.511e-09   5.511e-09    -8.259    -8.259     0.000      (0)
   NiOH+            3.506e-10   3.055e-10    -9.455    -9.515    -0.060      (0)
   Ni(OH)2          2.935e-11   2.935e-11   -10.532   -10.532     0.000      (0)
   NiCl+            2.472e-11   2.155e-11   -10.607   -10.667    -0.060      (0)
   NiF+             1.299e-11   1.132e-11   -10.887   -10.946    -0.060      (0)
   Ni(SO4)2-2       4.353e-13   2.511e-13   -12.361   -12.600    -0.239      (0)
   Ni(OH)3-         4.073e-14   3.550e-14   -13.390   -13.450    -0.060      (0)
   NiCl2            4.552e-17   4.552e-17   -16.342   -16.342     0.000      (0)
   NiSeO4           9.202e-19   9.202e-19   -18.036   -18.036     0.000      (0)
O(0)           0.000e+00
   O2               0.000e+00   0.000e+00   -40.512   -40.511     0.001      (0)
Pb             7.192e-08
   PbCO3            5.716e-08   5.716e-08    -7.243    -7.243     0.000      (0)
   PbOH+            4.555e-09   3.970e-09    -8.342    -8.401    -0.060      (0)
   Pb(CO3)2-2       4.158e-09   2.399e-09    -8.381    -8.620    -0.239      (0)
   PbHCO3+          2.878e-09   2.508e-09    -8.541    -8.601    -0.060      (0)
   Pb+2             2.097e-09   1.307e-09    -8.678    -8.884    -0.205      (0)
   PbSO4            8.808e-10   8.808e-10    -9.055    -9.055     0.000      (0)
   Pb(OH)2          1.518e-10   1.518e-10    -9.819    -9.819     0.000      (0)
   PbCl+            2.232e-11   1.945e-11   -10.651   -10.711    -0.060      (0)
   Pb(SO4)2-2       1.266e-11   7.304e-12   -10.898   -11.136    -0.239      (0)
   PbF+             2.372e-12   2.068e-12   -11.625   -11.685    -0.060      (0)
   Pb(OH)3-         2.107e-13   1.836e-13   -12.676   -12.736    -0.060      (0)
   PbCl2            3.646e-14   3.646e-14   -13.438   -13.438     0.000      (0)
   PbF2             9.136e-16   9.136e-16   -15.039   -15.039     0.000      (0)
   Pb2OH+3          2.833e-16   8.221e-17   -15.548   -16.085    -0.537      (0)
   Pb(OH)4-2        9.426e-17   5.439e-17   -16.026   -16.265    -0.239      (0)
   PbCl3-           6.989e-18   6.091e-18   -17.156   -17.215    -0.060      (0)
   Pb3(OH)4+2       1.042e-18   6.009e-19   -17.982   -18.221    -0.239      (0)
   PbF3-            4.464e-20   3.891e-20   -19.350   -19.410    -0.060      (0)
   PbCl4-2          2.025e-21   1.168e-21   -20.694   -20.932    -0.239      (0)
   Pb4(OH)4+4       5.628e-23   6.237e-24   -22.250   -23.205    -0.955      (0)
   PbF4-2           7.247e-25   4.181e-25   -24.140   -24.379    -0.239      (0)
   Pb(HS)2          0.000e+00   0.000e+00  -130.113  -130.113     0.000      (0)
   Pb(HS)3-         0.000e+00   0.000e+00  -197.003  -197.063    -0.060      (0)
S(-2)          0.000e+00
   HS-              0.000e+00   0.000e+00   -68.190   -68.250    -0.060      (0)
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   CdHS+            0.000e+00   0.000e+00   -68.221   -68.281    -0.060      (0)
   S5-2             0.000e+00   0.000e+00   -69.296   -69.535    -0.239      (0)
   H2S              0.000e+00   0.000e+00   -69.309   -69.309     0.000      (0)
   S6-2             0.000e+00   0.000e+00   -69.812   -70.051    -0.239      (0)
   S4-2             0.000e+00   0.000e+00   -69.892   -70.131    -0.239      (0)
   S3-2             0.000e+00   0.000e+00   -70.698   -70.937    -0.239      (0)
   S2-2             0.000e+00   0.000e+00   -71.714   -71.953    -0.239      (0)
   S-2              0.000e+00   0.000e+00   -77.270   -77.470    -0.200      (0)
   Cu(S4)2-3        0.000e+00   0.000e+00  -125.484  -125.769    -0.285      (0)
   CuS4S5-3         0.000e+00   0.000e+00  -126.225  -126.499    -0.274      (0)
   ZnS(HS)-         0.000e+00   0.000e+00  -128.047  -128.106    -0.060      (0)
   Cd(HS)2          0.000e+00   0.000e+00  -129.326  -129.326     0.000      (0)
   Pb(HS)2          0.000e+00   0.000e+00  -130.113  -130.113     0.000      (0)
   Zn(HS)2          0.000e+00   0.000e+00  -130.176  -130.176     0.000      (0)
   Fe(HS)2          0.000e+00   0.000e+00  -135.601  -135.601     0.000      (0)
   Cu(HS)3-         0.000e+00   0.000e+00  -187.008  -187.067    -0.060      (0)
   Zn(HS)3-         0.000e+00   0.000e+00  -195.086  -195.146    -0.060      (0)
   Cd(HS)3-         0.000e+00   0.000e+00  -195.616  -195.676    -0.060      (0)
   ZnS(HS)2-2       0.000e+00   0.000e+00  -196.807  -197.046    -0.239      (0)
   Pb(HS)3-         0.000e+00   0.000e+00  -197.003  -197.063    -0.060      (0)
   Fe(HS)3-         0.000e+00   0.000e+00  -201.754  -201.814    -0.060      (0)
   Cd(HS)4-2        0.000e+00   0.000e+00  -261.491  -261.730    -0.239      (0)
   Zn(HS)4-2        0.000e+00   0.000e+00  -264.617  -264.855    -0.239      (0)
S(6)           2.768e-03
   SO4-2            2.209e-03   1.376e-03    -2.656    -2.861    -0.205      (0)
   CaSO4            3.930e-04   3.930e-04    -3.406    -3.406     0.000      (0)
   MgSO4            1.404e-04   1.404e-04    -3.853    -3.853     0.000      (0)
   NaSO4-           2.065e-05   1.843e-05    -4.685    -4.734    -0.049      (0)
   KSO4-            5.402e-06   4.820e-06    -5.267    -5.317    -0.049      (0)
   MnSO4            1.994e-07   1.994e-07    -6.700    -6.700     0.000      (0)
   ZnSO4            9.590e-08   9.590e-08    -7.018    -7.018     0.000      (0)
   CoSO4            7.489e-09   7.489e-09    -8.126    -8.126     0.000      (0)
   NiSO4            5.511e-09   5.511e-09    -8.259    -8.259     0.000      (0)
   FeSO4            2.998e-09   2.998e-09    -8.523    -8.523     0.000      (0)
   CdSO4            2.948e-09   2.948e-09    -8.530    -8.530     0.000      (0)
   Zn(SO4)2-2       1.993e-09   1.150e-09    -8.701    -8.939    -0.239      (0)
   CuSO4            1.911e-09   1.911e-09    -8.719    -8.719     0.000      (0)
   HSO4-            1.259e-09   1.120e-09    -8.900    -8.951    -0.051      (0)
   PbSO4            8.808e-10   8.808e-10    -9.055    -9.055     0.000      (0)
   Cd(SO4)2-2       9.486e-11   5.473e-11   -10.023   -10.262    -0.239      (0)
   CrOHSO4          6.226e-11   6.226e-11   -10.206   -10.206     0.000      (0)
   Pb(SO4)2-2       1.266e-11   7.304e-12   -10.898   -11.136    -0.239      (0)
   Ni(SO4)2-2       4.353e-13   2.511e-13   -12.361   -12.600    -0.239      (0)
   CrSO4+           2.657e-14   2.315e-14   -13.576   -13.635    -0.060      (0)
   AlSO4+           7.909e-15   7.034e-15   -14.102   -14.153    -0.051      (0)
   UO2SO4           1.851e-16   1.851e-16   -15.733   -15.733     0.000      (0)
   Al(SO4)2-        1.166e-16   1.037e-16   -15.933   -15.984    -0.051      (0)
   FeSO4+           2.795e-17   2.491e-17   -16.554   -16.604    -0.050      (0)
   UO2(SO4)2-2      5.821e-18   3.359e-18   -17.235   -17.474    -0.239      (0)
   Cr2(OH)2SO4+2    1.859e-18   1.073e-18   -17.731   -17.970    -0.239      (0)
   Fe(SO4)2-        8.409e-19   7.329e-19   -18.075   -18.135    -0.060      (0)
   VO2SO4-          4.594e-19   4.004e-19   -18.338   -18.397    -0.060      (0)
   Cr2(OH)2(SO4)2   8.769e-20   8.769e-20   -19.057   -19.057     0.000      (0)
   VOSO4            1.309e-20   1.309e-20   -19.883   -19.883     0.000      (0)
   CrO3SO4-2        4.327e-27   2.497e-27   -26.364   -26.603    -0.239      (0)
   VSO4+            4.527e-34   3.945e-34   -33.344   -33.404    -0.060      (0)
   U(SO4)2          0.000e+00   0.000e+00   -40.959   -40.959     0.000      (0)
   USO4+2           0.000e+00   0.000e+00   -41.759   -41.998    -0.239      (0)
Se(-2)         1.482e-31
   HSe-             1.482e-31   1.291e-31   -30.829   -30.889    -0.060      (0)
   MnSe             5.207e-35   5.207e-35   -34.283   -34.283     0.000      (0)
   H2Se             8.343e-36   8.343e-36   -35.079   -35.079     0.000      (0)
   Se-2             2.689e-38   1.551e-38   -37.570   -37.809    -0.239      (0)
Se(4)          5.934e-08
   HSeO3-           3.445e-08   3.003e-08    -7.463    -7.522    -0.060      (0)
   SeO3-2           2.489e-08   1.436e-08    -7.604    -7.843    -0.239      (0)
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   H2SeO3           1.066e-13   1.066e-13   -12.972   -12.972     0.000      (0)
   Cd(SeO3)2-2      2.692e-18   1.553e-18   -17.570   -17.809    -0.239      (0)
   FeHSeO3+2        2.218e-22   1.280e-22   -21.654   -21.893    -0.239      (0)
Se(6)          1.574e-13
   SeO4-2           1.573e-13   9.803e-14   -12.803   -13.009    -0.205      (0)
   MnSeO4           2.149e-17   2.149e-17   -16.668   -16.668     0.000      (0)
   ZnSeO4           4.836e-18   4.836e-18   -17.316   -17.316     0.000      (0)
   CoSeO4           1.340e-18   1.340e-18   -17.873   -17.873     0.000      (0)
   NiSeO4           9.202e-19   9.202e-19   -18.036   -18.036     0.000      (0)
   CdSeO4           1.668e-19   1.668e-19   -18.778   -18.778     0.000      (0)
   HSeO4-           4.692e-20   4.090e-20   -19.329   -19.388    -0.060      (0)
   Zn(SeO4)2-2      8.331e-31   4.807e-31   -30.079   -30.318    -0.239      (0)
U(3)           0.000e+00
   U+3              0.000e+00   0.000e+00   -57.287   -57.824    -0.537      (0)
U(4)           3.991e-19
   U(OH)5-          3.990e-19   3.477e-19   -18.399   -18.459    -0.060      (0)
   U(OH)4           1.212e-22   1.212e-22   -21.916   -21.916     0.000      (0)
   U(OH)3+          4.234e-27   3.690e-27   -26.373   -26.433    -0.060      (0)
   U(OH)2+2         2.462e-32   1.421e-32   -31.609   -31.848    -0.239      (0)
   UOH+3            1.920e-38   5.571e-39   -37.717   -38.254    -0.537      (0)
   UF3+             9.482e-39   8.264e-39   -38.023   -38.083    -0.060      (0)
   UF2+2            4.025e-39   2.322e-39   -38.395   -38.634    -0.239      (0)
   UF+3             0.000e+00   0.000e+00   -40.548   -41.085    -0.537      (0)
   UF4              0.000e+00   0.000e+00   -40.692   -40.692     0.000      (0)
   U(SO4)2          0.000e+00   0.000e+00   -40.959   -40.959     0.000      (0)
   USO4+2           0.000e+00   0.000e+00   -41.759   -41.998    -0.239      (0)
   UF5-             0.000e+00   0.000e+00   -43.683   -43.742    -0.060      (0)
   U+4              0.000e+00   0.000e+00   -44.781   -45.737    -0.955      (0)
   UF6-2            0.000e+00   0.000e+00   -45.672   -45.911    -0.239      (0)
   UCl+3            0.000e+00   0.000e+00   -46.876   -47.414    -0.537      (0)
   U6(OH)15+9       0.000e+00   0.000e+00  -165.544  -170.381    -4.837      (0)
U(5)           3.177e-17
   UO2+             3.177e-17   2.769e-17   -16.498   -16.558    -0.060      (0)
U(6)           1.243e-08
   UO2(CO3)3-4      9.839e-09   1.090e-09    -8.007    -8.962    -0.955      (0)
   UO2(CO3)2-2      2.591e-09   1.495e-09    -8.587    -8.825    -0.239      (0)
   UO2CO3           5.149e-12   5.149e-12   -11.288   -11.288     0.000      (0)
   UO2OH+           1.553e-14   1.353e-14   -13.809   -13.869    -0.060      (0)
   UO2F+            3.161e-16   2.755e-16   -15.500   -15.560    -0.060      (0)
   UO2SO4           1.851e-16   1.851e-16   -15.733   -15.733     0.000      (0)
   UO2+2            1.426e-16   8.887e-17   -15.846   -16.051    -0.205      (0)
   UO2F2            1.784e-17   1.784e-17   -16.749   -16.749     0.000      (0)
   UO2(SO4)2-2      5.821e-18   3.359e-18   -17.235   -17.474    -0.239      (0)
   UO2F3-           1.154e-19   1.006e-19   -18.938   -18.997    -0.060      (0)
   UO2Cl+           6.939e-20   6.048e-20   -19.159   -19.218    -0.060      (0)
   (UO2)2(OH)2+2    5.267e-22   3.039e-22   -21.278   -21.517    -0.239      (0)
   UO2F4-2          3.110e-23   1.794e-23   -22.507   -22.746    -0.239      (0)
   (UO2)3(OH)5+     5.235e-24   4.562e-24   -23.281   -23.341    -0.060      (0)
V(2)           6.827e-40
   VOH+             6.827e-40   5.950e-40   -39.166   -39.225    -0.060      (0)
   V+2              0.000e+00   0.000e+00   -40.579   -40.818    -0.239      (0)
V(3)           8.666e-13
   V(OH)3           8.666e-13   8.666e-13   -12.062   -12.062     0.000      (0)
   V(OH)2+          5.349e-24   4.662e-24   -23.272   -23.331    -0.060      (0)
   VOH+2            6.380e-28   3.681e-28   -27.195   -27.434    -0.239      (0)
   V+3              2.093e-33   6.073e-34   -32.679   -33.217    -0.537      (0)
   VSO4+            4.527e-34   3.945e-34   -33.344   -33.404    -0.060      (0)
   V2(OH)3+3        0.000e+00   0.000e+00   -51.776   -52.314    -0.537      (0)
   V2(OH)2+4        0.000e+00   0.000e+00   -53.113   -54.068    -0.955      (0)
V(4)           9.635e-18
   V(OH)3+          9.557e-18   8.329e-18   -17.020   -17.079    -0.060      (0)
   VO+2             5.983e-20   3.452e-20   -19.223   -19.462    -0.239      (0)
   VOSO4            1.309e-20   1.309e-20   -19.883   -19.883     0.000      (0)
   VOF+             5.335e-21   4.649e-21   -20.273   -20.333    -0.060      (0)
   VOCl+            4.663e-23   4.064e-23   -22.331   -22.391    -0.060      (0)
   VOF2             3.915e-23   3.915e-23   -22.407   -22.407     0.000      (0)
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   VOF3-            3.578e-26   3.119e-26   -25.446   -25.506    -0.060      (0)
   H2V2O4+2         6.029e-30   3.478e-30   -29.220   -29.459    -0.239      (0)
   VOF4-2           4.899e-30   2.827e-30   -29.310   -29.549    -0.239      (0)
V(5)           1.472e-08
   H2VO4-           1.011e-08   8.810e-09    -7.995    -8.055    -0.060      (0)
   HVO4-2           4.608e-09   2.659e-09    -8.337    -8.575    -0.239      (0)
   H3VO4            7.333e-13   7.333e-13   -12.135   -12.135     0.000      (0)
   H3V2O7-          4.787e-14   4.172e-14   -13.320   -13.380    -0.060      (0)
   HV2O7-3          2.736e-14   7.938e-15   -13.563   -14.100    -0.537      (0)
   VO4-3            5.517e-15   1.601e-15   -14.258   -14.796    -0.537      (0)
   V2O7-4           2.316e-16   2.567e-17   -15.635   -16.591    -0.955      (0)
   VO2+             1.371e-17   1.218e-17   -16.863   -16.914    -0.051      (0)
   V3O9-3           2.470e-18   7.165e-19   -17.607   -18.145    -0.537      (0)
   VO2F             4.798e-19   4.798e-19   -18.319   -18.319     0.000      (0)
   VO2SO4-          4.594e-19   4.004e-19   -18.338   -18.397    -0.060      (0)
   VO2F2-           4.488e-21   3.912e-21   -20.348   -20.408    -0.060      (0)
   V4O12-4          2.375e-23   2.632e-24   -22.624   -23.580    -0.955      (0)
   VO2F3-2          1.899e-24   1.096e-24   -23.721   -23.960    -0.239      (0)
   VO2F4-3          4.172e-29   1.210e-29   -28.380   -28.917    -0.537      (0)
   V10O28-6         0.000e+00   0.000e+00   -61.812   -63.962    -2.150      (0)
   HV10O28-5        0.000e+00   0.000e+00   -62.362   -63.855    -1.493      (0)
   H2V10O28-4       0.000e+00   0.000e+00   -65.772   -66.727    -0.955      (0)
Zn             9.583e-07
   Zn+2             5.112e-07   3.185e-07    -6.291    -6.497    -0.205      (0)
   ZnCO3            2.667e-07   2.667e-07    -6.574    -6.574     0.000      (0)
   ZnSO4            9.590e-08   9.590e-08    -7.018    -7.018     0.000      (0)
   ZnOH+            4.420e-08   3.852e-08    -7.355    -7.414    -0.060      (0)
   ZnHCO3+          2.986e-08   2.602e-08    -7.525    -7.585    -0.060      (0)
   Zn(OH)2          7.384e-09   7.384e-09    -8.132    -8.132     0.000      (0)
   Zn(SO4)2-2       1.993e-09   1.150e-09    -8.701    -8.939    -0.239      (0)
   ZnOHCl           5.316e-10   5.316e-10    -9.274    -9.274     0.000      (0)
   ZnCl+            3.782e-10   3.357e-10    -9.422    -9.474    -0.052      (0)
   ZnF+             1.637e-10   1.427e-10    -9.786    -9.846    -0.060      (0)
   Zn(OH)3-         5.135e-11   4.476e-11   -10.289   -10.349    -0.060      (0)
   ZnCl2            2.233e-13   2.233e-13   -12.651   -12.651     0.000      (0)
   Zn(OH)4-2        3.735e-15   2.155e-15   -14.428   -14.667    -0.239      (0)
   ZnCl3-           8.384e-17   7.442e-17   -16.077   -16.128    -0.052      (0)
   ZnSeO4           4.836e-18   4.836e-18   -17.316   -17.316     0.000      (0)
   ZnCl4-2          2.477e-20   1.561e-20   -19.606   -19.806    -0.200      (0)
   Zn(SeO4)2-2      8.331e-31   4.807e-31   -30.079   -30.318    -0.239      (0)
   ZnS(HS)-         0.000e+00   0.000e+00  -128.047  -128.106    -0.060      (0)
   Zn(HS)2          0.000e+00   0.000e+00  -130.176  -130.176     0.000      (0)
   Zn(HS)3-         0.000e+00   0.000e+00  -195.086  -195.146    -0.060      (0)
   ZnS(HS)2-2       0.000e+00   0.000e+00  -196.807  -197.046    -0.239      (0)
   Zn(HS)4-2        0.000e+00   0.000e+00  -264.617  -264.855    -0.239      (0)

----------------------------Saturation indices----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.74      9.06   10.80  Al(OH)3
  Al2(MoO4)3      -54.90    -52.53    2.37  Al2(MoO4)3
  Al2O3            -1.54     18.11   19.65  Al2O3
  Al4(OH)10SO4     -5.49     17.21   22.70  Al4(OH)10SO4
  AlAsO4:2H2O      -9.74     -4.94    4.80  AlAsO4:2H2O
  AlOHSO4          -6.73     -9.96   -3.23  AlOHSO4
  Alunite          -4.70     -6.10   -1.40  KAl3(SO4)2(OH)6
  Anglesite        -3.96    -11.75   -7.79  PbSO4
  Anhydrite        -1.41     -5.77   -4.36  CaSO4
  Anilite         -43.57    -75.45  -31.88  Cu0.25Cu1.5S
  Antlerite        -3.98      4.80    8.79  Cu3(OH)4SO4
  Aragonite         0.56     -7.74   -8.30  CaCO3
  Arsenolite      -68.62    -71.38   -2.76  As4O6
  Artinite         -4.78      4.82    9.60  MgCO3:Mg(OH)2:3H2O
  As2O5           -34.71    -28.00    6.71  As2O5
  Atacamite        -2.96      4.43    7.39  Cu2(OH)3Cl
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Azurite	-1.26	-18.17	-16.91	Cu3(OH)2(CO3)2
Ba(OH)2:8H2O	-14.74	9.65	24.39	Ba(OH)2:8H2O
Ba2V2O7:2H2O	-14.24	1.63	15.87	Ba2V2O7:2H2O
Ba3(AsO4)2	9.86	0.95	-8.91	Ba3(AsO4)2
Ba3(VO4)2:4H2O	-21.66	11.28	32.94	Ba3(VO4)2:4H2O
BaCrO4	-13.41	-23.08	-9.67	BaCrO4
BaF2	-9.99	-15.81	-5.82	BaF2
BaMoO4	-6.94	-13.90	-6.96	BaMoO4
Barite	0.61	-9.37	-9.98	BaSO4
BaS	-82.86	-66.68	16.18	BaS
BaSeO3	-7.78	-5.95	1.83	BaSeO3
BaSeO4	-12.06	-19.52	-7.46	BaSeO4
Bianchite	-7.59	-9.36	-1.76	ZnSO4:6H2O
Birnessite	-10.63	7.46	18.09	MnO2
Bixbyite	-7.17	-7.82	-0.64	Mn2O3
BlaubleiI	-45.17	-69.33	-24.16	Cu0.9Cu0.2S
BlaubleiII	-44.88	-72.16	-27.28	Cu0.6Cu0.8S
Boehmite	0.48	9.06	8.58	AlOOH
Brochantite	-2.48	12.75	15.22	Cu4(OH)6SO4
Brucite	-3.94	12.91	16.84	Mg(OH)2
Bunsenite	-3.98	8.46	12.45	NiO
Ca(VO3)2	-10.07	-4.41	5.66	Ca(VO3)2
Ca2V2O7	-8.66	8.84	17.50	Ca2V2O7
Ca2V2O7:2H2O	-12.71	8.84	21.55	Ca2V2O7:2H2O
Ca3(AsO4)2:4H2O	-10.54	11.76	22.30	Ca3(AsO4)2:4H2O
Ca3(VO4)2	-16.86	22.10	38.96	Ca3(VO4)2
Ca3(VO4)2:4H2O	-17.76	22.10	39.86	Ca3(VO4)2:4H2O
CaCrO4	-17.21	-19.48	-2.27	CaCrO4
Calcite	0.74	-7.74	-8.48	CaCO3
CaMoO4	-2.34	-10.29	-7.95	CaMoO4
Carnotite	-4.18	-3.95	0.23	KUO2VO4
CaSeO3:2H2O	-5.16	-2.35	2.81	CaSeO3:2H2O
CaSeO4:2H2O	-12.89	-15.91	-3.02	CaSeO4:2H2O
Cd(BO2)2	-12.64	-2.80	9.84	Cd(BO2)2
Cd(OH)2	-5.52	8.12	13.64	Cd(OH)2
Cd(OH)2(am)	-5.61	8.12	13.73	Cd(OH)2
Cd3(OH)2(SO4)2	-20.39	-13.68	6.71	Cd3(OH)2(SO4)2
Cd3(OH)4SO4	-17.22	5.34	22.56	Cd3(OH)4SO4
Cd4(OH)6SO4	-14.94	13.46	28.40	Cd4(OH)6SO4
CdCl2	-14.13	-14.79	-0.66	CdCl2
CdCl2:1H2O	-13.10	-14.79	-1.69	CdCl2:1H2O
CdCl2:2.5H2O	-12.88	-14.79	-1.91	CdCl2:2.5H2O
CdF2	-16.12	-17.34	-1.21	CdF2
Cdmetal(alpha)	-28.14	-14.62	13.51	Cd
Cdmetal(gamma)	-28.24	-14.62	13.62	Cd
CdMoO4	-1.28	-15.43	-14.15	CdMoO4
CdOHCl	-6.87	-3.34	3.54	CdOHCl
CdSe	-10.65	-30.85	-20.20	CdSe
CdSeO4:2H2O	-19.20	-21.05	-1.85	CdSeO4:2H2O
CdSO4	-10.73	-10.90	-0.17	CdSO4
CdSO4:1H2O	-9.17	-10.90	-1.73	CdSO4:1H2O
CdSO4:2.67H2O	-9.03	-10.90	-1.87	CdSO4:2.67H2O
Cerussite	-0.59	-13.72	-13.13	PbCO3
CH4(g)	-70.92	-111.97	-41.05	CH4
Chalcanthite	-8.44	-11.08	-2.64	CuSO4:5H2O
Chalcocite	-42.89	-77.81	-34.92	Cu2S
Chalcopyrite	-101.34	-136.61	-35.27	CuFeS2
Claudetite	-68.32	-71.38	-3.06	As4O6
Clausthalite	-4.59	-31.69	-27.10	PbSe
Co(BO2)2	-29.39	-2.32	27.07	Co(BO2)2
Co(OH)2	-4.50	8.59	13.09	Co(OH)2
Co(OH)3	-10.13	-12.43	-2.31	Co(OH)3
CO2(g)	-2.85	-21.00	-18.15	CO2
Co3(AsO4)2	-15.25	-2.22	13.03	Co3(AsO4)2
Co3O4	-5.78	-16.27	-10.50	Co3O4
CoCl2	-22.59	-14.32	8.27	CoCl2

CoCl2:6H2O	-16.86	-14.32	2.54	CoCl2:6H2O
CoCO3	-2.42	-12.40	-9.98	CoCO3
CoF2	-15.26	-16.86	-1.60	CoF2
CoF3	-49.16	-50.62	-1.46	CoF3
CoFe2O4	25.02	21.49	-3.53	CoFe2O4
CoMoO4	-7.19	-14.95	-7.76	CoMoO4
CoO	-4.99	8.59	13.59	CoO
CoS(alpha)	-60.29	-67.73	-7.44	CoS
CoS(beta)	-56.66	-67.73	-11.07	CoS
CoSe	-14.17	-30.37	-16.20	CoSe
CoSeO3	-8.33	-7.01	1.32	CoSeO3
CoSeO4:6H2O	-19.04	-20.57	-1.53	CoSeO4:6H2O
CoSO4	-13.23	-10.43	2.80	CoSO4
CoSO4:6H2O	-7.95	-10.43	-2.47	CoSO4:6H2O
Cotunnite	-10.86	-15.64	-4.78	PbCl2
Covellite	-46.09	-68.39	-22.30	CuS
Cr(OH)2	-18.72	-7.90	10.82	Cr(OH)2
Cr(OH)3	-0.81	0.53	1.34	Cr(OH)3
Cr(OH)3(am)	1.28	0.53	-0.75	Cr(OH)3
Cr2O3	3.41	1.06	-2.36	Cr2O3
CrCl2	-44.90	-30.81	14.09	CrCl2
CrCl3	-48.96	-33.84	15.11	CrCl3
CrF3	-26.32	-37.66	-11.34	CrF3
Crmetal	-61.12	-30.64	30.48	Cr
CrO3	-29.52	-32.74	-3.21	CrO3
Cryolite	-17.04	-50.88	-33.84	Na3AlF6
Cu(OH)2	-0.73	7.94	8.67	Cu(OH)2
Cu2Se(alpha)	5.35	-40.45	-45.80	Cu2Se
Cu2SO4	-18.55	-20.50	-1.95	Cu2SO4
Cu3(AsO4)2:2H2O	-10.28	-4.18	6.10	Cu3(AsO4)2:2H2O
Cu3Se2	-7.98	-71.47	-63.49	Cu3Se2
CuCO3	-1.55	-13.05	-11.50	CuCO3
CuCrO4	-19.35	-24.79	-5.44	CuCrO4
CuF	-8.56	-13.47	-4.91	CuF
CuF2	-18.63	-17.51	1.12	CuF2
CuF2:2H2O	-12.97	-17.52	-4.55	CuF2:2H2O
Cumetal	-3.35	-12.11	-8.76	Cu
CuMoO4	-2.53	-15.61	-13.08	CuMoO4
CuOCuSO4	-13.44	-3.14	10.30	CuOCuSO4
Cupricferrite	14.85	20.83	5.99	CuFe2O4
Cuprite	-0.07	-1.48	-1.41	Cu2O
Cuprousferrite	14.62	5.71	-8.92	CuFeO2
CuSe	2.07	-31.03	-33.10	CuSe
CuSe2	-13.89	-47.25	-33.37	CuSe2
CuSeO3:2H2O	-8.17	-7.66	0.51	CuSeO3:2H2O
CuSeO4:5H2O	-18.79	-21.23	-2.44	CuSeO4:5H2O
CuSO4	-14.02	-11.08	2.94	CuSO4
Diaspore	2.18	9.06	6.87	AlOOH
Djurleite	-43.27	-77.19	-33.92	Cu0.066Cu1.868S
Dolomite(disordered)	0.71	-15.83	-16.54	CaMg(CO3)2
Dolomite(ordered)	1.26	-15.83	-17.09	CaMg(CO3)2
Epsomite	-3.99	-6.11	-2.13	MgSO4:7H2O
Fe(OH)2	-5.46	8.11	13.56	Fe(OH)2
Fe(OH)2.7Cl.3	6.05	3.01	-3.04	Fe(OH)2.7Cl.3
Fe(VO3)2	-5.84	-9.56	-3.72	Fe(VO3)2
Fe2(OH)4SeO3	-4.26	-2.71	1.55	Fe2(OH)4SeO3
Fe2(SeO3)3:2H2O	-13.29	-33.91	-20.63	Fe2(SeO3)3:2H2O
Fe2(SO4)3	-40.43	-44.17	-3.73	Fe2(SO4)3
Fe3(OH)8	0.78	21.00	20.22	Fe3(OH)8
FeAsO4:2H2O	-7.95	-7.55	0.40	FeAsO4:2H2O
FeCr2O4	1.96	9.16	7.20	FeCr2O4
FeMoO4	-5.35	-15.44	-10.09	FeMoO4
Ferrihydrite	3.26	6.45	3.19	Fe(OH)3
Ferroselite	-28.49	-47.09	-18.60	FeSe2
FeS(ppt)	-65.27	-68.22	-2.95	FeS
FeSe	-19.86	-30.86	-11.00	FeSe

Fluorite	-1.70	-12.20	-10.50	CaF2
Galena	-55.08	-69.05	-13.97	PbS
Gibbsite	0.77	9.06	8.29	Al(OH)3
Goethite	5.96	6.45	0.49	FeOOH
Goslarite	-7.35	-9.36	-2.01	ZnSO4:7H2O
Greenockite	-53.85	-68.21	-14.36	CdS
Greigite	-239.28	-284.32	-45.03	Fe3S4
Gummite	-7.56	0.11	7.67	UO3
Gypsum	-1.16	-5.77	-4.61	CaSO4:2H2O
H-Jarosite	-6.60	-18.70	-12.10	(H3O)Fe3(SO4)2(OH)6
H2MoO4	-10.67	-23.55	-12.88	H2MoO4
H2S(g)	-68.32	-76.33	-8.01	H2S
H2Se(g)	-34.01	-38.97	-4.96	H2Se
Halite	-7.58	-5.98	1.60	NaCl
Hausmannite	-8.08	52.95	61.03	Mn3O4
Hematite	14.31	12.89	-1.42	Fe2O3
Hercynite	3.33	26.22	22.89	FeAl2O4
Huntite	-2.04	-32.01	-29.97	CaMg3(CO3)4
Hydrocerussite	-1.40	-20.17	-18.77	Pb3(OH)2(CO3)2
Hydromagnesite	-10.68	-19.45	-8.77	Mg5(CO3)4(OH)2:4H2O
K-Alum	-19.04	-24.21	-5.17	KAl(SO4)2:12H2O
K-Jarosite	0.87	-13.93	-14.80	KFe3(SO4)2(OH)6
K2Cr2O7	-38.68	-55.92	-17.24	K2Cr2O7
K2CrO4	-22.67	-23.19	-0.51	K2CrO4
K2MoO4	-17.26	-14.00	3.26	K2MoO4
K2SeO4	-18.89	-19.62	-0.73	K2SeO4
Langite	-4.74	12.75	17.49	Cu4(OH)6SO4:H2O
Larnakite	-4.04	-4.47	-0.43	PbO:PbSO4
Laurionite	-4.80	-4.18	0.62	PbOHCl
Lepidocrocite	5.08	6.45	1.37	FeOOH
Lime	-19.44	13.25	32.70	CaO
Litharge	-5.42	7.28	12.69	PbO
Mackinawite	-64.62	-68.22	-3.60	FeS
Maghemite	6.51	12.89	6.39	Fe2O3
Magnesioferrite	8.94	25.80	16.86	Fe2MgO4
Magnesite	-0.63	-8.09	-7.46	MgCO3
Magnetite	17.60	21.00	3.40	Fe3O4
Malachite	0.19	-5.11	-5.31	Cu2(OH)2CO3
Manganite	-3.90	21.44	25.34	MnOOH
Massicot	-5.62	7.28	12.89	PbO
Matlockite	-7.94	-16.91	-8.97	PbClF
Melanothallite	-21.23	-14.97	6.26	CuCl2
Melanterite	-8.70	-10.91	-2.21	FeSO4:7H2O
Mg(OH)2(active)	-5.89	12.91	18.79	Mg(OH)2
Mg(VO3)2	-16.04	-4.76	11.28	Mg(VO3)2
Mg2V2O7	-18.21	8.15	26.36	Mg2V2O7
MgCr2O4	-2.24	13.96	16.20	MgCr2O4
MgCrO4	-25.21	-19.83	5.38	MgCrO4
MgF2	-4.42	-12.55	-8.13	MgF2
MgMoO4	-8.79	-10.64	-1.85	MgMoO4
MgSeO3:6H2O	-5.75	-2.69	3.06	MgSeO3:6H2O
MgSeO4:6H2O	-15.06	-16.26	-1.20	MgSeO4:6H2O
Minium	-28.95	44.57	73.52	Pb3O4
Mirabilite	-6.95	-8.07	-1.11	Na2SO4:10H2O
Mn(VO3)2	-12.50	-7.60	4.90	Mn(VO3)2
Mn2(SO4)3	-59.17	-64.88	-5.71	Mn2(SO4)3
Mn3(AsO4)2:8H2O	-10.29	2.21	12.50	Mn3(AsO4)2:8H2O
MnCl2:4H2O	-15.56	-12.84	2.72	MnCl2:4H2O
MnS(grn)	-66.43	-66.26	0.17	MnS
MnS(pnk)	-69.60	-66.26	3.34	MnS
MnSe	-32.40	-28.90	3.50	MnSe
MnSeO3	-6.66	-5.53	1.13	MnSeO3
MnSeO3:2H2O	-6.51	-5.53	0.98	MnSeO3:2H2O
MnSeO4:5H2O	-17.05	-19.10	-2.05	MnSeO4:5H2O
MnSO4	-11.53	-8.95	2.58	MnSO4
Monteponite	-6.98	8.12	15.10	CdO

MoO3	-15.55	-23.55	-8.00	MoO3
Morenosite	-8.41	-10.56	-2.14	NiSO4:7H2O
MoS2	-128.69	-198.95	-70.26	MoS2
Na-Jarosite	-2.03	-13.23	-11.20	NaFe3(SO4)2(OH)6
Na2Cr2O7	-44.62	-54.52	-9.90	Na2Cr2O7
Na2CrO4	-24.71	-21.78	2.93	Na2CrO4
Na2Mo2O7	-19.55	-36.14	-16.60	Na2Mo2O7
Na2MoO4	-14.08	-12.59	1.49	Na2MoO4
Na2MoO4:2H2O	-13.82	-12.59	1.22	Na2MoO4:2H2O
Na2SeO3:5H2O	-14.95	-4.65	10.30	Na2SeO3:5H2O
Na2SeO4	-19.49	-18.21	1.28	Na2SeO4
Na3VO4	-29.09	7.59	36.68	Na3VO4
Na4V2O7	-33.16	4.24	37.40	Na4V2O7
Nantokite	-5.47	-12.20	-6.73	CuCl
Natron	-8.73	-10.04	-1.31	Na2CO3:10H2O
NaVO3	-7.22	-3.36	3.86	NaVO3
Nesquehonite	-3.42	-8.09	-4.67	MgCO3:3H2O
Ni(OH)2	-4.33	8.46	12.79	Ni(OH)2
Ni3(AsO4)2:8H2O	-18.32	-2.62	15.70	Ni3(AsO4)2:8H2O
Ni4(OH)6SO4	-17.17	14.83	32.00	Ni4(OH)6SO4
NiCO3	-5.66	-12.53	-6.87	NiCO3
NiMoO4	-3.94	-15.09	-11.14	NiMoO4
NiS(alpha)	-62.27	-67.87	-5.60	NiS
NiS(beta)	-56.77	-67.87	-11.10	NiS
NiS(gamma)	-55.07	-67.87	-12.80	NiS
NiSe	-12.81	-30.51	-17.70	NiSe
NiSeO3:2H2O	-9.96	-7.14	2.81	NiSeO3:2H2O
NiSeO4:6H2O	-19.19	-20.71	-1.52	NiSeO4:6H2O
Nsutite	-10.04	7.46	17.50	MnO2
O2(g)	-37.61	45.48	83.09	O2
Orpiment	-203.61	-264.68	-61.07	As2S3
Otavite	-0.88	-12.88	-12.00	CdCO3
Pb(BO2)2	-10.16	-3.64	6.52	Pb(BO2)2
Pb(OH)2	-0.87	7.28	8.15	Pb(OH)2
Pb10(OH)6O(CO3)6	-44.46	-53.22	-8.76	Pb10(OH)6O(CO3)6
Pb2(OH)3Cl	-5.70	3.09	8.79	Pb2(OH)3Cl
Pb2O(OH)2	-11.64	14.55	26.19	Pb2O(OH)2
Pb2O3	-23.75	37.29	61.04	Pb2O3
Pb2OCO3	-5.89	-6.45	-0.56	Pb2OCO3
Pb2V2O7	-1.22	-3.12	-1.90	Pb2V2O7
Pb3(AsO4)2	-11.98	-6.18	5.80	Pb3(AsO4)2
Pb3(VO4)2	-1.98	4.16	6.14	Pb3(VO4)2
Pb3O2CO3	-10.19	0.83	11.02	Pb3O2CO3
Pb3O2SO4	-7.88	2.81	10.69	Pb3O2SO4
Pb4(OH)6SO4	-11.02	10.08	21.10	Pb4(OH)6SO4
Pb4O3SO4	-11.80	10.08	21.88	Pb4O3SO4
PbCrO4	-12.86	-25.46	-12.60	PbCrO4
PbF2	-10.74	-18.18	-7.44	PbF2
Pbmetal	-19.71	-15.47	4.25	Pb
PbMoO4	-0.65	-16.27	-15.62	PbMoO4
PbO:0.3H2O	-5.70	7.28	12.98	PbO:0.33H2O
PbSeO4	-15.05	-21.89	-6.84	PbSeO4
Periclase	-8.68	12.91	21.58	MgO
Phosgenite	-9.55	-29.36	-19.81	PbCl2:PbCO3
Plattnerite	-19.58	30.02	49.60	PbO2
Portlandite	-9.55	13.25	22.80	Ca(OH)2
Pyrite	-103.30	-121.81	-18.51	FeS2
Pyrochroite	-5.12	10.07	15.19	Mn(OH)2
Pyrolusite	-8.57	32.81	41.38	MnO2
Realgar	-85.80	-105.55	-19.75	AsS
Retgersite	-8.52	-10.56	-2.04	NiSO4:6H2O
Rhodochrosite	-0.35	-10.93	-10.58	MnCO3
Rutherfordine	-6.39	-20.89	-14.50	UO2CO3
Schoepite	-5.89	0.11	5.99	UO2(OH)2:H2O
Semetal(am)	-9.12	-16.23	-7.11	Se
Semetal(hex	-8.52	-16.23	-7.71	Se

```
  SeO2            -15.73    -15.60    0.12  SeO2
  SeO3            -50.21    -29.17   21.04  SeO3
  Siderite         -2.65    -12.89  -10.24  FeCO3
  Smithsonite      -1.33    -11.33  -10.00  ZnCO3
  Sphalerite      -55.22    -66.67  -11.45  ZnS
  Spinel           -5.83     31.02   36.85  MgAl2O4
  Sulfur          -51.44    -53.59   -2.14  S
  Tenorite          0.30      7.94    7.64  CuO
  Thenardite       -8.39     -8.07    0.32  Na2SO4
  Thermonatrite   -10.68    -10.04    0.64  Na2CO3:H2O
  Tyuyamunite      -8.28     -4.20    4.08  Ca(UO2)2(VO4)2
  U3O8            -15.85      5.23   21.08  U3O8
  U4O9            -27.91    -30.93   -3.02  U4O9
  UF4             -34.79    -64.33  -29.54  UF4
  UF4:2.5H2O      -31.61    -64.33  -32.72  UF4:2.5H2O
  UO2(am)         -14.35    -13.42    0.93  UO2
  UO2(OH)2(beta)   -5.50      0.11    5.61  UO2(OH)2
  UO2SeO4:4H2O    -26.81    -29.06   -2.25  UO2SeO4:4H2O
  UO3              -7.59      0.11    7.70  UO3
  Uraninite        -8.75    -13.42   -4.67  UO2
  V(OH)3          -16.57     -8.98    7.59  V(OH)3
  V2O5            -16.31    -17.67   -1.36  V2O5
  V3O5            -34.49    -32.65    1.84  V3O5
  V4O7            -43.14    -35.95    7.19  V4O7
  V6O13           -37.63    -98.49  -60.86  V6O13
  VCl2            -62.14    -43.26   18.87  VCl2
  VCl3            -66.78    -43.35   23.43  VCl3
  VF4             -69.15    -54.22   14.93  VF4
  Vmetal          -87.12    -43.09   44.03  V
  VO              -35.11    -20.35   14.76  VO
  VO(OH)2          -8.45     -3.30    5.15  VO(OH)2
  VO2Cl           -23.13    -20.29    2.84  VO2Cl
  VOCl            -31.59    -20.43   11.15  VOCl
  VOCl2           -38.98    -26.22   12.76  VOCl2
  VOSO4           -25.93    -22.32    3.61  VOSO4
  Witherite        -2.78    -11.35   -8.57  BaCO3
  Wurtzite        -57.72    -66.67   -8.95  ZnS
  Zincite          -1.67      9.66   11.33  ZnO
  Zincosite       -13.29     -9.36    3.93  ZnSO4
  Zn(BO2)2         -9.55     -1.26    8.29  Zn(BO2)2
  Zn(OH)2          -2.54      9.66   12.20  Zn(OH)2
  Zn(OH)2(am)      -2.81      9.66   12.47  Zn(OH)2
  Zn(OH)2(beta)    -2.09      9.66   11.75  Zn(OH)2
  Zn(OH)2(epsilon)  -1.87      9.66   11.53  Zn(OH)2
  Zn(OH)2(gamma)   -2.07      9.66   11.73  Zn(OH)2
  Zn2(OH)2SO4      -7.20      0.30    7.50  Zn2(OH)2SO4
  Zn2(OH)3Cl       -7.32      7.87   15.19  Zn2(OH)3Cl
  Zn3(AsO4)2:2.5H2O -12.67      0.98   13.65  Zn3(AsO4)2:2.5H2O
  Zn3O(SO4)2      -27.97     -9.05   18.91  Zn3O(SO4)2
  Zn4(OH)6SO4      -8.77     19.63   28.40  Zn4(OH)6SO4
  Zn5(OH)8Cl2     -13.10     25.40   38.50  Zn5(OH)8Cl2
  ZnCl2           -20.30    -13.25    7.05  ZnCl2
  ZnCO3:1H2O       -1.07    -11.33  -10.26  ZnCO3:1H2O
  ZnF2            -15.26    -15.79   -0.53  ZnF2
  Znmetal         -38.87    -13.08   25.79  Zn
  ZnMoO4           -3.76    -13.89  -10.13  ZnMoO4
  ZnO(active)      -1.53      9.66   11.19  ZnO
  ZnS(am)         -57.61    -66.67   -9.05  ZnS
  ZnSe            -14.91    -29.31  -14.40  ZnSe
  ZnSeO4:6H2O     -17.99    -19.51   -1.52  ZnSeO4:6H2O
  ZnSO4:1H2O       -8.72     -9.36   -0.64  ZnSO4:1H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

------------------
```

```
End of simulation.
------------------

------------------------------------
Reading input data for simulation 2.
------------------------------------

------------------------------
End of Run after 0.267 Seconds.
------------------------------
```

```
# P50 Scenario

SOLUTION 1 UG Water P50
    temp      25
    pH        8.112
    units     mg/L
    density   1
Al    0.0802
As    0.0026
Ba    0.1788
B     0.1294
Ca    84.0
Cl    49.1
Mg    41.0
Na    176.2
K     35.8
F     0.9179
S(6)  141.4
Cd    0.0075
Cr    0.0074
Co    0.0037
Cu    0.0710
Fe    0.1857
Pb    0.0464
Mn    0.0875
Mo    0.0067
Ni    0.0054
Se    0.0068
U     0.0074
V     0.0025
Zn    0.1983
Alkalinity 553.3 as HCO3
    -water    1 # kg

SOLUTION 2 PAF Material
    temp      25
    pH        7.5
    units     mg/L
    density   1
      Al    0.020
      As    0
      Ba    0.020
      B     0
      Ca    67.0
      Cl    0
      Mg    8.0
      Na    1.0
      K     13.0
      F     0.300
      S(6)  197.0
      Cd    0.000
      Cr    0
      Co    0.007
      Cu    0.028
      Fe    0
      Pb    0
      Mn    0.040
      Mo    0.003
      Ni    0.004
      Se    0
      U     0
      V     0
      Zn    0
      Alkalinity 22 as HCO3
    -water    1 # kg
```

```
SOLUTION 3 NAF Material
    temp      25
    pH        7.6
    units     mg/L
    density   1
      Al    0.140
      As    0.029
      Ba    0.020
      B     0
      Ca    122.0
      Cl    0
      Mg    18.0
      Na    1.0
      K     16.0
      F     0.300
      S(6)  331.0
      Cd    0.000
      Cr    0
      Co    0.002
      Cu    0.019
      Fe    0.070
      Pb    0
      Mn    0.130
      Mo    0.005
      Ni    0.001
      Se    0
      U     0.001
      V     0
      Zn    0
      Alkalinity 28 as HCO3
    -water    1 # kg


SOLUTION 4 Make-up Material
    temp      25
    pH        7.7
    units     mg/L
    density   1
      Al    0.020
      As    0
      Ba    0.020
      B     0
      Ca    67.0
      Cl    0
      Mg    8.0
      Na    1.0
      K     13.0
      F     0.300
      S(6)  197.0
      Cd    0.000
      Cr    0
      Co    0.007
      Cu    0.028
      Fe    0
      Pb    0
      Mn    0.040
      Mo    0.003
      Ni    0.004
      Se    0
      U     0
      V     0
      Zn    0
      Alkalinity 22 as HCO3
    -water    1 # kg

# Mix the three solutions together
```

```
MIX 1 Mix within UG Works
    1    0.308
    2    0.110
    3    0.400
    4    0.182

SAVE Solution 5

SELECTED_OUTPUT 2
    -file                D:\selected_output_3.txt
    -high_precision      true
    -reset               true
    -distance            false
    -time                false
    -temperature         false
    -ionic_strength      false
    -water               false
    -totals              pH Al As Ba B Ca Cl Mg
                         Na K  F  S(6) Cd Cr Co
                         Cu Fe Pb Mn Mo  Ni Se
                         U V Zn Alkalinity
END
```

```
   Input file: P:\J23011 - BCP Underground EA (Aeris)\2. Tech Work Area\2.08 Water Quality
Model\2.08.02 PAF Assessment\BPC_UG_PAF_Disposal_P50.pqi
   Output file: P:\J23011 - BCP Underground EA (Aeris)\2. Tech Work Area\2.08 Water Quality
Model\2.08.02 PAF Assessment\BPC_UG_PAF_Disposal_P50.pqo
Database file: c:\phreeqc\database\minteq.v4.dat

------------------
Reading data base.
------------------

      SOLUTION_MASTER_SPECIES
      SOLUTION_SPECIES
      SOLUTION_SPECIES
      PHASES
      PHASES
      SURFACE_MASTER_SPECIES
      SURFACE_SPECIES
      END
-----------------------------------
Reading input data for simulation 1.
-----------------------------------

      DATABASE c:\phreeqc\database\minteq.v4.dat
      SOLUTION 1 UG Water P50
          temp      25
          pH        8.112
          units     mg/L
          density   1
      Al    0.0802
      As    0.0026
      Ba    0.1788
      B     0.1294
      Ca    84.0
      Cl    49.1
      Mg    41.0
      Na    176.2
      K     35.8
      F     0.9179
      S(6)  141.4
      Cd    0.0075
      Cr    0.0074
      Co    0.0037
      Cu    0.0710
      Fe    0.1857
      Pb    0.0464
      Mn    0.0875
      Mo    0.0067
      Ni    0.0054
      Se    0.0068
      U     0.0074
      V     0.0025
      Zn    0.1983
      Alkalinity 553.3 as HCO3
          water    1 # kg
      SOLUTION 2 PAF Material
          temp      25
          pH        7.5
          units     mg/L
          density   1
            Al    0.020
            As    0
            Ba    0.020
            B     0
            Ca    67.0
            Cl    0
            Mg    8.0
```

```
            Na    1.0
            K     13.0
            F     0.300
            S(6)  197.0
            Cd    0.000
            Cr    0
            Co    0.007
            Cu    0.028
            Fe    0
            Pb    0
            Mn    0.040
            Mo    0.003
            Ni    0.004
            Se    0
            U     0
            V     0
            Zn    0
            Alkalinity 22 as HCO3
          water    1 # kg
      SOLUTION 3 NAF Material
          temp      25
          pH        7.6
          units     mg/L
          density   1
            Al    0.140
            As    0.029
            Ba    0.020
            B     0
            Ca    122.0
            Cl    0
            Mg    18.0
            Na    1.0
            K     16.0
            F     0.300
            S(6)  331.0
            Cd    0.000
            Cr    0
            Co    0.002
            Cu    0.019
            Fe    0.070
            Pb    0
            Mn    0.130
            Mo    0.005
            Ni    0.001
            Se    0
            U     0.001
            V     0
            Zn    0
            Alkalinity 28 as HCO3
          water    1 # kg
      SOLUTION 4 Make-up Material
          temp      25
          pH        7.7
          units     mg/L
          density   1
            Al    0.020
            As    0
            Ba    0.020
            B     0
            Ca    67.0
            Cl    0
            Mg    8.0
            Na    1.0
            K     13.0
            F     0.300
            S(6)  197.0
```

```
            Cd    0.000
            Cr    0
            Co    0.007
            Cu    0.028
            Fe    0
            Pb    0
            Mn    0.040
            Mo    0.003
            Ni    0.004
            Se    0
            U     0
            V     0
            Zn    0
            Alkalinity 22 as HCO3
          water    1 # kg
      MIX 1 Mix within UG Works
          1    0.308
          2    0.110
          3    0.400
          4    0.182
      SAVE Solution 5
      SELECTED_OUTPUT 2
          file                 D:\selected_output_3.txt
          high_precision       true
          reset                true
          distance             false
          time                 false
          temperature          false
          ionic_strength       false
          water                false
          totals               pH Al As Ba B Ca Cl Mg
WARNING: Expected element name to begin with upper case letter.
                                Na K  F  S(6) Cd Cr Co
                                Cu Fe Pb Mn Mo  Ni Se
                                U V Zn Alkalinity
      END
-------------------------------------------
Beginning of initial solution calculations.
-------------------------------------------

Initial solution 1.     UG Water P50

-----------------------------Solution composition------------------------------

      Elements           Molality       Moles

      Al                2.976e-06   2.976e-06
      Alkalinity        9.077e-03   9.077e-03
      As                3.474e-08   3.474e-08
      B                 1.198e-05   1.198e-05
      Ba                1.303e-06   1.303e-06
      Ca                2.098e-03   2.098e-03
      Cd                6.679e-08   6.679e-08
      Cl                1.386e-03   1.386e-03
      Co                6.285e-08   6.285e-08
      Cr                1.425e-07   1.425e-07
      Cu                1.119e-06   1.119e-06
      F                 4.837e-05   4.837e-05
      Fe                3.329e-06   3.329e-06
      K                 9.166e-04   9.166e-04
      Mg                1.689e-03   1.689e-03
      Mn                1.594e-06   1.594e-06
      Mo                6.991e-08   6.991e-08
      Na                7.673e-03   7.673e-03
      Ni                9.211e-08   9.211e-08
      Pb                2.242e-07   2.242e-07
```

```
    S(6)              1.474e-03   1.474e-03
    Se                8.621e-08   8.621e-08
    U                 3.112e-08   3.112e-08
    V                 4.913e-08   4.913e-08
    Zn                3.036e-06   3.036e-06

----------------------------Description of solution----------------------------

                                       pH  =   8.112
                                       pe  =   4.000
                     Activity of water  =   1.000
                 Ionic strength (mol/kgw)  =   1.820e-02
                      Mass of water (kg)  =   1.000e+00
                 Total carbon (mol/kg)  =   8.999e-03
                    Total CO2 (mol/kg)  =   8.999e-03
                      Temperature (°C)  =  25.00
                Electrical balance (eq)  =   2.731e-03
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =   9.92
                            Iterations  =  11
                               Total H  = 1.110227e+02
                               Total O  = 5.553978e+01

----------------------------Distribution of species----------------------------

                                          Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             1.494e-06   1.303e-06    -5.826    -5.885    -0.060     (0)
   H+              8.828e-09   7.727e-09    -8.054    -8.112    -0.058      0.00
   H2O             5.551e+01   9.996e-01     1.744    -0.000     0.000     18.07
Al            2.976e-06
   Al(OH)4-        2.959e-06   2.593e-06    -5.529    -5.586    -0.057     (0)
   Al(OH)3         1.581e-08   1.581e-08    -7.801    -7.801     0.000     (0)
   Al(OH)2+        6.913e-10   6.083e-10    -9.160    -9.216    -0.056     (0)
   AlF2+           2.963e-12   2.608e-12   -11.528   -11.584    -0.056     (0)
   AlF3            1.251e-12   1.251e-12   -11.903   -11.903     0.000     (0)
   AlOH+2          9.804e-13   5.879e-13   -12.009   -12.231    -0.222     (0)
   AlF+2           2.867e-13   1.719e-13   -12.543   -12.765    -0.222     (0)
   AlF4-           2.725e-14   2.388e-14   -13.565   -13.622    -0.057     (0)
   AlSO4+          2.756e-15   2.415e-15   -14.560   -14.617    -0.057     (0)
   Al+3            1.496e-15   4.513e-16   -14.825   -15.346    -0.521     (0)
   Al(SO4)2-       2.035e-17   1.783e-17   -16.691   -16.749    -0.057     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -52.726   -53.346    -0.619     (0)
As(3)         8.499e-21
   H3AsO3          7.885e-21   7.885e-21   -20.103   -20.103     0.000     (0)
   H2AsO3-         6.132e-22   5.234e-22   -21.212   -21.281    -0.069     (0)
   HAsO3-2         1.164e-25   6.177e-26   -24.934   -25.209    -0.275     (0)
   H4AsO3+         3.537e-29   3.019e-29   -28.451   -28.520    -0.069     (0)
   AsO3-3          1.282e-30   3.082e-31   -29.892   -30.511    -0.619     (0)
As(5)         3.474e-08
   HAsO4-2         3.325e-08   1.765e-08    -7.478    -7.753    -0.275     (0)
   H2AsO4-         1.457e-09   1.243e-09    -8.837    -8.905    -0.069     (0)
   AsO4-3          3.005e-11   7.222e-12   -10.522   -11.141    -0.619     (0)
   H3AsO4          1.663e-15   1.670e-15   -14.779   -14.777     0.002     (0)
B             1.198e-05
   H3BO3           1.094e-05   1.098e-05    -4.961    -4.959     0.002     (0)
   H2BO3-          9.522e-07   8.256e-07    -6.021    -6.083    -0.062     (0)
   CaH2BO3+        5.502e-08   4.771e-08    -7.259    -7.321    -0.062     (0)
   MgH2BO3+        2.847e-08   2.468e-08    -7.546    -7.608    -0.062     (0)
   NaH2BO3         8.717e-09   8.717e-09    -8.060    -8.060     0.000     (0)
   BF(OH)3-        1.926e-10   1.670e-10    -9.715    -9.777    -0.062     (0)
   BaH2BO3+        2.123e-11   1.841e-11   -10.673   -10.735    -0.062     (0)
   H5(BO3)2-       8.903e-12   7.719e-12   -11.050   -11.112    -0.062     (0)
   H8(BO3)3-       9.779e-15   8.479e-15   -14.010   -14.072    -0.062     (0)
   BF2(OH)2-       6.063e-15   5.257e-15   -14.217   -14.279    -0.062     (0)
   BF3OH-          6.946e-22   6.023e-22   -21.158   -21.220    -0.062     (0)
   BF4-            1.006e-27   8.726e-28   -26.997   -27.059    -0.062     (0)
Ba            1.303e-06
   Ba+2            1.229e-06   7.214e-07    -5.910    -6.142    -0.231     (0)
   BaHCO3+         5.785e-08   5.105e-08    -7.238    -7.292    -0.054     (0)
   BaCO3           1.663e-08   1.663e-08    -7.779    -7.779     0.000     (0)
   BaH2BO3+        2.123e-11   1.841e-11   -10.673   -10.735    -0.062     (0)
   BaOH+           4.670e-12   4.102e-12   -11.331   -11.387    -0.056     (0)
C(4)          8.999e-03
   HCO3-           8.420e-03   7.410e-03    -2.075    -2.130    -0.056     (0)
   CaHCO3+         1.570e-04   1.385e-04    -3.804    -3.858    -0.054     (0)
   H2CO3           1.288e-04   1.288e-04    -3.890    -3.890     0.000     (0)
   CO3-2           7.659e-05   4.496e-05    -4.116    -4.347    -0.231     (0)
   MgHCO3+         7.479e-05   6.538e-05    -4.126    -4.185    -0.058     (0)
   CaCO3           7.154e-05   7.154e-05    -4.145    -4.145     0.000     (0)
   MgCO3           3.224e-05   3.224e-05    -4.492    -4.492     0.000     (0)
   NaHCO3          2.776e-05   2.776e-05    -4.557    -4.557     0.000     (0)
   NaCO3-          6.337e-06   5.577e-06    -5.198    -5.254    -0.056     (0)
   ZnCO3           1.601e-06   1.601e-06    -5.796    -5.796     0.000     (0)
   CuCO3           8.880e-07   8.880e-07    -6.052    -6.052     0.000     (0)
   Cu(CO3)2-2      2.025e-07   1.074e-07    -6.694    -6.969    -0.275     (0)
   ZnHCO3+         1.699e-07   1.450e-07    -6.770    -6.839    -0.069     (0)
   PbCO3           1.677e-07   1.677e-07    -6.776    -6.776     0.000     (0)
   MnHCO3+         1.230e-07   1.080e-07    -6.910    -6.967    -0.056     (0)
   BaHCO3+         5.785e-08   5.105e-08    -7.238    -7.292    -0.054     (0)
   Pb(CO3)2-2      4.097e-08   2.174e-08    -7.388    -7.663    -0.275     (0)
   NiCO3           3.348e-08   3.348e-08    -7.475    -7.475     0.000     (0)
   UO2(CO3)3-4     2.919e-08   2.314e-09    -7.535    -8.636    -1.101     (0)
   CdCO3           2.185e-08   2.185e-08    -7.661    -7.661     0.000     (0)
   NiHCO3+         2.136e-08   1.823e-08    -7.670    -7.739    -0.069     (0)
   BaCO3           1.663e-08   1.663e-08    -7.779    -7.779     0.000     (0)
   CoCO3           1.366e-08   1.366e-08    -7.865    -7.865     0.000     (0)
   CoHCO3+         1.214e-08   1.036e-08    -7.916    -7.985    -0.069     (0)
   PbHCO3+         8.003e-09   6.831e-09    -8.097    -8.166    -0.069     (0)
   UO2(CO3)2-2     1.935e-09   1.027e-09    -8.713    -8.988    -0.275     (0)
   CuHCO3+         1.837e-09   1.568e-09    -8.736    -8.805    -0.069     (0)
   Cd(CO3)2-2      1.372e-09   7.282e-10    -8.863    -9.138    -0.275     (0)
   CdHCO3+         4.215e-10   3.597e-10    -9.375    -9.444    -0.069     (0)
   FeHCO3+         3.251e-10   2.869e-10    -9.488    -9.542    -0.054     (0)
   UO2CO3          1.145e-12   1.145e-12   -11.941   -11.941     0.000     (0)
Ca            2.098e-03
   Ca+2            1.711e-03   1.004e-03    -2.767    -2.998    -0.231     (0)
   CaSO4           1.585e-04   1.585e-04    -3.800    -3.800     0.000     (0)
   CaHCO3+         1.570e-04   1.385e-04    -3.804    -3.858    -0.054     (0)
   CaCO3           7.154e-05   7.154e-05    -4.145    -4.145     0.000     (0)
   CaF+            4.753e-07   4.175e-07    -6.323    -6.379    -0.056     (0)
   CaH2BO3+        5.502e-08   4.771e-08    -7.259    -7.321    -0.062     (0)
   CaOH+           2.958e-08   2.610e-08    -7.529    -7.583    -0.054     (0)
Cd            6.679e-08
   Cd+2            3.633e-08   2.132e-08    -7.440    -7.671    -0.231     (0)
   CdCO3           2.185e-08   2.185e-08    -7.661    -7.661     0.000     (0)
   CdSO4           3.445e-09   3.445e-09    -8.463    -8.463     0.000     (0)
   CdCl+           2.896e-09   2.471e-09    -8.538    -8.607    -0.069     (0)
   Cd(CO3)2-2      1.372e-09   7.282e-10    -8.863    -9.138    -0.275     (0)
   CdHCO3+         4.215e-10   3.597e-10    -9.375    -9.444    -0.069     (0)
   CdOH+           2.585e-10   2.206e-10    -9.588    -9.656    -0.069     (0)
   CdOHCl          1.321e-10   1.321e-10    -9.879    -9.879     0.000     (0)
   Cd(SO4)2-2      6.037e-11   3.204e-11   -10.219   -10.494    -0.275     (0)
   CdF+            1.509e-11   1.288e-11   -10.821   -10.890    -0.069     (0)
   CdCl2           1.250e-11   1.250e-11   -10.903   -10.903     0.000     (0)
   Cd(OH)2         1.814e-12   1.814e-12   -11.741   -11.741     0.000     (0)
   CdCl3-          1.122e-14   9.573e-15   -13.950   -14.019    -0.069     (0)
   CdF2            9.787e-16   9.787e-16   -15.009   -15.009     0.000     (0)
   Cd(OH)3-        1.691e-16   1.443e-16   -15.772   -15.841    -0.069     (0)
   Cd2OH+3         9.812e-17   2.358e-17   -16.008   -16.627    -0.619     (0)
   CdSeO4          1.703e-17   1.703e-17   -16.769   -16.769     0.000     (0)
   Cd(SeO3)2-2     1.423e-17   7.552e-18   -16.847   -17.122    -0.275     (0)
   Cd(OH)4-2       5.799e-23   3.077e-23   -22.237   -22.512    -0.275     (0)
Cl            1.386e-03
   Cl-             1.386e-03   1.214e-03    -2.858    -2.916    -0.058     (0)
   ZnOHCl          3.216e-09   3.216e-09    -8.493    -8.493     0.000     (0)
   CdCl+           2.896e-09   2.471e-09    -8.538    -8.607    -0.069     (0)
   ZnCl+           2.158e-09   1.886e-09    -8.666    -8.724    -0.058     (0)
   MnCl+           1.271e-09   1.116e-09    -8.896    -8.952    -0.056     (0)
   CuCl            2.510e-10   2.510e-10    -9.600    -9.600     0.000     (0)
   CdOHCl          1.321e-10   1.321e-10    -9.879    -9.879     0.000     (0)
   CoCl+           8.841e-11   7.546e-11   -10.054   -10.122    -0.069     (0)
   CuCl2-          7.280e-11   6.364e-11   -10.138   -10.196    -0.058     (0)
   NiCl+           7.262e-11   6.198e-11   -10.139   -10.208    -0.069     (0)
   PbCl+           6.259e-11   5.342e-11   -10.203   -10.272    -0.069     (0)
   CdCl2           1.250e-11   1.250e-11   -10.903   -10.903     0.000     (0)
   CuCl+           7.381e-12   6.452e-12   -11.132   -11.190    -0.058     (0)
   ZnCl2           3.627e-12   3.627e-12   -11.440   -11.440     0.000     (0)
   MnCl2           1.913e-12   1.913e-12   -11.718   -11.718     0.000     (0)
   PbCl2           2.896e-13   2.896e-13   -12.538   -12.538     0.000     (0)
   CuCl3-2         2.774e-14   1.651e-14   -13.557   -13.782    -0.225     (0)
   CdCl3-          1.122e-14   9.573e-15   -13.950   -14.019    -0.069     (0)
   ZnCl3-          4.000e-15   3.497e-15   -14.398   -14.456    -0.058     (0)
   CuCl2           2.715e-15   2.715e-15   -14.566   -14.566     0.000     (0)
   MnCl3-          7.280e-16   6.394e-16   -15.138   -15.194    -0.056     (0)
   NiCl2           3.787e-16   3.787e-16   -15.422   -15.422     0.000     (0)
   PbCl3-          1.639e-16   1.399e-16   -15.785   -15.854    -0.069     (0)
   CrCl+2          5.369e-17   2.849e-17   -16.270   -16.545    -0.275     (0)
   ZnCl4-2         3.564e-18   2.122e-18   -17.448   -17.673    -0.225     (0)
   CrOHCl2         8.559e-19   8.559e-19   -18.068   -18.068     0.000     (0)
   FeCl+2          1.759e-19   1.047e-19   -18.755   -18.980    -0.225     (0)
   PbCl4-2         1.463e-19   7.761e-20   -18.835   -19.110    -0.275     (0)
   CuCl3-          3.517e-20   3.075e-20   -19.454   -19.512    -0.058     (0)
   UO2Cl+          1.475e-20   1.259e-20   -19.831   -19.900    -0.069     (0)
   CrCl2+          3.843e-21   3.280e-21   -20.415   -20.484    -0.069     (0)
   FeCl2+          6.461e-22   5.675e-22   -21.190   -21.246    -0.056     (0)
   VOCl+           6.255e-23   5.339e-23   -22.204   -22.273    -0.069     (0)
   CuCl4-2         3.141e-25   1.870e-25   -24.503   -24.728    -0.225     (0)
   FeCl3           6.887e-26   6.887e-26   -25.162   -25.162     0.000     (0)
   CrO3Cl-         2.797e-26   2.387e-26   -25.553   -25.622    -0.069     (0)
   CoCl+2          3.330e-37   1.767e-37   -36.478   -36.753    -0.275     (0)
   UCl+3           0.000e+00   0.000e+00   -49.022   -49.642    -0.619     (0)
Co(2)         6.285e-08
   Co+2            3.387e-08   1.797e-08    -7.470    -7.745    -0.275     (0)
   CoCO3           1.366e-08   1.366e-08    -7.865    -7.865     0.000     (0)
   CoHCO3+         1.214e-08   1.036e-08    -7.916    -7.985    -0.069     (0)
   CoSO4           2.472e-09   2.472e-09    -8.607    -8.607     0.000     (0)
   CoOH+           5.474e-10   4.672e-10    -9.262    -9.331    -0.069     (0)
   CoCl+           8.841e-11   7.546e-11   -10.054   -10.122    -0.069     (0)
   Co(OH)2         4.834e-11   4.834e-11   -10.316   -10.316     0.000     (0)
   CoF+            2.537e-11   2.165e-11   -10.596   -10.664    -0.069     (0)
   Co(OH)3-        1.472e-15   1.256e-15   -14.832   -14.901    -0.069     (0)
   CoOOH-          3.695e-16   3.154e-16   -15.432   -15.501    -0.069     (0)
   CoSeO4          3.864e-17   3.864e-17   -16.413   -16.413     0.000     (0)
   Co2OH+3         1.751e-18   4.208e-19   -17.757   -18.376    -0.619     (0)
   Co(OH)4-2       4.888e-22   2.594e-22   -21.311   -21.586    -0.275     (0)
   Co4(OH)4+4      1.199e-28   9.503e-30   -27.921   -29.022    -1.101     (0)
Co(3)         8.926e-30
   CoOH+2          8.926e-30   4.737e-30   -29.049   -29.325    -0.275     (0)
   Co+3            2.372e-36   7.156e-37   -35.625   -36.145    -0.521     (0)
   CoCl+2          3.330e-37   1.767e-37   -36.478   -36.753    -0.275     (0)
Cr(2)         8.166e-25
   Cr+2            8.166e-25   4.333e-25   -24.088   -24.363    -0.275     (0)
Cr(3)         1.425e-07
   Cr(OH)2+        9.600e-08   8.193e-08    -7.018    -7.087    -0.069     (0)
   Cr(OH)3         4.009e-08   4.009e-08    -7.397    -7.397     0.000     (0)
   CrO2-           2.888e-09   2.465e-09    -8.539    -8.608    -0.069     (0)
   Cr(OH)4-        2.436e-09   2.079e-09    -8.613    -8.682    -0.069     (0)
   Cr(OH)+2        9.742e-10   5.169e-10    -9.011    -9.287    -0.275     (0)
   CrOHSO4         8.455e-11   8.455e-11   -10.073   -10.073     0.000     (0)
   CrF+2           2.064e-13   1.095e-13   -12.685   -12.961    -0.275     (0)
   Cr+3            7.547e-14   1.814e-14   -13.122   -13.741    -0.619     (0)
   CrSO4+          3.420e-14   2.919e-14   -13.466   -13.535    -0.069     (0)
   CrCl+2          5.369e-17   2.849e-17   -16.270   -16.545    -0.275     (0)
   Cr2(OH)2SO4+2   7.444e-18   3.950e-18   -17.128   -17.403    -0.275     (0)
   CrOHCl2         8.559e-19   8.559e-19   -18.068   -18.068     0.000     (0)
   Cr2(OH)2(SO4)2   1.617e-19   1.617e-19   -18.791   -18.791     0.000     (0)
   CrCl2+          3.843e-21   3.280e-21   -20.415   -20.484    -0.069     (0)
Cr(6)         2.873e-14
   CrO4-2          2.757e-14   1.618e-14   -13.560   -13.791    -0.231     (0)
   NaCrO4          6.277e-16   5.358e-16   -15.202   -15.271    -0.069     (0)
   HCrO4-          4.741e-16   4.047e-16   -15.324   -15.393    -0.069     (0)
   KCrO4           5.625e-17   4.801e-17   -16.250   -16.319    -0.069     (0)
   H2CrO4          2.535e-24   2.535e-24   -23.596   -23.596     0.000     (0)
   CrO3SO4-2       1.238e-24   6.567e-25   -23.907   -24.183    -0.275     (0)
   CrO3Cl-         2.797e-26   2.387e-26   -25.553   -25.622    -0.069     (0)
   Cr2O7-2         1.070e-29   5.680e-30   -28.970   -29.246    -0.275     (0)
Cu(1)         5.163e-10
   CuCl            2.510e-10   2.510e-10    -9.600    -9.600     0.000     (0)
   Cu+             1.925e-10   1.643e-10    -9.716    -9.784    -0.069     (0)
   CuCl2-          7.280e-11   6.364e-11   -10.138   -10.196    -0.058     (0)
   CuCl3-2         2.774e-14   1.651e-14   -13.557   -13.782    -0.225     (0)
Cu(2)         1.118e-06
   CuCO3           8.880e-07   8.880e-07    -6.052    -6.052     0.000     (0)
   Cu(CO3)2-2      2.025e-07   1.074e-07    -6.694    -6.969    -0.275     (0)
   CuOH+           1.581e-08   1.382e-08    -7.801    -7.860    -0.058     (0)
   Cu+2            5.714e-09   3.354e-09    -8.243    -8.474    -0.231     (0)
   Cu(OH)2         3.591e-09   3.591e-09    -8.445    -8.445     0.000     (0)
   CuHCO3+         1.837e-09   1.568e-09    -8.736    -8.805    -0.069     (0)
   CuSO4           5.296e-10   5.296e-10    -9.276    -9.276     0.000     (0)
   Cu(OH)3-        1.124e-11   9.596e-12   -10.949   -11.018    -0.069     (0)
   CuF+            9.447e-12   8.063e-12   -11.025   -11.094    -0.069     (0)
   Cu2(OH)2+2      9.038e-12   4.796e-12   -11.044   -11.319    -0.275     (0)
   CuCl+           7.381e-12   6.452e-12   -11.132   -11.190    -0.058     (0)
   CuCl2           2.715e-15   2.715e-15   -14.566   -14.566     0.000     (0)
   Cu(OH)4-2       1.854e-16   9.838e-17   -15.732   -16.007    -0.275     (0)
   CuCl3-          3.517e-20   3.075e-20   -19.454   -19.512    -0.058     (0)
   CuCl4-2         3.141e-25   1.870e-25   -24.503   -24.728    -0.225     (0)
F             4.837e-05
   F-              4.352e-05   3.810e-05    -4.361    -4.419    -0.058     (0)
   MgF+            4.206e-06   3.685e-06    -5.376    -5.434    -0.057     (0)
   CaF+            4.753e-07   4.175e-07    -6.323    -6.379    -0.056     (0)
   NaF             1.601e-07   1.601e-07    -6.796    -6.796     0.000     (0)
   MnF+            1.261e-09   1.108e-09    -8.899    -8.955    -0.056     (0)
   ZnF+            5.510e-10   4.703e-10    -9.259    -9.328    -0.069     (0)
   HF              4.354e-10   4.354e-10    -9.361    -9.361     0.000     (0)
   BF(OH)3-        1.926e-10   1.670e-10    -9.715    -9.777    -0.062     (0)
   CoF+            2.537e-11   2.165e-11   -10.596   -10.664    -0.069     (0)
   NiF+            2.238e-11   1.910e-11   -10.650   -10.719    -0.069     (0)
   CdF+            1.509e-11   1.288e-11   -10.821   -10.890    -0.069     (0)
   CuF+            9.447e-12   8.063e-12   -11.025   -11.094    -0.069     (0)
   PbF+            3.903e-12   3.331e-12   -11.409   -11.477    -0.069     (0)
   AlF2+           2.963e-12   2.608e-12   -11.528   -11.584    -0.056     (0)
   AlF3            1.251e-12   1.251e-12   -11.903   -11.903     0.000     (0)
   AlF+2           2.867e-13   1.719e-13   -12.543   -12.765    -0.222     (0)
   CrF+2           2.064e-13   1.095e-13   -12.685   -12.961    -0.275     (0)
   HF2-            7.233e-14   6.306e-14   -13.141   -13.200    -0.060     (0)
   AlF4-           2.725e-14   2.388e-14   -13.565   -13.622    -0.057     (0)
   BF2(OH)2-       6.063e-15   5.257e-15   -14.217   -14.279    -0.062     (0)
   PbF2            2.497e-15   2.497e-15   -14.603   -14.603     0.000     (0)
   CdF2            9.787e-16   9.787e-16   -15.009   -15.009     0.000     (0)
   FeF+2           2.005e-16   1.193e-16   -15.698   -15.923    -0.225     (0)
   FeF2+           1.385e-16   1.217e-16   -15.859   -15.915    -0.056     (0)
   UO2F+           3.941e-17   3.364e-17   -16.404   -16.473    -0.069     (0)
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FeF3	6.539e-18	6.539e-18	-17.184	-17.184	0.000	(0)
UO2F2	3.696e-18	3.696e-18	-17.432	-17.432	0.000	(0)
VO2F	2.193e-18	2.193e-18	-17.659	-17.659	0.000	(0)
H2F2	5.079e-19	5.079e-19	-18.294	-18.294	0.000	(0)
PbF3-	2.114e-19	1.804e-19	-18.675	-18.744	-0.069	(0)
UO2F3-	4.144e-20	3.537e-20	-19.383	-19.451	-0.069	(0)
VO2F2-	3.554e-20	3.034e-20	-19.449	-19.518	-0.069	(0)
VOF+	4.198e-21	3.583e-21	-20.377	-20.446	-0.069	(0)
BF3OH-	6.946e-22	6.023e-22	-21.158	-21.220	-0.062	(0)
VOF2	5.118e-23	5.118e-23	-22.291	-22.291	0.000	(0)
VO2F3-2	2.717e-23	1.442e-23	-22.566	-22.841	-0.275	(0)
UO2F4-2	2.017e-23	1.070e-23	-22.695	-22.971	-0.275	(0)
PbF4-2	6.200e-24	3.290e-24	-23.208	-23.483	-0.275	(0)
VOF3-	8.106e-26	6.919e-26	-25.091	-25.160	-0.069	(0)
VO2F4-3	1.124e-27	2.702e-28	-26.949	-27.568	-0.619	(0)
BF4-	1.006e-27	8.726e-28	-26.997	-27.059	-0.062	(0)
VOF4-2	2.005e-29	1.064e-29	-28.698	-28.973	-0.275	(0)
UF3+	0.000e+00	0.000e+00	-40.014	-40.083	-0.069	(0)
UF2+2	0.000e+00	0.000e+00	-40.589	-40.864	-0.275	(0)
UF4	0.000e+00	0.000e+00	-42.462	-42.462	0.000	(0)
UF+3	0.000e+00	0.000e+00	-42.926	-43.545	-0.619	(0)
UF5-	0.000e+00	0.000e+00	-45.214	-45.283	-0.069	(0)
UF6-2	0.000e+00	0.000e+00	-46.947	-47.222	-0.275	(0)
Fe(2)	6.822e-09					
Fe+2	5.795e-09	3.075e-09	-8.237	-8.512	-0.275	(0)
FeSO4	5.203e-10	5.203e-10	-9.284	-9.284	0.000	(0)
FeHCO3+	3.251e-10	2.869e-10	-9.488	-9.542	-0.054	(0)
FeOH+	1.816e-10	1.595e-10	-9.741	-9.797	-0.056	(0)
Fe(OH)2	1.650e-13	1.650e-13	-12.782	-12.782	0.000	(0)
Fe(OH)3-	7.739e-14	6.797e-14	-13.111	-13.168	-0.056	(0)
Fe(3)	3.322e-06					
Fe(OH)3	1.703e-06	1.703e-06	-5.769	-5.769	0.000	(0)
Fe(OH)2+	1.384e-06	1.218e-06	-5.859	-5.914	-0.056	(0)
Fe(OH)4-	2.348e-07	2.066e-07	-6.629	-6.685	-0.056	(0)
FeOH+2	4.036e-12	2.403e-12	-11.394	-11.619	-0.225	(0)
FeF+2	2.005e-16	1.193e-16	-15.698	-15.923	-0.225	(0)
FeF2+	1.385e-16	1.217e-16	-15.859	-15.915	-0.056	(0)
FeSO4+	2.515e-17	2.209e-17	-16.599	-16.656	-0.056	(0)
Fe+3	9.471e-18	2.857e-18	-17.024	-17.544	-0.521	(0)
FeF3	6.539e-18	6.539e-18	-17.184	-17.184	0.000	(0)
Fe(SO4)2-	3.814e-19	3.256e-19	-18.419	-18.487	-0.069	(0)
FeCl+2	1.759e-19	1.047e-19	-18.755	-18.980	-0.225	(0)
Fe2(OH)2+4	2.411e-21	1.912e-22	-20.618	-21.719	-1.101	(0)
FeCl2+	6.461e-22	5.675e-22	-21.190	-21.246	-0.056	(0)
FeHSeO3+2	5.723e-22	3.037e-22	-21.242	-21.518	-0.275	(0)
Fe3(OH)4+5	1.766e-25	3.364e-27	-24.753	-26.473	-1.720	(0)
FeCl3	6.887e-26	6.887e-26	-25.162	-25.162	0.000	(0)
H(0)	8.418e-28					
H2	4.209e-28	4.227e-28	-27.376	-27.374	0.002	(0)
K	9.166e-04					
K+	9.122e-04	7.985e-04	-3.040	-3.098	-0.058	(0)
KSO4-	4.427e-06	3.896e-06	-5.354	-5.409	-0.056	(0)
KCrO4-	5.625e-17	4.801e-17	-16.250	-16.319	-0.069	(0)
Mg	1.689e-03					
Mg+2	1.469e-03	8.622e-04	-2.833	-3.064	-0.231	(0)
MgSO4	1.081e-04	1.081e-04	-3.966	-3.966	0.000	(0)
MgHCO3+	7.479e-05	6.538e-05	-4.126	-4.185	-0.058	(0)
MgCO3	3.224e-05	3.224e-05	-4.492	-4.492	0.000	(0)
MgF+	4.206e-06	3.685e-06	-5.376	-5.434	-0.057	(0)
MgOH+	5.057e-07	4.471e-07	-6.296	-6.350	-0.053	(0)
MgH2BO3+	2.847e-08	2.468e-08	-7.546	-7.608	-0.062	(0)
Mn(2)	1.594e-06					
Mn+2	1.377e-06	7.305e-07	-5.861	-6.136	-0.275	(0)
MnHCO3+	1.230e-07	1.080e-07	-6.910	-6.967	-0.056	(0)
MnSO4	8.954e-08	8.954e-08	-7.048	-7.048	0.000	(0)
MnOH+	2.721e-09	2.390e-09	-8.565	-8.622	-0.056	(0)

MnCl+	1.271e-09	1.116e-09	-8.896	-8.952	-0.056	(0)
MnF+	1.261e-09	1.108e-09	-8.899	-8.955	-0.056	(0)
MnCl2	1.913e-12	1.913e-12	-11.718	-11.718	0.000	(0)
MnSeO4	8.434e-16	8.434e-16	-15.074	-15.074	0.000	(0)
MnCl3-	7.280e-16	6.394e-16	-15.138	-15.194	-0.056	(0)
Mn(OH)3-	2.854e-17	2.507e-17	-16.545	-16.601	-0.056	(0)
Mn(OH)4-2	1.771e-22	1.054e-22	-21.752	-21.977	-0.225	(0)
MnSe	2.420e-39	2.420e-39	-38.616	-38.616	0.000	(0)
Mn(3)	1.082e-27					
Mn+3	1.082e-27	3.263e-28	-26.966	-27.486	-0.521	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-43.438	-43.663	-0.225	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-48.974	-49.035	-0.061	(0)
Mo	6.991e-08					
MoO4-2	6.990e-08	4.103e-08	-7.156	-7.387	-0.231	(0)
HMoO4-	7.392e-12	6.309e-12	-11.131	-11.200	-0.069	(0)
H2MoO4	3.571e-16	3.571e-16	-15.447	-15.447	0.000	(0)
AlMo6O21-3	0.000e+00	0.000e+00	-52.726	-53.346	-0.619	(0)
Mo7O24-6	0.000e+00	0.000e+00	-61.136	-63.613	-2.477	(0)
HMo7O24-5	0.000e+00	0.000e+00	-63.618	-65.338	-1.720	(0)
H2Mo7O24-4	0.000e+00	0.000e+00	-67.567	-68.668	-1.101	(0)
H3Mo7O24-3	0.000e+00	0.000e+00	-72.915	-73.534	-0.619	(0)
Na	7.673e-03					
Na+	7.610e-03	6.661e-03	-2.119	-2.176	-0.058	(0)
NaSO4-	2.802e-05	2.466e-05	-4.553	-4.608	-0.056	(0)
NaHCO3	2.776e-05	2.776e-05	-4.557	-4.557	0.000	(0)
NaCO3-	6.337e-06	5.577e-06	-5.198	-5.254	-0.056	(0)
NaF	1.601e-07	1.601e-07	-6.796	-6.796	0.000	(0)
NaH2BO3	8.717e-09	8.717e-09	-8.060	-8.060	0.000	(0)
NaCrO4-	6.277e-16	5.358e-16	-15.202	-15.271	-0.069	(0)
Ni	9.211e-08					
Ni+2	3.401e-08	1.996e-08	-7.468	-7.700	-0.231	(0)
NiCO3	3.348e-08	3.348e-08	-7.475	-7.475	0.000	(0)
NiHCO3+	2.136e-08	1.823e-08	-7.670	-7.739	-0.069	(0)
NiSO4	2.745e-09	2.745e-09	-8.561	-8.561	0.000	(0)
NiOH+	3.835e-10	3.274e-10	-9.416	-9.485	-0.069	(0)
NiCl+	7.262e-11	6.198e-11	-10.139	-10.208	-0.069	(0)
Ni(OH)2	3.387e-11	3.387e-11	-10.470	-10.470	0.000	(0)
NiF+	2.238e-11	1.910e-11	-10.650	-10.719	-0.069	(0)
Ni(SO4)2-2	1.181e-13	6.265e-14	-12.928	-13.203	-0.275	(0)
Ni(OH)3-	5.170e-14	4.412e-14	-13.287	-13.355	-0.069	(0)
NiCl2	3.787e-16	3.787e-16	-15.422	-15.422	0.000	(0)
NiSeO4	4.005e-17	4.005e-17	-16.397	-16.397	0.000	(0)
O(0)	5.647e-38					
O2	2.823e-38	2.835e-38	-37.549	-37.547	0.002	(0)
Pb	2.242e-07					
PbCO3	1.677e-07	1.677e-07	-6.776	-6.776	0.000	(0)
Pb(CO3)2-2	4.097e-08	2.174e-08	-7.388	-7.663	-0.275	(0)
PbHCO3+	8.003e-09	6.831e-09	-8.097	-8.166	-0.069	(0)
PbOH+	4.757e-09	4.060e-09	-8.323	-8.391	-0.069	(0)
Pb+2	2.114e-09	1.241e-09	-8.675	-8.906	-0.231	(0)
PbSO4	4.189e-10	4.189e-10	-9.378	-9.378	0.000	(0)
Pb(OH)2	1.672e-10	1.672e-10	-9.777	-9.777	0.000	(0)
PbCl+	6.259e-11	5.342e-11	-10.203	-10.272	-0.069	(0)
PbF+	3.903e-12	3.331e-12	-11.409	-11.477	-0.069	(0)
Pb(SO4)2-2	3.278e-12	1.740e-12	-11.484	-11.760	-0.275	(0)
PbCl2	2.896e-13	2.896e-13	-12.538	-12.538	0.000	(0)
Pb(OH)3-	2.552e-13	2.178e-13	-12.593	-12.662	-0.069	(0)
PbF2	2.497e-15	2.497e-15	-14.603	-14.603	0.000	(0)
Pb2OH+3	3.322e-16	7.983e-17	-15.479	-16.098	-0.619	(0)
PbCl3-	1.639e-16	1.399e-16	-15.785	-15.854	-0.069	(0)
Pb(OH)4-2	1.310e-16	6.950e-17	-15.883	-16.158	-0.275	(0)
Pb3(OH)4+2	1.305e-18	6.924e-19	-17.884	-18.160	-0.275	(0)
PbF3-	2.114e-19	1.804e-19	-18.675	-18.744	-0.069	(0)
PbCl4-2	1.463e-19	7.761e-20	-18.835	-19.110	-0.275	(0)

Pb4(OH)4+4	8.607e-23	6.824e-24	-22.065	-23.166	-1.101	(0)
PbF4-2	6.200e-24	3.290e-24	-23.208	-23.483	-0.275	(0)
S(6)	1.474e-03					
SO4-2	1.174e-03	6.893e-04	-2.930	-3.162	-0.231	(0)
CaSO4	1.585e-04	1.585e-04	-3.800	-3.800	0.000	(0)
MgSO4	1.081e-04	1.081e-04	-3.966	-3.966	0.000	(0)
NaSO4-	2.802e-05	2.466e-05	-4.553	-4.608	-0.056	(0)
KSO4-	4.427e-06	3.896e-06	-5.354	-5.409	-0.056	(0)
ZnSO4	9.329e-08	9.329e-08	-7.030	-7.030	0.000	(0)
MnSO4	8.954e-08	8.954e-08	-7.048	-7.048	0.000	(0)
CdSO4	3.445e-09	3.445e-09	-8.463	-8.463	0.000	(0)
NiSO4	2.745e-09	2.745e-09	-8.561	-8.561	0.000	(0)
CoSO4	2.472e-09	2.472e-09	-8.607	-8.607	0.000	(0)
Zn(SO4)2-2	1.055e-09	5.601e-10	-8.977	-9.252	-0.275	(0)
HSO4-	5.939e-10	5.204e-10	-9.226	-9.284	-0.057	(0)
CuSO4	5.296e-10	5.296e-10	-9.276	-9.276	0.000	(0)
FeSO4	5.203e-10	5.203e-10	-9.284	-9.284	0.000	(0)
PbSO4	4.189e-10	4.189e-10	-9.378	-9.378	0.000	(0)
CrOHSO4	8.455e-11	8.455e-11	-10.073	-10.073	0.000	(0)
Cd(SO4)2-2	6.037e-11	3.204e-11	-10.219	-10.494	-0.275	(0)
Pb(SO4)2-2	3.278e-12	1.740e-12	-11.484	-11.760	-0.275	(0)
Ni(SO4)2-2	1.181e-13	6.265e-14	-12.928	-13.203	-0.275	(0)
CrSO4+	3.420e-14	2.919e-14	-13.466	-13.535	-0.069	(0)
AlSO4+	2.756e-15	2.415e-15	-14.560	-14.617	-0.057	(0)
FeSO4+	2.515e-17	2.209e-17	-16.599	-16.656	-0.056	(0)
Al(SO4)2-	2.035e-17	1.783e-17	-16.691	-16.749	-0.057	(0)
Cr2(OH)2SO4+2	7.444e-18	3.950e-18	-17.128	-17.403	-0.275	(0)
UO2SO4	6.673e-18	6.673e-18	-17.176	-17.176	0.000	(0)
VO2SO4-	6.330e-19	5.402e-19	-18.199	-18.267	-0.069	(0)
Fe(SO4)2-	3.814e-19	3.256e-19	-18.419	-18.487	-0.069	(0)
Cr2(OH)2(SO4)2	1.617e-19	1.617e-19	-18.791	-18.791	0.000	(0)
UO2(SO4)2-2	1.143e-19	6.064e-20	-18.942	-19.217	-0.275	(0)
VOSO4	2.977e-21	2.977e-21	-20.526	-20.526	0.000	(0)
CrO3SO4-2	1.238e-24	6.567e-25	-23.907	-24.183	-0.275	(0)
VSO4+	1.773e-35	1.513e-35	-34.751	-34.820	-0.069	(0)
U(SO4)2	0.000e+00	0.000e+00	-44.249	-44.249	0.000	(0)
USO4+2	0.000e+00	0.000e+00	-44.712	-44.987	-0.275	(0)
Se(-2)	7.279e-36					
HSe-	7.276e-36	6.210e-36	-35.138	-35.207	-0.069	(0)
MnSe	2.420e-39	2.420e-39	-38.616	-38.616	0.000	(0)
H2Se	3.725e-40	3.725e-40	-39.429	-39.429	0.000	(0)
Se-2	0.000e+00	0.000e+00	-41.820	-42.095	-0.275	(0)
Se(4)	8.621e-08					
HSeO3-	4.714e-08	4.023e-08	-7.327	-7.395	-0.069	(0)
SeO3-2	3.907e-08	2.073e-08	-7.408	-7.683	-0.275	(0)
H2SeO3	1.326e-13	1.326e-13	-12.877	-12.877	0.000	(0)
Cd(SeO3)2-2	1.423e-17	7.552e-18	-16.847	-17.122	-0.275	(0)
FeHSeO3+2	5.723e-22	3.037e-22	-21.242	-21.518	-0.275	(0)
Se(6)	7.309e-12					
SeO4-2	7.308e-12	4.290e-12	-11.136	-11.368	-0.231	(0)
MnSeO4	8.434e-16	8.434e-16	-15.074	-15.074	0.000	(0)
ZnSeO4	4.110e-16	4.110e-16	-15.386	-15.386	0.000	(0)
NiSeO4	4.005e-17	4.005e-17	-16.397	-16.397	0.000	(0)
CoSeO4	3.864e-17	3.864e-17	-16.413	-16.413	0.000	(0)
CdSeO4	1.703e-17	1.703e-17	-16.769	-16.769	0.000	(0)
HSeO4-	1.946e-18	1.661e-18	-17.711	-17.780	-0.069	(0)
Zn(SeO4)2-2	3.369e-27	1.788e-27	-26.472	-26.748	-0.275	(0)
U(3)	0.000e+00					
U+3	0.000e+00	0.000e+00	-60.602	-61.222	-0.619	(0)
U(4)	1.209e-21					
U(OH)5-	1.209e-21	1.031e-21	-20.918	-20.987	-0.069	(0)
U(OH)4	3.339e-25	3.339e-25	-24.476	-24.476	0.000	(0)
U(OH)3+	1.106e-29	9.436e-30	-28.956	-29.025	-0.069	(0)
U(OH)2+2	6.356e-35	3.373e-35	-34.197	-34.472	-0.275	(0)
UF3+	0.000e+00	0.000e+00	-40.014	-40.083	-0.069	(0)
UOH+3	0.000e+00	0.000e+00	-40.292	-40.911	-0.619	(0)

UF2+2	0.000e+00	0.000e+00	-40.589	-40.864	-0.275	(0)
UF4	0.000e+00	0.000e+00	-42.462	-42.462	0.000	(0)
UF+3	0.000e+00	0.000e+00	-42.926	-43.545	-0.619	(0)
U(SO4)2	0.000e+00	0.000e+00	-44.249	-44.249	0.000	(0)
USO4+2	0.000e+00	0.000e+00	-44.712	-44.987	-0.275	(0)
UF5-	0.000e+00	0.000e+00	-45.214	-45.283	-0.069	(0)
UF6-2	0.000e+00	0.000e+00	-46.947	-47.222	-0.275	(0)
U+4	0.000e+00	0.000e+00	-47.325	-48.426	-1.101	(0)
UCl+3	0.000e+00	0.000e+00	-49.022	-49.642	-0.619	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-180.459	-186.032	-5.573	(0)
U(5)	4.568e-19					
UO2+	4.568e-19	3.899e-19	-18.340	-18.409	-0.069	(0)
U(6)	3.112e-08					
UO2(CO3)3-4	2.919e-08	2.314e-09	-7.535	-8.636	-1.101	(0)
UO2(CO3)2-2	1.935e-09	1.027e-09	-8.713	-8.988	-0.275	(0)
UO2CO3	1.145e-12	1.145e-12	-11.941	-11.941	0.000	(0)
UO2OH+	1.229e-15	1.049e-15	-14.910	-14.979	-0.069	(0)
UO2F+	3.941e-17	3.364e-17	-16.404	-16.473	-0.069	(0)
UO2+2	1.090e-17	6.397e-18	-16.963	-17.194	-0.231	(0)
UO2SO4	6.673e-18	6.673e-18	-17.176	-17.176	0.000	(0)
UO2F2	3.696e-18	3.696e-18	-17.432	-17.432	0.000	(0)
UO2(SO4)2-2	1.143e-19	6.064e-20	-18.942	-19.217	-0.275	(0)
UO2F3-	4.144e-20	3.537e-20	-19.383	-19.451	-0.069	(0)
UO2Cl+	1.475e-20	1.259e-20	-19.831	-19.900	-0.069	(0)
UO2F4-2	2.017e-23	1.070e-23	-22.695	-22.971	-0.275	(0)
(UO2)2(OH)2+2	3.442e-24	1.826e-24	-23.463	-23.738	-0.275	(0)
(UO2)3(OH)5+	2.890e-27	2.466e-27	-26.539	-26.608	-0.069	(0)
V(2)	0.000e+00					
VOH+	0.000e+00	0.000e+00	-40.949	-41.018	-0.069	(0)
V+2	0.000e+00	0.000e+00	-42.367	-42.642	-0.275	(0)
V(3)	8.293e-14					
V(OH)3	8.293e-14	8.293e-14	-13.081	-13.081	0.000	(0)
V(OH)2+	4.853e-25	4.142e-25	-24.314	-24.383	-0.069	(0)
VOH+2	5.722e-29	3.037e-29	-28.242	-28.518	-0.275	(0)
V+3	1.935e-34	4.651e-35	-33.713	-34.332	-0.619	(0)
VSO4+	1.773e-35	1.513e-35	-34.751	-34.820	-0.069	(0)
V2(OH)3+3	0.000e+00	0.000e+00	-53.829	-54.449	-0.619	(0)
V2(OH)2+4	0.000e+00	0.000e+00	-55.134	-56.235	-1.101	(0)
V(4)	4.810e-18					
V(OH)3+	4.773e-18	4.074e-18	-17.321	-17.390	-0.069	(0)
VO+2	2.955e-20	1.568e-20	-19.529	-19.805	-0.275	(0)
VOF+	4.198e-21	3.583e-21	-20.377	-20.446	-0.069	(0)
VOSO4	2.977e-21	2.977e-21	-20.526	-20.526	0.000	(0)
VOCl+	6.255e-23	5.339e-23	-22.204	-22.273	-0.069	(0)
VOF2	5.118e-23	5.118e-23	-22.291	-22.291	0.000	(0)
VOF3-	8.106e-26	6.919e-26	-25.091	-25.160	-0.069	(0)
VOF4-2	2.005e-29	1.064e-29	-28.698	-28.973	-0.275	(0)
H2V2O4+2	1.569e-30	8.325e-31	-29.804	-30.080	-0.275	(0)
V(5)	4.913e-08					
H2VO4-	3.226e-08	2.753e-08	-7.491	-7.560	-0.069	(0)
HVO4-2	1.687e-08	8.951e-09	-7.773	-8.048	-0.275	(0)
H3VO4	2.127e-12	2.127e-12	-11.672	-11.672	0.000	(0)
H3V2O7-	4.433e-13	3.783e-13	-12.353	-12.422	-0.069	(0)
HV2O7-3	3.476e-13	8.354e-14	-12.459	-13.078	-0.619	(0)
VO4-3	2.416e-14	5.806e-15	-13.617	-14.236	-0.619	(0)
V2O7-4	3.670e-15	2.910e-16	-14.435	-15.536	-1.101	(0)
V3O9-3	9.105e-17	2.188e-17	-16.041	-16.660	-0.619	(0)
VO2+	3.750e-17	3.282e-17	-16.426	-16.484	-0.058	(0)
VO2F	2.193e-18	2.193e-18	-17.659	-17.659	0.000	(0)
VO2SO4-	6.330e-19	5.402e-19	-18.199	-18.267	-0.069	(0)
VO2F2-	3.554e-20	3.034e-20	-19.449	-19.518	-0.069	(0)
V4O12-4	3.169e-21	2.513e-22	-20.499	-21.600	-1.101	(0)
VO2F3-2	2.717e-23	1.442e-23	-22.566	-22.841	-0.275	(0)
VO2F4-3	1.124e-27	2.702e-28	-26.949	-27.568	-0.619	(0)
V10O28-6	0.000e+00	0.000e+00	-56.665	-59.142	-2.477	(0)
HV10O28-5	0.000e+00	0.000e+00	-57.347	-59.067	-1.720	(0)

H2V10O28-4	0.000e+00	0.000e+00	-60.871	-61.971	-1.101	(0)
Zn	3.036e-06					
ZnCO3	1.601e-06	1.601e-06	-5.796	-5.796	0.000	(0)
Zn+2	1.054e-06	6.187e-07	-5.977	-6.209	-0.231	(0)
ZnHCO3+	1.699e-07	1.450e-07	-6.770	-6.839	-0.069	(0)
ZnOH+	9.443e-08	8.059e-08	-7.025	-7.094	-0.069	(0)
ZnSO4	9.329e-08	9.329e-08	-7.030	-7.030	0.000	(0)
Zn(OH)2	1.664e-08	1.664e-08	-7.779	-7.779	0.000	(0)
ZnOHCl	3.216e-09	3.216e-09	-8.493	-8.493	0.000	(0)
ZnCl+	2.158e-09	1.886e-09	-8.666	-8.724	-0.058	(0)
Zn(SO4)2-2	1.055e-09	5.601e-10	-8.977	-9.252	-0.275	(0)
ZnF+	5.510e-10	4.703e-10	-9.259	-9.328	-0.069	(0)
Zn(OH)3-	1.273e-10	1.086e-10	-9.895	-9.964	-0.069	(0)
ZnCl2	3.627e-12	3.627e-12	-11.440	-11.440	0.000	(0)
Zn(OH)4-2	1.062e-14	5.633e-15	-13.974	-14.249	-0.275	(0)
ZnCl3-	4.000e-15	3.497e-15	-14.398	-14.456	-0.058	(0)
ZnSeO4	4.110e-16	4.110e-16	-15.386	-15.386	0.000	(0)
ZnCl4-2	3.564e-18	2.122e-18	-17.448	-17.673	-0.225	(0)
Zn(SeO4)2-2	3.369e-27	1.788e-27	-26.472	-26.748	-0.275	(0)

----------Saturation indices----------

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(am)	-1.81	8.99	10.80	Al(OH)3
Al2(MoO4)3	-55.22	-52.85	2.37	Al2(MoO4)3
Al2O3	-1.67	17.98	19.65	Al2O3
Al4(OH)10SO4	-6.13	16.57	22.70	Al4(OH)10SO4
AlAsO4:2H2O	-10.59	-5.79	4.80	AlAsO4:2H2O
AlOHSO4	-7.17	-10.40	-3.23	AlOHSO4
Alunite	-5.39	-6.79	-1.40	KAl3(SO4)2(OH)6
Anglesite	-4.28	-12.07	-7.79	PbSO4
Anhydrite	-1.80	-6.16	-4.36	CaSO4
Antlerite	-4.93	3.86	8.79	Cu3(OH)4SO4
Aragonite	0.95	-7.35	-8.30	CaCO3
Arsenolite	-77.65	-80.41	-2.76	As4O6
Artinite	-3.85	5.75	9.60	MgCO3:Mg(OH)2:3H2O
As2O5	-36.26	-29.55	6.71	As2O5
Atacamite	-2.92	4.47	7.39	Cu2(OH)3Cl
Azurite	-0.99	-17.89	-16.91	Cu3(OH)2(CO3)2
Ba(OH)2:8H2O	-14.31	10.08	24.39	Ba(OH)2:8H2O
Ba2V2O7:2H2O	-12.45	3.42	15.87	Ba2V2O7:2H2O
Ba3(AsO4)2	9.60	0.69	-8.91	Ba3(AsO4)2
Ba3(VO4)2:4H2O	-19.44	13.50	32.94	Ba3(VO4)2:4H2O
BaCrO4	-10.26	-19.93	-9.67	BaCrO4
BaF2	-9.16	-14.98	-5.82	BaF2
BaMoO4	-6.57	-13.53	-6.96	BaMoO4
Barite	0.68	-9.30	-9.98	BaSO4
BaSeO3	-7.26	-5.43	1.83	BaSeO3
BaSeO4	-10.05	-17.51	-7.46	BaSeO4
Bianchite	-7.61	-9.37	-1.76	ZnSO4:6H2O
Birnessite	-9.13	8.96	18.09	MnO2
Bixbyite	-5.66	-6.30	-0.64	Mn2O3
Boehmite	0.41	8.99	8.58	AlOOH
Brochantite	-3.61	11.61	15.22	Cu4(OH)6SO4
Brucite	-3.68	13.16	16.84	Mg(OH)2
Bunsenite	-3.92	8.52	12.45	NiO
Ca(VO3)2	-9.18	-3.52	5.66	Ca(VO3)2
Ca2V2O7	-7.79	9.71	17.50	Ca2V2O7
Ca2V2O7:2H2O	-11.84	9.71	21.55	Ca2V2O7:2H2O
Ca3(AsO4)2:4H2O	-12.18	10.12	22.30	Ca3(AsO4)2:4H2O
Ca3(VO4)2	-16.03	22.93	38.96	Ca3(VO4)2
Ca3(VO4)2:4H2O	-16.93	22.93	39.86	Ca3(VO4)2:4H2O
CaCrO4	-14.52	-16.79	-2.27	CaCrO4
Calcite	1.13	-7.35	-8.48	CaCO3
CaMoO4	-2.44	-10.39	-7.95	CaMoO4
Carnotite	-4.56	-4.33	0.23	KUO2VO4
CaSeO3:2H2O	-5.10	-2.28	2.81	CaSeO3:2H2O
CaSeO4:2H2O	-11.35	-14.37	-3.02	CaSeO4:2H2O
Cd(BO2)2	-11.21	-1.37	9.84	Cd(BO2)2
Cd(OH)2	-5.09	8.55	13.64	Cd(OH)2
Cd(OH)2(am)	-5.18	8.55	13.73	Cd(OH)2
Cd3(OH)2(SO4)2	-19.82	-13.11	6.71	Cd3(OH)2(SO4)2
Cd3(OH)4SO4	-16.29	6.27	22.56	Cd3(OH)4SO4
Cd4(OH)6SO4	-13.58	14.82	28.40	Cd4(OH)6SO4
CdCl2	-12.84	-13.50	-0.66	CdCl2
CdCl2:1H2O	-11.81	-13.50	-1.69	CdCl2:1H2O
CdCl2:2.5H2O	-11.59	-13.50	-1.91	CdCl2:2.5H2O
CdF2	-15.30	-16.51	-1.21	CdF2
Cdmetal(alpha)	-29.19	-15.67	13.51	Cd
Cdmetal(gamma)	-29.29	-15.67	13.62	Cd
CdMoO4	-0.91	-15.06	-14.15	CdMoO4
CdOHCl	-6.01	-2.48	3.54	CdOHCl
CdSe	-14.57	-34.77	-20.20	CdSe
CdSeO4:2H2O	-17.19	-19.04	-1.85	CdSeO4:2H2O
CdSO4	-10.66	-10.83	-0.17	CdSO4
CdSO4:1H2O	-9.11	-10.83	-1.73	CdSO4:1H2O
CdSO4:2.67H2O	-8.96	-10.83	-1.87	CdSO4:2.67H2O
Cerussite	-0.12	-13.25	-13.13	PbCO3
CH4(g)	-76.42	-117.47	-41.05	CH4
Chalcanthite	-9.00	-11.64	-2.64	CuSO4:5H2O
Claudetite	-77.35	-80.41	-3.06	As4O6
Clausthalite	-8.90	-36.00	-27.10	PbSe
Co(BO2)2	-28.51	-1.44	27.07	Co(BO2)2
Co(OH)2	-4.62	8.48	13.09	Co(OH)2
Co(OH)3	-9.50	-11.81	-2.31	Co(OH)3
CO2(g)	-2.42	-20.57	-18.15	CO2
Co3(AsO4)2	-17.15	-4.12	13.03	Co3(AsO4)2
Co3O4	-4.65	-15.14	-10.50	Co3O4
CoCl2	-21.84	-13.58	8.27	CoCl2
CoCl2:6H2O	-16.11	-13.58	2.54	CoCl2:6H2O
CoCO3	-2.11	-12.09	-9.98	CoCO3
CoF2	-14.99	-16.58	-1.60	CoF2
CoF3	-47.94	-49.40	-1.46	CoF3
CoFe2O4	25.59	22.06	-3.53	CoFe2O4
CoMoO4	-7.37	-15.13	-7.76	CoMoO4
CoO	-5.11	8.48	13.59	CoO
CoSe	-18.64	-34.84	-16.20	CoSe
CoSeO3	-8.35	-7.03	1.32	CoSeO3
CoSeO4:6H2O	-17.58	-19.11	-1.53	CoSeO4:6H2O
CoSO4	-13.71	-10.91	2.80	CoSO4
CoSO4:6H2O	-8.44	-10.91	-2.47	CoSO4:6H2O
Cotunnite	-9.96	-14.74	-4.78	PbCl2
Cr(OH)2	-18.96	-8.14	10.82	Cr(OH)2
Cr(OH)3	-0.31	1.03	1.34	Cr(OH)3
Cr(OH)3(am)	1.78	1.03	-0.75	Cr(OH)3
Cr2O3	4.41	2.05	-2.36	Cr2O3
CrCl2	-44.29	-30.20	14.09	CrCl2
CrCl3	-47.17	-32.06	15.11	CrCl3
CrF3	-25.23	-36.57	-11.34	CrF3
Crmetal	-62.85	-32.36	30.48	Cr
CrO3	-26.80	-30.01	-3.21	CrO3
Cryolite	-14.55	-48.39	-33.84	Na3AlF6
Cu(OH)2	-0.92	7.75	8.67	Cu(OH)2
Cu2Se(alpha)	-0.86	-46.66	-45.80	Cu2Se
Cu2SO4	-20.78	-22.73	-1.95	Cu2SO4
Cu3(AsO4)2:2H2O	-12.41	-6.31	6.10	Cu3(AsO4)2:2H2O
Cu3Se2	-18.74	-82.23	-63.49	Cu3Se2
CuCO3	-1.32	-12.82	-11.50	CuCO3
CuCrO4	-16.83	-22.27	-5.44	CuCrO4
CuF	-9.30	-14.20	-4.91	CuF
CuF2	-18.43	-17.31	1.12	CuF2
CuF2:2H2O	-12.76	-17.31	-4.55	CuF2:2H2O
Cumetal	-5.03	-13.78	-8.76	Cu
CuMoO4	-2.79	-15.86	-13.08	CuMoO4
CuOCuSO4	-14.19	-3.89	10.30	CuOCuSO4
Cupricferrite	15.34	21.33	5.99	CuFe2O4
Cuprite	-1.94	-3.34	-1.41	Cu2O
Cuprousferrite	14.04	5.12	-8.92	CuFeO2
CuSe	-2.47	-35.57	-33.10	CuSe
CuSe2	-21.30	-54.66	-33.37	CuSe2
CuSeO3:2H2O	-8.27	-7.76	0.51	CuSeO3:2H2O
CuSeO4:5H2O	-17.40	-19.84	-2.44	CuSeO4:5H2O
CuSO4	-14.58	-11.64	2.94	CuSO4
Diaspore	2.12	8.99	6.87	AlOOH
Dolomite(disordered)	1.78	-14.76	-16.54	CaMg(CO3)2
Dolomite(ordered)	2.33	-14.76	-17.09	CaMg(CO3)2
Epsomite	-4.10	-6.23	-2.13	MgSO4:7H2O
Fe(OH)2	-5.85	7.71	13.56	Fe(OH)2
Fe(OH)2.7Cl.3	6.52	3.48	-3.04	Fe(OH)2.7Cl.3
Fe(VO3)2	-5.31	-9.03	-3.72	Fe(VO3)2
Fe2(OH)4SeO3	-3.48	-1.92	1.55	Fe2(OH)4SeO3
Fe2(SeO3)3:2H2O	-12.31	-32.94	-20.63	Fe2(SeO3)3:2H2O
Fe2(SO4)3	-40.84	-44.57	-3.73	Fe2(SO4)3
Fe3(OH)8	1.07	21.29	20.22	Fe3(OH)8
FeAsO4:2H2O	-8.39	-7.99	0.40	FeAsO4:2H2O
FeCr2O4	2.56	9.76	7.20	FeCr2O4
FeMoO4	-5.81	-15.90	-10.09	FeMoO4
Ferrihydrite	3.60	6.79	3.19	Fe(OH)3
Ferroselite	-36.11	-54.70	-18.60	FeSe2
FeSe	-24.61	-35.61	-11.00	FeSe
Fluorite	-1.34	-11.84	-10.50	CaF2
Gibbsite	0.70	8.99	8.29	Al(OH)3
Goethite	6.30	6.79	0.49	FeOOH
Goslarite	-7.36	-9.37	-2.01	ZnSO4:7H2O
Gummite	-8.64	-0.97	7.67	UO3
Gypsum	-1.55	-6.16	-4.61	CaSO4:2H2O
H-Jarosite	-6.30	-18.40	-12.10	(H3O)Fe3(SO4)2(OH)6
H2MoO4	-10.73	-23.61	-12.88	H2MoO4
H2Se(g)	-38.36	-43.32	-4.96	H2Se
Halite	-6.69	-5.09	1.60	NaCl
Hausmannite	-6.54	54.49	61.03	Mn3O4
Hematite	15.00	13.58	-1.42	Fe2O3
Hercynite	2.80	25.69	22.89	FeAl2O4
Huntite	0.39	-29.58	-29.97	CaMg3(CO3)4
Hydrocerussite	-0.42	-19.19	-18.77	Pb3(OH)2(CO3)2
Hydromagnesite	-7.72	-16.49	-8.77	Mg5(CO3)4(OH)2:4H2O
K-Alum	-19.60	-24.77	-5.17	KAl(SO4)2:12H2O
K-Jarosite	1.42	-13.38	-14.80	KFe3(SO4)2(OH)6
K2Cr2O7	-32.76	-50.00	-17.24	K2Cr2O7
K2CrO4	-19.47	-19.99	-0.51	K2CrO4
K2MoO4	-16.84	-13.58	3.26	K2MoO4
K2SeO4	-16.83	-17.56	-0.73	K2SeO4
Langite	-5.88	11.61	17.49	Cu4(OH)6SO4:H2O
Larnakite	-4.32	-4.75	-0.43	PbO:PbSO4
Laurionite	-4.33	-3.71	0.62	PbOHCl
Lepidocrocite	5.42	6.79	1.37	FeOOH
Lime	-19.47	13.23	32.70	CaO
Litharge	-5.38	7.32	12.69	PbO
Maghemite	7.20	13.58	6.39	Fe2O3
Magnesioferrite	9.88	26.74	16.86	Fe2MgO4
Magnesite	0.05	-7.41	-7.46	MgCO3
Magnetite	17.89	21.29	3.40	Fe3O4
Malachite	0.23	-5.07	-5.31	Cu2(OH)2CO3
Manganite	-3.14	22.20	25.34	MnOOH
Massicot	-5.58	7.32	12.89	PbO
Matlockite	-7.27	-16.24	-8.97	PbClF
Melanothallite	-20.56	-14.31	6.26	CuCl2
Melanterite	-9.47	-11.67	-2.21	FeSO4:7H2O
Mg(OH)2(active)	-5.63	13.16	18.79	Mg(OH)2
Mg(VO3)2	-14.86	-3.58	11.28	Mg(VO3)2
Mg2V2O7	-16.78	9.58	26.36	Mg2V2O7
MgCr2O4	-0.99	15.21	16.20	MgCr2O4
MgCrO4	-22.24	-16.86	5.38	MgCrO4
MgF2	-3.77	-11.90	-8.13	MgF2
MgMoO4	-8.60	-10.45	-1.85	MgMoO4
MgSeO3:6H2O	-5.40	-2.35	3.06	MgSeO3:6H2O
MgSeO4:6H2O	-13.23	-14.43	-1.20	MgSeO4:6H2O
Minium	-27.35	46.18	73.52	Pb3O4
Mirabilite	-6.40	-7.52	-1.11	Na2SO4:10H2O
Mn(VO3)2	-11.56	-6.66	4.90	Mn(VO3)2
Mn2(SO4)3	-58.75	-64.46	-5.71	Mn2(SO4)3
Mn3(AsO4)2:8H2O	-11.79	0.71	12.50	Mn3(AsO4)2:8H2O
MnCl2:4H2O	-14.68	-11.97	2.72	MnCl2:4H2O
MnSe	-36.73	-33.23	3.50	MnSe
MnSeO3	-6.55	-5.42	1.13	MnSeO3
MnSeO3:2H2O	-6.40	-5.42	0.98	MnSeO3:2H2O
MnSeO4:5H2O	-15.45	-17.50	-2.05	MnSeO4:5H2O
MnSO4	-11.88	-9.30	2.58	MnSO4
Monteponite	-6.55	8.55	15.10	CdO
MoO3	-15.61	-23.61	-8.00	MoO3
Morenosite	-8.72	-10.86	-2.14	NiSO4:7H2O
Na-Jarosite	-1.26	-12.46	-11.20	NaFe3(SO4)2(OH)6
Na2Cr2O7	-38.26	-48.16	-9.90	Na2Cr2O7
Na2CrO4	-21.07	-18.14	2.93	Na2CrO4
Na2Mo2O7	-18.75	-35.35	-16.60	Na2Mo2O7
Na2MoO4	-13.23	-11.74	1.49	Na2MoO4
Na2MoO4:2H2O	-12.96	-11.74	1.22	Na2MoO4:2H2O
Na2SeO3:5H2O	-13.94	-3.64	10.30	Na2SeO3:5H2O
Na2SeO4	-17.00	-15.72	1.28	Na2SeO4
Na3VO4	-27.25	9.43	36.68	Na3VO4
Na4V2O7	-30.40	7.00	37.40	Na4V2O7
Nantokite	-5.97	-12.70	-6.73	CuCl
Natron	-7.39	-8.70	-1.31	Na2CO3:10H2O
NaVO3	-6.29	-2.44	3.86	NaVO3
Nesquehonite	-2.74	-7.41	-4.67	MgCO3:3H2O
Ni(OH)2	-4.27	8.52	12.79	Ni(OH)2
Ni3(AsO4)2:8H2O	-19.68	-3.98	15.70	Ni3(AsO4)2:8H2O
Ni4(OH)6SO4	-17.29	14.71	32.00	Ni4(OH)6SO4
NiCO3	-5.18	-12.05	-6.87	NiCO3
NiMoO4	-3.94	-15.09	-11.14	NiMoO4
NiSe	-17.09	-34.79	-17.70	NiSe
NiSeO3:2H2O	-9.80	-6.98	2.81	NiSeO3:2H2O
NiSeO4:6H2O	-17.55	-19.07	-1.52	NiSeO4:6H2O
Nsutite	-8.54	8.96	17.50	MnO2
O2(g)	-34.64	48.45	83.09	O2
Otavite	-0.02	-12.02	-12.00	CdCO3
Pb(BO2)2	-9.12	-2.60	6.52	Pb(BO2)2
Pb(OH)2	-0.83	7.32	8.15	Pb(OH)2
Pb10(OH)6O(CO3)6	-41.49	-50.25	-8.76	Pb10(OH)6O(CO3)6
Pb2(OH)3Cl	-5.19	3.61	8.79	Pb2(OH)3Cl
Pb2O(OH)2	-11.55	14.63	26.19	Pb2O(OH)2
Pb2O3	-22.18	38.86	61.04	Pb2O3
Pb2OCO3	-5.38	-5.94	-0.56	Pb2OCO3
Pb2V2O7	-0.21	-2.11	-1.90	Pb2V2O7
Pb3(AsO4)2	-13.40	-7.60	5.80	Pb3(AsO4)2
Pb3(VO4)2	-0.93	5.21	6.14	Pb3(VO4)2
Pb3O2CO3	-9.64	1.38	11.02	Pb3O2CO3
Pb3O2SO4	-8.12	2.57	10.69	Pb3O2SO4
Pb4(OH)6SO4	-11.22	9.88	21.10	Pb4(OH)6SO4
Pb4O3SO4	-11.99	9.88	21.88	Pb4O3SO4
PbCrO4	-10.10	-22.70	-12.60	PbCrO4
PbF2	-10.30	-17.74	-7.44	PbF2
Pbmetal	-21.15	-16.91	4.25	Pb

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   PbMoO4           -0.67    -16.29  -15.62  PbMoO4
   PbO:0.3H2O       -5.66      7.32   12.98  PbO:0.33H2O
   PbSeO4          -13.43    -20.27   -6.84  PbSeO4
   Periclase        -8.42     13.16   21.58  MgO
   Phosgenite       -8.18    -27.99  -19.81  PbCl2:PbCO3
   Plattnerite     -18.06     31.54   49.60  PbO2
   Portlandite      -9.58     13.23   22.80  Ca(OH)2
   Pyrochroite      -5.11     10.09   15.19  Mn(OH)2
   Pyrolusite       -7.07     34.31   41.38  MnO2
   Retgersite       -8.82    -10.86   -2.04  NiSO4:6H2O
   Rhodochrosite     0.10    -10.48  -10.58  MnCO3
   Rutherfordine    -7.04    -21.54  -14.50  UO2CO3
   Schoepite        -6.96     -0.97    5.99  UO2(OH)2:H2O
   Semetal(am)     -11.98    -19.09   -7.11  Se
   Semetal(hex     -11.39    -19.09   -7.71  Se
   SeO2            -15.63    -15.51    0.12  SeO2
   SeO3            -48.64    -27.59   21.04  SeO3
   Siderite         -2.62    -12.86  -10.24  FeCO3
   Smithsonite      -0.56    -10.56  -10.00  ZnCO3
   Spinel           -5.71     31.14   36.85  MgAl2O4
   Tenorite          0.11      7.75    7.64  CuO
   Thenardite       -7.84     -7.51    0.32  Na2SO4
   Thermonatrite    -9.34     -8.70    0.64  Na2CO3:H2O
   Tyuyamunite      -9.54     -5.46    4.08  Ca(UO2)2(VO4)2
   U3O8            -20.57      0.51   21.08  U3O8
   U4O9            -36.67    -39.69   -3.02  U4O9
   UF4             -36.57    -66.10  -29.54  UF4
   UF4:2.5H2O      -33.38    -66.10  -32.72  UF4:2.5H2O
   UO2(am)         -16.91    -15.98    0.93  UO2
   UO2(OH)2(beta)   -6.58     -0.97    5.61  UO2(OH)2
   UO2SeO4:4H2O    -26.31    -28.56   -2.25  UO2SeO4:4H2O
   UO3              -8.67     -0.97    7.70  UO3
   Uraninite       -11.31    -15.98   -4.67  UO2
   V(OH)3          -17.59    -10.00    7.59  V(OH)3
   V2O5            -15.38    -16.74   -1.36  V2O5
   V3O5            -36.80    -34.97    1.84  V3O5
   V4O7            -45.73    -38.55    7.19  V4O7
   V6O13           -37.82    -98.68  -60.86  V6O13
   VCl2            -63.04    -44.16   18.87  VCl2
   VCl3            -66.51    -43.08   23.43  VCl3
   VF4             -68.63    -53.70   14.93  VF4
   Vmetal          -90.36    -46.33   44.03  V
   VO              -36.86    -22.11   14.76  VO
   VO(OH)2          -8.73     -3.58    5.15  VO(OH)2
   VO2Cl           -22.24    -19.40    2.84  VO2Cl
   VOCl            -32.18    -21.02   11.15  VOCl
   VOCl2           -38.40    -25.64   12.76  VOCl2
   VOSO4           -26.58    -22.97    3.61  VOSO4
   Witherite        -1.92    -10.49   -8.57  BaCO3
   Zincite          -1.32     10.02   11.33  ZnO
   Zincosite       -13.30     -9.37    3.93  ZnSO4
   Zn(BO2)2         -8.19      0.10    8.29  Zn(BO2)2
   Zn(OH)2          -2.18     10.02   12.20  Zn(OH)2
   Zn(OH)2(am)      -2.46     10.02   12.47  Zn(OH)2
   Zn(OH)2(beta)    -1.74     10.02   11.75  Zn(OH)2
   Zn(OH)2(epsilon)  -1.52     10.02   11.53  Zn(OH)2
   Zn(OH)2(gamma)   -1.72     10.02   11.73  Zn(OH)2
   Zn2(OH)2SO4      -6.86      0.64    7.50  Zn2(OH)2SO4
   Zn2(OH)3Cl       -6.19      9.00   15.19  Zn2(OH)3Cl
   Zn3(AsO4)2:2.5H2O -13.16      0.49   13.65  Zn3(AsO4)2:2.5H2O
   Zn3O(SO4)2      -27.64     -8.72   18.91  Zn3O(SO4)2
   Zn4(OH)6SO4      -7.72     20.68   28.40  Zn4(OH)6SO4
   Zn5(OH)8Cl2     -10.48     28.02   38.50  Zn5(OH)8Cl2
   ZnCl2           -19.09    -12.04    7.05  ZnCl2
   ZnCO3:1H2O       -0.30    -10.56  -10.26  ZnCO3:1H2O
   ZnF2            -14.51    -15.05   -0.53  ZnF2
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   Znmetal         -40.00    -14.21   25.79  Zn
   ZnMoO4           -3.47    -13.60  -10.13  ZnMoO4
   ZnO(active)      -1.17     10.02   11.19  ZnO
   ZnSe            -18.90    -33.30  -14.40  ZnSe
   ZnSeO4:6H2O     -16.06    -17.58   -1.52  ZnSeO4:6H2O
   ZnSO4:1H2O       -8.73     -9.37   -0.64  ZnSO4:1H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 2.     PAF Material

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                7.415e-07   7.415e-07
      Alkalinity        3.607e-04   3.607e-04
      Ba                1.457e-07   1.457e-07
      Ca                1.672e-03   1.672e-03
      Co                1.188e-07   1.188e-07
      Cu                4.408e-07   4.408e-07
      F                 1.580e-05   1.580e-05
      K                 3.326e-04   3.326e-04
      Mg                3.293e-04   3.293e-04
      Mn                7.283e-07   7.283e-07
      Mo                3.128e-08   3.128e-08
      Na                4.351e-05   4.351e-05
      Ni                6.818e-08   6.818e-08
      S(6)              2.051e-03   2.051e-03

---------------------------Description of solution----------------------------

                                       pH  =   7.500
                                       pe  =   4.000
                              Activity of water  =   1.000
                       Ionic strength (mol/kgw)  =   7.200e-03
                           Mass of water (kg)  =   1.000e+00
                         Total carbon (mol/kg)  =   3.782e-04
                            Total CO2 (mol/kg)  =   3.782e-04
                              Temperature (°C)  =  25.00
                       Electrical balance (eq)  =  -9.478e-05
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  -1.25
                                    Iterations  =  13 (24 overall)
                                       Total H  = 1.110141e+02
                                       Total O  = 5.551618e+01

----------------------------Distribution of species----------------------------

                                                  Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             3.487e-07   3.184e-07    -6.458    -6.497    -0.039      (0)
   H+              3.458e-08   3.162e-08    -7.461    -7.500    -0.039      0.00
   H2O             5.551e+01   9.999e-01     1.744    -0.000     0.000     18.07
Al            7.415e-07
   Al(OH)4-        7.221e-07   6.609e-07    -6.141    -6.180    -0.038      (0)
   Al(OH)3         1.649e-08   1.649e-08    -7.783    -7.783     0.000      (0)
   Al(OH)2+        2.830e-09   2.595e-09    -8.548    -8.586    -0.038      (0)
   AlF2+           2.736e-11   2.509e-11   -10.563   -10.600    -0.038      (0)
   AlOH+2          1.451e-11   1.026e-11   -10.838   -10.989    -0.150      (0)
   AlF+2           6.374e-12   4.507e-12   -11.196   -11.346    -0.150      (0)
   AlF3            4.418e-12   4.418e-12   -11.355   -11.355     0.000      (0)
   AlSO4+          3.315e-13   3.034e-13   -12.480   -12.518    -0.038      (0)
   Al+3            7.201e-14   3.223e-14   -13.143   -13.492    -0.349      (0)
   AlF4-           3.383e-14   3.096e-14   -13.471   -13.509    -0.038      (0)
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   Al(SO4)2-       4.307e-15   3.942e-15   -14.366   -14.404    -0.038      (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -49.070   -49.460    -0.390      (0)
Ba            1.457e-07
   Ba+2            1.453e-07   1.017e-07    -6.838    -6.993    -0.155      (0)
   BaHCO3+         3.363e-10   3.088e-10    -9.473    -9.510    -0.037      (0)
   BaCO3           2.459e-11   2.459e-11   -10.609   -10.609     0.000      (0)
   BaOH+           1.542e-13   1.413e-13   -12.812   -12.850    -0.038      (0)
C(4)          3.782e-04
   HCO3-           3.469e-04   3.181e-04    -3.460    -3.497    -0.038      (0)
   H2CO3           2.262e-05   2.262e-05    -4.645    -4.645     0.000      (0)
   CaHCO3+         6.292e-06   5.777e-06    -5.201    -5.238    -0.037      (0)
   CaCO3           7.289e-07   7.289e-07    -6.137    -6.137     0.000      (0)
   MgHCO3+         7.079e-07   6.472e-07    -6.150    -6.189    -0.039      (0)
   CO3-2           6.741e-07   4.716e-07    -6.171    -6.326    -0.155      (0)
   CuCO3           2.133e-07   2.133e-07    -6.671    -6.671     0.000      (0)
   MgCO3           7.799e-08   7.799e-08    -7.108    -7.108     0.000      (0)
   NaHCO3          7.071e-09   7.071e-09    -8.151    -8.151     0.000      (0)
   MnHCO3+         2.944e-09   2.697e-09    -8.531    -8.569    -0.038      (0)
   CoHCO3+         1.830e-09   1.657e-09    -8.738    -8.781    -0.043      (0)
   CuHCO3+         1.703e-09   1.542e-09    -8.769    -8.812    -0.043      (0)
   NiHCO3+         1.700e-09   1.539e-09    -8.770    -8.813    -0.043      (0)
   NiCO3           6.904e-10   6.904e-10    -9.161    -9.161     0.000      (0)
   CoCO3           5.337e-10   5.337e-10    -9.273    -9.273     0.000      (0)
   Cu(CO3)2-2      4.033e-10   2.707e-10    -9.394    -9.567    -0.173      (0)
   NaCO3-          3.785e-10   3.471e-10    -9.422    -9.460    -0.038      (0)
   BaHCO3+         3.363e-10   3.088e-10    -9.473    -9.510    -0.037      (0)
   BaCO3           2.459e-11   2.459e-11   -10.609   -10.609     0.000      (0)
Ca            1.672e-03
   Ca+2            1.394e-03   9.753e-04    -2.856    -3.011    -0.155      (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000      (0)
   CaHCO3+         6.292e-06   5.777e-06    -5.201    -5.238    -0.037      (0)
   CaCO3           7.289e-07   7.289e-07    -6.137    -6.137     0.000      (0)
   CaF+            1.625e-07   1.489e-07    -6.789    -6.827    -0.038      (0)
   CaOH+           6.748e-09   6.196e-09    -8.171    -8.208    -0.037      (0)
Co(2)         1.188e-07
   Co+2            9.974e-08   6.695e-08    -7.001    -7.174    -0.173      (0)
   CoSO4           1.620e-08   1.620e-08    -7.791    -7.791     0.000      (0)
   CoHCO3+         1.830e-09   1.657e-09    -8.738    -8.781    -0.043      (0)
   CoCO3           5.337e-10   5.337e-10    -9.273    -9.273     0.000      (0)
   CoOH+           4.699e-10   4.253e-10    -9.328    -9.371    -0.043      (0)
   CoF+            3.271e-11   2.961e-11   -10.485   -10.529    -0.043      (0)
   Co(OH)2         1.076e-11   1.076e-11   -10.968   -10.968     0.000      (0)
   Co(OH)3-        7.550e-17   6.834e-17   -16.122   -16.165    -0.043      (0)
   CoOOH-          1.894e-17   1.715e-17   -16.723   -16.766    -0.043      (0)
   Co2OH+3         3.499e-18   1.427e-18   -17.456   -17.846    -0.390      (0)
   Co(OH)4-2       5.137e-24   3.448e-24   -23.289   -23.462    -0.173      (0)
   Co4(OH)4+4      3.216e-29   6.530e-30   -28.493   -29.185    -0.692      (0)
Co(3)         6.424e-30
   CoOH+2          6.424e-30   4.312e-30   -29.192   -29.365    -0.173      (0)
   Co+3            5.955e-36   2.665e-36   -35.225   -35.574    -0.349      (0)
Cu(1)         4.157e-09
   Cu+             4.157e-09   3.762e-09    -8.381    -8.425    -0.043      (0)
Cu(2)         4.366e-07
   CuCO3           2.133e-07   2.133e-07    -6.671    -6.671     0.000      (0)
   Cu+2            1.098e-07   7.682e-08    -6.959    -7.115    -0.155      (0)
   CuOH+           8.460e-08   7.735e-08    -7.073    -7.112    -0.039      (0)
   CuSO4           2.134e-08   2.134e-08    -7.671    -7.671     0.000      (0)
   Cu(OH)2         4.914e-09   4.914e-09    -8.309    -8.309     0.000      (0)
   CuHCO3+         1.703e-09   1.542e-09    -8.769    -8.812    -0.043      (0)
   Cu(CO3)2-2      4.033e-10   2.707e-10    -9.394    -9.567    -0.173      (0)
   Cu2(OH)2+2      2.239e-10   1.503e-10    -9.650    -9.823    -0.173      (0)
   CuF+            7.488e-11   6.778e-11   -10.126   -10.169    -0.043      (0)
   Cu(OH)3-        3.545e-12   3.209e-12   -11.450   -11.494    -0.043      (0)
   Cu(OH)4-2       1.198e-17   8.042e-18   -16.922   -17.095    -0.173      (0)
F             1.580e-05
   F-              1.529e-05   1.398e-05    -4.816    -4.854    -0.039      (0)
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   MgF+            3.409e-07   3.120e-07    -6.467    -6.506    -0.038      (0)
   CaF+            1.625e-07   1.489e-07    -6.789    -6.827    -0.038      (0)
   HF              6.541e-10   6.541e-10    -9.184    -9.184     0.000      (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000      (0)
   MnF+            2.582e-10   2.366e-10    -9.588    -9.626    -0.038      (0)
   CuF+            7.488e-11   6.778e-11   -10.126   -10.169    -0.043      (0)
   CoF+            3.271e-11   2.961e-11   -10.485   -10.529    -0.043      (0)
   AlF2+           2.736e-11   2.509e-11   -10.563   -10.600    -0.038      (0)
   NiF+            1.523e-11   1.379e-11   -10.817   -10.861    -0.043      (0)
   AlF+2           6.374e-12   4.507e-12   -11.196   -11.346    -0.150      (0)
   AlF3            4.418e-12   4.418e-12   -11.355   -11.355     0.000      (0)
   HF2-            3.808e-14   3.478e-14   -13.419   -13.459    -0.039      (0)
   AlF4-           3.383e-14   3.096e-14   -13.471   -13.509    -0.038      (0)
   H2F2            1.146e-18   1.146e-18   -17.941   -17.941     0.000      (0)
H(0)          1.414e-26
   H2              7.068e-27   7.079e-27   -26.151   -26.150     0.001      (0)
K             3.326e-04
   K+              3.298e-04   3.016e-04    -3.482    -3.521    -0.039      (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038      (0)
Mg            3.293e-04
   Mg+2            2.842e-04   1.988e-04    -3.546    -3.702    -0.155      (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000      (0)
   MgHCO3+         7.079e-07   6.472e-07    -6.150    -6.189    -0.039      (0)
   MgF+            3.409e-07   3.120e-07    -6.467    -6.506    -0.038      (0)
   MgCO3           7.799e-08   7.799e-08    -7.108    -7.108     0.000      (0)
   MgOH+           2.742e-08   2.520e-08    -7.562    -7.599    -0.037      (0)
Mn(2)         7.283e-07
   Mn+2            6.331e-07   4.250e-07    -6.199    -6.372    -0.173      (0)
   MnSO4           9.164e-08   9.164e-08    -7.038    -7.038     0.000      (0)
   MnHCO3+         2.944e-09   2.697e-09    -8.531    -8.569    -0.038      (0)
   MnOH+           3.710e-10   3.399e-10    -9.431    -9.469    -0.038      (0)
   MnF+            2.582e-10   2.366e-10    -9.588    -9.626    -0.038      (0)
   Mn(OH)3-        2.324e-19   2.129e-19   -18.634   -18.672    -0.038      (0)
   Mn(OH)4-2       3.106e-25   2.189e-25   -24.508   -24.660    -0.152      (0)
Mn(3)         4.241e-28
   Mn+3            4.241e-28   1.898e-28   -27.373   -27.722    -0.349      (0)
Mn(6)         0.000e+00
   MnO4-2          0.000e+00   0.000e+00   -48.642   -48.794    -0.152      (0)
Mn(7)         0.000e+00
   MnO4-           0.000e+00   0.000e+00   -54.126   -54.166    -0.040      (0)
Mo            3.128e-08
   MoO4-2          3.126e-08   2.187e-08    -7.505    -7.660    -0.155      (0)
   HMoO4-          1.520e-11   1.376e-11   -10.818   -10.861    -0.043      (0)
   H2MoO4          3.188e-15   3.188e-15   -14.497   -14.497     0.000      (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -49.070   -49.460    -0.390      (0)
   Mo7O24-6        0.000e+00   0.000e+00   -59.073   -60.631    -1.558      (0)
   HMo7O24-5       0.000e+00   0.000e+00   -60.662   -61.744    -1.082      (0)
   H2Mo7O24-4      0.000e+00   0.000e+00   -63.769   -64.462    -0.692      (0)
   H3Mo7O24-3      0.000e+00   0.000e+00   -68.326   -68.716    -0.390      (0)
Na            4.351e-05
   Na+             4.322e-05   3.953e-05    -4.364    -4.403    -0.039      (0)
   NaSO4           2.807e-07   2.574e-07    -6.552    -6.589    -0.038      (0)
   NaHCO3          7.071e-09   7.071e-09    -8.151    -8.151     0.000      (0)
   NaCO3-          3.785e-10   3.471e-10    -9.422    -9.460    -0.038      (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000      (0)
Ni            6.818e-08
   Ni+2            5.610e-08   3.924e-08    -7.251    -7.406    -0.155      (0)
   NiSO4           9.495e-09   9.495e-09    -8.023    -8.023     0.000      (0)
   NiHCO3+         1.700e-09   1.539e-09    -8.770    -8.813    -0.043      (0)
   NiCO3           6.904e-10   6.904e-10    -9.161    -9.161     0.000      (0)
   NiOH+           1.738e-10   1.573e-10    -9.760    -9.803    -0.043      (0)
   NiF+            1.523e-11   1.379e-11   -10.817   -10.861    -0.043      (0)
   Ni(OH)2         3.978e-12   3.978e-12   -11.400   -11.400     0.000      (0)
   Ni(SO4)2-2      5.679e-13   3.812e-13   -12.246   -12.419    -0.173      (0)
   Ni(OH)3-        1.399e-15   1.267e-15   -14.854   -14.897    -0.043      (0)
O(0)          2.019e-40
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   O2              1.010e-40   1.011e-40   -39.996   -39.995     0.001     (0)
S(6)          2.051e-03
   SO4-2           1.733e-03   1.213e-03    -2.761    -2.916    -0.155     (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000     (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000     (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038     (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   MnSO4           9.164e-08   9.164e-08    -7.038    -7.038     0.000     (0)
   CuSO4           2.134e-08   2.134e-08    -7.671    -7.671     0.000     (0)
   CoSO4           1.620e-08   1.620e-08    -7.791    -7.791     0.000     (0)
   NiSO4           9.495e-09   9.495e-09    -8.023    -8.023     0.000     (0)
   HSO4-           4.094e-09   3.747e-09    -8.388    -8.426    -0.038     (0)
   Ni(SO4)2-2      5.679e-13   3.812e-13   -12.246   -12.419    -0.173     (0)
   AlSO4+          3.315e-13   3.034e-13   -12.480   -12.518    -0.038     (0)
   Al(SO4)2-       4.307e-15   3.942e-15   -14.366   -14.404    -0.038     (0)

----------------------------Saturation indices----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.79      9.01   10.80  Al(OH)3
  Al2(MoO4)3      -52.33    -49.96    2.37  Al2(MoO4)3
  Al2O3            -1.64     18.02   19.65  Al2O3
  Al4(OH)10SO4     -4.58     18.12   22.70  Al4(OH)10SO4
  AlOHSO4          -5.68     -8.91   -3.23  AlOHSO4
  Alunite          -3.43     -4.83   -1.40  KAl3(SO4)2(OH)6
  Anhydrite        -1.57     -5.93   -4.36  CaSO4
  Antlerite        -3.05      5.74    8.79  Cu3(OH)4SO4
  Aragonite        -1.04     -9.34   -8.30  CaCO3
  Artinite         -8.33      1.27    9.60  MgCO3:Mg(OH)2:3H2O
  Azurite          -2.09    -19.00  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -16.39      8.01   24.39  Ba(OH)2:8H2O
  BaF2            -10.88    -16.70   -5.82  BaF2
  BaMoO4           -7.69    -14.65   -6.96  BaMoO4
  Barite            0.07     -9.91   -9.98  BaSO4
  Birnessite      -11.81      6.28   18.09  MnO2
  Bixbyite         -9.80    -10.44   -0.64  Mn2O3
  Boehmite          0.43      9.01    8.58  AlOOH
  Brochantite      -1.60     13.63   15.22  Cu4(OH)6SO4
  Brucite          -5.55     11.30   16.84  Mg(OH)2
  Bunsenite        -4.85      7.59   12.45  NiO
  Calcite          -0.86     -9.34   -8.48  CaCO3
  CaMoO4           -2.72    -10.67   -7.95  CaMoO4
  CH4(g)          -72.28   -113.33  -41.05  CH4
  Chalcanthite     -7.39    -10.03   -2.64  CuSO4:5H2O
  Co(OH)2          -5.27      7.83   13.09  Co(OH)2
  Co(OH)3         -10.77    -13.07   -2.31  Co(OH)3
  CO2(g)           -3.18    -21.33  -18.15  CO2
  Co3O4            -7.83    -18.32  -10.50  Co3O4
  CoCO3            -3.52    -13.50   -9.98  CoCO3
  CoF2            -15.29    -16.88   -1.60  CoF2
  CoF3            -48.68    -50.14   -1.46  CoF3
  CoMoO4           -7.07    -14.83   -7.76  CoMoO4
  CoO              -5.76      7.83   13.59  CoO
  CoSO4           -12.89    -10.09    2.80  CoSO4
  CoSO4:6H2O       -7.62    -10.09   -2.47  CoSO4:6H2O
  Cryolite        -21.99    -55.83  -33.84  Na3AlF6
  Cu(OH)2          -0.79      7.89    8.67  Cu(OH)2
  Cu2SO4          -17.82    -19.77   -1.95  Cu2SO4
  CuCO3            -1.94    -13.44  -11.50  CuCO3
  CuF              -8.37    -13.28   -4.91  CuF
  CuF2            -17.94    -16.82    1.12  CuF2
  CuF2:2H2O       -12.27    -16.82   -4.55  CuF2:2H2O
  Cumetal          -3.67    -12.42   -8.76  Cu
  CuMoO4           -1.70    -14.77  -13.08  CuMoO4
  CuOCuSO4        -12.45     -2.15   10.30  CuOCuSO4
  Cuprite          -0.44     -1.85   -1.41  Cu2O
  CuSO4           -12.97    -10.03    2.94  CuSO4
  Diaspore          2.14      9.01    6.87  AlOOH
  Dolomite(disordered)  -2.83    -19.37  -16.54  CaMg(CO3)2
  Dolomite(ordered)  -2.28    -19.37  -17.09  CaMg(CO3)2
  Epsomite         -4.49     -6.62   -2.13  MgSO4:7H2O
  Fluorite         -2.22    -12.72  -10.50  CaF2
  Gibbsite          0.72      9.01    8.29  Al(OH)3
  Gypsum           -1.32     -5.93   -4.61  CaSO4:2H2O
  H2MoO4           -9.78    -22.66  -12.88  H2MoO4
  Hausmannite     -12.15     48.88   61.03  Mn3O4
  Huntite          -9.45    -39.42  -29.97  CaMg3(CO3)4
  Hydromagnesite  -20.05    -28.81   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum          -17.68    -22.85   -5.17  KAl(SO4)2:12H2O
  K2MoO4          -17.96    -14.70    3.26  K2MoO4
  Langite          -3.86     13.63   17.49  Cu4(OH)6SO4:H2O
  Lime            -20.71     11.99   32.70  CaO
  Magnesite        -2.57    -10.03   -7.46  MgCO3
  Malachite        -0.25     -5.56   -5.31  Cu2(OH)2CO3
  Manganite        -5.21     20.13   25.34  MnOOH
  Mg(OH)2(active)  -7.50     11.30   18.79  Mg(OH)2
  MgF2             -5.28    -13.41   -8.13  MgF2
  MgMoO4           -9.51    -11.36   -1.85  MgMoO4
  Mirabilite      -10.61    -11.72   -1.11  Na2SO4:10H2O
  Mn2(SO4)3       -58.48    -64.19   -5.71  Mn2(SO4)3
  MnSO4           -11.87     -9.29    2.58  MnSO4
  MoO3            -14.66    -22.66   -8.00  MoO3
  Morenosite       -8.18    -10.32   -2.14  NiSO4:7H2O
  Na2Mo2O7        -22.53    -39.13  -16.60  Na2Mo2O7
  Na2MoO4         -17.96    -16.47    1.49  Na2MoO4
  Na2MoO4:2H2O    -17.69    -16.47    1.22  Na2MoO4:2H2O
  Natron          -13.82    -15.13   -1.31  Na2CO3:10H2O
  Nesquehonite     -5.36    -10.03   -4.67  MgCO3:3H2O
  Ni(OH)2          -5.20      7.59   12.79  Ni(OH)2
  Ni4(OH)6SO4     -19.54     12.46   32.00  Ni4(OH)6SO4
  NiCO3            -6.86    -13.73   -6.87  NiCO3
  NiMoO4           -3.92    -15.07  -11.14  NiMoO4
  Nsutite         -11.23      6.28   17.50  MnO2
  O2(g)           -37.09     46.00   83.09  O2
  Periclase       -10.29     11.30   21.58  MgO
  Portlandite     -10.81     11.99   22.80  Ca(OH)2
  Pyrochroite      -6.57      8.63   15.19  Mn(OH)2
  Pyrolusite       -9.75     31.63   41.38  MnO2
  Retgersite       -8.28    -10.32   -2.04  NiSO4:6H2O
  Rhodochrosite    -2.12    -12.70  -10.58  MnCO3
  Spinel           -7.53     29.31   36.85  MgAl2O4
  Tenorite          0.24      7.89    7.64  CuO
  Thenardite      -12.04    -11.72    0.32  Na2SO4
  Thermonatrite   -15.77    -15.13    0.64  Na2CO3:H2O
  Witherite        -4.75    -13.32   -8.57  BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 3.     NAF Material

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                5.191e-06   5.191e-06
      Alkalinity        4.591e-04   4.591e-04
      As                3.873e-07   3.873e-07
      Ba                1.457e-07   1.457e-07
      Ca                3.046e-03   3.046e-03
      Co                3.395e-08   3.395e-08
      Cu                2.992e-07   2.992e-07
      F                 1.580e-05   1.580e-05
      Fe                1.254e-06   1.254e-06
      K                 4.094e-04   4.094e-04
      Mg                7.410e-04   7.410e-04
      Mn                2.368e-06   2.368e-06
      Mo                5.214e-08   5.214e-08
      Na                4.352e-05   4.352e-05
      Ni                1.705e-08   1.705e-08
      S(6)              3.447e-03   3.447e-03
      U                 4.203e-09   4.203e-09

----------------------------Description of solution----------------------------

                                       pH  =   7.600
                                       pe  =   4.000
                              Activity of water  =   1.000
                       Ionic strength (mol/kgw)  =   1.193e-02
                            Mass of water (kg)  =   1.000e+00
                         Total carbon (mol/kg)  =   4.552e-04
                            Total CO2 (mol/kg)  =   4.552e-04
                              Temperature (°C)  =  25.00
                       Electrical balance (eq)  =   6.787e-04
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =   5.48
                                  Iterations  =  11 (35 overall)
                                     Total H  = 1.110142e+02
                                     Total O  = 5.552201e+01

----------------------------Distribution of species----------------------------

                                                  Log       Log       Log    mole V
   Species           Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-              4.492e-07   4.008e-07    -6.348    -6.397    -0.049     (0)
   H+               2.808e-08   2.512e-08    -7.552    -7.600    -0.048      0.00
   H2O              5.551e+01   1.999e-01     1.744    -0.000     0.000     18.07
Al            5.191e-06
   Al(OH)4-         5.088e-06   4.556e-06    -5.293    -5.341    -0.048     (0)
   Al(OH)3          9.030e-08   9.030e-08    -7.044    -7.044     0.000     (0)
   Al(OH)2+         1.257e-08   1.129e-08    -7.901    -7.947    -0.047     (0)
   AlF2+            6.958e-11   6.249e-11   -10.158   -10.204    -0.047     (0)
   AlOH+            5.451e-11   3.546e-11   -10.264   -10.450    -0.187     (0)
   AlF+2            1.811e-11   1.178e-11   -10.742   -10.929    -0.187     (0)
   AlF3             1.048e-11   1.048e-11   -10.980   -10.980     0.000     (0)
   AlSO4+           1.328e-12   1.189e-12   -11.877   -11.925    -0.048     (0)
   Al+3             2.412e-13   8.848e-14   -12.618   -13.053    -0.436     (0)
   AlF4-            7.812e-14   6.995e-14   -13.107   -13.155    -0.048     (0)
   Al(SO4)2-        2.463e-14   2.206e-14   -13.608   -13.656    -0.048     (0)
   AlMo6O21-3       0.000e+00   0.000e+00   -48.018   -48.520    -0.501     (0)
As(3)         1.024e-17
   H3AsO3           1.000e-17   1.000e-17   -17.000   -17.000     0.000     (0)
   H2AsO3-          2.322e-19   2.043e-19   -18.634   -18.690    -0.056     (0)
   HAsO3-2          1.239e-23   7.417e-24   -22.907   -23.130    -0.223     (0)
   H4AsO3+          1.416e-25   1.245e-25   -24.849   -24.905    -0.056     (0)
   AsO3-3           3.611e-29   1.138e-29   -28.442   -28.944    -0.501     (0)
As(5)         3.873e-07
   HAsO4-2          3.350e-07   2.005e-07    -6.475    -6.698    -0.223     (0)
   H2AsO4-          5.222e-08   4.594e-08    -7.282    -7.338    -0.056     (0)
   AsO4-3           8.009e-11   2.524e-11   -10.096   -10.598    -0.501     (0)
   H3AsO4           2.000e-13   2.005e-13   -12.699   -12.698     0.001     (0)
Ba            1.457e-07
   Ba+2             1.453e-07   9.304e-08    -6.838    -7.031    -0.194     (0)
   BaHCO3+          3.699e-10   3.328e-10    -9.432    -9.478    -0.046     (0)
   BaCO3            3.336e-11   3.336e-11   -10.477   -10.477     0.000     (0)
   BaOH+            1.815e-13   1.628e-13   -12.741   -12.788    -0.047     (0)
C(4)          4.552e-04
   HCO3-            4.171e-04   3.746e-04    -3.380    -3.426    -0.047     (0)
   H2CO3            2.116e-05   2.116e-05    -4.674    -4.674     0.000     (0)
   CaHCO3+          1.200e-05   1.080e-05    -4.921    -4.967    -0.046     (0)
   CaCO3            1.715e-06   1.715e-06    -5.766    -5.766     0.000     (0)
   MgHCO3+          1.687e-06   1.508e-06    -5.773    -5.822    -0.049     (0)
   CO3-2            1.092e-06   6.991e-07    -5.962    -6.155    -0.194     (0)
   MgCO3            2.288e-07   2.288e-07    -6.641    -6.641     0.000     (0)
   CuCO3            1.600e-07   1.600e-07    -6.796    -6.796     0.000     (0)
   MnHCO3+          9.921e-09   8.899e-09    -8.003    -8.051    -0.047     (0)
   NaHCO3           8.124e-09   8.124e-09    -8.090    -8.090     0.000     (0)
   UO2(CO3)2-2      3.482e-09   2.084e-09    -8.458    -8.681    -0.223     (0)
   CuHCO3+          1.044e-09   9.187e-10    -8.981    -9.037    -0.056     (0)
   UO2(CO3)3-4      5.687e-10   7.303e-11    -9.245   -10.136    -0.891     (0)
   NaCO3-           5.590e-10   5.020e-10    -9.253    -9.299    -0.047     (0)
   CoHCO3+          5.432e-10   4.778e-10    -9.265    -9.321    -0.056     (0)
   Cu(CO3)2-2       5.030e-10   3.011e-10    -9.298    -9.521    -0.223     (0)
   NiHCO3+          4.493e-10   3.952e-10    -9.347    -9.403    -0.056     (0)
   BaHCO3+          3.699e-10   3.328e-10    -9.432    -9.478    -0.046     (0)
   NiCO3            2.232e-10   2.232e-10    -9.651    -9.651     0.000     (0)
   CoCO3            1.938e-10   1.938e-10    -9.713    -9.713     0.000     (0)
   UO2CO3           1.494e-10   1.494e-10    -9.826    -9.826     0.000     (0)
   FeHCO3+          1.083e-10   9.748e-11    -9.965   -10.011    -0.046     (0)
   BaCO3            3.336e-11   3.336e-11   -10.477   -10.477     0.000     (0)
Ca            3.046e-03
   Ca+2             2.418e-03   1.548e-03    -2.617    -2.810    -0.194     (0)
   CaSO4            6.140e-04   6.140e-04    -3.212    -3.212     0.000     (0)
   CaHCO3+          1.200e-05   1.080e-05    -4.921    -4.967    -0.046     (0)
   CaCO3            1.715e-06   1.715e-06    -5.766    -5.766     0.000     (0)
   CaF+             2.509e-07   2.251e-07    -6.600    -6.648    -0.047     (0)
   CaOH+            1.376e-08   1.238e-08    -7.861    -7.907    -0.046     (0)
Co(2)         3.395e-08
   Co+2             2.739e-08   1.640e-08    -7.562    -7.785    -0.223     (0)
   CoSO4            5.664e-09   5.664e-09    -8.247    -8.247     0.000     (0)
   CoHCO3+          5.432e-10   4.778e-10    -9.265    -9.321    -0.056     (0)
   CoCO3            1.938e-10   1.938e-10    -9.713    -9.713     0.000     (0)
   CoOH+            1.491e-10   1.311e-10    -9.827    -9.882    -0.056     (0)
   CoF+             7.852e-12   6.907e-12   -11.105   -11.161    -0.056     (0)
   Co(OH)2          4.175e-12   4.175e-12   -11.379   -11.379     0.000     (0)
   Co(OH)3-         3.796e-17   3.339e-17   -16.421   -16.476    -0.056     (0)
   CoOOH-           9.525e-18   8.379e-18   -17.021   -17.077    -0.056     (0)
   Co2OH+3          3.419e-19   1.078e-19   -18.466   -18.968    -0.501     (0)
   Co(OH)4-2        3.543e-24   2.121e-24   -23.451   -23.673    -0.223     (0)
   Co4(OH)4+4       4.595e-31   5.900e-32   -30.338   -31.229    -0.891     (0)
Co(3)         2.221e-30
   CoOH+2           2.221e-30   1.330e-30   -29.653   -29.876    -0.223     (0)
   Co+3             1.780e-36   6.528e-37   -35.750   -36.185    -0.436     (0)
Cu(1)         2.164e-09
   Cu+              2.164e-09   1.904e-09    -8.665    -8.720    -0.056     (0)
Cu(2)         2.970e-07
   CuCO3            1.600e-07   1.600e-07    -6.796    -6.796     0.000     (0)
   Cu+2             6.070e-08   3.887e-08    -7.217    -7.410    -0.194     (0)
   CuOH+            5.512e-08   4.927e-08    -7.259    -7.307    -0.049     (0)
   CuSO4            1.542e-08   1.542e-08    -7.812    -7.812     0.000     (0)
   Cu(OH)2          3.940e-09   3.940e-09    -8.404    -8.404     0.000     (0)
   CuHCO3+          1.044e-09   9.187e-10    -8.981    -9.037    -0.056     (0)
   Cu(CO3)2-2       5.030e-10   3.011e-10    -9.298    -9.521    -0.223     (0)
   Cu2(OH)2+2       1.019e-10   6.097e-11    -9.992   -10.215    -0.223     (0)
   CuF+             3.714e-11   3.267e-11   -10.430   -10.486    -0.056     (0)
   Cu(OH)3-         3.683e-12   3.239e-12   -11.434   -11.490    -0.056     (0)
   Cu(OH)4-2        1.707e-17   1.022e-17   -16.768   -16.991    -0.223     (0)
F             1.580e-05
   F-               1.489e-05   1.332e-05    -4.827    -4.876    -0.048     (0)
   MgF+             6.566e-07   5.879e-07    -6.183    -6.231    -0.048     (0)
   CaF+             2.509e-07   2.251e-07    -6.600    -6.648    -0.047     (0)
   MnF+             7.039e-10   6.314e-10    -9.152    -9.200    -0.047     (0)
   HF               4.949e-10   4.949e-10    -9.306    -9.306     0.000     (0)
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   NaF             3.241e-10   3.241e-10    -9.489    -9.489     0.000     (0)
   AlF2+           6.958e-11   6.249e-11   -10.158   -10.204    -0.047     (0)
   CuF+            3.714e-11   3.267e-11   -10.430   -10.486    -0.056     (0)
   AlF+2           1.811e-11   1.178e-11   -10.742   -10.929    -0.187     (0)
   AlF3            1.048e-11   1.048e-11   -10.980   -10.980     0.000     (0)
   CoF+            7.852e-12   6.907e-12   -11.105   -11.161    -0.056     (0)
   NiF+            3.255e-12   2.863e-12   -11.487   -11.543    -0.056     (0)
   UO2F+           1.122e-13   9.871e-14   -12.950   -13.006    -0.056     (0)
   AlF4-           7.812e-14   6.995e-14   -13.107   -13.155    -0.048     (0)
   HF2-            2.808e-14   2.506e-14   -13.552   -13.601    -0.049     (0)
   UO2F2           3.792e-15   3.792e-15   -14.421   -14.421     0.000     (0)
   FeF+2           4.333e-16   2.804e-16   -15.363   -15.552    -0.189     (0)
   FeF2+           1.114e-16   9.996e-17   -15.953   -16.000    -0.047     (0)
   UO2F3-          1.442e-17   1.269e-17   -16.841   -16.897    -0.056     (0)
   FeF3            1.879e-18   1.879e-18   -17.726   -17.726     0.000     (0)
   H2F2            6.561e-19   6.561e-19   -18.183   -18.183     0.000     (0)
   UO2F4-2         2.242e-21   1.342e-21   -20.649   -20.872    -0.223     (0)
   UF3+            3.760e-36   3.307e-36   -35.425   -35.481    -0.056     (0)
   UF2+2           2.617e-36   1.567e-36   -35.582   -35.805    -0.223     (0)
   UF+3            2.964e-38   9.342e-39   -37.528   -38.030    -0.501     (0)
   UF4             4.830e-39   4.830e-39   -38.316   -38.316     0.000     (0)
   UF5-            0.000e+00   0.000e+00   -41.538   -41.594    -0.056     (0)
   UF6-2           0.000e+00   0.000e+00   -43.766   -43.989    -0.223     (0)
Fe(2)          4.379e-08
   Fe+2            3.453e-08   2.067e-08    -7.462    -7.685    -0.223     (0)
   FeSO4           8.785e-09   8.785e-09    -8.056    -8.056     0.000     (0)
   FeOH+           3.677e-10   3.298e-10    -9.434    -9.482    -0.047     (0)
   FeHCO3+         1.083e-10   9.748e-11    -9.965   -10.011    -0.046     (0)
   Fe(OH)2         1.050e-13   1.050e-13   -12.979   -12.979     0.000     (0)
   Fe(OH)3-        1.484e-14   1.331e-14   -13.829   -13.876    -0.047     (0)
Fe(3)          1.210e-06
   Fe(OH)2+        8.628e-07   7.749e-07    -6.064    -6.111    -0.047     (0)
   Fe(OH)3         3.336e-07   3.336e-07    -6.477    -6.477     0.000     (0)
   Fe(OH)4-        1.386e-08   1.245e-08    -7.858    -7.905    -0.047     (0)
   FeOH+2          7.678e-12   4.969e-12   -11.115   -11.304    -0.189     (0)
   FeF+2           4.333e-16   2.804e-16   -15.363   -15.552    -0.189     (0)
   FeSO4+          4.159e-16   3.730e-16   -15.381   -15.428    -0.047     (0)
   FeF2+           1.114e-16   9.996e-17   -15.953   -16.000    -0.047     (0)
   Fe+3            5.236e-17   1.920e-17   -16.281   -16.717    -0.436     (0)
   Fe(SO4)2-       1.570e-17   1.381e-17   -16.804   -16.860    -0.056     (0)
   FeF3            1.879e-18   1.879e-18   -17.726   -17.726     0.000     (0)
   Fe2(OH)2+4      6.368e-21   8.178e-22   -20.196   -21.087    -0.891     (0)
   Fe3(OH)4+5      2.263e-25   9.160e-27   -24.645   -26.038    -1.393     (0)
H(0)           8.909e-27
   H2              4.455e-27   4.467e-27   -26.351   -26.350     0.001     (0)
K              4.094e-04
   K+              4.045e-04   3.618e-04    -3.393    -3.441    -0.048     (0)
   KSO4-           4.938e-06   4.435e-06    -5.306    -5.353    -0.047     (0)
Mg             7.410e-04
   Mg+2            6.144e-04   3.934e-04    -3.212    -3.405    -0.194     (0)
   MgSO4           1.239e-04   1.239e-04    -3.907    -3.907     0.000     (0)
   MgHCO3+         1.687e-06   1.508e-06    -5.773    -5.822    -0.049     (0)
   MgF+            6.566e-07   5.879e-07    -6.183    -6.231    -0.048     (0)
   MgCO3           2.288e-07   2.288e-07    -6.641    -6.641     0.000     (0)
   MgOH+           6.966e-08   6.278e-08    -7.157    -7.202    -0.045     (0)
Mn(2)          2.368e-06
   Mn+2            1.989e-06   1.191e-06    -5.701    -5.924    -0.223     (0)
   MnSO4           3.666e-07   3.666e-07    -6.436    -6.436     0.000     (0)
   MnHCO3+         9.921e-09   8.899e-09    -8.003    -8.051    -0.047     (0)
   MnOH+           1.337e-09   1.199e-09    -8.874    -8.921    -0.047     (0)
   MnF+            7.039e-10   6.314e-10    -9.152    -9.200    -0.047     (0)
   Mn(OH)3-        1.327e-18   1.190e-18   -17.877   -17.924    -0.047     (0)
   Mn(OH)4-2       2.380e-24   1.540e-24   -23.623   -23.812    -0.189     (0)
Mn(3)          1.450e-27
   Mn+3            1.450e-27   5.318e-28   -26.839   -27.274    -0.436     (0)
Mn(6)          0.000e+00
   MnO4-2          0.000e+00   0.000e+00   -47.357   -47.546    -0.189     (0)
Mn(7)          0.000e+00
   MnO4-           0.000e+00   0.000e+00   -52.868   -52.918    -0.050     (0)
Mo             5.214e-08
   MoO4-2          5.212e-08   3.338e-08    -7.283    -7.477    -0.194     (0)
   HMoO4-          1.896e-11   1.668e-11   -10.722   -10.778    -0.056     (0)
   H2MoO4          3.069e-15   3.069e-15   -14.513   -14.513     0.000     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -48.018   -48.520    -0.501     (0)
   Mo7O24-6        0.000e+00   0.000e+00   -58.140   -60.146    -2.006     (0)
   HMo7O24-5       0.000e+00   0.000e+00   -59.966   -61.359    -1.393     (0)
   H2Mo7O24-4      0.000e+00   0.000e+00   -63.285   -64.177    -0.891     (0)
   H3Mo7O24-3      0.000e+00   0.000e+00   -68.029   -68.531    -0.501     (0)
Na             4.352e-05
   Na+             4.311e-05   3.857e-05    -4.365    -4.414    -0.048     (0)
   NaSO4           3.992e-07   3.586e-07    -6.399    -6.445    -0.047     (0)
   NaHCO3          8.124e-09   8.124e-09    -8.090    -8.090     0.000     (0)
   NaCO3-          5.590e-10   5.020e-10    -9.253    -9.299    -0.047     (0)
   NaF             3.241e-10   3.241e-10    -9.489    -9.489     0.000     (0)
Ni             1.705e-08
   Ni+2            1.336e-08   8.558e-09    -7.874    -8.068    -0.194     (0)
   NiSO4           2.956e-09   2.956e-09    -8.529    -8.529     0.000     (0)
   NiHCO3+         4.493e-10   3.952e-10    -9.347    -9.403    -0.056     (0)
   NiCO3           2.232e-10   2.232e-10    -9.651    -9.651     0.000     (0)
   NiOH+           4.909e-11   4.318e-11   -10.309   -10.365    -0.056     (0)
   NiF+            3.255e-12   2.863e-12   -11.487   -11.543    -0.056     (0)
   Ni(OH)2         1.375e-12   1.375e-12   -11.862   -11.862     0.000     (0)
   Ni(SO4)2-2      2.831e-13   1.695e-13   -12.548   -12.771    -0.223     (0)
   Ni(OH)3-        6.265e-16   5.511e-16   -15.203   -15.259    -0.056     (0)
O(0)           5.066e-40
   O2              2.533e-40   2.540e-40   -39.596   -39.595     0.001     (0)
S(6)           3.447e-03
   SO4-2           2.704e-03   1.731e-03    -2.568    -2.762    -0.194     (0)
   CaSO4           6.140e-04   6.140e-04    -3.212    -3.212     0.000     (0)
   MgSO4           1.239e-04   1.239e-04    -3.907    -3.907     0.000     (0)
   KSO4-           4.938e-06   4.435e-06    -5.306    -5.353    -0.047     (0)
   NaSO4-          3.992e-07   3.586e-07    -6.399    -6.445    -0.047     (0)
   MnSO4           3.666e-07   3.666e-07    -6.436    -6.436     0.000     (0)
   CuSO4           1.542e-08   1.542e-08    -7.812    -7.812     0.000     (0)
   FeSO4           8.785e-09   8.785e-09    -8.056    -8.056     0.000     (0)
   CoSO4           5.664e-09   5.664e-09    -8.247    -8.247     0.000     (0)
   HSO4-           4.746e-09   4.250e-09    -8.324    -8.372    -0.048     (0)
   NiSO4           2.956e-09   2.956e-09    -8.529    -8.529     0.000     (0)
   AlSO4+          1.328e-12   1.189e-12   -11.877   -11.925    -0.048     (0)
   Ni(SO4)2-2      2.831e-13   1.695e-13   -12.548   -12.771    -0.223     (0)
   UO2SO4          1.407e-13   1.407e-13   -12.852   -12.852     0.000     (0)
   Al(SO4)2-       2.463e-14   2.206e-14   -13.608   -13.656    -0.048     (0)
   UO2(SO4)2-2     5.363e-15   3.210e-15   -14.271   -14.493    -0.223     (0)
   FeSO4+          4.159e-16   3.730e-16   -15.381   -15.428    -0.047     (0)
   Fe(SO4)2-       1.570e-17   1.381e-17   -16.804   -16.860    -0.056     (0)
   U(SO4)2         3.332e-38   3.332e-38   -37.477   -37.477     0.000     (0)
   USO4+2          4.047e-39   2.423e-39   -38.393   -38.616    -0.223     (0)
U(3)           0.000e+00
   U+3             0.000e+00   0.000e+00   -54.749   -55.250    -0.501     (0)
U(4)           3.033e-18
   U(OH)5-         3.030e-18   2.665e-18   -17.519   -17.574    -0.056     (0)
   U(OH)4          2.804e-21   2.804e-21   -20.552   -20.552     0.000     (0)
   U(OH)3+         2.928e-25   2.575e-25   -24.533   -24.589    -0.056     (0)
   U(OH)2+2        4.997e-30   2.991e-30   -29.301   -29.524    -0.223     (0)
   UOH+3           1.123e-35   3.539e-36   -34.950   -35.451    -0.501     (0)
   UF3+            3.760e-36   3.307e-36   -35.425   -35.481    -0.056     (0)
   UF2+2           2.617e-36   1.567e-36   -35.582   -35.805    -0.223     (0)
   U(SO4)2         3.332e-38   3.332e-38   -37.477   -37.477     0.000     (0)
   UF+3            2.964e-38   9.342e-39   -37.528   -38.030    -0.501     (0)
   UF4             4.830e-39   4.830e-39   -38.316   -38.316     0.000     (0)
   USO4+2          4.047e-39   2.423e-39   -38.393   -38.616    -0.223     (0)
   UF5-            0.000e+00   0.000e+00   -41.538   -41.594    -0.056     (0)
   U+4             0.000e+00   0.000e+00   -41.563   -42.454    -0.891     (0)
   UF6-2           0.000e+00   0.000e+00   -43.766   -43.989    -0.223     (0)
   U6(OH)15+9      0.000e+00   0.000e+00  -153.367  -157.880    -4.513     (0)
U(5)           3.720e-15
   UO2+            3.720e-15   3.272e-15   -14.429   -14.485    -0.056     (0)
U(6)           4.203e-09
   UO2(CO3)2-2     3.482e-09   2.084e-09    -8.458    -8.681    -0.223     (0)
   UO2(CO3)3-4     5.687e-10   7.303e-11    -9.245   -10.136    -0.891     (0)
   UO2CO3          1.494e-10   1.494e-10    -9.826    -9.826     0.000     (0)
   UO2OH+          3.080e-12   2.709e-12   -11.511   -11.567    -0.056     (0)
   UO2SO4          1.407e-13   1.407e-13   -12.852   -12.852     0.000     (0)
   UO2F+           1.122e-13   9.871e-14   -12.950   -13.006    -0.056     (0)
   UO2+2           8.384e-14   5.369e-14   -13.077   -13.270    -0.194     (0)
   UO2(SO4)2-2     5.363e-15   3.210e-15   -14.271   -14.493    -0.223     (0)
   UO2F2           3.792e-15   3.792e-15   -14.421   -14.421     0.000     (0)
   (UO2)2(OH)2+2   2.034e-17   1.218e-17   -16.692   -16.914    -0.223     (0)
   UO2F3-          1.442e-17   1.269e-17   -16.841   -16.897    -0.056     (0)
   (UO2)3(OH)5+    4.571e-18   4.021e-18   -17.340   -17.396    -0.056     (0)
   UO2F4-2         2.242e-21   1.342e-21   -20.649   -20.872    -0.223     (0)

-----------------------------Saturation indices-----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.05      9.75   10.80  Al(OH)3
  Al2(MoO4)3      -50.90    -48.54    2.37  Al2(MoO4)3
  Al2O3            -0.16     19.49   19.65  Al2O3
  Al4(OH)10SO4     -1.67     21.03   22.70  Al4(OH)10SO4
  AlAsO4:2H2O      -7.75     -2.95    4.80  AlAsO4:2H2O
  AlOHSO4          -4.98     -8.21   -3.23  AlOHSO4
  Alunite          -1.12     -2.52   -1.40  KAl3(SO4)2(OH)6
  Anhydrite        -1.21     -5.57   -4.36  CaSO4
  Antlerite        -3.38      5.41    8.79  Cu3(OH)4SO4
  Aragonite        -0.67     -8.97   -8.30  CaCO3
  Arsenolite      -65.24    -68.00   -2.76  As4O6
  Artinite         -7.37      2.23    9.60  MgCO3:Mg(OH)2:3H2O
  As2O5           -32.10    -25.40    6.71  As2O5
  Azurite          -2.44    -19.34  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -16.23      8.17   24.39  Ba(OH)2:8H2O
  Ba3(AsO4)2        8.02     -0.89   -8.91  Ba3(AsO4)2
  BaF2             -10.96    -16.78   -5.82  BaF2
  BaMoO4           -7.55     -14.51   -6.96  BaMoO4
  Barite            0.19      -9.79   -9.98  BaSO4
  Birnessite       -10.97      7.13   18.09  MnO2
  Bixbyite         -8.30      -8.95   -0.64  Mn2O3
  Boehmite          1.17       9.75    8.58  AlOOH
  Brochantite      -2.03      13.20   15.22  Cu4(OH)6SO4
  Brucite          -5.05      11.79   16.84  Mg(OH)2
  Bunsenite        -5.31       7.13   12.45  NiO
  Ca3(AsO4)2:4H2O -10.53      11.77   22.30  Ca3(AsO4)2:4H2O
  Calcite          -0.49      -8.97   -8.48  CaCO3
  CaMoO4           -2.34     -10.29   -7.95  CaMoO4
  CH4(g)          -73.11    -114.16  -41.05  CH4
  Chalcanthite     -7.53     -10.17   -2.64  CuSO4:5H2O
  Claudetite      -64.93     -68.00   -3.06  As4O6
  Co(OH)2          -5.68       7.41   13.09  Co(OH)2
  Co(OH)3         -11.08     -13.39   -2.31  Co(OH)3
  CO2(g)           -3.21     -21.36  -18.15  CO2
  Co3(AsO4)2      -16.19      -3.15   13.03  Co3(AsO4)2
  Co3O4            -8.86     -19.36  -10.50  Co3O4
  CoCO3            -3.96     -13.94   -9.98  CoCO3
  CoF2            -15.94     -17.54   -1.60  CoF2
  CoF3            -49.35     -50.81   -1.46  CoF3
  CoFe2O4          23.11      19.58   -3.53  CoFe2O4
  CoMoO4           -7.50     -15.26   -7.76  CoMoO4
  CoO              -6.17       7.41   13.59  CoO
  CoSO4           -13.35     -10.55    2.80  CoSO4
  CoSO4:6H2O       -8.07     -10.55   -2.47  CoSO4:6H2O
  Cryolite        -21.71     -55.55  -33.84  Na3AlF6
  Cu(OH)2          -0.88       7.79    8.67  Cu(OH)2
  Cu2SO4          -18.25     -20.20   -1.95  Cu2SO4
  Cu3(AsO4)2:2H2O  -8.13      -2.03    6.10  Cu3(AsO4)2:2H2O
  CuCO3            -2.07     -13.57  -11.50  CuCO3
  CuF              -8.69     -13.60   -4.91  CuF
  CuF2            -18.28     -17.16    1.12  CuF2
  CuF2:2H2O       -12.61     -17.16   -4.55  CuF2:2H2O
  Cumetal          -3.96     -12.72   -8.76  Cu
  CuMoO4           -1.81     -14.89  -13.08  CuMoO4
  CuOCuSO4        -12.69      -2.38   10.30  CuOCuSO4
  Cupricferrite    13.97      19.96    5.99  CuFe2O4
  Cuprite          -0.83      -2.24   -1.41  Cu2O
  Cuprousferrite   13.88       4.96   -8.92  CuFeO2
  CuSO4           -13.11     -10.17    2.94  CuSO4
  Diaspore          2.87       9.75    6.87  AlOOH
  Dolomite(disordered)  -1.99    -18.53  -16.54  CaMg(CO3)2
  Dolomite(ordered)  -1.44    -18.53  -17.09  CaMg(CO3)2
  Epsomite         -4.04      -6.17   -2.13  MgSO4:7H2O
  Fe(OH)2          -6.05       7.52   13.56  Fe(OH)2
  Fe2(SO4)3       -37.98     -41.72   -3.73  Fe2(SO4)3
  Fe3(OH)8         -0.54      19.68   20.22  Fe3(OH)8
  FeAsO4:2H2O      -7.01      -6.61    0.40  FeAsO4:2H2O
  FeMoO4           -5.07     -15.16  -10.09  FeMoO4
  Ferrihydrite      2.89       6.08    3.19  Fe(OH)3
  Fluorite         -2.06     -12.56  -10.50  CaF2
  Gibbsite          1.46       9.75    8.29  Al(OH)3
  Goethite          5.59       6.08    0.49  FeOOH
  Gummite          -5.74       1.93    7.67  UO3
  Gypsum           -0.96      -5.57   -4.61  CaSO4:2H2O
  H-Jarosite       -5.57     -17.67  -12.10  (H3O)Fe3(SO4)2(OH)6
  H2MoO4           -9.80     -22.68  -12.88  H2MoO4
  Hausmannite     -10.00      51.03   61.03  Mn3O4
  Hematite         13.58      12.17   -1.42  Fe2O3
  Hercynite         4.12      27.01   22.89  FeAl2O4
  Huntite          -7.68     -37.65  -29.97  CaMg3(CO3)4
  Hydromagnesite  -17.68     -26.45   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum          -16.85     -22.02   -5.17  KAl(SO4)2:12H2O
  K-Jarosite        1.28     -13.52  -14.80  KFe3(SO4)2(OH)6
  K2MoO4          -17.62     -14.36    3.26  K2MoO4
  Langite          -4.29      13.20   17.49  Cu4(OH)6SO4:H2O
  Lepidocrocite     4.71       6.08    1.37  FeOOH
  Lime            -20.31      12.39   32.70  CaO
  Maghemite         5.78      12.17    6.39  Fe2O3
  Magnesioferrite   7.10      23.96   16.86  Fe2MgO4
  Magnesite        -2.10      -9.56   -7.46  MgCO3
  Magnetite        16.28      19.68    3.40  Fe3O4
  Malachite        -0.47      -5.78   -5.31  Cu2(OH)2CO3
  Manganite        -4.46      20.88   25.34  MnOOH
  Melanterite      -8.24     -10.45   -2.21  FeSO4:7H2O
  Mg(OH)2(active)  -7.00      11.79   18.79  Mg(OH)2
  MgF2             -5.03     -13.16   -8.13  MgF2
  MgMoO4           -9.03     -10.88   -1.85  MgMoO4
  Mirabilite      -10.48     -11.59   -1.11  Na2SO4:10H2O
  Mn2(SO4)3       -57.12     -62.83   -5.71  Mn2(SO4)3
  Mn3(AsO4)2:8H2O -10.07       2.43   12.50  Mn3(AsO4)2:8H2O
  MnSO4           -11.27      -8.69    2.58  MnSO4
  MoO3            -14.68     -22.68   -8.00  MoO3
  Morenosite       -8.68     -10.83   -2.14  NiSO4:7H2O
  Na-Jarosite      -3.29     -14.49  -11.20  NaFe3(SO4)2(OH)6
  Na2Mo2O7        -22.38     -38.98  -16.60  Na2Mo2O7
  Na2MoO4         -17.79     -16.30    1.49  Na2MoO4
  Na2MoO4:2H2O    -17.53     -16.30    1.22  Na2MoO4:2H2O
  Natron          -13.67     -14.98   -1.31  Na2CO3:10H2O
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  Nesquehonite     -4.89     -9.56   -4.67  MgCO3:3H2O
  Ni(OH)2          -5.66      7.13   12.79  Ni(OH)2
  Ni3(AsO4)2:8H2O -19.70     -4.00   15.70  Ni3(AsO4)2:8H2O
  Ni4(OH)6SO4     -21.43     10.57   32.00  Ni4(OH)6SO4
  NiCO3            -7.35    -14.22   -6.87  NiCO3
  NiMoO4           -4.40    -15.54  -11.14  NiMoO4
  Nsutite         -10.38      7.13   17.50  MnO2
  O2(g)           -36.69     46.40   83.09  O2
  Periclase        -9.79     11.79   21.58  MgO
  Portlandite     -10.41     12.39   22.80  Ca(OH)2
  Pyrochroite      -5.92      9.28   15.19  Mn(OH)2
  Pyrolusite       -8.90     32.48   41.38  MnO2
  Retgersite       -8.79    -10.83   -2.04  NiSO4:6H2O
  Rhodochrosite    -1.50    -12.08  -10.58  MnCO3
  Rutherfordine    -4.93    -19.43  -14.50  UO2CO3
  Schoepite        -4.06      1.93    5.99  UO2(OH)2:H2O
  Siderite         -3.60    -13.84  -10.24  FeCO3
  Spinel           -5.56     31.29   36.85  MgAl2O4
  Tenorite          0.15      7.79    7.64  CuO
  Thenardite      -11.91    -11.59    0.32  Na2SO4
  Thermonatrite   -15.62    -14.98    0.64  Na2CO3:H2O
  U3O8            -10.85     10.24   21.08  U3O8
  U4O9            -22.00    -25.02   -3.02  U4O9
  UF4             -32.42    -61.96  -29.54  UF4
  UF4:2.5H2O      -29.24    -61.96  -32.72  UF4:2.5H2O
  UO2(am)         -12.99    -12.05    0.93  UO2
  UO2(OH)2(beta)   -3.68      1.93    5.61  UO2(OH)2
  UO3              -5.77      1.93    7.70  UO3
  Uraninite        -7.38    -12.05   -4.67  UO2
  Witherite        -4.62    -13.19   -8.57  BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 4.     Make-up Material

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                7.415e-07   7.415e-07
      Alkalinity        3.607e-04   3.607e-04
      Ba                1.457e-07   1.457e-07
      Ca                1.672e-03   1.672e-03
      Co                1.188e-07   1.188e-07
      Cu                4.408e-07   4.408e-07
      F                 1.580e-05   1.580e-05
      K                 3.326e-04   3.326e-04
      Mg                3.293e-04   3.293e-04
      Mn                7.283e-07   7.283e-07
      Mo                3.128e-08   3.128e-08
      Na                4.351e-05   4.351e-05
      Ni                6.818e-08   6.818e-08
      S(6)              2.051e-03   2.051e-03

----------------------------Description of solution----------------------------

                                       pH  =   7.700
                                       pe  =   4.000
                              Activity of water  =   1.000
                       Ionic strength (mol/kgw)  =   7.199e-03
                            Mass of water (kg)  =   1.000e+00
                         Total carbon (mol/kg)  =   3.686e-04
                            Total CO2 (mol/kg)  =   3.686e-04
                              Temperature (°C)  =  25.00
                     Electrical balance (eq)  =  -9.478e-05

 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  -1.25
                                  Iterations  =  12 (47 overall)
                                     Total H  = 1.110140e+02
                                     Total O  = 5.551615e+01

----------------------------Distribution of species----------------------------

                                                  Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             5.526e-07   5.046e-07    -6.258    -6.297    -0.039      (0)
   H+              2.182e-08   1.995e-08    -7.661    -7.700    -0.039     0.00
   H2O             5.551e+01   9.999e-01     1.744    -0.000     0.000    18.07
Al            7.415e-07
   Al(OH)4-        7.298e-07   6.680e-07    -6.137    -6.175    -0.038      (0)
   Al(OH)3         1.051e-08   1.051e-08    -7.978    -7.978     0.000      (0)
   Al(OH)2+        1.139e-09   1.044e-09    -8.944    -8.981    -0.038      (0)
   AlF2+           4.383e-12   4.020e-12   -11.358   -11.396    -0.038      (0)
   AlOH+2          3.684e-12   2.605e-12   -11.434   -11.584    -0.150      (0)
   AlF+2           1.021e-12   7.220e-13   -11.991   -12.141    -0.150      (0)
   AlF3            7.077e-13   7.077e-13   -12.150   -12.150     0.000      (0)
   AlSO4+          5.310e-14   4.860e-14   -13.275   -13.313    -0.038      (0)
   Al+3            1.153e-14   5.163e-15   -13.938   -14.287    -0.349      (0)
   AlF4-           5.420e-15   4.960e-15   -14.266   -14.304    -0.038      (0)
   Al(SO4)2-       6.899e-16   6.315e-16   -15.161   -15.200    -0.038      (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -51.065   -51.455    -0.389      (0)
Ba            1.457e-07
   Ba+2            1.453e-07   1.017e-07    -6.838    -6.993    -0.155      (0)
   BaHCO3+         3.344e-10   3.070e-10    -9.476    -9.513    -0.037      (0)
   BaCO3           3.874e-11   3.874e-11   -10.412   -10.412     0.000      (0)
   BaOH+           2.444e-13   2.239e-13   -12.612   -12.650    -0.038      (0)
C(4)          3.686e-04
   HCO3-           3.449e-04   3.163e-04    -3.462    -3.500    -0.038      (0)
   H2CO3           1.419e-05   1.419e-05    -4.848    -4.848     0.000      (0)
   CaHCO3+         6.254e-06   5.742e-06    -5.204    -5.241    -0.037      (0)
   CaCO3           1.148e-06   1.148e-06    -5.940    -5.940     0.000      (0)
   CO3-2           1.062e-06   7.431e-07    -5.974    -6.129    -0.155      (0)
   MgHCO3+         7.037e-07   6.434e-07    -6.153    -6.192    -0.039      (0)
   CuCO3           2.384e-07   2.384e-07    -6.623    -6.623     0.000      (0)
   MgCO3           1.229e-07   1.229e-07    -6.911    -6.911     0.000      (0)
   NaHCO3          7.030e-09   7.030e-09    -8.153    -8.153     0.000      (0)
   MnHCO3+         2.926e-09   2.681e-09    -8.534    -8.572    -0.038      (0)
   CoHCO3+         1.811e-09   1.639e-09    -8.742    -8.785    -0.043      (0)
   NiHCO3+         1.678e-09   1.519e-09    -8.775    -8.818    -0.043      (0)
   CuHCO3+         1.201e-09   1.087e-09    -8.920    -8.964    -0.043      (0)
   NiCO3           1.080e-09   1.080e-09    -8.967    -8.967     0.000      (0)
   CoCO3           8.369e-10   8.369e-10    -9.077    -9.077     0.000      (0)
   Cu(CO3)2-2      7.104e-10   4.768e-10    -9.149    -9.322    -0.173      (0)
   NaCO3-          5.965e-10   5.470e-10    -9.224    -9.262    -0.038      (0)
   BaHCO3+         3.344e-10   3.070e-10    -9.476    -9.513    -0.037      (0)
   BaCO3           3.874e-11   3.874e-11   -10.412   -10.412     0.000      (0)
Ca            1.672e-03
   Ca+2            1.394e-03   9.751e-04    -2.856    -3.011    -0.155      (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000      (0)
   CaHCO3+         6.254e-06   5.742e-06    -5.204    -5.241    -0.037      (0)
   CaCO3           1.148e-06   1.148e-06    -5.940    -5.940     0.000      (0)
   CaF+            1.624e-07   1.488e-07    -6.789    -6.827    -0.038      (0)
   CaOH+           1.069e-08   9.818e-09    -7.971    -8.008    -0.037      (0)
Co(2)         1.188e-07
   Co+2            9.925e-08   6.662e-08    -7.003    -7.176    -0.173      (0)
   CoSO4           1.612e-08   1.612e-08    -7.793    -7.793     0.000      (0)
   CoHCO3+         1.811e-09   1.639e-09    -8.742    -8.785    -0.043      (0)
   CoCO3           8.369e-10   8.369e-10    -9.077    -9.077     0.000      (0)
   CoOH+           7.411e-10   6.708e-10    -9.130    -9.173    -0.043      (0)
   CoF+            3.255e-11   2.946e-11   -10.487   -10.531    -0.043      (0)
   Co(OH)2         2.689e-11   2.689e-11   -10.570   -10.570     0.000      (0)
   Co(OH)3-        2.991e-16   2.707e-16   -15.524   -15.567    -0.043      (0)
   CoOOH-          7.505e-17   6.793e-17   -16.125   -16.168    -0.043      (0)
   Co2OH+3         5.491e-18   2.240e-18   -17.260   -17.650    -0.389      (0)
   Co(OH)4-2       3.225e-23   2.165e-23   -22.491   -22.665    -0.173      (0)
   Co4(OH)4+4      1.990e-28   4.040e-29   -27.701   -28.394    -0.692      (0)
Co(3)         1.013e-29
   CoOH+2          1.013e-29   6.801e-30   -28.994   -29.167    -0.173      (0)
   Co+3            5.925e-36   2.652e-36   -35.227   -35.576    -0.349      (0)
Cu(1)         2.948e-09
   Cu+             2.948e-09   2.668e-09    -8.530    -8.574    -0.043      (0)
Cu(2)         4.378e-07
   CuCO3           2.384e-07   2.384e-07    -6.623    -6.623     0.000      (0)
   CuOH+           9.510e-08   8.694e-08    -7.022    -7.061    -0.039      (0)
   Cu+2            7.788e-08   5.448e-08    -7.109    -7.264    -0.155      (0)
   CuSO4           1.514e-08   1.514e-08    -7.820    -7.820     0.000      (0)
   Cu(OH)2         8.754e-09   8.754e-09    -8.058    -8.058     0.000      (0)
   CuHCO3+         1.201e-09   1.087e-09    -8.920    -8.964    -0.043      (0)
   Cu(CO3)2-2      7.104e-10   4.768e-10    -9.149    -9.322    -0.173      (0)
   Cu2(OH)2+2      2.829e-10   1.899e-10    -9.548    -9.722    -0.173      (0)
   CuF+            5.311e-11   4.808e-11   -10.275   -10.318    -0.043      (0)
   Cu(OH)3-        1.001e-11   9.061e-12   -11.000   -11.043    -0.043      (0)
   Cu(OH)4-2       5.361e-17   3.599e-17   -16.271   -16.444    -0.173      (0)
F             1.580e-05
   F-              1.529e-05   1.398e-05    -4.816    -4.854    -0.039      (0)
   MgF+            3.408e-07   3.119e-07    -6.467    -6.506    -0.038      (0)
   CaF+            1.624e-07   1.488e-07    -6.789    -6.827    -0.038      (0)
   HF              4.127e-10   4.127e-10    -9.384    -9.384     0.000      (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000      (0)
   MnF+            2.582e-10   2.365e-10    -9.588    -9.626    -0.038      (0)
   CuF+            5.311e-11   4.808e-11   -10.275   -10.318    -0.043      (0)
   CoF+            3.255e-11   2.946e-11   -10.487   -10.531    -0.043      (0)
   NiF+            1.512e-11   1.369e-11   -10.820   -10.864    -0.043      (0)
   AlF2+           4.383e-12   4.020e-12   -11.358   -11.396    -0.038      (0)
   AlF+2           1.021e-12   7.220e-13   -11.991   -12.141    -0.150      (0)
   AlF3            7.077e-13   7.077e-13   -12.150   -12.150     0.000      (0)
   HF2-            2.403e-14   2.194e-14   -13.619   -13.659    -0.039      (0)
   AlF4-           5.420e-15   4.960e-15   -14.266   -14.304    -0.038      (0)
   H2F2            4.564e-19   4.564e-19   -18.341   -18.341     0.000      (0)
H(0)          5.627e-27
   H2              2.814e-27   2.818e-27   -26.551   -26.550     0.001      (0)
K             3.326e-04
   K+              3.298e-04   3.016e-04    -3.482    -3.521    -0.039      (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038      (0)
Mg            3.293e-04
   Mg+2            2.842e-04   1.988e-04    -3.546    -3.702    -0.155      (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000      (0)
   MgHCO3+         7.037e-07   6.434e-07    -6.153    -6.192    -0.039      (0)
   MgF+            3.408e-07   3.119e-07    -6.467    -6.506    -0.038      (0)
   MgCO3           1.229e-07   1.229e-07    -6.911    -6.911     0.000      (0)
   MgOH+           4.345e-08   3.994e-08    -7.362    -7.399    -0.037      (0)
Mn(2)         7.283e-07
   Mn+2            6.329e-07   4.249e-07    -6.199    -6.372    -0.173      (0)
   MnSO4           9.162e-08   9.162e-08    -7.038    -7.038     0.000      (0)
   MnHCO3+         2.926e-09   2.681e-09    -8.534    -8.572    -0.038      (0)
   MnOH+           5.878e-10   5.385e-10    -9.231    -9.269    -0.038      (0)
   MnF+            2.582e-10   2.365e-10    -9.588    -9.626    -0.038      (0)
   Mn(OH)3-        9.250e-19   8.475e-19   -18.034   -18.072    -0.038      (0)
   Mn(OH)4-2       1.959e-24   1.381e-24   -23.708   -23.860    -0.152      (0)
Mn(3)         4.240e-28
   Mn+3            4.240e-28   1.898e-28   -27.373   -27.722    -0.349      (0)
Mn(6)         0.000e+00
   MnO4-2          0.000e+00   0.000e+00   -47.042   -47.194    -0.152      (0)
Mn(7)         0.000e+00
   MnO4-           0.000e+00   0.000e+00   -52.526   -52.566    -0.040      (0)
Mo            3.128e-08
   MoO4-2          3.127e-08   2.188e-08    -7.505    -7.660    -0.155      (0)
   HMoO4-          9.595e-12   8.685e-12   -11.018   -11.061    -0.043      (0)
   H2MoO4          1.269e-15   1.269e-15   -14.896   -14.896     0.000      (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -51.065   -51.455    -0.389      (0)
   Mo7O24-6        0.000e+00   0.000e+00   -60.672   -62.230    -1.558      (0)
   HMo7O24-5       0.000e+00   0.000e+00   -62.461   -63.543    -1.082      (0)
   H2Mo7O24-4      0.000e+00   0.000e+00   -65.769   -66.461    -0.692      (0)
   H3Mo7O24-3      0.000e+00   0.000e+00   -70.526   -70.915    -0.389      (0)
Na            4.351e-05
   Na+             4.322e-05   3.953e-05    -4.364    -4.403    -0.039      (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038      (0)
   NaHCO3          7.030e-09   7.030e-09    -8.153    -8.153     0.000      (0)
   NaCO3-          5.965e-10   5.470e-10    -9.224    -9.262    -0.038      (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000      (0)
Ni            6.818e-08
   Ni+2            5.569e-08   3.896e-08    -7.254    -7.409    -0.155      (0)
   NiSO4           9.427e-09   9.427e-09    -8.026    -8.026     0.000      (0)
   NiHCO3+         1.678e-09   1.519e-09    -8.775    -8.818    -0.043      (0)
   NiCO3           1.080e-09   1.080e-09    -8.967    -8.967     0.000      (0)
   NiOH+           2.734e-10   2.475e-10    -9.563    -9.606    -0.043      (0)
   NiF+            1.512e-11   1.369e-11   -10.820   -10.864    -0.043      (0)
   Ni(OH)2         9.921e-12   9.921e-12   -11.003   -11.003     0.000      (0)
   Ni(SO4)2-2      5.639e-13   3.785e-13   -12.249   -12.422    -0.173      (0)
   Ni(OH)3-        5.531e-15   5.006e-15   -14.257   -14.300    -0.043      (0)
O(0)          1.274e-39
   O2              6.370e-40   6.381e-40   -39.196   -39.195     0.001      (0)
S(6)          2.051e-03
   SO4-2           1.733e-03   1.213e-03    -2.761    -2.916    -0.155      (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000      (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000      (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038      (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038      (0)
   MnSO4           9.162e-08   9.162e-08    -7.038    -7.038     0.000      (0)
   CoSO4           1.612e-08   1.612e-08    -7.793    -7.793     0.000      (0)
   CuSO4           1.514e-08   1.514e-08    -7.820    -7.820     0.000      (0)
   NiSO4           9.427e-09   9.427e-09    -8.026    -8.026     0.000      (0)
   HSO4-           2.583e-09   2.364e-09    -8.588    -8.626    -0.038      (0)
   Ni(SO4)2-2      5.639e-13   3.785e-13   -12.249   -12.422    -0.173      (0)
   AlSO4+          5.310e-14   4.860e-14   -13.275   -13.313    -0.038      (0)
   Al(SO4)2-       6.899e-16   6.315e-16   -15.161   -15.200    -0.038      (0)

----------------------------Saturation indices----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.99      8.81   10.80  Al(OH)3
  Al2(MoO4)3      -53.92    -51.55    2.37  Al2(MoO4)3
  Al2O3            -2.03     17.63   19.65  Al2O3
  Al4(OH)10SO4     -5.77     16.93   22.70  Al4(OH)10SO4
  AlOHSO4          -6.27     -9.50   -3.23  AlOHSO4
  Alunite          -4.61     -6.01   -1.40  KAl3(SO4)2(OH)6
  Anhydrite        -1.57     -5.93   -4.36  CaSO4
  Antlerite        -2.70      6.09    8.79  Cu3(OH)4SO4
  Aragonite        -0.84     -9.14   -8.30  CaCO3
  Artinite         -7.73      1.87    9.60  MgCO3:Mg(OH)2:3H2O
  Azurite          -1.74    -18.65  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -15.99      8.41   24.39  Ba(OH)2:8H2O
  BaF2            -10.88    -16.70   -5.82  BaF2
  BaMoO4           -7.69    -14.65   -6.96  BaMoO4
  Barite            0.07     -9.91   -9.98  BaSO4
  Birnessite      -11.01      7.08   18.09  MnO2
  Bixbyite         -8.60     -9.24   -0.64  Mn2O3
  Boehmite          0.23      8.81    8.58  AlOOH
  Brochantite      -0.99     14.23   15.22  Cu4(OH)6SO4
  Brucite          -5.15     11.70   16.84  Mg(OH)2
  Bunsenite        -4.45      7.99   12.45  NiO
  Calcite          -0.66     -9.14   -8.48  CaCO3
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CaMoO4	-2.72	-10.67	-7.95	CaMoO4
CH4(g)	-74.08	-115.13	-41.05	CH4
Chalcanthite	-7.54	-10.18	-2.64	CuSO4:5H2O
Co(OH)2	-4.87	8.22	13.09	Co(OH)2
Co(OH)3	-10.17	-12.48	-2.31	Co(OH)3
CO2(g)	-3.38	-21.53	-18.15	CO2
Co3O4	-6.23	-16.73	-10.50	Co3O4
CoCO3	-3.33	-13.31	-9.98	CoCO3
CoF2	-15.29	-16.89	-1.60	CoF2
CoF3	-48.68	-50.14	-1.46	CoF3
CoMoO4	-7.08	-14.84	-7.76	CoMoO4
CoO	-5.36	8.22	13.59	CoO
CoSO4	-12.90	-10.09	2.80	CoSO4
CoSO4:6H2O	-7.62	-10.09	-2.47	CoSO4:6H2O
Cryolite	-22.78	-56.62	-33.84	Na3AlF6
Cu(OH)2	-0.54	8.14	8.67	Cu(OH)2
Cu2SO4	-18.11	-20.06	-1.95	Cu2SO4
CuCO3	-1.89	-13.39	-11.50	CuCO3
CuF	-8.52	-13.43	-4.91	CuF
CuF2	-18.09	-16.97	1.12	CuF2
CuF2:2H2O	-12.42	-16.97	-4.55	CuF2:2H2O
Cumetal	-3.82	-12.57	-8.76	Cu
CuMoO4	-1.85	-14.92	-13.08	CuMoO4
CuOCuSO4	-12.35	-2.04	10.30	CuOCuSO4
Cuprite	-0.34	-1.75	-1.41	Cu2O
CuSO4	-13.12	-10.18	2.94	CuSO4
Diaspore	1.94	8.81	6.87	AlOOH
Dolomite(disordered)	-2.43	-18.97	-16.54	CaMg(CO3)2
Dolomite(ordered)	-1.88	-18.97	-17.09	CaMg(CO3)2
Epsomite	-4.49	-6.62	-2.13	MgSO4:7H2O
Fluorite	-2.22	-12.72	-10.50	CaF2
Gibbsite	0.52	8.81	8.29	Al(OH)3
Gypsum	-1.32	-5.93	-4.61	CaSO4:2H2O
H2MoO4	-10.18	-23.06	-12.88	H2MoO4
Hausmannite	-10.55	50.48	61.03	Mn3O4
Huntite	-8.66	-38.63	-29.97	CaMg3(CO3)4
Hydromagnesite	-18.86	-27.62	-8.77	Mg5(CO3)4(OH)2:4H2O
K-Alum	-18.47	-23.64	-5.17	KAl(SO4)2:12H2O
K2MoO4	-17.96	-14.70	3.26	K2MoO4
Langite	-3.26	14.23	17.49	Cu4(OH)6SO4:H2O
Lime	-20.31	12.39	32.70	CaO
Magnesite	-2.37	-9.83	-7.46	MgCO3
Malachite	0.05	-5.26	-5.31	Cu2(OH)2CO3
Manganite	-4.61	20.73	25.34	MnOOH
Mg(OH)2(active)	-7.10	11.70	18.79	Mg(OH)2
MgF2	-5.28	-13.41	-8.13	MgF2
MgMoO4	-9.51	-11.36	-1.85	MgMoO4
Mirabilite	-10.61	-11.72	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-58.48	-64.19	-5.71	Mn2(SO4)3
MnSO4	-11.87	-9.29	2.58	MnSO4
MoO3	-15.06	-23.06	-8.00	MoO3
Morenosite	-8.18	-10.33	-2.14	NiSO4:7H2O
Na2Mo2O7	-22.93	-39.53	-16.60	Na2Mo2O7
Na2MoO4	-17.96	-16.47	1.49	Na2MoO4
Na2MoO4:2H2O	-17.69	-16.47	1.22	Na2MoO4:2H2O
Natron	-13.62	-14.94	-1.31	Na2CO3:10H2O
Nesquehonite	-5.16	-9.83	-4.67	MgCO3:3H2O
Ni(OH)2	-4.80	7.99	12.79	Ni(OH)2
Ni4(OH)6SO4	-18.35	13.65	32.00	Ni4(OH)6SO4
NiCO3	-6.67	-13.54	-6.87	NiCO3
NiMoO4	-3.93	-15.07	-11.14	NiMoO4
Nsutite	-10.43	7.08	17.50	MnO2
O2(g)	-36.29	46.80	83.09	O2
Periclase	-9.89	11.70	21.58	MgO
Portlandite	-10.42	12.39	22.80	Ca(OH)2
Pyrochroite	-6.17	9.03	15.19	Mn(OH)2
Pyrolusite	-8.95	32.43	41.38	MnO2
Retgersite	-8.29	-10.33	-2.04	NiSO4:6H2O
Rhodochrosite	-1.92	-12.50	-10.58	MnCO3
Spinel	-7.52	29.32	36.85	MgAl2O4
Tenorite	0.49	8.14	7.64	CuO
Thenardite	-12.04	-11.72	0.32	Na2SO4
Thermonatrite	-15.57	-14.94	0.64	Na2CO3:H2O
Witherite	-4.55	-13.12	-8.57	BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

Beginning of batch-reaction calculations.

Reaction step 1.

Using mix 1. Mix within UG Works

Mixture 1. Mix within UG Works

3.080e-01	Solution 1	UG Water P50
1.100e-01	Solution 2	PAF Material
4.000e-01	Solution 3	NAF Material
1.820e-01	Solution 4	Make-up Material

----------Solution composition----------

Elements	Molality	Moles
Al	3.210e-06	3.210e-06
As	1.656e-07	1.656e-07
B	3.691e-06	3.691e-06
Ba	5.023e-07	5.023e-07
C	3.062e-03	3.062e-03
Ca	2.353e-03	2.353e-03
Cd	2.057e-08	2.057e-08
Cl	4.270e-04	4.270e-04
Co	6.763e-08	6.763e-08
Cr	4.388e-08	4.388e-08
Cu	5.929e-07	5.929e-07
F	2.583e-05	2.583e-05
Fe	1.527e-06	1.527e-06
K	5.432e-04	5.432e-04
Mg	9.127e-04	9.127e-04
Mn	1.651e-06	1.651e-06
Mo	5.152e-08	5.152e-08
Na	2.393e-03	2.393e-03
Ni	5.510e-08	5.510e-08
Pb	6.905e-08	6.905e-08
S	2.432e-03	2.432e-03
Se	2.655e-08	2.655e-08
U	1.127e-08	1.127e-08
V	1.513e-08	1.513e-08
Zn	9.350e-07	9.350e-07

----------Description of solution----------

pH	=	8.065	Charge balance
pe	=	3.310	Adjusted to redox equilibrium
Activity of water	=	1.000	
Ionic strength (mol/kgw)	=	1.252e-02	
Mass of water (kg)	=	1.000e+00	
Total alkalinity (eq/kg)	=	3.085e-03	
Total CO2 (mol/kg)	=	3.062e-03	
Temperature (°C)	=	25.00	
Electrical balance (eq)	=	1.085e-03	
Percent error, 100*(Cat-|An|)/(Cat+|An|)	=	6.91	
Iterations	=	14	
Total H	=	1.110167e+02	
Total O	=	5.552578e+01	

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
OH-	1.313e-06	1.169e-06	-5.882	-5.932	-0.051	(0)
H+	9.652e-09	8.614e-09	-8.015	-8.065	-0.049	0.00
H2O	5.551e+01	9.998e-01	1.744	-0.000	0.000	18.07
Al 3.210e-06						
Al(OH)4-	3.189e-06	2.849e-06	-5.496	-5.545	-0.049	(0)
Al(OH)3	1.936e-08	1.936e-08	-7.713	-7.713	0.000	(0)
Al(OH)2+	9.267e-10	8.304e-10	-9.033	-9.081	-0.048	(0)
AlF2+	1.578e-12	1.415e-12	-11.802	-11.849	-0.048	(0)
AlOH+2	1.387e-12	8.945e-13	-11.858	-12.048	-0.190	(0)
AlF3	3.837e-13	3.837e-13	-12.416	-12.416	0.000	(0)
AlF+2	2.557e-13	1.649e-13	-12.592	-12.783	-0.190	(0)
AlSO4+	8.246e-15	7.366e-15	-14.084	-14.133	-0.049	(0)
AlF4-	4.638e-15	4.143e-15	-14.334	-14.383	-0.049	(0)
Al+3	2.131e-15	7.654e-16	-14.671	-15.116	-0.445	(0)
Al(SO4)2-	1.095e-16	9.786e-17	-15.960	-16.009	-0.049	(0)
AlMo6O21-3	0.000e+00	0.000e+00	-52.913	-53.426	-0.514	(0)
As(3) 1.645e-18						
H3AsO3	1.540e-18	1.540e-18	-17.812	-17.812	0.000	(0)
H2AsO3-	1.046e-19	9.169e-20	-18.981	-19.038	-0.057	(0)
HAsO3-2	1.642e-23	9.708e-24	-22.785	-23.013	-0.228	(0)
H4AsO3+	7.496e-27	6.573e-27	-26.125	-26.182	-0.057	(0)
AsO3-3	1.418e-28	4.344e-29	-27.848	-28.362	-0.514	(0)
As(5) 1.656e-07						
HAsO4-2	1.572e-07	9.292e-08	-6.804	-7.032	-0.228	(0)
H2AsO4-	8.325e-09	7.300e-09	-8.080	-8.137	-0.057	(0)
AsO4-3	1.113e-10	3.411e-11	-9.953	-10.467	-0.514	(0)
H3AsO4	1.090e-14	1.093e-14	-13.963	-13.961	0.001	(0)
B 3.691e-06						
H3BO3	3.408e-06	3.417e-06	-5.468	-5.466	0.001	(0)
H2BO3-	2.599e-07	2.304e-07	-6.585	-6.638	-0.052	(0)
CaH2BO3+	1.817e-08	1.611e-08	-7.741	-7.793	-0.052	(0)
MgH2BO3+	4.454e-09	3.949e-09	-8.351	-8.404	-0.052	(0)
NaH2BO3	7.736e-10	7.736e-10	-9.111	-9.111	0.000	(0)
BF(OH)3-	3.314e-11	2.938e-11	-10.480	-10.532	-0.052	(0)
BaH2BO3+	2.504e-12	2.220e-12	-11.601	-11.654	-0.052	(0)
H5(BO3)2-	7.559e-13	6.702e-13	-12.122	-12.174	-0.052	(0)
BF2(OH)2-	6.576e-16	5.831e-16	-15.182	-15.234	-0.052	(0)
H8(BO3)3-	2.583e-16	2.290e-16	-15.588	-15.640	-0.052	(0)
BF3OH-	4.749e-23	4.211e-23	-22.323	-22.376	-0.052	(0)
BF4-	4.338e-29	3.846e-29	-28.363	-28.415	-0.052	(0)
Ba 5.023e-07						
Ba+2	4.915e-07	3.118e-07	-6.308	-6.506	-0.198	(0)
BaHCO3+	8.539e-09	7.667e-09	-8.069	-8.115	-0.047	(0)
BaCO3	2.241e-09	2.241e-09	-8.650	-8.650	0.000	(0)
BaH2BO3+	2.504e-12	2.220e-12	-11.601	-11.654	-0.052	(0)
BaOH+	1.777e-12	1.591e-12	-11.750	-11.798	-0.048	(0)
C(4) 3.062e-03						
HCO3-	2.873e-03	2.575e-03	-2.542	-2.589	-0.048	(0)
CaHCO3+	6.489e-05	5.826e-05	-4.188	-4.235	-0.047	(0)
H2CO3	4.989e-05	4.989e-05	-4.302	-4.302	0.000	(0)
CaCO3	2.699e-05	2.699e-05	-4.569	-4.569	0.000	(0)
CO3-2	2.209e-05	1.401e-05	-4.656	-4.853	-0.198	(0)
MgHCO3+	1.461e-05	1.302e-05	-4.835	-4.885	-0.050	(0)
MgCO3	5.762e-06	5.762e-06	-5.239	-5.239	0.000	(0)
NaHCO3	3.068e-06	3.068e-06	-5.513	-5.513	0.000	(0)
NaCO3-	6.169e-07	5.529e-07	-6.210	-6.257	-0.048	(0)
CuCO3	5.136e-07	5.136e-07	-6.289	-6.289	0.000	(0)
ZnCO3	2.591e-07	2.591e-07	-6.586	-6.586	0.000	(0)
PbCO3	5.503e-08	5.503e-08	-7.259	-7.259	0.000	(0)
MnHCO3+	4.801e-08	4.296e-08	-7.319	-7.367	-0.048	(0)
Cu(CO3)2-2	3.277e-08	1.937e-08	-7.484	-7.713	-0.228	(0)
ZnHCO3+	2.984e-08	2.617e-08	-7.525	-7.582	-0.057	(0)
NiCO3	1.056e-08	1.056e-08	-7.976	-7.976	0.000	(0)
UO2(CO3)3-4	8.702e-09	1.063e-09	-8.060	-8.973	-0.913	(0)
BaHCO3+	8.539e-09	7.667e-09	-8.069	-8.115	-0.047	(0)
NiHCO3+	7.311e-09	6.410e-09	-8.136	-8.193	-0.057	(0)
CoCO3	6.580e-09	6.580e-09	-8.182	-8.182	0.000	(0)
CoHCO3+	6.344e-09	5.563e-09	-8.198	-8.255	-0.057	(0)
Pb(CO3)2-2	3.763e-09	2.224e-09	-8.425	-8.653	-0.228	(0)
CdCO3	2.906e-09	2.906e-09	-8.537	-8.537	0.000	(0)
PbHCO3+	2.850e-09	2.499e-09	-8.545	-8.602	-0.057	(0)
UO2(CO3)2-2	2.560e-09	1.513e-09	-8.592	-8.820	-0.228	(0)
BaCO3	2.241e-09	2.241e-09	-8.650	-8.650	0.000	(0)
CuHCO3+	1.153e-09	1.011e-09	-8.938	-8.995	-0.057	(0)
FeHCO3+	3.317e-10	2.978e-10	-9.479	-9.526	-0.047	(0)
CdHCO3+	6.082e-11	5.333e-11	-10.216	-10.273	-0.057	(0)
Cd(CO3)2-2	5.107e-11	3.019e-11	-10.292	-10.520	-0.228	(0)
UO2CO3	5.412e-12	5.412e-12	-11.267	-11.267	0.000	(0)
Ca 2.353e-03						
Ca+2	1.915e-03	1.215e-03	-2.718	-2.915	-0.198	(0)
CaSO4	3.451e-04	3.451e-04	-3.462	-3.462	0.000	(0)
CaHCO3+	6.489e-05	5.826e-05	-4.188	-4.235	-0.047	(0)
CaCO3	2.699e-05	2.699e-05	-4.569	-4.569	0.000	(0)
CaF+	3.193e-07	2.857e-07	-6.496	-6.544	-0.048	(0)
CaOH+	3.156e-08	2.834e-08	-7.501	-7.548	-0.047	(0)
CaH2BO3+	1.817e-08	1.611e-08	-7.741	-7.793	-0.052	(0)
Cd 2.057e-08						
Cd+2	1.434e-08	9.098e-09	-7.843	-8.041	-0.198	(0)
CdCO3	2.906e-09	2.906e-09	-8.537	-8.537	0.000	(0)
CdSO4	2.644e-09	2.644e-09	-8.578	-8.578	0.000	(0)
CdCl+	3.776e-10	3.311e-10	-9.423	-9.480	-0.057	(0)
CdOH+	9.632e-11	8.446e-11	-10.016	-10.073	-0.057	(0)
Cd(SO4)2-2	7.480e-11	4.422e-11	-10.126	-10.354	-0.228	(0)
CdHCO3+	6.082e-11	5.333e-11	-10.216	-10.273	-0.057	(0)
Cd(CO3)2-2	5.107e-11	3.019e-11	-10.292	-10.520	-0.228	(0)
CdOHCl	1.587e-11	1.587e-11	-10.799	-10.799	0.000	(0)
CdF+	3.543e-12	3.107e-12	-11.451	-11.508	-0.057	(0)
Cd(OH)2	6.228e-13	6.228e-13	-12.206	-12.206	0.000	(0)
CdCl2	5.260e-13	5.260e-13	-12.279	-12.279	0.000	(0)
CdCl3-	1.442e-16	1.265e-16	-15.841	-15.898	-0.057	(0)
CdF2	1.336e-16	1.336e-16	-15.874	-15.874	0.000	(0)
Cd(OH)3-	5.071e-17	4.447e-17	-16.295	-16.352	-0.057	(0)
Cd2OH+3	1.257e-17	3.851e-18	-16.901	-17.414	-0.514	(0)
Cd(SeO3)2-2	5.169e-19	3.056e-19	-18.287	-18.515	-0.228	(0)
CdSeO4	7.499e-20	7.499e-20	-19.125	-19.125	0.000	(0)
Cd(OH)4-2	1.439e-23	8.507e-24	-22.842	-23.070	-0.228	(0)
CdHS+	0.000e+00	0.000e+00	-68.283	-68.340	-0.057	(0)
Cd(HS)2	0.000e+00	0.000e+00	-129.444	-129.444	0.000	(0)
Cd(HS)3-	0.000e+00	0.000e+00	-195.794	-195.851	-0.057	(0)
Cd(HS)4-2	0.000e+00	0.000e+00	-261.734	-261.962	-0.228	(0)
Cl 4.270e-04						
Cl-	4.270e-04	3.811e-04	-3.370	-3.419	-0.049	(0)
CuCl	7.168e-10	7.168e-10	-9.145	-9.145	0.000	(0)
ZnOHCl	4.706e-10	4.706e-10	-9.327	-9.327	0.000	(0)
MnCl+	4.483e-10	4.012e-10	-9.348	-9.397	-0.048	(0)
CdCl+	3.776e-10	3.311e-10	-9.423	-9.480	-0.057	(0)
ZnCl+	3.449e-10	3.076e-10	-9.462	-9.512	-0.050	(0)
CuCl2-	6.400e-11	5.707e-11	-10.194	-10.244	-0.050	(0)
CoCl+	4.176e-11	3.661e-11	-10.379	-10.436	-0.057	(0)
NiCl+	2.245e-11	1.969e-11	-10.649	-10.706	-0.057	(0)

PbCl+	2.014e-11	1.766e-11	-10.696	-10.753	-0.057	(0)
CdOHCl	1.587e-11	1.587e-11	-10.799	-10.799	0.000	(0)
CuCl+	4.216e-12	3.759e-12	-11.375	-11.425	-0.050	(0)
CdCl2	5.260e-13	5.260e-13	-12.279	-12.279	0.000	(0)
MnCl2	2.160e-13	2.160e-13	-12.666	-12.666	0.000	(0)
ZnCl2	1.858e-13	1.858e-13	-12.731	-12.731	0.000	(0)
PbCl2	3.007e-14	3.007e-14	-13.522	-13.522	0.000	(0)
CuCl3-2	7.249e-15	4.650e-15	-14.140	-14.333	-0.193	(0)
CuCl2	4.968e-16	4.968e-16	-15.304	-15.304	0.000	(0)
CdCl3-	1.442e-16	1.265e-16	-15.841	-15.898	-0.057	(0)
ZnCl3-	6.307e-17	5.624e-17	-16.200	-16.250	-0.050	(0)
NiCl2	3.778e-17	3.778e-17	-16.423	-16.423	0.000	(0)
MnCl3-	2.533e-17	2.267e-17	-16.596	-16.645	-0.048	(0)
CrCl+2	6.123e-18	3.620e-18	-17.213	-17.441	-0.228	(0)
PbCl3-	5.203e-18	4.562e-18	-17.284	-17.341	-0.057	(0)
UO2Cl+	6.837e-20	5.995e-20	-19.165	-19.222	-0.057	(0)
FeCl+2	3.125e-20	2.004e-20	-19.505	-19.698	-0.193	(0)
CrOHCl2	3.064e-20	3.064e-20	-19.514	-19.514	0.000	(0)
ZnCl4-2	1.671e-20	1.072e-20	-19.777	-19.970	-0.193	(0)
CuCl3-	1.981e-21	1.767e-21	-20.703	-20.753	-0.050	(0)
PbCl4-2	1.344e-21	7.947e-22	-20.872	-21.100	-0.228	(0)
CrCl2+	1.493e-22	1.309e-22	-21.826	-21.883	-0.057	(0)
VOCl+	4.866e-23	4.266e-23	-22.313	-22.370	-0.057	(0)
FeCl2+	3.812e-23	3.412e-23	-22.419	-22.467	-0.048	(0)
CuCl4-2	5.261e-27	3.375e-27	-26.279	-26.472	-0.193	(0)
FeCl3	1.300e-27	1.300e-27	-26.886	-26.886	0.000	(0)
CrO3Cl-	1.532e-29	1.343e-29	-28.815	-28.872	-0.057	(0)
CoCl+2	2.959e-38	1.749e-38	-37.529	-37.757	-0.228	(0)
UCl+3	0.000e+00	0.000e+00	-46.881	-47.395	-0.514	(0)
Co(2)	6.763e-08					
Co+2	4.698e-08	2.777e-08	-7.328	-7.556	-0.228	(0)
CoSO4	6.870e-09	6.870e-09	-8.163	-8.163	0.000	(0)
CoCO3	6.580e-09	6.580e-09	-8.182	-8.182	0.000	(0)
CoHCO3+	6.344e-09	5.563e-09	-8.198	-8.255	-0.057	(0)
CoOH+	7.386e-10	6.476e-10	-9.132	-9.189	-0.057	(0)
Co(OH)2	6.012e-11	6.012e-11	-10.221	-10.221	0.000	(0)
CoCl+	4.176e-11	3.661e-11	-10.379	-10.436	-0.057	(0)
CoF+	2.158e-11	1.892e-11	-10.666	-10.723	-0.057	(0)
Co(OH)3-	1.599e-15	1.402e-15	-14.796	-14.853	-0.057	(0)
CoOOH-	4.012e-16	3.518e-16	-15.397	-15.454	-0.057	(0)
Co2OH+3	2.941e-18	9.015e-19	-17.531	-18.045	-0.514	(0)
CoSe04	6.162e-19	6.162e-19	-18.210	-18.210	0.000	(0)
Co(OH)4-2	4.393e-22	2.597e-22	-21.357	-21.586	-0.228	(0)
Co4(OH)4+4	2.873e-28	3.510e-29	-27.542	-28.455	-0.913	(0)
Co(3)	2.266e-30					
CoOH+2	2.266e-30	1.340e-30	-29.645	-29.873	-0.228	(0)
Co+3	6.281e-37	2.256e-37	-36.202	-36.647	-0.445	(0)
CoCl+2	2.959e-38	1.749e-38	-37.529	-37.757	-0.228	(0)
Cr(2)	1.453e-24					
Cr+2	1.453e-24	8.593e-25	-23.838	-24.066	-0.228	(0)
Cr(3)	4.388e-08					
Cr(OH)2+	3.043e-08	2.669e-08	-7.517	-7.574	-0.057	(0)
Cr(OH)3	1.172e-08	1.172e-08	-7.931	-7.931	0.000	(0)
CrO2-	7.368e-10	6.461e-10	-9.133	-9.190	-0.057	(0)
Cr(OH)4-	6.217e-10	5.451e-10	-9.206	-9.263	-0.057	(0)
Cr(OH)+2	3.174e-10	1.877e-10	-9.498	-9.727	-0.228	(0)
CrOHSO4	5.521e-11	5.521e-11	-10.258	-10.258	0.000	(0)
CrF+2	4.239e-14	2.506e-14	-13.373	-13.601	-0.228	(0)
CrSO4+	2.423e-14	2.125e-14	-13.616	-13.673	-0.057	(0)
Cr+3	2.395e-14	7.340e-15	-13.621	-14.134	-0.514	(0)
CrCl+2	6.123e-18	3.620e-18	-17.213	-17.441	-0.228	(0)
Cr2(OH)2SO4+2	1.584e-18	9.365e-19	-17.800	-18.028	-0.228	(0)
Cr2(OH)2(SO4)2	6.897e-20	6.897e-20	-19.161	-19.161	0.000	(0)
CrOHCl2	3.064e-20	3.064e-20	-19.514	-19.514	0.000	(0)
CrCl2+	1.493e-22	1.309e-22	-21.826	-21.883	-0.057	(0)
Cr(6)	3.786e-17					

CrO4-2	3.679e-17	2.334e-17	-16.434	-16.632	-0.198	(0)
HCrO4-	7.419e-19	6.506e-19	-18.130	-18.187	-0.057	(0)
NaCrO4-	2.802e-19	2.457e-19	-18.553	-18.610	-0.057	(0)
KCrO4-	4.753e-20	4.167e-20	-19.323	-19.380	-0.057	(0)
H2CrO4	4.542e-27	4.542e-27	-26.343	-26.343	0.000	(0)
CrO3SO4-2	3.580e-27	2.117e-27	-26.446	-26.674	-0.228	(0)
CrO3Cl-	1.532e-29	1.343e-29	-28.815	-28.872	-0.057	(0)
Cr2O7-2	2.483e-35	1.468e-35	-34.605	-34.833	-0.228	(0)
Cu(1)	2.485e-09					
Cu+	1.704e-09	1.494e-09	-8.769	-8.826	-0.057	(0)
CuCl	7.168e-10	7.168e-10	-9.145	-9.145	0.000	(0)
CuCl2-	6.400e-11	5.707e-11	-10.194	-10.244	-0.050	(0)
CuCl3-2	7.249e-15	4.650e-15	-14.140	-14.333	-0.193	(0)
Cu(S4)2-3	0.000e+00	0.000e+00	-125.642	-125.921	-0.278	(0)
CuS4S5-3	0.000e+00	0.000e+00	-126.383	-126.651	-0.268	(0)
Cu(2)	5.904e-07					
CuCO3	5.136e-07	5.136e-07	-6.289	-6.289	0.000	(0)
Cu(CO3)2-2	3.277e-08	1.937e-08	-7.484	-7.713	-0.228	(0)
CuOH+	2.580e-08	2.300e-08	-7.588	-7.638	-0.050	(0)
Cu+2	9.811e-09	6.224e-09	-8.008	-8.206	-0.198	(0)
Cu(OH)2	5.364e-09	5.364e-09	-8.270	-8.270	0.000	(0)
CuSO4	1.768e-09	1.768e-09	-8.753	-8.753	0.000	(0)
CuHCO3+	1.153e-09	1.011e-09	-8.938	-8.995	-0.057	(0)
Cu2(OH)2+2	2.248e-11	1.329e-11	-10.648	-10.876	-0.228	(0)
Cu(OH)3-	1.466e-11	1.286e-11	-10.834	-10.891	-0.057	(0)
CuF+	9.650e-12	8.461e-12	-11.015	-11.073	-0.057	(0)
CuCl+	4.216e-12	3.759e-12	-11.375	-11.425	-0.050	(0)
CuCl2	4.968e-16	4.968e-16	-15.304	-15.304	0.000	(0)
Cu(OH)4-2	2.001e-16	1.183e-16	-15.699	-15.927	-0.228	(0)
CuCl3-	1.981e-21	1.767e-21	-20.703	-20.753	-0.050	(0)
CuCl4-2	5.261e-27	3.375e-27	-26.279	-26.472	-0.193	(0)
Cu(HS)3-	0.000e+00	0.000e+00	-187.172	-187.229	-0.057	(0)
F	2.583e-05					
F-	2.414e-05	2.155e-05	-4.617	-4.667	-0.049	(0)
MgF+	1.338e-06	1.195e-06	-5.874	-5.923	-0.049	(0)
CaF+	3.193e-07	2.857e-07	-6.496	-6.544	-0.048	(0)
NaF	2.880e-08	2.880e-08	-7.541	-7.541	0.000	(0)
MnF+	8.014e-10	7.172e-10	-9.096	-9.144	-0.048	(0)
HF	2.745e-10	2.745e-10	-9.561	-9.561	0.000	(0)
ZnF+	1.575e-10	1.381e-10	-9.803	-9.860	-0.057	(0)
BF(OH)3-	3.314e-11	2.938e-11	-10.480	-10.532	-0.052	(0)
CoF+	2.158e-11	1.892e-11	-10.666	-10.723	-0.057	(0)
NiF+	1.246e-11	1.093e-11	-10.904	-10.961	-0.057	(0)
CuF+	9.650e-12	8.461e-12	-11.015	-11.073	-0.057	(0)
CdF+	3.543e-12	3.107e-12	-11.451	-11.508	-0.057	(0)
PbF+	2.262e-12	1.983e-12	-11.646	-11.703	-0.057	(0)
AlF2+	1.578e-12	1.415e-12	-11.802	-11.849	-0.048	(0)
AlF3	3.837e-13	3.837e-13	-12.416	-12.416	0.000	(0)
AlF+2	2.557e-13	1.649e-13	-12.592	-12.783	-0.190	(0)
CrF+2	4.239e-14	2.506e-14	-13.373	-13.601	-0.228	(0)
HF2-	2.526e-14	2.249e-14	-13.598	-13.648	-0.051	(0)
AlF4-	4.638e-15	4.143e-15	-14.334	-14.383	-0.049	(0)
PbF2	8.410e-16	8.410e-16	-15.075	-15.075	0.000	(0)
BF2(OH)2-	6.576e-16	5.831e-16	-15.182	-15.234	-0.052	(0)
UO2F+	3.290e-16	2.885e-16	-15.483	-15.540	-0.057	(0)
CdF2	1.336e-16	1.336e-16	-15.874	-15.874	0.000	(0)
FeF+2	6.414e-17	4.114e-17	-16.193	-16.386	-0.193	(0)
FeF2+	2.651e-17	2.372e-17	-16.577	-16.625	-0.048	(0)
UO2F2	1.793e-17	1.793e-17	-16.746	-16.746	0.000	(0)
FeF3	7.211e-19	7.211e-19	-18.142	-18.142	0.000	(0)
VO2F	5.184e-19	5.184e-19	-18.285	-18.285	0.000	(0)
H2F2	2.019e-19	2.019e-19	-18.695	-18.695	0.000	(0)
UO2F3-	1.106e-19	9.702e-20	-18.956	-19.013	-0.057	(0)
PbF3-	3.919e-20	3.437e-20	-19.407	-19.464	-0.057	(0)
VOF+	5.881e-21	5.157e-21	-20.231	-20.288	-0.057	(0)
VO2F2-	4.624e-21	4.055e-21	-20.335	-20.392	-0.057	(0)

BF3OH-	4.749e-23	4.211e-23	-22.323	-22.376	-0.052	(0)
VOF2	4.166e-23	4.166e-23	-22.380	-22.380	0.000	(0)
UO2F4-2	2.809e-23	1.660e-23	-22.551	-22.780	-0.228	(0)
VO2F3-2	1.843e-24	1.090e-24	-23.734	-23.963	-0.228	(0)
PbF4-2	5.995e-25	3.544e-25	-24.222	-24.450	-0.228	(0)
VOF3-	3.632e-26	3.185e-26	-25.440	-25.497	-0.057	(0)
BF4-	4.338e-29	3.846e-29	-28.363	-28.415	-0.052	(0)
VO2F4-3	3.770e-29	1.155e-29	-28.424	-28.937	-0.514	(0)
VOF4-2	4.685e-30	2.770e-30	-29.329	-29.558	-0.228	(0)
UF3+	9.582e-39	8.402e-39	-38.019	-38.076	-0.057	(0)
UF2+2	4.162e-39	2.461e-39	-38.381	-38.609	-0.228	(0)
UF+3	0.000e+00	0.000e+00	-40.529	-41.042	-0.514	(0)
UF4	0.000e+00	0.000e+00	-40.702	-40.702	0.000	(0)
UF5-	0.000e+00	0.000e+00	-43.714	-43.771	-0.057	(0)
UF6-2	0.000e+00	0.000e+00	-45.729	-45.958	-0.228	(0)
Fe(2)	1.915e-08					
Fe+2	1.554e-08	9.187e-09	-7.809	-8.037	-0.228	(0)
FeSO4	2.796e-09	2.796e-09	-8.553	-8.553	0.000	(0)
FeOH+	4.776e-10	4.274e-10	-9.321	-9.369	-0.048	(0)
FeHCO3+	3.317e-10	2.978e-10	-9.479	-9.526	-0.047	(0)
Fe(OH)2	3.968e-13	3.968e-13	-12.401	-12.401	0.000	(0)
Fe(OH)3-	1.639e-13	1.467e-13	-12.785	-12.834	-0.048	(0)
Fe(HS)2	0.000e+00	0.000e+00	-135.701	-135.701	0.000	(0)
Fe(HS)3-	0.000e+00	0.000e+00	-201.915	-201.972	-0.057	(0)
Fe(3)	1.508e-06					
Fe(OH)3	7.500e-07	7.500e-07	-6.125	-6.125	0.000	(0)
Fe(OH)2+	6.667e-07	5.975e-07	-6.176	-6.224	-0.048	(0)
Fe(OH)4-	9.107e-08	8.161e-08	-7.041	-7.088	-0.048	(0)
FeOH+2	2.049e-12	1.314e-12	-11.689	-11.881	-0.193	(0)
FeF+2	6.414e-17	4.114e-17	-16.193	-16.386	-0.193	(0)
FeSO4+	2.707e-17	2.423e-17	-16.568	-16.616	-0.048	(0)
FeF2+	2.651e-17	2.372e-17	-16.577	-16.625	-0.048	(0)
Fe+3	4.848e-18	1.741e-18	-17.314	-17.759	-0.445	(0)
Fe(SO4)2-	7.323e-19	6.421e-19	-18.135	-18.192	-0.057	(0)
FeF3	7.211e-19	7.211e-19	-18.142	-18.142	0.000	(0)
FeCl+2	3.125e-20	2.004e-20	-19.505	-19.698	-0.193	(0)
Fe2(OH)2+4	4.681e-22	5.718e-23	-21.330	-22.243	-0.913	(0)
FeHSeO3+2	1.075e-22	6.357e-23	-21.968	-22.197	-0.228	(0)
FeCl2+	3.812e-23	3.412e-23	-22.419	-22.467	-0.048	(0)
Fe3(OH)4+5	1.319e-26	4.938e-28	-25.880	-27.306	-1.427	(0)
FeCl3	1.300e-27	1.300e-27	-26.886	-26.886	0.000	(0)
H(0)	2.516e-26					
H2	1.258e-26	1.262e-26	-25.900	-25.899	0.001	(0)
K	5.432e-04					
K+	5.385e-04	4.806e-04	-3.269	-3.318	-0.049	(0)
KSO4-	4.707e-06	4.218e-06	-5.327	-5.375	-0.048	(0)
KCrO4-	4.753e-20	4.167e-20	-19.323	-19.380	-0.057	(0)
Mg	9.127e-04					
Mg+2	7.792e-04	4.943e-04	-3.108	-3.306	-0.198	(0)
MgSO4	1.115e-04	1.115e-04	-3.953	-3.953	0.000	(0)
MgHCO3+	1.461e-05	1.302e-05	-4.835	-4.885	-0.050	(0)
MgCO3	5.762e-06	5.762e-06	-5.239	-5.239	0.000	(0)
MgF+	1.338e-06	1.195e-06	-5.874	-5.923	-0.049	(0)
MgOH+	2.557e-07	2.300e-07	-6.592	-6.638	-0.046	(0)
MgH2BO3+	4.454e-09	3.949e-09	-8.351	-8.404	-0.052	(0)
Mn(2)	1.651e-06					
Mn+2	1.414e-06	8.362e-07	-5.849	-6.078	-0.228	(0)
MnSO4	1.844e-07	1.844e-07	-6.734	-6.734	0.000	(0)
MnHCO3+	4.801e-08	4.296e-08	-7.319	-7.367	-0.048	(0)
MnOH+	2.743e-09	2.455e-09	-8.562	-8.610	-0.048	(0)
MnF+	8.014e-10	7.172e-10	-9.096	-9.144	-0.048	(0)
MnCl+	4.483e-10	4.012e-10	-9.348	-9.397	-0.048	(0)
MnCl2	2.160e-13	2.160e-13	-12.666	-12.666	0.000	(0)
MnCl3-	2.533e-17	2.267e-17	-16.596	-16.645	-0.048	(0)
Mn(OH)3-	2.315e-17	2.072e-17	-16.635	-16.684	-0.048	(0)
MnSeO4	9.963e-18	9.963e-18	-17.002	-17.002	0.000	(0)

Mn(OH)4-2	1.219e-22	7.819e-23	-21.914	-22.107	-0.193	(0)
MnSe	2.267e-35	2.267e-35	-34.644	-34.644	0.000	(0)
Mn(3)	2.122e-28					
Mn+3	2.122e-28	7.621e-29	-27.673	-28.118	-0.445	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-46.550	-46.743	-0.193	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-52.754	-52.805	-0.051	(0)
Mo	5.152e-08					
MoO4-2	5.152e-08	3.268e-08	-7.288	-7.486	-0.198	(0)
HMoO4-	6.388e-12	5.602e-12	-11.195	-11.252	-0.057	(0)
H2MoO4	3.534e-16	3.534e-16	-15.452	-15.452	0.000	(0)
AlMo6O21-3	0.000e+00	0.000e+00	-52.913	-53.426	-0.514	(0)
Mo7O24-6	0.000e+00	0.000e+00	-61.873	-63.928	-2.054	(0)
HMo7O24-5	0.000e+00	0.000e+00	-64.179	-65.606	-1.427	(0)
H2Mo7O24-4	0.000e+00	0.000e+00	-67.975	-68.888	-0.913	(0)
H3Mo7O24-3	0.000e+00	0.000e+00	-73.194	-73.707	-0.514	(0)
Na	2.393e-03					
Na+	2.374e-03	2.119e-03	-2.625	-2.674	-0.049	(0)
NaSO4-	1.574e-05	1.411e-05	-4.803	-4.851	-0.048	(0)
NaHCO3	3.068e-06	3.068e-06	-5.513	-5.513	0.000	(0)
NaCO3-	6.169e-07	5.529e-07	-6.210	-6.257	-0.048	(0)
NaF	2.880e-08	2.880e-08	-7.541	-7.541	0.000	(0)
NaH2BO3	7.736e-10	7.736e-10	-9.111	-9.111	0.000	(0)
NaCrO4-	2.802e-19	2.457e-19	-18.553	-18.610	-0.057	(0)
Ni	5.510e-08					
Ni+2	3.183e-08	2.019e-08	-7.497	-7.695	-0.198	(0)
NiCO3	1.056e-08	1.056e-08	-7.976	-7.976	0.000	(0)
NiHCO3+	7.311e-09	6.410e-09	-8.136	-8.193	-0.057	(0)
NiSO4	4.995e-09	4.995e-09	-8.301	-8.301	0.000	(0)
NiOH+	3.388e-10	2.971e-10	-9.470	-9.527	-0.057	(0)
Ni(OH)2	2.758e-11	2.758e-11	-10.559	-10.559	0.000	(0)
NiCl+	2.245e-11	1.969e-11	-10.649	-10.706	-0.057	(0)
NiF+	1.246e-11	1.093e-11	-10.904	-10.961	-0.057	(0)
Ni(SO4)2-2	3.469e-13	2.051e-13	-12.460	-12.688	-0.228	(0)
Ni(OH)3-	3.676e-14	3.223e-14	-13.435	-13.492	-0.057	(0)
NiCl2	3.778e-17	3.778e-17	-16.423	-16.423	0.000	(0)
NiSeO4	4.181e-19	4.181e-19	-18.379	-18.379	0.000	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-40.498	-40.497	0.001	(0)
Pb	6.905e-08					
PbCO3	5.503e-08	5.503e-08	-7.259	-7.259	0.000	(0)
PbOH+	4.374e-09	3.835e-09	-8.359	-8.416	-0.057	(0)
Pb(CO3)2-2	3.763e-09	2.224e-09	-8.425	-8.653	-0.228	(0)
PbHCO3+	2.850e-09	2.499e-09	-8.545	-8.602	-0.057	(0)
Pb+2	2.059e-09	1.306e-09	-8.686	-8.884	-0.198	(0)
PbSO4	7.933e-10	7.933e-10	-9.101	-9.101	0.000	(0)
Pb(OH)2	1.417e-10	1.417e-10	-9.849	-9.849	0.000	(0)
PbCl+	2.014e-11	1.766e-11	-10.696	-10.753	-0.057	(0)
Pb(SO4)2-2	1.002e-11	5.926e-12	-10.999	-11.227	-0.228	(0)
PbF+	2.262e-12	1.983e-12	-11.646	-11.703	-0.057	(0)
Pb(OH)3-	1.889e-13	1.656e-13	-12.724	-12.781	-0.057	(0)
PbCl2	3.007e-14	3.007e-14	-13.522	-13.522	0.000	(0)
PbF2	8.410e-16	8.410e-16	-15.075	-15.075	0.000	(0)
Pb2OH+3	2.591e-16	7.940e-17	-15.587	-16.100	-0.514	(0)
Pb(OH)4-2	8.020e-17	4.741e-17	-16.096	-16.324	-0.228	(0)
PbCl3-	5.203e-18	4.562e-18	-17.284	-17.341	-0.057	(0)
Pb3(OH)4+2	8.857e-19	5.236e-19	-18.053	-18.281	-0.228	(0)
PbF3-	3.919e-20	3.437e-20	-19.407	-19.464	-0.057	(0)
PbCl4-2	1.344e-21	7.947e-22	-20.872	-21.100	-0.228	(0)
Pb4(OH)4+4	4.448e-23	5.433e-24	-22.352	-23.265	-0.913	(0)
PbF4-2	5.995e-25	3.544e-25	-24.222	-24.450	-0.228	(0)
Pb(HS)2	0.000e+00	0.000e+00	-130.229	-130.229	0.000	(0)
Pb(HS)3-	0.000e+00	0.000e+00	-197.179	-197.236	-0.057	(0)
S(-2)	0.000e+00					
HS-	0.000e+00	0.000e+00	-68.250	-68.307	-0.057	(0)

CdHS+	0.000e+00	0.000e+00	-68.283	-68.340	-0.057	(0)
H2S	0.000e+00	0.000e+00	-69.352	-69.352	0.000	(0)
S5-2	0.000e+00	0.000e+00	-69.379	-69.608	-0.228	(0)
S6-2	0.000e+00	0.000e+00	-69.895	-70.124	-0.228	(0)
S4-2	0.000e+00	0.000e+00	-69.975	-70.203	-0.228	(0)
S3-2	0.000e+00	0.000e+00	-70.781	-71.009	-0.228	(0)
S2-2	0.000e+00	0.000e+00	-71.797	-72.025	-0.228	(0)
S-2	0.000e+00	0.000e+00	-77.350	-77.543	-0.193	(0)
Cu(S4)2-3	0.000e+00	0.000e+00	-125.642	-125.921	-0.278	(0)
CuS4S5-3	0.000e+00	0.000e+00	-126.383	-126.651	-0.268	(0)
ZnS(HS)-	0.000e+00	0.000e+00	-128.176	-128.233	-0.057	(0)
Cd(HS)2	0.000e+00	0.000e+00	-129.444	-129.444	0.000	(0)
Pb(HS)2	0.000e+00	0.000e+00	-130.229	-130.229	0.000	(0)
Zn(HS)2	0.000e+00	0.000e+00	-130.288	-130.288	0.000	(0)
Fe(HS)2	0.000e+00	0.000e+00	-135.701	-135.701	0.000	(0)
Cu(HS)3-	0.000e+00	0.000e+00	-187.172	-187.229	-0.057	(0)
Zn(HS)3-	0.000e+00	0.000e+00	-195.258	-195.315	-0.057	(0)
Cd(HS)3-	0.000e+00	0.000e+00	-195.794	-195.851	-0.057	(0)
ZnS(HS)2-2	0.000e+00	0.000e+00	-197.002	-197.230	-0.228	(0)
Pb(HS)3-	0.000e+00	0.000e+00	-197.179	-197.236	-0.057	(0)
Fe(HS)3-	0.000e+00	0.000e+00	-201.915	-201.972	-0.057	(0)
Cd(HS)4-2	0.000e+00	0.000e+00	-261.734	-261.962	-0.228	(0)
Zn(HS)4-2	0.000e+00	0.000e+00	-264.854	-265.082	-0.228	(0)
S(6)	2.432e-03					
SO4-2	1.954e-03	1.240e-03	-2.709	-2.907	-0.198	(0)
CaSO4	3.451e-04	3.451e-04	-3.462	-3.462	0.000	(0)
MgSO4	1.115e-04	1.115e-04	-3.953	-3.953	0.000	(0)
NaSO4-	1.574e-05	1.411e-05	-4.803	-4.851	-0.048	(0)
KSO4-	4.707e-06	4.218e-06	-5.327	-5.375	-0.048	(0)
MnSO4	1.844e-07	1.844e-07	-6.734	-6.734	0.000	(0)
ZnSO4	8.716e-08	8.716e-08	-7.060	-7.060	0.000	(0)
CoSO4	6.870e-09	6.870e-09	-8.163	-8.163	0.000	(0)
NiSO4	4.995e-09	4.995e-09	-8.301	-8.301	0.000	(0)
FeSO4	2.796e-09	2.796e-09	-8.553	-8.553	0.000	(0)
CdSO4	2.644e-09	2.644e-09	-8.578	-8.578	0.000	(0)
CuSO4	1.768e-09	1.768e-09	-8.753	-8.753	0.000	(0)
Zn(SO4)2-2	1.592e-09	9.412e-10	-8.798	-9.026	-0.228	(0)
HSO4-	1.168e-09	1.044e-09	-8.932	-8.981	-0.049	(0)
PbSO4	7.933e-10	7.933e-10	-9.101	-9.101	0.000	(0)
Cd(SO4)2-2	7.480e-11	4.422e-11	-10.126	-10.354	-0.228	(0)
CrOHSO4	5.521e-11	5.521e-11	-10.258	-10.258	0.000	(0)
Pb(SO4)2-2	1.002e-11	5.926e-12	-10.999	-11.227	-0.228	(0)
Ni(SO4)2-2	3.469e-13	2.051e-13	-12.460	-12.688	-0.228	(0)
CrSO4+	2.423e-14	2.125e-14	-13.616	-13.673	-0.057	(0)
AlSO4+	8.246e-15	7.366e-15	-14.084	-14.133	-0.049	(0)
UO2SO4	1.820e-16	1.820e-16	-15.740	-15.740	0.000	(0)
Al(SO4)2-	1.095e-16	9.786e-17	-15.960	-16.009	-0.049	(0)
FeSO4+	2.707e-17	2.423e-17	-16.568	-16.616	-0.048	(0)
UO2(SO4)2-2	5.032e-18	2.975e-18	-17.298	-17.526	-0.228	(0)
Cr2(OH)2SO4+2	1.584e-18	9.365e-19	-17.800	-18.028	-0.228	(0)
Fe(SO4)2-	7.323e-19	6.421e-19	-18.135	-18.192	-0.057	(0)
VO2SO4-	4.631e-19	4.061e-19	-18.334	-18.391	-0.057	(0)
Cr2(OH)2(SO4)2	6.897e-20	6.897e-20	-19.161	-19.161	0.000	(0)
VOSO4	1.363e-20	1.363e-20	-19.866	-19.866	0.000	(0)
CrO3SO4-2	3.580e-27	2.117e-27	-26.446	-26.674	-0.228	(0)
VSO4+	4.811e-34	4.218e-34	-33.318	-33.375	-0.057	(0)
U(SO4)2	0.000e+00	0.000e+00	-40.989	-40.989	0.000	(0)
USO4+2	0.000e+00	0.000e+00	-41.754	-41.982	-0.228	(0)
Se(-2)	6.467e-32					
HSe-	6.464e-32	5.668e-32	-31.190	-31.247	-0.057	(0)
MnSe	2.267e-35	2.267e-35	-34.644	-34.644	0.000	(0)
H2Se	3.790e-36	3.790e-36	-35.421	-35.421	0.000	(0)
Se-2	1.113e-38	6.580e-39	-37.954	-38.182	-0.228	(0)
Se(4)	2.655e-08					
HSeO3-	1.575e-08	1.381e-08	-7.803	-7.860	-0.057	(0)
SeO3-2	1.080e-08	6.384e-09	-7.967	-8.195	-0.228	(0)
H2SeO3	5.076e-14	5.076e-14	-13.294	-13.294	0.000	(0)
Cd(SeO3)2-2	5.169e-19	3.056e-19	-18.287	-18.515	-0.228	(0)
FeHSeO3+2	1.075e-22	6.357e-23	-21.968	-22.197	-0.228	(0)
Se(6)	6.979e-14					
SeO4-2	6.978e-14	4.427e-14	-13.156	-13.354	-0.198	(0)
MnSeO4	9.963e-18	9.963e-18	-17.002	-17.002	0.000	(0)
ZnSeO4	2.203e-18	2.203e-18	-17.657	-17.657	0.000	(0)
CoSeO4	6.162e-19	6.162e-19	-18.210	-18.210	0.000	(0)
NiSeO4	4.181e-19	4.181e-19	-18.379	-18.379	0.000	(0)
CdSeO4	7.499e-20	7.499e-20	-19.125	-19.125	0.000	(0)
HSeO4-	2.180e-20	1.911e-20	-19.662	-19.719	-0.057	(0)
Zn(SeO4)2-2	1.673e-31	9.888e-32	-30.777	-31.005	-0.228	(0)
U(3)	0.000e+00					
U+3	0.000e+00	0.000e+00	-57.268	-57.781	-0.514	(0)
U(4)	3.846e-19					
U(OH)5-	3.845e-19	3.372e-19	-18.415	-18.472	-0.057	(0)
U(OH)4	1.217e-22	1.217e-22	-21.915	-21.915	0.000	(0)
U(OH)3+	4.370e-27	3.832e-27	-26.359	-26.417	-0.057	(0)
U(OH)2+2	2.582e-32	1.527e-32	-31.588	-31.816	-0.228	(0)
UOH+3	2.021e-38	6.195e-39	-37.694	-38.208	-0.514	(0)
UF3+	9.582e-39	8.402e-39	-38.019	-38.076	-0.057	(0)
UF2+2	4.162e-39	2.461e-39	-38.381	-38.609	-0.228	(0)
UF+3	0.000e+00	0.000e+00	-40.529	-41.042	-0.514	(0)
UF4	0.000e+00	0.000e+00	-40.702	-40.702	0.000	(0)
U(SO4)2	0.000e+00	0.000e+00	-40.989	-40.989	0.000	(0)
USO4+2	0.000e+00	0.000e+00	-41.754	-41.982	-0.228	(0)
UF5-	0.000e+00	0.000e+00	-43.714	-43.771	-0.057	(0)
U+4	0.000e+00	0.000e+00	-44.763	-45.676	-0.913	(0)
UF6-2	0.000e+00	0.000e+00	-45.729	-45.958	-0.228	(0)
UCl+3	0.000e+00	0.000e+00	-46.881	-47.395	-0.514	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-165.616	-170.239	-4.623	(0)
U(5)	3.305e-17					
UO2+	3.305e-17	2.898e-17	-16.481	-16.538	-0.057	(0)
U(6)	1.127e-08					
UO2(CO3)3-4	8.702e-09	1.063e-09	-8.060	-8.973	-0.913	(0)
UO2(CO3)2-2	2.560e-09	1.513e-09	-8.592	-8.820	-0.228	(0)
UO2CO3	5.412e-12	5.412e-12	-11.267	-11.267	0.000	(0)
UO2OH+	1.628e-14	1.427e-14	-13.788	-13.846	-0.057	(0)
UO2F+	3.290e-16	2.885e-16	-15.483	-15.540	-0.057	(0)
UO2SO4	1.820e-16	1.820e-16	-15.740	-15.740	0.000	(0)
UO2+2	1.529e-16	9.700e-17	-15.816	-16.013	-0.198	(0)
UO2F2	1.793e-17	1.793e-17	-16.746	-16.746	0.000	(0)
UO2(SO4)2-2	5.032e-18	2.975e-18	-17.298	-17.526	-0.228	(0)
UO2F3-	1.106e-19	9.702e-20	-18.956	-19.013	-0.057	(0)
UO2Cl+	6.837e-20	5.995e-20	-19.165	-19.222	-0.057	(0)
(UO2)2(OH)2+2	5.718e-22	3.380e-22	-21.243	-21.471	-0.228	(0)
UO2F4-2	2.809e-23	1.660e-23	-22.551	-22.780	-0.228	(0)
(UO2)3(OH)5+	5.701e-24	4.999e-24	-23.244	-23.301	-0.057	(0)
V(2)	7.462e-40					
VOH+	7.462e-40	6.543e-40	-39.127	-39.184	-0.057	(0)
V+2	0.000e+00	0.000e+00	-40.534	-40.762	-0.228	(0)
V(3)	9.282e-13					
V(OH)3	9.282e-13	9.282e-13	-12.032	-12.032	0.000	(0)
V(OH)2+	5.892e-24	5.167e-24	-23.230	-23.287	-0.057	(0)
VOH+2	7.141e-28	4.222e-28	-27.146	-27.374	-0.228	(0)
V+3	2.352e-33	7.208e-34	-32.629	-33.142	-0.514	(0)
VSO4+	4.811e-34	4.218e-34	-33.318	-33.375	-0.057	(0)
V2(OH)3+3	0.000e+00	0.000e+00	-51.696	-52.209	-0.514	(0)
V2(OH)2+4	0.000e+00	0.000e+00	-53.036	-53.949	-0.913	(0)
V(4)	1.070e-17					
V(OH)3+	1.061e-17	9.304e-18	-16.974	-17.031	-0.057	(0)
VO+2	6.750e-20	3.991e-20	-19.171	-19.399	-0.228	(0)
VOSO4	1.363e-20	1.363e-20	-19.866	-19.866	0.000	(0)
VOF+	5.881e-21	5.157e-21	-20.231	-20.288	-0.057	(0)
VOCl+	4.866e-23	4.266e-23	-22.313	-22.370	-0.057	(0)
VOF2	4.166e-23	4.166e-23	-22.380	-22.380	0.000	(0)
VOF3-	3.632e-26	3.185e-26	-25.440	-25.497	-0.057	(0)
H2V2O4+2	7.341e-30	4.340e-30	-29.134	-29.363	-0.228	(0)
VOF4-2	4.685e-30	2.770e-30	-29.329	-29.558	-0.228	(0)
V(5)	1.513e-08					
HVO4-	1.056e-08	9.261e-09	-7.976	-8.033	-0.057	(0)
HVO4-2	4.568e-09	2.701e-09	-8.340	-8.569	-0.228	(0)
H3VO4	7.978e-13	7.978e-13	-12.098	-12.098	0.000	(0)
H3V2O7-	5.442e-14	4.771e-14	-13.264	-13.321	-0.057	(0)
HV2O7-3	2.766e-14	8.477e-15	-13.558	-14.072	-0.514	(0)
VO4-3	5.127e-15	1.571e-15	-14.290	-14.804	-0.514	(0)
V2O7-4	2.168e-16	2.649e-17	-15.664	-16.577	-0.913	(0)
VO2+	1.537e-17	1.372e-17	-16.813	-16.863	-0.049	(0)
V3O9-3	2.716e-18	8.323e-19	-17.566	-18.080	-0.514	(0)
VO2F	5.184e-19	5.184e-19	-18.285	-18.285	0.000	(0)
VO2SO4-	4.631e-19	4.061e-19	-18.334	-18.391	-0.057	(0)
VO2F2-	4.624e-21	4.055e-21	-20.335	-20.392	-0.057	(0)
V4O12-4	2.631e-23	3.214e-24	-22.580	-23.493	-0.913	(0)
VO2F3-2	1.843e-24	1.090e-24	-23.734	-23.963	-0.228	(0)
VO2F4-3	3.770e-29	1.155e-29	-28.424	-28.937	-0.514	(0)
V10O28-6	0.000e+00	0.000e+00	-61.631	-63.686	-2.054	(0)
HV10O28-5	0.000e+00	0.000e+00	-62.137	-63.564	-1.427	(0)
H2V10O28-4	0.000e+00	0.000e+00	-65.508	-66.421	-0.913	(0)
Zn	9.350e-07					
Zn+2	5.065e-07	3.213e-07	-6.295	-6.493	-0.198	(0)
ZnCO3	2.591e-07	2.591e-07	-6.586	-6.586	0.000	(0)
ZnSO4	8.716e-08	8.716e-08	-7.060	-7.060	0.000	(0)
ZnOH+	4.283e-08	3.755e-08	-7.368	-7.425	-0.057	(0)
ZnHCO3+	2.984e-08	2.617e-08	-7.525	-7.582	-0.057	(0)
Zn(OH)2	6.956e-09	6.956e-09	-8.158	-8.158	0.000	(0)
Zn(SO4)2-2	1.592e-09	9.412e-10	-8.798	-9.026	-0.228	(0)
ZnOHCl	4.706e-10	4.706e-10	-9.327	-9.327	0.000	(0)
ZnCl+	3.449e-10	3.076e-10	-9.462	-9.512	-0.050	(0)
ZnF+	1.575e-10	1.381e-10	-9.803	-9.860	-0.057	(0)
Zn(OH)3-	4.647e-11	4.075e-11	-10.333	-10.390	-0.057	(0)
ZnCl2	1.858e-13	1.858e-13	-12.731	-12.731	0.000	(0)
Zn(OH)4-2	3.207e-15	1.896e-15	-14.494	-14.722	-0.228	(0)
ZnCl3-	6.307e-17	5.624e-17	-16.200	-16.250	-0.050	(0)
ZnSeO4	2.203e-18	2.203e-18	-17.657	-17.657	0.000	(0)
ZnCl4-2	1.671e-20	1.072e-20	-19.777	-19.970	-0.193	(0)
Zn(SeO4)2-2	1.673e-31	9.888e-32	-30.777	-31.005	-0.228	(0)
ZnS(HS)-	0.000e+00	0.000e+00	-128.176	-128.233	-0.057	(0)
Zn(HS)2	0.000e+00	0.000e+00	-130.288	-130.288	0.000	(0)
Zn(HS)3-	0.000e+00	0.000e+00	-195.258	-195.315	-0.057	(0)
ZnS(HS)2-2	0.000e+00	0.000e+00	-197.002	-197.230	-0.228	(0)
Zn(HS)4-2	0.000e+00	0.000e+00	-264.854	-265.082	-0.228	(0)

----------Saturation indices----------

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(am)	-1.72	9.08	10.80	Al(OH)3
Al2(MoO4)3	-55.06	-52.69	2.37	Al2(MoO4)3
Al2O3	-1.50	18.16	19.65	Al2O3
Al4(OH)10SO4	-5.42	17.28	22.70	Al4(OH)10SO4
AlAs O4:2H2O	-9.68	-4.88	4.80	AlAs O4:2H2O
AlOHSO4	-6.73	-9.96	-3.23	AlOHSO4
Alunite	-4.69	-6.09	-1.40	KAl3(SO4)2(OH)6
Anglesite	-4.00	-11.79	-7.79	PbSO4
Anhydrite	-1.46	-5.82	-4.36	CaSO4
Anilite	-43.65	-75.53	-31.88	Cu0.25Cu1.5S
Antlerite	-4.05	4.73	8.79	Cu3(OH)4SO4
Aragonite	0.53	-7.77	-8.30	CaCO3
Arsenolite	-68.49	-71.25	-2.76	As4O6
Artinite	-4.94	4.66	9.60	MgCO3:Mg(OH)2:3H2O
As2O5	-34.63	-27.92	6.71	As2O5
Atacamite	-3.03	4.36	7.39	Cu2(OH)3Cl
Azurite	-1.29	-18.20	-16.91	Cu3(OH)2(CO3)2
Ba(OH)2:8H2O	-14.77	9.62	24.39	Ba(OH)2:8H2O
Ba2V2O7:2H2O	-14.22	1.65	15.87	Ba2V2O7:2H2O
Ba3(AsO4)2	9.86	0.95	-8.91	Ba3(AsO4)2
Ba3(VO4)2:4H2O	-21.67	11.27	32.94	Ba3(VO4)2:4H2O
BaCrO4	-13.47	-23.14	-9.67	BaCrO4
BaF2	-10.02	-15.84	-5.82	BaF2
BaMoO4	-7.03	-13.99	-6.96	BaMoO4
Barite	0.57	-9.41	-9.98	BaSO4
BaS	-82.93	-66.75	16.18	BaS
BaSeO3	-8.13	-6.30	1.83	BaSeO3
BaSeO4	-12.40	-19.86	-7.46	BaSeO4
Bianchite	-7.64	-9.40	-1.76	ZnSO4:6H2O
Birnessite	-10.64	7.45	18.09	MnO2
Bixbyite	-7.20	-7.85	-0.64	Mn2O3
BlaubleiI	-45.23	-69.39	-24.16	Cu0.9Cu0.2S
BlaubleiII	-44.95	-72.23	-27.28	Cu0.6Cu0.8S
Boehmite	0.50	9.08	8.58	AlOOH
Brochantite	-2.56	12.66	15.22	Cu4(OH)6SO4
Brucite	-4.02	12.82	16.84	Mg(OH)2
Bunsenite	-4.01	8.43	12.45	NiO
Ca(VO3)2	-10.04	-4.38	5.66	Ca(VO3)2
Ca2V2O7	-8.67	8.83	17.50	Ca2V2O7
Ca2V2O7:2H2O	-12.72	8.83	21.55	Ca2V2O7:2H2O
Ca3(AsO4)2:4H2O	-10.58	11.72	22.30	Ca3(AsO4)2:4H2O
Ca3(VO4)2	-16.91	22.05	38.96	Ca3(VO4)2
Ca3(VO4)2:4H2O	-17.81	22.05	39.86	Ca3(VO4)2:4H2O
CaCrO4	-17.28	-19.55	-2.27	CaCrO4
Calcite	0.71	-7.77	-8.48	CaCO3
CaMoO4	-2.45	-10.40	-7.95	CaMoO4
Carnotite	-4.17	-3.94	0.23	KUO2VO4
CaSeO3:2H2O	-5.52	-2.71	2.81	CaSeO3:2H2O
CaSeO4:2H2O	-13.25	-16.27	-3.02	CaSeO4:2H2O
Cd(BO2)2	-12.68	-2.84	9.84	Cd(BO2)2
Cd(OH)2	-5.56	8.09	13.64	Cd(OH)2
Cd(OH)2(am)	-5.64	8.09	13.73	Cd(OH)2
Cd3(OH)2(SO4)2	-20.52	-13.81	6.71	Cd3(OH)2(SO4)2
Cd3(OH)4SO4	-17.33	5.23	22.56	Cd3(OH)4SO4
Cd4(OH)6SO4	-15.08	13.32	28.40	Cd4(OH)6SO4
CdCl2	-14.22	-14.88	-0.66	CdCl2
CdCl2:1H2O	-13.19	-14.88	-1.69	CdCl2:1H2O
CdCl2:2.5H2O	-12.97	-14.88	-1.91	CdCl2:2.5H2O
CdF2	-16.16	-17.37	-1.21	CdF2
Cdmetal(alpha)	-28.18	-14.66	13.51	Cd
Cdmetal(gamma)	-28.28	-14.66	13.62	Cd
CdMoO4	-1.38	-15.53	-14.15	CdMoO4
CdOHCl	-6.93	-3.40	3.54	CdOHCl
CdSe	-11.02	-31.22	-20.20	CdSe
CdSeO4:2H2O	-19.55	-21.40	-1.85	CdSeO4:2H2O
CdSO4	-10.78	-10.95	-0.17	CdSO4
CdSO4:1H2O	-9.22	-10.95	-1.73	CdSO4:1H2O
CdSO4:2.67H2O	-9.07	-10.95	-1.87	CdSO4:2.67H2O
Cerussite	-0.61	-13.74	-13.13	PbCO3
CH4(g)	-70.93	-111.98	-41.05	CH4
Chalcanthite	-8.47	-11.11	-2.64	CuSO4:5H2O
Chalcocite	-42.97	-77.89	-34.92	Cu2S
Chalcopyrite	-101.46	-136.73	-35.27	CuFeS2
Claudetite	-68.18	-71.25	-3.06	As4O6
Clausthalite	-4.97	-32.07	-27.10	PbSe
Co(BO2)2	-29.43	-2.36	27.07	Co(BO2)2
Co(OH)2	-4.52	8.57	13.09	Co(OH)2
Co(OH)3	-10.14	-12.45	-2.31	Co(OH)3
CO2(g)	-2.84	-20.98	-18.15	CO2
Co3(AsO4)2	-15.24	-2.20	13.03	Co3(AsO4)2
Co3O4	-5.84	-16.33	-10.50	Co3O4
CoCl2	-22.66	-14.39	8.27	CoCl2

CoCl2:6H2O	-16.93	-14.39	2.54	CoCl2:6H2O
CoCO3	-2.43	-12.41	-9.98	CoCO3
CoF2	-15.29	-16.89	-1.60	CoF2
CoF3	-49.19	-50.65	-1.46	CoF3
CoFe2O4	24.97	21.44	-3.53	CoFe2O4
CoMoO4	-7.28	-15.04	-7.76	CoMoO4
CoO	-5.01	8.57	13.59	CoO
CoS(alpha)	-60.36	-67.80	-7.44	CoS
CoS(beta)	-56.73	-67.80	-11.07	CoS
CoSe	-14.54	-30.74	-16.20	CoSe
CoSeO3	-8.67	-7.35	1.32	CoSeO3
CoSeO4:6H2O	-19.38	-20.91	-1.53	CoSeO4:6H2O
CoSO4	-13.27	-10.46	2.80	CoSO4
CoSO4:6H2O	-7.99	-10.46	-2.47	CoSO4:6H2O
Cotunnite	-10.94	-15.72	-4.78	PbCl2
Covellite	-46.15	-68.45	-22.30	CuS
Cr(OH)2	-18.76	-7.94	10.82	Cr(OH)2
Cr(OH)3	-0.84	0.49	1.34	Cr(OH)3
Cr(OH)3(am)	1.24	0.49	-0.75	Cr(OH)3
Cr2O3	3.34	0.98	-2.36	Cr2O3
CrCl2	-45.00	-30.90	14.09	CrCl2
CrCl3	-49.07	-33.96	15.11	CrCl3
CrF3	-26.37	-37.70	-11.34	CrF3
Crmetal	-61.17	-30.69	30.48	Cr
CrO3	-29.55	-32.76	-3.21	CrO3
Cryolite	-17.30	-51.14	-33.84	Na3AlF6
Cu(OH)2	-0.75	7.92	8.67	Cu(OH)2
Cu2Se(alpha)	4.97	-40.83	-45.80	Cu2Se
Cu2SO4	-18.61	-20.56	-1.95	Cu2SO4
Cu3(AsO4)2:2H2O	-10.25	-4.15	6.10	Cu3(AsO4)2:2H2O
Cu3Se2	-8.73	-72.22	-63.49	Cu3Se2
CuCO3	-1.56	-13.06	-11.50	CuCO3
CuCrO4	-19.40	-24.84	-5.44	CuCrO4
CuF	-8.59	-13.49	-4.91	CuF
CuF2	-18.65	-17.54	1.12	CuF2
CuF2:2H2O	-12.99	-17.54	-4.55	CuF2:2H2O
Cumetal	-3.38	-12.14	-8.76	Cu
CuMoO4	-2.62	-15.69	-13.08	CuMoO4
CuOCuSO4	-13.49	-3.19	10.30	CuOCuSO4
Cupricferrite	14.81	20.79	5.99	CuFe2O4
Cuprite	-0.12	-1.52	-1.41	Cu2O
Cuprousferrite	14.59	5.67	-8.92	CuFeO2
CuSe	1.71	-31.39	-33.10	CuSe
CuSe2	-14.58	-47.95	-33.37	CuSe2
CuSeO3:2H2O	-8.51	-8.00	0.51	CuSeO3:2H2O
CuSeO4:5H2O	-19.12	-21.56	-2.44	CuSeO4:5H2O
CuSO4	-14.05	-11.11	2.94	CuSO4
Diaspore	2.21	9.08	6.87	AlOOH
Djurleite	-43.35	-77.27	-33.92	Cu0.066Cu1.868S
Dolomite(disordered)	0.61	-15.93	-16.54	CaMg(CO3)2
Dolomite(ordered)	1.16	-15.93	-17.09	CaMg(CO3)2
Epsomite	-4.09	-6.21	-2.13	MgSO4:7H2O
Fe(OH)2	-5.47	8.09	13.56	Fe(OH)2
Fe(OH)2.7Cl.3	6.03	2.99	-3.04	Fe(OH)2.7Cl.3
Fe(VO3)2	-5.78	-9.50	-3.72	Fe(VO3)2
Fe2(OH)4SeO3	-4.61	-3.05	1.55	Fe2(OH)4SeO3
Fe2(SeO3)3:2H2O	-14.28	-34.90	-20.63	Fe2(SeO3)3:2H2O
Fe2(SO4)3	-40.50	-44.24	-3.73	Fe2(SO4)3
Fe3(OH)8	0.74	20.96	20.22	Fe3(OH)8
FeAsO4:2H2O	-7.93	-7.53	0.40	FeAsO4:2H2O
FeCr2O4	1.87	9.07	7.20	FeCr2O4
FeMoO4	-5.43	-15.52	-10.09	FeMoO4
Ferrihydrite	3.24	6.44	3.19	Fe(OH)3
Ferroselite	-29.19	-47.78	-18.60	FeSe2
FeS(ppt)	-65.33	-68.28	-2.95	FeS
FeSe	-20.22	-31.22	-11.00	FeSe

Fluorite	-1.75	-12.25	-10.50	CaF2
Galena	-55.16	-69.13	-13.97	PbS
Gibbsite	0.79	9.08	8.29	Al(OH)3
Goethite	5.94	6.44	0.49	FeOOH
Goslarite	-7.39	-9.40	-2.01	ZnSO4:7H2O
Greenockite	-53.92	-68.28	-14.36	CdS
Greigite	-239.49	-284.53	-45.03	Fe3S4
Gummite	-7.56	0.12	7.67	UO3
Gypsum	-1.21	-5.82	-4.61	CaSO4:2H2O
H-Jarosite	-6.67	-18.77	-12.10	(H3O)Fe3(SO4)2(OH)6
H2MoO4	-10.74	-23.62	-12.88	H2MoO4
H2S(g)	-68.36	-76.37	-8.01	H2S
H2Se(g)	-34.35	-39.31	-4.96	H2Se
Halite	-7.70	-6.09	1.60	NaCl
Hausmannite	-8.13	52.90	61.03	Mn3O4
Hematite	14.29	12.87	-1.42	Fe2O3
Hercynite	3.36	26.25	22.89	FeAl2O4
Huntite	-2.28	-32.25	-29.97	CaMg3(CO3)4
Hydrocerussite	-1.46	-20.23	-18.77	Pb3(OH)2(CO3)2
Hydromagnesite	-11.05	-19.81	-8.77	Mg5(CO3)4(OH)2:4H2O
K-Alum	-19.08	-24.25	-5.17	KAl(SO4)2:12H2O
K-Jarosite	0.78	-14.02	-14.80	KFe3(SO4)2(OH)6
K2Cr2O7	-38.79	-56.03	-17.24	K2Cr2O7
K2CrO4	-22.75	-23.27	-0.51	K2CrO4
K2MoO4	-17.38	-14.12	3.26	K2MoO4
K2SeO4	-19.26	-19.99	-0.73	K2SeO4
Langite	-4.83	12.66	17.49	Cu4(OH)6SO4:H2O
Larnakite	-4.11	-4.55	-0.43	PbO:PbSO4
Laurionite	-4.86	-4.24	0.62	PbOHCl
Lepidocrocite	5.06	6.44	1.37	FeOOH
Lime	-19.49	13.21	32.70	CaO
Litharge	-5.45	7.25	12.69	PbO
Mackinawite	-64.68	-68.28	-3.60	FeS
Maghemite	6.48	12.87	6.39	Fe2O3
Magnesioferrite	8.83	25.69	16.86	Fe2MgO4
Magnesite	-0.70	-8.16	-7.46	MgCO3
Magnetite	17.56	20.96	3.40	Fe3O4
Malachite	0.17	-5.14	-5.31	Cu2(OH)2CO3
Manganite	-3.91	21.43	25.34	MnOOH
Massicot	-5.65	7.25	12.89	PbO
Matlockite	-8.00	-16.97	-8.97	PbClF
Melanothallite	-21.30	-15.04	6.26	CuCl2
Melanterite	-8.74	-10.94	-2.21	FeSO4:7H2O
Mg(OH)2(active)	-5.97	12.82	18.79	Mg(OH)2
Mg(VO3)2	-16.05	-4.77	11.28	Mg(VO3)2
Mg2V2O7	-18.31	8.05	26.36	Mg2V2O7
MgCr2O4	-2.39	13.81	16.20	MgCr2O4
MgCrO4	-25.32	-19.94	5.38	MgCrO4
MgF2	-4.51	-12.64	-8.13	MgF2
MgMoO4	-8.94	-10.79	-1.85	MgMoO4
MgSeO3:6H2O	-6.16	-3.10	3.06	MgSeO3:6H2O
MgSeO4:6H2O	-15.46	-16.66	-1.20	MgSeO4:6H2O
Minium	-29.04	44.49	73.52	Pb3O4
Mirabilite	-7.14	-8.26	-1.11	Na2SO4:10H2O
Mn(VO3)2	-12.44	-7.54	4.90	Mn(VO3)2
Mn2(SO4)3	-59.24	-64.96	-5.71	Mn2(SO4)3
Mn3(AsO4)2:8H2O	-10.27	2.23	12.50	Mn3(AsO4)2:8H2O
MnCl2:4H2O	-15.63	-12.92	2.72	MnCl2:4H2O
MnS(grn)	-66.49	-66.32	0.17	MnS
MnS(pnk)	-69.66	-66.32	3.34	MnS
MnSe	-32.76	-29.26	3.50	MnSe
MnSeO3	-7.00	-5.87	1.13	MnSeO3
MnSeO3:2H2O	-6.85	-5.87	0.98	MnSeO3:2H2O
MnSeO4:5H2O	-17.38	-19.43	-2.05	MnSeO4:5H2O
MnSO4	-11.57	-8.98	2.58	MnSO4
Monteponite	-7.01	8.09	15.10	CdO

MoO3	-15.62	-23.62	-8.00	MoO3
Morenosite	-8.46	-10.60	-2.14	NiSO4:7H2O
MoS2	-128.85	-199.11	-70.26	MoS2
Na-Jarosite	-2.18	-13.38	-11.20	NaFe3(SO4)2(OH)6
Na2Cr2O7	-44.85	-54.74	-9.90	Na2Cr2O7
Na2CrO4	-24.91	-21.98	2.93	Na2CrO4
Na2Mo2O7	-19.85	-36.45	-16.60	Na2Mo2O7
Na2MoO4	-14.32	-12.83	1.49	Na2MoO4
Na2MoO4:2H2O	-14.06	-12.83	1.22	Na2MoO4:2H2O
Na2SeO3:5H2O	-15.44	-5.14	10.30	Na2SeO3:5H2O
Na2SeO4	-19.98	-18.70	1.28	Na2SeO4
Na3VO4	-29.31	7.37	36.68	Na3VO4
Na4V2O7	-33.43	3.97	37.40	Na4V2O7
Nantokite	-5.51	-12.24	-6.73	CuCl
Natron	-8.89	-10.20	-1.31	Na2CO3:10H2O
NaVO3	-7.27	-3.41	3.86	NaVO3
Nesquehonite	-3.49	-8.16	-4.67	MgCO3:3H2O
Ni(OH)2	-4.36	8.43	12.79	Ni(OH)2
Ni3(AsO4)2:8H2O	-18.32	-2.62	15.70	Ni3(AsO4)2:8H2O
Ni4(OH)6SO4	-17.30	14.70	32.00	Ni4(OH)6SO4
NiCO3	-5.68	-12.55	-6.87	NiCO3
NiMoO4	-4.04	-15.18	-11.14	NiMoO4
NiS(alpha)	-62.34	-67.94	-5.60	NiS
NiS(beta)	-56.84	-67.94	-11.10	NiS
NiS(gamma)	-55.14	-67.94	-12.80	NiS
NiSe	-13.18	-30.88	-17.70	NiSe
NiSeO3:2H2O	-10.30	-7.49	2.81	NiSeO3:2H2O
NiSeO4:6H2O	-19.53	-21.05	-1.52	NiSeO4:6H2O
Nsutite	-10.05	7.45	17.50	MnO2
O2(g)	-37.59	45.50	83.09	O2
Orpiment	-203.67	-264.74	-61.07	As2S3
Otavite	-0.89	-12.89	-12.00	CdCO3
Pb(BO2)2	-10.21	-3.69	6.52	Pb(BO2)2
Pb(OH)2	-0.90	7.25	8.15	Pb(OH)2
Pb10(OH)6O(CO3)6	-44.68	-53.44	-8.76	Pb10(OH)6O(CO3)6
Pb2(OH)3Cl	-5.79	3.01	8.79	Pb2(OH)3Cl
Pb2O(OH)2	-11.70	14.49	26.19	Pb2O(OH)2
Pb2O3	-23.80	37.24	61.04	Pb2O3
Pb2OCO3	-5.93	-6.49	-0.56	Pb2OCO3
Pb2V2O7	-1.20	-3.10	-1.90	Pb2V2O7
Pb3(AsO4)2	-11.99	-6.19	5.80	Pb3(AsO4)2
Pb3(VO4)2	-2.00	4.14	6.14	Pb3(VO4)2
Pb3O2CO3	-10.27	0.75	11.02	Pb3O2CO3
Pb3O2SO4	-7.99	2.70	10.69	Pb3O2SO4
Pb4(OH)6SO4	-11.15	9.95	21.10	Pb4(OH)6SO4
Pb4O3SO4	-11.93	9.95	21.88	Pb4O3SO4
PbCrO4	-12.92	-25.52	-12.60	PbCrO4
PbF2	-10.78	-18.22	-7.44	PbF2
Pbmetal	-19.75	-15.50	4.25	Pb
PbMoO4	-0.75	-16.37	-15.62	PbMoO4
PbO:0.3H2O	-5.73	7.25	12.98	PbO:0.33H2O
PbSeO4	-15.40	-22.24	-6.84	PbSeO4
Periclase	-8.76	12.82	21.58	MgO
Phosgenite	-9.65	-29.46	-19.81	PbCl2:PbCO3
Plattnerite	-19.61	29.99	49.60	PbO2
Portlandite	-9.59	13.21	22.80	Ca(OH)2
Pyrite	-103.39	-121.90	-18.51	FeS2
Pyrochroite	-5.14	10.05	15.19	Mn(OH)2
Pyrolusite	-8.58	32.80	41.38	MnO2
Realgar	-85.81	-105.56	-19.75	AsS
Retgersite	-8.56	-10.60	-2.04	NiSO4:6H2O
Rhodochrosite	-0.35	-10.93	-10.58	MnCO3
Rutherfordine	-6.37	-20.87	-14.50	UO2CO3
Schoepite	-5.88	0.12	5.99	UO2(OH)2:H2O
Semetal(am)	-9.45	-16.56	-7.11	Se
Semetal(hex	-8.85	-16.56	-7.71	Se

SeO2	-16.05	-15.92	0.12	SeO2
SeO3	-50.53	-29.48	21.04	SeO3
Siderite	-2.65	-12.89	-10.24	FeCO3
Smithsonite	-1.35	-11.35	-10.00	ZnCO3
Sphalerite	-55.29	-66.74	-11.45	ZnS
Spinel	-5.87	30.98	36.85	MgAl2O4
Sulfur	-51.48	-53.62	-2.14	S
Tenorite	0.28	7.92	7.64	CuO
Thenardite	-8.58	-8.25	0.32	Na2SO4
Thermonatrite	-10.84	-10.20	0.64	Na2CO3:H2O
Tyuyamunite	-8.23	-4.15	4.08	Ca(UO2)2(VO4)2
U3O8	-15.84	5.25	21.08	U3O8
U4O9	-27.90	-30.92	-3.02	U4O9
UF4	-34.81	-64.34	-29.54	UF4
UF4:2.5H2O	-31.62	-64.34	-32.72	UF4:2.5H2O
UO2(am)	-14.35	-13.42	0.93	UO2
UO2(OH)2(beta)	-5.50	0.12	5.61	UO2(OH)2
UO2SeO4:4H2O	-27.12	-29.37	-2.25	UO2SeO4:4H2O
UO3	-7.58	0.12	7.70	UO3
Uraninite	-8.75	-13.42	-4.67	UO2
V(OH)3	-16.54	-8.95	7.59	V(OH)3
V2O5	-16.24	-17.60	-1.36	V2O5
V3O5	-34.39	-32.56	1.84	V3O5
V4O7	-43.01	-35.83	7.19	V4O7
V6O13	-37.43	-98.29	-60.86	V6O13
VCl2	-62.16	-43.29	18.87	VCl2
VCl3	-66.83	-43.40	23.43	VCl3
VF4	-69.13	-54.20	14.93	VF4
Vmetal	-87.10	-43.07	44.03	V
VO	-35.08	-20.32	14.76	VO
VO(OH)2	-8.42	-3.27	5.15	VO(OH)2
VO2Cl	-23.12	-20.28	2.84	VO2Cl
VOCl	-31.58	-20.43	11.15	VOCl
VOCl2	-39.00	-26.24	12.76	VOCl2
VOSO4	-25.92	-22.31	3.61	VOSO4
Witherite	-2.79	-11.36	-8.57	BaCO3
Wurtzite	-57.79	-66.74	-8.95	ZnS
Zincite	-1.70	9.64	11.33	ZnO
Zincosite	-13.33	-9.40	3.93	ZnSO4
Zn(BO2)2	-9.59	-1.30	8.29	Zn(BO2)2
Zn(OH)2	-2.56	9.64	12.20	Zn(OH)2
Zn(OH)2(am)	-2.84	9.64	12.47	Zn(OH)2
Zn(OH)2(beta)	-2.12	9.64	11.75	Zn(OH)2
Zn(OH)2(epsilon)	-1.90	9.64	11.53	Zn(OH)2
Zn(OH)2(gamma)	-2.10	9.64	11.73	Zn(OH)2
Zn2(OH)2SO4	-7.26	0.24	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-7.40	7.79	15.19	Zn2(OH)3Cl
Zn3(AsO4)2:2.5H2O	-12.66	0.99	13.65	Zn3(AsO4)2:2.5H2O
Zn3O(SO4)2	-28.08	-9.16	18.91	Zn3O(SO4)2
Zn4(OH)6SO4	-8.89	19.51	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-13.29	25.21	38.50	Zn5(OH)8Cl2
ZnCl2	-20.38	-13.33	7.05	ZnCl2
ZnCO3:1H2O	-1.09	-11.35	-10.26	ZnCO3:1H2O
ZnF2	-15.29	-15.83	-0.53	ZnF2
Znmetal	-38.90	-13.11	25.79	Zn
ZnMoO4	-3.85	-13.98	-10.13	ZnMoO4
ZnO(active)	-1.55	9.64	11.19	ZnO
ZnS(am)	-57.68	-66.74	-9.05	ZnS
ZnSe	-15.27	-29.67	-14.40	ZnSe
ZnSeO4:6H2O	-18.33	-19.85	-1.52	ZnSeO4:6H2O
ZnSO4:1H2O	-8.76	-9.40	-0.64	ZnSO4:1H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

```
End of simulation.
------------------

------------------------------------
Reading input data for simulation 2.
------------------------------------

------------------------------
End of Run after 0.236 Seconds.
------------------------------
```

```
# P75Scenario

SOLUTION 1 UG Water P75
    temp      25
    pH        8.112
    units     mg/L
    density   1
Al    0.0784
As    0.0029
Ba    0.1829
B     0.1305
Ca    108.3
Cl    56.4
Mg    54.6
Na    209.6
K     39.8
F     1.0230
S(6)  286.6
Cd    0.0089
Cr    0.0083
Co    0.0040
Cu    0.0817
Fe    0.2095
Pb    0.0552
Mn    0.1027
Mo    0.0124
Ni    0.0058
Se    0.0180
U     0.0083
V     0.0024
Zn    0.2240
Alkalinity 540.5 as HCO3
    -water    1 # kg

SOLUTION 2 PAF Material
    temp      25
    pH        7.5
    units     mg/L
    density   1
      Al    0.020
      As    0
      Ba    0.020
      B     0
      Ca    67.0
      Cl    0
      Mg    8.0
      Na    1.0
      K     13.0
      F     0.300
      S(6)  197.0
      Cd    0.000
      Cr    0
      Co    0.007
      Cu    0.028
      Fe    0
      Pb    0
      Mn    0.040
      Mo    0.003
      Ni    0.004
      Se    0
      U     0
      V     0
      Zn    0
      Alkalinity 22 as HCO3
    -water    1 # kg
```

```
SOLUTION 3 NAF Material
    temp      25
    pH        7.6
    units     mg/L
    density   1
      Al    0.140
      As    0.029
      Ba    0.020
      B     0
      Ca    122.0
      Cl    0
      Mg    18.0
      Na    1.0
      K     16.0
      F     0.300
      S(6)  331.0
      Cd    0.000
      Cr    0
      Co    0.002
      Cu    0.019
      Fe    0.070
      Pb    0
      Mn    0.130
      Mo    0.005
      Ni    0.001
      Se    0
      U     0.001
      V     0
      Zn    0
      Alkalinity 28 as HCO3
    -water    1 # kg


SOLUTION 4 Make-up Material
    temp      25
    pH        7.7
    units     mg/L
    density   1
      Al    0.020
      As    0
      Ba    0.020
      B     0
      Ca    67.0
      Cl    0
      Mg    8.0
      Na    1.0
      K     13.0
      F     0.300
      S(6)  197.0
      Cd    0.000
      Cr    0
      Co    0.007
      Cu    0.028
      Fe    0
      Pb    0
      Mn    0.040
      Mo    0.003
      Ni    0.004
      Se    0
      U     0
      V     0
      Zn    0
      Alkalinity 22 as HCO3
    -water    1 # kg

# Mix the three solutions together
```

```
MIX 1 Mix within UG Works
    1    0.278
    2    0.114
    3    0.418
    4    0.190

SAVE Solution 5

SELECTED_OUTPUT 2
    -file                 D:\selected_output_3.txt
    -high_precision       true
    -reset                true
    -distance             false
    -time                 false
    -temperature          false
    -ionic_strength       false
    -water                false
    -totals               pH Al As Ba B Ca Cl Mg
                          Na K  F  S(6) Cd Cr Co
                          Cu Fe Pb Mn Mo  Ni Se
                          U V Zn Alkalinity
END
```

```
   Input file: P:\J23011 - BCP Underground EA (Aeris)\2. Tech Work Area\2.08 Water Quality
Model\2.08.02 PAF Assessment\BPC_UG_PAF_Disposal_P75.pqi
  Output file: P:\J23011 - BCP Underground EA (Aeris)\2. Tech Work Area\2.08 Water Quality
Model\2.08.02 PAF Assessment\BPC_UG_PAF_Disposal_P75.pqo
Database file: c:\phreeqc\database\minteq.v4.dat

------------------
Reading data base.
------------------

      SOLUTION_MASTER_SPECIES
      SOLUTION_SPECIES
      SOLUTION_SPECIES
      PHASES
      PHASES
      SURFACE_MASTER_SPECIES
      SURFACE_SPECIES
      END
-----------------------------------
Reading input data for simulation 1.
-----------------------------------

      DATABASE c:\phreeqc\database\minteq.v4.dat
      SOLUTION 1 UG Water P75
          temp      25
          pH        8.112
          units     mg/L
          density   1
      Al    0.0784
      As    0.0029
      Ba    0.1829
      B     0.1305
      Ca    108.3
      Cl    56.4
      Mg    54.6
      Na    209.6
      K     39.8
      F     1.0230
      S(6)  286.6
      Cd    0.0089
      Cr    0.0083
      Co    0.0040
      Cu    0.0817
      Fe    0.2095
      Pb    0.0552
      Mn    0.1027
      Mo    0.0124
      Ni    0.0058
      Se    0.0180
      U     0.0083
      V     0.0024
      Zn    0.2240
      Alkalinity 540.5 as HCO3
          water    1 # kg
      SOLUTION 2 PAF Material
          temp      25
          pH        7.5
          units     mg/L
          density   1
            Al    0.020
            As    0
            Ba    0.020
            B     0
            Ca    67.0
            Cl    0
            Mg    8.0
            Na    1.0
            K     13.0
            F     0.300
            S(6)  197.0
            Cd    0.000
            Cr    0
            Co    0.007
            Cu    0.028
            Fe    0
            Pb    0
            Mn    0.040
            Mo    0.003
            Ni    0.004
            Se    0
            U     0
            V     0
            Zn    0
            Alkalinity 22 as HCO3
          water    1 # kg
      SOLUTION 3 NAF Material
          temp      25
          pH        7.6
          units     mg/L
          density   1
            Al    0.140
            As    0.029
            Ba    0.020
            B     0
            Ca    122.0
            Cl    0
            Mg    18.0
            Na    1.0
            K     16.0
            F     0.300
            S(6)  331.0
            Cd    0.000
            Cr    0
            Co    0.002
            Cu    0.019
            Fe    0.070
            Pb    0
            Mn    0.130
            Mo    0.005
            Ni    0.001
            Se    0
            U     0.001
            V     0
            Zn    0
            Alkalinity 28 as HCO3
          water    1 # kg
      SOLUTION 4 Make-up Material
          temp      25
          pH        7.7
          units     mg/L
          density   1
            Al    0.020
            As    0
            Ba    0.020
            B     0
            Ca    67.0
            Cl    0
            Mg    8.0
            Na    1.0
            K     13.0
            F     0.300
            S(6)  197.0
            Cd    0.000
            Cr    0
            Co    0.007
            Cu    0.028
            Fe    0
            Pb    0
            Mn    0.040
            Mo    0.003
            Ni    0.004
            Se    0
            U     0
            V     0
            Zn    0
            Alkalinity 22 as HCO3
          water    1 # kg
      MIX 1 Mix within UG Works
          1    0.278
          2    0.114
          3    0.418
          4    0.190
      SAVE Solution 5
      SELECTED_OUTPUT 2
          file                 D:\selected_output_3.txt
          high_precision       true
          reset                true
          distance             false
          time                 false
          temperature          false
          ionic_strength       false
          water                false
          totals               pH Al As Ba B Ca Cl Mg
WARNING: Expected element name to begin with upper case letter.
                                Na K  F  S(6) Cd Cr Co
                                Cu Fe Pb Mn Mo  Ni Se
                                U V Zn Alkalinity
      END
-------------------------------------------
Beginning of initial solution calculations.
-------------------------------------------

Initial solution 1.     UG Water P75

-----------------------------Solution composition------------------------------

      Elements           Molality       Moles

      Al                2.909e-06   2.909e-06
      Alkalinity        8.869e-03   8.869e-03
      As                3.876e-08   3.876e-08
      B                 1.209e-05   1.209e-05
      Ba                1.334e-06   1.334e-06
      Ca                2.706e-03   2.706e-03
      Cd                7.928e-08   7.928e-08
      Cl                1.593e-03   1.593e-03
      Co                6.796e-08   6.796e-08
      Cr                1.598e-07   1.598e-07
      Cu                1.287e-06   1.287e-06
      F                 5.392e-05   5.392e-05
      Fe                3.756e-06   3.756e-06
      K                 1.019e-03   1.019e-03
      Mg                2.249e-03   2.249e-03
      Mn                1.872e-06   1.872e-06
      Mo                1.294e-07   1.294e-07
      Na                9.129e-03   9.129e-03
      Ni                9.895e-08   9.895e-08
      Pb                2.668e-07   2.668e-07
      S(6)              2.987e-03   2.987e-03
      Se                2.283e-07   2.283e-07
      U                 3.492e-08   3.492e-08
      V                 4.718e-08   4.718e-08
      Zn                3.430e-06   3.430e-06

----------------------------Description of solution----------------------------

                                       pH  =   8.112
                                       pe  =   4.000
                                 Activity of water  =   1.000
                          Ionic strength (mol/kgw)  =   2.285e-02
                                Mass of water (kg)  =   1.000e+00
                           Total carbon (mol/kgw)  =   8.770e-03
                              Total CO2 (mol/kgw)  =   8.770e-03
                                Temperature (°C)  =  25.00
                           Electrical balance (eq)  =   3.597e-03
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  10.92
                                     Iterations  =  10
                                        Total H  = 1.110224e+02
                                        Total O  = 5.554515e+01

----------------------------Distribution of species----------------------------

                                                  Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             1.515e-06   1.303e-06    -5.820    -5.885    -0.066     (0)
   H+              8.943e-09   7.727e-09    -8.049    -8.112    -0.063      0.00
   H2O             5.551e+01   9.995e-01     1.744    -0.000     0.000     18.07
Al            2.909e-06
   Al(OH)4-        2.894e-06   2.503e-06    -5.539    -5.602    -0.063     (0)
   Al(OH)3         1.526e-08   1.526e-08    -7.816    -7.816     0.000     (0)
   Al(OH)2+        6.755e-10   5.872e-10    -9.170    -9.231    -0.061     (0)
   AlF2+           3.367e-12   2.927e-12   -11.473   -11.534    -0.061     (0)
   AlF3            1.514e-12   1.514e-12   -11.820   -11.820     0.000     (0)
   AlOH+2          9.936e-13   5.676e-13   -12.003   -12.246    -0.243     (0)
   AlF+2           3.133e-13   1.790e-13   -12.504   -12.747    -0.243     (0)
   AlF4-           3.604e-14   3.117e-14   -13.443   -13.506    -0.063     (0)
   AlSO4+          5.061e-15   4.378e-15   -14.296   -14.359    -0.063     (0)
   Al+3            1.624e-15   4.357e-16   -14.790   -15.361    -0.571     (0)
   Al(SO4)2-       7.019e-17   6.071e-17   -16.154   -16.217    -0.063     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -51.198   -51.891    -0.694     (0)
As(3)         8.817e-21
   H3AsO3          8.169e-21   8.169e-21   -20.088   -20.088     0.000     (0)
   H2AsO3-         6.475e-22   5.422e-22   -21.189   -21.266    -0.077     (0)
   HAsO3-2         1.302e-25   6.400e-26   -24.885   -25.194    -0.308     (0)
   H4AsO3+         3.735e-29   3.127e-29   -28.428   -28.505    -0.077     (0)
   AsO3-3          1.578e-30   3.193e-31   -29.802   -30.496    -0.694     (0)
As(5)         3.876e-08
   HAsO4-2         3.718e-08   1.828e-08    -7.430    -7.738    -0.308     (0)
   H2AsO4-         1.538e-09   1.288e-09    -8.813    -8.890    -0.077     (0)
   AsO4-3          3.696e-11   7.481e-12   -10.432   -11.126    -0.694     (0)
   H3AsO4          1.721e-15   1.730e-15   -14.764   -14.762     0.002     (0)
B             1.209e-05
   H3BO3           1.100e-05   1.106e-05    -4.958    -4.956     0.002     (0)
   H2BO3-          9.736e-07   8.314e-07    -6.012    -6.080    -0.069     (0)
   CaH2BO3+        6.560e-08   5.602e-08    -7.183    -7.252    -0.069     (0)
   MgH2BO3+        3.523e-08   3.008e-08    -7.453    -7.522    -0.069     (0)
   NaH2BO3         1.028e-08   1.028e-08    -7.988    -7.988     0.000     (0)
   BF(OH)3-        2.123e-10   1.813e-10    -9.673    -9.742    -0.069     (0)
   BaH2BO3+        2.118e-11   1.809e-11   -10.674   -10.743    -0.069     (0)
   H5(BO3)2-       9.166e-12   7.827e-12   -11.038   -11.106    -0.069     (0)
   H8(BO3)3-       1.014e-14   8.657e-15   -13.994   -14.063    -0.069     (0)
   BF2(OH)2-       7.208e-15   6.156e-15   -14.142   -14.211    -0.069     (0)
   BF3OH-          8.906e-22   7.605e-22   -21.050   -21.119    -0.069     (0)
```

BF4-	1.392e-27	1.188e-27	-26.856	-26.925	-0.069	(0)
Ba 1.334e-06						
Ba+2	1.263e-06	7.041e-07	-5.898	-6.152	-0.254	(0)
BaHCO3+	5.460e-08	4.762e-08	-7.263	-7.322	-0.059	(0)
BaCO3	1.552e-08	1.552e-08	-7.809	-7.809	0.000	(0)
BaH2BO3+	2.118e-11	1.809e-11	-10.674	-10.743	-0.069	(0)
BaOH+	4.615e-12	4.004e-12	-11.336	-11.398	-0.062	(0)
C(4) 8.770e-03						
HCO3-	8.146e-03	7.082e-03	-2.089	-2.150	-0.061	(0)
CaHCO3+	1.770e-04	1.544e-04	-3.752	-3.811	-0.059	(0)
H2CO3	1.231e-04	1.231e-04	-3.910	-3.910	0.000	(0)
MgHCO3+	8.769e-05	7.562e-05	-4.057	-4.121	-0.064	(0)
CaCO3	7.974e-05	7.974e-05	-4.098	-4.098	0.000	(0)
CO3-2	7.709e-05	4.297e-05	-4.113	-4.367	-0.254	(0)
MgCO3	3.729e-05	3.729e-05	-4.428	-4.428	0.000	(0)
NaHCO3	3.106e-05	3.106e-05	-4.508	-4.508	0.000	(0)
NaCO3-	7.179e-06	6.241e-06	-5.144	-5.205	-0.061	(0)
ZnCO3	1.690e-06	1.690e-06	-5.772	-5.772	0.000	(0)
CuCO3	1.014e-06	1.014e-06	-5.994	-5.994	0.000	(0)
Cu(CO3)2-2	2.385e-07	1.173e-07	-6.622	-6.931	-0.308	(0)
PbCO3	1.974e-07	1.974e-07	-6.705	-6.705	0.000	(0)
ZnHCO3+	1.828e-07	1.531e-07	-6.738	-6.815	-0.077	(0)
MnHCO3+	1.252e-07	1.086e-07	-6.902	-6.964	-0.062	(0)
BaHCO3+	5.460e-08	4.762e-08	-7.263	-7.322	-0.059	(0)
Pb(CO3)2-2	4.975e-08	2.446e-08	-7.303	-7.612	-0.308	(0)
NiCO3	3.357e-08	3.357e-08	-7.474	-7.474	0.000	(0)
UO2(CO3)3-4	3.309e-08	1.933e-09	-7.480	-8.714	-1.233	(0)
CdCO3	2.319e-08	2.319e-08	-7.635	-7.635	0.000	(0)
NiHCO3+	2.184e-08	1.828e-08	-7.661	-7.738	-0.077	(0)
BaCO3	1.552e-08	1.552e-08	-7.809	-7.809	0.000	(0)
CoCO3	1.328e-08	1.328e-08	-7.877	-7.877	0.000	(0)
CoHCO3+	1.203e-08	1.007e-08	-7.920	-7.997	-0.077	(0)
PbHCO3+	9.604e-09	8.042e-09	-8.018	-8.095	-0.077	(0)
CuHCO3+	2.139e-09	1.791e-09	-8.670	-8.747	-0.077	(0)
UO2(CO3)2-2	1.826e-09	8.976e-10	-8.739	-9.047	-0.308	(0)
Cd(CO3)2-2	1.502e-09	7.385e-10	-8.823	-9.132	-0.308	(0)
CdHCO3+	4.559e-10	3.817e-10	-9.341	-9.418	-0.077	(0)
FeHCO3+	3.526e-10	3.075e-10	-9.453	-9.512	-0.059	(0)
UO2CO3	1.047e-12	1.047e-12	-11.980	-11.980	0.000	(0)
Ca 2.706e-03						
Ca+2	2.101e-03	1.171e-03	-2.678	-2.931	-0.254	(0)
CaSO4	3.472e-04	3.472e-04	-3.459	-3.459	0.000	(0)
CaHCO3+	1.770e-04	1.544e-04	-3.752	-3.811	-0.059	(0)
CaCO3	7.974e-05	7.974e-05	-4.098	-4.098	0.000	(0)
CaF+	6.053e-07	5.250e-07	-6.218	-6.280	-0.062	(0)
CaH2BO3+	6.560e-08	5.602e-08	-7.183	-7.252	-0.069	(0)
CaOH+	3.489e-08	3.043e-08	-7.457	-7.517	-0.059	(0)
Cd 7.928e-08						
Cd+2	4.248e-08	2.368e-08	-7.372	-7.626	-0.254	(0)
CdCO3	2.319e-08	2.319e-08	-7.635	-7.635	0.000	(0)
CdSO4	7.183e-09	7.183e-09	-8.144	-8.144	0.000	(0)
CdCl+	3.716e-09	3.112e-09	-8.430	-8.507	-0.077	(0)
Cd(CO3)2-2	1.502e-09	7.385e-10	-8.823	-9.132	-0.308	(0)
CdHCO3+	4.559e-10	3.817e-10	-9.341	-9.418	-0.077	(0)
CdOH+	2.925e-10	2.450e-10	-9.534	-9.611	-0.077	(0)
Cd(SO4)2-2	2.551e-10	1.254e-10	-9.593	-9.902	-0.308	(0)
CdOHCl	1.663e-10	1.663e-10	-9.779	-9.779	0.000	(0)
CdF+	1.841e-11	1.541e-11	-10.735	-10.812	-0.077	(0)
CdCl2	1.785e-11	1.785e-11	-10.748	-10.748	0.000	(0)
Cd(OH)2	2.013e-12	2.013e-12	-11.696	-11.696	0.000	(0)
CdCl3-	1.852e-14	1.550e-14	-13.732	-13.810	-0.077	(0)
CdF2	1.263e-15	1.263e-15	-14.898	-14.898	0.000	(0)
Cd(OH)3-	1.913e-16	1.602e-16	-15.718	-15.795	-0.077	(0)
Cd2OH+3	1.436e-16	2.907e-17	-15.843	-16.537	-0.694	(0)
Cd(SeO3)2-2	1.092e-16	5.367e-17	-15.962	-16.270	-0.308	(0)
CdSeO4	4.784e-17	4.784e-17	-16.320	-16.320	0.000	(0)

Cd(OH)4-2	6.948e-23	3.416e-23	-22.158	-22.467	-0.308	(0)
Cl 1.593e-03						
Cl-	1.593e-03	1.376e-03	-2.798	-2.861	-0.063	(0)
ZnOHCl	4.030e-09	4.030e-09	-8.395	-8.395	0.000	(0)
CdCl+	3.716e-09	3.112e-09	-8.430	-8.507	-0.077	(0)
ZnCl+	2.741e-09	2.363e-09	-8.562	-8.626	-0.064	(0)
MnCl+	1.536e-09	1.332e-09	-8.814	-8.875	-0.062	(0)
CuCl	3.401e-10	3.401e-10	-9.468	-9.468	0.000	(0)
CdOHCl	1.663e-10	1.663e-10	-9.779	-9.779	0.000	(0)
CuCl2-	1.134e-10	9.781e-11	-9.945	-10.010	-0.064	(0)
CoCl+	1.040e-10	8.704e-11	-9.983	-10.060	-0.077	(0)
PbCl+	8.913e-11	7.463e-11	-10.050	-10.127	-0.077	(0)
NiCl+	8.807e-11	7.375e-11	-10.055	-10.132	-0.077	(0)
CdCl2	1.785e-11	1.785e-11	-10.748	-10.748	0.000	(0)
CuCl+	1.014e-11	8.743e-12	-10.994	-11.058	-0.064	(0)
ZnCl2	5.155e-12	5.155e-12	-11.288	-11.288	0.000	(0)
MnCl2	2.590e-12	2.590e-12	-11.587	-11.587	0.000	(0)
PbCl2	4.588e-13	4.588e-13	-12.338	-12.338	0.000	(0)
CuCl3-2	5.083e-14	2.878e-14	-13.294	-13.541	-0.247	(0)
CdCl3-	1.852e-14	1.550e-14	-13.732	-13.810	-0.077	(0)
ZnCl3-	6.536e-15	5.636e-15	-14.185	-14.249	-0.064	(0)
CuCl2	4.172e-15	4.172e-15	-14.380	-14.380	0.000	(0)
MnCl3-	1.132e-15	9.816e-16	-14.946	-15.008	-0.062	(0)
NiCl2	5.111e-16	5.111e-16	-15.292	-15.292	0.000	(0)
PbCl3-	3.002e-16	2.514e-16	-15.523	-15.600	-0.077	(0)
CrCl+2	7.266e-17	3.572e-17	-16.139	-16.447	-0.308	(0)
ZnCl4-2	6.850e-18	3.879e-18	-17.164	-17.411	-0.247	(0)
CrOHCl2	1.217e-18	1.217e-18	-17.915	-17.915	0.000	(0)
PbCl4-2	3.217e-19	1.581e-19	-18.493	-18.801	-0.308	(0)
FeCl+2	2.352e-19	1.332e-19	-18.629	-18.876	-0.247	(0)
CuCl3-	6.215e-20	5.359e-20	-19.207	-19.271	-0.064	(0)
UO2Cl+	1.632e-20	1.366e-20	-19.787	-19.864	-0.077	(0)
CrCl2+	5.571e-21	4.665e-21	-20.254	-20.331	-0.077	(0)
FeCl2+	9.438e-22	8.187e-22	-21.025	-21.087	-0.062	(0)
VOCl+	6.678e-23	5.592e-23	-22.175	-22.252	-0.077	(0)
CuCl4-2	6.529e-25	3.697e-25	-24.185	-24.432	-0.247	(0)
FeCl3	1.127e-25	1.127e-25	-24.948	-24.948	0.000	(0)
CrO3Cl-	3.575e-26	2.993e-26	-25.447	-25.524	-0.077	(0)
CoCl+2	4.146e-37	2.038e-37	-36.382	-36.691	-0.308	(0)
UCl+3	0.000e+00	0.000e+00	-48.912	-49.606	-0.694	(0)
Co(2) 6.796e-08						
Co+2	3.719e-08	1.828e-08	-7.430	-7.738	-0.308	(0)
CoCO3	1.328e-08	1.328e-08	-7.877	-7.877	0.000	(0)
CoHCO3+	1.203e-08	1.007e-08	-7.920	-7.997	-0.077	(0)
CoSO4	4.721e-09	4.721e-09	-8.326	-8.326	0.000	(0)
CoOH+	5.674e-10	4.751e-10	-9.246	-9.323	-0.077	(0)
CoCl+	1.040e-10	8.704e-11	-9.983	-10.060	-0.077	(0)
Co(OH)2	4.916e-11	4.916e-11	-10.308	-10.308	0.000	(0)
CoF+	2.836e-11	2.375e-11	-10.547	-10.624	-0.077	(0)
Co(OH)3-	1.526e-15	1.278e-15	-14.816	-14.894	-0.077	(0)
CoOOH-	3.830e-16	3.207e-16	-15.417	-15.494	-0.077	(0)
CoSeO4	9.943e-17	9.943e-17	-16.002	-16.002	0.000	(0)
Co2OH+3	2.151e-18	4.354e-19	-17.667	-18.361	-0.694	(0)
Co(OH)4-2	5.365e-22	2.638e-22	-21.270	-21.579	-0.308	(0)
Co4(OH)4+4	1.741e-28	1.017e-29	-27.759	-28.993	-1.233	(0)
Co(3) 9.799e-30						
CoOH+2	9.799e-30	4.817e-30	-29.009	-29.317	-0.308	(0)
Co+3	2.712e-36	7.278e-37	-35.567	-36.138	-0.571	(0)
CoCl+2	4.146e-37	2.038e-37	-36.382	-36.691	-0.308	(0)
Cr(2) 9.745e-25						
Cr+2	9.745e-25	4.791e-25	-24.011	-24.320	-0.308	(0)
Cr(3) 1.598e-07						
Cr(OH)2+	1.082e-07	9.058e-08	-6.966	-7.043	-0.077	(0)
Cr(OH)3	4.432e-08	4.432e-08	-7.353	-7.353	0.000	(0)
CrO2-	3.255e-09	2.725e-09	-8.487	-8.565	-0.077	(0)
Cr(OH)4-	2.745e-09	2.298e-09	-8.561	-8.639	-0.077	(0)

Cr(OH)+2	1.163e-09	5.715e-10	-8.935	-9.243	-0.308	(0)
CrOHSO4	1.755e-10	1.755e-10	-9.756	-9.756	0.000	(0)
CrF+2	2.656e-13	1.306e-13	-12.576	-12.884	-0.308	(0)
Cr+3	9.910e-14	2.006e-14	-13.004	-13.698	-0.694	(0)
CrSO4+	7.239e-14	6.061e-14	-13.140	-13.217	-0.077	(0)
CrCl+2	7.266e-17	3.572e-17	-16.139	-16.447	-0.308	(0)
Cr2(OH)2SO4+2	1.844e-17	9.068e-18	-16.734	-17.043	-0.308	(0)
CrOHCl2	1.217e-18	1.217e-18	-17.915	-17.915	0.000	(0)
Cr2(OH)2(SO4)2	6.971e-19	6.971e-19	-18.157	-18.157	0.000	(0)
CrCl2+	5.571e-21	4.665e-21	-20.254	-20.331	-0.077	(0)
Cr(6) 3.353e-14						
CrO4-2	3.210e-14	1.789e-14	-13.493	-13.747	-0.254	(0)
NaCrO4-	8.282e-16	6.935e-16	-15.082	-15.159	-0.077	(0)
HCrO4-	5.342e-16	4.473e-16	-15.272	-15.349	-0.077	(0)
KCrO4-	6.928e-17	5.801e-17	-16.159	-16.236	-0.077	(0)
H2CrO4	2.802e-24	2.802e-24	-23.553	-23.553	0.000	(0)
CrO3SO4-2	2.773e-24	1.363e-24	-23.557	-23.865	-0.308	(0)
CrO3Cl-	3.575e-26	2.993e-26	-25.447	-25.524	-0.077	(0)
Cr2O7-2	1.412e-29	6.942e-30	-28.850	-29.159	-0.308	(0)
Cu(1) 6.881e-10						
CuCl	3.401e-10	3.401e-10	-9.468	-9.468	0.000	(0)
Cu+	2.344e-10	1.963e-10	-9.630	-9.707	-0.077	(0)
CuCl2-	1.134e-10	9.781e-11	-9.945	-10.010	-0.064	(0)
CuCl3-2	5.083e-14	2.878e-14	-13.294	-13.541	-0.247	(0)
Cu(2) 1.287e-06						
CuCO3	1.014e-06	1.014e-06	-5.994	-5.994	0.000	(0)
Cu(CO3)2-2	2.385e-07	1.173e-07	-6.622	-6.931	-0.308	(0)
CuOH+	1.915e-08	1.651e-08	-7.718	-7.782	-0.064	(0)
Cu+2	7.192e-09	4.008e-09	-8.143	-8.397	-0.254	(0)
Cu(OH)2	4.291e-09	4.291e-09	-8.367	-8.367	0.000	(0)
CuHCO3+	2.139e-09	1.791e-09	-8.670	-8.747	-0.077	(0)
CuSO4	1.188e-09	1.188e-09	-8.925	-8.925	0.000	(0)
Cu2(OH)2+2	1.393e-11	6.847e-12	-10.856	-11.165	-0.308	(0)
Cu(OH)3-	1.369e-11	1.146e-11	-10.864	-10.941	-0.077	(0)
CuF+	1.241e-11	1.039e-11	-10.906	-10.983	-0.077	(0)
CuCl+	1.014e-11	8.743e-12	-10.994	-11.058	-0.064	(0)
CuCl2	4.172e-15	4.172e-15	-14.380	-14.380	0.000	(0)
Cu(OH)4-2	2.391e-16	1.175e-16	-15.621	-15.930	-0.308	(0)
CuCl3-	6.215e-20	5.359e-20	-19.207	-19.271	-0.064	(0)
CuCl4-2	6.529e-25	3.697e-25	-24.185	-24.432	-0.247	(0)
F 5.392e-05						
F-	4.755e-05	4.108e-05	-4.323	-4.386	-0.063	(0)
MgF+	5.561e-06	4.810e-06	-5.255	-5.318	-0.063	(0)
CaF+	6.053e-07	5.250e-07	-6.218	-6.280	-0.062	(0)
NaF	2.022e-07	2.022e-07	-6.694	-6.694	0.000	(0)
MnF+	1.449e-09	1.257e-09	-8.839	-8.901	-0.062	(0)
ZnF+	6.692e-10	5.603e-10	-9.174	-9.252	-0.077	(0)
HF	4.695e-10	4.695e-10	-9.328	-9.328	0.000	(0)
BF(OH)3-	2.123e-10	1.813e-10	-9.673	-9.742	-0.069	(0)
CoF+	2.836e-11	2.375e-11	-10.547	-10.624	-0.077	(0)
NiF+	2.581e-11	2.161e-11	-10.588	-10.665	-0.077	(0)
CdF+	1.841e-11	1.541e-11	-10.735	-10.812	-0.077	(0)
CuF+	1.241e-11	1.039e-11	-10.906	-10.983	-0.077	(0)
PbF+	5.284e-12	4.424e-12	-11.277	-11.354	-0.077	(0)
AlF2+	3.367e-12	2.927e-12	-11.473	-11.534	-0.061	(0)
AlF3	1.514e-12	1.514e-12	-11.820	-11.820	0.000	(0)
AlF+2	3.133e-13	1.790e-13	-12.504	-12.747	-0.243	(0)
CrF+2	2.656e-13	1.306e-13	-12.576	-12.884	-0.308	(0)
HF2-	8.530e-14	7.333e-14	-13.069	-13.135	-0.066	(0)
AlF4-	3.604e-14	3.117e-14	-13.443	-13.506	-0.063	(0)
BF2(OH)2-	7.208e-15	6.156e-15	-14.142	-14.211	-0.069	(0)
PbF2	3.577e-15	3.577e-15	-14.447	-14.447	0.000	(0)
CdF2	1.263e-15	1.263e-15	-14.898	-14.898	0.000	(0)
FeF+2	2.549e-16	1.443e-16	-15.594	-15.841	-0.247	(0)
FeF2+	1.829e-16	1.587e-16	-15.738	-15.800	-0.062	(0)
UO2F+	4.145e-17	3.471e-17	-16.382	-16.460	-0.077	(0)

FeF3	9.196e-18	9.196e-18	-17.036	-17.036	0.000	(0)
UO2F2	4.112e-18	4.112e-18	-17.386	-17.386	0.000	(0)
VO2F	2.184e-18	2.184e-18	-17.661	-17.661	0.000	(0)
H2F2	5.906e-19	5.906e-19	-18.229	-18.229	0.000	(0)
PbF3-	3.328e-19	2.787e-19	-18.478	-18.555	-0.077	(0)
UO2F3-	5.068e-20	4.244e-20	-19.295	-19.372	-0.077	(0)
VO2F2-	3.890e-20	3.258e-20	-19.410	-19.487	-0.077	(0)
VOF+	4.261e-21	3.568e-21	-20.370	-20.448	-0.077	(0)
BF3OH-	8.906e-22	7.605e-22	-21.050	-21.119	-0.069	(0)
VOF2	5.497e-23	5.497e-23	-22.260	-22.260	0.000	(0)
VO2F3-2	3.395e-23	1.669e-23	-22.469	-22.777	-0.308	(0)
UO2F4-2	2.817e-23	1.385e-23	-22.550	-22.859	-0.308	(0)
PbF4-2	1.115e-23	5.480e-24	-22.953	-23.261	-0.308	(0)
VOF3-	9.568e-26	8.012e-26	-25.019	-25.096	-0.077	(0)
VO2F4-3	1.667e-27	3.374e-28	-26.778	-27.472	-0.694	(0)
BF4-	1.392e-27	1.188e-27	-26.856	-26.925	-0.069	(0)
VOF4-2	2.702e-29	1.329e-29	-28.568	-28.877	-0.308	(0)
UF3+	1.184e-40	0.000e+00	-39.927	-40.004	-0.077	(0)
UF2+2	0.000e+00	0.000e+00	-40.509	-40.817	-0.308	(0)
UF4	0.000e+00	0.000e+00	-42.350	-42.350	0.000	(0)
UF+3	0.000e+00	0.000e+00	-42.837	-43.531	-0.694	(0)
UF5-	0.000e+00	0.000e+00	-45.062	-45.139	-0.077	(0)
UF6-2	0.000e+00	0.000e+00	-46.737	-47.045	-0.308	(0)
Fe(2) 8.671e-09						
Fe+2	7.016e-09	3.449e-09	-8.154	-8.462	-0.308	(0)
FeSO4	1.096e-09	1.096e-09	-8.960	-8.960	0.000	(0)
FeHCO3+	3.526e-10	3.075e-10	-9.453	-9.512	-0.059	(0)
FeOH+	2.062e-10	1.789e-10	-9.686	-9.747	-0.062	(0)
Fe(OH)2	1.851e-13	1.851e-13	-12.733	-12.733	0.000	(0)
Fe(OH)3-	8.787e-14	7.623e-14	-13.056	-13.118	-0.062	(0)
Fe(3) 3.748e-06						
Fe(OH)3	1.910e-06	1.910e-06	-5.719	-5.719	0.000	(0)
Fe(OH)2+	1.571e-06	1.366e-06	-5.804	-5.865	-0.061	(0)
Fe(OH)4-	2.665e-07	2.317e-07	-6.574	-6.635	-0.061	(0)
FeOH+2	4.759e-12	2.695e-12	-11.322	-11.569	-0.247	(0)
FeF+2	2.549e-16	1.443e-16	-15.594	-15.841	-0.247	(0)
FeF2+	1.829e-16	1.587e-16	-15.738	-15.800	-0.062	(0)
FeSO4+	5.364e-17	4.653e-17	-16.271	-16.332	-0.062	(0)
Fe+3	1.194e-17	3.204e-18	-16.923	-17.494	-0.571	(0)
FeF3	9.196e-18	9.196e-18	-17.036	-17.036	0.000	(0)
Fe(SO4)2-	1.538e-18	1.288e-18	-17.813	-17.890	-0.077	(0)
FeCl+2	2.352e-19	1.332e-19	-18.629	-18.876	-0.247	(0)
Fe2(OH)2+4	4.116e-21	2.404e-22	-20.386	-21.619	-1.233	(0)
FeHSeO3+2	1.753e-21	8.618e-22	-20.756	-21.065	-0.308	(0)
FeCl2+	9.438e-22	8.187e-22	-21.025	-21.087	-0.062	(0)
Fe3(OH)4+5	4.014e-25	4.746e-27	-24.396	-26.324	-1.927	(0)
FeCl3	1.127e-25	1.127e-25	-24.948	-24.948	0.000	(0)
H(0) 8.409e-28						
H2	4.205e-28	4.227e-28	-27.376	-27.374	0.002	(0)
K 1.019e-03						
K+	1.010e-03	8.727e-04	-2.996	-3.059	-0.063	(0)
KSO4-	9.198e-06	7.997e-06	-5.036	-5.097	-0.061	(0)
KCrO4-	6.928e-17	5.801e-17	-16.159	-16.236	-0.077	(0)
Mg 2.249e-03						
Mg+2	1.872e-03	1.044e-03	-2.728	-2.981	-0.254	(0)
MgSO4	2.458e-04	2.458e-04	-3.609	-3.609	0.000	(0)
MgHCO3+	8.769e-05	7.562e-05	-4.057	-4.121	-0.064	(0)
MgCO3	3.729e-05	3.729e-05	-4.428	-4.428	0.000	(0)
MgF+	5.561e-06	4.810e-06	-5.255	-5.318	-0.063	(0)
MgOH+	6.188e-07	5.411e-07	-6.208	-6.267	-0.058	(0)
MgH2BO3+	3.523e-08	3.008e-08	-7.453	-7.522	-0.069	(0)
Mn(2) 1.872e-06						
Mn+2	1.564e-06	7.688e-07	-5.806	-6.114	-0.308	(0)
MnSO4	1.769e-07	1.769e-07	-6.752	-6.752	0.000	(0)
MnHCO3+	1.252e-07	1.086e-07	-6.902	-6.964	-0.062	(0)
MnOH+	2.900e-09	2.515e-09	-8.538	-8.599	-0.062	(0)

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   MnCl+          1.536e-09   1.332e-09    -8.814    -8.875    -0.062     (0)
   MnF+           1.449e-09   1.257e-09    -8.839    -8.901    -0.062     (0)
   MnCl2          2.590e-12   2.590e-12   -11.587   -11.587     0.000     (0)
   MnSeO4         2.245e-15   2.245e-15   -14.649   -14.649     0.000     (0)
   MnCl3-         1.132e-15   9.816e-16   -14.946   -15.008    -0.062     (0)
   Mn(OH)3-       3.041e-17   2.638e-17   -16.517   -16.579    -0.062     (0)
   Mn(OH)4-2      1.959e-22   1.109e-22   -21.708   -21.955    -0.247     (0)
   MnSe           6.443e-39   6.443e-39   -38.191   -38.191     0.000     (0)
Mn(3)         1.280e-27
   Mn+3           1.280e-27   3.434e-28   -26.893   -27.464    -0.571     (0)
Mn(6)         0.000e+00
   MnO4-2         0.000e+00   0.000e+00   -43.394   -43.641    -0.247     (0)
Mn(7)         0.000e+00
   MnO4-          0.000e+00   0.000e+00   -48.946   -49.013    -0.067     (0)
Mo            1.294e-07
   MoO4-2         1.294e-07   7.212e-08    -6.888    -7.142    -0.254     (0)
   HMoO4-         1.324e-11   1.109e-11   -10.878   -10.955    -0.077     (0)
   H2MoO4         6.276e-16   6.276e-16   -15.202   -15.202     0.000     (0)
   AlMo6O21-3     0.000e+00   0.000e+00   -51.198   -51.891    -0.694     (0)
   Mo7O24-6       0.000e+00   0.000e+00   -59.124   -61.899    -2.775     (0)
   HMo7O24-5      0.000e+00   0.000e+00   -61.697   -63.624    -1.927     (0)
   H2Mo7O24-4     0.000e+00   0.000e+00   -65.720   -66.954    -1.233     (0)
   H3Mo7O24-3     0.000e+00   0.000e+00   -71.126   -71.820    -0.694     (0)
Na            9.129e-03
   Na+            9.028e-03   7.801e-03    -2.044    -2.108    -0.063     (0)
   NaSO4-         6.237e-05   5.422e-05    -4.205    -4.266    -0.061     (0)
   NaHCO3         3.106e-05   3.106e-05    -4.508    -4.508     0.000     (0)
   NaCO3-         7.179e-06   6.241e-06    -5.144    -5.205    -0.061     (0)
   NaF            2.022e-07   2.022e-07    -6.694    -6.694     0.000     (0)
   NaH2BO3        1.028e-08   1.028e-08    -7.988    -7.988     0.000     (0)
   NaCrO4-        8.282e-16   6.935e-16   -15.082   -15.159    -0.077     (0)
Ni            9.895e-08
   Ni+2           3.758e-08   2.094e-08    -7.425    -7.679    -0.254     (0)
   NiCO3          3.357e-08   3.357e-08    -7.474    -7.474     0.000     (0)
   NiHCO3+        2.184e-08   1.828e-08    -7.661    -7.738    -0.077     (0)
   NiSO4          5.408e-09   5.408e-09    -8.267    -8.267     0.000     (0)
   NiOH+          4.101e-10   3.434e-10    -9.387    -9.464    -0.077     (0)
   NiCl+          8.807e-11   7.375e-11   -10.055   -10.132    -0.077     (0)
   Ni(OH)2        3.553e-11   3.553e-11   -10.449   -10.449     0.000     (0)
   NiF+           2.581e-11   2.161e-11   -10.588   -10.665    -0.077     (0)
   Ni(SO4)2-2     4.715e-13   2.318e-13   -12.327   -12.635    -0.308     (0)
   Ni(OH)3-       5.527e-14   4.628e-14   -13.257   -13.335    -0.077     (0)
   NiCl2          5.111e-16   5.111e-16   -15.292   -15.292     0.000     (0)
   NiSeO4         1.063e-16   1.063e-16   -15.973   -15.973     0.000     (0)
O(0)          5.640e-38
   O2             2.820e-38   2.835e-38   -37.550   -37.547     0.002     (0)
Pb            2.668e-07
   PbCO3          1.974e-07   1.974e-07    -6.705    -6.705     0.000     (0)
   Pb(CO3)2-2     4.975e-08   2.446e-08    -7.303    -7.612    -0.308     (0)
   PbHCO3+        9.604e-09   8.042e-09    -8.018    -8.095    -0.077     (0)
   PbOH+          5.972e-09   5.000e-09    -8.224    -8.301    -0.077     (0)
   Pb+2           2.742e-09   1.528e-09    -8.562    -8.816    -0.254     (0)
   PbSO4          9.688e-10   9.688e-10    -9.014    -9.014     0.000     (0)
   Pb(OH)2        2.060e-10   2.060e-10    -9.686    -9.686     0.000     (0)
   PbCl+          8.913e-11   7.463e-11   -10.050   -10.127    -0.077     (0)
   Pb(SO4)2-2     1.537e-11   7.556e-12   -10.813   -11.122    -0.308     (0)
   PbF+           5.284e-12   4.424e-12   -11.277   -11.354    -0.077     (0)
   PbCl2          4.588e-13   4.588e-13   -12.338   -12.338     0.000     (0)
   Pb(OH)3-       3.204e-13   2.683e-13   -12.494   -12.571    -0.077     (0)
   PbF2           3.577e-15   3.577e-15   -14.447   -14.447     0.000     (0)
   Pb2OH+3        5.985e-16   1.211e-16   -15.223   -15.917    -0.694     (0)
   PbCl3-         3.002e-16   2.514e-16   -15.523   -15.600    -0.077     (0)
   Pb(OH)4-2      1.741e-16   8.559e-17   -15.759   -16.068    -0.308     (0)
   Pb3(OH)4+2     2.631e-18   1.294e-18   -17.580   -17.888    -0.308     (0)
   PbF3-          3.328e-19   2.787e-19   -18.478   -18.555    -0.077     (0)
   PbCl4-2        3.217e-19   1.581e-19   -18.493   -18.801    -0.308     (0)
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   Pb4(OH)4+4     2.688e-22   1.571e-23   -21.570   -22.804    -1.233     (0)
   PbF4-2         1.115e-23   5.480e-24   -22.953   -23.261    -0.308     (0)
S(6)          2.987e-03
   SO4-2          2.322e-03   1.294e-03    -2.634    -2.888    -0.254     (0)
   CaSO4          3.472e-04   3.472e-04    -3.459    -3.459     0.000     (0)
   MgSO4          2.458e-04   2.458e-04    -3.609    -3.609     0.000     (0)
   NaSO4-         6.237e-05   5.422e-05    -4.205    -4.266    -0.061     (0)
   KSO4-          9.198e-06   7.997e-06    -5.036    -5.097    -0.061     (0)
   ZnSO4          1.936e-07   1.936e-07    -6.713    -6.713     0.000     (0)
   MnSO4          1.769e-07   1.769e-07    -6.752    -6.752     0.000     (0)
   CdSO4          7.183e-09   7.183e-09    -8.144    -8.144     0.000     (0)
   NiSO4          5.408e-09   5.408e-09    -8.267    -8.267     0.000     (0)
   CoSO4          4.721e-09   4.721e-09    -8.326    -8.326     0.000     (0)
   Zn(SO4)2-2     4.439e-09   2.182e-09    -8.353    -8.661    -0.308     (0)
   CuSO4          1.188e-09   1.188e-09    -8.925    -8.925     0.000     (0)
   HSO4-          1.130e-09   9.773e-10    -8.947    -9.010    -0.063     (0)
   FeSO4          1.096e-09   1.096e-09    -8.960    -8.960     0.000     (0)
   PbSO4          9.688e-10   9.688e-10    -9.014    -9.014     0.000     (0)
   Cd(SO4)2-2     2.551e-10   1.254e-10    -9.593    -9.902    -0.308     (0)
   CrOHSO4        1.755e-10   1.755e-10    -9.756    -9.756     0.000     (0)
   Pb(SO4)2-2     1.537e-11   7.556e-12   -10.813   -11.122    -0.308     (0)
   Ni(SO4)2-2     4.715e-13   2.318e-13   -12.327   -12.635    -0.308     (0)
   CrSO4+         7.239e-14   6.061e-14   -13.140   -13.217    -0.077     (0)
   AlSO4+         5.061e-15   4.378e-15   -14.296   -14.359    -0.063     (0)
   Al(SO4)2-      7.019e-17   6.071e-17   -16.154   -16.217    -0.063     (0)
   FeSO4+         5.364e-17   4.653e-17   -16.271   -16.332    -0.062     (0)
   Cr2(OH)2SO4+2  1.844e-17   9.068e-18   -16.734   -17.043    -0.308     (0)
   UO2SO4         1.199e-17   1.199e-17   -16.921   -16.921     0.000     (0)
   Fe(SO4)2-      1.538e-18   1.288e-18   -17.813   -17.890    -0.077     (0)
   VO2SO4-        1.119e-18   9.368e-19   -17.951   -18.028    -0.077     (0)
   Cr2(OH)2(SO4)2   6.971e-19   6.971e-19   -18.157   -18.157     0.000     (0)
   UO2(SO4)2-2    4.162e-19   2.046e-19   -18.381   -18.689    -0.308     (0)
   VOSO4          5.163e-21   5.163e-21   -20.287   -20.287     0.000     (0)
   CrO3SO4-2      2.773e-24   1.363e-24   -23.557   -23.865    -0.308     (0)
   VSO4+          3.134e-35   2.625e-35   -34.504   -34.581    -0.077     (0)
   U(SO4)2        0.000e+00   0.000e+00   -43.721   -43.721     0.000     (0)
   USO4+2         0.000e+00   0.000e+00   -44.424   -44.733    -0.308     (0)
Se(-2)        1.877e-35
   HSe-           1.877e-35   1.572e-35   -34.727   -34.804    -0.077     (0)
   MnSe           6.443e-39   6.443e-39   -38.191   -38.191     0.000     (0)
   H2Se           9.426e-40   9.426e-40   -39.026   -39.026     0.000     (0)
   Se-2           0.000e+00   0.000e+00   -41.383   -41.692    -0.308     (0)
Se(4)         2.282e-07
   HSeO3-         1.216e-07   1.018e-07    -6.915    -6.992    -0.077     (0)
   SeO3-2         1.067e-07   5.245e-08    -6.972    -7.280    -0.308     (0)
   H2SeO3         3.355e-13   3.355e-13   -12.474   -12.474     0.000     (0)
   Cd(SeO3)2-2    1.092e-16   5.367e-17   -15.962   -16.270    -0.308     (0)
   FeHSeO3+2      1.753e-21   8.618e-22   -20.756   -21.065    -0.308     (0)
Se(6)         1.948e-11
   SeO4-2         1.947e-11   1.085e-11   -10.711   -10.964    -0.254     (0)
   MnSeO4         2.245e-15   2.245e-15   -14.649   -14.649     0.000     (0)
   ZnSeO4         1.149e-15   1.149e-15   -14.940   -14.940     0.000     (0)
   NiSeO4         1.063e-16   1.063e-16   -15.973   -15.973     0.000     (0)
   CoSeO4         9.943e-17   9.943e-17   -16.002   -16.002     0.000     (0)
   CdSeO4         4.784e-17   4.784e-17   -16.320   -16.320     0.000     (0)
   HSeO4-         5.019e-18   4.202e-18   -17.299   -17.376    -0.077     (0)
   Zn(SeO4)2-2    2.572e-26   1.264e-26   -25.590   -25.898    -0.308     (0)
U(3)          0.000e+00
   U+3            0.000e+00   0.000e+00   -60.547   -61.241    -0.694     (0)
U(4)          1.179e-21
   U(OH)5-        1.178e-21   9.868e-22   -20.929   -21.006    -0.077     (0)
   U(OH)4         3.195e-25   3.195e-25   -24.496   -24.496     0.000     (0)
   U(OH)3+        1.078e-29   9.029e-30   -28.967   -29.044    -0.077     (0)
   U(OH)2+2       6.564e-35   3.227e-35   -34.183   -34.491    -0.308     (0)
   UF3+           1.184e-40   0.000e+00   -39.927   -40.004    -0.077     (0)
   UOH+3          0.000e+00   0.000e+00   -40.236   -40.930    -0.694     (0)
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   UF2+2          0.000e+00   0.000e+00   -40.509   -40.817    -0.308     (0)
   UF4            0.000e+00   0.000e+00   -42.350   -42.350     0.000     (0)
   UF+3           0.000e+00   0.000e+00   -42.837   -43.531    -0.694     (0)
   U(SO4)2        0.000e+00   0.000e+00   -43.721   -43.721     0.000     (0)
   USO4+2         0.000e+00   0.000e+00   -44.424   -44.733    -0.308     (0)
   UF5-           0.000e+00   0.000e+00   -45.062   -45.139    -0.077     (0)
   UF6-2          0.000e+00   0.000e+00   -46.737   -47.045    -0.308     (0)
   U+4            0.000e+00   0.000e+00   -47.211   -48.445    -1.233     (0)
   UCl+3          0.000e+00   0.000e+00   -48.912   -49.606    -0.694     (0)
   U6(OH)15+9     0.000e+00   0.000e+00  -179.902  -186.147    -6.244     (0)
U(5)          4.456e-19
   UO2+           4.456e-19   3.731e-19   -18.351   -18.428    -0.077     (0)
U(6)          3.492e-08
   UO2(CO3)3-4    3.309e-08   1.933e-09    -7.480    -8.714    -1.233     (0)
   UO2(CO3)2-2    1.826e-09   8.976e-10    -8.739    -9.047    -0.308     (0)
   UO2CO3         1.047e-12   1.047e-12   -11.980   -11.980     0.000     (0)
   UO2OH+         1.199e-15   1.004e-15   -14.921   -14.998    -0.077     (0)
   UO2F+          4.145e-17   3.471e-17   -16.382   -16.460    -0.077     (0)
   UO2SO4         1.199e-17   1.199e-17   -16.921   -16.921     0.000     (0)
   UO2+2          1.098e-17   6.121e-18   -16.959   -17.213    -0.254     (0)
   UO2F2          4.112e-18   4.112e-18   -17.386   -17.386     0.000     (0)
   UO2(SO4)2-2    4.162e-19   2.046e-19   -18.381   -18.689    -0.308     (0)
   UO2F3-         5.068e-20   4.244e-20   -19.295   -19.372    -0.077     (0)
   UO2Cl+         1.632e-20   1.366e-20   -19.787   -19.864    -0.077     (0)
   UO2F4-2        2.817e-23   1.385e-23   -22.550   -22.859    -0.308     (0)
   (UO2)2(OH)2+2  3.401e-24   1.672e-24   -23.468   -23.777    -0.308     (0)
   (UO2)3(OH)5+   2.580e-27   2.160e-27   -26.588   -26.666    -0.077     (0)
V(2)          0.000e+00
   VOH+           0.000e+00   0.000e+00   -40.975   -41.052    -0.077     (0)
   V+2            0.000e+00   0.000e+00   -42.369   -42.677    -0.308     (0)
V(3)          7.658e-14
   V(OH)3         7.658e-14   7.658e-14   -13.116   -13.116     0.000     (0)
   V(OH)2+        4.568e-25   3.825e-25   -24.340   -24.417    -0.077     (0)
   VOH+2          5.704e-29   2.804e-29   -28.244   -28.552    -0.308     (0)
   V+3            2.123e-34   4.296e-35   -33.673   -34.367    -0.694     (0)
   VSO4+          3.134e-35   2.625e-35   -34.504   -34.581    -0.077     (0)
   V2(OH)3+3      0.000e+00   0.000e+00   -53.824   -54.518    -0.694     (0)
   V2(OH)2+4      0.000e+00   0.000e+00   -55.071   -56.304    -1.233     (0)
V(4)          4.532e-18
   V(OH)3+        4.493e-18   3.762e-18   -17.347   -17.425    -0.077     (0)
   VO+2           2.946e-20   1.448e-20   -19.531   -19.839    -0.308     (0)
   VOSO4          5.163e-21   5.163e-21   -20.287   -20.287     0.000     (0)
   VOF+           4.261e-21   3.568e-21   -20.370   -20.448    -0.077     (0)
   VOCl+          6.678e-23   5.592e-23   -22.175   -22.252    -0.077     (0)
   VOF2           5.497e-23   5.497e-23   -22.260   -22.260     0.000     (0)
   VOF3-          9.568e-26   8.012e-26   -25.019   -25.096    -0.077     (0)
   VOF4-2         2.702e-29   1.329e-29   -28.568   -28.877    -0.308     (0)
   H2V2O4+2       1.444e-30   7.100e-31   -29.840   -30.149    -0.308     (0)
V(5)          4.718e-08
   H2VO4-         3.036e-08   2.542e-08    -7.518    -7.595    -0.077     (0)
   HVO4-2         1.681e-08   8.265e-09    -7.774    -8.083    -0.308     (0)
   H3VO4          1.964e-12   1.964e-12   -11.707   -11.707     0.000     (0)
   H3V2O7-        3.853e-13   3.226e-13   -12.414   -12.491    -0.077     (0)
   HV2O7-3        3.519e-13   7.123e-14   -12.454   -13.147    -0.694     (0)
   VO4-3          2.649e-14   5.361e-15   -13.577   -14.271    -0.694     (0)
   V2O7-4         4.247e-15   2.481e-16   -14.372   -15.605    -1.233     (0)
   V3O9-3         8.513e-17   1.723e-17   -16.070   -16.764    -0.694     (0)
   VO2+           3.508e-17   3.031e-17   -16.455   -16.518    -0.063     (0)
   VO2F           2.184e-18   2.184e-18   -17.661   -17.661     0.000     (0)
   VO2SO4-        1.119e-18   9.368e-19   -17.951   -18.028    -0.077     (0)
   VO2F2-         3.890e-20   3.258e-20   -19.410   -19.487    -0.077     (0)
   V4O12-4        3.127e-21   1.827e-22   -20.505   -21.738    -1.233     (0)
   VO2F3-2        3.395e-23   1.669e-23   -22.469   -22.777    -0.308     (0)
   VO2F4-3        1.667e-27   3.374e-28   -26.778   -27.472    -0.694     (0)
   V10O28-6       0.000e+00   0.000e+00   -56.712   -59.488    -2.775     (0)
   HV10O28-5      0.000e+00   0.000e+00   -57.486   -59.413    -1.927     (0)
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   H2V10O28-4     0.000e+00   0.000e+00   -61.084   -62.317    -1.233     (0)
Zn            3.430e-06
   ZnCO3          1.690e-06   1.690e-06    -5.772    -5.772     0.000     (0)
   Zn+2           1.227e-06   6.836e-07    -5.911    -6.165    -0.254     (0)
   ZnSO4          1.936e-07   1.936e-07    -6.713    -6.713     0.000     (0)
   ZnHCO3+        1.828e-07   1.531e-07    -6.738    -6.815    -0.077     (0)
   ZnOH+          1.063e-07   8.905e-08    -6.973    -7.050    -0.077     (0)
   Zn(OH)2        1.838e-08   1.838e-08    -7.736    -7.736     0.000     (0)
   Zn(SO4)2-2     4.439e-09   2.182e-09    -8.353    -8.661    -0.308     (0)
   ZnOHCl         4.030e-09   4.030e-09    -8.395    -8.395     0.000     (0)
   ZnCl+          2.741e-09   2.363e-09    -8.562    -8.626    -0.064     (0)
   ZnF+           6.692e-10   5.603e-10    -9.174    -9.252    -0.077     (0)
   Zn(OH)3-       1.433e-10   1.200e-10    -9.844    -9.921    -0.077     (0)
   ZnCl2          5.155e-12   5.155e-12   -11.288   -11.288     0.000     (0)
   Zn(OH)4-2      1.266e-14   6.223e-15   -13.898   -14.206    -0.308     (0)
   ZnCl3-         6.536e-15   5.636e-15   -14.185   -14.249    -0.064     (0)
   ZnSeO4         1.149e-15   1.149e-15   -14.940   -14.940     0.000     (0)
   ZnCl4-2        6.850e-18   3.879e-18   -17.164   -17.411    -0.247     (0)
   Zn(SeO4)2-2    2.572e-26   1.264e-26   -25.590   -25.898    -0.308     (0)

----------------------------Saturation indices----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.83      8.97   10.80  Al(OH)3
  Al2(MoO4)3      -54.51    -52.15    2.37  Al2(MoO4)3
  Al2O3            -1.70     17.95   19.65  Al2O3
  Al4(OH)10SO4     -5.91     16.79   22.70  Al4(OH)10SO4
  AlAsO4:2H2O     -10.59     -5.79    4.80  AlAsO4:2H2O
  AlOHSO4          -6.91    -10.14   -3.23  AlOHSO4
  Alunite          -4.85     -6.25   -1.40  KAl3(SO4)2(OH)6
  Anglesite        -3.91    -11.70   -7.79  PbSO4
  Anhydrite        -1.46     -5.82   -4.36  CaSO4
  Antlerite        -4.42      4.37    8.79  Cu3(OH)4SO4
  Aragonite         1.00     -7.30   -8.30  CaCO3
  Arsenolite      -77.59    -80.35   -2.76  As4O6
  Artinite         -3.71      5.89    9.60  MgCO3:Mg(OH)2:3H2O
  As2O5           -36.23    -29.52    6.71  As2O5
  Atacamite        -2.71      4.68    7.39  Cu2(OH)3Cl
  Azurite          -0.80    -17.70  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -14.32     10.07   24.39  Ba(OH)2:8H2O
  Ba2V2O7:2H2O    -12.54      3.33   15.87  Ba2V2O7:2H2O
  Ba3(AsO4)2        9.60      0.69   -8.91  Ba3(AsO4)2
  Ba3(VO4)2:4H2O  -19.54     13.40   32.94  Ba3(VO4)2:4H2O
  BaCrO4          -10.23    -19.90   -9.67  BaCrO4
  BaF2             -9.11    -14.93   -5.82  BaF2
  BaMoO4           -6.33    -13.29   -6.96  BaMoO4
  Barite            0.94     -9.04   -9.98  BaSO4
  BaSeO3           -6.86     -5.03    1.83  BaSeO3
  BaSeO4           -9.66    -17.12   -7.46  BaSeO4
  Bianchite        -7.29     -9.05   -1.76  ZnSO4:6H2O
  Birnessite       -9.11      8.98   18.09  MnO2
  Bixbyite         -5.61     -6.26   -0.64  Mn2O3
  Boehmite          0.40      8.97    8.58  AlOOH
  Brochantite      -3.03     12.19   15.22  Cu4(OH)6SO4
  Brucite          -3.60     13.24   16.84  Mg(OH)2
  Bunsenite        -3.90      8.54   12.45  NiO
  Ca(VO3)2         -9.18     -3.52    5.66  Ca(VO3)2
  Ca2V2O7          -7.73      9.77   17.50  Ca2V2O7
  Ca2V2O7:2H2O    -11.78      9.77   21.55  Ca2V2O7:2H2O
  Ca3(AsO4)2:4H2O -11.95     10.35   22.30  Ca3(AsO4)2:4H2O
  Ca3(VO4)2       -15.90     23.06   38.96  Ca3(VO4)2
  Ca3(VO4)2:4H2O  -16.80     23.06   39.86  Ca3(VO4)2:4H2O
  CaCrO4          -14.41    -16.68   -2.27  CaCrO4
  Calcite           1.18     -7.30   -8.48  CaCO3
  CaMoO4           -2.12    -10.07   -7.95  CaMoO4
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Carnotite	-4.57	-4.34	0.23	KUO2VO4
CaSeO3:2H2O	-4.63	-1.81	2.81	CaSeO3:2H2O
CaSeO4:2H2O	-10.88	-13.90	-3.02	CaSeO4:2H2O
Cd(BO2)2	-11.15	-1.31	9.84	Cd(BO2)2
Cd(OH)2	-5.05	8.60	13.64	Cd(OH)2
Cd(OH)2(am)	-5.13	8.60	13.73	Cd(OH)2
Cd3(OH)2(SO4)2	-19.14	-12.43	6.71	Cd3(OH)2(SO4)2
Cd3(OH)4SO4	-15.88	6.68	22.56	Cd3(OH)4SO4
Cd4(OH)6SO4	-13.12	15.28	28.40	Cd4(OH)6SO4
CdCl2	-12.69	-13.35	-0.66	CdCl2
CdCl2:1H2O	-11.66	-13.35	-1.69	CdCl2:1H2O
CdCl2:2.5H2O	-11.44	-13.35	-1.91	CdCl2:2.5H2O
CdF2	-15.19	-16.40	-1.21	CdF2
Cdmetal(alpha)	-29.14	-15.63	13.51	Cd
Cdmetal(gamma)	-29.24	-15.63	13.62	Cd
CdMoO4	-0.62	-14.77	-14.15	CdMoO4
CdOHCl	-5.91	-2.38	3.54	CdOHCl
CdSe	-14.12	-34.32	-20.20	CdSe
CdSeO4:2H2O	-16.74	-18.59	-1.85	CdSeO4:2H2O
CdSO4	-10.34	-10.51	-0.17	CdSO4
CdSO4:1H2O	-8.79	-10.51	-1.73	CdSO4:1H2O
CdSO4:2.67H2O	-8.64	-10.51	-1.87	CdSO4:2.67H2O
Cerussite	-0.05	-13.18	-13.13	PbCO3
CH4(g)	-76.44	-117.49	-41.05	CH4
Chalcanthite	-8.65	-11.29	-2.64	CuSO4:5H2O
Claudetite	-77.29	-80.35	-3.06	As4O6
Clausthalite	-8.41	-35.51	-27.10	PbSe
Co(BO2)2	-28.50	-1.43	27.07	Co(BO2)2
Co(OH)2	-4.61	8.49	13.09	Co(OH)2
Co(OH)3	-9.49	-11.80	-2.31	Co(OH)3
CO2(g)	-2.44	-20.59	-18.15	CO2
Co3(AsO4)2	-17.10	-4.07	13.03	Co3(AsO4)2
Co3O4	-4.62	-15.12	-10.50	Co3O4
CoCl2	-21.73	-13.46	8.27	CoCl2
CoCl2:6H2O	-16.00	-13.46	2.54	CoCl2:6H2O
CoCO3	-2.12	-12.10	-9.98	CoCO3
CoF2	-14.91	-16.51	-1.60	CoF2
CoF3	-47.84	-49.30	-1.46	CoF3
CoFe2O4	25.70	22.17	-3.53	CoFe2O4
CoMoO4	-7.12	-14.88	-7.76	CoMoO4
CoO	-5.10	8.49	13.59	CoO
CoSe	-18.23	-34.43	-16.20	CoSe
CoSeO3	-7.94	-6.62	1.32	CoSeO3
CoSeO4:6H2O	-17.17	-18.70	-1.53	CoSeO4:6H2O
CoSO4	-13.43	-10.63	2.80	CoSO4
CoSO4:6H2O	-8.15	-10.63	-2.47	CoSO4:6H2O
Cotunnite	-9.76	-14.54	-4.78	PbCl2
Cr(OH)2	-18.91	-8.10	10.82	Cr(OH)2
Cr(OH)3	-0.27	1.07	1.34	Cr(OH)3
Cr(OH)3(am)	1.82	1.07	-0.75	Cr(OH)3
Cr2O3	4.50	2.14	-2.36	Cr2O3
CrCl2	-44.13	-30.04	14.09	CrCl2
CrCl3	-46.96	-31.85	15.11	CrCl3
CrF3	-25.09	-36.43	-11.34	CrF3
Crmetal	-62.80	-32.32	30.48	Cr
CrO3	-26.76	-29.97	-3.21	CrO3
Cryolite	-14.16	-48.00	-33.84	Na3AlF6
Cu(OH)2	-0.85	7.83	8.67	Cu(OH)2
Cu2Se(alpha)	-0.31	-46.11	-45.80	Cu2Se
Cu2SO4	-20.35	-22.30	-1.95	Cu2SO4
Cu3(AsO4)2:2H2O	-12.14	-6.04	6.10	Cu3(AsO4)2:2H2O
Cu3Se2	-17.70	-81.19	-63.49	Cu3Se2
CuCO3	-1.26	-12.76	-11.50	CuCO3
CuCrO4	-16.70	-22.14	-5.44	CuCrO4
CuF	-9.19	-14.09	-4.91	CuF
CuF2	-18.28	-17.17	1.12	CuF2

CuF2:2H2O	-12.62	-17.17	-4.55	CuF2:2H2O
Cumetal	-4.95	-13.71	-8.76	Cu
CuMoO4	-2.46	-15.54	-13.08	CuMoO4
CuOCuSO4	-13.76	-3.46	10.30	CuOCuSO4
Cupricferrite	15.52	21.51	5.99	CuFe2O4
Cuprite	-1.78	-3.19	-1.41	Cu2O
Cuprousferrite	14.16	5.25	-8.92	CuFeO2
CuSe	-1.99	-35.09	-33.10	CuSe
CuSe2	-20.41	-53.78	-33.37	CuSe2
CuSeO3:2H2O	-7.79	-7.28	0.51	CuSeO3:2H2O
CuSeO4:5H2O	-16.92	-19.36	-2.44	CuSeO4:5H2O
CuSO4	-14.22	-11.29	2.94	CuSO4
Diaspore	2.10	8.97	6.87	AlOOH
Dolomite(disordered)	1.89	-14.65	-16.54	CaMg(CO3)2
Dolomite(ordered)	2.44	-14.65	-17.09	CaMg(CO3)2
Epsomite	-3.74	-5.87	-2.13	MgSO4:7H2O
Fe(OH)2	-5.80	7.76	13.56	Fe(OH)2
Fe(OH)2.7Cl.3	6.59	3.55	-3.04	Fe(OH)2.7Cl.3
Fe(VO3)2	-5.33	-9.05	-3.72	Fe(VO3)2
Fe2(OH)4SeO3	-2.98	-1.42	1.55	Fe2(OH)4SeO3
Fe2(SeO3)3:2H2O	-11.00	-31.63	-20.63	Fe2(SeO3)3:2H2O
Fe2(SO4)3	-39.92	-43.65	-3.73	Fe2(SO4)3
Fe3(OH)8	1.22	21.44	20.22	Fe3(OH)8
FeAsO4:2H2O	-8.32	-7.92	0.40	FeAsO4:2H2O
FeCr2O4	2.70	9.90	7.20	FeCr2O4
FeMoO4	-5.51	-15.60	-10.09	FeMoO4
Ferrihydrite	3.65	6.84	3.19	Fe(OH)3
Ferroselite	-35.25	-53.85	-18.60	FeSe2
FeSe	-24.15	-35.15	-11.00	FeSe
Fluorite	-1.20	-11.70	-10.50	CaF2
Gibbsite	0.68	8.97	8.29	Al(OH)3
Goethite	6.35	6.84	0.49	FeOOH
Goslarite	-7.04	-9.05	-2.01	ZnSO4:7H2O
Gummite	-8.66	-0.99	7.67	UO3
Gypsum	-1.21	-5.82	-4.61	CaSO4:2H2O
H-Jarosite	-5.60	-17.70	-12.10	(H3O)Fe3(SO4)2(OH)6
H2MoO4	-10.49	-23.37	-12.88	H2MoO4
H2Se(g)	-37.96	-42.92	-4.96	H2Se
Halite	-6.57	-4.97	1.60	NaCl
Hausmannite	-6.48	54.55	61.03	Mn3O4
Hematite	15.10	13.68	-1.42	Fe2O3
Hercynite	2.82	25.71	22.89	FeAl2O4
Huntite	0.62	-29.34	-29.97	CaMg3(CO3)4
Hydrocerussite	-0.19	-18.96	-18.77	Pb3(OH)2(CO3)2
Hydromagnesite	-7.39	-16.15	-8.77	Mg5(CO3)4(OH)2:4H2O
K-Alum	-19.03	-24.20	-5.17	KAl(SO4)2:12H2O
K-Jarosite	2.15	-12.65	-14.80	KFe3(SO4)2(OH)6
K2Cr2O7	-32.59	-49.84	-17.24	K2Cr2O7
K2CrO4	-19.35	-19.87	-0.51	K2CrO4
K2MoO4	-16.52	-13.26	3.26	K2MoO4
K2SeO4	-16.35	-17.08	-0.73	K2SeO4
Langite	-5.29	12.19	17.49	Cu4(OH)6SO4:H2O
Larnakite	-3.86	-4.30	-0.43	PbO:PbSO4
Laurionite	-4.19	-3.57	0.62	PbOHCl
Lepidocrocite	5.47	6.84	1.37	FeOOH
Lime	-19.41	13.29	32.70	CaO
Litharge	-5.29	7.41	12.69	PbO
Maghemite	7.30	13.68	6.39	Fe2O3
Magnesioferrite	10.07	26.93	16.86	Fe2MgO4
Magnesite	0.11	-7.35	-7.46	MgCO3
Magnetite	18.04	21.44	3.40	Fe3O4
Malachite	0.37	-4.94	-5.31	Cu2(OH)2CO3
Manganite	-3.12	22.22	25.34	MnOOH
Massicot	-5.49	7.41	12.89	PbO
Matlockite	-7.09	-16.06	-8.97	PbClF
Melanothallite	-20.38	-14.12	6.26	CuCl2

Melanterite	-9.14	-11.35	-2.21	FeSO4:7H2O
Mg(OH)2(active)	-5.55	13.24	18.79	Mg(OH)2
Mg(VO3)2	-14.85	-3.57	11.28	Mg(VO3)2
Mg2V2O7	-16.69	9.67	26.36	Mg2V2O7
MgCr2O4	-0.82	15.38	16.20	MgCr2O4
MgCrO4	-22.11	-16.73	5.38	MgCrO4
MgF2	-3.62	-11.75	-8.13	MgF2
MgMoO4	-8.27	-10.12	-1.85	MgMoO4
MgSeO3:6H2O	-4.92	-1.86	3.06	MgSeO3:6H2O
MgSeO4:6H2O	-12.75	-13.95	-1.20	MgSeO4:6H2O
Minium	-27.07	46.45	73.52	Pb3O4
Mirabilite	-5.99	-7.11	-1.11	Na2SO4:10H2O
Mn(VO3)2	-11.60	-6.70	4.90	Mn(VO3)2
Mn2(SO4)3	-57.88	-63.59	-5.71	Mn2(SO4)3
Mn3(AsO4)2:8H2O	-11.70	0.80	12.50	Mn3(AsO4)2:8H2O
MnCl2:4H2O	-14.55	-11.84	2.72	MnCl2:4H2O
MnSe	-36.31	-32.81	3.50	MnSe
MnSeO3	-6.12	-4.99	1.13	MnSeO3
MnSeO3:2H2O	-5.98	-4.99	0.98	MnSeO3:2H2O
MnSeO4:5H2O	-15.03	-17.08	-2.05	MnSeO4:5H2O
MnSO4	-11.59	-9.00	2.58	MnSO4
Monteponite	-6.51	8.60	15.10	CdO
MoO3	-15.37	-23.37	-8.00	MoO3
Morenosite	-8.42	-10.57	-2.14	NiSO4:7H2O
Na-Jarosite	-0.50	-11.70	-11.20	NaFe3(SO4)2(OH)6
Na2Cr2O7	-38.04	-47.93	-9.90	Na2Cr2O7
Na2CrO4	-20.89	-17.96	2.93	Na2CrO4
Na2Mo2O7	-18.13	-34.72	-16.60	Na2Mo2O7
Na2MoO4	-12.85	-11.36	1.49	Na2MoO4
Na2MoO4:2H2O	-12.58	-11.36	1.22	Na2MoO4:2H2O
Na2SeO3:5H2O	-13.40	-3.10	10.30	Na2SeO3:5H2O
Na2SeO4	-16.46	-15.18	1.28	Na2SeO4
Na3VO4	-27.08	9.61	36.68	Na3VO4
Na4V2O7	-30.20	7.20	37.40	Na4V2O7
Nantokite	-5.84	-12.57	-6.73	CuCl
Natron	-7.27	-8.58	-1.31	Na2CO3:10H2O
NaVO3	-6.26	-2.40	3.86	NaVO3
Nesquehonite	-2.68	-7.35	-4.67	MgCO3:3H2O
Ni(OH)2	-4.25	8.54	12.79	Ni(OH)2
Ni3(AsO4)2:8H2O	-19.59	-3.89	15.70	Ni3(AsO4)2:8H2O
Ni4(OH)6SO4	-16.93	15.07	32.00	Ni4(OH)6SO4
NiCO3	-5.18	-12.05	-6.87	NiCO3
NiMoO4	-3.68	-14.82	-11.14	NiMoO4
NiSe	-16.67	-34.37	-17.70	NiSe
NiSeO3:2H2O	-9.37	-6.56	2.81	NiSeO3:2H2O
NiSeO4:6H2O	-17.12	-18.64	-1.52	NiSeO4:6H2O
Nsutite	-8.52	8.98	17.50	MnO2
O2(g)	-34.64	48.45	83.09	O2
Otavite	0.01	-11.99	-12.00	CdCO3
Pb(BO2)2	-9.02	-2.50	6.52	Pb(BO2)2
Pb(OH)2	-0.74	7.41	8.15	Pb(OH)2
Pb10(OH)6O(CO3)6	-40.70	-49.46	-8.76	Pb10(OH)6O(CO3)6
Pb2(OH)3Cl	-4.95	3.84	8.79	Pb2(OH)3Cl
Pb2O(OH)2	-11.37	14.82	26.19	Pb2O(OH)2
Pb2O3	-22.00	39.04	61.04	Pb2O3
Pb2OCO3	-5.22	-5.77	-0.56	Pb2OCO3
Pb2V2O7	-0.10	-2.00	-1.90	Pb2V2O7
Pb3(AsO4)2	-13.10	-7.30	5.80	Pb3(AsO4)2
Pb3(VO4)2	-0.73	5.41	6.14	Pb3(VO4)2
Pb3O2CO3	-9.39	1.63	11.02	Pb3O2CO3
Pb3O2SO4	-7.57	3.11	10.69	Pb3O2SO4
Pb4(OH)6SO4	-10.58	10.52	21.10	Pb4(OH)6SO4
Pb4O3SO4	-11.36	10.52	21.88	Pb4O3SO4
PbCrO4	-9.96	-22.56	-12.60	PbCrO4
PbF2	-10.15	-17.59	-7.44	PbF2
Pbmetal	-21.06	-16.82	4.25	Pb

PbMoO4	-0.34	-15.96	-15.62	PbMoO4
PbO:0.3H2O	-5.57	7.41	12.98	PbO:0.33H2O
PbSeO4	-12.94	-19.78	-6.84	PbSeO4
Periclase	-8.34	13.24	21.58	MgO
Phosgenite	-7.91	-27.72	-19.81	PbCl2:PbCO3
Plattnerite	-17.97	31.63	49.60	PbO2
Portlandite	-9.51	13.29	22.80	Ca(OH)2
Pyrochroite	-5.08	10.11	15.19	Mn(OH)2
Pyrolusite	-7.05	34.33	41.38	MnO2
Retgersite	-8.53	-10.57	-2.04	NiSO4:6H2O
Rhodochrosite	0.10	-10.48	-10.58	MnCO3
Rutherfordine	-7.08	-21.58	-14.50	UO2CO3
Schoepite	-6.98	-0.99	5.99	UO2(OH)2:H2O
Semetal(am)	-11.58	-18.69	-7.11	Se
Semetal(hex	-10.98	-18.69	-7.71	Se
SeO2	-15.23	-15.10	0.12	SeO2
SeO3	-48.23	-27.19	21.04	SeO3
Siderite	-2.59	-12.83	-10.24	FeCO3
Smithsonite	-0.53	-10.53	-10.00	ZnCO3
Spinel	-5.66	31.19	36.85	MgAl2O4
Tenorite	0.18	7.83	7.64	CuO
Thenardite	-7.43	-7.10	0.32	Na2SO4
Thermonatrite	-9.22	-8.58	0.64	Na2CO3:H2O
Tyuyamunite	-9.58	-5.50	4.08	Ca(UO2)2(VO4)2
U3O8	-20.63	0.46	21.08	U3O8
U4O9	-36.75	-39.76	-3.02	U4O9
UF4	-36.45	-65.99	-29.54	UF4
UF4:2.5H2O	-33.27	-65.99	-32.72	UF4:2.5H2O
UO2(am)	-16.93	-16.00	0.93	UO2
UO2(OH)2(beta)	-6.60	-0.99	5.61	UO2(OH)2
UO2SeO4:4H2O	-25.93	-28.18	-2.25	UO2SeO4:4H2O
UO3	-8.69	-0.99	7.70	UO3
Uraninite	-11.33	-16.00	-4.67	UO2
V(OH)3	-17.62	-10.03	7.59	V(OH)3
V2O5	-15.45	-16.81	-1.36	V2O5
V3O5	-36.91	-35.07	1.84	V3O5
V4O7	-45.87	-38.69	7.19	V4O7
V6O13	-38.03	-98.89	-60.86	V6O13
VCl2	-62.96	-44.09	18.87	VCl2
VCl3	-66.38	-42.95	23.43	VCl3
VF4	-68.54	-53.61	14.93	VF4
Vmetal	-90.39	-46.37	44.03	V
VO	-36.90	-22.14	14.76	VO
VO(OH)2	-8.77	-3.62	5.15	VO(OH)2
VO2Cl	-22.22	-19.38	2.84	VO2Cl
VOCl	-32.16	-21.00	11.15	VOCl
VOCl2	-38.32	-25.56	12.76	VOCl2
VOSO4	-26.34	-22.73	3.61	VOSO4
Witherite	-1.95	-10.52	-8.57	BaCO3
Zincite	-1.28	10.06	11.33	ZnO
Zincosite	-12.98	-9.05	3.93	ZnSO4
Zn(BO2)2	-8.14	0.15	8.29	Zn(BO2)2
Zn(OH)2	-2.14	10.06	12.20	Zn(OH)2
Zn(OH)2(am)	-2.42	10.06	12.47	Zn(OH)2
Zn(OH)2(beta)	-1.70	10.06	11.75	Zn(OH)2
Zn(OH)2(epsilon)	-1.48	10.06	11.53	Zn(OH)2
Zn(OH)2(gamma)	-1.68	10.06	11.73	Zn(OH)2
Zn2(OH)2SO4	-6.49	1.01	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-6.05	9.14	15.19	Zn2(OH)3Cl
Zn3(AsO4)2:2.5H2O	-13.00	0.65	13.65	Zn3(AsO4)2:2.5H2O
Zn3O(SO4)2	-26.96	-8.05	18.91	Zn3O(SO4)2
Zn4(OH)6SO4	-7.28	21.12	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-10.15	28.35	38.50	Zn5(OH)8Cl2
ZnCl2	-18.94	-11.89	7.05	ZnCl2
ZnCO3:1H2O	-0.27	-10.53	-10.26	ZnCO3:1H2O
ZnF2	-14.40	-14.94	-0.53	ZnF2

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  Znmetal         -39.95    -14.17   25.79  Zn
  ZnMoO4           -3.18    -13.31  -10.13  ZnMoO4
  ZnO(active)      -1.13     10.06   11.19  ZnO
  ZnSe            -18.46    -32.86  -14.40  ZnSe
  ZnSeO4:6H2O     -15.61    -17.13   -1.52  ZnSeO4:6H2O
  ZnSO4:1H2O       -8.42     -9.05   -0.64  ZnSO4:1H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 2.     PAF Material

-----------------------------Solution composition-----------------------------

      Elements           Molality       Moles

      Al               7.415e-07   7.415e-07
      Alkalinity       3.607e-04   3.607e-04
      Ba               1.457e-07   1.457e-07
      Ca               1.672e-03   1.672e-03
      Co               1.188e-07   1.188e-07
      Cu               4.408e-07   4.408e-07
      F                1.580e-05   1.580e-05
      K                3.326e-04   3.326e-04
      Mg               3.293e-04   3.293e-04
      Mn               7.283e-07   7.283e-07
      Mo               3.128e-08   3.128e-08
      Na               4.351e-05   4.351e-05
      Ni               6.818e-08   6.818e-08
      S(6)             2.051e-03   2.051e-03

----------------------------Description of solution----------------------------

                                       pH  =   7.500
                                       pe  =   4.000
                      Activity of water  =   1.000
                 Ionic strength (mol/kgw)  =   7.200e-03
                      Mass of water (kg)  =   1.000e+00
                 Total carbon (mol/kg)  =   3.782e-04
                    Total CO2 (mol/kg)  =   3.782e-04
                       Temperature (°C)  =  25.00
                 Electrical balance (eq)  =  -9.478e-05
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  -1.25
                              Iterations  =  13 (23 overall)
                                 Total H  = 1.110141e+02
                                 Total O  = 5.551618e+01

----------------------------Distribution of species----------------------------

                                            Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             3.487e-07   3.184e-07    -6.458    -6.497    -0.039     (0)
   H+              3.458e-08   3.162e-08    -7.461    -7.500    -0.039      0.00
   H2O             5.551e+01   9.999e-01     1.744    -0.000     0.000     18.07
Al            7.415e-07
   Al(OH)4-        7.221e-07   6.609e-07    -6.141    -6.180    -0.038     (0)
   Al(OH)3         1.649e-08   1.649e-08    -7.783    -7.783     0.000     (0)
   Al(OH)2+        2.830e-09   2.595e-09    -8.548    -8.586    -0.038     (0)
   AlF2+           2.736e-11   2.509e-11   -10.563   -10.600    -0.038     (0)
   AlOH+2          1.451e-11   1.026e-11   -10.838   -10.989    -0.150     (0)
   AlF+2           6.374e-12   4.507e-12   -11.196   -11.346    -0.150     (0)
   AlF3            4.418e-12   4.418e-12   -11.355   -11.355     0.000     (0)
   AlSO4+          3.315e-13   3.034e-13   -12.480   -12.518    -0.038     (0)
   Al+3            7.201e-14   3.223e-14   -13.143   -13.492    -0.349     (0)
   AlF4-           3.383e-14   3.096e-14   -13.471   -13.509    -0.038     (0)
   Al(SO4)2-       4.307e-15   3.942e-15   -14.366   -14.404    -0.038     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -49.070   -49.460    -0.390     (0)
Ba            1.457e-07
   Ba+2            1.453e-07   1.017e-07    -6.838    -6.993    -0.155     (0)
   BaHCO3+         3.363e-10   3.088e-10    -9.473    -9.510    -0.037     (0)
   BaCO3           2.459e-11   2.459e-11   -10.609   -10.609     0.000     (0)
   BaOH+           1.542e-13   1.413e-13   -12.812   -12.850    -0.038     (0)
C(4)          3.782e-04
   HCO3-           3.469e-04   3.181e-04    -3.460    -3.497    -0.038     (0)
   H2CO3           2.262e-05   2.262e-05    -4.645    -4.645     0.000     (0)
   CaHCO3+         6.292e-06   5.777e-06    -5.201    -5.238    -0.037     (0)
   CaCO3           7.289e-07   7.289e-07    -6.137    -6.137     0.000     (0)
   MgHCO3+         7.079e-07   6.472e-07    -6.150    -6.189    -0.039     (0)
   CO3-2           6.741e-07   4.716e-07    -6.171    -6.326    -0.155     (0)
   CuCO3           2.133e-07   2.133e-07    -6.671    -6.671     0.000     (0)
   MgCO3           7.799e-08   7.799e-08    -7.108    -7.108     0.000     (0)
   NaHCO3          7.071e-09   7.071e-09    -8.151    -8.151     0.000     (0)
   MnHCO3+         2.944e-09   2.697e-09    -8.531    -8.569    -0.038     (0)
   CoHCO3+         1.830e-09   1.657e-09    -8.738    -8.781    -0.043     (0)
   CuHCO3+         1.703e-09   1.542e-09    -8.769    -8.812    -0.043     (0)
   NiHCO3+         1.700e-09   1.539e-09    -8.770    -8.813    -0.043     (0)
   NiCO3           6.904e-10   6.904e-10    -9.161    -9.161     0.000     (0)
   CoCO3           5.337e-10   5.337e-10    -9.273    -9.273     0.000     (0)
   Cu(CO3)2-2      4.033e-10   2.707e-10    -9.394    -9.567    -0.173     (0)
   NaCO3-          3.785e-10   3.471e-10    -9.422    -9.460    -0.038     (0)
   BaHCO3+         3.363e-10   3.088e-10    -9.473    -9.510    -0.037     (0)
   BaCO3           2.459e-11   2.459e-11   -10.609   -10.609     0.000     (0)
Ca            1.672e-03
   Ca+2            1.394e-03   9.753e-04    -2.856    -3.011    -0.155     (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000     (0)
   CaHCO3+         6.292e-06   5.777e-06    -5.201    -5.238    -0.037     (0)
   CaCO3           7.289e-07   7.289e-07    -6.137    -6.137     0.000     (0)
   CaF+            1.625e-07   1.489e-07    -6.789    -6.827    -0.038     (0)
   CaOH+           6.748e-09   6.196e-09    -8.171    -8.208    -0.037     (0)
Co(2)         1.188e-07
   Co+2            9.974e-08   6.695e-08    -7.001    -7.174    -0.173     (0)
   CoSO4           1.620e-08   1.620e-08    -7.791    -7.791     0.000     (0)
   CoHCO3+         1.830e-09   1.657e-09    -8.738    -8.781    -0.043     (0)
   CoCO3           5.337e-10   5.337e-10    -9.273    -9.273     0.000     (0)
   CoOH+           4.699e-10   4.253e-10    -9.328    -9.371    -0.043     (0)
   CoF+            3.271e-11   2.961e-11   -10.485   -10.529    -0.043     (0)
   Co(OH)2         1.076e-11   1.076e-11   -10.968   -10.968     0.000     (0)
   Co(OH)3-        7.550e-17   6.834e-17   -16.122   -16.165    -0.043     (0)
   CoOOH-          1.894e-17   1.715e-17   -16.723   -16.766    -0.043     (0)
   Co2OH+3         3.499e-18   1.427e-18   -17.456   -17.846    -0.390     (0)
   Co(OH)4-2       5.137e-24   3.448e-24   -23.289   -23.462    -0.173     (0)
   Co4(OH)4+4      3.216e-29   6.530e-30   -28.493   -29.185    -0.692     (0)
Co(3)         6.424e-30
   CoOH+2          6.424e-30   4.312e-30   -29.192   -29.365    -0.173     (0)
   Co+3            5.955e-36   2.665e-36   -35.225   -35.574    -0.349     (0)
Cu(1)         4.157e-09
   Cu+             4.157e-09   3.762e-09    -8.381    -8.425    -0.043     (0)
Cu(2)         4.366e-07
   CuCO3           2.133e-07   2.133e-07    -6.671    -6.671     0.000     (0)
   Cu+2            1.098e-07   7.682e-08    -6.959    -7.115    -0.155     (0)
   CuOH+           8.460e-08   7.735e-08    -7.073    -7.112    -0.039     (0)
   CuSO4           2.134e-08   2.134e-08    -7.671    -7.671     0.000     (0)
   Cu(OH)2         4.914e-09   4.914e-09    -8.309    -8.309     0.000     (0)
   CuHCO3+         1.703e-09   1.542e-09    -8.769    -8.812    -0.043     (0)
   Cu(CO3)2-2      4.033e-10   2.707e-10    -9.394    -9.567    -0.173     (0)
   Cu2(OH)2+2      2.239e-10   1.503e-10    -9.650    -9.823    -0.173     (0)
   CuF+            7.488e-11   6.778e-11   -10.126   -10.169    -0.043     (0)
   Cu(OH)3-        3.545e-12   3.209e-12   -11.450   -11.494    -0.043     (0)
   Cu(OH)4-2       1.198e-17   8.042e-18   -16.922   -17.095    -0.173     (0)
F             1.580e-05
   F-              1.529e-05   1.398e-05    -4.816    -4.854    -0.039     (0)
   MgF+            3.409e-07   3.120e-07    -6.467    -6.506    -0.038     (0)
   CaF+            1.625e-07   1.489e-07    -6.789    -6.827    -0.038     (0)
   HF              6.541e-10   6.541e-10    -9.184    -9.184     0.000     (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000     (0)
   MnF+            2.582e-10   2.366e-10    -9.588    -9.626    -0.038     (0)
   CuF+            7.488e-11   6.778e-11   -10.126   -10.169    -0.043     (0)
   CoF+            3.271e-11   2.961e-11   -10.485   -10.529    -0.043     (0)
   AlF2+           2.736e-11   2.509e-11   -10.563   -10.600    -0.038     (0)
   NiF+            1.523e-11   1.379e-11   -10.817   -10.861    -0.043     (0)
   AlF+2           6.374e-12   4.507e-12   -11.196   -11.346    -0.150     (0)
   AlF3            4.418e-12   4.418e-12   -11.355   -11.355     0.000     (0)
   HF2-            3.808e-14   3.478e-14   -13.419   -13.459    -0.039     (0)
   AlF4-           3.383e-14   3.096e-14   -13.471   -13.509    -0.038     (0)
   H2F2            1.146e-18   1.146e-18   -17.941   -17.941     0.000     (0)
H(0)          1.414e-26
   H2              7.068e-27   7.079e-27   -26.151   -26.150     0.001     (0)
K             3.326e-04
   K+              3.298e-04   3.016e-04    -3.482    -3.521    -0.039     (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038     (0)
Mg            3.293e-04
   Mg+2            2.842e-04   1.988e-04    -3.546    -3.702    -0.155     (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000     (0)
   MgHCO3+         7.079e-07   6.472e-07    -6.150    -6.189    -0.039     (0)
   MgF+            3.409e-07   3.120e-07    -6.467    -6.506    -0.038     (0)
   MgCO3           7.799e-08   7.799e-08    -7.108    -7.108     0.000     (0)
   MgOH+           2.742e-08   2.520e-08    -7.562    -7.599    -0.037     (0)
Mn(2)         7.283e-07
   Mn+2            6.331e-07   4.250e-07    -6.199    -6.372    -0.173     (0)
   MnSO4           9.164e-08   9.164e-08    -7.038    -7.038     0.000     (0)
   MnHCO3+         2.944e-09   2.697e-09    -8.531    -8.569    -0.038     (0)
   MnOH+           3.710e-10   3.399e-10    -9.431    -9.469    -0.038     (0)
   MnF+            2.582e-10   2.366e-10    -9.588    -9.626    -0.038     (0)
   Mn(OH)3-        2.324e-19   2.129e-19   -18.634   -18.672    -0.038     (0)
   Mn(OH)4-2       3.106e-25   2.189e-25   -24.508   -24.660    -0.152     (0)
Mn(3)         4.241e-28
   Mn+3            4.241e-28   1.898e-28   -27.373   -27.722    -0.349     (0)
Mn(6)         0.000e+00
   MnO4-2          0.000e+00   0.000e+00   -48.642   -48.794    -0.152     (0)
Mn(7)         0.000e+00
   MnO4-           0.000e+00   0.000e+00   -54.126   -54.166    -0.040     (0)
Mo            3.128e-08
   MoO4-2          3.126e-08   2.187e-08    -7.505    -7.660    -0.155     (0)
   HMoO4-          1.520e-11   1.376e-11   -10.818   -10.861    -0.043     (0)
   H2MoO4          3.188e-15   3.188e-15   -14.497   -14.497     0.000     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -49.070   -49.460    -0.390     (0)
   Mo7O24-6        0.000e+00   0.000e+00   -59.073   -60.631    -1.558     (0)
   HMo7O24-5       0.000e+00   0.000e+00   -60.662   -61.744    -1.082     (0)
   H2Mo7O24-4      0.000e+00   0.000e+00   -63.769   -64.462    -0.692     (0)
   H3Mo7O24-3      0.000e+00   0.000e+00   -68.326   -68.716    -0.390     (0)
Na            4.351e-05
   Na+             4.322e-05   3.953e-05    -4.364    -4.403    -0.039     (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   NaHCO3          7.071e-09   7.071e-09    -8.151    -8.151     0.000     (0)
   NaCO3-          3.785e-10   3.471e-10    -9.422    -9.460    -0.038     (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000     (0)
Ni            6.818e-08
   Ni+2            5.610e-08   3.924e-08    -7.251    -7.406    -0.155     (0)
   NiSO4           9.495e-09   9.495e-09    -8.023    -8.023     0.000     (0)
   NiHCO3+         1.700e-09   1.539e-09    -8.770    -8.813    -0.043     (0)
   NiCO3           6.904e-10   6.904e-10    -9.161    -9.161     0.000     (0)
   NiOH+           1.738e-10   1.573e-10    -9.760    -9.803    -0.043     (0)
   NiF+            1.523e-11   1.379e-11   -10.817   -10.861    -0.043     (0)
   Ni(OH)2         3.978e-12   3.978e-12   -11.400   -11.400     0.000     (0)
   Ni(SO4)2-2      5.679e-13   3.812e-13   -12.246   -12.419    -0.173     (0)
   Ni(OH)3-        1.399e-15   1.267e-15   -14.854   -14.897    -0.043     (0)
O(0)          2.019e-40
   O2              1.010e-40   1.011e-40   -39.996   -39.995     0.001     (0)
S(6)          2.051e-03
   SO4-2           1.733e-03   1.213e-03    -2.761    -2.916    -0.155     (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000     (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000     (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038     (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   MnSO4           9.164e-08   9.164e-08    -7.038    -7.038     0.000     (0)
   CuSO4           2.134e-08   2.134e-08    -7.671    -7.671     0.000     (0)
   CoSO4           1.620e-08   1.620e-08    -7.791    -7.791     0.000     (0)
   NiSO4           9.495e-09   9.495e-09    -8.023    -8.023     0.000     (0)
   HSO4-           4.094e-09   3.747e-09    -8.388    -8.426    -0.038     (0)
   Ni(SO4)2-2      5.679e-13   3.812e-13   -12.246   -12.419    -0.173     (0)
   AlSO4+          3.315e-13   3.034e-13   -12.480   -12.518    -0.038     (0)
   Al(SO4)2-       4.307e-15   3.942e-15   -14.366   -14.404    -0.038     (0)

-----------------------------Saturation indices-------------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.79      9.01   10.80  Al(OH)3
  Al2(MoO4)3      -52.33    -49.96    2.37  Al2(MoO4)3
  Al2O3            -1.64     18.02   19.65  Al2O3
  Al4(OH)10SO4     -4.58     18.12   22.70  Al4(OH)10SO4
  AlOHSO4          -5.68     -8.91   -3.23  AlOHSO4
  Alunite          -3.43     -4.83   -1.40  KAl3(SO4)2(OH)6
  Anhydrite        -1.57     -5.93   -4.36  CaSO4
  Antlerite        -3.05      5.74    8.79  Cu3(OH)4SO4
  Aragonite        -1.04     -9.34   -8.30  CaCO3
  Artinite         -8.33      1.27    9.60  MgCO3:Mg(OH)2:3H2O
  Azurite          -2.09    -19.00  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -16.39      8.01   24.39  Ba(OH)2:8H2O
  BaF2            -10.88    -16.70   -5.82  BaF2
  BaMoO4           -7.69    -14.65   -6.96  BaMoO4
  Barite            0.07     -9.91   -9.98  BaSO4
  Birnessite      -11.81      6.28   18.09  MnO2
  Bixbyite         -9.80    -10.44   -0.64  Mn2O3
  Boehmite          0.43      9.01    8.58  AlOOH
  Brochantite      -1.60     13.63   15.22  Cu4(OH)6SO4
  Brucite          -5.55     11.30   16.84  Mg(OH)2
  Bunsenite        -4.85      7.59   12.45  NiO
  Calcite          -0.86     -9.34   -8.48  CaCO3
  CaMoO4           -2.72    -10.67   -7.95  CaMoO4
  CH4(g)          -72.28   -113.33  -41.05  CH4
  Chalcanthite     -7.39    -10.03   -2.64  CuSO4:5H2O
  Co(OH)2          -5.27      7.83   13.09  Co(OH)2
  Co(OH)3         -10.77    -13.07   -2.31  Co(OH)3
  CO2(g)           -3.18    -21.33  -18.15  CO2
  Co3O4            -7.83    -18.32  -10.50  Co3O4
  CoCO3            -3.52    -13.50   -9.98  CoCO3
  CoF2            -15.29    -16.88   -1.60  CoF2
  CoF3            -48.68    -50.14   -1.46  CoF3
  CoMoO4           -7.07    -14.83   -7.76  CoMoO4
  CoO              -5.76      7.83   13.59  CoO
  CoSO4           -12.89    -10.09    2.80  CoSO4
  CoSO4:6H2O       -7.62    -10.09   -2.47  CoSO4:6H2O
  Cryolite        -21.99    -55.83  -33.84  Na3AlF6
  Cu(OH)2          -0.79      7.89    8.67  Cu(OH)2
  Cu2SO4          -17.82    -19.77   -1.95  Cu2SO4
  CuCO3            -1.94    -13.44  -11.50  CuCO3
  CuF              -8.37    -13.28   -4.91  CuF
  CuF2            -17.94    -16.82    1.12  CuF2
  CuF2:2H2O       -12.27    -16.82   -4.55  CuF2:2H2O
  Cumetal          -3.67    -12.42   -8.76  Cu
  CuMoO4           -1.70    -14.77  -13.08  CuMoO4
  CuOCuSO4        -12.45     -2.15   10.30  CuOCuSO4
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  Cuprite          -0.44     -1.85   -1.41  Cu2O
  CuSO4          -12.97    -10.03    2.94  CuSO4
  Diaspore         2.14      9.01    6.87  AlOOH
  Dolomite(disordered)  -2.83    -19.37  -16.54  CaMg(CO3)2
  Dolomite(ordered)  -2.28    -19.37  -17.09  CaMg(CO3)2
  Epsomite         -4.49     -6.62   -2.13  MgSO4:7H2O
  Fluorite         -2.22    -12.72  -10.50  CaF2
  Gibbsite          0.72      9.01    8.29  Al(OH)3
  Gypsum           -1.32     -5.93   -4.61  CaSO4:2H2O
  H2MoO4           -9.78    -22.66  -12.88  H2MoO4
  Hausmannite     -12.15     48.88   61.03  Mn3O4
  Huntite          -9.45    -39.42  -29.97  CaMg3(CO3)4
  Hydromagnesite  -20.05    -28.81   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum          -17.68    -22.85   -5.17  KAl(SO4)2:12H2O
  K2MoO4          -17.96    -14.70    3.26  K2MoO4
  Langite          -3.86     13.63   17.49  Cu4(OH)6SO4:H2O
  Lime            -20.71     11.99   32.70  CaO
  Magnesite        -2.57    -10.03   -7.46  MgCO3
  Malachite        -0.25     -5.56   -5.31  Cu2(OH)2CO3
  Manganite        -5.21     20.13   25.34  MnOOH
  Mg(OH)2(active)  -7.50     11.30   18.79  Mg(OH)2
  MgF2             -5.28    -13.41   -8.13  MgF2
  MgMoO4           -9.51    -11.36   -1.85  MgMoO4
  Mirabilite      -10.61    -11.72   -1.11  Na2SO4:10H2O
  Mn2(SO4)3       -58.48    -64.19   -5.71  Mn2(SO4)3
  MnSO4           -11.87     -9.29    2.58  MnSO4
  MoO3            -14.66    -22.66   -8.00  MoO3
  Morenosite       -8.18    -10.32   -2.14  NiSO4:7H2O
  Na2Mo2O7        -22.53    -39.13  -16.60  Na2Mo2O7
  Na2MoO4         -17.96    -16.47    1.49  Na2MoO4
  Na2MoO4:2H2O    -17.69    -16.47    1.22  Na2MoO4:2H2O
  Natron          -13.82    -15.13   -1.31  Na2CO3:10H2O
  Nesquehonite     -5.36    -10.03   -4.67  MgCO3:3H2O
  Ni(OH)2          -5.20      7.59   12.79  Ni(OH)2
  Ni4(OH)6SO4     -19.54     12.46   32.00  Ni4(OH)6SO4
  NiCO3            -6.86    -13.73   -6.87  NiCO3
  NiMoO4           -3.92    -15.07  -11.14  NiMoO4
  Nsutite         -11.23      6.28   17.50  MnO2
  O2(g)           -37.09     46.00   83.09  O2
  Periclase       -10.29     11.30   21.58  MgO
  Portlandite     -10.81     11.99   22.80  Ca(OH)2
  Pyrochroite      -6.57      8.63   15.19  Mn(OH)2
  Pyrolusite       -9.75     31.63   41.38  MnO2
  Retgersite       -8.28    -10.32   -2.04  NiSO4:6H2O
  Rhodochrosite    -2.12    -12.70  -10.58  MnCO3
  Spinel           -7.53     29.31   36.85  MgAl2O4
  Tenorite          0.24      7.89    7.64  CuO
  Thenardite      -12.04    -11.72    0.32  Na2SO4
  Thermonatrite   -15.77    -15.13    0.64  Na2CO3:H2O
  Witherite        -4.75    -13.32   -8.57  BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 3.     NAF Material

-----------------------------Solution composition-----------------------------

      Elements           Molality       Moles

      Al                5.191e-06   5.191e-06
      Alkalinity        4.591e-04   4.591e-04
      As                3.873e-07   3.873e-07
      Ba                1.457e-07   1.457e-07
      Ca                3.046e-03   3.046e-03
      Co                3.395e-08   3.395e-08
      Cu                2.992e-07   2.992e-07
      F                 1.580e-05   1.580e-05
      Fe                1.254e-06   1.254e-06
      K                 4.094e-04   4.094e-04
      Mg                7.410e-04   7.410e-04
      Mn                2.368e-06   2.368e-06
      Mo                5.214e-08   5.214e-08
      Na                4.352e-05   4.352e-05
      Ni                1.705e-08   1.705e-08
      S(6)              3.447e-03   3.447e-03
      U                 4.203e-09   4.203e-09

----------------------------Description of solution----------------------------

                                       pH  =   7.600
                                       pe  =   4.000
                              Activity of water  =   1.000
                       Ionic strength (mol/kgw)  =   1.193e-02
                            Mass of water (kg)  =   1.000e+00
                         Total carbon (mol/kg)  =   4.552e-04
                            Total CO2 (mol/kg)  =   4.552e-04
                              Temperature (°C)  =  25.00
                        Electrical balance (eq)  =   6.787e-04
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =   5.48
                                  Iterations  =  11 (34 overall)
                                     Total H  = 1.110142e+02
                                     Total O  = 5.552201e+01

----------------------------Distribution of species----------------------------

                                                  Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             4.492e-07   4.008e-07    -6.348    -6.397    -0.049      (0)
   H+              2.808e-08   2.512e-08    -7.552    -7.600    -0.048     0.00
   H2O             5.551e+01   9.999e-01     1.744    -0.000     0.000    18.07
Al            5.191e-06
   Al(OH)4-        5.088e-06   4.556e-06    -5.293    -5.341    -0.048      (0)
   Al(OH)3         9.030e-08   9.030e-08    -7.044    -7.044     0.000      (0)
   Al(OH)2+        1.257e-08   1.129e-08    -7.901    -7.947    -0.047      (0)
   AlF2+           6.958e-11   6.249e-11   -10.158   -10.204    -0.047      (0)
   AlOH+2          5.451e-11   3.546e-11   -10.264   -10.450    -0.187      (0)
   AlF+2           1.811e-11   1.178e-11   -10.742   -10.929    -0.187      (0)
   AlF3            1.048e-11   1.048e-11   -10.980   -10.980     0.000      (0)
   AlSO4+          1.328e-12   1.189e-12   -11.877   -11.925    -0.048      (0)
   Al+3            2.412e-13   8.848e-14   -12.618   -13.053    -0.436      (0)
   AlF4-           7.812e-14   6.995e-14   -13.107   -13.155    -0.048      (0)
   Al(SO4)2-       2.463e-14   2.206e-14   -13.608   -13.656    -0.048      (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -48.018   -48.520    -0.501      (0)
As(3)         1.024e-17
   H3AsO3          1.000e-17   1.000e-17   -17.000   -17.000     0.000      (0)
   H2AsO3-         2.322e-19   2.043e-19   -18.634   -18.690    -0.056      (0)
   HAsO3-2         1.239e-23   7.417e-24   -22.907   -23.130    -0.223      (0)
   H4AsO3+         1.416e-25   1.245e-25   -24.849   -24.905    -0.056      (0)
   AsO3-3          3.611e-29   1.138e-29   -28.442   -28.944    -0.501      (0)
As(5)         3.873e-07
   HAsO4-2         3.350e-07   2.005e-07    -6.475    -6.698    -0.223      (0)
   H2AsO4-         5.222e-08   4.594e-08    -7.282    -7.338    -0.056      (0)
   AsO4-3          8.009e-11   2.524e-11   -10.096   -10.598    -0.501      (0)
   H3AsO4          2.000e-13   2.005e-13   -12.699   -12.698     0.001      (0)
Ba            1.457e-07
   Ba+2            1.453e-07   9.304e-08    -6.838    -7.031    -0.194      (0)
   BaHCO3+         3.699e-10   3.328e-10    -9.432    -9.478    -0.046      (0)
   BaCO3           3.336e-11   3.336e-11   -10.477   -10.477     0.000      (0)
   BaOH+           1.815e-13   1.628e-13   -12.741   -12.788    -0.047      (0)
C(4)          4.552e-04
   HCO3-           4.171e-04   3.746e-04    -3.380    -3.426    -0.047      (0)
   H2CO3           2.116e-05   2.116e-05    -4.674    -4.674     0.000      (0)
   CaHCO3+         1.200e-05   1.080e-05    -4.921    -4.967    -0.046      (0)
   CaCO3           1.715e-06   1.715e-06    -5.766    -5.766     0.000      (0)
   MgHCO3+         1.687e-06   1.508e-06    -5.773    -5.822    -0.049      (0)
   CO3-2           1.092e-06   6.991e-07    -5.962    -6.155    -0.194      (0)
   MgCO3           2.288e-07   2.288e-07    -6.641    -6.641     0.000      (0)
   CuCO3           1.600e-07   1.600e-07    -6.796    -6.796     0.000      (0)
   MnHCO3+         9.921e-09   8.899e-09    -8.003    -8.051    -0.047      (0)
   NaHCO3          8.124e-09   8.124e-09    -8.090    -8.090     0.000      (0)
   UO2(CO3)2-2     3.482e-09   2.084e-09    -8.458    -8.681    -0.223      (0)
   CuHCO3+         1.044e-09   9.187e-10    -8.981    -9.037    -0.056      (0)
   UO2(CO3)3-4     5.687e-10   7.303e-11    -9.245   -10.136    -0.891      (0)
   NaCO3-          5.590e-10   5.020e-10    -9.253    -9.299    -0.047      (0)
   CoHCO3+         5.432e-10   4.778e-10    -9.265    -9.321    -0.056      (0)
   Cu(CO3)2-2      5.030e-10   3.011e-10    -9.298    -9.521    -0.223      (0)
   NiHCO3+         4.493e-10   3.952e-10    -9.347    -9.403    -0.056      (0)
   BaHCO3+         3.699e-10   3.328e-10    -9.432    -9.478    -0.046      (0)
   NiCO3           2.232e-10   2.232e-10    -9.651    -9.651     0.000      (0)
   CoCO3           1.938e-10   1.938e-10    -9.713    -9.713     0.000      (0)
   UO2CO3          1.494e-10   1.494e-10    -9.826    -9.826     0.000      (0)
   FeHCO3+         1.083e-10   9.748e-11    -9.965   -10.011    -0.046      (0)
   BaCO3           3.336e-11   3.336e-11   -10.477   -10.477     0.000      (0)
Ca            3.046e-03
   Ca+2            2.418e-03   1.548e-03    -2.617    -2.810    -0.194      (0)
   CaSO4           6.140e-04   6.140e-04    -3.212    -3.212     0.000      (0)
   CaHCO3+         1.200e-05   1.080e-05    -4.921    -4.967    -0.046      (0)
   CaCO3           1.715e-06   1.715e-06    -5.766    -5.766     0.000      (0)
   CaF+            2.509e-07   2.251e-07    -6.600    -6.648    -0.047      (0)
   CaOH+           1.376e-08   1.238e-08    -7.861    -7.907    -0.046      (0)
Co(2)         3.395e-08
   Co+2            2.739e-08   1.640e-08    -7.562    -7.785    -0.223      (0)
   CoSO4           5.664e-09   5.664e-09    -8.247    -8.247     0.000      (0)
   CoHCO3+         5.432e-10   4.778e-10    -9.265    -9.321    -0.056      (0)
   CoCO3           1.938e-10   1.938e-10    -9.713    -9.713     0.000      (0)
   CoOH+           1.491e-10   1.311e-10    -9.827    -9.882    -0.056      (0)
   CoF+            7.852e-12   6.907e-12   -11.105   -11.161    -0.056      (0)
   Co(OH)2         4.175e-12   4.175e-12   -11.379   -11.379     0.000      (0)
   Co(OH)3-        3.796e-17   3.339e-17   -16.421   -16.476    -0.056      (0)
   CoOOH-          9.525e-18   8.379e-18   -17.021   -17.077    -0.056      (0)
   Co2OH+3         3.419e-19   1.078e-19   -18.466   -18.968    -0.501      (0)
   Co(OH)4-2       3.543e-24   2.121e-24   -23.451   -23.673    -0.223      (0)
   Co4(OH)4+4      4.595e-31   5.900e-32   -30.338   -31.229    -0.891      (0)
Co(3)         2.221e-30
   CoOH+2          2.221e-30   1.330e-30   -29.653   -29.876    -0.223      (0)
   Co+3            1.780e-36   6.528e-37   -35.750   -36.185    -0.436      (0)
Cu(1)         2.164e-09
   Cu+             2.164e-09   1.904e-09    -8.665    -8.720    -0.056      (0)
Cu(2)         2.970e-07
   CuCO3           1.600e-07   1.600e-07    -6.796    -6.796     0.000      (0)
   Cu+2            6.070e-08   3.887e-08    -7.217    -7.410    -0.194      (0)
   CuOH+           5.512e-08   4.927e-08    -7.259    -7.307    -0.049      (0)
   CuSO4           1.542e-08   1.542e-08    -7.812    -7.812     0.000      (0)
   Cu(OH)2         3.940e-09   3.940e-09    -8.404    -8.404     0.000      (0)
   CuHCO3+         1.044e-09   9.187e-10    -8.981    -9.037    -0.056      (0)
   Cu(CO3)2-2      5.030e-10   3.011e-10    -9.298    -9.521    -0.223      (0)
   Cu2(OH)2+2      1.019e-10   6.097e-11    -9.992   -10.215    -0.223      (0)
   CuF+            3.714e-11   3.267e-11   -10.430   -10.486    -0.056      (0)
   Cu(OH)3-        3.683e-12   3.239e-12   -11.434   -11.490    -0.056      (0)
   Cu(OH)4-2       1.707e-17   1.022e-17   -16.768   -16.991    -0.223      (0)
F             1.580e-05
   F-              1.489e-05   1.332e-05    -4.827    -4.876    -0.048      (0)
   MgF+            6.566e-07   5.879e-07    -6.183    -6.231    -0.048      (0)
   CaF+            2.509e-07   2.251e-07    -6.600    -6.648    -0.047      (0)
   MnF+            7.039e-10   6.314e-10    -9.152    -9.200    -0.047      (0)
   HF              4.949e-10   4.949e-10    -9.306    -9.306     0.000      (0)
   NaF             3.241e-10   3.241e-10    -9.489    -9.489     0.000      (0)
   AlF2+           6.958e-11   6.249e-11   -10.158   -10.204    -0.047      (0)
   CuF+            3.714e-11   3.267e-11   -10.430   -10.486    -0.056      (0)
   AlF+2           1.811e-11   1.178e-11   -10.742   -10.929    -0.187      (0)
   AlF3            1.048e-11   1.048e-11   -10.980   -10.980     0.000      (0)
   CoF+            7.852e-12   6.907e-12   -11.105   -11.161    -0.056      (0)
   NiF+            3.255e-12   2.863e-12   -11.487   -11.543    -0.056      (0)
   UO2F+           1.122e-13   9.871e-14   -12.950   -13.006    -0.056      (0)
   AlF4-           7.812e-14   6.995e-14   -13.107   -13.155    -0.048      (0)
   HF2-            2.808e-14   2.506e-14   -13.552   -13.601    -0.049      (0)
   UO2F2           3.792e-15   3.792e-15   -14.421   -14.421     0.000      (0)
   FeF+2           4.333e-16   2.804e-16   -15.363   -15.552    -0.189      (0)
   FeF2+           1.114e-16   9.996e-17   -15.953   -16.000    -0.047      (0)
   UO2F3-          1.442e-17   1.269e-17   -16.841   -16.897    -0.056      (0)
   FeF3            1.879e-18   1.879e-18   -17.726   -17.726     0.000      (0)
   H2F2            6.561e-19   6.561e-19   -18.183   -18.183     0.000      (0)
   UO2F4-2         2.242e-21   1.342e-21   -20.649   -20.872    -0.223      (0)
   UF3+            3.760e-36   3.307e-36   -35.425   -35.481    -0.056      (0)
   UF2+2           2.617e-36   1.567e-36   -35.582   -35.805    -0.223      (0)
   UF+3            2.964e-38   9.342e-39   -37.528   -38.030    -0.501      (0)
   UF4             4.830e-39   4.830e-39   -38.316   -38.316     0.000      (0)
   UF5-            0.000e+00   0.000e+00   -41.538   -41.594    -0.056      (0)
   UF6-2           0.000e+00   0.000e+00   -43.766   -43.989    -0.223      (0)
Fe(2)         4.379e-08
   Fe+2            3.453e-08   2.067e-08    -7.462    -7.685    -0.223      (0)
   FeSO4           8.785e-09   8.785e-09    -8.056    -8.056     0.000      (0)
   FeOH+           3.677e-10   3.298e-10    -9.434    -9.482    -0.047      (0)
   FeHCO3+         1.083e-10   9.748e-11    -9.965   -10.011    -0.046      (0)
   Fe(OH)2         1.050e-13   1.050e-13   -12.979   -12.979     0.000      (0)
   Fe(OH)3-        1.484e-14   1.331e-14   -13.829   -13.876    -0.047      (0)
Fe(3)         1.210e-06
   Fe(OH)2+        8.628e-07   7.749e-07    -6.064    -6.111    -0.047      (0)
   Fe(OH)3         3.336e-07   3.336e-07    -6.477    -6.477     0.000      (0)
   Fe(OH)4-        1.386e-08   1.245e-08    -7.858    -7.905    -0.047      (0)
   FeOH+2          7.678e-12   4.969e-12   -11.115   -11.304    -0.189      (0)
   FeF+2           4.333e-16   2.804e-16   -15.363   -15.552    -0.189      (0)
   FeSO4+          4.159e-16   3.730e-16   -15.381   -15.428    -0.047      (0)
   FeF2+           1.114e-16   9.996e-17   -15.953   -16.000    -0.047      (0)
   Fe+3            5.236e-17   1.920e-17   -16.281   -16.717    -0.436      (0)
   Fe(SO4)2-       1.570e-17   1.381e-17   -16.804   -16.860    -0.056      (0)
   FeF3            1.879e-18   1.879e-18   -17.726   -17.726     0.000      (0)
   Fe2(OH)2+4      6.368e-21   8.178e-22   -20.196   -21.087    -0.891      (0)
   Fe3(OH)4+5      2.263e-25   9.160e-27   -24.645   -26.038    -1.393      (0)
H(0)          8.909e-27
   H2              4.455e-27   4.467e-27   -26.351   -26.350     0.001      (0)
K             4.094e-04
   K+              4.045e-04   3.618e-04    -3.393    -3.441    -0.048      (0)
   KSO4-           4.938e-06   4.435e-06    -5.306    -5.353    -0.047      (0)
Mg            7.410e-04
   Mg+2            6.144e-04   3.934e-04    -3.212    -3.405    -0.194      (0)
   MgSO4           1.239e-04   1.239e-04    -3.907    -3.907     0.000      (0)
   MgHCO3+         1.687e-06   1.508e-06    -5.773    -5.822    -0.049      (0)
   MgF+            6.566e-07   5.879e-07    -6.183    -6.231    -0.048      (0)
   MgCO3           2.288e-07   2.288e-07    -6.641    -6.641     0.000      (0)
   MgOH+           6.966e-08   6.278e-08    -7.157    -7.202    -0.045      (0)
Mn(2)         2.368e-06
   Mn+2            1.989e-06   1.191e-06    -5.701    -5.924    -0.223      (0)
   MnSO4           3.666e-07   3.666e-07    -6.436    -6.436     0.000      (0)
   MnHCO3+         9.921e-09   8.899e-09    -8.003    -8.051    -0.047      (0)
   MnOH+           1.337e-09   1.199e-09    -8.874    -8.921    -0.047      (0)
   MnF+            7.039e-10   6.314e-10    -9.152    -9.200    -0.047      (0)
   Mn(OH)3-        1.327e-18   1.190e-18   -17.877   -17.924    -0.047      (0)
   Mn(OH)4-2       2.380e-24   1.540e-24   -23.623   -23.812    -0.189      (0)
Mn(3)         1.450e-27
   Mn+3            1.450e-27   5.318e-28   -26.839   -27.274    -0.436      (0)
Mn(6)         0.000e+00
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   MnO4-2          0.000e+00   0.000e+00   -47.357   -47.546    -0.189     (0)
Mn(7)          0.000e+00
   MnO4-           0.000e+00   0.000e+00   -52.868   -52.918    -0.050     (0)
Mo             5.214e-08
   MoO4-2          5.212e-08   3.338e-08    -7.283    -7.477    -0.194     (0)
   HMoO4           1.896e-11   1.668e-11   -10.722   -10.778    -0.056     (0)
   H2MoO4          3.069e-15   3.069e-15   -14.513   -14.513     0.000     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -48.018   -48.520    -0.501     (0)
   Mo7O24-6        0.000e+00   0.000e+00   -58.140   -60.146    -2.006     (0)
   HMo7O24-5       0.000e+00   0.000e+00   -59.966   -61.359    -1.393     (0)
   H2Mo7O24-4      0.000e+00   0.000e+00   -63.285   -64.177    -0.891     (0)
   H3Mo7O24-3      0.000e+00   0.000e+00   -68.029   -68.531    -0.501     (0)
Na             4.352e-05
   Na+             4.311e-05   3.857e-05    -4.365    -4.414    -0.048     (0)
   NaSO4-          3.992e-07   3.586e-07    -6.399    -6.445    -0.047     (0)
   NaHCO3          8.124e-09   8.124e-09    -8.090    -8.090     0.000     (0)
   NaCO3-          5.590e-10   5.020e-10    -9.253    -9.299    -0.047     (0)
   NaF             3.241e-10   3.241e-10    -9.489    -9.489     0.000     (0)
Ni             1.705e-08
   Ni+2            1.336e-08   8.558e-09    -7.874    -8.068    -0.194     (0)
   NiSO4           2.956e-09   2.956e-09    -8.529    -8.529     0.000     (0)
   NiHCO3+         4.493e-10   3.952e-10    -9.347    -9.403    -0.056     (0)
   NiCO3           2.232e-10   2.232e-10    -9.651    -9.651     0.000     (0)
   NiOH+           4.909e-11   4.318e-11   -10.309   -10.365    -0.056     (0)
   NiF+            3.255e-12   2.863e-12   -11.487   -11.543    -0.056     (0)
   Ni(OH)2         1.375e-12   1.375e-12   -11.862   -11.862     0.000     (0)
   Ni(SO4)2-2      2.831e-13   1.695e-13   -12.548   -12.771    -0.223     (0)
   Ni(OH)3-        6.265e-16   5.511e-16   -15.203   -15.259    -0.056     (0)
O(0)           5.066e-40
   O2              2.533e-40   2.540e-40   -39.596   -39.595     0.001     (0)
S(6)           3.447e-03
   SO4-2           2.704e-03   1.731e-03    -2.568    -2.762    -0.194     (0)
   CaSO4           6.140e-04   6.140e-04    -3.212    -3.212     0.000     (0)
   MgSO4           1.239e-04   1.239e-04    -3.907    -3.907     0.000     (0)
   KSO4-           4.938e-06   4.435e-06    -5.306    -5.353    -0.047     (0)
   NaSO4-          3.992e-07   3.586e-07    -6.399    -6.445    -0.047     (0)
   MnSO4           3.666e-07   3.666e-07    -6.436    -6.436     0.000     (0)
   CuSO4           1.542e-08   1.542e-08    -7.812    -7.812     0.000     (0)
   FeSO4           8.785e-09   8.785e-09    -8.056    -8.056     0.000     (0)
   CoSO4           5.664e-09   5.664e-09    -8.247    -8.247     0.000     (0)
   HSO4-           4.746e-09   4.250e-09    -8.324    -8.372    -0.048     (0)
   NiSO4           2.956e-09   2.956e-09    -8.529    -8.529     0.000     (0)
   AlSO4+          1.328e-12   1.189e-12   -11.877   -11.925    -0.048     (0)
   Ni(SO4)2-2      2.831e-13   1.695e-13   -12.548   -12.771    -0.223     (0)
   UO2SO4          1.407e-13   1.407e-13   -12.852   -12.852     0.000     (0)
   Al(SO4)2-       2.463e-14   2.206e-14   -13.608   -13.656    -0.048     (0)
   UO2(SO4)2-2     5.363e-15   3.210e-15   -14.271   -14.493    -0.223     (0)
   FeSO4+          4.159e-16   3.730e-16   -15.381   -15.428    -0.047     (0)
   Fe(SO4)2-       1.570e-17   1.381e-17   -16.804   -16.860    -0.056     (0)
   U(SO4)2         3.332e-38   3.332e-38   -37.477   -37.477     0.000     (0)
   USO4+2          4.047e-39   2.423e-39   -38.393   -38.616    -0.223     (0)
U(3)           0.000e+00
   U+3             0.000e+00   0.000e+00   -54.749   -55.250    -0.501     (0)
U(4)           3.033e-18
   U(OH)5-         3.030e-18   2.665e-18   -17.519   -17.574    -0.056     (0)
   U(OH)4          2.804e-21   2.804e-21   -20.552   -20.552     0.000     (0)
   U(OH)3+         2.928e-25   2.575e-25   -24.533   -24.589    -0.056     (0)
   U(OH)2+2        4.997e-30   2.991e-30   -29.301   -29.524    -0.223     (0)
   UOH+3           1.123e-35   3.539e-36   -34.950   -35.451    -0.501     (0)
   UF3+            3.760e-36   3.307e-36   -35.425   -35.481    -0.056     (0)
   UF2+2           2.617e-36   1.567e-36   -35.582   -35.805    -0.223     (0)
   U(SO4)2         3.332e-38   3.332e-38   -37.477   -37.477     0.000     (0)
   UF+3            2.964e-38   9.342e-39   -37.528   -38.030    -0.501     (0)
   UF4             4.830e-39   4.830e-39   -38.316   -38.316     0.000     (0)
   USO4+2          4.047e-39   2.423e-39   -38.393   -38.616    -0.223     (0)
   UF5-            0.000e+00   0.000e+00   -41.538   -41.594    -0.056     (0)
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   U+              0.000e+00   0.000e+00   -41.563   -42.454    -0.891     (0)
   UF6-2           0.000e+00   0.000e+00   -43.766   -43.989    -0.223     (0)
   U6(OH)15+9      0.000e+00   0.000e+00  -153.367  -157.880    -4.513     (0)
U(5)           3.720e-15
   UO2+            3.720e-15   3.272e-15   -14.429   -14.485    -0.056     (0)
U(6)           4.203e-09
   UO2(CO3)2-2     3.482e-09   2.084e-09    -8.458    -8.681    -0.223     (0)
   UO2(CO3)3-4     5.687e-10   7.303e-11    -9.245   -10.136    -0.891     (0)
   UO2CO3          1.494e-10   1.494e-10    -9.826    -9.826     0.000     (0)
   UO2OH+          3.080e-12   2.709e-12   -11.511   -11.567    -0.056     (0)
   UO2SO4          1.407e-13   1.407e-13   -12.852   -12.852     0.000     (0)
   UO2F+           1.122e-13   9.871e-14   -12.950   -13.006    -0.056     (0)
   UO2+2           8.384e-14   5.369e-14   -13.077   -13.270    -0.194     (0)
   UO2(SO4)2-2     5.363e-15   3.210e-15   -14.271   -14.493    -0.223     (0)
   UO2F2           3.792e-15   3.792e-15   -14.421   -14.421     0.000     (0)
   (UO2)2(OH)2+2   2.034e-17   1.218e-17   -16.692   -16.914    -0.223     (0)
   UO2F3-          1.442e-17   1.269e-17   -16.841   -16.897    -0.056     (0)
   (UO2)3(OH)5+    4.571e-18   4.021e-18   -17.340   -17.396    -0.056     (0)
   UO2F4-2         2.242e-21   1.342e-21   -20.649   -20.872    -0.223     (0)

----------------------------Saturation indices----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.05      9.75   10.80  Al(OH)3
  Al2(MoO4)3      -50.90    -48.54    2.37  Al2(MoO4)3
  Al2O3            -0.16     19.49   19.65  Al2O3
  Al4(OH)10SO4     -1.67     21.03   22.70  Al4(OH)10SO4
  AlAsO4:2H2O      -7.75     -2.95    4.80  AlAsO4:2H2O
  AlOHSO4          -4.98     -8.21   -3.23  AlOHSO4
  Alunite          -1.12     -2.52   -1.40  KAl3(SO4)2(OH)6
  Anhydrite        -1.21     -5.57   -4.36  CaSO4
  Antlerite        -3.38      5.41    8.79  Cu3(OH)4SO4
  Aragonite        -0.67     -8.97   -8.30  CaCO3
  Arsenolite      -65.24    -68.00   -2.76  As4O6
  Artinite         -7.37      2.23    9.60  MgCO3:Mg(OH)2:3H2O
  As2O5           -32.10    -25.40    6.71  As2O5
  Azurite          -2.44    -19.34  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -16.23      8.17   24.39  Ba(OH)2:8H2O
  Ba3(AsO4)2        8.02     -0.89   -8.91  Ba3(AsO4)2
  BaF2            -10.96    -16.78   -5.82  BaF2
  BaMoO4           -7.55    -14.51   -6.96  BaMoO4
  Barite            0.19     -9.79   -9.98  BaSO4
  Birnessite      -10.97      7.13   18.09  MnO2
  Bixbyite         -8.30     -8.95   -0.64  Mn2O3
  Boehmite          1.17      9.75    8.58  AlOOH
  Brochantite      -2.03     13.20   15.22  Cu4(OH)6SO4
  Brucite          -5.05     11.79   16.84  Mg(OH)2
  Bunsenite        -5.31      7.13   12.45  NiO
  Ca3(AsO4)2:4H2O -10.53     11.77   22.30  Ca3(AsO4)2:4H2O
  Calcite          -0.49     -8.97   -8.48  CaCO3
  CaMoO4           -2.34    -10.29   -7.95  CaMoO4
  CH4(g)          -73.11   -114.16  -41.05  CH4
  Chalcanthite     -7.53    -10.17   -2.64  CuSO4:5H2O
  Claudetite      -64.93    -68.00   -3.06  As4O6
  Co(OH)2          -5.68      7.41   13.09  Co(OH)2
  Co(OH)3         -11.08    -13.39   -2.31  Co(OH)3
  CO2(g)           -3.21    -21.36  -18.15  CO2
  Co3(AsO4)2      -16.19     -3.15   13.03  Co3(AsO4)2
  Co3O4            -8.86    -19.36  -10.50  Co3O4
  CoCO3            -3.96    -13.94   -9.98  CoCO3
  CoF2            -15.94    -17.54   -1.60  CoF2
  CoF3            -49.35    -50.81   -1.46  CoF3
  CoFe2O4          23.11     19.58   -3.53  CoFe2O4
  CoMoO4           -7.50    -15.26   -7.76  CoMoO4
  CoO              -6.17      7.41   13.59  CoO
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  CoSO4           -13.35    -10.55    2.80  CoSO4
  CoSO4:6H2O       -8.07    -10.55   -2.47  CoSO4:6H2O
  Cryolite        -21.71    -55.55  -33.84  Na3AlF6
  Cu(OH)2          -0.88      7.79    8.67  Cu(OH)2
  Cu2SO4          -18.25    -20.20   -1.95  Cu2SO4
  Cu3(AsO4)2:2H2O  -8.13     -2.03    6.10  Cu3(AsO4)2:2H2O
  CuCO3            -2.07    -13.57  -11.50  CuCO3
  CuF              -8.69    -13.60   -4.91  CuF
  CuF2            -18.28    -17.16    1.12  CuF2
  CuF2:2H2O       -12.61    -17.16   -4.55  CuF2:2H2O
  Cumetal          -3.96    -12.72   -8.76  Cu
  CuMoO4           -1.81    -14.89  -13.08  CuMoO4
  CuOCuSO4        -12.69     -2.38   10.30  CuOCuSO4
  Cupricferrite    13.97     19.96    5.99  CuFe2O4
  Cuprite          -0.83     -2.24   -1.41  Cu2O
  Cuprousferrite   13.88      4.96   -8.92  CuFeO2
  CuSO4           -13.11    -10.17    2.94  CuSO4
  Diaspore          2.87      9.75    6.87  AlOOH
  Dolomite(disordered)  -1.99    -18.53  -16.54  CaMg(CO3)2
  Dolomite(ordered)  -1.44    -18.53  -17.09  CaMg(CO3)2
  Epsomite         -4.04     -6.17   -2.13  MgSO4:7H2O
  Fe(OH)2          -6.05      7.52   13.56  Fe(OH)2
  Fe2(SO4)3       -37.98    -41.72   -3.73  Fe2(SO4)3
  Fe3(OH)8         -0.54     19.68   20.22  Fe3(OH)8
  FeAsO4:2H2O      -7.01     -6.61    0.40  FeAsO4:2H2O
  FeMoO4           -5.07    -15.16  -10.09  FeMoO4
  Ferrihydrite      2.89      6.08    3.19  Fe(OH)3
  Fluorite         -2.06    -12.56  -10.50  CaF2
  Gibbsite          1.46      9.75    8.29  Al(OH)3
  Goethite          5.59      6.08    0.49  FeOOH
  Gummite          -5.74      1.93    7.67  UO3
  Gypsum           -0.96     -5.57   -4.61  CaSO4:2H2O
  H-Jarosite       -5.57    -17.67  -12.10  (H3O)Fe3(SO4)2(OH)6
  H2MoO4           -9.80    -22.68  -12.88  H2MoO4
  Hausmannite     -10.00     51.03   61.03  Mn3O4
  Hematite         13.58     12.17   -1.42  Fe2O3
  Hercynite         4.12     27.01   22.89  FeAl2O4
  Huntite          -7.68    -37.65  -29.97  CaMg3(CO3)4
  Hydromagnesite  -17.68    -26.45   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum          -16.85    -22.02   -5.17  KAl(SO4)2:12H2O
  K-Jarosite        1.28    -13.52  -14.80  KFe3(SO4)2(OH)6
  K2MoO4          -17.62    -14.36    3.26  K2MoO4
  Langite          -4.29     13.20   17.49  Cu4(OH)6SO4:H2O
  Lepidocrocite     4.71      6.08    1.37  FeOOH
  Lime            -20.31     12.39   32.70  CaO
  Maghemite         5.78     12.17    6.39  Fe2O3
  Magnesioferrite   7.10     23.96   16.86  Fe2MgO4
  Magnesite        -2.10     -9.56   -7.46  MgCO3
  Magnetite        16.28     19.68    3.40  Fe3O4
  Malachite        -0.47     -5.78   -5.31  Cu2(OH)2CO3
  Manganite        -4.46     20.88   25.34  MnOOH
  Melanterite      -8.24    -10.45   -2.21  FeSO4:7H2O
  Mg(OH)2(active)  -7.00     11.79   18.79  Mg(OH)2
  MgF2             -5.03    -13.16   -8.13  MgF2
  MgMoO4           -9.03    -10.88   -1.85  MgMoO4
  Mirabilite      -10.48    -11.59   -1.11  Na2SO4:10H2O
  Mn2(SO4)3       -57.12    -62.83   -5.71  Mn2(SO4)3
  Mn3(AsO4)2:8H2O -10.07      2.43   12.50  Mn3(AsO4)2:8H2O
  MnSO4           -11.27     -8.69    2.58  MnSO4
  MoO3            -14.68    -22.68   -8.00  MoO3
  Morenosite       -8.68    -10.83   -2.14  NiSO4:7H2O
  Na-Jarosite      -3.29    -14.49  -11.20  NaFe3(SO4)2(OH)6
  Na2Mo2O7        -22.38    -38.98  -16.60  Na2Mo2O7
  Na2MoO4         -17.79    -16.30    1.49  Na2MoO4
  Na2MoO4:2H2O    -17.53    -16.30    1.22  Na2MoO4:2H2O
  Natron          -13.67    -14.98   -1.31  Na2CO3:10H2O
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  Nesquehonite     -4.89     -9.56   -4.67  MgCO3:3H2O
  Ni(OH)2          -5.66      7.13   12.79  Ni(OH)2
  Ni3(AsO4)2:8H2O -19.70     -4.00   15.70  Ni3(AsO4)2:8H2O
  Ni4(OH)6SO4     -21.43     10.57   32.00  Ni4(OH)6SO4
  NiCO3            -7.35    -14.22   -6.87  NiCO3
  NiMoO4           -4.40    -15.54  -11.14  NiMoO4
  Nsutite         -10.38      7.13   17.50  MnO2
  O2(g)           -36.69     46.40   83.09  O2
  Periclase        -9.79     11.79   21.58  MgO
  Portlandite     -10.41     12.39   22.80  Ca(OH)2
  Pyrochroite      -5.92      9.28   15.19  Mn(OH)2
  Pyrolusite       -8.90     32.48   41.38  MnO2
  Retgersite       -8.79    -10.83   -2.04  NiSO4:6H2O
  Rhodochrosite    -1.50    -12.08  -10.58  MnCO3
  Rutherfordine    -4.93    -19.43  -14.50  UO2CO3
  Schoepite        -4.06      1.93    5.99  UO2(OH)2:H2O
  Siderite         -3.60    -13.84  -10.24  FeCO3
  Spinel           -5.56     31.29   36.85  MgAl2O4
  Tenorite          0.15      7.79    7.64  CuO
  Thenardite      -11.91    -11.59    0.32  Na2SO4
  Thermonatrite   -15.62    -14.98    0.64  Na2CO3:H2O
  U3O8            -10.85     10.24   21.08  U3O8
  U4O9            -22.00    -25.02   -3.02  U4O9
  UF4             -32.42    -61.96  -29.54  UF4
  UF4:2.5H2O      -29.24    -61.96  -32.72  UF4:2.5H2O
  UO2(am)         -12.99    -12.05    0.93  UO2
  UO2(OH)2(beta)   -3.68      1.93    5.61  UO2(OH)2
  UO3              -5.77      1.93    7.70  UO3
  Uraninite        -7.38    -12.05   -4.67  UO2
  Witherite        -4.62    -13.19   -8.57  BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 4.     Make-up Material

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                7.415e-07   7.415e-07
      Alkalinity        3.607e-04   3.607e-04
      Ba                1.457e-07   1.457e-07
      Ca                1.672e-03   1.672e-03
      Co                1.188e-07   1.188e-07
      Cu                4.408e-07   4.408e-07
      F                 1.580e-05   1.580e-05
      K                 3.326e-04   3.326e-04
      Mg                3.293e-04   3.293e-04
      Mn                7.283e-07   7.283e-07
      Mo                3.128e-08   3.128e-08
      Na                4.351e-05   4.351e-05
      Ni                6.818e-08   6.818e-08
      S(6)              2.051e-03   2.051e-03

----------------------------Description of solution----------------------------

                                       pH  =   7.700
                                       pe  =   4.000
                                 Activity of water  =   1.000
                     Ionic strength (mol/kgw)  =   7.199e-03
                        Mass of water (kg)  =   1.000e+00
                     Total carbon (mol/kg)  =   3.686e-04
                        Total CO2 (mol/kg)  =   3.686e-04
                              Temperature (°C)  =  25.00
                     Electrical balance (eq)  =  -9.478e-05
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 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  -1.25
                                Iterations  =  12 (46 overall)
                                   Total H  = 1.110140e+02
                                   Total O  = 5.551615e+01

----------------------------Distribution of species----------------------------

                                                Log        Log        Log    mole V
   Species           Molality    Activity  Molality  Activity      Gamma    cm³/mol

   OH-              5.526e-07   5.046e-07    -6.258    -6.297     -0.039      (0)
   H+               2.182e-08   1.995e-08    -7.661    -7.700     -0.039      0.00
   H2O              5.551e+01   9.999e-01     1.744     -0.000      0.000     18.07
Al            7.415e-07
   Al(OH)4-         7.298e-07   6.680e-07    -6.137    -6.175     -0.038      (0)
   Al(OH)3          1.051e-08   1.051e-08    -7.978    -7.978      0.000      (0)
   Al(OH)2+         1.139e-09   1.044e-09    -8.944    -8.981     -0.038      (0)
   AlF2+            4.383e-12   4.020e-12   -11.358   -11.396     -0.038      (0)
   AlOH+2           3.684e-12   2.605e-12   -11.434   -11.584     -0.150      (0)
   AlF+2            1.021e-12   7.220e-13   -11.991   -12.141     -0.150      (0)
   AlF3             7.077e-13   7.077e-13   -12.150   -12.150      0.000      (0)
   AlSO4+           5.310e-14   4.860e-14   -13.275   -13.313     -0.038      (0)
   Al+3             1.153e-14   5.163e-15   -13.938   -14.287     -0.349      (0)
   AlF4-            5.420e-15   4.960e-15   -14.266   -14.304     -0.038      (0)
   Al(SO4)2-        6.899e-16   6.315e-16   -15.161   -15.200     -0.038      (0)
   AlMo6O21-3       0.000e+00   0.000e+00   -51.065   -51.455     -0.389      (0)
Ba            1.457e-07
   Ba+2             1.453e-07   1.017e-07    -6.838    -6.993     -0.155      (0)
   BaHCO3+          3.344e-10   3.070e-10    -9.476    -9.513     -0.037      (0)
   BaCO3            3.874e-11   3.874e-11   -10.412   -10.412      0.000      (0)
   BaOH+            2.444e-13   2.239e-13   -12.612   -12.650     -0.038      (0)
C(4)          3.686e-04
   HCO3-            3.449e-04   3.163e-04    -3.462    -3.500     -0.038      (0)
   H2CO3            1.419e-05   1.419e-05    -4.848    -4.848      0.000      (0)
   CaHCO3+          6.254e-06   5.742e-06    -5.204    -5.241     -0.037      (0)
   CaCO3            1.148e-06   1.148e-06    -5.940    -5.940      0.000      (0)
   CO3-2            1.062e-06   7.431e-07    -5.974    -6.129     -0.155      (0)
   MgHCO3+          7.037e-07   6.434e-07    -6.153    -6.192     -0.039      (0)
   CuCO3            2.384e-07   2.384e-07    -6.623    -6.623      0.000      (0)
   MgCO3            1.229e-07   1.229e-07    -6.911    -6.911      0.000      (0)
   NaHCO3           7.030e-09   7.030e-09    -8.153    -8.153      0.000      (0)
   MnHCO3+          2.926e-09   2.681e-09    -8.534    -8.572     -0.038      (0)
   CoHCO3+          1.811e-09   1.639e-09    -8.742    -8.785     -0.043      (0)
   NiHCO3+          1.678e-09   1.519e-09    -8.775    -8.818     -0.043      (0)
   CuHCO3+          1.201e-09   1.087e-09    -8.920    -8.964     -0.043      (0)
   NiCO3            1.080e-09   1.080e-09    -8.967    -8.967      0.000      (0)
   CoCO3            8.369e-10   8.369e-10    -9.077    -9.077      0.000      (0)
   Cu(CO3)2-2       7.104e-10   4.768e-10    -9.149    -9.322     -0.173      (0)
   NaCO3-           5.965e-10   5.470e-10    -9.224    -9.262     -0.038      (0)
   BaHCO3+          3.344e-10   3.070e-10    -9.476    -9.513     -0.037      (0)
   BaCO3            3.874e-11   3.874e-11   -10.412   -10.412      0.000      (0)
Ca            1.672e-03
   Ca+2             1.394e-03   9.751e-04    -2.856    -3.011     -0.155      (0)
   CaSO4            2.709e-04   2.709e-04    -3.567    -3.567      0.000      (0)
   CaHCO3+          6.254e-06   5.742e-06    -5.204    -5.241     -0.037      (0)
   CaCO3            1.148e-06   1.148e-06    -5.940    -5.940      0.000      (0)
   CaF+             1.624e-07   1.488e-07    -6.789    -6.827     -0.038      (0)
   CaOH+            1.069e-08   9.818e-09    -7.971    -8.008     -0.037      (0)
Co(2)         1.188e-07
   Co+2             9.925e-08   6.662e-08    -7.003    -7.176     -0.173      (0)
   CoSO4            1.612e-08   1.612e-08    -7.793    -7.793      0.000      (0)
   CoHCO3+          1.811e-09   1.639e-09    -8.742    -8.785     -0.043      (0)
   CoCO3            8.369e-10   8.369e-10    -9.077    -9.077      0.000      (0)
   CoOH+            7.411e-10   6.708e-10    -9.130    -9.173     -0.043      (0)
   CoF+             3.255e-11   2.946e-11   -10.487   -10.531     -0.043      (0)
   Co(OH)2          2.689e-11   2.689e-11   -10.570   -10.570      0.000      (0)
   Co(OH)3-         2.991e-16   2.707e-16   -15.524   -15.567     -0.043      (0)
   CoOOH-           7.505e-17   6.793e-17   -16.125   -16.168     -0.043      (0)
   Co2OH+3          5.491e-18   2.240e-18   -17.260   -17.650     -0.389      (0)
   Co(OH)4-2        3.225e-23   2.165e-23   -22.491   -22.665     -0.173      (0)
   Co4(OH)4+4       1.990e-28   4.040e-29   -27.701   -28.394     -0.692      (0)
Co(3)         1.013e-29
   CoOH+2           1.013e-29   6.801e-30   -28.994   -29.167     -0.173      (0)
   Co+3             5.925e-36   2.652e-36   -35.227   -35.576     -0.349      (0)
Cu(1)         2.948e-09
   Cu+              2.948e-09   2.668e-09    -8.530    -8.574     -0.043      (0)
Cu(2)         4.378e-07
   CuCO3            2.384e-07   2.384e-07    -6.623    -6.623      0.000      (0)
   CuOH+            9.510e-08   8.694e-08    -7.022    -7.061     -0.039      (0)
   Cu+2             7.788e-08   5.448e-08    -7.109    -7.264     -0.155      (0)
   CuSO4            1.514e-08   1.514e-08    -7.820    -7.820      0.000      (0)
   Cu(OH)2          8.754e-09   8.754e-09    -8.058    -8.058      0.000      (0)
   CuHCO3+          1.201e-09   1.087e-09    -8.920    -8.964     -0.043      (0)
   Cu(CO3)2-2       7.104e-10   4.768e-10    -9.149    -9.322     -0.173      (0)
   Cu2(OH)2+2       2.829e-10   1.899e-10    -9.548    -9.722     -0.173      (0)
   CuF+             5.311e-11   4.808e-11   -10.275   -10.318     -0.043      (0)
   Cu(OH)3-         1.001e-11   9.061e-12   -11.000   -11.043     -0.043      (0)
   Cu(OH)4-2        5.361e-17   3.599e-17   -16.271   -16.444     -0.173      (0)
F             1.580e-05
   F-               1.529e-05   1.398e-05    -4.816    -4.854     -0.039      (0)
   MgF+             3.408e-07   3.119e-07    -6.467    -6.506     -0.038      (0)
   CaF+             1.624e-07   1.488e-07    -6.789    -6.827     -0.038      (0)
   HF               4.127e-10   4.127e-10    -9.384    -9.384      0.000      (0)
   NaF              3.488e-10   3.488e-10    -9.457    -9.457      0.000      (0)
   MnF+             2.582e-10   2.365e-10    -9.588    -9.626     -0.038      (0)
   CuF+             5.311e-11   4.808e-11   -10.275   -10.318     -0.043      (0)
   CoF+             3.255e-11   2.946e-11   -10.487   -10.531     -0.043      (0)
   NiF+             1.512e-11   1.369e-11   -10.820   -10.864     -0.043      (0)
   AlF2+            4.383e-12   4.020e-12   -11.358   -11.396     -0.038      (0)
   AlF+2            1.021e-12   7.220e-13   -11.991   -12.141     -0.150      (0)
   AlF3             7.077e-13   7.077e-13   -12.150   -12.150      0.000      (0)
   HF2-             2.403e-14   2.194e-14   -13.619   -13.659     -0.039      (0)
   AlF4-            5.420e-15   4.960e-15   -14.266   -14.304     -0.038      (0)
   H2F2             4.564e-19   4.564e-19   -18.341   -18.341      0.000      (0)
H(0)          5.627e-27
   H2               2.814e-27   2.818e-27   -26.551   -26.550      0.001      (0)
K             3.326e-04
   K+               3.298e-04   3.016e-04    -3.482    -3.521     -0.039      (0)
   KSO4-            2.823e-06   2.589e-06    -5.549    -5.587     -0.038      (0)
Mg            3.293e-04
   Mg+2             2.842e-04   1.988e-04    -3.546    -3.702     -0.155      (0)
   MgSO4            4.387e-05   4.387e-05    -4.358    -4.358      0.000      (0)
   MgHCO3+          7.037e-07   6.434e-07    -6.153    -6.192     -0.039      (0)
   MgF+             3.408e-07   3.119e-07    -6.467    -6.506     -0.038      (0)
   MgCO3            1.229e-07   1.229e-07    -6.911    -6.911      0.000      (0)
   MgOH+            4.345e-08   3.994e-08    -7.362    -7.399     -0.037      (0)
Mn(2)         7.283e-07
   Mn+2             6.329e-07   4.249e-07    -6.199    -6.372     -0.173      (0)
   MnSO4            9.162e-08   9.162e-08    -7.038    -7.038      0.000      (0)
   MnHCO3+          2.926e-09   2.681e-09    -8.534    -8.572     -0.038      (0)
   MnOH+            5.878e-10   5.385e-10    -9.231    -9.269     -0.038      (0)
   MnF+             2.582e-10   2.365e-10    -9.588    -9.626     -0.038      (0)
   Mn(OH)3-         9.250e-19   8.475e-19   -18.034   -18.072     -0.038      (0)
   Mn(OH)4-2        1.959e-24   1.381e-24   -23.708   -23.860     -0.152      (0)
Mn(3)         4.240e-28
   Mn+3             4.240e-28   1.898e-28   -27.373   -27.722     -0.349      (0)
Mn(6)         0.000e+00
   MnO4-2           0.000e+00   0.000e+00   -47.042   -47.194     -0.152      (0)
Mn(7)         0.000e+00
   MnO4-            0.000e+00   0.000e+00   -52.526   -52.566     -0.040      (0)
Mo            3.128e-08
   MoO4-2           3.127e-08   2.188e-08    -7.505    -7.660     -0.155      (0)
   HMoO4-           9.595e-12   8.685e-12   -11.018   -11.061     -0.043      (0)
   H2MoO4           1.269e-15   1.269e-15   -14.896   -14.896      0.000      (0)
   AlMo6O21-3       0.000e+00   0.000e+00   -51.065   -51.455     -0.389      (0)
   Mo7O24-6         0.000e+00   0.000e+00   -60.672   -62.230     -1.558      (0)
   HMo7O24-5        0.000e+00   0.000e+00   -62.461   -63.543     -1.082      (0)
   H2Mo7O24-4       0.000e+00   0.000e+00   -65.769   -66.461     -0.692      (0)
   H3Mo7O24-3       0.000e+00   0.000e+00   -70.526   -70.915     -0.389      (0)
Na            4.351e-05
   Na+              4.322e-05   3.953e-05    -4.364    -4.403     -0.039      (0)
   NaSO4-           2.807e-07   2.574e-07    -6.552    -6.589     -0.038      (0)
   NaHCO3           7.030e-09   7.030e-09    -8.153    -8.153      0.000      (0)
   NaCO3-           5.965e-10   5.470e-10    -9.224    -9.262     -0.038      (0)
   NaF              3.488e-10   3.488e-10    -9.457    -9.457      0.000      (0)
Ni            6.818e-08
   Ni+2             5.569e-08   3.896e-08    -7.254    -7.409     -0.155      (0)
   NiSO4            9.427e-09   9.427e-09    -8.026    -8.026      0.000      (0)
   NiHCO3+          1.678e-09   1.519e-09    -8.775    -8.818     -0.043      (0)
   NiCO3            1.080e-09   1.080e-09    -8.967    -8.967      0.000      (0)
   NiOH+            2.734e-10   2.475e-10    -9.563    -9.606     -0.043      (0)
   NiF+             1.512e-11   1.369e-11   -10.820   -10.864     -0.043      (0)
   Ni(OH)2          9.921e-12   9.921e-12   -11.003   -11.003      0.000      (0)
   Ni(SO4)2-2       5.639e-13   3.785e-13   -12.249   -12.422     -0.173      (0)
   Ni(OH)3-         5.531e-15   5.006e-15   -14.257   -14.300     -0.043      (0)
O(0)          1.274e-39
   O2               6.370e-40   6.381e-40   -39.196   -39.195      0.001      (0)
S(6)          2.051e-03
   SO4-2            1.733e-03   1.213e-03    -2.761    -2.916     -0.155      (0)
   CaSO4            2.709e-04   2.709e-04    -3.567    -3.567      0.000      (0)
   MgSO4            4.387e-05   4.387e-05    -4.358    -4.358      0.000      (0)
   KSO4-            2.823e-06   2.589e-06    -5.549    -5.587     -0.038      (0)
   NaSO4-           2.807e-07   2.574e-07    -6.552    -6.589     -0.038      (0)
   MnSO4            9.162e-08   9.162e-08    -7.038    -7.038      0.000      (0)
   CoSO4            1.612e-08   1.612e-08    -7.793    -7.793      0.000      (0)
   CuSO4            1.514e-08   1.514e-08    -7.820    -7.820      0.000      (0)
   NiSO4            9.427e-09   9.427e-09    -8.026    -8.026      0.000      (0)
   HSO4-            2.583e-09   2.364e-09    -8.588    -8.626     -0.038      (0)
   Ni(SO4)2-2       5.639e-13   3.785e-13   -12.249   -12.422     -0.173      (0)
   AlSO4+           5.310e-14   4.860e-14   -13.275   -13.313     -0.038      (0)
   Al(SO4)2-        6.899e-16   6.315e-16   -15.161   -15.200     -0.038      (0)

-----------------------------Saturation indices-----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.99      8.81   10.80  Al(OH)3
  Al2(MoO4)3      -53.92    -51.55    2.37  Al2(MoO4)3
  Al2O3            -2.03     17.63   19.65  Al2O3
  Al4(OH)10SO4     -5.77     16.93   22.70  Al4(OH)10SO4
  AlOHSO4          -6.27     -9.50   -3.23  AlOHSO4
  Alunite          -4.61     -6.01   -1.40  KAl3(SO4)2(OH)6
  Anhydrite        -1.57     -5.93   -4.36  CaSO4
  Antlerite        -2.70      6.09    8.79  Cu3(OH)4SO4
  Aragonite        -0.84     -9.14   -8.30  CaCO3
  Artinite         -7.73      1.87    9.60  MgCO3:Mg(OH)2:3H2O
  Azurite          -1.74    -18.65  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -15.99      8.41   24.39  Ba(OH)2:8H2O
  BaF2            -10.88    -16.70   -5.82  BaF2
  BaMoO4           -7.69    -14.65   -6.96  BaMoO4
  Barite            0.07     -9.91   -9.98  BaSO4
  Birnessite      -11.01      7.08   18.09  MnO2
  Bixbyite         -8.60     -9.24   -0.64  Mn2O3
  Boehmite          0.23      8.81    8.58  AlOOH
  Brochantite      -0.99     14.23   15.22  Cu4(OH)6SO4
  Brucite          -5.15     11.70   16.84  Mg(OH)2
  Bunsenite        -4.45      7.99   12.45  NiO
  Calcite          -0.66     -9.14   -8.48  CaCO3
  CaMoO4           -2.72    -10.67   -7.95  CaMoO4
  CH4(g)          -74.08   -115.13  -41.05  CH4
  Chalcanthite     -7.54    -10.18   -2.64  CuSO4:5H2O
  Co(OH)2          -4.87      8.22   13.09  Co(OH)2
  Co(OH)3         -10.17    -12.48   -2.31  Co(OH)3
  CO2(g)           -3.38    -21.53  -18.15  CO2
  Co3O4            -6.23    -16.73  -10.50  Co3O4
  CoCO3            -3.33    -13.31   -9.98  CoCO3
  CoF2            -15.29    -16.89   -1.60  CoF2
  CoF3            -48.68    -50.14   -1.46  CoF3
  CoMoO4           -7.08    -14.84   -7.76  CoMoO4
  CoO              -5.36      8.22   13.59  CoO
  CoSO4           -12.90    -10.09    2.80  CoSO4
  CoSO4:6H2O       -7.62    -10.09   -2.47  CoSO4:6H2O
  Cryolite        -22.78    -56.62  -33.84  Na3AlF6
  Cu(OH)2          -0.54      8.14    8.67  Cu(OH)2
  Cu2SO4          -18.11    -20.06   -1.95  Cu2SO4
  CuCO3            -1.89    -13.39  -11.50  CuCO3
  CuF              -8.52    -13.43   -4.91  CuF
  CuF2            -18.09    -16.97    1.12  CuF2
  CuF2:2H2O       -12.42    -16.97   -4.55  CuF2:2H2O
  Cumetal          -3.82    -12.57   -8.76  Cu
  CuMoO4           -1.85    -14.92  -13.08  CuMoO4
  CuOCuSO4        -12.35     -2.04   10.30  CuOCuSO4
  Cuprite          -0.34     -1.75   -1.41  Cu2O
  CuSO4           -13.12    -10.18    2.94  CuSO4
  Diaspore          1.94      8.81    6.87  AlOOH
  Dolomite(disordered)  -2.43    -18.97  -16.54  CaMg(CO3)2
  Dolomite(ordered)  -1.88    -18.97  -17.09  CaMg(CO3)2
  Epsomite         -4.49     -6.62   -2.13  MgSO4:7H2O
  Fluorite         -2.22    -12.72  -10.50  CaF2
  Gibbsite          0.52      8.81    8.29  Al(OH)3
  Gypsum           -1.32     -5.93   -4.61  CaSO4:2H2O
  H2MoO4          -10.18    -23.06  -12.88  H2MoO4
  Hausmannite     -10.55     50.48   61.03  Mn3O4
  Huntite          -8.66    -38.63  -29.97  CaMg3(CO3)4
  Hydromagnesite  -18.86    -27.62   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum          -18.47    -23.64   -5.17  KAl(SO4)2:12H2O
  K2MoO4          -17.96    -14.70    3.26  K2MoO4
  Langite          -3.26     14.23   17.49  Cu4(OH)6SO4:H2O
  Lime            -20.31     12.39   32.70  CaO
  Magnesite        -2.37     -9.83   -7.46  MgCO3
  Malachite         0.05     -5.26   -5.31  Cu2(OH)2CO3
  Manganite        -4.61     20.73   25.34  MnOOH
  Mg(OH)2(active)  -7.10     11.70   18.79  Mg(OH)2
  MgF2             -5.28    -13.41   -8.13  MgF2
  MgMoO4           -9.51    -11.36   -1.85  MgMoO4
  Mirabilite      -10.61    -11.72   -1.11  Na2SO4:10H2O
  Mn2(SO4)3       -58.48    -64.19   -5.71  Mn2(SO4)3
  MnSO4           -11.87     -9.29    2.58  MnSO4
  MoO3            -15.06    -23.06   -8.00  MoO3
  Morenosite       -8.18    -10.33   -2.14  NiSO4:7H2O
  Na2Mo2O7        -22.93    -39.53  -16.60  Na2Mo2O7
  Na2MoO4         -17.96    -16.47    1.49  Na2MoO4
  Na2MoO4:2H2O    -17.69    -16.47    1.22  Na2MoO4:2H2O
  Natron          -13.62    -14.94   -1.31  Na2CO3:10H2O
  Nesquehonite     -5.16     -9.83   -4.67  MgCO3:3H2O
  Ni(OH)2          -4.80      7.99   12.79  Ni(OH)2
  Ni4(OH)6SO4     -18.35     13.65   32.00  Ni4(OH)6SO4
  NiCO3            -6.67    -13.54   -6.87  NiCO3
  NiMoO4           -3.93    -15.07  -11.14  NiMoO4
  Nsutite         -10.43     7.08   17.50  MnO2
  O2(g)           -36.29    46.80   83.09  O2
  Periclase        -9.89    11.70   21.58  MgO
  Portlandite     -10.42    12.39   22.80  Ca(OH)2
  Pyrochroite      -6.17     9.03   15.19  Mn(OH)2
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  Pyrolusite       -8.95     32.43   41.38  MnO2
  Retgersite       -8.29    -10.33   -2.04  NiSO4:6H2O
  Rhodochrosite    -1.92    -12.50  -10.58  MnCO3
  Spinel           -7.52     29.32   36.85  MgAl2O4
  Tenorite          0.49      8.14    7.64  CuO
  Thenardite      -12.04    -11.72    0.32  Na2SO4
  Thermonatrite   -15.57    -14.94    0.64  Na2CO3:H2O
  Witherite        -4.55    -13.12   -8.57  BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

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Beginning of batch-reaction calculations.
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Reaction step 1.

Using mix 1.      Mix within UG Works

Mixture 1.  Mix within UG Works

        2.780e-01 Solution 1  UG Water P75
        1.140e-01 Solution 2  PAF Material
        4.180e-01 Solution 3  NAF Material
        1.900e-01 Solution 4  Make-up Material

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                3.204e-06   3.204e-06
      As                1.727e-07   1.727e-07
      B                 3.360e-06   3.360e-06
      Ba                4.759e-07   4.759e-07
      C                 2.741e-03   2.741e-03
      Ca                2.534e-03   2.534e-03
      Cd                2.204e-08   2.204e-08
      Cl                4.428e-04   4.428e-04
      Co                6.921e-08   6.921e-08
      Cr                4.443e-08   4.443e-08
      Cu                6.169e-07   6.169e-07
      F                 2.639e-05   2.639e-05
      Fe                1.568e-06   1.568e-06
      K                 5.556e-04   5.556e-04
      Mg                1.035e-03   1.035e-03
      Mn                1.731e-06   1.731e-06
      Mo                6.728e-08   6.728e-08
      Na                2.569e-03   2.569e-03
      Ni                5.536e-08   5.536e-08
      Pb                7.416e-08   7.416e-08
      S                 2.895e-03   2.895e-03
      Se                6.346e-08   6.346e-08
      U                 1.146e-08   1.146e-08
      V                 1.311e-08   1.311e-08
      Zn                9.536e-07   9.536e-07

---------------------------Description of solution---------------------------

                                     pH  =   8.074      Charge balance
                                     pe  =   3.297      Adjusted to redox equilibrium
                            Activity of water  =   1.000
                     Ionic strength (mol/kgw)  =   1.358e-02
                           Mass of water (kg)  =   1.000e+00
                     Total alkalinity (eq/kg)  =   2.767e-03
                           Total CO2 (mol/kg)  =   2.741e-03
                              Temperature (°C)  =  25.00
                       Electrical balance (eq)  =   1.255e-03
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =   7.51
                                   Iterations  =  12
                                      Total H  = 1.110164e+02
                                      Total O  = 5.552667e+01

----------------------------Distribution of species----------------------------

                                                  Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             1.347e-06   1.194e-06    -5.871    -5.923    -0.052     (0)
   H+              9.488e-09   8.434e-09    -8.023    -8.074    -0.051      0.00
   H2O             5.551e+01   9.998e-01     1.744     -0.000     0.000     18.07
Al            3.204e-06
   Al(OH)4-        3.185e-06   2.834e-06    -5.497    -5.548    -0.051     (0)
   Al(OH)3         1.886e-08   1.886e-08    -7.725    -7.725     0.000     (0)
   Al(OH)2+        8.868e-10   7.917e-10    -9.052    -9.101    -0.049     (0)
   AlF2+           1.483e-12   1.324e-12   -11.829   -11.878    -0.049     (0)
   AlOH+2          1.314e-12   8.350e-13   -11.881   -12.078    -0.197     (0)
   AlF3            3.634e-13   3.634e-13   -12.440   -12.440     0.000     (0)
   AlF+2           2.401e-13   1.525e-13   -12.620   -12.817    -0.197     (0)
   AlSO4+          8.795e-15   7.826e-15   -14.056   -14.106    -0.051     (0)
   AlF4-           4.463e-15   3.971e-15   -14.350   -14.401    -0.051     (0)
   Al+3            2.019e-15   6.995e-16   -14.695   -15.155    -0.460     (0)
   Al(SO4)2-       1.358e-16   1.209e-16   -15.867   -15.918    -0.051     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -52.332   -52.867    -0.535     (0)
As(3)         1.638e-18
   H3AsO3          1.531e-18   1.531e-18   -17.815   -17.815     0.000     (0)
   H2AsO3-         1.068e-19   9.312e-20   -18.971   -19.031    -0.059     (0)
   HAsO3-2         1.741e-23   1.007e-23   -22.759   -22.997    -0.238     (0)
   H4AsO3+         7.338e-27   6.399e-27   -26.134   -26.194    -0.059     (0)
   AsO3-3          1.578e-28   4.603e-29   -27.802   -28.337    -0.535     (0)
As(5)         1.727e-07
   HAsO4-2         1.642e-07   9.495e-08    -6.785    -7.023    -0.238     (0)
   H2AsO4-         8.375e-09   7.303e-09    -8.077    -8.136    -0.059     (0)
   AsO4-3          1.220e-10   3.560e-11    -9.914   -10.449    -0.535     (0)
   H3AsO4          1.067e-14   1.070e-14   -13.972   -13.970     0.001     (0)
B             3.360e-06
   H3BO3           3.095e-06   3.105e-06    -5.509    -5.508     0.001     (0)
   H2BO3-          2.422e-07   2.138e-07    -6.616    -6.670    -0.054     (0)
   CaH2BO3+        1.766e-08   1.558e-08    -7.753    -7.807    -0.054     (0)
   MgH2BO3+        4.566e-09   4.029e-09    -8.341    -8.395    -0.054     (0)
   NaH2BO3         7.669e-10   7.669e-10    -9.115    -9.115     0.000     (0)
   BF(OH)3-        3.061e-11   2.701e-11   -10.514   -10.568    -0.054     (0)
   BaH2BO3+        2.182e-12   1.926e-12   -11.661   -11.715    -0.054     (0)
   H5(BO3)2-       6.402e-13   5.650e-13   -12.194   -12.248    -0.054     (0)
   BF2(OH)2-       6.018e-16   5.312e-16   -15.221   -15.275    -0.054     (0)
   H8(BO3)3-       1.988e-16   1.754e-16   -15.702   -15.756    -0.054     (0)
   BF3OH-          4.306e-23   3.801e-23   -22.366   -22.420    -0.054     (0)
   BF4-            3.897e-29   3.440e-29   -28.409   -28.463    -0.054     (0)
Ba            4.759e-07
   Ba+2            4.669e-07   2.915e-07    -6.331    -6.535    -0.205     (0)
   BaHCO3+         7.130e-09   6.379e-09    -8.147    -8.195    -0.048     (0)
   BaCO3           1.904e-09   1.904e-09    -8.720    -8.720     0.000     (0)
   BaH2BO3+        2.182e-12   1.926e-12   -11.661   -11.715    -0.054     (0)
   BaOH+           1.704e-12   1.519e-12   -11.769   -11.819    -0.050     (0)
C(4)          2.741e-03
   HCO3-           2.567e-03   2.292e-03    -2.591    -2.640    -0.049     (0)
   CaHCO3+         6.041e-05   5.405e-05    -4.219    -4.267    -0.048     (0)
   H2CO3           4.347e-05   4.347e-05    -4.362    -4.362     0.000     (0)
   CaCO3           2.557e-05   2.557e-05    -4.592    -4.592     0.000     (0)
   CO3-2           2.041e-05   1.274e-05    -4.690    -4.895    -0.205     (0)
   MgHCO3+         1.435e-05   1.275e-05    -4.843    -4.895    -0.052     (0)
   MgCO3           5.759e-06   5.759e-06    -5.240    -5.240     0.000     (0)
   NaHCO3          2.916e-06   2.916e-06    -5.535    -5.535     0.000     (0)
   NaCO3-          6.013e-07   5.368e-07    -6.221    -6.270    -0.049     (0)
   CuCO3           5.311e-07   5.311e-07    -6.275    -6.275     0.000     (0)
   ZnCO3           2.408e-07   2.408e-07    -6.618    -6.618     0.000     (0)
   PbCO3           5.847e-08   5.847e-08    -7.233    -7.233     0.000     (0)
   MnHCO3+         4.350e-08   3.878e-08    -7.361    -7.411    -0.050     (0)
   Cu(CO3)2-2      3.148e-08   1.821e-08    -7.502    -7.740    -0.238     (0)
   ZnHCO3+         2.730e-08   2.380e-08    -7.564    -7.623    -0.059     (0)
   NiCO3           9.711e-09   9.711e-09    -8.013    -8.013     0.000     (0)
   UO2(CO3)3-4     8.792e-09   9.841e-10    -8.056    -9.007    -0.951     (0)
   BaHCO3+         7.130e-09   6.379e-09    -8.147    -8.195    -0.048     (0)
   NiHCO3+         6.620e-09   5.773e-09    -8.179    -8.239    -0.059     (0)
   CoCO3           6.038e-09   6.038e-09    -8.219    -8.219     0.000     (0)
   CoHCO3+         5.731e-09   4.998e-09    -8.242    -8.301    -0.059     (0)
   Pb(CO3)2-2      3.714e-09   2.148e-09    -8.430    -8.668    -0.238     (0)
   PbHCO3+         2.981e-09   2.600e-09    -8.526    -8.585    -0.059     (0)
   CdCO3           2.772e-09   2.772e-09    -8.557    -8.557     0.000     (0)
   UO2(CO3)2-2     2.665e-09   1.541e-09    -8.574    -8.812    -0.238     (0)
   BaCO3           1.904e-09   1.904e-09    -8.720    -8.720     0.000     (0)
   CuHCO3+         1.174e-09   1.024e-09    -8.930    -8.990    -0.059     (0)
   FeHCO3+         2.957e-10   2.645e-10    -9.529    -9.578    -0.048     (0)
   CdHCO3+         5.711e-11   4.981e-11   -10.243   -10.303    -0.059     (0)
   Cd(CO3)2-2      4.525e-11   2.618e-11   -10.344   -10.582    -0.238     (0)
   UO2CO3          6.065e-12   6.065e-12   -11.217   -11.217     0.000     (0)
Ca            2.534e-03
   Ca+2            2.029e-03   1.267e-03    -2.693    -2.897    -0.205     (0)
   CaSO4           4.182e-04   4.182e-04    -3.379    -3.379     0.000     (0)
   CaHCO3+         6.041e-05   5.405e-05    -4.219    -4.267    -0.048     (0)
   CaCO3           2.557e-05   2.557e-05    -4.592    -4.592     0.000     (0)
   CaF+            3.381e-07   3.014e-07    -6.471    -6.521    -0.050     (0)
   CaOH+           3.372e-08   3.017e-08    -7.472    -7.520    -0.048     (0)
   CaH2BO3+        1.766e-08   1.558e-08    -7.753    -7.807    -0.054     (0)
Cd            2.204e-08
   Cd+2            1.529e-08   9.547e-09    -7.816    -8.020    -0.205     (0)
   CdSO4           3.225e-09   3.225e-09    -8.491    -8.491     0.000     (0)
   CdCO3           2.772e-09   2.772e-09    -8.557    -8.557     0.000     (0)
   CdCl+           4.115e-10   3.589e-10    -9.386    -9.445    -0.059     (0)
   Cd(SO4)2-2      1.084e-10   6.271e-11    -9.965   -10.203    -0.238     (0)
   CdOH+           1.038e-10   9.052e-11    -9.984   -10.043    -0.059     (0)
   CdHCO3+         5.711e-11   4.981e-11   -10.243   -10.303    -0.059     (0)
   Cd(CO3)2-2      4.525e-11   2.618e-11   -10.344   -10.582    -0.238     (0)
   CdOHCl          1.757e-11   1.757e-11   -10.755   -10.755     0.000     (0)
   CdF+            3.783e-12   3.299e-12   -11.422   -11.482    -0.059     (0)
   Cd(OH)2         6.817e-13   6.817e-13   -12.166   -12.166     0.000     (0)
   CdCl2           5.889e-13   5.889e-13   -12.230   -12.230     0.000     (0)
   CdCl3-          1.677e-16   1.462e-16   -15.775   -15.835    -0.059     (0)
   CdF2            1.435e-16   1.435e-16   -15.843   -15.843     0.000     (0)
   Cd(OH)3-        5.701e-17   4.972e-17   -16.244   -16.303    -0.059     (0)
   Cd2OH+3         1.484e-17   4.331e-18   -16.828   -17.363    -0.535     (0)
   Cd(SeO3)2-2     3.168e-18   1.832e-18   -17.499   -17.737    -0.238     (0)
   CdSeO4          1.853e-19   1.853e-19   -18.732   -18.732     0.000     (0)
   Cd(OH)4-2       1.679e-23   9.714e-24   -22.775   -23.013    -0.238     (0)
   CdHS+           0.000e+00   0.000e+00   -68.178   -68.237    -0.059     (0)
   Cd(HS)2         0.000e+00   0.000e+00  -129.258  -129.258     0.000     (0)
   Cd(HS)3-        0.000e+00   0.000e+00  -195.524  -195.583    -0.059     (0)
   Cd(HS)4-2       0.000e+00   0.000e+00  -261.375  -261.612    -0.238     (0)
Cl            4.428e-04
   Cl-             4.428e-04   3.936e-04    -3.354    -3.405    -0.051     (0)
   CuCl            8.666e-10   8.666e-10    -9.062    -9.062     0.000     (0)
   ZnOHCl          5.075e-10   5.075e-10    -9.295    -9.295     0.000     (0)
   MnCl+           4.715e-10   4.203e-10    -9.327    -9.376    -0.050     (0)
   CdCl+           4.115e-10   3.589e-10    -9.386    -9.445    -0.059     (0)
   ZnCl+           3.657e-10   3.248e-10    -9.437    -9.488    -0.052     (0)
   CuCl2-          8.025e-11   7.127e-11   -10.096   -10.147    -0.052     (0)
   CoCl+           4.378e-11   3.818e-11   -10.359   -10.418    -0.059     (0)
   PbCl+           2.445e-11   2.133e-11   -10.612   -10.671    -0.059     (0)
   NiCl+           2.360e-11   2.058e-11   -10.627   -10.687    -0.059     (0)
   CdOHCl          1.757e-11   1.757e-11   -10.755   -10.755     0.000     (0)
   CuCl+           4.974e-12   4.417e-12   -11.303   -11.355    -0.052     (0)
   CdCl2           5.889e-13   5.889e-13   -12.230   -12.230     0.000     (0)
   MnCl2           2.337e-13   2.337e-13   -12.631   -12.631     0.000     (0)
   ZnCl2           2.026e-13   2.026e-13   -12.693   -12.693     0.000     (0)
   PbCl2           3.750e-14   3.750e-14   -13.426   -13.426     0.000     (0)
   CuCl3-2         9.496e-15   5.997e-15   -14.022   -14.222    -0.200     (0)
   CuCl2           6.028e-16   6.028e-16   -15.220   -15.220     0.000     (0)
   CdCl3-          1.677e-16   1.462e-16   -15.775   -15.835    -0.059     (0)
   ZnCl3-          7.133e-17   6.335e-17   -16.147   -16.198    -0.052     (0)
   NiCl2           4.079e-17   4.079e-17   -16.389   -16.389     0.000     (0)
   MnCl3-          2.842e-17   2.533e-17   -16.546   -16.596    -0.050     (0)
   PbCl3-          6.737e-18   5.876e-18   -17.172   -17.231    -0.059     (0)
   CrCl+2          6.205e-18   3.589e-18   -17.207   -17.445    -0.238     (0)
   UO2Cl+          8.754e-20   7.634e-20   -19.058   -19.117    -0.059     (0)
   CrOHCl2         3.205e-20   3.205e-20   -19.494   -19.494     0.000     (0)
   FeCl+2          3.179e-20   2.008e-20   -19.498   -19.697    -0.200     (0)
   ZnCl4-2         1.974e-20   1.247e-20   -19.705   -19.904    -0.200     (0)
   CuCl3-          2.494e-21   2.214e-21   -20.603   -20.655    -0.052     (0)
   PbCl4-2         1.828e-21   1.057e-21   -20.738   -20.976    -0.238     (0)
   CrCl2+          1.537e-22   1.341e-22   -21.813   -21.873    -0.059     (0)
   VOCl+           4.072e-23   3.551e-23   -22.390   -22.450    -0.059     (0)
   FeCl2+          3.960e-23   3.530e-23   -22.402   -22.452    -0.050     (0)
   CuCl4-2         6.917e-27   4.369e-27   -26.160   -26.360    -0.200     (0)
   FeCl3           1.389e-27   1.389e-27   -26.857   -26.857     0.000     (0)
   CrO3Cl-         1.591e-29   1.388e-29   -28.798   -28.858    -0.059     (0)
   CoCl+2          3.065e-38   1.773e-38   -37.514   -37.751    -0.238     (0)
   UCl+3           0.000e+00   0.000e+00   -46.767   -47.302    -0.535     (0)
Co(2)         6.921e-08
   Co+2            4.848e-08   2.804e-08    -7.314    -7.552    -0.238     (0)
   CoSO4           8.063e-09   8.063e-09    -8.093    -8.093     0.000     (0)
   CoCO3           6.038e-09   6.038e-09    -8.219    -8.219     0.000     (0)
   CoHCO3+         5.731e-09   4.998e-09    -8.242    -8.301    -0.059     (0)
   CoOH+           7.658e-10   6.678e-10    -9.116    -9.175    -0.059     (0)
   Co(OH)2         6.332e-11   6.332e-11   -10.198   -10.198     0.000     (0)
   CoCl+           4.378e-11   3.818e-11   -10.359   -10.418    -0.059     (0)
   CoF+            2.217e-11   1.933e-11   -10.654   -10.714    -0.059     (0)
   Co(OH)3-        1.729e-15   1.508e-15   -14.762   -14.822    -0.059     (0)
   CoOOH-          4.340e-16   3.785e-16   -15.363   -15.422    -0.059     (0)
   Co2OH+3         3.217e-18   9.385e-19   -17.493   -18.028    -0.535     (0)
   CoSeO4          1.465e-18   1.465e-18   -17.834   -17.834     0.000     (0)
   Co(OH)4-2       4.933e-22   2.853e-22   -21.307   -21.545    -0.238     (0)
   Co4(OH)4+4      3.546e-28   3.969e-29   -27.450   -28.401    -0.951     (0)
Co(3)         2.321e-30
   CoOH+2          2.321e-30   1.343e-30   -29.634   -29.872    -0.238     (0)
   Co+3            6.390e-37   2.214e-37   -36.194   -36.655    -0.460     (0)
   CoCl+2          3.065e-38   1.773e-38   -37.514   -37.751    -0.238     (0)
Cr(2)         1.468e-24
   Cr+2            1.468e-24   8.488e-25   -23.833   -24.071    -0.238     (0)
Cr(3)         4.443e-08
   Cr(OH)2+        3.064e-08   2.672e-08    -7.514    -7.573    -0.059     (0)
   Cr(OH)3         1.198e-08   1.198e-08    -7.921    -7.921     0.000     (0)
   CrO2-           7.739e-10   6.749e-10    -9.111    -9.171    -0.059     (0)
   Cr(OH)4-        6.530e-10   5.694e-10    -9.185    -9.245    -0.059     (0)
   Cr(OH)+2        3.181e-10   1.840e-10    -9.497    -9.735    -0.238     (0)
   CrOHSO4         6.293e-11   6.293e-11   -10.201   -10.201     0.000     (0)
   CrF+2           4.209e-14   2.435e-14   -13.376   -13.614    -0.238     (0)
   CrSO4+          2.719e-14   2.371e-14   -13.566   -13.625    -0.059     (0)
   Cr+3            7.046e-15   1.473e-15   -13.617   -14.152    -0.535     (0)
   CrCl+2          6.205e-18   3.589e-18   -17.207   -17.445    -0.238     (0)
   Cr2(OH)2SO4+2   1.809e-18   1.047e-18   -17.742   -17.980    -0.238     (0)
   Cr2(OH)2(SO4)2   8.960e-20   8.960e-20   -19.048   -19.048     0.000     (0)
   CrOHCl2         3.205e-20   3.205e-20   -19.494   -19.494     0.000     (0)
   CrCl2+          1.537e-22   1.341e-22   -21.813   -21.873    -0.059     (0)
Cr(6)         4.013e-17
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CrO4-2	3.900e-17	2.435e-17	-16.409	-16.614	-0.205	(0)
HCrO4-	7.619e-19	6.645e-19	-18.118	-18.178	-0.059	(0)
NaCrO4-	3.140e-19	2.738e-19	-18.503	-18.563	-0.059	(0)
KCrO4-	5.071e-20	4.423e-20	-19.295	-19.354	-0.059	(0)
H2CrO4	4.543e-27	4.543e-27	-26.343	-26.343	0.000	(0)
CrO3SO4-2	4.254e-27	2.461e-27	-26.371	-26.609	-0.238	(0)
CrO3Cl-	1.591e-29	1.388e-29	-28.798	-28.858	-0.059	(0)
Cr2O7-2	2.647e-35	1.531e-35	-34.577	-34.815	-0.238	(0)
Cu(1)	2.952e-09					
Cu+	2.005e-09	1.749e-09	-8.698	-8.757	-0.059	(0)
CuCl	8.666e-10	8.666e-10	-9.062	-9.062	0.000	(0)
CuCl2-	8.025e-11	7.127e-11	-10.096	-10.147	-0.052	(0)
CuCl3-2	9.496e-15	5.997e-15	-14.022	-14.222	-0.200	(0)
Cu(S4)2-3	0.000e+00	0.000e+00	-125.385	-125.669	-0.284	(0)
CuS4S5-3	0.000e+00	0.000e+00	-126.126	-126.399	-0.273	(0)
Cu(2)	6.140e-07					
CuCO3	5.311e-07	5.311e-07	-6.275	-6.275	0.000	(0)
Cu(CO3)2-2	3.148e-08	1.821e-08	-7.502	-7.740	-0.238	(0)
CuOH+	3.009e-08	2.673e-08	-7.522	-7.573	-0.052	(0)
Cu+2	1.134e-08	7.080e-09	-7.945	-8.150	-0.205	(0)
Cu(OH)2	6.365e-09	6.365e-09	-8.196	-8.196	0.000	(0)
CuSO4	2.338e-09	2.338e-09	-8.631	-8.631	0.000	(0)
CuHCO3+	1.174e-09	1.024e-09	-8.930	-8.990	-0.059	(0)
Cu2(OH)2+2	3.102e-11	1.794e-11	-10.508	-10.746	-0.238	(0)
Cu(OH)3-	1.787e-11	1.558e-11	-10.748	-10.807	-0.059	(0)
CuF+	1.117e-11	9.740e-12	-10.952	-11.011	-0.059	(0)
CuCl+	4.974e-12	4.417e-12	-11.303	-11.355	-0.052	(0)
CuCl2	6.028e-16	6.028e-16	-15.220	-15.220	0.000	(0)
Cu(OH)4-2	2.531e-16	1.464e-16	-15.597	-15.834	-0.238	(0)
CuCl3-	2.494e-21	2.214e-21	-20.603	-20.655	-0.052	(0)
CuCl4-2	6.917e-27	4.369e-27	-26.160	-26.360	-0.200	(0)
Cu(HS)3-	0.000e+00	0.000e+00	-186.867	-186.926	-0.059	(0)
F	2.639e-05					
F-	2.453e-05	2.180e-05	-4.610	-4.661	-0.051	(0)
MgF+	1.494e-06	1.330e-06	-5.826	-5.876	-0.051	(0)
CaF+	3.381e-07	3.014e-07	-6.471	-6.521	-0.050	(0)
NaF	3.113e-08	3.113e-08	-7.507	-7.507	0.000	(0)
MnF+	8.258e-10	7.362e-10	-9.083	-9.133	-0.050	(0)
HF	2.720e-10	2.720e-10	-9.565	-9.565	0.000	(0)
ZnF+	1.639e-10	1.429e-10	-9.786	-9.845	-0.059	(0)
BF(OH)3-	3.061e-11	2.701e-11	-10.514	-10.568	-0.054	(0)
CoF+	2.217e-11	1.933e-11	-10.654	-10.714	-0.059	(0)
NiF+	1.283e-11	1.119e-11	-10.892	-10.951	-0.059	(0)
CuF+	1.117e-11	9.740e-12	-10.952	-11.011	-0.059	(0)
CdF+	3.783e-12	3.299e-12	-11.422	-11.482	-0.059	(0)
PbF+	2.690e-12	2.346e-12	-11.570	-11.630	-0.059	(0)
AlF2+	1.483e-12	1.324e-12	-11.829	-11.878	-0.049	(0)
AlF3	3.634e-13	3.634e-13	-12.440	-12.440	0.000	(0)
AlF+2	2.401e-13	1.525e-13	-12.620	-12.817	-0.197	(0)
CrF+2	4.209e-14	2.435e-14	-13.376	-13.614	-0.238	(0)
HF2-	2.544e-14	2.255e-14	-13.594	-13.647	-0.052	(0)
AlF4-	4.463e-15	3.971e-15	-14.350	-14.401	-0.051	(0)
PbF2	1.007e-15	1.007e-15	-14.997	-14.997	0.000	(0)
BF2(OH)2-	6.018e-16	5.312e-16	-15.221	-15.275	-0.054	(0)
UO2F+	4.127e-16	3.599e-16	-15.384	-15.444	-0.059	(0)
CdF2	1.435e-16	1.435e-16	-15.843	-15.843	0.000	(0)
FeF+2	6.393e-17	4.038e-17	-16.194	-16.394	-0.200	(0)
FeF2+	2.643e-17	2.356e-17	-16.578	-16.628	-0.050	(0)
UO2F2	2.263e-17	2.263e-17	-16.645	-16.645	0.000	(0)
FeF3	7.248e-19	7.248e-19	-18.140	-18.140	0.000	(0)
VO2F	4.285e-19	4.285e-19	-18.368	-18.368	0.000	(0)
H2F2	1.982e-19	1.982e-19	-18.703	-18.703	0.000	(0)
UO2F3-	1.421e-19	1.240e-19	-18.847	-18.907	-0.059	(0)
PbF3-	4.774e-20	4.163e-20	-19.321	-19.381	-0.059	(0)
VOF+	4.822e-21	4.205e-21	-20.317	-20.376	-0.059	(0)
VO2F2-	3.890e-21	3.392e-21	-20.410	-20.470	-0.059	(0)

BF3OH-	4.306e-23	3.801e-23	-22.366	-22.420	-0.054	(0)
UO2F4-2	3.712e-23	2.147e-23	-22.430	-22.668	-0.238	(0)
VOF2	3.438e-23	3.438e-23	-22.464	-22.464	0.000	(0)
VO2F3-2	1.595e-24	9.226e-25	-23.797	-24.035	-0.238	(0)
PbF4-2	7.512e-25	4.345e-25	-24.124	-24.362	-0.238	(0)
VOF3-	3.050e-26	2.660e-26	-25.516	-25.575	-0.059	(0)
BF4-	3.897e-29	3.440e-29	-28.409	-28.463	-0.054	(0)
VO2F4-3	3.393e-29	9.898e-30	-28.469	-29.004	-0.535	(0)
VOF4-2	4.047e-30	2.341e-30	-29.393	-29.631	-0.238	(0)
UF3+	1.198e-38	1.045e-38	-37.922	-37.981	-0.059	(0)
UF2+2	5.226e-39	3.023e-39	-38.282	-38.520	-0.238	(0)
UF+3	0.000e+00	0.000e+00	-40.423	-40.958	-0.535	(0)
UF4	0.000e+00	0.000e+00	-40.602	-40.602	0.000	(0)
UF5-	0.000e+00	0.000e+00	-43.607	-43.666	-0.059	(0)
UF6-2	0.000e+00	0.000e+00	-45.610	-45.847	-0.238	(0)
Fe(2)	1.988e-08					
Fe+2	1.585e-08	9.169e-09	-7.800	-8.038	-0.238	(0)
FeSO4	3.244e-09	3.244e-09	-8.489	-8.489	0.000	(0)
FeOH+	4.888e-10	4.357e-10	-9.311	-9.361	-0.050	(0)
FeHCO3+	2.957e-10	2.645e-10	-9.529	-9.578	-0.048	(0)
Fe(OH)2	4.131e-13	4.131e-13	-12.384	-12.384	0.000	(0)
Fe(OH)3-	1.749e-13	1.559e-13	-12.757	-12.807	-0.050	(0)
Fe(HS)2	0.000e+00	0.000e+00	-135.538	-135.538	0.000	(0)
Fe(HS)3-	0.000e+00	0.000e+00	-201.666	-201.726	-0.059	(0)
Fe(3)	1.549e-06					
Fe(OH)3	7.750e-07	7.750e-07	-6.111	-6.111	0.000	(0)
Fe(OH)2+	6.771e-07	6.045e-07	-6.169	-6.219	-0.049	(0)
Fe(OH)4-	9.648e-08	8.613e-08	-7.016	-7.065	-0.049	(0)
FeOH+2	2.061e-12	1.302e-12	-11.686	-11.885	-0.200	(0)
FeF+2	6.393e-17	4.038e-17	-16.194	-16.394	-0.200	(0)
FeSO4+	3.064e-17	2.731e-17	-16.514	-16.564	-0.050	(0)
FeF2+	2.643e-17	2.356e-17	-16.578	-16.628	-0.050	(0)
Fe+3	4.876e-18	1.689e-18	-17.312	-17.772	-0.460	(0)
Fe(SO4)2-	9.650e-19	8.416e-19	-18.015	-18.075	-0.059	(0)
FeF3	7.248e-19	7.248e-19	-18.140	-18.140	0.000	(0)
FeCl+2	3.179e-20	2.008e-20	-19.498	-19.697	-0.200	(0)
Fe2(OH)2+4	5.013e-22	5.611e-23	-21.300	-22.251	-0.951	(0)
FeHSeO3+2	2.495e-22	1.443e-22	-21.603	-21.841	-0.238	(0)
FeCl2+	3.960e-23	3.530e-23	-22.402	-22.452	-0.050	(0)
Fe3(OH)4+5	1.501e-26	4.903e-28	-25.824	-27.310	-1.486	(0)
FeCl3	1.389e-27	1.389e-27	-26.857	-26.857	0.000	(0)
H(0)	2.553e-26					
H2	1.277e-26	1.281e-26	-25.894	-25.893	0.001	(0)
K	5.556e-04					
K+	5.500e-04	4.889e-04	-3.260	-3.311	-0.051	(0)
KSO4-	5.587e-06	4.988e-06	-5.253	-5.302	-0.049	(0)
KCrO4-	5.071e-20	4.423e-20	-19.295	-19.354	-0.059	(0)
Mg	1.035e-03					
Mg+2	8.707e-04	5.435e-04	-3.060	-3.265	-0.205	(0)
MgSO4	1.426e-04	1.426e-04	-3.846	-3.846	0.000	(0)
MgHCO3+	1.435e-05	1.275e-05	-4.843	-4.895	-0.052	(0)
MgCO3	5.759e-06	5.759e-06	-5.240	-5.240	0.000	(0)
MgF+	1.494e-06	1.330e-06	-5.826	-5.876	-0.051	(0)
MgOH+	2.882e-07	2.583e-07	-6.540	-6.588	-0.048	(0)
MgH2BO3+	4.566e-09	4.029e-09	-8.341	-8.395	-0.054	(0)
Mn(2)	1.731e-06					
Mn+2	1.466e-06	8.482e-07	-5.834	-6.072	-0.238	(0)
MnSO4	2.174e-07	2.174e-07	-6.663	-6.663	0.000	(0)
MnHCO3+	4.350e-08	3.878e-08	-7.361	-7.411	-0.050	(0)
MnOH+	2.853e-09	2.543e-09	-8.545	-8.595	-0.050	(0)
MnF+	8.258e-10	7.362e-10	-9.083	-9.133	-0.050	(0)
MnCl+	4.715e-10	4.203e-10	-9.327	-9.376	-0.050	(0)
MnCl2	2.337e-13	2.337e-13	-12.631	-12.631	0.000	(0)
MnCl3-	2.842e-17	2.533e-17	-16.546	-16.596	-0.050	(0)
Mn(OH)3-	2.512e-17	2.239e-17	-16.600	-16.650	-0.050	(0)
MnSeO4	2.380e-17	2.380e-17	-16.623	-16.623	0.000	(0)

Mn(OH)4-2	1.366e-22	8.630e-23	-21.864	-22.064	-0.200	(0)
MnSe	5.750e-35	5.750e-35	-34.240	-34.240	0.000	(0)
Mn(3)	2.169e-28					
Mn+3	2.169e-28	7.512e-29	-27.664	-28.124	-0.460	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-46.513	-46.713	-0.200	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-52.734	-52.788	-0.053	(0)
Mo	6.728e-08					
MoO4-2	6.727e-08	4.200e-08	-7.172	-7.377	-0.205	(0)
HMoO4-	8.081e-12	7.048e-12	-11.093	-11.152	-0.059	(0)
H2MoO4	4.354e-16	4.354e-16	-15.361	-15.361	0.000	(0)
AlMo6O21-3	0.000e+00	0.000e+00	-52.332	-52.867	-0.535	(0)
Mo7O24-6	0.000e+00	0.000e+00	-61.099	-63.239	-2.140	(0)
HMo7O24-5	0.000e+00	0.000e+00	-63.440	-64.926	-1.486	(0)
H2Mo7O24-4	0.000e+00	0.000e+00	-67.267	-68.218	-0.951	(0)
H3Mo7O24-3	0.000e+00	0.000e+00	-72.511	-73.046	-0.535	(0)
Na	2.569e-03					
Na+	2.546e-03	2.263e-03	-2.594	-2.645	-0.051	(0)
NaSO4-	1.962e-05	1.752e-05	-4.707	-4.757	-0.049	(0)
NaHCO3	2.916e-06	2.916e-06	-5.535	-5.535	0.000	(0)
NaCO3-	6.013e-07	5.368e-07	-6.221	-6.270	-0.049	(0)
NaF	3.113e-08	3.113e-08	-7.507	-7.507	0.000	(0)
NaH2BO3	7.669e-10	7.669e-10	-9.115	-9.115	0.000	(0)
NaCrO4-	3.140e-19	2.738e-19	-18.503	-18.563	-0.059	(0)
Ni	5.536e-08					
Ni+2	3.273e-08	2.043e-08	-7.485	-7.690	-0.205	(0)
NiCO3	9.711e-09	9.711e-09	-8.013	-8.013	0.000	(0)
NiHCO3+	6.620e-09	5.773e-09	-8.179	-8.239	-0.059	(0)
NiSO4	5.876e-09	5.876e-09	-8.231	-8.231	0.000	(0)
NiOH+	3.521e-10	3.071e-10	-9.453	-9.513	-0.059	(0)
Ni(OH)2	2.912e-11	2.912e-11	-10.536	-10.536	0.000	(0)
NiCl+	2.360e-11	2.058e-11	-10.627	-10.687	-0.059	(0)
NiF+	1.283e-11	1.119e-11	-10.892	-10.951	-0.059	(0)
Ni(SO4)2-2	4.848e-13	2.804e-13	-12.314	-12.552	-0.238	(0)
Ni(OH)3-	3.985e-14	3.475e-14	-13.400	-13.459	-0.059	(0)
NiCl2	4.079e-17	4.079e-17	-16.389	-16.389	0.000	(0)
NiSeO4	9.963e-19	9.963e-19	-18.002	-18.002	0.000	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-40.512	-40.510	0.001	(0)
Pb	7.416e-08					
PbCO3	5.847e-08	5.847e-08	-7.233	-7.233	0.000	(0)
PbOH+	5.250e-09	4.578e-09	-8.280	-8.339	-0.059	(0)
Pb(CO3)2-2	3.714e-09	2.148e-09	-8.430	-8.668	-0.238	(0)
PbHCO3+	2.981e-09	2.600e-09	-8.526	-8.585	-0.059	(0)
Pb+2	2.446e-09	1.527e-09	-8.612	-8.816	-0.205	(0)
PbSO4	1.078e-09	1.078e-09	-8.967	-8.967	0.000	(0)
Pb(OH)2	1.728e-10	1.728e-10	-9.762	-9.762	0.000	(0)
PbCl+	2.445e-11	2.133e-11	-10.612	-10.671	-0.059	(0)
Pb(SO4)2-2	1.618e-11	9.361e-12	-10.791	-11.029	-0.238	(0)
PbF+	2.690e-12	2.346e-12	-11.570	-11.630	-0.059	(0)
Pb(OH)3-	2.365e-13	2.063e-13	-12.626	-12.686	-0.059	(0)
PbCl2	3.750e-14	3.750e-14	-13.426	-13.426	0.000	(0)
PbF2	1.007e-15	1.007e-15	-14.997	-14.997	0.000	(0)
Pb2OH+3	3.798e-16	1.108e-16	-15.420	-15.955	-0.535	(0)
Pb(OH)4-2	1.043e-16	6.031e-17	-15.982	-16.220	-0.238	(0)
PbCl3-	6.737e-18	5.876e-18	-17.172	-17.231	-0.059	(0)
Pb3(OH)4+2	1.573e-18	9.100e-19	-17.803	-18.041	-0.238	(0)
PbF3-	4.774e-20	4.163e-20	-19.321	-19.381	-0.059	(0)
PbCl4-2	1.828e-21	1.057e-21	-20.738	-20.976	-0.238	(0)
Pb4(OH)4+4	9.861e-23	1.104e-23	-22.006	-22.957	-0.951	(0)
PbF4-2	7.512e-25	4.345e-25	-24.124	-24.362	-0.238	(0)
Pb(HS)2	0.000e+00	0.000e+00	-129.996	-129.996	0.000	(0)
Pb(HS)3-	0.000e+00	0.000e+00	-196.862	-196.921	-0.059	(0)
S(-2)	0.000e+00					
HS-	0.000e+00	0.000e+00	-68.166	-68.225	-0.059	(0)

CdHS+	0.000e+00	0.000e+00	-68.178	-68.237	-0.059	(0)
S5-2	0.000e+00	0.000e+00	-69.278	-69.516	-0.238	(0)
H2S	0.000e+00	0.000e+00	-69.279	-69.279	0.000	(0)
S6-2	0.000e+00	0.000e+00	-69.794	-70.032	-0.238	(0)
S4-2	0.000e+00	0.000e+00	-69.874	-70.112	-0.238	(0)
S3-2	0.000e+00	0.000e+00	-70.680	-70.918	-0.238	(0)
S2-2	0.000e+00	0.000e+00	-71.696	-71.934	-0.238	(0)
S-2	0.000e+00	0.000e+00	-77.252	-77.451	-0.200	(0)
Cu(S4)2-3	0.000e+00	0.000e+00	-125.385	-125.669	-0.284	(0)
CuS4S5-3	0.000e+00	0.000e+00	-126.126	-126.399	-0.273	(0)
ZnS(HS)-	0.000e+00	0.000e+00	-127.990	-128.050	-0.059	(0)
Cd(HS)2	0.000e+00	0.000e+00	-129.258	-129.258	0.000	(0)
Pb(HS)2	0.000e+00	0.000e+00	-129.996	-129.996	0.000	(0)
Zn(HS)2	0.000e+00	0.000e+00	-130.114	-130.114	0.000	(0)
Fe(HS)2	0.000e+00	0.000e+00	-135.538	-135.538	0.000	(0)
Cu(HS)3-	0.000e+00	0.000e+00	-186.867	-186.926	-0.059	(0)
Zn(HS)3-	0.000e+00	0.000e+00	-194.999	-195.059	-0.059	(0)
Cd(HS)3-	0.000e+00	0.000e+00	-195.524	-195.583	-0.059	(0)
ZnS(HS)2-2	0.000e+00	0.000e+00	-196.727	-196.965	-0.238	(0)
Pb(HS)3-	0.000e+00	0.000e+00	-196.862	-196.921	-0.059	(0)
Fe(HS)3-	0.000e+00	0.000e+00	-201.666	-201.726	-0.059	(0)
Cd(HS)4-2	0.000e+00	0.000e+00	-261.375	-261.612	-0.238	(0)
Zn(HS)4-2	0.000e+00	0.000e+00	-264.506	-264.744	-0.238	(0)
S(6)	2.895e-03					
SO4-2	2.309e-03	1.441e-03	-2.637	-2.841	-0.205	(0)
CaSO4	4.182e-04	4.182e-04	-3.379	-3.379	0.000	(0)
MgSO4	1.426e-04	1.426e-04	-3.846	-3.846	0.000	(0)
NaSO4-	1.962e-05	1.752e-05	-4.707	-4.757	-0.049	(0)
KSO4-	5.587e-06	4.988e-06	-5.253	-5.302	-0.049	(0)
MnSO4	2.174e-07	2.174e-07	-6.663	-6.663	0.000	(0)
ZnSO4	1.036e-07	1.036e-07	-6.985	-6.985	0.000	(0)
CoSO4	8.063e-09	8.063e-09	-8.093	-8.093	0.000	(0)
NiSO4	5.876e-09	5.876e-09	-8.231	-8.231	0.000	(0)
FeSO4	3.244e-09	3.244e-09	-8.489	-8.489	0.000	(0)
CdSO4	3.225e-09	3.225e-09	-8.491	-8.491	0.000	(0)
CuSO4	2.338e-09	2.338e-09	-8.631	-8.631	0.000	(0)
Zn(SO4)2-2	2.248e-09	1.300e-09	-8.648	-8.886	-0.238	(0)
HSO4-	1.335e-09	1.188e-09	-8.875	-8.925	-0.051	(0)
PbSO4	1.078e-09	1.078e-09	-8.967	-8.967	0.000	(0)
Cd(SO4)2-2	1.084e-10	6.271e-11	-9.965	-10.203	-0.238	(0)
CrOHSO4	6.293e-11	6.293e-11	-10.201	-10.201	0.000	(0)
Pb(SO4)2-2	1.618e-11	9.361e-12	-10.791	-11.029	-0.238	(0)
Ni(SO4)2-2	4.848e-13	2.804e-13	-12.314	-12.552	-0.238	(0)
CrSO4+	2.719e-14	2.371e-14	-13.566	-13.625	-0.059	(0)
AlSO4+	8.795e-15	7.826e-15	-14.056	-14.106	-0.051	(0)
UO2SO4	2.609e-16	2.609e-16	-15.584	-15.584	0.000	(0)
Al(SO4)2-	1.358e-16	1.209e-16	-15.867	-15.918	-0.051	(0)
FeSO4+	3.064e-17	2.731e-17	-16.514	-16.564	-0.050	(0)
UO2(SO4)2-2	8.569e-18	4.956e-18	-17.067	-17.305	-0.238	(0)
Cr2(OH)2SO4+2	1.809e-18	1.047e-18	-17.742	-17.980	-0.238	(0)
Fe(SO4)2-	9.650e-19	8.416e-19	-18.015	-18.075	-0.059	(0)
VO2SO4-	4.422e-19	3.856e-19	-18.354	-18.414	-0.059	(0)
Cr2(OH)2(SO4)2	8.960e-20	8.960e-20	-19.048	-19.048	0.000	(0)
VOSO4	1.276e-20	1.276e-20	-19.894	-19.894	0.000	(0)
CrO3SO4-2	4.254e-27	2.461e-27	-26.371	-26.609	-0.238	(0)
VSO4+	4.470e-34	3.898e-34	-33.350	-33.409	-0.059	(0)
U(SO4)2	0.000e+00	0.000e+00	-40.779	-40.779	0.000	(0)
USO4+2	0.000e+00	0.000e+00	-41.600	-41.838	-0.238	(0)
Se(-2)	1.592e-31					
HSe-	1.591e-31	1.387e-31	-30.798	-30.858	-0.059	(0)
MnSe	5.750e-35	5.750e-35	-34.240	-34.240	0.000	(0)
H2Se	9.083e-36	9.083e-36	-35.042	-35.042	0.000	(0)
Se-2	2.844e-38	1.645e-38	-37.546	-37.784	-0.238	(0)
Se(4)	6.346e-08					
HSeO3-	3.707e-08	3.233e-08	-7.431	-7.490	-0.059	(0)
SeO3-2	2.638e-08	1.526e-08	-7.579	-7.816	-0.238	(0)

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   H2SeO3          1.163e-13   1.163e-13   -12.934   -12.934     0.000     (0)
   Cd(SeO3)2-2     3.168e-18   1.832e-18   -17.499   -17.737    -0.238     (0)
   FeHSeO3+2       2.495e-22   1.443e-22   -21.603   -21.841    -0.238     (0)
Se(6)          1.670e-13
   SeO4-2          1.670e-13   1.042e-13   -12.777   -12.982    -0.205     (0)
   MnSeO4          2.380e-17   2.380e-17   -16.623   -16.623     0.000     (0)
   ZnSeO4          5.303e-18   5.303e-18   -17.275   -17.275     0.000     (0)
   CoSeO4          1.465e-18   1.465e-18   -17.834   -17.834     0.000     (0)
   NiSeO4          9.963e-19   9.963e-19   -18.002   -18.002     0.000     (0)
   CdSeO4          1.853e-19   1.853e-19   -18.732   -18.732     0.000     (0)
   HSeO4-          5.053e-20   4.406e-20   -19.296   -19.356    -0.059     (0)
   Zn(SeO4)2-2     9.691e-31   5.605e-31   -30.014   -30.251    -0.238     (0)
U(3)           0.000e+00
   U+3             0.000e+00   0.000e+00   -57.155   -57.690    -0.535     (0)
U(4)           5.157e-19
   U(OH)5-         5.155e-19   4.496e-19   -18.288   -18.347    -0.059     (0)
   U(OH)4          1.588e-22   1.588e-22   -21.799   -21.799     0.000     (0)
   U(OH)3+         5.616e-27   4.898e-27   -26.251   -26.310    -0.059     (0)
   U(OH)2+2        3.303e-32   1.910e-32   -31.481   -31.719    -0.238     (0)
   UOH+3           2.602e-38   7.590e-39   -37.585   -38.120    -0.535     (0)
   UF3+            1.198e-38   1.045e-38   -37.922   -37.981    -0.059     (0)
   UF2+2           5.226e-39   3.023e-39   -38.282   -38.520    -0.238     (0)
   UF+3            0.000e+00   0.000e+00   -40.423   -40.958    -0.535     (0)
   UF4             0.000e+00   0.000e+00   -40.602   -40.602     0.000     (0)
   U(SO4)2         0.000e+00   0.000e+00   -40.779   -40.779     0.000     (0)
   USO4+2          0.000e+00   0.000e+00   -41.600   -41.838    -0.238     (0)
   UF5-            0.000e+00   0.000e+00   -43.607   -43.666    -0.059     (0)
   U+4             0.000e+00   0.000e+00   -44.646   -45.597    -0.951     (0)
   UF6-2           0.000e+00   0.000e+00   -45.610   -45.847    -0.238     (0)
   UCl+3           0.000e+00   0.000e+00   -46.767   -47.302    -0.535     (0)
   U6(OH)15+9      0.000e+00   0.000e+00  -164.812  -169.627    -4.815     (0)
U(5)           4.215e-17
   UO2+            4.215e-17   3.676e-17   -16.375   -16.435    -0.059     (0)
U(6)           1.146e-08
   UO2(CO3)3-4     8.792e-09   9.841e-10    -8.056    -9.007    -0.951     (0)
   UO2(CO3)2-2     2.665e-09   1.541e-09    -8.574    -8.812    -0.238     (0)
   UO2CO3          6.065e-12   6.065e-12   -11.217   -11.217     0.000     (0)
   UO2OH+          2.061e-14   1.797e-14   -13.686   -13.745    -0.059     (0)
   UO2F+           4.127e-16   3.599e-16   -15.384   -15.444    -0.059     (0)
   UO2SO4          2.609e-16   2.609e-16   -15.584   -15.584     0.000     (0)
   UO2+2           1.916e-16   1.196e-16   -15.718   -15.922    -0.205     (0)
   UO2F2           2.263e-17   2.263e-17   -16.645   -16.645     0.000     (0)
   UO2(SO4)2-2     8.569e-18   4.956e-18   -17.067   -17.305    -0.238     (0)
   UO2F3-          1.421e-19   1.240e-19   -18.847   -18.907    -0.059     (0)
   UO2Cl+          8.754e-20   7.634e-20   -19.058   -19.117    -0.059     (0)
   (UO2)2(OH)2+2   9.266e-22   5.360e-22   -21.033   -21.271    -0.238     (0)
   UO2F4-2         3.712e-23   2.147e-23   -22.430   -22.668    -0.238     (0)
   (UO2)3(OH)5+    1.194e-23   1.041e-23   -22.923   -22.983    -0.059     (0)
V(2)           6.268e-40
   VOH+            6.268e-40   5.466e-40   -39.203   -39.262    -0.059     (0)
   V+2             0.000e+00   0.000e+00   -40.611   -40.849    -0.238     (0)
V(3)           7.861e-13
   V(OH)3          7.861e-13   7.861e-13   -12.105   -12.105     0.000     (0)
   V(OH)2+         4.913e-24   4.284e-24   -23.309   -23.368    -0.059     (0)
   VOH+2           5.926e-28   3.428e-28   -27.227   -27.465    -0.238     (0)
   V+3             1.964e-33   5.729e-34   -32.707   -33.242    -0.535     (0)
   VSO4+           4.470e-34   3.898e-34   -33.350   -33.409    -0.059     (0)
   V2(OH)3+3       0.000e+00   0.000e+00   -51.846   -52.381    -0.535     (0)
   V2(OH)2+4       0.000e+00   0.000e+00   -53.179   -54.130    -0.951     (0)
V(4)           8.853e-18
   V(OH)3+         8.780e-18   7.657e-18   -17.057   -17.116    -0.059     (0)
   VO+2            5.559e-20   3.216e-20   -19.255   -19.493    -0.238     (0)
   VOSO4           1.276e-20   1.276e-20   -19.894   -19.894     0.000     (0)
   VOF+            4.822e-21   4.205e-21   -20.317   -20.376    -0.059     (0)
   VOCl+           4.072e-23   3.551e-23   -22.390   -22.450    -0.059     (0)
   VOF2            3.438e-23   3.438e-23   -22.464   -22.464     0.000     (0)
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   VOF3-           3.050e-26   2.660e-26   -25.516   -25.575    -0.059     (0)
   H2V2O4+2        5.082e-30   2.940e-30   -29.294   -29.532    -0.238     (0)
   VOF4-2          4.047e-30   2.341e-30   -29.393   -29.631    -0.238     (0)
V(5)           1.311e-08
   H2VO4-          9.050e-09   7.892e-09    -8.043    -8.103    -0.059     (0)
   HVO4-2          4.064e-09   2.350e-09    -8.391    -8.629    -0.238     (0)
   H3VO4           6.656e-13   6.656e-13   -12.177   -12.177     0.000     (0)
   H3V2O7-         3.890e-14   3.392e-14   -13.410   -13.470    -0.059     (0)
   HV2O7-3         2.155e-14   6.287e-15   -13.667   -14.202    -0.535     (0)
   VO4-3           4.787e-15   1.397e-15   -14.320   -14.855    -0.535     (0)
   V2O7-4          1.793e-16   2.006e-17   -15.747   -16.698    -0.951     (0)
   VO2+            1.261e-17   1.121e-17   -16.899   -16.951    -0.051     (0)
   V3O9-3          1.765e-18   5.150e-19   -17.753   -18.288    -0.535     (0)
   VO2SO4-         4.422e-19   3.856e-19   -18.354   -18.414    -0.059     (0)
   VO2F            4.285e-19   4.285e-19   -18.368   -18.368     0.000     (0)
   VO2F2-          3.890e-21   3.392e-21   -20.410   -20.470    -0.059     (0)
   V4O12-4         1.514e-23   1.695e-24   -22.820   -23.771    -0.951     (0)
   VO2F3-2         1.595e-24   9.226e-25   -23.797   -24.035    -0.238     (0)
   VO2F4-3         3.393e-29   9.898e-30   -28.469   -29.004    -0.535     (0)
   V10O28-6        0.000e+00   0.000e+00   -62.277   -64.417    -2.140     (0)
   HV10O28-5       0.000e+00   0.000e+00   -62.819   -64.305    -1.486     (0)
   H2V10O28-4      0.000e+00   0.000e+00   -66.220   -67.171    -0.951     (0)
Zn             9.536e-07
   Zn+2            5.262e-07   3.285e-07    -6.279    -6.483    -0.205     (0)
   ZnCO3           2.408e-07   2.408e-07    -6.618    -6.618     0.000     (0)
   ZnSO4           1.036e-07   1.036e-07    -6.985    -6.985     0.000     (0)
   ZnOH+           4.496e-08   3.921e-08    -7.347    -7.407    -0.059     (0)
   ZnHCO3+         2.730e-08   2.380e-08    -7.564    -7.623    -0.059     (0)
   Zn(OH)2         7.418e-09   7.418e-09    -8.130    -8.130     0.000     (0)
   Zn(SO4)2-2      2.248e-09   1.300e-09    -8.648    -8.886    -0.238     (0)
   ZnOHCl          5.075e-10   5.075e-10    -9.295    -9.295     0.000     (0)
   ZnCl+           3.657e-10   3.248e-10    -9.437    -9.488    -0.052     (0)
   ZnF+            1.639e-10   1.429e-10    -9.786    -9.845    -0.059     (0)
   Zn(OH)3-        5.089e-11   4.438e-11   -10.293   -10.353    -0.059     (0)
   ZnCl2           2.026e-13   2.026e-13   -12.693   -12.693     0.000     (0)
   Zn(OH)4-2       3.646e-15   2.109e-15   -14.438   -14.676    -0.238     (0)
   ZnCl3-          7.133e-17   6.335e-17   -16.147   -16.198    -0.052     (0)
   ZnSeO4          5.303e-18   5.303e-18   -17.275   -17.275     0.000     (0)
   ZnCl4-2         1.974e-20   1.247e-20   -19.705   -19.904    -0.200     (0)
   Zn(SeO4)2-2     9.691e-31   5.605e-31   -30.014   -30.251    -0.238     (0)
   ZnS(HS)-        0.000e+00   0.000e+00  -127.990  -128.050    -0.059     (0)
   Zn(HS)2         0.000e+00   0.000e+00  -130.114  -130.114     0.000     (0)
   Zn(HS)3-        0.000e+00   0.000e+00  -194.999  -195.059    -0.059     (0)
   ZnS(HS)2-2      0.000e+00   0.000e+00  -196.727  -196.965    -0.238     (0)
   Zn(HS)4-2       0.000e+00   0.000e+00  -264.506  -264.744    -0.238     (0)

------------------------------Saturation indices------------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.73      9.07   10.80  Al(OH)3
  Al2(MoO4)3      -54.81    -52.44    2.37  Al2(MoO4)3
  Al2O3            -1.52     18.13   19.65  Al2O3
  Al4(OH)10SO4     -5.42     17.28   22.70  Al4(OH)10SO4
  AlAsO4:2H2O      -9.70     -4.90    4.80  AlAsO4:2H2O
  AlOHSO4          -6.69     -9.92   -3.23  AlOHSO4
  Alunite          -4.62     -6.02   -1.40  KAl3(SO4)2(OH)6
  Anglesite        -3.87    -11.66   -7.79  PbSO4
  Anhydrite        -1.38     -5.74   -4.36  CaSO4
  Anilite         -43.45    -75.32  -31.88  Cu0.25Cu1.5S
  Antlerite        -3.78      5.00    8.79  Cu3(OH)4SO4
  Aragonite         0.51     -7.79   -8.30  CaCO3
  Arsenolite      -68.50    -71.26   -2.76  As4O6
  Artinite         -4.88      4.72    9.60  MgCO3:Mg(OH)2:3H2O
  As2O5           -34.65    -27.94    6.71  As2O5
  Atacamite        -2.87      4.52    7.39  Cu2(OH)3Cl
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  Azurite          -1.19    -18.09  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -14.78      9.61   24.39  Ba(OH)2:8H2O
  Ba2V2O7:2H2O    -14.40      1.47   15.87  Ba2V2O7:2H2O
  Ba3(AsO4)2        9.81      0.90   -8.91  Ba3(AsO4)2
  Ba3(VO4)2:4H2O  -21.86     11.08   32.94  Ba3(VO4)2:4H2O
  BaCrO4          -13.48    -23.15   -9.67  BaCrO4
  BaF2            -10.04    -15.86   -5.82  BaF2
  BaMoO4           -6.95    -13.91   -6.96  BaMoO4
  Barite            0.60     -9.38   -9.98  BaSO4
  BaS             -82.87    -66.69   16.18  BaS
  BaSeO3           -7.78     -5.95    1.83  BaSeO3
  BaSeO4          -12.06    -19.52   -7.46  BaSeO4
  Bianchite        -7.56     -9.33   -1.76  ZnSO4:6H2O
  Birnessite      -10.62      7.47   18.09  MnO2
  Bixbyite         -7.16     -7.80   -0.64  Mn2O3
  BlaubleiI       -45.08    -69.24  -24.16  Cu0.9Cu0.2S
  BlaubleiII      -44.77    -72.05  -27.28  Cu0.6Cu0.8S
  Boehmite         0.49      9.07    8.58  AlOOH
  Brochantite      -2.22     13.00   15.22  Cu4(OH)6SO4
  Brucite          -3.96     12.88   16.84  Mg(OH)2
  Bunsenite        -3.99      8.46   12.45  NiO
  Ca(VO3)2        -10.16     -4.50    5.66  Ca(VO3)2
  Ca2V2O7          -8.75      8.75   17.50  Ca2V2O7
  Ca2V2O7:2H2O    -12.80      8.75   21.55  Ca2V2O7:2H2O
  Ca3(AsO4)2:4H2O -10.49     11.81   22.30  Ca3(AsO4)2:4H2O
  Ca3(VO4)2       -16.96     22.00   38.96  Ca3(VO4)2
  Ca3(VO4)2:4H2O  -17.86     22.00   39.86  Ca3(VO4)2:4H2O
  CaCrO4          -17.25    -19.51   -2.27  CaCrO4
  Calcite           0.69     -7.79   -8.48  CaCO3
  CaMoO4           -2.32    -10.27   -7.95  CaMoO4
  Carnotite        -4.12     -3.89    0.23  KUO2VO4
  CaSeO3:2H2O      -5.13     -2.31    2.81  CaSeO3:2H2O
  CaSeO4:2H2O     -12.86    -15.88   -3.02  CaSeO4:2H2O
  Cd(BO2)2        -12.73     -2.89    9.84  Cd(BO2)2
  Cd(OH)2          -5.52      8.13   13.64  Cd(OH)2
  Cd(OH)2(am)      -5.60      8.13   13.73  Cd(OH)2
  Cd3(OH)2(SO4)2  -20.31    -13.60    6.71  Cd3(OH)2(SO4)2
  Cd3(OH)4SO4     -17.17      5.39   22.56  Cd3(OH)4SO4
  Cd4(OH)6SO4     -14.88     13.52   28.40  Cd4(OH)6SO4
  CdCl2           -14.17    -14.83   -0.66  CdCl2
  CdCl2:1H2O      -13.14    -14.83   -1.69  CdCl2:1H2O
  CdCl2:2.5H2O    -12.92    -14.83   -1.91  CdCl2:2.5H2O
  CdF2            -16.13    -17.34   -1.21  CdF2
  Cdmetal(alpha)  -28.13    -14.61   13.51  Cd
  Cdmetal(gamma)  -28.23    -14.61   13.62  Cd
  CdMoO4           -1.25    -15.40  -14.15  CdMoO4
  CdOHCl           -6.89     -3.35    3.54  CdOHCl
  CdSe            -10.60    -30.80  -20.20  CdSe
  CdSeO4:2H2O     -19.15    -21.00   -1.85  CdSeO4:2H2O
  CdSO4           -10.69    -10.86   -0.17  CdSO4
  CdSO4:1H2O       -9.14    -10.86   -1.73  CdSO4:1H2O
  CdSO4:2.67H2O    -8.99    -10.86   -1.87  CdSO4:2.67H2O
  Cerussite        -0.58    -13.71  -13.13  PbCO3
  CH4(g)          -70.97   -112.01  -41.05  CH4
  Chalcanthite     -8.35    -10.99   -2.64  CuSO4:5H2O
  Chalcocite      -42.75    -77.67  -34.92  Cu2S
  Chalcopyrite   -101.22   -136.49  -35.27  CuFeS2
  Claudetite      -68.19    -71.26   -3.06  As4O6
  Clausthalite     -4.50    -31.60  -27.10  PbSe
  Co(BO2)2        -29.49     -2.42   27.07  Co(BO2)2
  Co(OH)2          -4.50      8.60   13.09  Co(OH)2
  Co(OH)3         -10.12    -12.43   -2.31  Co(OH)3
  CO2(g)           -2.90    -21.04  -18.15  CO2
  Co3(AsO4)2      -15.19     -2.15   13.03  Co3(AsO4)2
  Co3O4            -5.78    -16.27  -10.50  Co3O4
  CoCl2           -22.63    -14.36    8.27  CoCl2
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  CoCl2:6H2O      -16.90    -14.36    2.54  CoCl2:6H2O
  CoCO3            -2.47    -12.45   -9.98  CoCO3
  CoF2            -15.28    -16.88   -1.60  CoF2
  CoF3            -49.18    -50.64   -1.46  CoF3
  CoFe2O4          25.02     21.49   -3.53  CoFe2O4
  CoMoO4           -7.17    -14.93   -7.76  CoMoO4
  CoO              -4.99      8.60   13.59  CoO
  CoS(alpha)      -60.26    -67.70   -7.44  CoS
  CoS(beta)       -56.63    -67.70  -11.07  CoS
  CoSe            -14.14    -30.34  -16.20  CoSe
  CoSeO3           -8.29     -6.97    1.32  CoSeO3
  CoSeO4:6H2O     -19.00    -20.53   -1.53  CoSeO4:6H2O
  CoSO4           -13.20    -10.39    2.80  CoSO4
  CoSO4:6H2O       -7.92    -10.39   -2.47  CoSO4:6H2O
  Cotunnite       -10.85    -15.63   -4.78  PbCl2
  Covellite       -46.00    -68.30  -22.30  CuS
  Cr(OH)2         -18.74     -7.92   10.82  Cr(OH)2
  Cr(OH)3          -0.83      0.50    1.34  Cr(OH)3
  Cr(OH)3(am)       1.25      0.50   -0.75  Cr(OH)3
  Cr2O3             3.36      1.00   -2.36  Cr2O3
  CrCl2           -44.97    -30.88   14.09  CrCl2
  CrCl3           -49.05    -33.94   15.11  CrCl3
  CrF3            -26.37    -37.71  -11.34  CrF3
  Crmetal         -61.15    -30.67   30.48  Cr
  CrO3            -29.55    -32.76   -3.21  CrO3
  Cryolite        -17.22    -51.06  -33.84  Na3AlF6
  Cu(OH)2          -0.68      8.00    8.67  Cu(OH)2
  Cu2Se(alpha)      5.50    -40.30  -45.80  Cu2Se
  Cu2SO4          -18.41    -20.36   -1.95  Cu2SO4
  Cu3(AsO4)2:2H2O -10.05     -3.95    6.10  Cu3(AsO4)2:2H2O
  Cu3Se2           -7.74    -71.23  -63.49  Cu3Se2
  CuCO3            -1.54    -13.04  -11.50  CuCO3
  CuCrO4          -19.32    -24.76   -5.44  CuCrO4
  CuF              -8.51    -13.42   -4.91  CuF
  CuF2            -18.59    -17.47    1.12  CuF2
  CuF2:2H2O       -12.92    -17.47   -4.55  CuF2:2H2O
  Cumetal          -3.30    -12.05   -8.76  Cu
  CuMoO4           -2.45    -15.53  -13.08  CuMoO4
  CuOCuSO4        -13.30     -2.99   10.30  CuOCuSO4
  Cupricferrite    14.91     20.90    5.99  CuFe2O4
  Cuprite           0.04     -1.37   -1.41  Cu2O
  Cuprousferrite   14.68      5.77   -8.92  CuFeO2
  CuSe              2.17    -30.93  -33.10  CuSe
  CuSe2           -13.76    -47.12  -33.37  CuSe2
  CuSeO3:2H2O      -8.08     -7.57    0.51  CuSeO3:2H2O
  CuSeO4:5H2O     -18.69    -21.13   -2.44  CuSeO4:5H2O
  CuSO4           -13.93    -10.99    2.94  CuSO4
  Diaspore          2.19      9.07    6.87  AlOOH
  Djurleite       -43.13    -77.05  -33.92  Cu0.066Cu1.868S
  Dolomite(disordered)   0.59    -15.95  -16.54  CaMg(CO3)2
  Dolomite(ordered)   1.14    -15.95  -17.09  CaMg(CO3)2
  Epsomite         -3.98     -6.11   -2.13  MgSO4:7H2O
  Fe(OH)2          -5.45      8.11   13.56  Fe(OH)2
  Fe(OH)2.7Cl.3     6.05      3.01   -3.04  Fe(OH)2.7Cl.3
  Fe(VO3)2         -5.92     -9.64   -3.72  Fe(VO3)2
  Fe2(OH)4SeO3     -4.22     -2.67    1.55  Fe2(OH)4SeO3
  Fe2(SeO3)3:2H2O -13.17    -33.79  -20.63  Fe2(SeO3)3:2H2O
  Fe2(SO4)3       -40.33    -44.07   -3.73  Fe2(SO4)3
  Fe3(OH)8          0.79     21.01   20.22  Fe3(OH)8
  FeAsO4:2H2O      -7.92     -7.52    0.40  FeAsO4:2H2O
  FeCr2O4           1.91      9.11    7.20  FeCr2O4
  FeMoO4           -5.32    -15.41  -10.09  FeMoO4
  Ferrihydrite      3.26      6.45    3.19  Fe(OH)3
  Ferroselite     -28.41    -47.01  -18.60  FeSe2
  FeS(ppt)        -65.24    -68.19   -2.95  FeS
  FeSe            -19.82    -30.82  -11.00  FeSe
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Fluorite	-1.72	-12.22	-10.50	CaF2
Galena	-55.00	-68.97	-13.97	PbS
Gibbsite	0.78	9.07	8.29	Al(OH)3
Goethite	5.96	6.45	0.49	FeOOH
Goslarite	-7.31	-9.33	-2.01	ZnSO4:7H2O
Greenockite	-53.81	-68.17	-14.36	CdS
Greigite	-239.15	-284.19	-45.03	Fe3S4
Gummite	-7.45	0.23	7.67	UO3
Gypsum	-1.13	-5.74	-4.61	CaSO4:2H2O
H-Jarosite	-6.53	-18.63	-12.10	(H3O)Fe3(SO4)2(OH)6
H2MoO4	-10.65	-23.52	-12.88	H2MoO4
H2S(g)	-68.29	-76.30	-8.01	H2S
H2Se(g)	-33.97	-38.93	-4.96	H2Se
Halite	-7.65	-6.05	1.60	NaCl
Hausmannite	-8.06	52.97	61.03	Mn3O4
Hematite	14.32	12.90	-1.42	Fe2O3
Hercynite	3.35	26.24	22.89	FeAl2O4
Huntite	-2.30	-32.27	-29.97	CaMg3(CO3)4
Hydrocerussite	-1.32	-20.09	-18.77	Pb3(OH)2(CO3)2
Hydromagnesite	-10.99	-19.76	-8.77	Mg5(CO3)4(OH)2:4H2O
K-Alum	-18.98	-24.15	-5.17	KAl(SO4)2:12H2O
K-Jarosite	0.93	-13.87	-14.80	KFe3(SO4)2(OH)6
K2Cr2O7	-38.75	-56.00	-17.24	K2Cr2O7
K2CrO4	-22.72	-23.24	-0.51	K2CrO4
K2MoO4	-17.26	-14.00	3.26	K2MoO4
K2SeO4	-18.87	-19.60	-0.73	K2SeO4
Langite	-4.49	13.00	17.49	Cu4(OH)6SO4:H2O
Larnakite	-3.89	-4.33	-0.43	PbO:PbSO4
Laurionite	-4.77	-4.15	0.62	PbOHCl
Lepidocrocite	5.08	6.45	1.37	FeOOH
Lime	-19.45	13.25	32.70	CaO
Litharge	-5.36	7.33	12.69	PbO
Mackinawite	-64.59	-68.19	-3.60	FeS
Maghemite	6.51	12.90	6.39	Fe2O3
Magnesioferrite	8.92	25.78	16.86	Fe2MgO4
Magnesite	-0.70	-8.16	-7.46	MgCO3
Magnetite	17.61	21.01	3.40	Fe3O4
Malachite	0.26	-5.05	-5.31	Cu2(OH)2CO3
Manganite	-3.89	21.45	25.34	MnOOH
Massicot	-5.56	7.33	12.89	PbO
Matlockite	-7.91	-16.88	-8.97	PbClF
Melanothallite	-21.22	-14.96	6.26	CuCl2
Melanterite	-8.67	-10.88	-2.21	FeSO4:7H2O
Mg(OH)2(active)	-5.91	12.88	18.79	Mg(OH)2
Mg(VO3)2	-16.15	-4.87	11.28	Mg(VO3)2
Mg2V2O7	-18.35	8.01	26.36	Mg2V2O7
MgCr2O4	-2.32	13.88	16.20	MgCr2O4
MgCrO4	-25.26	-19.88	5.38	MgCrO4
MgF2	-4.46	-12.59	-8.13	MgF2
MgMoO4	-8.79	-10.64	-1.85	MgMoO4
MgSeO3:6H2O	-5.74	-2.68	3.06	MgSeO3:6H2O
MgSeO4:6H2O	-15.05	-16.25	-1.20	MgSeO4:6H2O
Minium	-28.78	44.74	73.52	Pb3O4
Mirabilite	-7.02	-8.13	-1.11	Na2SO4:10H2O
Mn(VO3)2	-12.58	-7.68	4.90	Mn(VO3)2
Mn2(SO4)3	-59.06	-64.77	-5.71	Mn2(SO4)3
Mn3(AsO4)2:8H2O	-10.21	2.29	12.50	Mn3(AsO4)2:8H2O
MnCl2:4H2O	-15.60	-12.88	2.72	MnCl2:4H2O
MnS(grn)	-66.39	-66.22	0.17	MnS
MnS(pnk)	-69.56	-66.22	3.34	MnS
MnSe	-32.36	-28.86	3.50	MnSe
MnSeO3	-6.62	-5.49	1.13	MnSeO3
MnSeO3:2H2O	-6.47	-5.49	0.98	MnSeO3:2H2O
MnSeO4:5H2O	-17.00	-19.05	-2.05	MnSeO4:5H2O
MnSO4	-11.50	-8.91	2.58	MnSO4
Monteponite	-6.98	8.13	15.10	CdO

MoO3	-15.52	-23.52	-8.00	MoO3
Morenosite	-8.39	-10.53	-2.14	NiSO4:7H2O
MoS2	-128.61	-198.87	-70.26	MoS2
Na-Jarosite	-2.00	-13.20	-11.20	NaFe3(SO4)2(OH)6
Na2Cr2O7	-44.77	-54.67	-9.90	Na2Cr2O7
Na2CrO4	-24.83	-21.90	2.93	Na2CrO4
Na2Mo2O7	-19.60	-36.19	-16.60	Na2Mo2O7
Na2MoO4	-14.16	-12.67	1.49	Na2MoO4
Na2MoO4:2H2O	-13.89	-12.67	1.22	Na2MoO4:2H2O
Na2SeO3:5H2O	-15.01	-4.71	10.30	Na2SeO3:5H2O
Na2SeO4	-19.55	-18.27	1.28	Na2SeO4
Na3VO4	-29.27	7.41	36.68	Na3VO4
Na4V2O7	-33.44	3.96	37.40	Na4V2O7
Nantokite	-5.43	-12.16	-6.73	CuCl
Natron	-8.88	-10.19	-1.31	Na2CO3:10H2O
NaVO3	-7.31	-3.45	3.86	NaVO3
Nesquehonite	-3.49	-8.16	-4.67	MgCO3:3H2O
Ni(OH)2	-4.34	8.46	12.79	Ni(OH)2
Ni3(AsO4)2:8H2O	-18.27	-2.57	15.70	Ni3(AsO4)2:8H2O
Ni4(OH)6SO4	-17.16	14.84	32.00	Ni4(OH)6SO4
NiCO3	-5.71	-12.58	-6.87	NiCO3
NiMoO4	-3.92	-15.07	-11.14	NiMoO4
NiS(alpha)	-62.24	-67.84	-5.60	NiS
NiS(beta)	-56.74	-67.84	-11.10	NiS
NiS(gamma)	-55.04	-67.84	-12.80	NiS
NiSe	-12.77	-30.47	-17.70	NiSe
NiSeO3:2H2O	-9.92	-7.11	2.81	NiSeO3:2H2O
NiSeO4:6H2O	-19.15	-20.67	-1.52	NiSeO4:6H2O
Nsutite	-10.04	7.47	17.50	MnO2
O2(g)	-37.60	45.48	83.09	O2
Orpiment	-203.46	-264.53	-61.07	As2S3
Otavite	-0.92	-12.92	-12.00	CdCO3
Pb(BO2)2	-10.20	-3.68	6.52	Pb(BO2)2
Pb(OH)2	-0.82	7.33	8.15	Pb(OH)2
Pb10(OH)6O(CO3)6	-44.18	-52.94	-8.76	Pb10(OH)6O(CO3)6
Pb2(OH)3Cl	-5.61	3.18	8.79	Pb2(OH)3Cl
Pb2O(OH)2	-11.52	14.66	26.19	Pb2O(OH)2
Pb2O3	-23.63	37.41	61.04	Pb2O3
Pb2OCO3	-5.82	-6.38	-0.56	Pb2OCO3
Pb2V2O7	-1.19	-3.09	-1.90	Pb2V2O7
Pb3(AsO4)2	-11.75	-5.95	5.80	Pb3(AsO4)2
Pb3(VO4)2	-1.90	4.24	6.14	Pb3(VO4)2
Pb3O2CO3	-10.07	0.95	11.02	Pb3O2CO3
Pb3O2SO4	-7.68	3.01	10.69	Pb3O2SO4
Pb4(OH)6SO4	-10.76	10.34	21.10	Pb4(OH)6SO4
Pb4O3SO4	-11.54	10.34	21.88	Pb4O3SO4
PbCrO4	-12.83	-25.43	-12.60	PbCrO4
PbF2	-10.70	-18.14	-7.44	PbF2
Pbmetal	-19.66	-15.41	4.25	Pb
PbMoO4	-0.57	-16.19	-15.62	PbMoO4
PbO:0.3H2O	-5.65	7.33	12.98	PbO:0.33H2O
PbSeO4	-14.96	-21.80	-6.84	PbSeO4
Periclase	-8.70	12.88	21.58	MgO
Phosgenite	-9.53	-29.34	-19.81	PbCl2:PbCO3
Plattnerite	-19.53	30.07	49.60	PbO2
Portlandite	-9.55	13.25	22.80	Ca(OH)2
Pyrite	-103.24	-121.75	-18.51	FeS2
Pyrochroite	-5.12	10.08	15.19	Mn(OH)2
Pyrolusite	-8.56	32.82	41.38	MnO2
Realgar	-85.74	-105.48	-19.75	AsS
Retgersite	-8.49	-10.53	-2.04	NiSO4:6H2O
Rhodochrosite	-0.39	-10.97	-10.58	MnCO3
Rutherfordine	-6.32	-20.82	-14.50	UO2CO3
Schoepite	-5.77	0.23	5.99	UO2(OH)2:H2O
Semetal(am)	-9.08	-16.19	-7.11	Se
Semetal(hex	-8.48	-16.19	-7.71	Se

SeO2	-15.69	-15.56	0.12	SeO2
SeO3	-50.17	-29.13	21.04	SeO3
Siderite	-2.69	-12.93	-10.24	FeCO3
Smithsonite	-1.38	-11.38	-10.00	ZnCO3
Sphalerite	-55.18	-66.63	-11.45	ZnS
Spinel	-5.83	31.02	36.85	MgAl2O4
Sulfur	-51.41	-53.56	-2.14	S
Tenorite	0.35	8.00	7.64	CuO
Thenardite	-8.45	-8.13	0.32	Na2SO4
Thermonatrite	-10.82	-10.19	0.64	Na2CO3:H2O
Tyuyamunite	-8.13	-4.05	4.08	Ca(UO2)2(VO4)2
U3O8	-15.50	5.58	21.08	U3O8
U4O9	-27.44	-30.46	-3.02	U4O9
UF4	-34.71	-64.24	-29.54	UF4
UF4:2.5H2O	-31.52	-64.24	-32.72	UF4:2.5H2O
UO2(am)	-14.23	-13.30	0.93	UO2
UO2(OH)2(beta)	-5.39	0.23	5.61	UO2(OH)2
UO2SeO4:4H2O	-26.65	-28.90	-2.25	UO2SeO4:4H2O
UO3	-7.47	0.23	7.70	UO3
Uraninite	-8.63	-13.30	-4.67	UO2
V(OH)3	-16.61	-9.02	7.59	V(OH)3
V2O5	-16.39	-17.75	-1.36	V2O5
V3O5	-34.61	-32.78	1.84	V3O5
V4O7	-43.31	-36.12	7.19	V4O7
V6O13	-37.88	-98.74	-60.86	V6O13
VCl2	-62.22	-43.35	18.87	VCl2
VCl3	-66.89	-43.46	23.43	VCl3
VF4	-69.22	-54.29	14.93	VF4
Vmetal	-87.16	-43.13	44.03	V
VO	-35.15	-20.39	14.76	VO
VO(OH)2	-8.50	-3.34	5.15	VO(OH)2
VO2Cl	-23.20	-20.36	2.84	VO2Cl
VOCl	-31.65	-20.50	11.15	VOCl
VOCl2	-39.06	-26.30	12.76	VOCl2
VOSO4	-25.94	-22.33	3.61	VOSO4
Witherite	-2.86	-11.43	-8.57	BaCO3
Wurtzite	-57.68	-66.63	-8.95	ZnS
Zincite	-1.67	9.66	11.33	ZnO
Zincosite	-13.25	-9.32	3.93	ZnSO4
Zn(BO2)2	-9.64	-1.35	8.29	Zn(BO2)2
Zn(OH)2	-2.54	9.66	12.20	Zn(OH)2
Zn(OH)2(am)	-2.81	9.66	12.47	Zn(OH)2
Zn(OH)2(beta)	-2.09	9.66	11.75	Zn(OH)2
Zn(OH)2(epsilon)	-1.87	9.66	11.53	Zn(OH)2
Zn(OH)2(gamma)	-2.07	9.66	11.73	Zn(OH)2
Zn2(OH)2SO4	-7.16	0.34	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-7.34	7.85	15.19	Zn2(OH)3Cl
Zn3(AsO4)2:2.5H2O	-12.60	1.05	13.65	Zn3(AsO4)2:2.5H2O
Zn3O(SO4)2	-27.90	-8.99	18.91	Zn3O(SO4)2
Zn4(OH)6SO4	-8.73	19.67	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-13.14	25.36	38.50	Zn5(OH)8Cl2
ZnCl2	-20.34	-13.29	7.05	ZnCl2
ZnCO3:1H2O	-1.12	-11.38	-10.26	ZnCO3:1H2O
ZnF2	-15.27	-15.81	-0.53	ZnF2
Znmetal	-38.87	-13.08	25.79	Zn
ZnMoO4	-3.73	-13.86	-10.13	ZnMoO4
ZnO(active)	-1.52	9.66	11.19	ZnO
ZnS(am)	-57.58	-66.63	-9.05	ZnS
ZnSe	-14.87	-29.27	-14.40	ZnSe
ZnSeO4:6H2O	-17.95	-19.47	-1.52	ZnSeO4:6H2O
ZnSO4:1H2O	-8.69	-9.32	-0.64	ZnSO4:1H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

End of simulation.

Reading input data for simulation 2.

End of Run after 0.273 Seconds.

```
# P100 Scenario

SOLUTION 1 UG Water P100
    temp      25
    pH        8.112
    units     mg/L
    density   1
Al    0.0806
As    0.0026
Ba    0.1761
B     0.1387
Ca    116.6
Cl    50.3
Mg    59.1
Na    224.5
K     35.4
F     1.0796
S(6)  319.6
Cd    0.0063
Cr    0.0071
Co    0.0036
Cu    0.0628
Fe    0.1666
Pb    0.0389
Mn    0.0740
Mo    0.0139
Ni    0.0054
Se    0.0205
U     0.0088
V     0.0026
Zn    0.1776
Alkalinity 558.0 as HCO3
    -water    1 # kg

SOLUTION 2 PAF Material
    temp      25
    pH        7.5
    units     mg/L
    density   1
      Al    0.020
      As    0
      Ba    0.020
      B     0
      Ca    67.0
      Cl    0
      Mg    8.0
      Na    1.0
      K     13.0
      F     0.300
      S(6)  197.0
      Cd    0.000
      Cr    0
      Co    0.007
      Cu    0.028
      Fe    0
      Pb    0
      Mn    0.040
      Mo    0.003
      Ni    0.004
      Se    0
      U     0
      V     0
      Zn    0
      Alkalinity 22 as HCO3
    -water    1 # kg

SOLUTION 3 NAF Material
    temp      25
    pH        7.6
    units     mg/L
    density   1
      Al    0.140
      As    0.029
      Ba    0.020
      B     0
      Ca    122.0
      Cl    0
      Mg    18.0
      Na    1.0
      K     16.0
      F     0.300
      S(6)  331.0
      Cd    0.000
      Cr    0
      Co    0.002
      Cu    0.019
      Fe    0.070
      Pb    0
      Mn    0.130
      Mo    0.005
      Ni    0.001
      Se    0
      U     0.001
      V     0
      Zn    0
      Alkalinity 28 as HCO3
    -water    1 # kg


SOLUTION 4 Make-up Material
    temp      25
    pH        7.7
    units     mg/L
    density   1
      Al    0.020
      As    0
      Ba    0.020
      B     0
      Ca    67.0
      Cl    0
      Mg    8.0
      Na    1.0
      K     13.0
      F     0.300
      S(6)  197.0
      Cd    0.000
      Cr    0
      Co    0.007
      Cu    0.028
      Fe    0
      Pb    0
      Mn    0.040
      Mo    0.003
      Ni    0.004
      Se    0
      U     0
      V     0
      Zn    0
      Alkalinity 22 as HCO3
    -water    1 # kg

# Mix the three solutions together

MIX 1 Mix within UG Works
    1    0.235
    2    0.122
    3    0.442
    4    0.201

SAVE Solution 5

SELECTED_OUTPUT 2
    -file                 D:\selected_output_3.txt
    -high_precision       true
    -reset                true
    -distance             false
    -time                 false
    -temperature          false
    -ionic_strength       false
    -water                false
    -totals               pH Al As Ba B Ca Cl Mg
                          Na K  F  S(6) Cd Cr Co
                          Cu Fe Pb Mn Mo  Ni Se
                          U V Zn Alkalinity
END
```

```
   Input file: P:\J23011 - BCP Underground EA (Aeris)\2. Tech Work Area\2.08 Water Quality
Model\2.08.02 PAF Assessment\BPC_UG_PAF_Disposal_P100.pqi
  Output file: P:\J23011 - BCP Underground EA (Aeris)\2. Tech Work Area\2.08 Water Quality
Model\2.08.02 PAF Assessment\BPC_UG_PAF_Disposal_P100.pqo
Database file: c:\phreeqc\database\minteq.v4.dat

------------------
Reading data base.
------------------

      SOLUTION_MASTER_SPECIES
      SOLUTION_SPECIES
      SOLUTION_SPECIES
      PHASES
      PHASES
      SURFACE_MASTER_SPECIES
      SURFACE_SPECIES
      END
------------------------------------
Reading input data for simulation 1.
------------------------------------

      DATABASE c:\phreeqc\database\minteq.v4.dat
      SOLUTION 1 UG Water P100
          temp      25
          pH        8.112
          units     mg/L
          density   1
      Al    0.0806
      As    0.0026
      Ba    0.1761
      B     0.1387
      Ca    116.6
      Cl    50.3
      Mg    59.1
      Na    224.5
      K     35.4
      F     1.0796
      S(6)  319.6
      Cd    0.0063
      Cr    0.0071
      Co    0.0036
      Cu    0.0628
      Fe    0.1666
      Pb    0.0389
      Mn    0.0740
      Mo    0.0139
      Ni    0.0054
      Se    0.0205
      U     0.0088
      V     0.0026
      Zn    0.1776
      Alkalinity 558.0 as HCO3
          water    1 # kg
      SOLUTION 2 PAF Material
          temp      25
          pH        7.5
          units     mg/L
          density   1
            Al    0.020
            As    0
            Ba    0.020
            B     0
            Ca    67.0
            Cl    0
            Mg    8.0
```

```
            Na    1.0
            K     13.0
            F     0.300
            S(6)  197.0
            Cd    0.000
            Cr    0
            Co    0.007
            Cu    0.028
            Fe    0
            Pb    0
            Mn    0.040
            Mo    0.003
            Ni    0.004
            Se    0
            U     0
            V     0
            Zn    0
            Alkalinity 22 as HCO3
        water    1 # kg
    SOLUTION 3 NAF Material
        temp      25
        pH        7.6
        units     mg/L
        density   1
            Al    0.140
            As    0.029
            Ba    0.020
            B     0
            Ca    122.0
            Cl    0
            Mg    18.0
            Na    1.0
            K     16.0
            F     0.300
            S(6)  331.0
            Cd    0.000
            Cr    0
            Co    0.002
            Cu    0.019
            Fe    0.070
            Pb    0
            Mn    0.130
            Mo    0.005
            Ni    0.001
            Se    0
            U     0.001
            V     0
            Zn    0
            Alkalinity 28 as HCO3
        water    1 # kg
    SOLUTION 4 Make-up Material
        temp      25
        pH        7.7
        units     mg/L
        density   1
            Al    0.020
            As    0
            Ba    0.020
            B     0
            Ca    67.0
            Cl    0
            Mg    8.0
            Na    1.0
            K     13.0
            F     0.300
            S(6)  197.0
            Cd    0.000
            Cr    0
            Co    0.007
            Cu    0.028
            Fe    0
            Pb    0
            Mn    0.040
            Mo    0.003
            Ni    0.004
            Se    0
            U     0
            V     0
            Zn    0
            Alkalinity 22 as HCO3
        water    1 # kg
    MIX 1 Mix within UG Works
        1    0.235
        2    0.122
        3    0.442
        4    0.201
    SAVE Solution 5
    SELECTED_OUTPUT 2
        file                 D:\selected_output_3.txt
        high_precision       true
        reset                true
        distance             false
        time                 false
        temperature          false
        ionic_strength       false
        water                false
        totals               pH Al As Ba B Ca Cl Mg
WARNING: Expected element name to begin with upper case letter.
                              Na K  F  S(6) Cd Cr Co
                              Cu Fe Pb Mn Mo  Ni Se
                              U V Zn Alkalinity
    END
------------------------------------------
Beginning of initial solution calculations.
------------------------------------------

Initial solution 1.     UG Water P100

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                2.991e-06   2.991e-06
      Alkalinity        9.157e-03   9.157e-03
      As                3.475e-08   3.475e-08
      B                 1.285e-05   1.285e-05
      Ba                1.284e-06   1.284e-06
      Ca                2.913e-03   2.913e-03
      Cd                5.612e-08   5.612e-08
      Cl                1.421e-03   1.421e-03
      Co                6.117e-08   6.117e-08
      Cr                1.367e-07   1.367e-07
      Cu                9.896e-07   9.896e-07
      F                 5.690e-05   5.690e-05
      Fe                2.987e-06   2.987e-06
      K                 9.066e-04   9.066e-04
      Mg                2.435e-03   2.435e-03
      Mn                1.349e-06   1.349e-06
      Mo                1.451e-07   1.451e-07
      Na                9.779e-03   9.779e-03
      Ni                9.213e-08   9.213e-08
      Pb                1.880e-07   1.880e-07
      S(6)              3.331e-03   3.331e-03
      Se                2.600e-07   2.600e-07
      U                 3.702e-08   3.702e-08
      V                 5.111e-08   5.111e-08
      Zn                2.720e-06   2.720e-06

---------------------------Description of solution---------------------------

                                       pH  =   8.112
                                       pe  =   4.000
                      Activity of water  =   1.000
                 Ionic strength (mol/kgw)  =   2.420e-02
                      Mass of water (kg)  =   1.000e+00
                 Total carbon (mol/kg)  =   9.048e-03
                    Total CO2 (mol/kg)  =   9.048e-03
                      Temperature (°C)  =  25.00
            Electrical balance (eq)  =   4.109e-03
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  11.87
                             Iterations  =  11
                                Total H  = 1.110227e+02
                                Total O  = 5.554737e+01

----------------------------Distribution of species---------------------------

                                          Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             1.521e-06   1.303e-06    -5.818    -5.885    -0.067     (0)
   H+              8.973e-09   7.727e-09    -8.047    -8.112    -0.065      0.00
   H2O             5.551e+01   9.995e-01     1.744    -0.000     0.000     18.07
Al            2.991e-06
   Al(OH)4-        2.975e-06   2.564e-06    -5.527    -5.591    -0.065     (0)
   Al(OH)3         1.564e-08   1.564e-08    -7.806    -7.806     0.000     (0)
   Al(OH)2+        6.944e-10   6.017e-10    -9.158    -9.221    -0.062     (0)
   AlF2+           3.778e-12   3.274e-12   -11.423   -11.485    -0.062     (0)
   AlF3            1.769e-12   1.769e-12   -11.752   -11.752     0.000     (0)
   AlOH+2          1.031e-12   5.816e-13   -11.987   -12.235    -0.249     (0)
   AlF+2           3.398e-13   1.916e-13   -12.469   -12.718    -0.249     (0)
   AlF4-           4.414e-14   3.805e-14   -13.355   -13.420    -0.065     (0)
   AlSO4+          5.677e-15   4.893e-15   -14.246   -14.310    -0.065     (0)
   Al+3            1.716e-15   4.465e-16   -14.766   -15.350    -0.585     (0)
   Al(SO4)2-       8.587e-17   7.402e-17   -16.066   -16.131    -0.065     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -50.905   -51.619    -0.714     (0)
As(3)         7.751e-21
   H3AsO3          7.179e-21   7.179e-21   -20.144   -20.144     0.000     (0)
   H2AsO3-         5.720e-22   4.765e-22   -21.243   -21.322    -0.079     (0)
   HAsO3-2         1.168e-25   5.624e-26   -24.933   -25.250    -0.317     (0)
   H4AsO3+         3.299e-29   2.748e-29   -28.482   -28.561    -0.079     (0)
   AsO3-3          1.452e-30   2.806e-31   -29.838   -30.552    -0.714     (0)
As(5)         3.475e-08
   HAsO4-2         3.336e-08   1.606e-08    -7.477    -7.794    -0.317     (0)
   H2AsO4-         1.359e-09   1.132e-09    -8.867    -8.946    -0.079     (0)
   AsO4-3          3.403e-11   6.574e-12   -10.468   -11.182    -0.714     (0)
   H3AsO4          1.512e-15   1.520e-15   -14.821   -14.818     0.002     (0)
B             1.285e-05
   H3BO3           1.168e-05   1.175e-05    -4.932    -4.930     0.002     (0)
   H2BO3-          1.038e-06   8.832e-07    -5.984    -6.054    -0.070     (0)
   CaH2BO3+        7.350e-08   6.251e-08    -7.134    -7.204    -0.070     (0)
   MgH2BO3+        3.976e-08   3.381e-08    -7.401    -7.471    -0.070     (0)
   NaH2BO3         1.165e-08   1.165e-08    -7.934    -7.934     0.000     (0)
   BF(OH)3-        2.366e-10   2.012e-10    -9.626    -9.696    -0.070     (0)
   BaH2BO3+        2.145e-11   1.824e-11   -10.669   -10.739    -0.070     (0)
   H5(BO3)2-       1.039e-11   8.832e-12   -10.984   -11.054    -0.070     (0)
   H8(BO3)3-       1.220e-14   1.038e-14   -13.914   -13.984    -0.070     (0)
   BF2(OH)2-       8.392e-15   7.137e-15   -14.076   -14.146    -0.070     (0)
   BF3OH-          1.083e-21   9.212e-22   -20.965   -21.036    -0.070     (0)
   BF4-            1.768e-27   1.504e-27   -26.752   -26.823    -0.070     (0)
Ba            1.284e-06
   Ba+2            1.216e-06   6.683e-07    -5.915    -6.175    -0.260     (0)
   BaHCO3+         5.333e-08   4.637e-08    -7.273    -7.334    -0.061     (0)
   BaCO3           1.511e-08   1.511e-08    -7.821    -7.821     0.000     (0)
   BaH2BO3+        2.145e-11   1.824e-11   -10.669   -10.739    -0.070     (0)
   BaOH+           4.395e-12   3.800e-12   -11.357   -11.420    -0.063     (0)
C(4)          9.048e-03
   HCO3-           8.384e-03   7.265e-03    -2.077    -2.139    -0.062     (0)
   CaHCO3+         1.914e-04   1.664e-04    -3.718    -3.779    -0.061     (0)
   H2CO3           1.263e-04   1.263e-04    -3.899    -3.899     0.000     (0)
   MgHCO3+         9.553e-05   8.209e-05    -4.020    -4.086    -0.066     (0)
   CaCO3           8.593e-05   8.593e-05    -4.066    -4.066     0.000     (0)
   CO3-2           8.018e-05   4.408e-05    -4.096    -4.356    -0.260     (0)
   MgCO3           4.048e-05   4.048e-05    -4.393    -4.393     0.000     (0)
   NaHCO3          3.400e-05   3.400e-05    -4.469    -4.469     0.000     (0)
   NaCO3-          7.882e-06   6.830e-06    -5.103    -5.166    -0.062     (0)
   ZnCO3           1.342e-06   1.342e-06    -5.872    -5.872     0.000     (0)
   CuCO3           7.731e-07   7.731e-07    -6.112    -6.112     0.000     (0)
   Cu(CO3)2-2      1.905e-07   9.173e-08    -6.720    -7.037    -0.317     (0)
   ZnHCO3+         1.459e-07   1.215e-07    -6.836    -6.915    -0.079     (0)
   PbCO3           1.379e-07   1.379e-07    -6.860    -6.860     0.000     (0)
   MnHCO3+         9.035e-08   7.812e-08    -7.044    -7.107    -0.063     (0)
   BaHCO3+         5.333e-08   4.637e-08    -7.273    -7.334    -0.061     (0)
   Pb(CO3)2-2      3.641e-08   1.753e-08    -7.439    -7.756    -0.317     (0)
   UO2(CO3)3-4     3.524e-08   1.895e-09    -7.453    -8.722    -1.269     (0)
   NiCO3           3.126e-08   3.126e-08    -7.505    -7.505     0.000     (0)
   NiHCO3+         2.044e-08   1.703e-08    -7.690    -7.769    -0.079     (0)
   CdCO3           1.651e-08   1.651e-08    -7.782    -7.782     0.000     (0)
   BaCO3           1.511e-08   1.511e-08    -7.821    -7.821     0.000     (0)
   CoCO3           1.192e-08   1.192e-08    -7.924    -7.924     0.000     (0)
   CoHCO3+         1.086e-08   9.044e-09    -7.964    -8.044    -0.079     (0)
   PbHCO3+         6.745e-09   5.619e-09    -8.171    -8.250    -0.079     (0)
   UO2(CO3)2-2     1.781e-09   8.577e-10    -8.749    -9.067    -0.317     (0)
   CuHCO3+         1.639e-09   1.365e-09    -8.785    -8.865    -0.079     (0)
   Cd(CO3)2-2      1.120e-09   5.394e-10    -8.951    -9.268    -0.317     (0)
   CdHCO3+         3.262e-10   2.717e-10    -9.487    -9.566    -0.079     (0)
   FeHCO3+         2.881e-10   2.505e-10    -9.540    -9.601    -0.061     (0)
   UO2CO3          9.751e-13   9.751e-13   -12.011   -12.011     0.000     (0)
Ca            2.913e-03
   Ca+2            2.237e-03   1.230e-03    -2.650    -2.910    -0.260     (0)
   CaSO4           3.978e-04   3.978e-04    -3.400    -3.400     0.000     (0)
   CaHCO3+         1.914e-04   1.664e-04    -3.718    -3.779    -0.061     (0)
   CaCO3           8.593e-05   8.593e-05    -4.066    -4.066     0.000     (0)
   CaF+            6.664e-07   5.762e-07    -6.176    -6.239    -0.063     (0)
   CaH2BO3+        7.350e-08   6.251e-08    -7.134    -7.204    -0.070     (0)
   CaOH+           3.676e-08   3.197e-08    -7.435    -7.495    -0.061     (0)
Cd            5.612e-08
   Cd+2            2.988e-08   1.643e-08    -7.525    -7.784    -0.260     (0)
   CdCO3           1.651e-08   1.651e-08    -7.782    -7.782     0.000     (0)
   CdSO4           5.437e-09   5.437e-09    -8.265    -8.265     0.000     (0)
   CdCl+           2.304e-09   1.919e-09    -8.638    -8.717    -0.079     (0)
   Cd(CO3)2-2      1.120e-09   5.394e-10    -8.951    -9.268    -0.317     (0)
   CdHCO3+         3.262e-10   2.717e-10    -9.487    -9.566    -0.079     (0)
   Cd(SO4)2-2      2.150e-10   1.035e-10    -9.668    -9.985    -0.317     (0)
   CdOH+           2.040e-10   1.700e-10    -9.690    -9.770    -0.079     (0)
   CdOHCl          1.025e-10   1.025e-10    -9.989    -9.989     0.000     (0)
   CdF+            1.341e-11   1.117e-11   -10.872   -10.952    -0.079     (0)
   CdCl2           9.788e-12   9.788e-12   -11.009   -11.009     0.000     (0)
   Cd(OH)2         1.397e-12   1.397e-12   -11.855   -11.855     0.000     (0)
   CdCl3-          9.069e-15   7.555e-15   -14.042   -14.122    -0.079     (0)
   CdF2            9.569e-16   9.569e-16   -15.019   -15.019     0.000     (0)
   Cd(OH)3-        1.334e-16   1.112e-16   -15.875   -15.954    -0.079     (0)
   Cd(SeO3)2-2     9.785e-17   4.712e-17   -16.009   -16.327    -0.317     (0)
   Cd2OH+3         7.245e-17   1.399e-17   -16.140   -16.854    -0.714     (0)
   CdSeO4          3.734e-17   3.734e-17   -16.428   -16.428     0.000     (0)
```

Cd(OH)4-2	4.922e-23	2.370e-23	-22.308	-22.625	-0.317	(0)
Cl	1.421e-03					
Cl-	1.421e-03	1.223e-03	-2.847	-2.912	-0.065	(0)
ZnOHCl	2.772e-09	2.772e-09	-8.557	-8.557	0.000	(0)
CdCl+	2.304e-09	1.919e-09	-8.638	-8.717	-0.079	(0)
ZnCl+	1.892e-09	1.626e-09	-8.723	-8.789	-0.066	(0)
MnCl+	9.600e-10	8.300e-10	-9.018	-9.081	-0.063	(0)
CuCl	2.247e-10	2.247e-10	-9.648	-9.648	0.000	(0)
CdOHCl	1.025e-10	1.025e-10	-9.989	-9.989	0.000	(0)
CoCl+	8.130e-11	6.772e-11	-10.090	-10.169	-0.079	(0)
NiCl+	7.143e-11	5.950e-11	-10.146	-10.225	-0.079	(0)
CuCl2-	6.683e-11	5.743e-11	-10.175	-10.241	-0.066	(0)
PbCl+	5.424e-11	4.518e-11	-10.266	-10.345	-0.079	(0)
CdCl2	9.788e-12	9.788e-12	-11.009	-11.009	0.000	(0)
CuCl+	6.721e-12	5.775e-12	-11.173	-11.238	-0.066	(0)
ZnCl2	3.152e-12	3.152e-12	-11.501	-11.501	0.000	(0)
MnCl2	1.434e-12	1.434e-12	-11.843	-11.843	0.000	(0)
PbCl2	2.469e-13	2.469e-13	-12.608	-12.608	0.000	(0)
CuCl3-2	2.688e-14	1.502e-14	-13.571	-13.823	-0.253	(0)
CdCl3-	9.069e-15	7.555e-15	-14.042	-14.122	-0.079	(0)
ZnCl3-	3.564e-15	3.063e-15	-14.448	-14.514	-0.066	(0)
CuCl2	2.450e-15	2.450e-15	-14.611	-14.611	0.000	(0)
MnCl3-	5.589e-16	4.832e-16	-15.253	-15.316	-0.063	(0)
NiCl2	3.665e-16	3.665e-16	-15.436	-15.436	0.000	(0)
PbCl3-	1.443e-16	1.202e-16	-15.841	-15.920	-0.079	(0)
CrCl+2	5.619e-17	2.706e-17	-16.250	-16.568	-0.317	(0)
ZnCl4-2	3.353e-18	1.873e-18	-17.475	-17.727	-0.253	(0)
CrOHCl2	8.195e-19	8.195e-19	-18.086	-18.086	0.000	(0)
FeCl+2	1.682e-19	9.399e-20	-18.774	-19.027	-0.253	(0)
PbCl4-2	1.396e-19	6.723e-20	-18.855	-19.172	-0.317	(0)
CuCl3-	3.255e-20	2.797e-20	-19.487	-19.553	-0.066	(0)
UO2Cl+	1.323e-20	1.102e-20	-19.878	-19.958	-0.079	(0)
CrCl2+	3.770e-21	3.141e-21	-20.424	-20.503	-0.079	(0)
FeCl2+	5.941e-22	5.136e-22	-21.226	-21.289	-0.063	(0)
VOCl+	6.395e-23	5.328e-23	-22.194	-22.273	-0.079	(0)
CuCl4-2	3.069e-25	1.715e-25	-24.513	-24.766	-0.253	(0)
FeCl3	6.283e-26	6.283e-26	-25.202	-25.202	0.000	(0)
CrO3Cl-	2.721e-26	2.267e-26	-25.565	-25.645	-0.079	(0)
CoCl+2	3.293e-37	1.586e-37	-36.482	-36.800	-0.317	(0)
UCl+3	0.000e+00	0.000e+00	-48.985	-49.699	-0.714	(0)
Co(2)	1.117e-08					
Co+2	3.323e-08	1.600e-08	-7.478	-7.796	-0.317	(0)
CoCO3	1.192e-08	1.192e-08	-7.924	-7.924	0.000	(0)
CoHCO3+	1.086e-08	9.044e-09	-7.964	-8.044	-0.079	(0)
CoSO4	4.508e-09	4.508e-09	-8.346	-8.346	0.000	(0)
CoOH+	4.993e-10	4.159e-10	-9.302	-9.381	-0.079	(0)
CoCl+	8.130e-11	6.772e-11	-10.090	-10.169	-0.079	(0)
Co(OH)2	4.303e-11	4.303e-11	-10.366	-10.366	0.000	(0)
CoF+	2.607e-11	2.172e-11	-10.584	-10.663	-0.079	(0)
Co(OH)3-	1.342e-15	1.118e-15	-14.872	-14.951	-0.079	(0)
CoOOH-	3.370e-16	2.807e-16	-15.472	-15.552	-0.079	(0)
CoSeO4	9.790e-17	9.790e-17	-16.009	-16.009	0.000	(0)
Co2OH+3	1.727e-18	3.336e-19	-17.763	-18.477	-0.714	(0)
Co(OH)4-2	4.794e-22	2.309e-22	-21.319	-21.637	-0.317	(0)
Co4(OH)4+4	1.110e-28	5.969e-30	-27.955	-29.224	-1.269	(0)
Co(3)	8.757e-30					
CoOH+2	8.757e-30	4.217e-30	-29.058	-29.375	-0.317	(0)
Co+3	2.448e-36	6.371e-37	-35.611	-36.196	-0.585	(0)
CoCl+2	3.293e-37	1.586e-37	-36.482	-36.800	-0.317	(0)
Cr(2)	8.478e-25					
Cr+2	8.478e-25	4.083e-25	-24.072	-24.389	-0.317	(0)
Cr(3)	1.367e-07					
Cr(OH)2+	9.265e-08	7.718e-08	-7.033	-7.112	-0.079	(0)
Cr(OH)3	3.777e-08	3.777e-08	-7.423	-7.423	0.000	(0)
CrO2-	2.788e-09	2.322e-09	-8.555	-8.634	-0.079	(0)
Cr(OH)4-	2.351e-09	1.958e-09	-8.629	-8.708	-0.079	(0)

Cr(OH)+2	1.011e-09	4.870e-10	-8.995	-9.312	-0.317	(0)
CrOHSO4	1.632e-10	1.632e-10	-9.787	-9.787	0.000	(0)
CrF+2	2.414e-13	1.162e-13	-12.617	-12.935	-0.317	(0)
Cr+3	8.847e-14	1.709e-14	-13.053	-13.767	-0.714	(0)
CrSO4+	6.763e-14	5.634e-14	-13.170	-13.249	-0.079	(0)
CrCl+2	5.619e-17	2.706e-17	-16.250	-16.568	-0.317	(0)
Cr2(OH)2SO4+2	1.491e-17	7.182e-18	-16.826	-17.144	-0.317	(0)
CrOHCl2	8.195e-19	8.195e-19	-18.086	-18.086	0.000	(0)
Cr2(OH)2(SO4)2	6.023e-19	6.023e-19	-18.220	-18.220	0.000	(0)
CrCl2+	3.770e-21	3.141e-21	-20.424	-20.503	-0.079	(0)
Cr(6)	2.900e-14					
CrO4-2	2.773e-14	1.524e-14	-13.557	-13.817	-0.260	(0)
NaCrO4-	7.567e-16	6.304e-16	-15.121	-15.200	-0.079	(0)
HCrO4-	4.576e-16	3.812e-16	-15.340	-15.419	-0.079	(0)
KCrO4-	5.256e-17	4.378e-17	-16.279	-16.359	-0.079	(0)
CrO3SO4-2	2.631e-24	1.267e-24	-23.580	-23.897	-0.317	(0)
H2CrO4	2.387e-24	2.387e-24	-23.622	-23.622	0.000	(0)
CrO3Cl-	2.721e-26	2.267e-26	-25.565	-25.645	-0.079	(0)
Cr2O7-2	1.047e-29	5.040e-30	-28.980	-29.298	-0.317	(0)
Cu(1)	4.667e-10					
CuCl	2.247e-10	2.247e-10	-9.648	-9.648	0.000	(0)
Cu+	1.751e-10	1.459e-10	-9.757	-9.836	-0.079	(0)
CuCl2-	6.683e-11	5.743e-11	-10.175	-10.241	-0.066	(0)
CuCl3-2	2.688e-14	1.502e-14	-13.571	-13.823	-0.253	(0)
Cu(2)	9.891e-07					
CuCO3	7.731e-07	7.731e-07	-6.112	-6.112	0.000	(0)
Cu(CO3)2-2	1.905e-07	9.173e-08	-6.720	-7.037	-0.317	(0)
CuOH+	1.428e-08	1.227e-08	-7.845	-7.911	-0.066	(0)
Cu+2	5.418e-09	2.979e-09	-8.266	-8.526	-0.260	(0)
Cu(OH)2	3.188e-09	3.188e-09	-8.496	-8.496	0.000	(0)
CuHCO3+	1.639e-09	1.365e-09	-8.785	-8.865	-0.079	(0)
CuSO4	9.633e-10	9.633e-10	-9.016	-9.016	0.000	(0)
Cu(OH)3-	1.023e-11	8.519e-12	-10.990	-11.070	-0.079	(0)
CuF+	9.682e-12	8.066e-12	-11.014	-11.093	-0.079	(0)
Cu2(OH)2+2	7.851e-12	3.781e-12	-11.105	-11.422	-0.317	(0)
CuCl+	6.721e-12	5.775e-12	-11.173	-11.238	-0.066	(0)
CuCl2	2.450e-15	2.450e-15	-14.611	-14.611	0.000	(0)
Cu(OH)4-2	1.814e-16	8.733e-17	-15.741	-16.059	-0.317	(0)
CuCl3-	3.255e-20	2.797e-20	-19.487	-19.553	-0.066	(0)
CuCl4-2	3.069e-25	1.715e-25	-24.513	-24.766	-0.253	(0)
F	5.690e-05					
F-	4.984e-05	4.292e-05	-4.302	-4.367	-0.065	(0)
MgF+	6.168e-06	5.317e-06	-5.210	-5.274	-0.065	(0)
CaF+	6.664e-07	5.762e-07	-6.176	-6.239	-0.063	(0)
NaF	2.253e-07	2.253e-07	-6.647	-6.647	0.000	(0)
MnF+	1.065e-09	9.207e-10	-8.973	-9.036	-0.063	(0)
ZnF+	5.438e-10	4.530e-10	-9.265	-9.344	-0.079	(0)
HF	4.905e-10	4.905e-10	-9.309	-9.309	0.000	(0)
BF(OH)3-	2.366e-10	2.012e-10	-9.626	-9.696	-0.070	(0)
CoF+	2.607e-11	2.172e-11	-10.584	-10.663	-0.079	(0)
NiF+	2.460e-11	2.049e-11	-10.609	-10.688	-0.079	(0)
CdF+	1.341e-11	1.117e-11	-10.872	-10.952	-0.079	(0)
CuF+	9.682e-12	8.066e-12	-11.014	-11.093	-0.079	(0)
PbF+	3.779e-12	3.148e-12	-11.423	-11.502	-0.079	(0)
AlF2+	3.778e-12	3.274e-12	-11.423	-11.485	-0.062	(0)
AlF3	1.769e-12	1.769e-12	-11.752	-11.752	0.000	(0)
AlF+2	3.398e-13	1.916e-13	-12.469	-12.718	-0.249	(0)
CrF+2	2.414e-13	1.162e-13	-12.617	-12.935	-0.317	(0)
HF2-	9.345e-14	8.003e-14	-13.029	-13.097	-0.067	(0)
AlF4-	4.414e-14	3.805e-14	-13.355	-13.420	-0.065	(0)
BF2(OH)2-	8.392e-15	7.137e-15	-14.076	-14.146	-0.070	(0)
PbF2	2.659e-15	2.659e-15	-14.575	-14.575	0.000	(0)
CdF2	9.569e-16	9.569e-16	-15.019	-15.019	0.000	(0)
FeF+2	2.143e-16	1.197e-16	-15.669	-15.922	-0.253	(0)
FeF2+	1.590e-16	1.375e-16	-15.798	-15.862	-0.063	(0)
UO2F+	3.952e-17	3.292e-17	-16.403	-16.483	-0.079	(0)

FeF3	8.326e-18	8.326e-18	-17.080	-17.080	0.000	(0)
UO2F2	4.075e-18	4.075e-18	-17.390	-17.390	0.000	(0)
VO2F	2.446e-18	2.446e-18	-17.612	-17.612	0.000	(0)
H2F2	6.446e-19	6.446e-19	-18.191	-18.191	0.000	(0)
PbF3-	2.598e-19	2.164e-19	-18.585	-18.665	-0.079	(0)
UO2F3-	5.273e-20	4.393e-20	-19.278	-19.357	-0.079	(0)
VO2F2-	4.575e-20	3.811e-20	-19.340	-19.419	-0.079	(0)
VOF+	4.797e-21	3.996e-21	-20.319	-20.398	-0.079	(0)
BF3OH-	1.083e-21	9.212e-22	-20.965	-21.036	-0.070	(0)
VOF2	6.431e-23	6.431e-23	-22.192	-22.192	0.000	(0)
VO2F3-2	4.237e-23	2.040e-23	-22.373	-22.690	-0.317	(0)
UO2F4-2	3.110e-23	1.497e-23	-22.507	-22.825	-0.317	(0)
PbF4-2	9.232e-24	4.446e-24	-23.035	-23.352	-0.317	(0)
VOF3-	1.175e-25	9.792e-26	-24.930	-25.009	-0.079	(0)
VO2F4-3	2.230e-27	4.308e-28	-26.652	-27.366	-0.714	(0)
BF4-	1.768e-27	1.504e-27	-26.752	-26.823	-0.070	(0)
VOF4-2	3.523e-29	1.696e-29	-28.453	-28.770	-0.317	(0)
UF3+	1.232e-40	1.026e-40	-39.910	-39.989	-0.079	(0)
UF2+2	0.000e+00	0.000e+00	-40.504	-40.821	-0.317	(0)
UF4	0.000e+00	0.000e+00	-42.316	-42.316	0.000	(0)
UF+3	0.000e+00	0.000e+00	-42.840	-43.554	-0.714	(0)
UF5-	0.000e+00	0.000e+00	-45.006	-45.086	-0.079	(0)
UF6-2	0.000e+00	0.000e+00	-46.656	-46.973	-0.317	(0)
Fe(2)	7.089e-09					
Fe+2	5.687e-09	2.739e-09	-8.245	-8.562	-0.317	(0)
FeSO4	9.491e-10	9.491e-10	-9.023	-9.023	0.000	(0)
FeHCO3+	2.881e-10	2.505e-10	-9.540	-9.601	-0.061	(0)
FeOH+	1.643e-10	1.420e-10	-9.784	-9.848	-0.063	(0)
Fe(OH)2	1.469e-13	1.469e-13	-12.833	-12.833	0.000	(0)
Fe(OH)3-	7.000e-14	6.052e-14	-13.155	-13.218	-0.063	(0)
Fe(3)	2.980e-06					
Fe(OH)3	1.517e-06	1.517e-06	-5.819	-5.819	0.000	(0)
Fe(OH)2+	1.251e-06	1.084e-06	-5.903	-5.965	-0.062	(0)
Fe(OH)4-	2.123e-07	1.839e-07	-6.673	-6.735	-0.062	(0)
FeOH+2	3.829e-12	2.140e-12	-11.417	-11.670	-0.253	(0)
FeF+2	2.143e-16	1.197e-16	-15.669	-15.922	-0.253	(0)
FeF2+	1.590e-16	1.375e-16	-15.798	-15.862	-0.063	(0)
FeSO4+	4.661e-17	4.030e-17	-16.332	-16.395	-0.063	(0)
Fe+3	9.776e-18	2.544e-18	-17.010	-17.594	-0.585	(0)
FeF3	8.326e-18	8.326e-18	-17.080	-17.080	0.000	(0)
Fe(SO4)2-	1.460e-18	1.216e-18	-17.836	-17.915	-0.079	(0)
FeCl+2	1.682e-19	9.399e-20	-18.774	-19.027	-0.253	(0)
Fe2(OH)2+4	2.819e-21	1.516e-22	-20.550	-21.819	-1.269	(0)
FeHSeO3+2	1.598e-21	7.697e-22	-20.796	-21.114	-0.317	(0)
FeCl2+	5.941e-22	5.136e-22	-21.226	-21.289	-0.063	(0)
Fe3(OH)4+5	2.287e-25	2.376e-27	-24.641	-26.624	-1.984	(0)
FeCl3	6.283e-26	6.283e-26	-25.202	-25.202	0.000	(0)
H(0)	8.406e-28					
H2	4.203e-28	4.227e-28	-27.376	-27.374	0.002	(0)
K	9.066e-04					
K+	8.977e-04	7.730e-04	-3.047	-3.112	-0.065	(0)
KSO4-	8.915e-06	7.726e-06	-5.050	-5.112	-0.062	(0)
KCrO4-	5.256e-17	4.378e-17	-16.279	-16.359	-0.079	(0)
Mg	2.435e-03					
Mg+2	2.008e-03	1.104e-03	-2.697	-2.957	-0.260	(0)
MgSO4	2.836e-04	2.836e-04	-3.547	-3.547	0.000	(0)
MgHCO3+	9.553e-05	8.209e-05	-4.020	-4.086	-0.066	(0)
MgCO3	4.048e-05	4.048e-05	-4.393	-4.393	0.000	(0)
MgF+	6.168e-06	5.317e-06	-5.210	-5.274	-0.065	(0)
MgOH+	6.567e-07	5.725e-07	-6.183	-6.242	-0.060	(0)
MgH2BO3+	3.976e-08	3.381e-08	-7.401	-7.471	-0.070	(0)
Mn(2)	1.349e-06					
Mn+2	1.119e-06	5.389e-07	-5.951	-6.268	-0.317	(0)
MnSO4	1.353e-07	1.353e-07	-6.869	-6.869	0.000	(0)
MnHCO3+	9.035e-08	7.812e-08	-7.044	-7.107	-0.063	(0)
MnOH+	2.039e-09	1.763e-09	-8.691	-8.754	-0.063	(0)

MnF+	1.065e-09	9.207e-10	-8.973	-9.036	-0.063	(0)
MnCl+	9.600e-10	8.300e-10	-9.018	-9.081	-0.063	(0)
MnCl2	1.434e-12	1.434e-12	-11.843	-11.843	0.000	(0)
MnSeO4	1.771e-15	1.771e-15	-14.752	-14.752	0.000	(0)
MnCl3-	5.589e-16	4.832e-16	-15.253	-15.316	-0.063	(0)
Mn(OH)3-	2.138e-17	1.849e-17	-16.670	-16.733	-0.063	(0)
Mn(OH)4-2	1.391e-22	7.774e-23	-21.857	-22.109	-0.253	(0)
MnSe	5.081e-39	5.081e-39	-38.294	-38.294	0.000	(0)
Mn(3)	9.250e-28					
Mn+3	9.250e-28	2.407e-28	-27.034	-27.618	-0.585	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-43.543	-43.795	-0.253	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-49.099	-49.167	-0.069	(0)
Mo	1.451e-07					
MoO4-2	1.451e-07	7.975e-08	-6.838	-7.098	-0.260	(0)
HMoO4-	1.472e-11	1.226e-11	-10.832	-10.911	-0.079	(0)
H2MoO4	6.940e-16	6.940e-16	-15.159	-15.159	0.000	(0)
AlMo6O21-3	0.000e+00	0.000e+00	-50.905	-51.619	-0.714	(0)
Mo7O24-6	0.000e+00	0.000e+00	-58.737	-61.593	-2.856	(0)
HMo7O24-5	0.000e+00	0.000e+00	-61.335	-63.318	-1.984	(0)
H2Mo7O24-4	0.000e+00	0.000e+00	-65.379	-66.648	-1.269	(0)
H3Mo7O24-3	0.000e+00	0.000e+00	-70.800	-71.514	-0.714	(0)
Na	9.779e-03					
Na+	9.664e-03	8.321e-03	-2.015	-2.080	-0.065	(0)
NaSO4-	7.280e-05	6.309e-05	-4.138	-4.200	-0.062	(0)
NaHCO3	3.400e-05	3.400e-05	-4.469	-4.469	0.000	(0)
NaCO3-	7.882e-06	6.830e-06	-5.103	-5.166	-0.062	(0)
NaF	2.253e-07	2.253e-07	-6.647	-6.647	0.000	(0)
NaH2BO3	1.165e-08	1.165e-08	-7.934	-7.934	0.000	(0)
NaCrO4-	7.567e-16	6.304e-16	-15.121	-15.200	-0.079	(0)
Ni	9.213e-08					
Ni+2	3.458e-08	1.901e-08	-7.461	-7.721	-0.260	(0)
NiCO3	3.126e-08	3.126e-08	-7.505	-7.505	0.000	(0)
NiHCO3+	2.044e-08	1.703e-08	-7.690	-7.769	-0.079	(0)
NiSO4	5.354e-09	5.354e-09	-8.271	-8.271	0.000	(0)
NiOH+	3.742e-10	3.117e-10	-9.427	-9.506	-0.079	(0)
NiCl+	7.143e-11	5.950e-11	-10.146	-10.225	-0.079	(0)
Ni(OH)2	3.225e-11	3.225e-11	-10.491	-10.491	0.000	(0)
NiF+	2.460e-11	2.049e-11	-10.609	-10.688	-0.079	(0)
Ni(SO4)2-2	5.198e-13	2.503e-13	-12.284	-12.602	-0.317	(0)
Ni(OH)3-	5.043e-14	4.201e-14	-13.297	-13.377	-0.079	(0)
NiCl2	3.665e-16	3.665e-16	-15.436	-15.436	0.000	(0)
NiSeO4	1.085e-16	1.085e-16	-15.964	-15.964	0.000	(0)
O(0)	5.638e-38					
O2	2.819e-38	2.835e-38	-37.550	-37.547	0.002	(0)
Pb	1.880e-07					
PbCO3	1.379e-07	1.379e-07	-6.860	-6.860	0.000	(0)
Pb(CO3)2-2	3.641e-08	1.753e-08	-7.439	-7.756	-0.317	(0)
PbHCO3+	6.745e-09	5.619e-09	-8.171	-8.250	-0.079	(0)
PbOH+	4.088e-09	3.406e-09	-8.388	-8.468	-0.079	(0)
Pb+2	1.893e-09	1.041e-09	-8.723	-8.983	-0.260	(0)
PbSO4	7.197e-10	7.197e-10	-9.143	-9.143	0.000	(0)
Pb(OH)2	1.403e-10	1.403e-10	-9.853	-9.853	0.000	(0)
PbCl+	5.424e-11	4.518e-11	-10.266	-10.345	-0.079	(0)
Pb(SO4)2-2	1.271e-11	6.122e-12	-10.896	-11.213	-0.317	(0)
PbF+	3.779e-12	3.148e-12	-11.423	-11.502	-0.079	(0)
PbCl2	2.469e-13	2.469e-13	-12.608	-12.608	0.000	(0)
Pb(OH)3-	2.193e-13	1.827e-13	-12.659	-12.738	-0.079	(0)
PbF2	2.659e-15	2.659e-15	-14.575	-14.575	0.000	(0)
Pb2OH+3	2.908e-16	5.618e-17	-15.536	-16.250	-0.714	(0)
PbCl3-	1.443e-16	1.202e-16	-15.841	-15.920	-0.079	(0)
Pb(OH)4-2	1.210e-16	5.828e-17	-15.917	-16.234	-0.317	(0)
Pb3(OH)4+2	8.486e-19	4.087e-19	-18.071	-18.389	-0.317	(0)
PbF3-	2.598e-19	2.164e-19	-18.585	-18.665	-0.079	(0)
PbCl4-2	1.396e-19	6.723e-20	-18.855	-19.172	-0.317	(0)

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   Pb4(OH)4+4      6.284e-23   3.379e-24   -22.202   -23.471    -1.269     (0)
   PbF4-2          9.232e-24   4.446e-24   -23.035   -23.352    -0.317     (0)
S(6)          3.331e-03
   SO4-2           2.568e-03   1.412e-03    -2.590    -2.850    -0.260     (0)
   CaSO4           3.978e-04   3.978e-04    -3.400    -3.400     0.000     (0)
   MgSO4           2.836e-04   2.836e-04    -3.547    -3.547     0.000     (0)
   NaSO4-          7.280e-05   6.309e-05    -4.138    -4.200    -0.062     (0)
   KSO4-           8.915e-06   7.726e-06    -5.050    -5.112    -0.062     (0)
   ZnSO4           1.634e-07   1.634e-07    -6.787    -6.787     0.000     (0)
   MnSO4           1.353e-07   1.353e-07    -6.869    -6.869     0.000     (0)
   CdSO4           5.437e-09   5.437e-09    -8.265    -8.265     0.000     (0)
   NiSO4           5.354e-09   5.354e-09    -8.271    -8.271     0.000     (0)
   CoSO4           4.508e-09   4.508e-09    -8.346    -8.346     0.000     (0)
   Zn(SO4)2-2      4.172e-09   2.009e-09    -8.380    -8.697    -0.317     (0)
   HSO4-           1.237e-09   1.066e-09    -8.908    -8.972    -0.065     (0)
   CuSO4           9.633e-10   9.633e-10    -9.016    -9.016     0.000     (0)
   FeSO4           9.491e-10   9.491e-10    -9.023    -9.023     0.000     (0)
   PbSO4           7.197e-10   7.197e-10    -9.143    -9.143     0.000     (0)
   Cd(SO4)2-2      2.150e-10   1.035e-10    -9.668    -9.985    -0.317     (0)
   CrOHSO4         1.632e-10   1.632e-10    -9.787    -9.787     0.000     (0)
   Pb(SO4)2-2      1.271e-11   6.122e-12   -10.896   -11.213    -0.317     (0)
   Ni(SO4)2-2      5.198e-13   2.503e-13   -12.284   -12.602    -0.317     (0)
   CrSO4+          6.763e-14   5.634e-14   -13.170   -13.249    -0.079     (0)
   AlSO4+          5.677e-15   4.893e-15   -14.246   -14.310    -0.065     (0)
   Al(SO4)2-       8.587e-17   7.402e-17   -16.066   -16.131    -0.065     (0)
   FeSO4+          4.661e-17   4.030e-17   -16.332   -16.395    -0.063     (0)
   Cr2(OH)2SO4+2   1.491e-17   7.182e-18   -16.826   -17.144    -0.317     (0)
   UO2SO4          1.187e-17   1.187e-17   -16.925   -16.925     0.000     (0)
   Fe(SO4)2-       1.460e-18   1.216e-18   -17.836   -17.915    -0.079     (0)
   VO2SO4-         1.315e-18   1.095e-18   -17.881   -17.960    -0.079     (0)
   Cr2(OH)2(SO4)2   6.023e-19   6.023e-19   -18.220   -18.220     0.000     (0)
   UO2(SO4)2-2     4.589e-19   2.210e-19   -18.338   -18.656    -0.317     (0)
   VOSO4           6.036e-21   6.036e-21   -20.219   -20.219     0.000     (0)
   CrO3SO4-2       2.631e-24   1.267e-24   -23.580   -23.897    -0.317     (0)
   VSO4+           3.684e-35   3.069e-35   -34.434   -34.513    -0.079     (0)
   U(SO4)2         0.000e+00   0.000e+00   -43.687   -43.687     0.000     (0)
   USO4+2          0.000e+00   0.000e+00   -44.420   -44.737    -0.317     (0)
Se(-2)        2.123e-35
   HSe-            2.122e-35   1.768e-35   -34.673   -34.753    -0.079     (0)
   MnSe            5.081e-39   5.081e-39   -38.294   -38.294     0.000     (0)
   H2Se            1.060e-39   1.060e-39   -38.975   -38.975     0.000     (0)
   Se-2            0.000e+00   0.000e+00   -41.323   -41.641    -0.317     (0)
Se(4)         2.600e-07
   HSeO3-          1.374e-07   1.145e-07    -6.862    -6.941    -0.079     (0)
   SeO3-2          1.225e-07   5.899e-08    -6.912    -7.229    -0.317     (0)
   H2SeO3          3.774e-13   3.774e-13   -12.423   -12.423     0.000     (0)
   Cd(SeO3)2-2     9.785e-17   4.712e-17   -16.009   -16.327    -0.317     (0)
   FeHSeO3+2       1.598e-21   7.697e-22   -20.796   -21.114    -0.317     (0)
Se(6)         2.221e-11
   SeO4-2          2.220e-11   1.221e-11   -10.654   -10.913    -0.260     (0)
   MnSeO4          1.771e-15   1.771e-15   -14.752   -14.752     0.000     (0)
   ZnSeO4          1.000e-15   1.000e-15   -15.000   -15.000     0.000     (0)
   NiSeO4          1.085e-16   1.085e-16   -15.964   -15.964     0.000     (0)
   CoSeO4          9.790e-17   9.790e-17   -16.009   -16.009     0.000     (0)
   CdSeO4          3.734e-17   3.734e-17   -16.428   -16.428     0.000     (0)
   HSeO4-          5.675e-18   4.727e-18   -17.246   -17.325    -0.079     (0)
   Zn(SeO4)2-2     2.570e-26   1.238e-26   -25.590   -25.907    -0.317     (0)
U(3)          0.000e+00
   U+3             0.000e+00   0.000e+00   -60.569   -61.283    -0.714     (0)
U(4)          1.076e-21
   U(OH)5-         1.075e-21   8.958e-22   -20.968   -21.048    -0.079     (0)
   U(OH)4          2.900e-25   2.900e-25   -24.538   -24.538     0.000     (0)
   U(OH)3+         9.839e-30   8.196e-30   -29.007   -29.086    -0.079     (0)
   U(OH)2+2        6.084e-35   2.930e-35   -34.216   -34.533    -0.317     (0)
   UF3+            1.232e-40   1.026e-40   -39.910   -39.989    -0.079     (0)
   UOH+3           0.000e+00   0.000e+00   -40.258   -40.972    -0.714     (0)
   UF2+2           0.000e+00   0.000e+00   -40.504   -40.821    -0.317     (0)
   UF4             0.000e+00   0.000e+00   -42.316   -42.316     0.000     (0)
   UF+3            0.000e+00   0.000e+00   -42.840   -43.554    -0.714     (0)
   U(SO4)2         0.000e+00   0.000e+00   -43.687   -43.687     0.000     (0)
   USO4+2          0.000e+00   0.000e+00   -44.420   -44.737    -0.317     (0)
   UF5-            0.000e+00   0.000e+00   -45.006   -45.086    -0.079     (0)
   UF6-2           0.000e+00   0.000e+00   -46.656   -46.973    -0.317     (0)
   U+4             0.000e+00   0.000e+00   -47.217   -48.487    -1.269     (0)
   UCl+3           0.000e+00   0.000e+00   -48.985   -49.699    -0.714     (0)
   U6(OH)15+9      0.000e+00   0.000e+00  -179.972  -186.399    -6.427     (0)
U(5)          4.066e-19
   UO2+            4.066e-19   3.387e-19   -18.391   -18.470    -0.079     (0)
U(6)          3.702e-08
   UO2(CO3)3-4     3.524e-08   1.895e-09    -7.453    -8.722    -1.269     (0)
   UO2(CO3)2-2     1.781e-09   8.577e-10    -8.749    -9.067    -0.317     (0)
   UO2CO3          9.751e-13   9.751e-13   -12.011   -12.011     0.000     (0)
   UO2OH+          1.094e-15   9.112e-16   -14.961   -15.040    -0.079     (0)
   UO2F+           3.952e-17   3.292e-17   -16.403   -16.483    -0.079     (0)
   UO2SO4          1.187e-17   1.187e-17   -16.925   -16.925     0.000     (0)
   UO2+2           1.011e-17   5.557e-18   -16.995   -17.255    -0.260     (0)
   UO2F2           4.075e-18   4.075e-18   -17.390   -17.390     0.000     (0)
   UO2(SO4)2-2     4.589e-19   2.210e-19   -18.338   -18.656    -0.317     (0)
   UO2F3-          5.273e-20   4.393e-20   -19.278   -19.357    -0.079     (0)
   UO2Cl+          1.323e-20   1.102e-20   -19.878   -19.958    -0.079     (0)
   UO2F4-2         3.110e-23   1.497e-23   -22.507   -22.825    -0.317     (0)
   (UO2)2(OH)2+2   2.861e-24   1.378e-24   -23.543   -23.861    -0.317     (0)
   (UO2)3(OH)5+    1.940e-27   1.616e-27   -26.712   -26.792    -0.079     (0)
V(2)          0.000e+00
   VOH+            0.000e+00   0.000e+00   -40.943   -41.022    -0.079     (0)
   V+2             0.000e+00   0.000e+00   -42.329   -42.647    -0.317     (0)
V(3)          8.208e-14
   V(OH)3          8.208e-14   8.208e-14   -13.086   -13.086     0.000     (0)
   V(OH)2+         4.922e-25   4.100e-25   -24.308   -24.387    -0.079     (0)
   VOH+2           6.242e-29   3.006e-29   -28.205   -28.522    -0.317     (0)
   V+3             2.384e-34   4.605e-35   -33.623   -34.337    -0.714     (0)
   VSO4+           3.684e-35   3.069e-35   -34.434   -34.513    -0.079     (0)
   V2(OH)3+3       0.000e+00   0.000e+00   -53.743   -54.457    -0.714     (0)
   V2(OH)2+4       0.000e+00   0.000e+00   -54.975   -56.244    -1.269     (0)
V(4)          4.884e-18
   V(OH)3+         4.841e-18   4.032e-18   -17.315   -17.394    -0.079     (0)
   VO+2            3.224e-20   1.552e-20   -19.492   -19.809    -0.317     (0)
   VOSO4           6.036e-21   6.036e-21   -20.219   -20.219     0.000     (0)
   VOF+            4.797e-21   3.996e-21   -20.319   -20.398    -0.079     (0)
   VOF2            6.431e-23   6.431e-23   -22.192   -22.192     0.000     (0)
   VOCl+           6.395e-23   5.328e-23   -22.194   -22.273    -0.079     (0)
   VOF3-           1.175e-25   9.792e-26   -24.930   -25.009    -0.079     (0)
   VOF4-2          3.523e-29   1.696e-29   -28.453   -28.770    -0.317     (0)
   H2V2O4+2        1.694e-30   8.157e-31   -29.771   -30.088    -0.317     (0)
V(5)          5.111e-08
   H2VO4-          3.271e-08   2.725e-08    -7.485    -7.565    -0.079     (0)
   HVO4-2          1.840e-08   8.858e-09    -7.735    -8.053    -0.317     (0)
   H3VO4           2.105e-12   2.105e-12   -11.677   -11.677     0.000     (0)
   H3V2O7-         4.449e-13   3.706e-13   -12.352   -12.431    -0.079     (0)
   HV2O7-3         4.236e-13   8.183e-14   -12.373   -13.087    -0.714     (0)
   VO4-3           2.975e-14   5.746e-15   -13.527   -14.241    -0.714     (0)
   V2O7-4          5.301e-15   2.850e-16   -14.276   -15.545    -1.269     (0)
   V3O9-3          1.098e-16   2.122e-17   -15.959   -16.673    -0.714     (0)
   VO2+            3.773e-17   3.249e-17   -16.423   -16.488    -0.065     (0)
   VO2F            2.446e-18   2.446e-18   -17.612   -17.612     0.000     (0)
   VO2SO4-         1.315e-18   1.095e-18   -17.881   -17.960    -0.079     (0)
   VO2F2-          4.575e-20   3.811e-20   -19.340   -19.419    -0.079     (0)
   V4O12-4         4.484e-21   2.411e-22   -20.348   -21.618    -1.269     (0)
   VO2F3-2         4.237e-23   2.040e-23   -22.373   -22.690    -0.317     (0)
   VO2F4-3         2.230e-27   4.308e-28   -26.652   -27.366    -0.714     (0)
   V10O28-6        0.000e+00   0.000e+00   -56.330   -59.186    -2.856     (0)
   HV10O28-5       0.000e+00   0.000e+00   -57.128   -59.112    -1.984     (0)
   H2V10O28-4      0.000e+00   0.000e+00   -60.747   -62.016    -1.269     (0)
Zn            2.720e-06
   ZnCO3           1.342e-06   1.342e-06    -5.872    -5.872     0.000     (0)
   Zn+2            9.622e-07   5.290e-07    -6.017    -6.277    -0.260     (0)
   ZnSO4           1.634e-07   1.634e-07    -6.787    -6.787     0.000     (0)
   ZnHCO3+         1.459e-07   1.215e-07    -6.836    -6.915    -0.079     (0)
   ZnOH+           8.271e-08   6.890e-08    -7.082    -7.162    -0.079     (0)
   Zn(OH)2         1.422e-08   1.422e-08    -7.847    -7.847     0.000     (0)
   Zn(SO4)2-2      4.172e-09   2.009e-09    -8.380    -8.697    -0.317     (0)
   ZnOHCl          2.772e-09   2.772e-09    -8.557    -8.557     0.000     (0)
   ZnCl+           1.892e-09   1.626e-09    -8.723    -8.789    -0.066     (0)
   ZnF+            5.438e-10   4.530e-10    -9.265    -9.344    -0.079     (0)
   Zn(OH)3-        1.115e-10   9.286e-11    -9.953   -10.032    -0.079     (0)
   ZnCl2           3.152e-12   3.152e-12   -11.501   -11.501     0.000     (0)
   Zn(OH)4-2       9.999e-15   4.815e-15   -14.000   -14.317    -0.317     (0)
   ZnCl3-          3.564e-15   3.063e-15   -14.448   -14.514    -0.066     (0)
   ZnSeO4          1.000e-15   1.000e-15   -15.000   -15.000     0.000     (0)
   ZnCl4-2         3.353e-18   1.873e-18   -17.475   -17.727    -0.253     (0)
   Zn(SeO4)2-2     2.570e-26   1.238e-26   -25.590   -25.907    -0.317     (0)

----------------------------Saturation indices----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)       -1.81      8.99   10.80  Al(OH)3
  Al2(MoO4)3       -54.36    -52.00    2.37  Al2(MoO4)3
  Al2O3             -1.68     17.97   19.65  Al2O3
  Al4(OH)10SO4      -5.83     16.87   22.70  Al4(OH)10SO4
  AlAsO4:2H2O      -10.63     -5.83    4.80  AlAsO4:2H2O
  AlOHSO4           -6.86    -10.09   -3.23  AlOHSO4
  Alunite           -4.79     -6.19   -1.40  KAl3(SO4)2(OH)6
  Anglesite         -4.04    -11.83   -7.79  PbSO4
  Anhydrite         -1.40     -5.76   -4.36  CaSO4
  Antlerite         -4.77      4.02    8.79  Cu3(OH)4SO4
  Aragonite          1.03     -7.27   -8.30  CaCO3
  Arsenolite       -77.81    -80.57   -2.76  As4O6
  Artinite          -3.65      5.95    9.60  MgCO3:Mg(OH)2:3H2O
  As2O5            -36.34    -29.64    6.71  As2O5
  Atacamite         -3.02      4.37    7.39  Cu2(OH)3Cl
  Azurite           -1.16    -18.07  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O     -14.35     10.05   24.39  Ba(OH)2:8H2O
  Ba2V2O7:2H2O     -12.53      3.34   15.87  Ba2V2O7:2H2O
  Ba3(AsO4)2         9.42      0.51   -8.91  Ba3(AsO4)2
  Ba3(VO4)2:4H2O   -19.55     13.39   32.94  Ba3(VO4)2:4H2O
  BaCrO4           -10.32    -19.99   -9.67  BaCrO4
  BaF2              -9.09    -14.91   -5.82  BaF2
  BaMoO4            -6.31    -13.27   -6.96  BaMoO4
  Barite             0.95     -9.03   -9.98  BaSO4
  BaSeO3            -6.83     -5.00    1.83  BaSeO3
  BaSeO4            -9.63    -17.09   -7.46  BaSeO4
  Bianchite         -7.36     -9.13   -1.76  ZnSO4:6H2O
  Birnessite        -9.26      8.83   18.09  MnO2
  Bixbyite          -5.92     -6.57   -0.64  Mn2O3
  Boehmite           0.41      8.99    8.58  AlOOH
  Brochantite       -3.51     11.72   15.22  Cu4(OH)6SO4
  Brucite           -3.58     13.27   16.84  Mg(OH)2
  Bunsenite         -3.94      8.50   12.45  NiO
  Ca(VO3)2          -9.10     -3.44    5.66  Ca(VO3)2
  Ca2V2O7           -7.63      9.87   17.50  Ca2V2O7
  Ca2V2O7:2H2O     -11.68      9.87   21.55  Ca2V2O7:2H2O
  Ca3(AsO4)2:4H2O  -12.00     10.30   22.30  Ca3(AsO4)2:4H2O
  Ca3(VO4)2        -15.77     23.19   38.96  Ca3(VO4)2
  Ca3(VO4)2:4H2O   -16.67     23.19   39.86  Ca3(VO4)2:4H2O
  CaCrO4           -14.46    -16.73   -2.27  CaCrO4
  Calcite            1.21     -7.27   -8.48  CaCO3
  CaMoO4            -2.06    -10.01   -7.95  CaMoO4
  Carnotite         -4.64     -4.41    0.23  KUO2VO4
  CaSeO3:2H2O       -4.55     -1.74    2.81  CaSeO3:2H2O
  CaSeO4:2H2O      -10.80    -13.82   -3.02  CaSeO4:2H2O
  Cd(BO2)2         -11.26     -1.42    9.84  Cd(BO2)2
  Cd(OH)2           -5.20      8.44   13.64  Cd(OH)2
  Cd(OH)2(am)       -5.29      8.44   13.73  Cd(OH)2
  Cd3(OH)2(SO4)2   -19.54    -12.83    6.71  Cd3(OH)2(SO4)2
  Cd3(OH)4SO4      -16.32      6.24   22.56  Cd3(OH)4SO4
  Cd4(OH)6SO4      -13.72     14.68   28.40  Cd4(OH)6SO4
  CdCl2            -12.95    -13.61   -0.66  CdCl2
  CdCl2:1H2O       -11.92    -13.61   -1.69  CdCl2:1H2O
  CdCl2:2.5H2O     -11.70    -13.61   -1.91  CdCl2:2.5H2O
  CdF2             -15.31    -16.52   -1.21  CdF2
  Cdmetal(alpha)   -29.30    -15.78   13.51  Cd
  Cdmetal(gamma)   -29.40    -15.78   13.62  Cd
  CdMoO4            -0.73    -14.88  -14.15  CdMoO4
  CdOHCl            -6.12     -2.59    3.54  CdOHCl
  CdSe             -14.22    -34.42  -20.20  CdSe
  CdSeO4:2H2O      -16.85    -18.70   -1.85  CdSeO4:2H2O
  CdSO4            -10.46    -10.63   -0.17  CdSO4
  CdSO4:1H2O        -8.91    -10.63   -1.73  CdSO4:1H2O
  CdSO4:2.67H2O     -8.76    -10.64   -1.87  CdSO4:2.67H2O
  Cerussite         -0.21    -13.34  -13.13  PbCO3
  CH4(g)           -76.43   -117.48  -41.05  CH4
  Chalcanthite      -8.74    -11.38   -2.64  CuSO4:5H2O
  Claudetite       -77.51    -80.57   -3.06  As4O6
  Clausthalite      -8.52    -35.62  -27.10  PbSe
  Co(BO2)2         -28.50     -1.43   27.07  Co(BO2)2
  Co(OH)2           -4.67      8.43   13.09  Co(OH)2
  Co(OH)3           -9.55    -11.86   -2.31  Co(OH)3
  CO2(g)            -2.43    -20.58  -18.15  CO2
  Co3(AsO4)2       -17.39     -4.35   13.03  Co3(AsO4)2
  Co3O4             -4.80    -15.29  -10.50  Co3O4
  CoCl2            -21.89    -13.62    8.27  CoCl2
  CoCl2:6H2O       -16.16    -13.62    2.54  CoCl2:6H2O
  CoCO3             -2.17    -12.15   -9.98  CoCO3
  CoF2             -14.93    -16.53   -1.60  CoF2
  CoF3             -47.84    -49.30   -1.46  CoF3
  CoFe2O4           25.44     21.91   -3.53  CoFe2O4
  CoMoO4            -7.13    -14.89   -7.76  CoMoO4
  CoO               -5.16      8.43   13.59  CoO
  CoSe             -18.24    -34.44  -16.20  CoSe
  CoSeO3            -7.95     -6.63    1.32  CoSeO3
  CoSeO4:6H2O      -17.18    -18.71   -1.53  CoSeO4:6H2O
  CoSO4            -13.45    -10.65    2.80  CoSO4
  CoSO4:6H2O        -8.17    -10.65   -2.47  CoSO4:6H2O
  Cotunnite        -10.03    -14.81   -4.78  PbCl2
  Cr(OH)2          -18.98     -8.17   10.82  Cr(OH)2
  Cr(OH)3           -0.34      1.00    1.34  Cr(OH)3
  Cr(OH)3(am)        1.75      1.00   -0.75  Cr(OH)3
  Cr2O3              4.36      2.00   -2.36  Cr2O3
  CrCl2            -44.31    -30.21   14.09  CrCl2
  CrCl3            -47.19    -32.07   15.11  CrCl3
  CrF3             -25.10    -36.44  -11.34  CrF3
  Crmetal          -62.87    -32.39   30.48  Cr
  CrO3             -26.83    -30.04   -3.21  CrO3
  Cryolite         -13.95    -47.79  -33.84  Na3AlF6
  Cu(OH)2           -0.98      7.70    8.67  Cu(OH)2
  Cu2Se(alpha)      -0.51    -46.31  -45.80  Cu2Se
  Cu2SO4           -20.57    -22.52   -1.95  Cu2SO4
  Cu3(AsO4)2:2H2O  -12.64     -6.54    6.10  Cu3(AsO4)2:2H2O
  Cu3Se2           -17.99    -81.48  -63.49  Cu3Se2
  CuCO3             -1.38    -12.88  -11.50  CuCO3
  CuCrO4           -16.90    -22.34   -5.44  CuCrO4
  CuF               -9.30    -14.20   -4.91  CuF
  CuF2             -18.38    -17.26    1.12  CuF2
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CuF2:2H2O	-12.71	-17.26	-4.55	CuF2:2H2O
Cumetal	-5.08	-13.84	-8.76	Cu
CuMoO4	-2.55	-15.62	-13.08	CuMoO4
CuOCuSO4	-13.98	-3.68	10.30	CuOCuSO4
Cupricferrite	15.19	21.18	5.99	CuFe2O4
Cuprite	-2.04	-3.45	-1.41	Cu2O
Cuprousferrite	13.93	5.02	-8.92	CuFeO2
CuSe	-2.07	-35.17	-33.10	CuSe
CuSe2	-20.44	-53.81	-33.37	CuSe2
CuSeO3:2H2O	-7.87	-7.36	0.51	CuSeO3:2H2O
CuSeO4:5H2O	-17.00	-19.44	-2.44	CuSeO4:5H2O
CuSO4	-14.32	-11.38	2.94	CuSO4
Diaspore	2.11	8.99	6.87	AlOOH
Dolomite(disordered)	1.96	-14.58	-16.54	CaMg(CO3)2
Dolomite(ordered)	2.51	-14.58	-17.09	CaMg(CO3)2
Epsomite	-3.68	-5.81	-2.13	MgSO4:7H2O
Fe(OH)2	-5.90	7.66	13.56	Fe(OH)2
Fe(OH)2.7Cl.3	6.47	3.43	-3.04	Fe(OH)2.7Cl.3
Fe(VO3)2	-5.37	-9.09	-3.72	Fe(VO3)2
Fe2(OH)4SeO3	-3.12	-1.57	1.55	Fe2(OH)4SeO3
Fe2(SeO3)3:2H2O	-11.05	-31.68	-20.63	Fe2(SeO3)3:2H2O
Fe2(SO4)3	-40.01	-43.74	-3.73	Fe2(SO4)3
Fe3(OH)8	0.92	21.14	20.22	Fe3(OH)8
FeAsO4:2H2O	-8.48	-8.08	0.40	FeAsO4:2H2O
FeCr2O4	2.46	9.66	7.20	FeCr2O4
FeMoO4	-5.57	-15.66	-10.09	FeMoO4
Ferrihydrite	3.55	6.74	3.19	Fe(OH)3
Ferroselite	-35.25	-53.84	-18.60	FeSe2
FeSe	-24.20	-35.20	-11.00	FeSe
Fluorite	-1.14	-11.64	-10.50	CaF2
Gibbsite	0.69	8.99	8.29	Al(OH)3
Goethite	6.25	6.74	0.49	FeOOH
Goslarite	-7.12	-9.13	-2.01	ZnSO4:7H2O
Gummite	-8.70	-1.03	7.67	UO3
Gypsum	-1.15	-5.76	-4.61	CaSO4:2H2O
H-Jarosite	-5.83	-17.93	-12.10	(H3O)Fe3(SO4)2(OH)6
H2MoO4	-10.45	-23.32	-12.88	H2MoO4
H2Se(g)	-37.90	-42.86	-4.96	H2Se
Halite	-6.59	-4.99	1.60	NaCl
Hausmannite	-6.94	54.09	61.03	Mn3O4
Hematite	14.90	13.48	-1.42	Fe2O3
Hercynite	2.74	25.63	22.89	FeAl2O4
Huntite	0.76	-29.20	-29.97	CaMg3(CO3)4
Hydrocerussite	-0.67	-19.44	-18.77	Pb3(OH)2(CO3)2
Hydromagnesite	-7.22	-15.99	-8.77	Mg5(CO3)4(OH)2:4H2O
K-Alum	-19.00	-24.17	-5.17	KAl(SO4)2:12H2O
K-Jarosite	1.88	-12.92	-14.80	KFe3(SO4)2(OH)6
K2Cr2O7	-32.84	-50.08	-17.24	K2Cr2O7
K2CrO4	-19.53	-20.04	-0.51	K2CrO4
K2MoO4	-16.58	-13.32	3.26	K2MoO4
K2SeO4	-16.41	-17.14	-0.73	K2SeO4
Langite	-5.77	11.72	17.49	Cu4(OH)6SO4:H2O
Larnakite	-4.16	-4.59	-0.43	PbO:PbSO4
Laurionite	-4.41	-3.78	0.62	PbOHCl
Lepidocrocite	5.37	6.74	1.37	FeOOH
Lime	-19.39	13.31	32.70	CaO
Litharge	-5.45	7.24	12.69	PbO
Maghemite	7.10	13.48	6.39	Fe2O3
Magnesioferrite	9.89	26.75	16.86	Fe2MgO4
Magnesite	0.15	-7.31	-7.46	MgCO3
Magnetite	17.74	21.14	3.40	Fe3O4
Malachite	0.12	-5.18	-5.31	Cu2(OH)2CO3
Manganite	-3.27	22.07	25.34	MnOOH
Massicot	-5.65	7.24	12.89	PbO
Matlockite	-7.29	-16.26	-8.97	PbClF
Melanothallite	-20.61	-14.35	6.26	CuCl2

Melanterite	-9.21	-11.41	-2.21	FeSO4:7H2O
Mg(OH)2(active)	-5.53	13.27	18.79	Mg(OH)2
Mg(VO3)2	-14.77	-3.49	11.28	Mg(VO3)2
Mg2V2O7	-16.58	9.78	26.36	Mg2V2O7
MgCr2O4	-0.93	15.27	16.20	MgCr2O4
MgCrO4	-22.15	-16.77	5.38	MgCrO4
MgF2	-3.56	-11.69	-8.13	MgF2
MgMoO4	-8.21	-10.06	-1.85	MgMoO4
MgSeO3:6H2O	-4.84	-1.79	3.06	MgSeO3:6H2O
MgSeO4:6H2O	-12.67	-13.87	-1.20	MgSeO4:6H2O
Minium	-27.57	45.95	73.52	Pb3O4
Mirabilite	-5.90	-7.01	-1.11	Na2SO4:10H2O
Mn(VO3)2	-11.70	-6.80	4.90	Mn(VO3)2
Mn2(SO4)3	-58.08	-63.79	-5.71	Mn2(SO4)3
Mn3(AsO4)2:8H2O	-12.27	0.23	12.50	Mn3(AsO4)2:8H2O
MnCl2:4H2O	-14.81	-12.09	2.72	MnCl2:4H2O
MnSe	-36.41	-32.91	3.50	MnSe
MnSeO3	-6.23	-5.10	1.13	MnSeO3
MnSeO3:2H2O	-6.08	-5.10	0.98	MnSeO3:2H2O
MnSeO4:5H2O	-15.13	-17.18	-2.05	MnSeO4:5H2O
MnSO4	-11.70	-9.12	2.58	MnSO4
Monteponite	-6.66	8.44	15.10	CdO
MoO3	-15.32	-23.32	-8.00	MoO3
Morenosite	-8.43	-10.57	-2.14	NiSO4:7H2O
Na-Jarosite	-0.69	-11.89	-11.20	NaFe3(SO4)2(OH)6
Na2Cr2O7	-38.12	-48.02	-9.90	Na2Cr2O7
Na2CrO4	-20.91	-17.98	2.93	Na2CrO4
Na2Mo2O7	-17.98	-34.58	-16.60	Na2Mo2O7
Na2MoO4	-12.75	-11.26	1.49	Na2MoO4
Na2MoO4:2H2O	-12.48	-11.26	1.22	Na2MoO4:2H2O
Na2SeO3:5H2O	-13.29	-2.99	10.30	Na2SeO3:5H2O
Na2SeO4	-16.35	-15.07	1.28	Na2SeO4
Na3VO4	-26.96	9.72	36.68	Na3VO4
Na4V2O7	-30.02	7.38	37.40	Na4V2O7
Nantokite	-6.02	-12.75	-6.73	CuCl
Natron	-7.21	-8.52	-1.31	Na2CO3:10H2O
NaVO3	-6.20	-2.34	3.86	NaVO3
Nesquehonite	-2.64	-7.31	-4.67	MgCO3:3H2O
Ni(OH)2	-4.29	8.50	12.79	Ni(OH)2
Ni3(AsO4)2:8H2O	-19.83	-4.13	15.70	Ni3(AsO4)2:8H2O
Ni4(OH)6SO4	-17.06	14.94	32.00	Ni4(OH)6SO4
NiCO3	-5.21	-12.08	-6.87	NiCO3
NiMoO4	-3.68	-14.82	-11.14	NiMoO4
NiSe	-16.66	-34.36	-17.70	NiSe
NiSeO3:2H2O	-9.37	-6.55	2.81	NiSeO3:2H2O
NiSeO4:6H2O	-17.12	-18.64	-1.52	NiSeO4:6H2O
Nsutite	-8.67	8.83	17.50	MnO2
O2(g)	-34.64	48.45	83.09	O2
Otavite	-0.14	-12.14	-12.00	CdCO3
Pb(BO2)2	-9.14	-2.62	6.52	Pb(BO2)2
Pb(OH)2	-0.91	7.24	8.15	Pb(OH)2
Pb10(OH)6O(CO3)6	-42.31	-51.07	-8.76	Pb10(OH)6O(CO3)6
Pb2(OH)3Cl	-5.34	3.46	8.79	Pb2(OH)3Cl
Pb2O(OH)2	-11.71	14.48	26.19	Pb2O(OH)2
Pb2O3	-22.33	38.71	61.04	Pb2O3
Pb2OCO3	-5.54	-6.10	-0.56	Pb2OCO3
Pb2V2O7	-0.37	-2.27	-1.90	Pb2V2O7
Pb3(AsO4)2	-13.71	-7.91	5.80	Pb3(AsO4)2
Pb3(VO4)2	-1.17	4.97	6.14	Pb3(VO4)2
Pb3O2CO3	-9.88	1.14	11.02	Pb3O2CO3
Pb3O2SO4	-8.04	2.65	10.69	Pb3O2SO4
Pb4(OH)6SO4	-11.21	9.89	21.10	Pb4(OH)6SO4
Pb4O3SO4	-11.99	9.89	21.88	Pb4O3SO4
PbCrO4	-10.20	-22.80	-12.60	PbCrO4
PbF2	-10.28	-17.72	-7.44	PbF2
Pbmetal	-21.23	-16.98	4.25	Pb

PbMoO4	-0.46	-16.08	-15.62	PbMoO4
PbO:0.3H2O	-5.74	7.24	12.98	PbO:0.33H2O
PbSeO4	-13.06	-19.90	-6.84	PbSeO4
Periclase	-8.32	13.27	21.58	MgO
Phosgenite	-8.34	-28.15	-19.81	PbCl2:PbCO3
Plattnerite	-18.14	31.46	49.60	PbO2
Portlandite	-9.49	13.31	22.80	Ca(OH)2
Pyrochroite	-5.24	9.96	15.19	Mn(OH)2
Pyrolusite	-7.20	34.18	41.38	MnO2
Retgersite	-8.53	-10.57	-2.04	NiSO4:6H2O
Rhodochrosite	-0.04	-10.62	-10.58	MnCO3
Rutherfordine	-7.11	-21.61	-14.50	UO2CO3
Schoepite	-7.03	-1.03	5.99	UO2(OH)2:H2O
Semetal(am)	-11.53	-18.64	-7.11	Se
Semetal(hex	-10.93	-18.64	-7.71	Se
SeO2	-15.18	-15.05	0.12	SeO2
SeO3	-48.18	-27.14	21.04	SeO3
Siderite	-2.68	-12.92	-10.24	FeCO3
Smithsonite	-0.63	-10.63	-10.00	ZnCO3
Spinel	-5.61	31.24	36.85	MgAl2O4
Tenorite	0.05	7.70	7.64	CuO
Thenardite	-7.33	-7.01	0.32	Na2SO4
Thermonatrite	-9.15	-8.52	0.64	Na2CO3:H2O
Tyuyamunite	-9.58	-5.50	4.08	Ca(UO2)2(VO4)2
U3O8	-20.75	0.33	21.08	U3O8
U4O9	-36.91	-39.93	-3.02	U4O9
UF4	-36.42	-65.96	-29.54	UF4
UF4:2.5H2O	-33.24	-65.96	-32.72	UF4:2.5H2O
UO2(am)	-16.97	-16.04	0.93	UO2
UO2(OH)2(beta)	-6.64	-1.03	5.61	UO2(OH)2
UO2SeO4:4H2O	-25.92	-28.17	-2.25	UO2SeO4:4H2O
UO3	-8.73	-1.03	7.70	UO3
Uraninite	-11.37	-16.04	-4.67	UO2
V(OH)3	-17.59	-10.00	7.59	V(OH)3
V2O5	-15.39	-16.75	-1.36	V2O5
V3O5	-36.82	-34.98	1.84	V3O5
V4O7	-45.75	-38.56	7.19	V4O7
V6O13	-37.85	-98.71	-60.86	V6O13
VCl2	-63.04	-44.16	18.87	VCl2
VCl3	-66.51	-43.07	23.43	VCl3
VF4	-68.43	-53.50	14.93	VF4
Vmetal	-90.36	-46.34	44.03	V
VO	-36.87	-22.11	14.76	VO
VO(OH)2	-8.74	-3.59	5.15	VO(OH)2
VO2Cl	-22.24	-19.40	2.84	VO2Cl
VOCl	-32.18	-21.03	11.15	VOCl
VOCl2	-38.39	-25.63	12.76	VOCl2
VOSO4	-26.27	-22.66	3.61	VOSO4
Witherite	-1.96	-10.53	-8.57	BaCO3
Zincite	-1.39	9.95	11.33	ZnO
Zincosite	-13.06	-9.13	3.93	ZnSO4
Zn(BO2)2	-8.20	0.09	8.29	Zn(BO2)2
Zn(OH)2	-2.25	9.95	12.20	Zn(OH)2
Zn(OH)2(am)	-2.53	9.95	12.47	Zn(OH)2
Zn(OH)2(beta)	-1.81	9.95	11.75	Zn(OH)2
Zn(OH)2(epsilon)	-1.59	9.95	11.53	Zn(OH)2
Zn(OH)2(gamma)	-1.79	9.95	11.73	Zn(OH)2
Zn2(OH)2SO4	-6.68	0.82	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-6.32	8.87	15.19	Zn2(OH)3Cl
Zn3(AsO4)2:2.5H2O	-13.44	0.21	13.65	Zn3(AsO4)2:2.5H2O
Zn3O(SO4)2	-27.22	-8.31	18.91	Zn3O(SO4)2
Zn4(OH)6SO4	-7.69	20.71	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-10.81	27.69	38.50	Zn5(OH)8Cl2
ZnCl2	-19.15	-12.10	7.05	ZnCl2
ZnCO3:1H2O	-0.37	-10.63	-10.26	ZnCO3:1H2O
ZnF2	-14.48	-15.01	-0.53	ZnF2

Znmetal	-40.07	-14.28	25.79	Zn
ZnMoO4	-3.25	-13.37	-10.13	ZnMoO4
ZnO(active)	-1.24	9.95	11.19	ZnO
ZnSe	-18.52	-32.92	-14.40	ZnSe
ZnSeO4:6H2O	-15.67	-17.19	-1.52	ZnSeO4:6H2O
ZnSO4:1H2O	-8.49	-9.13	-0.64	ZnSO4:1H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

Initial solution 2. PAF Material

----------Solution composition----------

Elements	Molality	Moles
Al	7.415e-07	7.415e-07
Alkalinity	3.607e-04	3.607e-04
Ba	1.457e-07	1.457e-07
Ca	1.672e-03	1.672e-03
Co	1.188e-07	1.188e-07
Cu	4.408e-07	4.408e-07
F	1.580e-05	1.580e-05
K	3.326e-04	3.326e-04
Mg	3.293e-04	3.293e-04
Mn	7.283e-07	7.283e-07
Mo	3.128e-08	3.128e-08
Na	4.351e-05	4.351e-05
Ni	6.818e-08	6.818e-08
S(6)	2.051e-03	2.051e-03

----------Description of solution----------

```
                                    pH  =   7.500
                                    pe  =   4.000
                       Activity of water  =   1.000
                  Ionic strength (mol/kgw)  =   7.200e-03
                        Mass of water (kg)  =   1.000e+00
                     Total carbon (mol/kg)  =   3.782e-04
                        Total CO2 (mol/kg)  =   3.782e-04
                          Temperature (°C)  =  25.00
                   Electrical balance (eq)  =  -9.478e-05
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  -1.25
                                Iterations  =  13 (24 overall)
                                   Total H  = 1.110141e+02
                                   Total O  = 5.551618e+01
```

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
OH-	3.487e-07	3.184e-07	-6.458	-6.497	-0.039	(0)
H+	3.458e-08	3.162e-08	-7.461	-7.500	-0.039	0.00
H2O	5.551e+01	9.999e-01	1.744	-0.000	0.000	18.07
Al	7.415e-07					
Al(OH)4-	7.221e-07	6.609e-07	-6.141	-6.180	-0.038	(0)
Al(OH)3	1.649e-08	1.649e-08	-7.783	-7.783	0.000	(0)
Al(OH)2+	2.830e-09	2.595e-09	-8.548	-8.586	-0.038	(0)
AlF2+	2.736e-11	2.509e-11	-10.563	-10.600	-0.038	(0)
AlOH+2	1.451e-11	1.026e-11	-10.838	-10.989	-0.150	(0)
AlF+2	6.374e-12	4.507e-12	-11.196	-11.346	-0.150	(0)
AlF3	4.418e-12	4.418e-12	-11.355	-11.355	0.000	(0)
AlSO4+	3.315e-13	3.034e-13	-12.480	-12.518	-0.038	(0)
Al+3	7.201e-14	3.223e-14	-13.143	-13.492	-0.349	(0)
AlF4-	3.383e-14	3.096e-14	-13.471	-13.509	-0.038	(0)

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   Al(SO4)2-       4.307e-15   3.942e-15   -14.366   -14.404    -0.038     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -49.070   -49.460    -0.390     (0)
Ba            1.457e-07
   Ba+2            1.453e-07   1.017e-07    -6.838    -6.993    -0.155     (0)
   BaHCO3+         3.363e-10   3.088e-10    -9.473    -9.510    -0.037     (0)
   BaCO3           2.459e-11   2.459e-11   -10.609   -10.609     0.000     (0)
   BaOH+           1.542e-13   1.413e-13   -12.812   -12.850    -0.038     (0)
C(4)          3.782e-04
   HCO3-           3.469e-04   3.181e-04    -3.460    -3.497    -0.038     (0)
   H2CO3           2.262e-05   2.262e-05    -4.645    -4.645     0.000     (0)
   CaHCO3+         6.292e-06   5.777e-06    -5.201    -5.238    -0.037     (0)
   CaCO3           7.289e-07   7.289e-07    -6.137    -6.137     0.000     (0)
   MgHCO3+         7.079e-07   6.472e-07    -6.150    -6.189    -0.039     (0)
   CO3-2           6.741e-07   4.716e-07    -6.171    -6.326    -0.155     (0)
   CuCO3           2.133e-07   2.133e-07    -6.671    -6.671     0.000     (0)
   MgCO3           7.799e-08   7.799e-08    -7.108    -7.108     0.000     (0)
   NaHCO3          7.071e-09   7.071e-09    -8.151    -8.151     0.000     (0)
   MnHCO3+         2.944e-09   2.697e-09    -8.531    -8.569    -0.038     (0)
   CoHCO3+         1.830e-09   1.657e-09    -8.738    -8.781    -0.043     (0)
   CuHCO3+         1.703e-09   1.542e-09    -8.769    -8.812    -0.043     (0)
   NiHCO3+         1.700e-09   1.539e-09    -8.770    -8.813    -0.043     (0)
   NiCO3           6.904e-10   6.904e-10    -9.161    -9.161     0.000     (0)
   CoCO3           5.337e-10   5.337e-10    -9.273    -9.273     0.000     (0)
   Cu(CO3)2-2      4.033e-10   2.707e-10    -9.394    -9.567    -0.173     (0)
   NaCO3-          3.785e-10   3.471e-10    -9.422    -9.460    -0.038     (0)
   BaHCO3+         3.363e-10   3.088e-10    -9.473    -9.510    -0.037     (0)
   BaCO3           2.459e-11   2.459e-11   -10.609   -10.609     0.000     (0)
Ca            1.672e-03
   Ca+2            1.394e-03   9.753e-04    -2.856    -3.011    -0.155     (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000     (0)
   CaHCO3+         6.292e-06   5.777e-06    -5.201    -5.238    -0.037     (0)
   CaCO3           7.289e-07   7.289e-07    -6.137    -6.137     0.000     (0)
   CaF+            1.625e-07   1.489e-07    -6.789    -6.827    -0.038     (0)
   CaOH+           6.748e-09   6.196e-09    -8.171    -8.208    -0.037     (0)
Co(2)         1.188e-07
   Co+2            9.974e-08   6.695e-08    -7.001    -7.174    -0.173     (0)
   CoSO4           1.620e-08   1.620e-08    -7.791    -7.791     0.000     (0)
   CoHCO3+         1.830e-09   1.657e-09    -8.738    -8.781    -0.043     (0)
   CoCO3           5.337e-10   5.337e-10    -9.273    -9.273     0.000     (0)
   CoOH+           4.699e-10   4.253e-10    -9.328    -9.371    -0.043     (0)
   CoF+            3.271e-11   2.961e-11   -10.485   -10.529    -0.043     (0)
   Co(OH)2         1.076e-11   1.076e-11   -10.968   -10.968     0.000     (0)
   Co(OH)3-        7.550e-17   6.834e-17   -16.122   -16.165    -0.043     (0)
   CoOOH-          1.894e-17   1.715e-17   -16.723   -16.766    -0.043     (0)
   Co2OH+3         3.499e-18   1.427e-18   -17.456   -17.846    -0.390     (0)
   Co(OH)4-2       5.137e-24   3.448e-24   -23.289   -23.462    -0.173     (0)
   Co4(OH)4+4      3.216e-29   6.530e-30   -28.493   -29.185    -0.692     (0)
Co(3)         6.424e-30
   CoOH+2          6.424e-30   4.312e-30   -29.192   -29.365    -0.173     (0)
   Co+3            5.955e-36   2.665e-36   -35.225   -35.574    -0.349     (0)
Cu(1)         4.157e-09
   Cu+             4.157e-09   3.762e-09    -8.381    -8.425    -0.043     (0)
Cu(2)         4.366e-07
   CuCO3           2.133e-07   2.133e-07    -6.671    -6.671     0.000     (0)
   Cu+2            1.098e-07   7.682e-08    -6.959    -7.115    -0.155     (0)
   CuOH+           8.460e-08   7.735e-08    -7.073    -7.112    -0.039     (0)
   CuSO4           2.134e-08   2.134e-08    -7.671    -7.671     0.000     (0)
   Cu(OH)2         4.914e-09   4.914e-09    -8.309    -8.309     0.000     (0)
   CuHCO3+         1.703e-09   1.542e-09    -8.769    -8.812    -0.043     (0)
   Cu(CO3)2-2      4.033e-10   2.707e-10    -9.394    -9.567    -0.173     (0)
   Cu2(OH)2+2      2.239e-10   1.503e-10    -9.650    -9.823    -0.173     (0)
   CuF+            7.488e-11   6.778e-11   -10.126   -10.169    -0.043     (0)
   Cu(OH)3-        3.545e-12   3.209e-12   -11.450   -11.494    -0.043     (0)
   Cu(OH)4-2       1.198e-17   8.042e-18   -16.922   -17.095    -0.173     (0)
F             1.580e-05
   F-              1.529e-05   1.398e-05    -4.816    -4.854    -0.039     (0)
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   MgF+            3.409e-07   3.120e-07    -6.467    -6.506    -0.038     (0)
   CaF+            1.625e-07   1.489e-07    -6.789    -6.827    -0.038     (0)
   HF              6.541e-10   6.541e-10    -9.184    -9.184     0.000     (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000     (0)
   MnF+            2.582e-10   2.366e-10    -9.588    -9.626    -0.038     (0)
   CuF+            7.488e-11   6.778e-11   -10.126   -10.169    -0.043     (0)
   CoF+            3.271e-11   2.961e-11   -10.485   -10.529    -0.043     (0)
   AlF2+           2.736e-11   2.509e-11   -10.563   -10.600    -0.038     (0)
   NiF+            1.523e-11   1.379e-11   -10.817   -10.861    -0.043     (0)
   AlF+2           6.374e-12   4.507e-12   -11.196   -11.346    -0.150     (0)
   AlF3            4.418e-12   4.418e-12   -11.355   -11.355     0.000     (0)
   HF2-            3.808e-14   3.478e-14   -13.419   -13.459    -0.039     (0)
   AlF4-           3.383e-14   3.096e-14   -13.471   -13.509    -0.038     (0)
   H2F2            1.146e-18   1.146e-18   -17.941   -17.941     0.000     (0)
H(0)          1.414e-26
   H2              7.068e-27   7.079e-27   -26.151   -26.150     0.001     (0)
K             3.326e-04
   K+              3.298e-04   3.016e-04    -3.482    -3.521    -0.039     (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038     (0)
Mg            3.293e-04
   Mg+2            2.842e-04   1.988e-04    -3.546    -3.702    -0.155     (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000     (0)
   MgHCO3+         7.079e-07   6.472e-07    -6.150    -6.189    -0.039     (0)
   MgF+            3.409e-07   3.120e-07    -6.467    -6.506    -0.038     (0)
   MgCO3           7.799e-08   7.799e-08    -7.108    -7.108     0.000     (0)
   MgOH+           2.742e-08   2.520e-08    -7.562    -7.599    -0.037     (0)
Mn(2)         7.283e-07
   Mn+2            6.331e-07   4.250e-07    -6.199    -6.372    -0.173     (0)
   MnSO4           9.164e-08   9.164e-08    -7.038    -7.038     0.000     (0)
   MnHCO3+         2.944e-09   2.697e-09    -8.531    -8.569    -0.038     (0)
   MnOH+           3.710e-10   3.399e-10    -9.431    -9.469    -0.038     (0)
   MnF+            2.582e-10   2.366e-10    -9.588    -9.626    -0.038     (0)
   Mn(OH)3-        2.324e-19   2.129e-19   -18.634   -18.672    -0.038     (0)
   Mn(OH)4-2       3.106e-25   2.189e-25   -24.508   -24.660    -0.152     (0)
Mn(3)         4.241e-28
   Mn+3            4.241e-28   1.898e-28   -27.373   -27.722    -0.349     (0)
Mn(6)         0.000e+00
   MnO4-2          0.000e+00   0.000e+00   -48.642   -48.794    -0.152     (0)
Mn(7)         0.000e+00
   MnO4-           0.000e+00   0.000e+00   -54.126   -54.166    -0.040     (0)
Mo            3.128e-08
   MoO4-2          3.126e-08   2.187e-08    -7.505    -7.660    -0.155     (0)
   HMoO4-          1.520e-11   1.376e-11   -10.818   -10.861    -0.043     (0)
   H2MoO4          3.188e-15   3.188e-15   -14.497   -14.497     0.000     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -49.070   -49.460    -0.390     (0)
   Mo7O24-6        0.000e+00   0.000e+00   -59.073   -60.631    -1.558     (0)
   HMo7O24-5       0.000e+00   0.000e+00   -60.662   -61.744    -1.082     (0)
   H2Mo7O24-4      0.000e+00   0.000e+00   -63.769   -64.462    -0.692     (0)
   H3Mo7O24-3      0.000e+00   0.000e+00   -68.326   -68.716    -0.390     (0)
Na            4.351e-05
   Na+             4.322e-05   3.953e-05    -4.364    -4.403    -0.039     (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   NaHCO3          7.071e-09   7.071e-09    -8.151    -8.151     0.000     (0)
   NaCO3-          3.785e-10   3.471e-10    -9.422    -9.460    -0.038     (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000     (0)
Ni            6.818e-08
   Ni+2            5.610e-08   3.924e-08    -7.251    -7.406    -0.155     (0)
   NiSO4           9.495e-09   9.495e-09    -8.023    -8.023     0.000     (0)
   NiHCO3+         1.700e-09   1.539e-09    -8.770    -8.813    -0.043     (0)
   NiCO3           6.904e-10   6.904e-10    -9.161    -9.161     0.000     (0)
   NiOH+           1.738e-10   1.573e-10    -9.760    -9.803    -0.043     (0)
   NiF+            1.523e-11   1.379e-11   -10.817   -10.861    -0.043     (0)
   Ni(OH)2         3.978e-12   3.978e-12   -11.400   -11.400     0.000     (0)
   Ni(SO4)2-2      5.679e-13   3.812e-13   -12.246   -12.419    -0.173     (0)
   Ni(OH)3-        1.399e-15   1.267e-15   -14.854   -14.897    -0.043     (0)
O(0)          2.019e-40
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   O2              1.010e-40   1.011e-40   -39.996   -39.995     0.001     (0)
S(6)          2.051e-03
   SO4-2           1.733e-03   1.213e-03    -2.761    -2.916    -0.155     (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000     (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000     (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038     (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   MnSO4           9.164e-08   9.164e-08    -7.038    -7.038     0.000     (0)
   CuSO4           2.134e-08   2.134e-08    -7.671    -7.671     0.000     (0)
   CoSO4           1.620e-08   1.620e-08    -7.791    -7.791     0.000     (0)
   NiSO4           9.495e-09   9.495e-09    -8.023    -8.023     0.000     (0)
   HSO4-           4.094e-09   3.747e-09    -8.388    -8.426    -0.038     (0)
   Ni(SO4)2-2      5.679e-13   3.812e-13   -12.246   -12.419    -0.173     (0)
   AlSO4+          3.315e-13   3.034e-13   -12.480   -12.518    -0.038     (0)
   Al(SO4)2-       4.307e-15   3.942e-15   -14.366   -14.404    -0.038     (0)

----------------------------Saturation indices----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.79      9.01   10.80  Al(OH)3
  Al2(MoO4)3      -52.33    -49.96    2.37  Al2(MoO4)3
  Al2O3            -1.64     18.02   19.65  Al2O3
  Al4(OH)10SO4     -4.58     18.12   22.70  Al4(OH)10SO4
  AlOHSO4          -5.68     -8.91   -3.23  AlOHSO4
  Alunite          -3.43     -4.83   -1.40  KAl3(SO4)2(OH)6
  Anhydrite        -1.57     -5.93   -4.36  CaSO4
  Antlerite        -3.05      5.74    8.79  Cu3(OH)4SO4
  Aragonite        -1.04     -9.34   -8.30  CaCO3
  Artinite         -8.33      1.27    9.60  MgCO3:Mg(OH)2:3H2O
  Azurite          -2.09    -19.00  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -16.39      8.01   24.39  Ba(OH)2:8H2O
  BaF2            -10.88    -16.70   -5.82  BaF2
  BaMoO4           -7.69    -14.65   -6.96  BaMoO4
  Barite            0.07     -9.91   -9.98  BaSO4
  Birnessite      -11.81      6.28   18.09  MnO2
  Bixbyite         -9.80    -10.44   -0.64  Mn2O3
  Boehmite          0.43      9.01    8.58  AlOOH
  Brochantite      -1.60     13.63   15.22  Cu4(OH)6SO4
  Brucite          -5.55     11.30   16.84  Mg(OH)2
  Bunsenite        -4.85      7.59   12.45  NiO
  Calcite          -0.86     -9.34   -8.48  CaCO3
  CaMoO4           -2.72    -10.67   -7.95  CaMoO4
  CH4(g)          -72.28   -113.33  -41.05  CH4
  Chalcanthite     -7.39    -10.03   -2.64  CuSO4:5H2O
  Co(OH)2          -5.27      7.83   13.09  Co(OH)2
  Co(OH)3         -10.77    -13.07   -2.31  Co(OH)3
  CO2(g)           -3.18    -21.33  -18.15  CO2
  Co3O4            -7.83    -18.32  -10.50  Co3O4
  CoCO3            -3.52    -13.50   -9.98  CoCO3
  CoF2            -15.29    -16.88   -1.60  CoF2
  CoF3            -48.68    -50.14   -1.46  CoF3
  CoMoO4           -7.07    -14.83   -7.76  CoMoO4
  CoO              -5.76      7.83   13.59  CoO
  CoSO4           -12.89    -10.09    2.80  CoSO4
  CoSO4:6H2O       -7.62    -10.09   -2.47  CoSO4:6H2O
  Cryolite        -21.99    -55.83  -33.84  Na3AlF6
  Cu(OH)2          -0.79      7.89    8.67  Cu(OH)2
  Cu2SO4          -17.82    -19.77   -1.95  Cu2SO4
  CuCO3            -1.94    -13.44  -11.50  CuCO3
  CuF              -8.37    -13.28   -4.91  CuF
  CuF2            -17.94    -16.82    1.12  CuF2
  CuF2:2H2O       -12.27    -16.82   -4.55  CuF2:2H2O
  Cumetal          -3.67    -12.42   -8.76  Cu
  CuMoO4           -1.70    -14.77  -13.08  CuMoO4
  CuOCuSO4        -12.45     -2.15   10.30  CuOCuSO4
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  Cuprite          -0.44     -1.85   -1.41  Cu2O
  CuSO4           -12.97    -10.03    2.94  CuSO4
  Diaspore          2.14      9.01    6.87  AlOOH
  Dolomite(disordered)  -2.83    -19.37  -16.54  CaMg(CO3)2
  Dolomite(ordered)  -2.28    -19.37  -17.09  CaMg(CO3)2
  Epsomite         -4.49     -6.62   -2.13  MgSO4:7H2O
  Fluorite         -2.22    -12.72  -10.50  CaF2
  Gibbsite          0.72      9.01    8.29  Al(OH)3
  Gypsum           -1.32     -5.93   -4.61  CaSO4:2H2O
  H2MoO4           -9.78    -22.66  -12.88  H2MoO4
  Hausmannite     -12.15     48.88   61.03  Mn3O4
  Huntite          -9.45    -39.42  -29.97  CaMg3(CO3)4
  Hydromagnesite  -20.05    -28.81   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum          -17.68    -22.85   -5.17  KAl(SO4)2:12H2O
  K2MoO4          -17.96    -14.70    3.26  K2MoO4
  Langite          -3.86     13.63   17.49  Cu4(OH)6SO4:H2O
  Lime            -20.71     11.99   32.70  CaO
  Magnesite        -2.57    -10.03   -7.46  MgCO3
  Malachite        -0.25     -5.56   -5.31  Cu2(OH)2CO3
  Manganite        -5.21     20.13   25.34  MnOOH
  Mg(OH)2(active)  -7.50     11.30   18.79  Mg(OH)2
  MgF2             -5.28    -13.41   -8.13  MgF2
  MgMoO4           -9.51    -11.36   -1.85  MgMoO4
  Mirabilite      -10.61    -11.72   -1.11  Na2SO4:10H2O
  Mn2(SO4)3       -58.48    -64.19   -5.71  Mn2(SO4)3
  MnSO4           -11.87     -9.29    2.58  MnSO4
  MoO3            -14.66    -22.66   -8.00  MoO3
  Morenosite       -8.18    -10.32   -2.14  NiSO4:7H2O
  Na2Mo2O7        -22.53    -39.13  -16.60  Na2Mo2O7
  Na2MoO4         -17.96    -16.47    1.49  Na2MoO4
  Na2MoO4:2H2O    -17.69    -16.47    1.22  Na2MoO4:2H2O
  Natron          -13.82    -15.13   -1.31  Na2CO3:10H2O
  Nesquehonite     -5.36    -10.03   -4.67  MgCO3:3H2O
  Ni(OH)2          -5.20      7.59   12.79  Ni(OH)2
  Ni4(OH)6SO4     -19.54     12.46   32.00  Ni4(OH)6SO4
  NiCO3            -6.86    -13.73   -6.87  NiCO3
  NiMoO4           -3.92    -15.07  -11.14  NiMoO4
  Nsutite         -11.23      6.28   17.50  MnO2
  O2(g)           -37.09     46.00   83.09  O2
  Periclase       -10.29     11.30   21.58  MgO
  Portlandite     -10.81     11.99   22.80  Ca(OH)2
  Pyrochroite      -6.57      8.63   15.19  Mn(OH)2
  Pyrolusite       -9.75     31.63   41.38  MnO2
  Retgersite       -8.28    -10.32   -2.04  NiSO4:6H2O
  Rhodochrosite    -2.12    -12.70  -10.58  MnCO3
  Spinel           -7.53     29.31   36.85  MgAl2O4
  Tenorite          0.24      7.89    7.64  CuO
  Thenardite      -12.04    -11.72    0.32  Na2SO4
  Thermonatrite   -15.77    -15.13    0.64  Na2CO3:H2O
  Witherite        -4.75    -13.32   -8.57  BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 3.     NAF Material

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                5.191e-06   5.191e-06
      Alkalinity        4.591e-04   4.591e-04
      As                3.873e-07   3.873e-07
      Ba                1.457e-07   1.457e-07
      Ca                3.046e-03   3.046e-03
      Co                3.395e-08   3.395e-08
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      Cu                2.992e-07   2.992e-07
      F                 1.580e-05   1.580e-05
      Fe                1.254e-06   1.254e-06
      K                 4.094e-04   4.094e-04
      Mg                7.410e-04   7.410e-04
      Mn                2.368e-06   2.368e-06
      Mo                5.214e-08   5.214e-08
      Na                4.352e-05   4.352e-05
      Ni                1.705e-08   1.705e-08
      S(6)              3.447e-03   3.447e-03
      U                 4.203e-09   4.203e-09

----------------------------Description of solution----------------------------

                                       pH  =   7.600
                                       pe  =   4.000
                      Activity of water  =   1.000
                 Ionic strength (mol/kgw)  =   1.193e-02
                      Mass of water (kg)  =   1.000e+00
                 Total carbon (mol/kg)  =   4.552e-04
                    Total CO2 (mol/kg)  =   4.552e-04
                      Temperature (°C)  =  25.00
              Electrical balance (eq)  =   6.787e-04
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =   5.48
                             Iterations  =  11 (35 overall)
                                Total H  = 1.110142e+02
                                Total O  = 5.552201e+01

----------------------------Distribution of species----------------------------

                                          Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             4.492e-07   4.008e-07   -6.348    -6.397    -0.049     (0)
   H+              2.808e-08   2.512e-08   -7.552    -7.600    -0.048     0.00
   H2O             5.551e+01   9.999e-01    1.744    -0.000     0.000    18.07
Al              5.191e-06
   Al(OH)4-        5.088e-06   4.556e-06   -5.293    -5.341    -0.048     (0)
   Al(OH)3         9.030e-08   9.030e-08   -7.044    -7.044     0.000     (0)
   Al(OH)2+        1.257e-08   1.129e-08   -7.901    -7.947    -0.047     (0)
   AlF2+           6.958e-11   6.249e-11  -10.158   -10.204    -0.047     (0)
   AlOH+2          5.451e-11   3.546e-11  -10.264   -10.450    -0.187     (0)
   AlF+2           1.811e-11   1.178e-11  -10.742   -10.929    -0.187     (0)
   AlF3            1.048e-11   1.048e-11  -10.980   -10.980     0.000     (0)
   AlSO4+          1.328e-12   1.189e-12  -11.877   -11.925    -0.048     (0)
   Al+3            2.412e-13   8.848e-14  -12.618   -13.053    -0.436     (0)
   AlF4-           7.812e-14   6.995e-14  -13.107   -13.155    -0.048     (0)
   Al(SO4)2-       2.463e-14   2.206e-14  -13.608   -13.656    -0.048     (0)
   AlMo6O21-3      0.000e+00   0.000e+00  -48.018   -48.520    -0.501     (0)
As(3)           1.024e-17
   H3AsO3          1.000e-17   1.000e-17  -17.000   -17.000     0.000     (0)
   H2AsO3-         2.322e-19   2.043e-19  -18.634   -18.690    -0.056     (0)
   HAsO3-2         1.239e-23   7.417e-24  -22.907   -23.130    -0.223     (0)
   H4AsO3+         1.416e-25   1.245e-25  -24.849   -24.905    -0.056     (0)
   AsO3-3          3.611e-29   1.138e-29  -28.442   -28.944    -0.501     (0)
As(5)           3.873e-07
   HAsO4-2         3.350e-07   2.005e-07   -6.475    -6.698    -0.223     (0)
   H2AsO4-         5.222e-08   4.594e-08   -7.282    -7.338    -0.056     (0)
   AsO4-3          8.009e-11   2.524e-11  -10.096   -10.598    -0.501     (0)
   H3AsO4          2.000e-13   2.005e-13  -12.699   -12.698     0.001     (0)
Ba              1.457e-07
   Ba+2            1.453e-07   9.304e-08   -6.838    -7.031    -0.194     (0)
   BaHCO3+         3.699e-10   3.328e-10   -9.432    -9.478    -0.046     (0)
   BaCO3           3.336e-11   3.336e-11  -10.477   -10.477     0.000     (0)
   BaOH+           1.815e-13   1.628e-13  -12.741   -12.788    -0.047     (0)
C(4)            4.552e-04
   HCO3-           4.171e-04   3.746e-04   -3.380    -3.426    -0.047     (0)
   H2CO3           2.116e-05   2.116e-05   -4.674    -4.674     0.000     (0)
   CaHCO3+         1.200e-05   1.080e-05   -4.921    -4.967    -0.046     (0)
   CaCO3           1.715e-06   1.715e-06   -5.766    -5.766     0.000     (0)
   MgHCO3+         1.687e-06   1.508e-06   -5.773    -5.822    -0.049     (0)
   CO3-2           1.092e-06   6.991e-07   -5.962    -6.155    -0.194     (0)
   MgCO3           2.288e-07   2.288e-07   -6.641    -6.641     0.000     (0)
   CuCO3           1.600e-07   1.600e-07   -6.796    -6.796     0.000     (0)
   MnHCO3+         9.921e-09   8.899e-09   -8.003    -8.051    -0.047     (0)
   NaHCO3          8.124e-09   8.124e-09   -8.090    -8.090     0.000     (0)
   UO2(CO3)2-2     3.482e-09   2.084e-09   -8.458    -8.681    -0.223     (0)
   CuHCO3+         1.044e-09   9.187e-10   -8.981    -9.037    -0.056     (0)
   UO2(CO3)3-4     5.687e-10   7.303e-11   -9.245   -10.136    -0.891     (0)
   NaCO3-          5.590e-10   5.020e-10   -9.253    -9.299    -0.047     (0)
   CoHCO3+         5.432e-10   4.778e-10   -9.265    -9.321    -0.056     (0)
   Cu(CO3)2-2      5.030e-10   3.011e-10   -9.298    -9.521    -0.223     (0)
   NiHCO3+         4.493e-10   3.952e-10   -9.347    -9.403    -0.056     (0)
   BaHCO3+         3.699e-10   3.328e-10   -9.432    -9.478    -0.046     (0)
   NiCO3           2.232e-10   2.232e-10   -9.651    -9.651     0.000     (0)
   CoCO3           1.938e-10   1.938e-10   -9.713    -9.713     0.000     (0)
   UO2CO3          1.494e-10   1.494e-10   -9.826    -9.826     0.000     (0)
   FeHCO3+         1.083e-10   9.748e-11   -9.965   -10.011    -0.046     (0)
   BaCO3           3.336e-11   3.336e-11  -10.477   -10.477     0.000     (0)
Ca              3.046e-03
   Ca+2            2.418e-03   1.548e-03   -2.617    -2.810    -0.194     (0)
   CaSO4           6.140e-04   6.140e-04   -3.212    -3.212     0.000     (0)
   CaHCO3+         1.200e-05   1.080e-05   -4.921    -4.967    -0.046     (0)
   CaCO3           1.715e-06   1.715e-06   -5.766    -5.766     0.000     (0)
   CaF+            2.509e-07   2.251e-07   -6.600    -6.648    -0.047     (0)
   CaOH+           1.376e-08   1.238e-08   -7.861    -7.907    -0.046     (0)
Co(2)           3.395e-08
   Co+2            2.739e-08   1.640e-08   -7.562    -7.785    -0.223     (0)
   CoSO4           5.664e-09   5.664e-09   -8.247    -8.247     0.000     (0)
   CoHCO3+         5.432e-10   4.778e-10   -9.265    -9.321    -0.056     (0)
   CoCO3           1.938e-10   1.938e-10   -9.713    -9.713     0.000     (0)
   CoOH+           1.491e-10   1.311e-10   -9.827    -9.882    -0.056     (0)
   CoF+            7.852e-12   6.907e-12  -11.105   -11.161    -0.056     (0)
   Co(OH)2         4.175e-12   4.175e-12  -11.379   -11.379     0.000     (0)
   Co(OH)3-        3.796e-17   3.339e-17  -16.421   -16.476    -0.056     (0)
   CoOOH-          9.525e-18   8.379e-18  -17.021   -17.077    -0.056     (0)
   Co2OH+3         3.419e-19   1.078e-19  -18.466   -18.968    -0.501     (0)
   Co(OH)4-2       3.543e-24   2.121e-24  -23.451   -23.673    -0.223     (0)
   Co4(OH)4+4      4.595e-31   5.900e-32  -30.338   -31.229    -0.891     (0)
Co(3)           2.221e-30
   CoOH+2          2.221e-30   1.330e-30  -29.653   -29.876    -0.223     (0)
   Co+3            1.780e-36   6.528e-37  -35.750   -36.185    -0.436     (0)
Cu(1)           2.164e-09
   Cu+             2.164e-09   1.904e-09   -8.665    -8.720    -0.056     (0)
Cu(2)           2.970e-07
   CuCO3           1.600e-07   1.600e-07   -6.796    -6.796     0.000     (0)
   Cu+2            6.070e-08   3.887e-08   -7.217    -7.410    -0.194     (0)
   CuOH+           5.512e-08   4.927e-08   -7.259    -7.307    -0.049     (0)
   CuSO4           1.542e-08   1.542e-08   -7.812    -7.812     0.000     (0)
   Cu(OH)2         3.940e-09   3.940e-09   -8.404    -8.404     0.000     (0)
   CuHCO3+         1.044e-09   9.187e-10   -8.981    -9.037    -0.056     (0)
   Cu(CO3)2-2      5.030e-10   3.011e-10   -9.298    -9.521    -0.223     (0)
   Cu2(OH)2+2      1.019e-10   6.097e-11   -9.992   -10.215    -0.223     (0)
   CuF+            3.714e-11   3.267e-11  -10.430   -10.486    -0.056     (0)
   Cu(OH)3-        3.683e-12   3.239e-12  -11.434   -11.490    -0.056     (0)
   Cu(OH)4-2       1.707e-17   1.022e-17  -16.768   -16.991    -0.223     (0)
F               1.580e-05
   F-              1.489e-05   1.332e-05   -4.827    -4.876    -0.048     (0)
   MgF+            6.566e-07   5.879e-07   -6.183    -6.231    -0.048     (0)
   CaF+            2.509e-07   2.251e-07   -6.600    -6.648    -0.047     (0)
   MnF+            7.039e-10   6.314e-10   -9.152    -9.200    -0.047     (0)
   HF              4.949e-10   4.949e-10   -9.306    -9.306     0.000     (0)
   NaF             3.241e-10   3.241e-10   -9.489    -9.489     0.000     (0)
   AlF2+           6.958e-11   6.249e-11  -10.158   -10.204    -0.047     (0)
   CuF+            3.714e-11   3.267e-11  -10.430   -10.486    -0.056     (0)
   AlF+2           1.811e-11   1.178e-11  -10.742   -10.929    -0.187     (0)
   AlF3            1.048e-11   1.048e-11  -10.980   -10.980     0.000     (0)
   CoF+            7.852e-12   6.907e-12  -11.105   -11.161    -0.056     (0)
   NiF+            3.255e-12   2.863e-12  -11.487   -11.543    -0.056     (0)
   UO2F+           1.122e-13   9.871e-14  -12.950   -13.006    -0.056     (0)
   AlF4-           7.812e-14   6.995e-14  -13.107   -13.155    -0.048     (0)
   HF2-            2.808e-14   2.506e-14  -13.552   -13.601    -0.049     (0)
   UO2F2           3.792e-15   3.792e-15  -14.421   -14.421     0.000     (0)
   FeF+2           4.333e-16   2.804e-16  -15.363   -15.552    -0.189     (0)
   FeF2+           1.114e-16   9.996e-17  -15.953   -16.000    -0.047     (0)
   UO2F3-          1.442e-17   1.269e-17  -16.841   -16.897    -0.056     (0)
   FeF3            1.879e-18   1.879e-18  -17.726   -17.726     0.000     (0)
   H2F2            6.561e-19   6.561e-19  -18.183   -18.183     0.000     (0)
   UO2F4-2         2.242e-21   1.342e-21  -20.649   -20.872    -0.223     (0)
   UF3+            3.760e-36   3.307e-36  -35.425   -35.481    -0.056     (0)
   UF2+2           2.617e-36   1.567e-36  -35.582   -35.805    -0.223     (0)
   UF+3            2.964e-38   9.342e-39  -37.528   -38.030    -0.501     (0)
   UF4             4.830e-39   4.830e-39  -38.316   -38.316     0.000     (0)
   UF5-            0.000e+00   0.000e+00  -41.538   -41.594    -0.056     (0)
   UF6-2           0.000e+00   0.000e+00  -43.766   -43.989    -0.223     (0)
Fe(2)           4.379e-08
   Fe+2            3.453e-08   2.067e-08   -7.462    -7.685    -0.223     (0)
   FeSO4           8.785e-09   8.785e-09   -8.056    -8.056     0.000     (0)
   FeOH+           3.677e-10   3.298e-10   -9.434    -9.482    -0.047     (0)
   FeHCO3+         1.083e-10   9.748e-11   -9.965   -10.011    -0.046     (0)
   Fe(OH)2         1.050e-13   1.050e-13  -12.979   -12.979     0.000     (0)
   Fe(OH)3-        1.484e-14   1.331e-14  -13.829   -13.876    -0.047     (0)
Fe(3)           1.210e-06
   Fe(OH)2+        8.628e-07   7.749e-07   -6.064    -6.111    -0.047     (0)
   Fe(OH)3         3.336e-07   3.336e-07   -6.477    -6.477     0.000     (0)
   Fe(OH)4-        1.386e-08   1.245e-08   -7.858    -7.905    -0.047     (0)
   FeOH+2          7.678e-12   4.969e-12  -11.115   -11.304    -0.189     (0)
   FeF+2           4.333e-16   2.804e-16  -15.363   -15.552    -0.189     (0)
   FeSO4+          4.159e-16   3.730e-16  -15.381   -15.428    -0.047     (0)
   FeF2+           1.114e-16   9.996e-17  -15.953   -16.000    -0.047     (0)
   Fe+3            5.236e-17   1.920e-17  -16.281   -16.717    -0.436     (0)
   Fe(SO4)2-       1.570e-17   1.381e-17  -16.804   -16.860    -0.056     (0)
   FeF3            1.879e-18   1.879e-18  -17.726   -17.726     0.000     (0)
   Fe2(OH)2+4      6.368e-21   8.178e-22  -20.196   -21.087    -0.891     (0)
   Fe3(OH)4+5      2.263e-25   9.160e-27  -24.645   -26.038    -1.393     (0)
H(0)            8.909e-27
   H2              4.455e-27   4.467e-27  -26.351   -26.350     0.001     (0)
K               4.094e-04
   K+              4.045e-04   3.618e-04   -3.393    -3.441    -0.048     (0)
   KSO4-           4.938e-06   4.435e-06   -5.306    -5.353    -0.047     (0)
Mg              7.410e-04
   Mg+2            6.144e-04   3.934e-04   -3.212    -3.405    -0.194     (0)
   MgSO4           1.239e-04   1.239e-04   -3.907    -3.907     0.000     (0)
   MgHCO3+         1.687e-06   1.508e-06   -5.773    -5.822    -0.049     (0)
   MgF+            6.566e-07   5.879e-07   -6.183    -6.231    -0.048     (0)
   MgCO3           2.288e-07   2.288e-07   -6.641    -6.641     0.000     (0)
   MgOH+           6.966e-08   6.278e-08   -7.157    -7.202    -0.045     (0)
Mn(2)           2.368e-06
   Mn+2            1.989e-06   1.191e-06   -5.701    -5.924    -0.223     (0)
   MnSO4           3.666e-07   3.666e-07   -6.436    -6.436     0.000     (0)
   MnHCO3+         9.921e-09   8.899e-09   -8.003    -8.051    -0.047     (0)
   MnOH+           1.337e-09   1.199e-09   -8.874    -8.921    -0.047     (0)
   MnF+            7.039e-10   6.314e-10   -9.152    -9.200    -0.047     (0)
   Mn(OH)3-        1.327e-18   1.190e-18  -17.877   -17.924    -0.047     (0)
   Mn(OH)4-2       2.380e-24   1.540e-24  -23.623   -23.812    -0.189     (0)
Mn(3)           1.450e-27
   Mn+3            1.450e-27   5.318e-28  -26.839   -27.274    -0.436     (0)
Mn(6)           0.000e+00
   MnO4-2          0.000e+00   0.000e+00  -47.357   -47.546    -0.189     (0)
Mn(7)           0.000e+00
   MnO4-           0.000e+00   0.000e+00  -52.868   -52.918    -0.050     (0)
Mo              5.214e-08
   MoO4-2          5.212e-08   3.338e-08   -7.283    -7.477    -0.194     (0)
   HMoO4-          1.896e-11   1.668e-11  -10.722   -10.778    -0.056     (0)
   H2MoO4          3.069e-15   3.069e-15  -14.513   -14.513     0.000     (0)
   AlMo6O21-3      0.000e+00   0.000e+00  -48.018   -48.520    -0.501     (0)
   Mo7O24-6        0.000e+00   0.000e+00  -58.140   -60.146    -2.006     (0)
   HMo7O24-5       0.000e+00   0.000e+00  -59.966   -61.359    -1.393     (0)
   H2Mo7O24-4      0.000e+00   0.000e+00  -63.285   -64.177    -0.891     (0)
   H3Mo7O24-3      0.000e+00   0.000e+00  -68.029   -68.531    -0.501     (0)
Na              4.352e-05
   Na+             4.311e-05   3.857e-05   -4.365    -4.414    -0.048     (0)
   NaSO4-          3.992e-07   3.586e-07   -6.399    -6.445    -0.047     (0)
   NaHCO3          8.124e-09   8.124e-09   -8.090    -8.090     0.000     (0)
   NaCO3-          5.590e-10   5.020e-10   -9.253    -9.299    -0.047     (0)
   NaF             3.241e-10   3.241e-10   -9.489    -9.489     0.000     (0)
Ni              1.705e-08
   Ni+2            1.336e-08   8.558e-09   -7.874    -8.068    -0.194     (0)
   NiSO4           2.956e-09   2.956e-09   -8.529    -8.529     0.000     (0)
   NiHCO3+         4.493e-10   3.952e-10   -9.347    -9.403    -0.056     (0)
   NiCO3           2.232e-10   2.232e-10   -9.651    -9.651     0.000     (0)
   NiOH+           4.909e-11   4.318e-11  -10.309   -10.365    -0.056     (0)
   NiF+            3.255e-12   2.863e-12  -11.487   -11.543    -0.056     (0)
   Ni(OH)2         1.375e-12   1.375e-12  -11.862   -11.862     0.000     (0)
   Ni(SO4)2-2      2.831e-13   1.695e-13  -12.548   -12.771    -0.223     (0)
   Ni(OH)3-        6.265e-16   5.511e-16  -15.203   -15.259    -0.056     (0)
O(0)            5.066e-40
   O2              2.533e-40   2.540e-40  -39.596   -39.595     0.001     (0)
S(6)            3.447e-03
   SO4-2           2.704e-03   1.731e-03   -2.568    -2.762    -0.194     (0)
   CaSO4           6.140e-04   6.140e-04   -3.212    -3.212     0.000     (0)
   MgSO4           1.239e-04   1.239e-04   -3.907    -3.907     0.000     (0)
   KSO4-           4.938e-06   4.435e-06   -5.306    -5.353    -0.047     (0)
   NaSO4-          3.992e-07   3.586e-07   -6.399    -6.445    -0.047     (0)
   MnSO4           3.666e-07   3.666e-07   -6.436    -6.436     0.000     (0)
   CuSO4           1.542e-08   1.542e-08   -7.812    -7.812     0.000     (0)
   FeSO4           8.785e-09   8.785e-09   -8.056    -8.056     0.000     (0)
   CoSO4           5.664e-09   5.664e-09   -8.247    -8.247     0.000     (0)
   HSO4-           4.746e-09   4.250e-09   -8.324    -8.372    -0.048     (0)
   NiSO4           2.956e-09   2.956e-09   -8.529    -8.529     0.000     (0)
   AlSO4+          1.328e-12   1.189e-12  -11.877   -11.925    -0.048     (0)
   Ni(SO4)2-2      2.831e-13   1.695e-13  -12.548   -12.771    -0.223     (0)
   UO2SO4          1.407e-13   1.407e-13  -12.852   -12.852     0.000     (0)
   Al(SO4)2-       2.463e-14   2.206e-14  -13.608   -13.656    -0.048     (0)
   UO2(SO4)2-2     5.363e-15   3.210e-15  -14.271   -14.493    -0.223     (0)
   FeSO4+          4.159e-16   3.730e-16  -15.381   -15.428    -0.047     (0)
   Fe(SO4)2-       1.570e-17   1.381e-17  -16.804   -16.860    -0.056     (0)
   U(SO4)2         3.332e-38   3.332e-38  -37.477   -37.477     0.000     (0)
   USO4+2          4.047e-39   2.423e-39  -38.393   -38.616    -0.223     (0)
U(3)            0.000e+00
   U+3             0.000e+00   0.000e+00  -54.749   -55.250    -0.501     (0)
U(4)            3.033e-18
   U(OH)5-         3.030e-18   2.665e-18  -17.519   -17.574    -0.056     (0)
   U(OH)4          2.804e-21   2.804e-21  -20.552   -20.552     0.000     (0)
   U(OH)3+         2.928e-25   2.575e-25  -24.533   -24.589    -0.056     (0)
   U(OH)2+2        4.997e-30   2.991e-30  -29.301   -29.524    -0.223     (0)
   UOH+3           1.123e-35   3.539e-36  -34.950   -35.451    -0.501     (0)
   UF3+            3.760e-36   3.307e-36  -35.425   -35.481    -0.056     (0)
   UF2+2           2.617e-36   1.567e-36  -35.582   -35.805    -0.223     (0)
   U(SO4)2         3.332e-38   3.332e-38  -37.477   -37.477     0.000     (0)
   UF+3            2.964e-38   9.342e-39  -37.528   -38.030    -0.501     (0)
   UF4             4.830e-39   4.830e-39  -38.316   -38.316     0.000     (0)
   USO4+2          4.047e-39   2.423e-39  -38.393   -38.616    -0.223     (0)
   UF5-            0.000e+00   0.000e+00  -41.538   -41.594    -0.056     (0)
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   U+4             0.000e+00   0.000e+00   -41.563   -42.454    -0.891     (0)
   UF6-2           0.000e+00   0.000e+00   -43.766   -43.989    -0.223     (0)
   U6(OH)15+9      0.000e+00   0.000e+00  -153.367  -157.880    -4.513     (0)
U(5)          3.720e-15
   UO2+            3.720e-15   3.272e-15   -14.429   -14.485    -0.056     (0)
U(6)          4.203e-09
   UO2(CO3)2-2     3.482e-09   2.084e-09    -8.458    -8.681    -0.223     (0)
   UO2(CO3)3-4     5.687e-10   7.303e-11    -9.245   -10.136    -0.891     (0)
   UO2CO3          1.494e-10   1.494e-10    -9.826    -9.826     0.000     (0)
   UO2OH+          3.080e-12   2.709e-12   -11.511   -11.567    -0.056     (0)
   UO2SO4          1.407e-13   1.407e-13   -12.852   -12.852     0.000     (0)
   UO2F+           1.122e-13   9.871e-14   -12.950   -13.006    -0.056     (0)
   UO2+2           8.384e-14   5.369e-14   -13.077   -13.270    -0.194     (0)
   UO2(SO4)2-2     5.363e-15   3.210e-15   -14.271   -14.493    -0.223     (0)
   UO2F2           3.792e-15   3.792e-15   -14.421   -14.421     0.000     (0)
   (UO2)2(OH)2+2   2.034e-17   1.218e-17   -16.692   -16.914    -0.223     (0)
   UO2F3-          1.442e-17   1.269e-17   -16.841   -16.897    -0.056     (0)
   (UO2)3(OH)5+    4.571e-18   4.021e-18   -17.340   -17.396    -0.056     (0)
   UO2F4-2         2.242e-21   1.342e-21   -20.649   -20.872    -0.223     (0)

----------------------------Saturation indices----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.05      9.75   10.80  Al(OH)3
  Al2(MoO4)3      -50.90    -48.54    2.37  Al2(MoO4)3
  Al2O3            -0.16     19.49   19.65  Al2O3
  Al4(OH)10SO4     -1.67     21.03   22.70  Al4(OH)10SO4
  AlAsO4:2H2O      -7.75     -2.95    4.80  AlAsO4:2H2O
  AlOHSO4          -4.98     -8.21   -3.23  AlOHSO4
  Alunite          -1.12     -2.52   -1.40  KAl3(SO4)2(OH)6
  Anhydrite        -1.21     -5.57   -4.36  CaSO4
  Antlerite        -3.38      5.41    8.79  Cu3(OH)4SO4
  Aragonite        -0.67     -8.97   -8.30  CaCO3
  Arsenolite      -65.24    -68.00   -2.76  As4O6
  Artinite         -7.37      2.23    9.60  MgCO3:Mg(OH)2:3H2O
  As2O5           -32.10    -25.40    6.71  As2O5
  Azurite          -2.44    -19.34  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -16.23      8.17   24.39  Ba(OH)2:8H2O
  Ba3(AsO4)2        8.02     -0.89   -8.91  Ba3(AsO4)2
  BaF2            -10.96    -16.78   -5.82  BaF2
  BaMoO4           -7.55    -14.51   -6.96  BaMoO4
  Barite            0.19     -9.79   -9.98  BaSO4
  Birnessite      -10.97      7.13   18.09  MnO2
  Bixbyite         -8.30     -8.95   -0.64  Mn2O3
  Boehmite          1.17      9.75    8.58  AlOOH
  Brochantite      -2.03     13.20   15.22  Cu4(OH)6SO4
  Brucite          -5.05     11.79   16.84  Mg(OH)2
  Bunsenite        -5.31      7.13   12.45  NiO
  Ca3(AsO4)2:4H2O -10.53     11.77   22.30  Ca3(AsO4)2:4H2O
  Calcite          -0.49     -8.97   -8.48  CaCO3
  CaMoO4           -2.34    -10.29   -7.95  CaMoO4
  CH4(g)          -73.11   -114.16  -41.05  CH4
  Chalcanthite     -7.53    -10.17   -2.64  CuSO4:5H2O
  Claudetite      -64.93    -68.00   -3.06  As4O6
  Co(OH)2          -5.68      7.41   13.09  Co(OH)2
  Co(OH)3         -11.08    -13.39   -2.31  Co(OH)3
  CO2(g)           -3.21    -21.36  -18.15  CO2
  Co3(AsO4)2      -16.19     -3.15   13.03  Co3(AsO4)2
  Co3O4            -8.86    -19.36  -10.50  Co3O4
  CoCO3            -3.96    -13.94   -9.98  CoCO3
  CoF2            -15.94    -17.54   -1.60  CoF2
  CoF3            -49.35    -50.81   -1.46  CoF3
  CoFe2O4          23.11     19.58   -3.53  CoFe2O4
  CoMoO4           -7.50    -15.26   -7.76  CoMoO4
  CoO              -6.17      7.41   13.59  CoO
  CoSO4           -13.35    -10.55    2.80  CoSO4
  CoSO4:6H2O       -8.07    -10.55   -2.47  CoSO4:6H2O
  Cryolite        -21.71    -55.55  -33.84  Na3AlF6
  Cu(OH)2          -0.88      7.79    8.67  Cu(OH)2
  Cu2SO4          -18.25    -20.20   -1.95  Cu2SO4
  Cu3(AsO4)2:2H2O  -8.13     -2.03    6.10  Cu3(AsO4)2:2H2O
  CuCO3            -2.07    -13.57  -11.50  CuCO3
  CuF              -8.69    -13.60   -4.91  CuF
  CuF2            -18.28    -17.16    1.12  CuF2
  CuF2:2H2O       -12.61    -17.16   -4.55  CuF2:2H2O
  Cumetal          -3.96    -12.72   -8.76  Cu
  CuMoO4           -1.81    -14.89  -13.08  CuMoO4
  CuOCuSO4        -12.69     -2.38   10.30  CuOCuSO4
  Cupricferrite    13.97     19.96    5.99  CuFe2O4
  Cuprite          -0.83     -2.24   -1.41  Cu2O
  Cuprousferrite   13.88      4.96   -8.92  CuFeO2
  CuSO4           -13.11    -10.17    2.94  CuSO4
  Diaspore          2.87      9.75    6.87  AlOOH
  Dolomite(disordered)  -1.99    -18.53  -16.54  CaMg(CO3)2
  Dolomite(ordered)  -1.44    -18.53  -17.09  CaMg(CO3)2
  Epsomite         -4.04     -6.17   -2.13  MgSO4:7H2O
  Fe(OH)2          -6.05      7.52   13.56  Fe(OH)2
  Fe2(SO4)3       -37.98    -41.72   -3.73  Fe2(SO4)3
  Fe3(OH)8         -0.54     19.68   20.22  Fe3(OH)8
  FeAsO4:2H2O      -7.01     -6.61    0.40  FeAsO4:2H2O
  FeMoO4           -5.07    -15.16  -10.09  FeMoO4
  Ferrihydrite      2.89      6.08    3.19  Fe(OH)3
  Fluorite         -2.06    -12.56  -10.50  CaF2
  Gibbsite          1.46      9.75    8.29  Al(OH)3
  Goethite          5.59      6.08    0.49  FeOOH
  Gummite          -5.74      1.93    7.67  UO3
  Gypsum           -0.96     -5.57   -4.61  CaSO4:2H2O
  H-Jarosite       -5.57    -17.67  -12.10  (H3O)Fe3(SO4)2(OH)6
  H2MoO4           -9.80    -22.68  -12.88  H2MoO4
  Hausmannite     -10.00     51.03   61.03  Mn3O4
  Hematite         13.58     12.17   -1.42  Fe2O3
  Hercynite         4.12     27.01   22.89  FeAl2O4
  Huntite          -7.68    -37.65  -29.97  CaMg3(CO3)4
  Hydromagnesite  -17.68    -26.45   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum          -16.85    -22.02   -5.17  KAl(SO4)2:12H2O
  K-Jarosite        1.28    -13.52  -14.80  KFe3(SO4)2(OH)6
  K2MoO4          -17.62    -14.36    3.26  K2MoO4
  Langite          -4.29     13.20   17.49  Cu4(OH)6SO4:H2O
  Lepidocrocite     4.71      6.08    1.37  FeOOH
  Lime            -20.31     12.39   32.70  CaO
  Maghemite         5.78     12.17    6.39  Fe2O3
  Magnesioferrite   7.10     23.96   16.86  Fe2MgO4
  Magnesite        -2.10     -9.56   -7.46  MgCO3
  Magnetite        16.28     19.68    3.40  Fe3O4
  Malachite        -0.47     -5.78   -5.31  Cu2(OH)2CO3
  Manganite        -4.46     20.88   25.34  MnOOH
  Melanterite      -8.24    -10.45   -2.21  FeSO4:7H2O
  Mg(OH)2(active)  -7.00     11.79   18.79  Mg(OH)2
  MgF2             -5.03    -13.16   -8.13  MgF2
  MgMoO4           -9.03    -10.88   -1.85  MgMoO4
  Mirabilite      -10.48    -11.59   -1.11  Na2SO4:10H2O
  Mn2(SO4)3       -57.12    -62.83   -5.71  Mn2(SO4)3
  Mn3(AsO4)2:8H2O -10.07      2.43   12.50  Mn3(AsO4)2:8H2O
  MnSO4           -11.27     -8.69    2.58  MnSO4
  MoO3            -14.68    -22.68   -8.00  MoO3
  Morenosite       -8.68    -10.83   -2.14  NiSO4:7H2O
  Na-Jarosite      -3.29    -14.49  -11.20  NaFe3(SO4)2(OH)6
  Na2Mo2O7        -22.38    -38.98  -16.60  Na2Mo2O7
  Na2MoO4         -17.79    -16.30    1.49  Na2MoO4
  Na2MoO4:2H2O    -17.53    -16.30    1.22  Na2MoO4:2H2O
  Natron          -13.67    -14.98   -1.31  Na2CO3:10H2O
  Nesquehonite     -4.89     -9.56   -4.67  MgCO3:3H2O
  Ni(OH)2          -5.66      7.13   12.79  Ni(OH)2
  Ni3(AsO4)2:8H2O -19.70     -4.00   15.70  Ni3(AsO4)2:8H2O
  Ni4(OH)6SO4     -21.43     10.57   32.00  Ni4(OH)6SO4
  NiCO3            -7.35    -14.22   -6.87  NiCO3
  NiMoO4           -4.40    -15.54  -11.14  NiMoO4
  Nsutite         -10.38      7.13   17.50  MnO2
  O2(g)           -36.69     46.40   83.09  O2
  Periclase        -9.79     11.79   21.58  MgO
  Portlandite     -10.41     12.39   22.80  Ca(OH)2
  Pyrochroite      -5.92      9.28   15.19  Mn(OH)2
  Pyrolusite       -8.90     32.48   41.38  MnO2
  Retgersite       -8.79    -10.83   -2.04  NiSO4:6H2O
  Rhodochrosite    -1.50    -12.08  -10.58  MnCO3
  Rutherfordine    -4.93    -19.43  -14.50  UO2CO3
  Schoepite        -4.06      1.93    5.99  UO2(OH)2:H2O
  Siderite         -3.60    -13.84  -10.24  FeCO3
  Spinel           -5.56     31.29   36.85  MgAl2O4
  Tenorite          0.15      7.79    7.64  CuO
  Thenardite      -11.91    -11.59    0.32  Na2SO4
  Thermonatrite   -15.62    -14.98    0.64  Na2CO3:H2O
  U3O8            -10.85     10.24   21.08  U3O8
  U4O9            -22.00    -25.02   -3.02  U4O9
  UF4             -32.42    -61.96  -29.54  UF4
  UF4:2.5H2O      -29.24    -61.96  -32.72  UF4:2.5H2O
  UO2(am)         -12.99    -12.05    0.93  UO2
  UO2(OH)2(beta)   -3.68      1.93    5.61  UO2(OH)2
  UO3              -5.77      1.93    7.70  UO3
  Uraninite        -7.38    -12.05   -4.67  UO2
  Witherite        -4.62    -13.19   -8.57  BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 4.     Make-up Material

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                7.415e-07   7.415e-07
      Alkalinity        3.607e-04   3.607e-04
      Ba                1.457e-07   1.457e-07
      Ca                1.672e-03   1.672e-03
      Co                1.188e-07   1.188e-07
      Cu                4.408e-07   4.408e-07
      F                 1.580e-05   1.580e-05
      K                 3.326e-04   3.326e-04
      Mg                3.293e-04   3.293e-04
      Mn                7.283e-07   7.283e-07
      Mo                3.128e-08   3.128e-08
      Na                4.351e-05   4.351e-05
      Ni                6.818e-08   6.818e-08
      S(6)              2.051e-03   2.051e-03

----------------------------Description of solution----------------------------

                                     pH  =   7.700
                                     pe  =   4.000
                     Activity of water  =   1.000
                 Ionic strength (mol/kgw)  =   7.199e-03
                    Mass of water (kg)  =   1.000e+00
                Total carbon (mol/kg)  =   3.686e-04
                   Total CO2 (mol/kg)  =   3.686e-04
                       Temperature (°C)  =  25.00
              Electrical balance (eq)  =  -9.478e-05

 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  -1.25
                                  Iterations  =  12 (47 overall)
                                     Total H  = 1.110140e+02
                                     Total O  = 5.551615e+01

----------------------------Distribution of species----------------------------

                                                  Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma   cm³/mol

   OH-             5.526e-07   5.046e-07    -6.258    -6.297    -0.039     (0)
   H+              2.182e-08   1.995e-08    -7.661    -7.700    -0.039      0.00
   H2O             5.551e+01   9.999e-01     1.744    -0.000     0.000     18.07
Al            7.415e-07
   Al(OH)4-        7.298e-07   6.680e-07    -6.137    -6.175    -0.038     (0)
   Al(OH)3         1.051e-08   1.051e-08    -7.978    -7.978     0.000     (0)
   Al(OH)2+        1.139e-09   1.044e-09    -8.944    -8.981    -0.038     (0)
   AlF2+           4.383e-12   4.020e-12   -11.358   -11.396    -0.038     (0)
   AlOH+2          3.684e-12   2.605e-12   -11.434   -11.584    -0.150     (0)
   AlF+2           1.021e-12   7.220e-13   -11.991   -12.141    -0.150     (0)
   AlF3            7.077e-13   7.077e-13   -12.150   -12.150     0.000     (0)
   AlSO4+          5.310e-14   4.860e-14   -13.275   -13.313    -0.038     (0)
   Al+3            1.153e-14   5.163e-15   -13.938   -14.287    -0.349     (0)
   AlF4-           5.420e-15   4.960e-15   -14.266   -14.304    -0.038     (0)
   Al(SO4)2-       6.899e-16   6.315e-16   -15.161   -15.200    -0.038     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -51.065   -51.455    -0.389     (0)
Ba            1.457e-07
   Ba+2            1.453e-07   1.017e-07    -6.838    -6.993    -0.155     (0)
   BaHCO3+         3.344e-10   3.070e-10    -9.476    -9.513    -0.037     (0)
   BaCO3           3.874e-11   3.874e-11   -10.412   -10.412     0.000     (0)
   BaOH+           2.444e-13   2.239e-13   -12.612   -12.650    -0.038     (0)
C(4)          3.686e-04
   HCO3-           3.449e-04   3.163e-04    -3.462    -3.500    -0.038     (0)
   H2CO3           1.419e-05   1.419e-05    -4.848    -4.848     0.000     (0)
   CaHCO3+         6.254e-06   5.742e-06    -5.204    -5.241    -0.037     (0)
   CaCO3           1.148e-06   1.148e-06    -5.940    -5.940     0.000     (0)
   CO3-2           1.062e-06   7.431e-07    -5.974    -6.129    -0.155     (0)
   MgHCO3+         7.037e-07   6.434e-07    -6.153    -6.192    -0.039     (0)
   CuCO3           2.384e-07   2.384e-07    -6.623    -6.623     0.000     (0)
   MgCO3           1.229e-07   1.229e-07    -6.911    -6.911     0.000     (0)
   NaHCO3          7.030e-09   7.030e-09    -8.153    -8.153     0.000     (0)
   MnHCO3+         2.926e-09   2.681e-09    -8.534    -8.572    -0.038     (0)
   CoHCO3+         1.811e-09   1.639e-09    -8.742    -8.785    -0.043     (0)
   NiHCO3+         1.678e-09   1.519e-09    -8.775    -8.818    -0.043     (0)
   CuHCO3+         1.201e-09   1.087e-09    -8.920    -8.964    -0.043     (0)
   NiCO3           1.080e-09   1.080e-09    -8.967    -8.967     0.000     (0)
   CoCO3           8.369e-10   8.369e-10    -9.077    -9.077     0.000     (0)
   Cu(CO3)2-2      7.104e-10   4.768e-10    -9.149    -9.322    -0.173     (0)
   NaCO3-          5.965e-10   5.470e-10    -9.224    -9.262    -0.038     (0)
   BaHCO3+         3.344e-10   3.070e-10    -9.476    -9.513    -0.037     (0)
   BaCO3           3.874e-11   3.874e-11   -10.412   -10.412     0.000     (0)
Ca            1.672e-03
   Ca+2            1.394e-03   9.751e-04    -2.856    -3.011    -0.155     (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000     (0)
   CaHCO3+         6.254e-06   5.742e-06    -5.204    -5.241    -0.037     (0)
   CaCO3           1.148e-06   1.148e-06    -5.940    -5.940     0.000     (0)
   CaF+            1.624e-07   1.488e-07    -6.789    -6.827    -0.038     (0)
   CaOH+           1.069e-08   9.818e-09    -7.971    -8.008    -0.037     (0)
Co(2)         1.188e-07
   Co+2            9.925e-08   6.662e-08    -7.003    -7.176    -0.173     (0)
   CoSO4           1.612e-08   1.612e-08    -7.793    -7.793     0.000     (0)
   CoHCO3+         1.811e-09   1.639e-09    -8.742    -8.785    -0.043     (0)
   CoCO3           8.369e-10   8.369e-10    -9.077    -9.077     0.000     (0)
   CoOH+           7.411e-10   6.708e-10    -9.130    -9.173    -0.043     (0)
   CoF+            3.255e-11   2.946e-11   -10.487   -10.531    -0.043     (0)
   Co(OH)2         2.689e-11   2.689e-11   -10.570   -10.570     0.000     (0)
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   Co(OH)3-        2.991e-16   2.707e-16   -15.524   -15.567    -0.043     (0)
   CoOOH-          7.505e-17   6.793e-17   -16.125   -16.168    -0.043     (0)
   Co2OH+3         5.491e-18   2.240e-18   -17.260   -17.650    -0.389     (0)
   Co(OH)4-2       3.225e-23   2.165e-23   -22.491   -22.665    -0.173     (0)
   Co4(OH)4+4      1.990e-28   4.040e-29   -27.701   -28.394    -0.692     (0)
Co(3)          1.013e-29
   CoOH+2          1.013e-29   6.801e-30   -28.994   -29.167    -0.173     (0)
   Co+3            5.925e-36   2.652e-36   -35.227   -35.576    -0.349     (0)
Cu(1)          2.948e-09
   Cu+             2.948e-09   2.668e-09    -8.530    -8.574    -0.043     (0)
Cu(2)          4.378e-07
   CuCO3           2.384e-07   2.384e-07    -6.623    -6.623     0.000     (0)
   CuOH+           9.510e-08   8.694e-08    -7.022    -7.061    -0.039     (0)
   Cu+2            7.788e-08   5.448e-08    -7.109    -7.264    -0.155     (0)
   CuSO4           1.514e-08   1.514e-08    -7.820    -7.820     0.000     (0)
   Cu(OH)2         8.754e-09   8.754e-09    -8.058    -8.058     0.000     (0)
   CuHCO3+         1.201e-09   1.087e-09    -8.920    -8.964    -0.043     (0)
   Cu(CO3)2-2      7.104e-10   4.768e-10    -9.149    -9.322    -0.173     (0)
   Cu2(OH)2+2      2.829e-10   1.899e-10    -9.548    -9.722    -0.173     (0)
   CuF+            5.311e-11   4.808e-11   -10.275   -10.318    -0.043     (0)
   Cu(OH)3-        1.001e-11   9.061e-12   -11.000   -11.043    -0.043     (0)
   Cu(OH)4-2       5.361e-17   3.599e-17   -16.271   -16.444    -0.173     (0)
F              1.580e-05
   F-              1.529e-05   1.398e-05    -4.816    -4.854    -0.039     (0)
   MgF+            3.408e-07   3.119e-07    -6.467    -6.506    -0.038     (0)
   CaF+            1.624e-07   1.488e-07    -6.789    -6.827    -0.038     (0)
   HF              4.127e-10   4.127e-10    -9.384    -9.384     0.000     (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000     (0)
   MnF+            2.582e-10   2.365e-10    -9.588    -9.626    -0.038     (0)
   CuF+            5.311e-11   4.808e-11   -10.275   -10.318    -0.043     (0)
   CoF+            3.255e-11   2.946e-11   -10.487   -10.531    -0.043     (0)
   NiF+            1.512e-11   1.369e-11   -10.820   -10.864    -0.043     (0)
   AlF2+           4.383e-12   4.020e-12   -11.358   -11.396    -0.038     (0)
   AlF+2           1.021e-12   7.220e-13   -11.991   -12.141    -0.150     (0)
   AlF3            7.077e-13   7.077e-13   -12.150   -12.150     0.000     (0)
   HF2-            2.403e-14   2.194e-14   -13.619   -13.659    -0.039     (0)
   AlF4-           5.420e-15   4.960e-15   -14.266   -14.304    -0.038     (0)
   H2F2            4.564e-19   4.564e-19   -18.341   -18.341     0.000     (0)
H(0)           5.627e-27
   H2              2.814e-27   2.818e-27   -26.551   -26.550     0.001     (0)
K              3.326e-04
   K+              3.298e-04   3.016e-04    -3.482    -3.521    -0.039     (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038     (0)
Mg             3.293e-04
   Mg+2            2.842e-04   1.988e-04    -3.546    -3.702    -0.155     (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000     (0)
   MgHCO3+         7.037e-07   6.434e-07    -6.153    -6.192    -0.039     (0)
   MgF+            3.408e-07   3.119e-07    -6.467    -6.506    -0.038     (0)
   MgCO3           1.229e-07   1.229e-07    -6.911    -6.911     0.000     (0)
   MgOH+           4.345e-08   3.994e-08    -7.362    -7.399    -0.037     (0)
Mn(2)          7.283e-07
   Mn+2            6.329e-07   4.249e-07    -6.199    -6.372    -0.173     (0)
   MnSO4           9.162e-08   9.162e-08    -7.038    -7.038     0.000     (0)
   MnHCO3+         2.926e-09   2.681e-09    -8.534    -8.572    -0.038     (0)
   MnOH+           5.878e-10   5.385e-10    -9.231    -9.269    -0.038     (0)
   MnF+            2.582e-10   2.365e-10    -9.588    -9.626    -0.038     (0)
   Mn(OH)3-        9.250e-19   8.475e-19   -18.034   -18.072    -0.038     (0)
   Mn(OH)4-2       1.959e-24   1.381e-24   -23.708   -23.860    -0.152     (0)
Mn(3)          4.240e-28
   Mn+3            4.240e-28   1.898e-28   -27.373   -27.722    -0.349     (0)
Mn(6)          0.000e+00
   MnO4-2          0.000e+00   0.000e+00   -47.042   -47.194    -0.152     (0)
Mn(7)          0.000e+00
   MnO4-           0.000e+00   0.000e+00   -52.526   -52.566    -0.040     (0)
Mo             3.128e-08
   MoO4-2          3.127e-08   2.188e-08    -7.505    -7.660    -0.155     (0)
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   HMoO4-          9.595e-12   8.685e-12   -11.018   -11.061    -0.043     (0)
   H2MoO4          1.269e-15   1.269e-15   -14.896   -14.896     0.000     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -51.065   -51.455    -0.389     (0)
   Mo7O24-6        0.000e+00   0.000e+00   -60.672   -62.230    -1.558     (0)
   HMo7O24-5       0.000e+00   0.000e+00   -62.461   -63.543    -1.082     (0)
   H2Mo7O24-4      0.000e+00   0.000e+00   -65.769   -66.461    -0.692     (0)
   H3Mo7O24-3      0.000e+00   0.000e+00   -70.526   -70.915    -0.389     (0)
Na             4.351e-05
   Na+             4.322e-05   3.953e-05    -4.364    -4.403    -0.039     (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   NaHCO3          7.030e-09   7.030e-09    -8.153    -8.153     0.000     (0)
   NaCO3-          5.965e-10   5.470e-10    -9.224    -9.262    -0.038     (0)
   NaF             3.488e-10   3.488e-10    -9.457    -9.457     0.000     (0)
Ni             6.818e-08
   Ni+2            5.569e-08   3.896e-08    -7.254    -7.409    -0.155     (0)
   NiSO4           9.427e-09   9.427e-09    -8.026    -8.026     0.000     (0)
   NiHCO3+         1.678e-09   1.519e-09    -8.775    -8.818    -0.043     (0)
   NiCO3           1.080e-09   1.080e-09    -8.967    -8.967     0.000     (0)
   NiOH+           2.734e-10   2.475e-10    -9.563    -9.606    -0.043     (0)
   NiF+            1.512e-11   1.369e-11   -10.820   -10.864    -0.043     (0)
   Ni(OH)2         9.921e-12   9.921e-12   -11.003   -11.003     0.000     (0)
   Ni(SO4)2-2      5.639e-13   3.785e-13   -12.249   -12.422    -0.173     (0)
   Ni(OH)3-        5.531e-15   5.006e-15   -14.257   -14.300    -0.043     (0)
O(0)           1.274e-39
   O2              6.370e-40   6.381e-40   -39.196   -39.195     0.001     (0)
S(6)           2.051e-03
   SO4-2           1.733e-03   1.213e-03    -2.761    -2.916    -0.155     (0)
   CaSO4           2.709e-04   2.709e-04    -3.567    -3.567     0.000     (0)
   MgSO4           4.387e-05   4.387e-05    -4.358    -4.358     0.000     (0)
   KSO4-           2.823e-06   2.589e-06    -5.549    -5.587    -0.038     (0)
   NaSO4-          2.807e-07   2.574e-07    -6.552    -6.589    -0.038     (0)
   MnSO4           9.162e-08   9.162e-08    -7.038    -7.038     0.000     (0)
   CoSO4           1.612e-08   1.612e-08    -7.793    -7.793     0.000     (0)
   CuSO4           1.514e-08   1.514e-08    -7.820    -7.820     0.000     (0)
   NiSO4           9.427e-09   9.427e-09    -8.026    -8.026     0.000     (0)
   HSO4-           2.583e-09   2.364e-09    -8.588    -8.626    -0.038     (0)
   Ni(SO4)2-2      5.639e-13   3.785e-13   -12.249   -12.422    -0.173     (0)
   AlSO4+          5.310e-14   4.860e-14   -13.275   -13.313    -0.038     (0)
   Al(SO4)2-       6.899e-16   6.315e-16   -15.161   -15.200    -0.038     (0)

-----------------------------Saturation indices-----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.99      8.81   10.80  Al(OH)3
  Al2(MoO4)3      -53.92    -51.55    2.37  Al2(MoO4)3
  Al2O3            -2.03     17.63   19.65  Al2O3
  Al4(OH)10SO4     -5.77     16.93   22.70  Al4(OH)10SO4
  AlOHSO4          -6.27     -9.50   -3.23  AlOHSO4
  Alunite          -4.61     -6.01   -1.40  KAl3(SO4)2(OH)6
  Anhydrite        -1.57     -5.93   -4.36  CaSO4
  Antlerite        -2.70      6.09    8.79  Cu3(OH)4SO4
  Aragonite        -0.84     -9.14   -8.30  CaCO3
  Artinite         -7.73      1.87    9.60  MgCO3:Mg(OH)2:3H2O
  Azurite          -1.74    -18.65  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -15.99      8.41   24.39  Ba(OH)2:8H2O
  BaF2            -10.88    -16.70   -5.82  BaF2
  BaMoO4           -7.69    -14.65   -6.96  BaMoO4
  Barite            0.07     -9.91   -9.98  BaSO4
  Birnessite      -11.01      7.08   18.09  MnO2
  Bixbyite         -8.60     -9.24   -0.64  Mn2O3
  Boehmite          0.23      8.81    8.58  AlOOH
  Brochantite      -0.99     14.23   15.22  Cu4(OH)6SO4
  Brucite          -5.15     11.70   16.84  Mg(OH)2
  Bunsenite        -4.45      7.99   12.45  NiO
  Calcite          -0.66     -9.14   -8.48  CaCO3
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  CaMoO4           -2.72    -10.67   -7.95  CaMoO4
  CH4(g)          -74.08   -115.13  -41.05  CH4
  Chalcanthite     -7.54    -10.18   -2.64  CuSO4:5H2O
  Co(OH)2          -4.87      8.22   13.09  Co(OH)2
  Co(OH)3         -10.17    -12.48   -2.31  Co(OH)3
  CO2(g)           -3.38    -21.53  -18.15  CO2
  Co3O4            -6.23    -16.73  -10.50  Co3O4
  CoCO3            -3.33    -13.31   -9.98  CoCO3
  CoF2            -15.29    -16.89   -1.60  CoF2
  CoF3            -48.68    -50.14   -1.46  CoF3
  CoMoO4           -7.08    -14.84   -7.76  CoMoO4
  CoO              -5.36      8.22   13.59  CoO
  CoSO4           -12.90    -10.09    2.80  CoSO4
  CoSO4:6H2O       -7.62    -10.09   -2.47  CoSO4:6H2O
  Cryolite        -22.78    -56.62  -33.84  Na3AlF6
  Cu(OH)2          -0.54      8.14    8.67  Cu(OH)2
  Cu2SO4          -18.11    -20.06   -1.95  Cu2SO4
  CuCO3            -1.89    -13.39  -11.50  CuCO3
  CuF              -8.52    -13.43   -4.91  CuF
  CuF2            -18.09    -16.97    1.12  CuF2
  CuF2:2H2O       -12.42    -16.97   -4.55  CuF2:2H2O
  Cumetal          -3.82    -12.57   -8.76  Cu
  CuMoO4           -1.85    -14.92  -13.08  CuMoO4
  CuOCuSO4        -12.35     -2.04   10.30  CuOCuSO4
  Cuprite          -0.34     -1.75   -1.41  Cu2O
  CuSO4           -13.12    -10.18    2.94  CuSO4
  Diaspore          1.94      8.81    6.87  AlOOH
  Dolomite(disordered)  -2.43    -18.97  -16.54  CaMg(CO3)2
  Dolomite(ordered)     -1.88    -18.97  -17.09  CaMg(CO3)2
  Epsomite         -4.49     -6.62   -2.13  MgSO4:7H2O
  Fluorite         -2.22    -12.72  -10.50  CaF2
  Gibbsite          0.52      8.81    8.29  Al(OH)3
  Gypsum           -1.32     -5.93   -4.61  CaSO4:2H2O
  H2MoO4          -10.18    -23.06  -12.88  H2MoO4
  Hausmannite     -10.55     50.48   61.03  Mn3O4
  Huntite          -8.66    -38.63  -29.97  CaMg3(CO3)4
  Hydromagnesite  -18.86    -27.62   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum          -18.47    -23.64   -5.17  KAl(SO4)2:12H2O
  K2MoO4          -17.96    -14.70    3.26  K2MoO4
  Langite          -3.26     14.23   17.49  Cu4(OH)6SO4:H2O
  Lime            -20.31     12.39   32.70  CaO
  Magnesite        -2.37     -9.83   -7.46  MgCO3
  Malachite         0.05     -5.26   -5.31  Cu2(OH)2CO3
  Manganite        -4.61     20.73   25.34  MnOOH
  Mg(OH)2(active)  -7.10     11.70   18.79  Mg(OH)2
  MgF2             -5.28    -13.41   -8.13  MgF2
  MgMoO4           -9.51    -11.36   -1.85  MgMoO4
  Mirabilite      -10.61    -11.72   -1.11  Na2SO4:10H2O
  Mn2(SO4)3       -58.48    -64.19   -5.71  Mn2(SO4)3
  MnSO4           -11.87     -9.29    2.58  MnSO4
  MoO3            -15.06    -23.06   -8.00  MoO3
  Morenosite       -8.18    -10.33   -2.14  NiSO4:7H2O
  Na2Mo2O7        -22.93    -39.53  -16.60  Na2Mo2O7
  Na2MoO4         -17.96    -16.47    1.49  Na2MoO4
  Na2MoO4:2H2O    -17.69    -16.47    1.22  Na2MoO4:2H2O
  Natron          -13.62    -14.94   -1.31  Na2CO3:10H2O
  Nesquehonite     -5.16     -9.83   -4.67  MgCO3:3H2O
  Ni(OH)2          -4.80      7.99   12.79  Ni(OH)2
  Ni4(OH)6SO4     -18.35     13.65   32.00  Ni4(OH)6SO4
  NiCO3            -6.67    -13.54   -6.87  NiCO3
  NiMoO4           -3.93    -15.07  -11.14  NiMoO4
  Nsutite         -10.43      7.08   17.50  MnO2
  O2(g)           -36.29     46.80   83.09  O2
  Periclase        -9.89     11.70   21.58  MgO
  Portlandite     -10.42     12.39   22.80  Ca(OH)2
  Pyrochroite      -6.17      9.03   15.19  Mn(OH)2
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  Pyrolusite       -8.95     32.43   41.38  MnO2
  Retgersite       -8.29    -10.33   -2.04  NiSO4:6H2O
  Rhodochrosite    -1.92    -12.50  -10.58  MnCO3
  Spinel           -7.52     29.32   36.85  MgAl2O4
  Tenorite          0.49      8.14    7.64  CuO
  Thenardite      -12.04    -11.72    0.32  Na2SO4
  Thermonatrite   -15.57    -14.94    0.64  Na2CO3:H2O
  Witherite        -4.55    -13.12   -8.57  BaCO3

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

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Beginning of batch-reaction calculations.
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Reaction step 1.

Using mix 1.      Mix within UG Works

Mixture 1.  Mix within UG Works

        2.350e-01 Solution 1  UG Water P100
        1.220e-01 Solution 2  PAF Material
        4.420e-01 Solution 3  NAF Material
        2.010e-01 Solution 4  Make-up Material

----------------------------Solution composition----------------------------

      Elements           Molality       Moles

      Al                3.237e-06   3.237e-06
      As                1.793e-07   1.793e-07
      B                 3.019e-06   3.019e-06
      Ba                4.132e-07   4.132e-07
      C                 2.448e-03   2.448e-03
      Ca                2.571e-03   2.571e-03
      Cd                1.319e-08   1.319e-08
      Cl                3.339e-04   3.339e-04
      Co                6.776e-08   6.776e-08
      Cr                3.213e-08   3.213e-08
      Cu                5.071e-07   5.071e-07
      F                 2.546e-05   2.546e-05
      Fe                1.256e-06   1.256e-06
      K                 5.015e-04   5.015e-04
      Mg                1.006e-03   1.006e-03
      Mn                1.599e-06   1.599e-06
      Mo                6.724e-08   6.724e-08
      Na                2.331e-03   2.331e-03
      Ni                5.121e-08   5.121e-08
      Pb                4.418e-08   4.418e-08
      S                 2.969e-03   2.969e-03
      Se                6.110e-08   6.110e-08
      U                 1.056e-08   1.056e-08
      V                 1.201e-08   1.201e-08
      Zn                6.391e-07   6.391e-07

---------------------------Description of solution---------------------------

                                       pH  =   8.069      Charge balance
                                       pe  =   3.208      Adjusted to redox equilibrium
                             Activity of water  =   1.000
                       Ionic strength (mol/kgw)  =   1.335e-02
                            Mass of water (kg)  =   1.000e+00
                       Total alkalinity (eq/kg)  =   2.471e-03
                             Total CO2 (mol/kg)  =   2.448e-03
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                    Temperature (°C)  =  25.00
              Electrical balance (eq)  =   1.235e-03
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =   7.66
                           Iterations  =   9
                              Total H  = 1.110161e+02
                              Total O  = 5.552608e+01

----------------------------Distribution of species----------------------------

                                                  Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma    cm³/mol

   OH-             1.329e-06   1.179e-06    -5.876    -5.928    -0.052     (0)
   H+              9.598e-09   8.539e-09    -8.018    -8.069    -0.051      0.00
   H2O             5.551e+01   9.998e-01     1.744    -0.000     0.000     18.07
Al            3.237e-06
   Al(OH)4-        3.217e-06   2.865e-06    -5.493    -5.543    -0.050     (0)
   Al(OH)3         1.930e-08   1.930e-08    -7.714    -7.714     0.000     (0)
   Al(OH)2+        9.183e-10   8.205e-10    -9.037    -9.086    -0.049     (0)
   AlF2+           1.471e-12   1.314e-12   -11.832   -11.881    -0.049     (0)
   AlOH+2          1.375e-12   8.762e-13   -11.862   -12.057    -0.196     (0)
   AlF3            3.488e-13   3.488e-13   -12.457   -12.457     0.000     (0)
   AlF+2           2.458e-13   1.566e-13   -12.609   -12.805    -0.196     (0)
   AlSO4+          9.599e-15   8.549e-15   -14.018   -14.068    -0.050     (0)
   AlF4-           4.137e-15   3.685e-15   -14.383   -14.434    -0.050     (0)
   Al+3            2.129e-15   7.432e-16   -14.672   -15.129    -0.457     (0)
   Al(SO4)2-       1.524e-16   1.357e-16   -15.817   -15.867    -0.050     (0)
   AlMo6O21-3      0.000e+00   0.000e+00   -52.270   -52.801    -0.530     (0)
As(3)         2.700e-18
   H3AsO3          2.526e-18   2.526e-18   -17.598   -17.598     0.000     (0)
   H2AsO3-         1.738e-19   1.517e-19   -18.760   -18.819    -0.059     (0)
   HAsO3-2         2.788e-23   1.620e-23   -22.555   -22.790    -0.236     (0)
   H4AsO3+         1.224e-26   1.069e-26   -25.912   -25.971    -0.059     (0)
   AsO3-3          2.481e-28   7.315e-29   -27.605   -28.136    -0.530     (0)
As(5)         1.793e-07
   HAsO4-2         1.704e-07   9.902e-08    -6.769    -7.004    -0.236     (0)
   H2AsO4-         8.832e-09   7.711e-09    -8.054    -8.113    -0.059     (0)
   AsO4-3          1.244e-10   3.667e-11    -9.905   -10.436    -0.530     (0)
   H3AsO4          1.141e-14   1.144e-14   -13.943   -13.941     0.001     (0)
B             3.019e-06
   H3BO3           2.784e-06   2.792e-06    -5.555    -5.554     0.001     (0)
   H2BO3-          2.150e-07   1.899e-07    -6.668    -6.721    -0.054     (0)
   CaH2BO3+        1.593e-08   1.407e-08    -7.798    -7.852    -0.054     (0)
   MgH2BO3+        3.943e-09   3.483e-09    -8.404    -8.458    -0.054     (0)
   NaH2BO3         6.186e-10   6.186e-10    -9.209    -9.209     0.000     (0)
   BF(OH)3-        2.658e-11   2.349e-11   -10.575   -10.629    -0.054     (0)
   BaH2BO3+        1.690e-12   1.493e-12   -11.772   -11.826    -0.054     (0)
   H5(BO3)2-       5.109e-13   4.514e-13   -12.292   -12.345    -0.054     (0)
   BF2(OH)2-       5.116e-16   4.520e-16   -15.291   -15.345    -0.054     (0)
   H8(BO3)3-       1.427e-16   1.260e-16   -15.846   -15.899    -0.054     (0)
   BF3OH-          3.583e-23   3.166e-23   -22.446   -22.500    -0.054     (0)
   BF4-            3.174e-29   2.804e-29   -28.498   -28.552    -0.054     (0)
Ba            4.132e-07
   Ba+2            4.062e-07   2.544e-07    -6.391    -6.594    -0.203     (0)
   BaHCO3+         5.557e-09   4.976e-09    -8.255    -8.303    -0.048     (0)
   BaCO3           1.467e-09   1.467e-09    -8.834    -8.834     0.000     (0)
   BaH2BO3+        1.690e-12   1.493e-12   -11.772   -11.826    -0.054     (0)
   BaOH+           1.468e-12   1.309e-12   -11.833   -11.883    -0.050     (0)
C(4)          2.448e-03
   HCO3-           2.292e-03   2.048e-03    -2.640    -2.689    -0.049     (0)
   CaHCO3+         5.484e-05   4.910e-05    -4.261    -4.309    -0.048     (0)
   H2CO3           3.932e-05   3.932e-05    -4.405    -4.405     0.000     (0)
   CaCO3           2.294e-05   2.294e-05    -4.639    -4.639     0.000     (0)
   CO3-2           1.795e-05   1.124e-05    -4.746    -4.949    -0.203     (0)
   MgHCO3+         1.247e-05   1.108e-05    -4.904    -4.955    -0.051     (0)
   MgCO3           4.946e-06   4.946e-06    -5.306    -5.306     0.000     (0)
   NaHCO3          2.366e-06   2.366e-06    -5.626    -5.626     0.000     (0)
   NaCO3-          4.815e-07   4.302e-07    -6.317    -6.366    -0.049     (0)
   CuCO3           4.344e-07   4.344e-07    -6.362    -6.362     0.000     (0)
   ZnCO3           1.472e-07   1.472e-07    -6.832    -6.832     0.000     (0)
   MnHCO3+         3.598e-08   3.210e-08    -7.444    -7.493    -0.050     (0)
   PbCO3           3.450e-08   3.450e-08    -7.462    -7.462     0.000     (0)
   Cu(CO3)2-2      2.262e-08   1.314e-08    -7.646    -7.881    -0.236     (0)
   ZnHCO3+         1.688e-08   1.474e-08    -7.773    -7.832    -0.059     (0)
   NiCO3           8.196e-09   8.196e-09    -8.086    -8.086     0.000     (0)
   UO2(CO3)3-4     7.825e-09   8.925e-10    -8.107    -9.049    -0.943     (0)
   NiHCO3+         5.650e-09   4.933e-09    -8.248    -8.307    -0.059     (0)
   BaHCO3+         5.557e-09   4.976e-09    -8.255    -8.303    -0.048     (0)
   CoCO3           5.321e-09   5.321e-09    -8.274    -8.274     0.000     (0)
   CoHCO3+         5.108e-09   4.460e-09    -8.292    -8.351    -0.059     (0)
   UO2(CO3)2-2     2.726e-09   1.584e-09    -8.565    -8.800    -0.236     (0)
   Pb(CO3)2-2      1.925e-09   1.119e-09    -8.716    -8.951    -0.236     (0)
   PbHCO3+         1.779e-09   1.553e-09    -8.750    -8.809    -0.059     (0)
   CdCO3           1.491e-09   1.491e-09    -8.826    -8.826     0.000     (0)
   BaCO3           1.467e-09   1.467e-09    -8.834    -8.834     0.000     (0)
   CuHCO3+         9.711e-10   8.479e-10    -9.013    -9.072    -0.059     (0)
   FeHCO3+         2.672e-10   2.392e-10    -9.573    -9.621    -0.048     (0)
   CdHCO3+         3.108e-11   2.713e-11   -10.508   -10.567    -0.059     (0)
   Cd(CO3)2-2      2.139e-11   1.243e-11   -10.670   -10.906    -0.236     (0)
   UO2CO3          7.062e-12   7.062e-12   -11.151   -11.151     0.000     (0)
Ca            2.571e-03
   Ca+2            2.056e-03   1.288e-03    -2.687    -2.890    -0.203     (0)
   CaSO4           4.371e-04   4.371e-04    -3.359    -3.359     0.000     (0)
   CaHCO3+         5.484e-05   4.910e-05    -4.261    -4.309    -0.048     (0)
   CaCO3           2.294e-05   2.294e-05    -4.639    -4.639     0.000     (0)
   CaF+            3.320e-07   2.962e-07    -6.479    -6.528    -0.050     (0)
   CaOH+           3.383e-08   3.029e-08    -7.471    -7.519    -0.048     (0)
   CaH2BO3+        1.593e-08   1.407e-08    -7.798    -7.852    -0.054     (0)
Cd            1.319e-08
   Cd+2            9.291e-09   5.820e-09    -8.032    -8.235    -0.203     (0)
   CdSO4           2.022e-09   2.022e-09    -8.694    -8.694     0.000     (0)
   CdCO3           1.491e-09   1.491e-09    -8.826    -8.826     0.000     (0)
   CdCl+           1.891e-10   1.651e-10    -9.723    -9.782    -0.059     (0)
   Cd(SO4)2-2      6.955e-11   4.042e-11   -10.158   -10.393    -0.236     (0)
   CdOH+           6.243e-11   5.450e-11   -10.205   -10.264    -0.059     (0)
   CdHCO3+         3.108e-11   2.713e-11   -10.508   -10.567    -0.059     (0)
   Cd(CO3)2-2      2.139e-11   1.243e-11   -10.670   -10.906    -0.236     (0)
   CdOHCl          7.984e-12   7.984e-12   -11.098   -11.098     0.000     (0)
   CdF+            2.227e-12   1.944e-12   -11.652   -11.711    -0.059     (0)
   Cd(OH)2         4.054e-13   4.054e-13   -12.392   -12.392     0.000     (0)
   CdCl2           2.044e-13   2.044e-13   -12.689   -12.689     0.000     (0)
   CdF2            8.177e-17   8.177e-17   -16.087   -16.087     0.000     (0)
   CdCl3-          4.388e-17   3.831e-17   -16.358   -16.417    -0.059     (0)
   Cd(OH)3-        3.345e-17   2.920e-17   -16.476   -16.535    -0.059     (0)
   Cd2OH+3         5.392e-18   1.590e-18   -17.268   -17.799    -0.530     (0)
   Cd(SeO3)2-2     1.765e-18   1.026e-18   -17.753   -17.989    -0.236     (0)
   CdSeO4          7.016e-20   7.016e-20   -19.154   -19.154     0.000     (0)
   Cd(OH)4-2       9.697e-24   5.636e-24   -23.013   -23.249    -0.236     (0)
   CdHS+           0.000e+00   0.000e+00   -67.622   -67.681    -0.059     (0)
   Cd(HS)2         0.000e+00   0.000e+00  -127.931  -127.931     0.000     (0)
   Cd(HS)3-        0.000e+00   0.000e+00  -193.426  -193.485    -0.059     (0)
   Cd(HS)4-2       0.000e+00   0.000e+00  -258.508  -258.743    -0.236     (0)
Cl            3.339e-04
   Cl-             3.339e-04   2.970e-04    -3.476    -3.527    -0.051     (0)
   CuCl            7.437e-10   7.437e-10    -9.129    -9.129     0.000     (0)
   MnCl+           3.293e-10   2.938e-10    -9.482    -9.532    -0.050     (0)
   ZnOHCl          2.621e-10   2.621e-10    -9.582    -9.582     0.000     (0)
   ZnCl+           1.910e-10   1.698e-10    -9.719    -9.770    -0.051     (0)
   CdCl+           1.891e-10   1.651e-10    -9.723    -9.782    -0.059     (0)
   CuCl2-          5.192e-11   4.615e-11   -10.285   -10.336    -0.051     (0)
   CoCl+           3.295e-11   2.877e-11   -10.482   -10.541    -0.059     (0)
   NiCl+           1.701e-11   1.485e-11   -10.769   -10.828    -0.059     (0)
   PbCl+           1.232e-11   1.076e-11   -10.909   -10.968    -0.059     (0)
   CdOHCl          7.984e-12   7.984e-12   -11.098   -11.098     0.000     (0)
   CuCl+           3.476e-12   3.089e-12   -11.459   -11.510    -0.051     (0)
   CdCl2           2.044e-13   2.044e-13   -12.689   -12.689     0.000     (0)
   MnCl2           1.233e-13   1.233e-13   -12.909   -12.909     0.000     (0)
   ZnCl2           7.993e-14   7.993e-14   -13.097   -13.097     0.000     (0)
   PbCl2           1.428e-14   1.428e-14   -13.845   -13.845     0.000     (0)
   CuCl3-2         4.625e-15   2.931e-15   -14.335   -14.533    -0.198     (0)
   CuCl2           3.182e-16   3.182e-16   -15.497   -15.497     0.000     (0)
   CdCl3-          4.388e-17   3.831e-17   -16.358   -16.417    -0.059     (0)
   NiCl2           2.221e-17   2.221e-17   -16.653   -16.653     0.000     (0)
   ZnCl3-          2.122e-17   1.886e-17   -16.673   -16.725    -0.051     (0)
   MnCl3-          1.130e-17   1.008e-17   -16.947   -16.996    -0.050     (0)
   CrCl+2          3.472e-18   2.018e-18   -17.459   -17.695    -0.236     (0)
   PbCl3-          1.933e-18   1.688e-18   -17.714   -17.773    -0.059     (0)
   UO2Cl+          8.706e-20   7.601e-20   -19.060   -19.119    -0.059     (0)
   FeCl+2          1.972e-20   1.250e-20   -19.705   -19.903    -0.198     (0)
   CrOHCl2         1.343e-20   1.343e-20   -19.872   -19.872     0.000     (0)
   ZnCl4-2         4.420e-21   2.801e-21   -20.355   -20.553    -0.198     (0)
   CuCl3-          9.922e-22   8.820e-22   -21.003   -21.055    -0.051     (0)
   PbCl4-2         3.944e-22   2.292e-22   -21.404   -21.640    -0.236     (0)
   CrCl2+          6.512e-23   5.686e-23   -22.186   -22.245    -0.059     (0)
   VOCl+           3.646e-23   3.183e-23   -22.438   -22.497    -0.059     (0)
   FeCl2+          1.859e-23   1.658e-23   -22.731   -22.780    -0.050     (0)
   CuCl4-2         2.072e-27   1.313e-27   -26.684   -26.882    -0.198     (0)
   FeCl3           4.926e-28   4.926e-28   -27.308   -27.308     0.000     (0)
   CrO3Cl-         4.490e-30   3.921e-30   -29.348   -29.407    -0.059     (0)
   CoCl+2          1.874e-38   1.089e-38   -37.727   -37.963    -0.236     (0)
   UCl+3           0.000e+00   0.000e+00   -46.574   -47.104    -0.530     (0)
Co(2)         6.776e-08
   Co+2            4.818e-08   2.800e-08    -7.317    -7.553    -0.236     (0)
   CoSO4           8.279e-09   8.279e-09    -8.082    -8.082     0.000     (0)
   CoCO3           5.321e-09   5.321e-09    -8.274    -8.274     0.000     (0)
   CoHCO3+         5.108e-09   4.460e-09    -8.292    -8.351    -0.059     (0)
   CoOH+           7.544e-10   6.587e-10    -9.122    -9.181    -0.059     (0)
   Co(OH)2         6.168e-11   6.168e-11   -10.210   -10.210     0.000     (0)
   CoCl+           3.295e-11   2.877e-11   -10.482   -10.541    -0.059     (0)
   CoF+            2.138e-11   1.866e-11   -10.670   -10.729    -0.059     (0)
   Co(OH)3-        1.662e-15   1.451e-15   -14.779   -14.838    -0.059     (0)
   CoOOH-          4.170e-16   3.641e-16   -15.380   -15.439    -0.059     (0)
   Co2OH+3         3.135e-18   9.243e-19   -17.504   -18.034    -0.530     (0)
   CoSeO4          9.085e-19   9.085e-19   -18.042   -18.042     0.000     (0)
   Co(OH)4-2       4.665e-22   2.711e-22   -21.331   -21.567    -0.236     (0)
   Co4(OH)4+4      3.292e-28   3.756e-29   -27.482   -28.425    -0.943     (0)
Co(3)         1.857e-30
   CoOH+2          1.857e-30   1.079e-30   -29.731   -29.967    -0.236     (0)
   Co+3            5.161e-37   1.802e-37   -36.287   -36.744    -0.457     (0)
   CoCl+2          1.874e-38   1.089e-38   -37.727   -37.963    -0.236     (0)
Cr(2)         1.335e-24
   Cr+2            1.335e-24   7.758e-25   -23.875   -24.110    -0.236     (0)
Cr(3)         3.213e-08
   Cr(OH)2+        2.224e-08   1.942e-08    -7.653    -7.712    -0.059     (0)
   Cr(OH)3         8.601e-09   8.601e-09    -8.065    -8.065     0.000     (0)
   CrO2-           5.479e-10   4.784e-10    -9.261    -9.320    -0.059     (0)
   Cr(OH)4-        4.623e-10   4.037e-10    -9.335    -9.394    -0.059     (0)
   Cr(OH)+2        2.329e-10   1.354e-10    -9.633    -9.868    -0.236     (0)
   CrOHSO4         4.760e-11   4.760e-11   -10.322   -10.322     0.000     (0)
   CrF+2           3.017e-14   1.753e-14   -13.520   -13.756    -0.236     (0)
   CrSO4+          2.080e-14   1.816e-14   -13.682   -13.741    -0.059     (0)
   Cr+3            1.780e-14   5.248e-15   -13.750   -14.280    -0.530     (0)
   CrCl+2          3.472e-18   2.018e-18   -17.459   -17.695    -0.236     (0)
   Cr2(OH)2SO4+2   1.002e-18   5.825e-19   -17.999   -18.235    -0.236     (0)
   Cr2(OH)2(SO4)2   5.127e-20   5.127e-20   -19.290   -19.290     0.000     (0)
   CrOHCl2         1.343e-20   1.343e-20   -19.872   -19.872     0.000     (0)
   CrCl2+          6.512e-23   5.686e-23   -22.186   -22.245    -0.059     (0)
Cr(6)         1.460e-17
   CrO4-2          1.420e-17   8.893e-18   -16.848   -17.051    -0.203     (0)
   HCrO4-          2.814e-19   2.457e-19   -18.551   -18.610    -0.059     (0)
   NaCrO4-         1.040e-19   9.082e-20   -18.983   -19.042    -0.059     (0)
   KCrO4-          1.671e-20   1.459e-20   -19.777   -19.836    -0.059     (0)
   H2CrO4          1.701e-27   1.701e-27   -26.769   -26.769     0.000     (0)
   CrO3SO4-2       1.630e-27   9.473e-28   -26.788   -27.024    -0.236     (0)
   CrO3Cl-         4.490e-30   3.921e-30   -29.348   -29.407    -0.059     (0)
   Cr2O7-2         3.604e-36   2.094e-36   -35.443   -35.679    -0.236     (0)
Cu(1)         3.073e-09
   Cu+             2.278e-09   1.989e-09    -8.642    -8.701    -0.059     (0)
   CuCl            7.437e-10   7.437e-10    -9.129    -9.129     0.000     (0)
   CuCl2-          5.192e-11   4.615e-11   -10.285   -10.336    -0.051     (0)
   CuCl3-2         4.625e-15   2.931e-15   -14.335   -14.533    -0.198     (0)
   Cu(S4)2-3       0.000e+00   0.000e+00  -123.799  -124.082    -0.283     (0)
   CuS4S5-3        0.000e+00   0.000e+00  -124.540  -124.812    -0.272     (0)
Cu(2)         5.041e-07
   CuCO3           4.344e-07   4.344e-07    -6.362    -6.362     0.000     (0)
   CuOH+           2.753e-08   2.447e-08    -7.560    -7.611    -0.051     (0)
   Cu(CO3)2-2      2.262e-08   1.314e-08    -7.646    -7.881    -0.236     (0)
   Cu+2            1.048e-08   6.563e-09    -7.980    -8.183    -0.203     (0)
   Cu(OH)2         5.755e-09   5.755e-09    -8.240    -8.240     0.000     (0)
   CuSO4           2.228e-09   2.228e-09    -8.652    -8.652     0.000     (0)
   CuHCO3+         9.711e-10   8.479e-10    -9.013    -9.072    -0.059     (0)
   Cu2(OH)2+2      2.587e-11   1.504e-11   -10.587   -10.823    -0.236     (0)
   Cu(OH)3-        1.594e-11   1.392e-11   -10.797   -10.856    -0.059     (0)
   CuF+            9.996e-12   8.728e-12   -11.000   -11.059    -0.059     (0)
   CuCl+           3.476e-12   3.089e-12   -11.459   -11.510    -0.051     (0)
   CuCl2           3.182e-16   3.182e-16   -15.497   -15.497     0.000     (0)
   Cu(OH)4-2       2.222e-16   1.291e-16   -15.653   -15.889    -0.236     (0)
   CuCl3-          9.922e-22   8.820e-22   -21.003   -21.055    -0.051     (0)
   CuCl4-2         2.072e-27   1.313e-27   -26.684   -26.882    -0.198     (0)
   Cu(HS)3-        0.000e+00   0.000e+00  -184.587  -184.646    -0.059     (0)
F             2.546e-05
   F-              2.369e-05   2.108e-05    -4.625    -4.676    -0.051     (0)
   MgF+            1.405e-06   1.251e-06    -5.852    -5.903    -0.050     (0)
   CaF+            3.320e-07   2.962e-07    -6.479    -6.528    -0.050     (0)
   NaF             2.733e-08   2.733e-08    -7.563    -7.563     0.000     (0)
   MnF+            7.389e-10   6.593e-10    -9.131    -9.181    -0.050     (0)
   HF              2.662e-10   2.662e-10    -9.575    -9.575     0.000     (0)
   ZnF+            1.096e-10   9.571e-11    -9.960   -10.019    -0.059     (0)
   BF(OH)3-        2.658e-11   2.349e-11   -10.575   -10.629    -0.054     (0)
   CoF+            2.138e-11   1.866e-11   -10.670   -10.729    -0.059     (0)
   NiF+            1.185e-11   1.035e-11   -10.926   -10.985    -0.059     (0)
   CuF+            9.996e-12   8.728e-12   -11.000   -11.059    -0.059     (0)
   CdF+            2.227e-12   1.944e-12   -11.652   -11.711    -0.059     (0)
   PbF+            1.737e-12   1.517e-12   -11.760   -11.819    -0.059     (0)
   AlF2+           1.471e-12   1.314e-12   -11.832   -11.881    -0.049     (0)
   AlF3            3.488e-13   3.488e-13   -12.457   -12.457     0.000     (0)
   AlF+2           2.458e-13   1.566e-13   -12.609   -12.805    -0.196     (0)
   CrF+2           3.017e-14   1.753e-14   -13.520   -13.756    -0.236     (0)
   HF2-            2.405e-14   2.133e-14   -13.619   -13.671    -0.052     (0)
   AlF4-           4.137e-15   3.685e-15   -14.383   -14.434    -0.050     (0)
   PbF2            6.290e-16   6.290e-16   -15.201   -15.201     0.000     (0)
   UO2F+           5.258e-16   4.591e-16   -15.279   -15.338    -0.059     (0)
   BF2(OH)2-       5.116e-16   4.520e-16   -15.291   -15.345    -0.054     (0)
   CdF2            8.177e-17   8.177e-17   -16.087   -16.087     0.000     (0)
   FeF+2           5.082e-17   3.220e-17   -16.294   -16.492    -0.198     (0)
   UO2F2           2.791e-17   2.791e-17   -16.554   -16.554     0.000     (0)
   FeF2+           2.036e-17   1.817e-17   -16.691   -16.741    -0.050     (0)
   FeF3            5.402e-19   5.402e-19   -18.267   -18.267     0.000     (0)
   VO2F            3.913e-19   3.913e-19   -18.408   -18.408     0.000     (0)
   H2F2            1.899e-19   1.899e-19   -18.722   -18.722     0.000     (0)
   UO2F3-          1.692e-19   1.478e-19   -18.771   -18.830    -0.059     (0)
   PbF3-           2.880e-20   2.515e-20   -19.541   -19.600    -0.059     (0)
   VOF+            5.531e-21   4.829e-21   -20.257   -20.316    -0.059     (0)
   VO2F2-          3.429e-21   2.994e-21   -20.465   -20.524    -0.059     (0)
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UO2F4-2	4.257e-23	2.474e-23	-22.371	-22.607	-0.236	(0)
VOF2	3.817e-23	3.817e-23	-22.418	-22.418	0.000	(0)
BF3OH-	3.583e-23	3.166e-23	-22.446	-22.500	-0.054	(0)
VO2F3-2	1.355e-24	7.872e-25	-23.868	-24.104	-0.236	(0)
PbF4-2	4.366e-25	2.537e-25	-24.360	-24.596	-0.236	(0)
VOF3-	3.269e-26	2.854e-26	-25.486	-25.544	-0.059	(0)
BF4-	3.174e-29	2.804e-29	-28.498	-28.552	-0.054	(0)
VO2F4-3	2.769e-29	8.165e-30	-28.558	-29.088	-0.530	(0)
VOF4-2	4.179e-30	2.429e-30	-29.379	-29.615	-0.236	(0)
UF3+	2.256e-38	1.970e-38	-37.647	-37.706	-0.059	(0)
UF2+2	1.015e-38	5.897e-39	-37.994	-38.229	-0.236	(0)
UF+3	0.000e+00	0.000e+00	-40.123	-40.653	-0.530	(0)
UF4	0.000e+00	0.000e+00	-40.342	-40.342	0.000	(0)
UF5-	0.000e+00	0.000e+00	-43.361	-43.420	-0.059	(0)
UF6-2	0.000e+00	0.000e+00	-45.380	-45.616	-0.236	(0)
Fe(2)	2.010e-08					
Fe+2	1.597e-08	9.281e-09	-7.797	-8.032	-0.236	(0)
FeSO4	3.376e-09	3.376e-09	-8.472	-8.472	0.000	(0)
FeOH+	4.882e-10	4.356e-10	-9.311	-9.361	-0.050	(0)
FeHCO3+	2.672e-10	2.392e-10	-9.573	-9.621	-0.048	(0)
Fe(OH)2	4.079e-13	4.079e-13	-12.389	-12.389	0.000	(0)
Fe(OH)3-	1.705e-13	1.521e-13	-12.768	-12.818	-0.050	(0)
Fe(HS)2	0.000e+00	0.000e+00	-133.991	-133.991	0.000	(0)
Fe(HS)3-	0.000e+00	0.000e+00	-199.349	-199.408	-0.059	(0)
Fe(3)	1.236e-06					
Fe(OH)3	6.160e-07	6.160e-07	-6.210	-6.210	0.000	(0)
Fe(OH)2+	5.445e-07	4.865e-07	-6.264	-6.313	-0.049	(0)
Fe(OH)4-	7.568e-08	6.762e-08	-7.121	-7.170	-0.049	(0)
FeOH+2	1.674e-12	1.061e-12	-11.776	-11.974	-0.198	(0)
FeF+2	5.082e-17	3.220e-17	-16.294	-16.492	-0.198	(0)
FeSO4+	2.597e-17	2.317e-17	-16.586	-16.635	-0.050	(0)
FeF2+	2.036e-17	1.817e-17	-16.691	-16.741	-0.050	(0)
Fe+3	3.991e-18	1.393e-18	-17.399	-17.856	-0.457	(0)
Fe(SO4)2-	8.407e-19	7.340e-19	-18.075	-18.134	-0.059	(0)
FeF3	5.402e-19	5.402e-19	-18.267	-18.267	0.000	(0)
FeCl+2	1.972e-20	1.250e-20	-19.705	-19.903	-0.198	(0)
Fe2(OH)2+4	3.266e-22	3.725e-23	-21.486	-22.429	-0.943	(0)
FeHSeO3+2	1.988e-22	1.155e-22	-21.702	-21.937	-0.236	(0)
FeCl2+	1.859e-23	1.658e-23	-22.731	-22.780	-0.050	(0)
Fe3(OH)4+5	7.789e-27	2.620e-28	-26.109	-27.582	-1.473	(0)
FeCl3	4.926e-28	4.926e-28	-27.308	-27.308	0.000	(0)
H(0)	3.940e-26					
H2	1.970e-26	1.976e-26	-25.705	-25.704	0.001	(0)
K	5.015e-04					
K+	4.963e-04	4.415e-04	-3.304	-3.355	-0.051	(0)
KSO4-	5.184e-06	4.632e-06	-5.285	-5.334	-0.049	(0)
KCrO4-	1.671e-20	1.459e-20	-19.777	-19.836	-0.059	(0)
Mg	1.006e-03					
Mg+2	8.443e-04	5.289e-04	-3.073	-3.277	-0.203	(0)
MgSO4	1.426e-04	1.426e-04	-3.846	-3.846	0.000	(0)
MgHCO3+	1.247e-05	1.108e-05	-4.904	-4.955	-0.051	(0)
MgCO3	4.946e-06	4.946e-06	-5.306	-5.306	0.000	(0)
MgF+	1.405e-06	1.251e-06	-5.852	-5.903	-0.050	(0)
MgOH+	2.768e-07	2.482e-07	-6.558	-6.605	-0.047	(0)
MgH2BO3+	3.943e-09	3.483e-09	-8.404	-8.458	-0.054	(0)
Mn(2)	1.599e-06					
Mn+2	1.352e-06	7.857e-07	-5.869	-6.105	-0.236	(0)
MnSO4	2.070e-07	2.070e-07	-6.684	-6.684	0.000	(0)
MnHCO3+	3.598e-08	3.210e-08	-7.444	-7.493	-0.050	(0)
MnOH+	2.608e-09	2.327e-09	-8.584	-8.633	-0.050	(0)
MnF+	7.389e-10	6.593e-10	-9.131	-9.181	-0.050	(0)
MnCl+	3.293e-10	2.938e-10	-9.482	-9.532	-0.050	(0)
MnCl2	1.233e-13	1.233e-13	-12.909	-12.909	0.000	(0)
Mn(OH)3-	2.240e-17	1.999e-17	-16.650	-16.699	-0.050	(0)
MnSeO4	1.369e-17	1.369e-17	-16.864	-16.864	0.000	(0)
MnCl3-	1.130e-17	1.008e-17	-16.947	-16.996	-0.050	(0)

Mn(OH)4-2	1.201e-22	7.608e-23	-21.921	-22.119	-0.198	(0)
MnSe	1.876e-34	1.876e-34	-33.727	-33.727	0.000	(0)
Mn(3)	1.625e-28					
Mn+3	1.625e-28	5.672e-29	-27.789	-28.246	-0.457	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-46.946	-47.144	-0.198	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-53.255	-53.308	-0.053	(0)
Mo	6.724e-08					
MoO4-2	6.724e-08	4.212e-08	-7.172	-7.376	-0.203	(0)
HMoO4-	8.196e-12	7.156e-12	-11.086	-11.145	-0.059	(0)
H2MoO4	4.476e-16	4.476e-16	-15.349	-15.349	0.000	(0)
AlMo6O21-3	0.000e+00	0.000e+00	-52.270	-52.801	-0.530	(0)
Mo7O24-6	0.000e+00	0.000e+00	-61.066	-63.187	-2.121	(0)
HMo7O24-5	0.000e+00	0.000e+00	-63.396	-64.869	-1.473	(0)
H2Mo7O24-4	0.000e+00	0.000e+00	-67.212	-68.155	-0.943	(0)
H3Mo7O24-3	0.000e+00	0.000e+00	-72.447	-72.978	-0.530	(0)
Na	2.331e-03					
Na+	2.310e-03	2.055e-03	-2.636	-2.687	-0.051	(0)
NaSO4-	1.830e-05	1.636e-05	-4.737	-4.786	-0.049	(0)
NaHCO3	2.366e-06	2.366e-06	-5.626	-5.626	0.000	(0)
NaCO3-	4.815e-07	4.302e-07	-6.317	-6.366	-0.049	(0)
NaF	2.733e-08	2.733e-08	-7.563	-7.563	0.000	(0)
NaH2BO3	6.186e-10	6.186e-10	-9.209	-9.209	0.000	(0)
NaCrO4-	1.040e-19	9.082e-20	-18.983	-19.042	-0.059	(0)
Ni	5.121e-08					
Ni+2	3.120e-08	1.954e-08	-7.506	-7.709	-0.203	(0)
NiCO3	8.196e-09	8.196e-09	-8.086	-8.086	0.000	(0)
NiSO4	5.778e-09	5.778e-09	-8.238	-8.238	0.000	(0)
NiHCO3+	5.650e-09	4.933e-09	-8.248	-8.307	-0.059	(0)
NiOH+	3.322e-10	2.900e-10	-9.479	-9.538	-0.059	(0)
Ni(OH)2	2.716e-11	2.716e-11	-10.566	-10.566	0.000	(0)
NiCl+	1.701e-11	1.485e-11	-10.769	-10.828	-0.059	(0)
NiF+	1.185e-11	1.035e-11	-10.926	-10.985	-0.059	(0)
Ni(SO4)2-2	4.879e-13	2.835e-13	-12.312	-12.547	-0.236	(0)
Ni(OH)3-	3.668e-14	3.202e-14	-13.436	-13.495	-0.059	(0)
NiCl2	2.221e-17	2.221e-17	-16.653	-16.653	0.000	(0)
NiSeO4	5.917e-19	5.917e-19	-18.228	-18.228	0.000	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-40.888	-40.887	0.001	(0)
Pb	4.418e-08					
PbCO3	3.450e-08	3.450e-08	-7.462	-7.462	0.000	(0)
PbOH+	3.463e-09	3.024e-09	-8.461	-8.519	-0.059	(0)
Pb(CO3)2-2	1.925e-09	1.119e-09	-8.716	-8.951	-0.236	(0)
PbHCO3+	1.779e-09	1.553e-09	-8.750	-8.809	-0.059	(0)
Pb+2	1.630e-09	1.021e-09	-8.788	-8.991	-0.203	(0)
PbSO4	7.410e-10	7.410e-10	-9.130	-9.130	0.000	(0)
Pb(OH)2	1.127e-10	1.127e-10	-9.948	-9.948	0.000	(0)
PbCl+	1.232e-11	1.076e-11	-10.909	-10.968	-0.059	(0)
Pb(SO4)2-2	1.139e-11	6.617e-12	-10.944	-11.179	-0.236	(0)
PbF+	1.737e-12	1.517e-12	-11.760	-11.819	-0.059	(0)
Pb(OH)3-	1.522e-13	1.329e-13	-12.818	-12.876	-0.059	(0)
PbCl2	1.428e-14	1.428e-14	-13.845	-13.845	0.000	(0)
PbF2	6.290e-16	6.290e-16	-15.201	-15.201	0.000	(0)
Pb2OH+3	1.659e-16	4.893e-17	-15.780	-16.310	-0.530	(0)
Pb(OH)4-2	6.603e-17	3.837e-17	-16.180	-16.416	-0.236	(0)
PbCl3-	1.933e-18	1.688e-18	-17.714	-17.773	-0.059	(0)
Pb3(OH)4+2	4.454e-19	2.589e-19	-18.351	-18.587	-0.236	(0)
PbF3-	2.880e-20	2.515e-20	-19.541	-19.600	-0.059	(0)
PbCl4-2	3.944e-22	2.292e-22	-21.404	-21.640	-0.236	(0)
Pb4(OH)4+4	1.841e-23	2.099e-24	-22.735	-23.678	-0.943	(0)
PbF4-2	4.366e-25	2.537e-25	-24.360	-24.596	-0.236	(0)
Pb(HS)2	0.000e+00	0.000e+00	-128.629	-128.629	0.000	(0)
Pb(HS)3-	0.000e+00	0.000e+00	-194.724	-194.783	-0.059	(0)
S(-2)	0.000e+00					
HS-	0.000e+00	0.000e+00	-67.395	-67.454	-0.059	(0)

CdHS+	0.000e+00	0.000e+00	-67.622	-67.681	-0.059	(0)
H2S	0.000e+00	0.000e+00	-68.503	-68.503	0.000	(0)
S5-2	0.000e+00	0.000e+00	-68.515	-68.751	-0.236	(0)
S6-2	0.000e+00	0.000e+00	-69.031	-69.266	-0.236	(0)
S4-2	0.000e+00	0.000e+00	-69.111	-69.346	-0.236	(0)
S3-2	0.000e+00	0.000e+00	-69.916	-70.152	-0.236	(0)
S2-2	0.000e+00	0.000e+00	-70.933	-71.168	-0.236	(0)
S-2	0.000e+00	0.000e+00	-76.487	-76.685	-0.198	(0)
Cu(S4)2-3	0.000e+00	0.000e+00	-123.799	-124.082	-0.283	(0)
CuS4S5-3	0.000e+00	0.000e+00	-124.540	-124.812	-0.272	(0)
ZnS(HS)-	0.000e+00	0.000e+00	-126.613	-126.672	-0.059	(0)
Cd(HS)2	0.000e+00	0.000e+00	-127.931	-127.931	0.000	(0)
Pb(HS)2	0.000e+00	0.000e+00	-128.629	-128.629	0.000	(0)
Zn(HS)2	0.000e+00	0.000e+00	-128.731	-128.731	0.000	(0)
Fe(HS)2	0.000e+00	0.000e+00	-133.991	-133.991	0.000	(0)
Cu(HS)3-	0.000e+00	0.000e+00	-184.587	-184.646	-0.059	(0)
Zn(HS)3-	0.000e+00	0.000e+00	-192.846	-192.905	-0.059	(0)
Cd(HS)3-	0.000e+00	0.000e+00	-193.426	-193.485	-0.059	(0)
ZnS(HS)2-2	0.000e+00	0.000e+00	-194.581	-194.816	-0.236	(0)
Pb(HS)3-	0.000e+00	0.000e+00	-194.724	-194.783	-0.059	(0)
Fe(HS)3-	0.000e+00	0.000e+00	-199.349	-199.408	-0.059	(0)
Cd(HS)4-2	0.000e+00	0.000e+00	-258.508	-258.743	-0.236	(0)
Zn(HS)4-2	0.000e+00	0.000e+00	-261.583	-261.819	-0.236	(0)
S(6)	2.969e-03					
SO4-2	2.366e-03	1.482e-03	-2.626	-2.829	-0.203	(0)
CaSO4	4.371e-04	4.371e-04	-3.359	-3.359	0.000	(0)
MgSO4	1.426e-04	1.426e-04	-3.846	-3.846	0.000	(0)
NaSO4-	1.830e-05	1.636e-05	-4.737	-4.786	-0.049	(0)
KSO4-	5.184e-06	4.632e-06	-5.285	-5.334	-0.049	(0)
MnSO4	2.070e-07	2.070e-07	-6.684	-6.684	0.000	(0)
ZnSO4	7.378e-08	7.378e-08	-7.132	-7.132	0.000	(0)
CoSO4	8.279e-09	8.279e-09	-8.082	-8.082	0.000	(0)
NiSO4	5.778e-09	5.778e-09	-8.238	-8.238	0.000	(0)
FeSO4	3.376e-09	3.376e-09	-8.472	-8.472	0.000	(0)
CuSO4	2.228e-09	2.228e-09	-8.652	-8.652	0.000	(0)
CdSO4	2.022e-09	2.022e-09	-8.694	-8.694	0.000	(0)
Zn(SO4)2-2	1.639e-09	9.522e-10	-8.786	-9.021	-0.236	(0)
HSO4-	1.389e-09	1.237e-09	-8.857	-8.908	-0.050	(0)
PbSO4	7.410e-10	7.410e-10	-9.130	-9.130	0.000	(0)
Cd(SO4)2-2	6.955e-11	4.042e-11	-10.158	-10.393	-0.236	(0)
CrOHSO4	4.760e-11	4.760e-11	-10.322	-10.322	0.000	(0)
Pb(SO4)2-2	1.139e-11	6.617e-12	-10.944	-11.179	-0.236	(0)
Ni(SO4)2-2	4.879e-13	2.835e-13	-12.312	-12.547	-0.236	(0)
CrSO4+	2.080e-14	1.816e-14	-13.682	-13.741	-0.059	(0)
AlSO4+	9.599e-15	8.549e-15	-14.018	-14.068	-0.050	(0)
UO2SO4	3.539e-16	3.539e-16	-15.451	-15.451	0.000	(0)
Al(SO4)2-	1.524e-16	1.357e-16	-15.817	-15.867	-0.050	(0)
FeSO4+	2.597e-17	2.317e-17	-16.586	-16.635	-0.050	(0)
UO2(SO4)2-2	1.190e-17	6.914e-18	-16.925	-17.160	-0.236	(0)
Cr2(OH)2SO4+2	1.002e-18	5.825e-19	-17.999	-18.235	-0.236	(0)
Fe(SO4)2-	8.407e-19	7.340e-19	-18.075	-18.134	-0.059	(0)
VO2SO4-	4.289e-19	3.745e-19	-18.368	-18.427	-0.059	(0)
Cr2(OH)2(SO4)2	5.127e-20	5.127e-20	-19.290	-19.290	0.000	(0)
VOSO4	1.559e-20	1.559e-20	-19.807	-19.807	0.000	(0)
CrO3SO4-2	1.630e-27	9.473e-28	-26.788	-27.024	-0.236	(0)
VSO4+	6.858e-34	5.988e-34	-33.164	-33.223	-0.059	(0)
U(SO4)2	0.000e+00	0.000e+00	-40.435	-40.435	0.000	(0)
USO4+2	0.000e+00	0.000e+00	-41.271	-41.506	-0.236	(0)
Se(-2)	5.668e-31					
HSe-	5.665e-31	4.947e-31	-30.247	-30.306	-0.059	(0)
MnSe	1.876e-34	1.876e-34	-33.727	-33.727	0.000	(0)
H2Se	3.279e-35	3.279e-35	-34.484	-34.484	0.000	(0)
Se-2	9.968e-38	5.793e-38	-37.001	-37.237	-0.236	(0)
Se(4)	6.110e-08					
HSeO3-	3.593e-08	3.137e-08	-7.445	-7.503	-0.059	(0)
SeO3-2	2.517e-08	1.463e-08	-7.599	-7.835	-0.236	(0)

H2SeO3	1.143e-13	1.143e-13	-12.942	-12.942	0.000	(0)
Cd(SeO3)2-2	1.765e-18	1.026e-18	-17.753	-17.989	-0.236	(0)
FeHSeO3+2	1.988e-22	1.155e-22	-21.702	-21.937	-0.236	(0)
Se(6)	1.034e-13					
SeO4-2	1.033e-13	6.474e-14	-12.986	-13.189	-0.203	(0)
MnSeO4	1.369e-17	1.369e-17	-16.864	-16.864	0.000	(0)
ZnSeO4	2.282e-18	2.282e-18	-17.642	-17.642	0.000	(0)
CoSeO4	9.085e-19	9.085e-19	-18.042	-18.042	0.000	(0)
NiSeO4	5.917e-19	5.917e-19	-18.228	-18.228	0.000	(0)
CdSeO4	7.016e-20	7.016e-20	-19.154	-19.154	0.000	(0)
HSeO4-	3.173e-20	2.771e-20	-19.498	-19.557	-0.059	(0)
Zn(SeO4)2-2	2.577e-31	1.498e-31	-30.589	-30.825	-0.236	(0)
U(3)	0.000e+00					
U+3	0.000e+00	0.000e+00	-56.751	-57.282	-0.530	(0)
U(4)	1.010e-18					
U(OH)5-	1.010e-18	8.820e-19	-17.996	-18.055	-0.059	(0)
U(OH)4	3.155e-22	3.155e-22	-21.501	-21.501	0.000	(0)
U(OH)3+	1.128e-26	9.850e-27	-25.948	-26.007	-0.059	(0)
U(OH)2+2	6.694e-32	3.890e-32	-31.174	-31.410	-0.236	(0)
UOH+3	5.306e-38	1.565e-38	-37.275	-37.806	-0.530	(0)
UF3+	2.256e-38	1.970e-38	-37.647	-37.706	-0.059	(0)
UF2+2	1.015e-38	5.897e-39	-37.994	-38.229	-0.236	(0)
UF+3	0.000e+00	0.000e+00	-40.123	-40.653	-0.530	(0)
UF4	0.000e+00	0.000e+00	-40.342	-40.342	0.000	(0)
U(SO4)2	0.000e+00	0.000e+00	-40.435	-40.435	0.000	(0)
USO4+2	0.000e+00	0.000e+00	-41.271	-41.506	-0.236	(0)
UF5-	0.000e+00	0.000e+00	-43.361	-43.420	-0.059	(0)
U+4	0.000e+00	0.000e+00	-44.334	-45.277	-0.943	(0)
UF6-2	0.000e+00	0.000e+00	-45.380	-45.616	-0.236	(0)
UCl+3	0.000e+00	0.000e+00	-46.574	-47.104	-0.530	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-163.017	-167.790	-4.773	(0)
U(5)	6.816e-17					
UO2+	6.816e-17	5.951e-17	-16.166	-16.225	-0.059	(0)
U(6)	1.056e-08					
UO2(CO3)3-4	7.825e-09	8.925e-10	-8.107	-9.049	-0.943	(0)
UO2(CO3)2-2	2.726e-09	1.584e-09	-8.565	-8.800	-0.236	(0)
UO2CO3	7.062e-12	7.062e-12	-11.151	-11.151	0.000	(0)
UO2OH+	2.682e-14	2.342e-14	-13.571	-13.630	-0.059	(0)
UO2F+	5.258e-16	4.591e-16	-15.279	-15.338	-0.059	(0)
UO2SO4	3.539e-16	3.539e-16	-15.451	-15.451	0.000	(0)
UO2+2	2.519e-16	1.578e-16	-15.599	-15.802	-0.203	(0)
UO2F2	2.791e-17	2.791e-17	-16.554	-16.554	0.000	(0)
UO2(SO4)2-2	1.190e-17	6.914e-18	-16.925	-17.160	-0.236	(0)
UO2F3-	1.692e-19	1.478e-19	-18.771	-18.830	-0.059	(0)
UO2Cl+	8.706e-20	7.601e-20	-19.060	-19.119	-0.059	(0)
(UO2)2(OH)2+2	1.566e-21	9.104e-22	-20.805	-21.041	-0.236	(0)
UO2F4-2	4.257e-23	2.474e-23	-22.371	-22.607	-0.236	(0)
(UO2)3(OH)5+	2.575e-23	2.248e-23	-22.589	-22.648	-0.059	(0)
V(2)	1.133e-39					
VOH+	1.133e-39	9.896e-40	-38.946	-39.005	-0.059	(0)
V+2	0.000e+00	0.000e+00	-40.350	-40.586	-0.236	(0)
V(3)	1.132e-12					
V(OH)3	1.132e-12	1.132e-12	-11.946	-11.946	0.000	(0)
V(OH)2+	7.152e-24	6.244e-24	-23.146	-23.205	-0.059	(0)
VOH+2	8.703e-28	5.058e-28	-27.060	-27.296	-0.236	(0)
V+3	2.903e-33	8.560e-34	-32.537	-33.068	-0.530	(0)
VSO4+	6.858e-34	5.988e-34	-33.164	-33.223	-0.059	(0)
V2(OH)3+3	0.000e+00	0.000e+00	-51.518	-52.049	-0.530	(0)
V2(OH)2+4	0.000e+00	0.000e+00	-52.849	-53.792	-0.943	(0)
V(4)	1.038e-17					
V(OH)3+	1.029e-17	8.984e-18	-16.988	-17.047	-0.059	(0)
VO+2	6.573e-20	3.820e-20	-19.182	-19.418	-0.236	(0)
VOSO4	1.559e-20	1.559e-20	-19.807	-19.807	0.000	(0)
VOF+	5.531e-21	4.829e-21	-20.257	-20.316	-0.059	(0)
VOF2	3.817e-23	3.817e-23	-22.418	-22.418	0.000	(0)
VOCl+	3.646e-23	3.183e-23	-22.438	-22.497	-0.059	(0)

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   VOF3-          3.269e-26   2.854e-26   -25.486   -25.544    -0.059     (0)
   H2V2O4+2       6.963e-30   4.047e-30   -29.157   -29.393    -0.236     (0)
   VOF4-2         4.179e-30   2.429e-30   -29.379   -29.615    -0.236     (0)
V(5)          1.201e-08
   H2VO4-         8.328e-09   7.272e-09    -8.079    -8.138    -0.059     (0)
   HVO4-2         3.681e-09   2.139e-09    -8.434    -8.670    -0.236     (0)
   H3VO4          6.209e-13   6.209e-13   -12.207   -12.207     0.000     (0)
   H3V2O7-        3.340e-14   2.916e-14   -13.476   -13.535    -0.059     (0)
   HV2O7-3        1.788e-14   5.271e-15   -13.748   -14.278    -0.530     (0)
   VO4-3          4.258e-15   1.255e-15   -14.371   -14.901    -0.530     (0)
   V2O7-4         1.457e-16   1.662e-17   -15.837   -16.779    -0.943     (0)
   VO2+           1.190e-17   1.058e-17   -16.925   -16.975    -0.051     (0)
   V3O9-3         1.366e-18   4.029e-19   -17.864   -18.395    -0.530     (0)
   VO2SO4-        4.289e-19   3.745e-19   -18.368   -18.427    -0.059     (0)
   VO2F           3.913e-19   3.913e-19   -18.408   -18.408     0.000     (0)
   VO2F2-         3.429e-21   2.994e-21   -20.465   -20.524    -0.059     (0)
   V4O12-4        1.071e-23   1.221e-24   -22.970   -23.913    -0.943     (0)
   VO2F3-2        1.355e-24   7.872e-25   -23.868   -24.104    -0.236     (0)
   VO2F4-3        2.769e-29   8.165e-30   -28.558   -29.088    -0.530     (0)
   V10O28-6       0.000e+00   0.000e+00   -62.630   -64.751    -2.121     (0)
   HV10O28-5      0.000e+00   0.000e+00   -63.160   -64.633    -1.473     (0)
   H2V10O28-4     0.000e+00   0.000e+00   -66.551   -67.494    -0.943     (0)
Zn            6.391e-07
   Zn+2           3.633e-07   2.276e-07    -6.440    -6.643    -0.203     (0)
   ZnCO3          1.472e-07   1.472e-07    -6.832    -6.832     0.000     (0)
   ZnSO4          7.378e-08   7.378e-08    -7.132    -7.132     0.000     (0)
   ZnOH+          3.073e-08   2.683e-08    -7.512    -7.571    -0.059     (0)
   ZnHCO3+        1.688e-08   1.474e-08    -7.773    -7.832    -0.059     (0)
   Zn(OH)2        5.013e-09   5.013e-09    -8.300    -8.300     0.000     (0)
   Zn(SO4)2-2     1.639e-09   9.522e-10    -8.786    -9.021    -0.236     (0)
   ZnOHCl         2.621e-10   2.621e-10    -9.582    -9.582     0.000     (0)
   ZnCl+          1.910e-10   1.698e-10    -9.719    -9.770    -0.051     (0)
   ZnF+           1.096e-10   9.571e-11    -9.960   -10.019    -0.059     (0)
   Zn(OH)3-       3.393e-11   2.962e-11   -10.469   -10.528    -0.059     (0)
   ZnCl2          7.993e-14   7.993e-14   -13.097   -13.097     0.000     (0)
   Zn(OH)4-2      2.392e-15   1.390e-15   -14.621   -14.857    -0.236     (0)
   ZnCl3-         2.122e-17   1.886e-17   -16.673   -16.725    -0.051     (0)
   ZnSeO4         2.282e-18   2.282e-18   -17.642   -17.642     0.000     (0)
   ZnCl4-2        4.420e-21   2.801e-21   -20.355   -20.553    -0.198     (0)
   Zn(SeO4)2-2    2.577e-31   1.498e-31   -30.589   -30.825    -0.236     (0)
   ZnS(HS)-       0.000e+00   0.000e+00  -126.613  -126.672    -0.059     (0)
   Zn(HS)2        0.000e+00   0.000e+00  -128.731  -128.731     0.000     (0)
   Zn(HS)3-       0.000e+00   0.000e+00  -192.846  -192.905    -0.059     (0)
   ZnS(HS)2-2     0.000e+00   0.000e+00  -194.581  -194.816    -0.236     (0)
   Zn(HS)4-2      0.000e+00   0.000e+00  -261.583  -261.819    -0.236     (0)

-----------------------------Saturation indices-----------------------------

  Phase               SI** log IAP   log K(298 K,   1 atm)

  Al(OH)3(am)      -1.72      9.08   10.80  Al(OH)3
  Al2(MoO4)3      -54.75    -52.38    2.37  Al2(MoO4)3
  Al2O3            -1.50     18.15   19.65  Al2O3
  Al4(OH)10SO4     -5.36     17.34   22.70  Al4(OH)10SO4
  AlAsO4:2H2O      -9.66     -4.86    4.80  AlAsO4:2H2O
  AlOHSO4          -6.66     -9.89   -3.23  AlOHSO4
  Alunite          -4.59     -5.99   -1.40  KAl3(SO4)2(OH)6
  Anglesite        -4.03    -11.82   -7.79  PbSO4
  Anhydrite        -1.36     -5.72   -4.36  CaSO4
  Anilite         -42.61    -74.48  -31.88  Cu0.25Cu1.5S
  Antlerite        -3.89      4.90    8.79  Cu3(OH)4SO4
  Aragonite         0.46     -7.84   -8.30  CaCO3
  Arsenolite      -67.63    -70.39   -2.76  As4O6
  Artinite         -4.97      4.63    9.60  MgCO3:Mg(OH)2:3H2O
  As2O5           -34.59    -27.88    6.71  As2O5
  Atacamite        -3.08      4.31    7.39  Cu2(OH)3Cl
  Azurite          -1.40    -18.31  -16.91  Cu3(OH)2(CO3)2
  Ba(OH)2:8H2O    -14.85      9.54   24.39  Ba(OH)2:8H2O
  Ba2V2O7:2H2O    -14.60      1.27   15.87  Ba2V2O7:2H2O
  Ba3(AsO4)2        9.66      0.75   -8.91  Ba3(AsO4)2
  Ba3(VO4)2:4H2O   -22.13     10.81   32.94  Ba3(VO4)2:4H2O
  BaCrO4           -13.98    -23.65   -9.67  BaCrO4
  BaF2             -10.13    -15.95   -5.82  BaF2
  BaMoO4            -7.01    -13.97   -6.96  BaMoO4
  Barite             0.56     -9.42   -9.98  BaSO4
  BaS              -82.16    -65.98   16.18  BaS
  BaSeO3            -7.86     -6.03    1.83  BaSeO3
  BaSeO4           -12.32    -19.78   -7.46  BaSeO4
  Bianchite         -7.71     -9.47   -1.76  ZnSO4:6H2O
  Birnessite       -10.85      7.24   18.09  MnO2
  Bixbyite          -7.44     -8.08   -0.64  Mn2O3
  BlaubleiI        -44.33    -68.49  -24.16  Cu0.9Cu0.2S
  BlaubleiII       -43.98    -71.26  -27.28  Cu0.6Cu0.8S
  Boehmite           0.50      9.08    8.58  AlOOH
  Brochantite       -2.37     12.85   15.22  Cu4(OH)6SO4
  Brucite           -3.98     12.86   16.84  Mg(OH)2
  Bunsenite         -4.02      8.43   12.45  NiO
  Ca(VO3)2         -10.23     -4.57    5.66  Ca(VO3)2
  Ca2V2O7           -8.82      8.68   17.50  Ca2V2O7
  Ca2V2O7:2H2O     -12.87      8.68   21.55  Ca2V2O7:2H2O
  Ca3(AsO4)2:4H2O  -10.44     11.86   22.30  Ca3(AsO4)2:4H2O
  Ca3(VO4)2        -17.03     21.93   38.96  Ca3(VO4)2
  Ca3(VO4)2:4H2O   -17.93     21.93   39.86  Ca3(VO4)2:4H2O
  CaCrO4           -17.68    -19.94   -2.27  CaCrO4
  Calcite            0.64     -7.84   -8.48  CaCO3
  CaMoO4            -2.32    -10.27   -7.95  CaMoO4
  Carnotite         -4.09     -3.86    0.23  KUO2VO4
  CaSeO3:2H2O       -5.14     -2.33    2.81  CaSeO3:2H2O
  CaSeO4:2H2O      -13.06    -16.08   -3.02  CaSeO4:2H2O
  Cd(BO2)2         -13.05     -3.21    9.84  Cd(BO2)2
  Cd(OH)2           -5.74      7.90   13.64  Cd(OH)2
  Cd(OH)2(am)       -5.83      7.90   13.73  Cd(OH)2
  Cd3(OH)2(SO4)2   -20.94    -14.23    6.71  Cd3(OH)2(SO4)2
  Cd3(OH)4SO4      -17.82      4.74   22.56  Cd3(OH)4SO4
  Cd4(OH)6SO4      -15.76     12.64   28.40  Cd4(OH)6SO4
  CdCl2            -14.63    -15.29   -0.66  CdCl2
  CdCl2:1H2O       -13.60    -15.29   -1.69  CdCl2:1H2O
  CdCl2:2.5H2O     -13.38    -15.29   -1.91  CdCl2:2.5H2O
  CdF2             -16.38    -17.59   -1.21  CdF2
  Cdmetal(alpha)   -28.17    -14.65   13.51  Cd
  Cdmetal(gamma)   -28.27    -14.65   13.62  Cd
  CdMoO4            -1.46    -15.61  -14.15  CdMoO4
  CdOHCl            -7.23     -3.69    3.54  CdOHCl
  CdSe             -10.27    -30.47  -20.20  CdSe
  CdSeO4:2H2O      -19.57    -21.42   -1.85  CdSeO4:2H2O
  CdSO4            -10.89    -11.06   -0.17  CdSO4
  CdSO4:1H2O        -9.34    -11.06   -1.73  CdSO4:1H2O
  CdSO4:2.67H2O     -9.19    -11.06   -1.87  CdSO4:2.67H2O
  Cerussite         -0.81    -13.94  -13.13  PbCO3
  CH4(g)           -70.26   -111.30  -41.05  CH4
  Chalcanthite      -8.37    -11.01   -2.64  CuSO4:5H2O
  Chalcocite       -41.87    -76.79  -34.92  Cu2S
  Chalcopyrite     -99.72   -134.99  -35.27  CuFeS2
  Claudetite       -67.32    -70.39   -3.06  As4O6
  Clausthalite      -4.13    -31.23  -27.10  PbSe
  Co(BO2)2         -29.59     -2.52   27.07  Co(BO2)2
  Co(OH)2           -4.51      8.58   13.09  Co(OH)2
  Co(OH)3          -10.23    -12.54   -2.31  Co(OH)3
  CO2(g)            -2.94    -21.09  -18.15  CO2
  Co3(AsO4)2       -15.16     -2.13   13.03  Co3(AsO4)2
  Co3O4             -6.00    -16.49  -10.50  Co3O4
  CoCl2            -22.87    -14.61    8.27  CoCl2
  CoCl2:6H2O       -17.14    -14.61    2.54  CoCl2:6H2O
  CoCO3             -2.52    -12.50   -9.98  CoCO3
  CoF2             -15.31    -16.91   -1.60  CoF2
  CoF3             -49.31    -50.77   -1.46  CoF3
  CoFe2O4           24.81     21.28   -3.53  CoFe2O4
  CoMoO4            -7.17    -14.93   -7.76  CoMoO4
  CoO               -5.00      8.58   13.59  CoO
  CoS(alpha)       -59.50    -66.94   -7.44  CoS
  CoS(beta)        -55.87    -66.94  -11.07  CoS
  CoSe             -13.59    -29.79  -16.20  CoSe
  CoSeO3            -8.31     -6.99    1.32  CoSeO3
  CoSeO4:6H2O      -19.21    -20.74   -1.53  CoSeO4:6H2O
  CoSO4            -13.18    -10.38    2.80  CoSO4
  CoSO4:6H2O        -7.91    -10.38   -2.47  CoSO4:6H2O
  Cotunnite        -11.27    -16.05   -4.78  PbCl2
  Covellite        -45.27    -67.57  -22.30  CuS
  Cr(OH)2          -18.79     -7.97   10.82  Cr(OH)2
  Cr(OH)3           -0.98      0.36    1.34  Cr(OH)3
  Cr(OH)3(am)        1.11      0.36   -0.75  Cr(OH)3
  Cr2O3              3.07      0.71   -2.36  Cr2O3
  CrCl2            -45.26    -31.16   14.09  CrCl2
  CrCl3            -49.54    -34.43   15.11  CrCl3
  CrF3             -26.54    -37.88  -11.34  CrF3
  Crmetal          -61.01    -30.53   30.48  Cr
  CrO3             -29.98    -33.19   -3.21  CrO3
  Cryolite         -17.41    -51.25  -33.84  Na3AlF6
  Cu(OH)2           -0.72      7.95    8.67  Cu(OH)2
  Cu2Se(alpha)       6.16    -39.64  -45.80  Cu2Se
  Cu2SO4          -18.28    -20.23   -1.95  Cu2SO4
  Cu3(AsO4)2:2H2O -10.12     -4.02    6.10  Cu3(AsO4)2:2H2O
  Cu3Se2            -6.57    -70.06  -63.49  Cu3Se2
  CuCO3             -1.63    -13.13  -11.50  CuCO3
  CuCrO4           -19.79    -25.23   -5.44  CuCrO4
  CuF               -8.47    -13.38   -4.91  CuF
  CuF2             -18.65    -17.54    1.12  CuF2
  CuF2:2H2O        -12.99    -17.54   -4.55  CuF2:2H2O
  Cumetal           -3.15    -11.91   -8.76  Cu
  CuMoO4            -2.48    -15.56  -13.08  CuMoO4
  CuOCuSO4         -13.36     -3.06   10.30  CuOCuSO4
  Cupricferrite     14.67     20.65    5.99  CuFeO2
  Cuprite            0.14     -1.27   -1.41  Cu2O
  Cuprousferrite    14.63      5.72   -8.92  CuFeO2
  CuSe               2.68    -30.42  -33.10  CuSe
  CuSe2            -12.87    -46.24  -33.37  CuSe2
  CuSeO3:2H2O       -8.13     -7.62    0.51  CuSeO3:2H2O
  CuSeO4:5H2O      -18.93    -21.37   -2.44  CuSeO4:5H2O
  CuSO4            -13.95    -11.01    2.94  CuSO4
  Diaspore           2.20      9.08    6.87  AlOOH
  Djurleite        -42.26    -76.18  -33.92  Cu0.066Cu1.868S
  Dolomite(disordered)   0.47    -16.07  -16.54  CaMg(CO3)2
  Dolomite(ordered)   1.02    -16.07  -17.09  CaMg(CO3)2
  Epsomite         -3.98     -6.11   -2.13  MgSO4:7H2O
  Fe(OH)2          -5.46      8.10   13.56  Fe(OH)2
  Fe(OH)2.7Cl.3     5.91      2.87   -3.04  Fe(OH)2.7Cl.3
  Fe(VO3)2         -5.99     -9.71   -3.72  Fe(VO3)2
  Fe2(OH)4SeO3     -4.43     -2.87    1.55  Fe2(OH)4SeO3
  Fe2(SeO3)3:2H2O -13.39    -34.02  -20.63  Fe2(SeO3)3:2H2O
  Fe2(SO4)3        -40.47    -44.20   -3.73  Fe2(SO4)3
  Fe3(OH)8           0.58     20.80   20.22  Fe3(OH)8
  FeAsO4:2H2O       -7.99     -7.59    0.40  FeAsO4:2H2O
  FeCr2O4            1.62      8.82    7.20  FeCr2O4
  FeMoO4            -5.32    -15.41  -10.09  FeMoO4
  Ferrihydrite       3.16      6.35    3.19  Fe(OH)3
  Ferroselite      -27.49    -46.09  -18.60  FeSe2
  FeS(ppt)         -64.47    -67.42   -2.95  FeS
  FeSe             -19.27    -30.27  -11.00  FeSe
  Fluorite          -1.74    -12.24  -10.50  CaF2
  Galena           -54.41    -68.38  -13.97  PbS
  Gibbsite           0.79      9.08    8.29  Al(OH)3
  Goethite           5.86      6.35    0.49  FeOOH
  Goslarite         -7.46     -9.47   -2.01  ZnSO4:7H2O
  Greenockite      -53.26    -67.62  -14.36  CdS
  Greigite        -236.25   -281.29  -45.03  Fe3S4
  Gummite           -7.34      0.34    7.67  UO3
  Gypsum            -1.11     -5.72   -4.61  CaSO4:2H2O
  H-Jarosite        -6.78    -18.88  -12.10  (H3O)Fe3(SO4)2(OH)6
  H2MoO4           -10.64    -23.51  -12.88  H2MoO4
  H2S(g)           -67.51    -75.52   -8.01  H2S
  H2Se(g)          -33.41    -38.37   -4.96  H2Se
  Halite            -7.82     -6.21    1.60  NaCl
  Hausmannite       -8.38     52.65   61.03  Mn3O4
  Hematite          14.12     12.70   -1.42  Fe2O3
  Hercynite          3.37     26.26   22.89  FeAl2O4
  Huntite           -2.55    -32.52  -29.97  CaMg3(CO3)4
  Hydrocerussite    -1.96    -20.73  -18.77  Pb3(OH)2(CO3)2
  Hydromagnesite   -11.28    -20.04   -8.77  Mg5(CO3)4(OH)2:4H2O
  K-Alum           -18.97    -24.14   -5.17  KAl(SO4)2:12H2O
  K-Jarosite         0.63    -14.17  -14.80  KFe3(SO4)2(OH)6
  K2Cr2O7          -39.71    -56.95  -17.24  K2Cr2O7
  K2CrO4           -23.25    -23.76   -0.51  K2CrO4
  K2MoO4           -17.35    -14.09    3.26  K2MoO4
  K2SeO4           -19.17    -19.90   -0.73  K2SeO4
  Langite           -4.64     12.85   17.49  Cu4(OH)6SO4:H2O
  Larnakite         -4.24     -4.67   -0.43  PbO:PbSO4
  Laurionite        -5.07     -4.45    0.62  PbOHCl
  Lepidocrocite      4.98      6.35    1.37  FeOOH
  Lime             -19.45     13.25   32.70  CaO
  Litharge          -5.55      7.15   12.69  PbO
  Mackinawite      -63.82    -67.42   -3.60  FeS
  Maghemite          6.31     12.70    6.39  Fe2O3
  Magnesioferrite    8.70     25.56   16.86  Fe2MgO4
  Magnesite         -0.77     -8.23   -7.46  MgCO3
  Magnetite         17.40     20.80    3.40  Fe3O4
  Malachite          0.13     -5.18   -5.31  Cu2(OH)2CO3
  Manganite         -4.03     21.31   25.34  MnOOH
  Massicot          -5.75      7.15   12.89  PbO
  Matlockite        -8.22    -17.19   -8.97  PbClF
  Melanothallite   -21.49    -15.24    6.26  CuCl2
  Melanterite       -8.65    -10.86   -2.21  FeSO4:7H2O
  Mg(OH)2(active)   -5.93     12.86   18.79  Mg(OH)2
  Mg(VO3)2         -16.23     -4.95   11.28  Mg(VO3)2
  Mg2V2O7          -18.45      7.91   26.36  Mg2V2O7
  MgCr2O4           -2.63     13.57   16.20  MgCr2O4
  MgCrO4           -25.71    -20.33    5.38  MgCrO4
  MgF2              -4.50    -12.63   -8.13  MgF2
  MgMoO4            -8.80    -10.65   -1.85  MgMoO4
  MgSeO3:6H2O       -5.77     -2.71    3.06  MgSeO3:6H2O
  MgSeO4:6H2O      -15.27    -16.47   -1.20  MgSeO4:6H2O
  Minium           -29.53     43.99   73.52  Pb3O4
  Mirabilite        -7.09     -8.20   -1.11  Na2SO4:10H2O
  Mn(VO3)2         -12.68     -7.78    4.90  Mn(VO3)2
  Mn2(SO4)3        -59.27    -64.98   -5.71  Mn2(SO4)3
  Mn3(AsO4)2:8H2O  -10.29      2.21   12.50  Mn3(AsO4)2:8H2O
  MnCl2:4H2O       -15.87    -13.16    2.72  MnCl2:4H2O
  MnS(grn)         -65.66    -65.49    0.17  MnS
  MnS(pnk)         -68.83    -65.49    3.34  MnS
  MnSe             -31.84    -28.34    3.50  MnSe
  MnSeO3            -6.67     -5.54    1.13  MnSeO3
  MnSeO3:2H2O       -6.52     -5.54    0.98  MnSeO3:2H2O
  MnSeO4:5H2O      -17.24    -19.29   -2.05  MnSeO4:5H2O
  MnSO4            -11.52     -8.93    2.58  MnSO4
  Monteponite       -7.20      7.90   15.10  CdO
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MoO3	-15.51	-23.51	-8.00	MoO3
Morenosite	-8.39	-10.54	-2.14	NiSO4:7H2O
MoS2	-126.85	-197.11	-70.26	MoS2
Na-Jarosite	-2.30	-13.50	-11.20	NaFe3(SO4)2(OH)6
Na2Cr2O7	-45.72	-55.61	-9.90	Na2Cr2O7
Na2CrO4	-25.36	-22.43	2.93	Na2CrO4
Na2Mo2O7	-19.67	-36.26	-16.60	Na2Mo2O7
Na2MoO4	-14.24	-12.75	1.49	Na2MoO4
Na2MoO4:2H2O	-13.97	-12.75	1.22	Na2MoO4:2H2O
Na2SeO3:5H2O	-15.11	-4.81	10.30	Na2SeO3:5H2O
Na2SeO4	-19.84	-18.56	1.28	Na2SeO4
Na3VO4	-29.44	7.24	36.68	Na3VO4
Na4V2O7	-33.69	3.71	37.40	Na4V2O7
Nantokite	-5.50	-12.23	-6.73	CuCl
Natron	-9.01	-10.32	-1.31	Na2CO3:10H2O
NaVO3	-7.38	-3.53	3.86	NaVO3
Nesquehonite	-3.56	-8.23	-4.67	MgCO3:3H2O
Ni(OH)2	-4.37	8.43	12.79	Ni(OH)2
Ni3(AsO4)2:8H2O	-18.30	-2.60	15.70	Ni3(AsO4)2:8H2O
Ni4(OH)6SO4	-17.25	14.75	32.00	Ni4(OH)6SO4
NiCO3	-5.79	-12.66	-6.87	NiCO3
NiMoO4	-3.94	-15.08	-11.14	NiMoO4
NiS(alpha)	-61.49	-67.09	-5.60	NiS
NiS(beta)	-55.99	-67.09	-11.10	NiS
NiS(gamma)	-54.29	-67.09	-12.80	NiS
NiSe	-12.25	-29.95	-17.70	NiSe
NiSeO3:2H2O	-9.96	-7.14	2.81	NiSeO3:2H2O
NiSeO4:6H2O	-19.38	-20.90	-1.52	NiSeO4:6H2O
Nsutite	-10.27	7.24	17.50	MnO2
O2(g)	-37.98	45.11	83.09	O2
Orpiment	-200.70	-261.76	-61.07	As2S3
Otavite	-1.18	-13.18	-12.00	CdCO3
Pb(BO2)2	-10.48	-3.96	6.52	Pb(BO2)2
Pb(OH)2	-1.00	7.15	8.15	Pb(OH)2
Pb10(OH)6O(CO3)6	-46.30	-55.06	-8.76	Pb10(OH)6O(CO3)6
Pb2(OH)3Cl	-6.10	2.70	8.79	Pb2(OH)3Cl
Pb2O(OH)2	-11.90	14.29	26.19	Pb2O(OH)2
Pb2O3	-24.19	36.85	61.04	Pb2O3
Pb2OCO3	-6.24	-6.79	-0.56	Pb2OCO3
Pb2V2O7	-1.62	-3.52	-1.90	Pb2V2O7
Pb3(AsO4)2	-12.24	-6.44	5.80	Pb3(AsO4)2
Pb3(VO4)2	-2.52	3.62	6.14	Pb3(VO4)2
Pb3O2CO3	-10.67	0.35	11.02	Pb3O2CO3
Pb3O2SO4	-8.21	2.47	10.69	Pb3O2SO4
Pb4(OH)6SO4	-11.48	9.62	21.10	Pb4(OH)6SO4
Pb4O3SO4	-12.26	9.62	21.88	Pb4O3SO4
PbCrO4	-13.44	-26.04	-12.60	PbCrO4
PbF2	-10.90	-18.34	-7.44	PbF2
Pbmetal	-19.65	-15.41	4.25	Pb
PbMoO4	-0.75	-16.37	-15.62	PbMoO4
PbO:0.3H2O	-5.83	7.15	12.98	PbO:0.33H2O
PbSeO4	-15.34	-22.18	-6.84	PbSeO4
Periclase	-8.72	12.86	21.58	MgO
Phosgenite	-10.18	-29.99	-19.81	PbCl2:PbCO3
Plattnerite	-19.90	29.70	49.60	PbO2
Portlandite	-9.56	13.25	22.80	Ca(OH)2
Pyrite	-101.88	-120.39	-18.51	FeS2
Pyrochroite	-5.16	10.03	15.19	Mn(OH)2
Pyrolusite	-8.79	32.59	41.38	MnO2
Realgar	-84.65	-104.40	-19.75	AsS
Retgersite	-8.50	-10.54	-2.04	NiSO4:6H2O
Rhodochrosite	-0.47	-11.05	-10.58	MnCO3
Rutherfordine	-6.25	-20.75	-14.50	UO2CO3
Schoepite	-5.66	0.34	5.99	UO2(OH)2:H2O
Semetal(am)	-8.71	-15.82	-7.11	Se
Semetal(hex	-8.11	-15.82	-7.71	Se

SeO2	-15.70	-15.57	0.12	SeO2
SeO3	-50.37	-29.33	21.04	SeO3
Siderite	-2.74	-12.98	-10.24	FeCO3
Smithsonite	-1.59	-11.59	-10.00	ZnCO3
Sphalerite	-54.58	-66.03	-11.45	ZnS
Spinel	-5.83	31.01	36.85	MgAl2O4
Sulfur	-50.82	-52.97	-2.14	S
Tenorite	0.31	7.95	7.64	CuO
Thenardite	-8.53	-8.20	0.32	Na2SO4
Thermonatrite	-10.96	-10.32	0.64	Na2CO3:H2O
Tyuyamunite	-7.98	-3.90	4.08	Ca(UO2)2(VO4)2
U3O8	-14.98	6.10	21.08	U3O8
U4O9	-26.44	-29.46	-3.02	U4O9
UF4	-34.44	-63.98	-29.54	UF4
UF4:2.5H2O	-31.26	-63.98	-32.72	UF4:2.5H2O
UO2(am)	-13.94	-13.00	0.93	UO2
UO2(OH)2(beta)	-5.28	0.34	5.61	UO2(OH)2
UO2SeO4:4H2O	-26.74	-28.99	-2.25	UO2SeO4:4H2O
UO3	-7.36	0.34	7.70	UO3
Uraninite	-8.33	-13.00	-4.67	UO2
V(OH)3	-16.45	-8.86	7.59	V(OH)3
V2O5	-16.45	-17.81	-1.36	V2O5
V3O5	-34.23	-32.40	1.84	V3O5
V4O7	-42.86	-35.68	7.19	V4O7
V6O13	-37.69	-98.55	-60.86	V6O13
VCl2	-62.20	-43.33	18.87	VCl2
VCl3	-67.08	-43.65	23.43	VCl3
VF4	-69.19	-54.26	14.93	VF4
Vmetal	-86.72	-42.69	44.03	V
VO	-34.90	-20.14	14.76	VO
VO(OH)2	-8.43	-3.28	5.15	VO(OH)2
VO2Cl	-23.34	-20.50	2.84	VO2Cl
VOCl	-31.61	-20.46	11.15	VOCl
VOCl2	-39.23	-26.47	12.76	VOCl2
VOSO4	-25.86	-22.25	3.61	VOSO4
Witherite	-2.97	-11.54	-8.57	BaCO3
Wurtzite	-57.08	-66.03	-8.95	ZnS
Zincite	-1.84	9.49	11.33	ZnO
Zincosite	-13.40	-9.47	3.93	ZnSO4
Zn(BO2)2	-9.90	-1.61	8.29	Zn(BO2)2
Zn(OH)2	-2.71	9.49	12.20	Zn(OH)2
Zn(OH)2(am)	-2.98	9.49	12.47	Zn(OH)2
Zn(OH)2(beta)	-2.26	9.49	11.75	Zn(OH)2
Zn(OH)2(epsilon)	-2.04	9.49	11.53	Zn(OH)2
Zn(OH)2(gamma)	-2.24	9.49	11.73	Zn(OH)2
Zn2(OH)2SO4	-7.48	0.02	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-7.80	7.39	15.19	Zn2(OH)3Cl
Zn3(AsO4)2:2.5H2O	-13.05	0.60	13.65	Zn3(AsO4)2:2.5H2O
Zn3O(SO4)2	-28.36	-9.45	18.91	Zn3O(SO4)2
Zn4(OH)6SO4	-9.39	19.01	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-14.22	24.28	38.50	Zn5(OH)8Cl2
ZnCl2	-20.75	-13.70	7.05	ZnCl2
ZnCO3:1H2O	-1.33	-11.59	-10.26	ZnCO3:1H2O
ZnF2	-15.46	-16.00	-0.53	ZnF2
Znmetal	-38.85	-13.06	25.79	Zn
ZnMoO4	-3.89	-14.02	-10.13	ZnMoO4
ZnO(active)	-1.69	9.49	11.19	ZnO
ZnS(am)	-56.98	-66.03	-9.05	ZnS
ZnSe	-14.48	-28.88	-14.40	ZnSe
ZnSeO4:6H2O	-18.31	-19.83	-1.52	ZnSeO4:6H2O
ZnSO4:1H2O	-8.83	-9.47	-0.64	ZnSO4:1H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

End of simulation.

Reading input data for simulation 2.

End of Run after 0.254 Seconds.

Appendix L Summary of AMD Investigations

L.1 Kinetic column leach test results

APPENDIX A-1: Leachate assay results for the Barbara column leach tests: PAF1

Parameters		Sample #16993 - PAF1														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	612	496	489	477	553	555	551	542	543	546	545	549	555	559	535
pH	-	7.7	7.7	7.3	7.3	6.8	7.1	7.2	7.3	7.4	7.4	7.5	7.4	7.4	7.5	7.3
EC	µS/cm	231	496	621	625	381	395	391	429	445	441	436	376	371	366	444
Alkalinity	mg/l	29	15	19	16	18	11	14	14	16	13	15	16	17	22	16
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.07	0.11	0.04	0.04	0.01	0.01	0.04	0.03	0.02	0.02	0.02	0.03	0.04	0.02	0.03
As	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
B	mg/l	0.05	0.05	0.28	0.08	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.07
Ba	mg/l	0.03	0.02	0.04	0.04	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.024
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	44	54	67	40	89	85	76	80	80	77	60	70	67	68
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	6	5	2	1	1	1	1	1	1	1	1	1	1	2
Co	mg/l	0.001	0.013	0.018	0.020	0.007	0.02	0.01	0.01	0.007	0.008	0.008	0.006	0.007	0.007	0.011
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.01	0.13	0.06	0.05	0.03	0.07	0.05	0.04	0.038	0.030	0.033	0.031	0.033	0.028	0.048
F	mg/l	0.3	0.9	1.0	0.8	0.5	0.6	0.4	0.4	0.6	0.3	0.4	0.2	0.3	0.3	0.5
Fe	mg/l	0.05	0.21	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	14	16	14	11	18	15	14	14	15	13	12	12	13	14
Mg	mg/l	12	29	28	30	17	28	20	15	15	14	12	8	8	8	18
Mn	mg/l	0.06	0.14	0.08	0.07	0.03	0.05	0.05	0.04	0.04	0.044	0.04	0.036	0.04	0.04	0.05
Mo	mg/l	0.002	0.006	0.004	0.003	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.003	0.002	0.003	0.003
Na	mg/l	30	19	15	13	6	9	6	5	3	3	2	2	1	1	7
Ni	mg/l	0.005	0.017	0.024	0.027	0.009	0.020	0.012	0.006	0.005	0.004	0.005	0.004	0.004	0.004	0.011
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.06	0.04	0.04	0.02	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02
Si	mg/l	0.6	1.1	1.9	1.5	1.0	1.4	3.4	1.5	1.5	1.8	1.3	1.5	1.5	1.6	1.6
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	247	310	275	157	273	334	265	228	233	185	164	155	197	233
Sr	mg/l	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.10	0.09	0.09	0.08	0.08	0.08	0.10
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-2: Leachate assay results for the Barbara column leach tests: NAF1

Parameters		Sample #16995 - NAF1														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	614	503	496	491	549	551	548	546	549	551	555	557	560	561	540
pH	-	8.5	8.1	7.6	7.5	7.3	7.4	7.4	7.5	7.6	7.6	7.7	7.6	7.6	7.6	7.6
EC	µS/cm	119	126	135	139	105	121	126	142	152	140	139	128	125	131	131
Alkalinity	mg/l	40	26	27	23	19	26	22	19	24	22	23	21	22	25	23
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.1	0.3	0.3	0.3	0.1	0.2	0.2	0.23	0.17	0.19	0.15	0.15	0.16	0.14	0.2
As	mg/l	0.001	0.001	0.002	0.003	0.002	0.003	0.004	0.003	0.003	0.004	0.003	0.003	0.003	0.003	0.003
B	mg/l	0.05	0.05	0.3	0.08	0.05	0.18	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08
Ba	mg/l	0.032	0.003	0.006	0.005	0.003	0.003	0.003	0.005	0.003	0.003	0.003	0.002	0.003	0.002	0.003
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	5	8	10	10	12	10	16	12	14	12	12	14	11	11
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	2	5	1	1	1	1	1	1	1	1	1	1	1	1
Co	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.005	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F	mg/l	0.3	0.2	0.3	0.2	0.1	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Fe	mg/l	0.1	0.2	0.2	0.1	0.05	0.1	0.1	0.1	0.08	0.05	0.08	0.05	0.05	0.05	0.10
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	10	14	6	8	7	4	6	5	5	4	4	3	3	6
Mg	mg/l	12	2	2	1	1	1	1	1	1	1	1	1	1	1	1
Mn	mg/l	0.06	0.07	0.07	0.04	0.03	0.02	0.007	0.005	0.004	0.002	0.002	0.002	0.001	0.001	0.019
Mo	mg/l	0.002	0.015	0.009	0.008	0.008	0.005	0.005	0.007	0.007	0.004	0.003	0.004	0.004	0.004	0.006
Na	mg/l	30	9	5	4	4	6	2	4	2	2	1	1	1	1	3
Ni	mg/l	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1.000
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	0.6	0.9	1.5	0.9	0.7	1.1	3	1.1	0.9	1.1	0.7	1.0	1.0	1.0	1.2
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	19	30	17	24	21	33	36	16	18	12	9	11	10	20
Sr	mg/l	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.006	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.01	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-3: Leachate assay results for the Barbara column leach tests: NAF2

Parameters		Sample #16996 - NAF2														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	602	510	500	496	512	515	520	532	535	539	542	551	559	563	529
pH	-	8.2	8.0	7.5	7.5	7.3	7.4	7.5	7.5	7.6	7.5	7.6	7.5	7.5	7.6	7.5
EC	µS/cm	111	149	179	175	139	141	145	210	222	225	221	196	187	182	182
Alkalinity	mg/l	31	31	29	24	20	22	27	21	23	26	25	23	24	25	25
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.07	0.32	0.29	0.22	0.10	0.18	0.17	0.17	0.14	0.14	0.09	0.15	0.13	0.14	0.17
As	mg/l	0.001	0.006	0.015	0.021	0.018	0.030	0.030	0.033	0.035	0.036	0.029	0.034	0.029	0.029	0.027
B	mg/l	0.05	0.05	0.3	0.1	0.05	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08
Ba	mg/l	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	6	11	17	13	20	21	29	30	35	28	21	23	20	21
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	5	2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1
Co	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.01	0.003	0.005	0.005	0.001	0.004	0.003	0.005	0.004	0.002	0.005	0.003	0.002	0.005	0.004
F	mg/l	0.3	0.3	0.4	0.3	0.1	0.2	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.2
Fe	mg/l	0.1	0.2	0.2	0.1	0.05	0.1	0.1	0.1	0.07	0.06	0.08	0.07	0.07	0.07	0.10
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	16	14	14	10	13	10	9	10	11	9	8	7	7	11
Mg	mg/l	12	3	4	4	3	4	3	4	3	4	3	2	2	2	3
Mn	mg/l	0.06	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.003	0.002	0.002	0.002	0.001	0.001	0.008
Mo	mg/l	0.002	0.01	0.008	0.008	0.005	0.005	0.004	0.007	0.006	0.007	0.004	0.004	0.004	0.005	0.006
Na	mg/l	30	10	6	5	3	4	2	2	2	4	1	1	1	1	3
Ni	mg/l	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.003	0.003	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	0.6	0.9	1.6	1.1	0.9	1.2	3.4	1.4	1.3	1.6	1.2	1.7	1.4	1.4	1.5
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	30	52	52	36	50	65	74	59	64	43	26	30	29	47
Sr	mg/l	0.09	0.01	0.02	0.03	0.02	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.02	0.02	0.03
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-4: Leachate assay results for the Barbara column leach tests: NAF3 (previously PAF2)

Parameters		Sample #16994 - NAF3														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	609	510	499	Column terminated	-	-	-	-	-	-	-	-	-	-	505
pH	-	7.9	8.1	7.7		-	-	-	-	-	-	-	-	-	-	7.9
EC	µS/cm	109	101	96		-	-	-	-	-	-	-	-	-	-	99
Alkalinity	mg/l	28	28	34		-	-	-	-	-	-	-	-	-	-	31
Acidity	mg/l	-	-	-		-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Al	mg/l	0.07	0.4	1.0		-	-	-	-	-	-	-	-	-	-	0.7
As	mg/l	0.001	0.01	0.01		-	-	-	-	-	-	-	-	-	-	0.012
B	mg/l	0.05	0.05	0.3		-	-	-	-	-	-	-	-	-	-	0.16
Ba	mg/l	0.03	0.009	0.01		-	-	-	-	-	-	-	-	-	-	0.011
Be	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Ca	mg/l	43	1	1		-	-	-	-	-	-	-	-	-	-	1
Cd	mg/l	0.0001	0.0001	0.0001		-	-	-	-	-	-	-	-	-	-	0.0001
Cl	mg/l	28	5	3		-	-	-	-	-	-	-	-	-	-	4
Co	mg/l	0.001	0.003	0.003		-	-	-	-	-	-	-	-	-	-	0.003
Cr	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Cu	mg/l	0.005	0.1	0.2		-	-	-	-	-	-	-	-	-	-	0.14
F	mg/l	0.3	0.8	0.8		-	-	-	-	-	-	-	-	-	-	0.8
Fe	mg/l	0.05	0.5	1.1		-	-	-	-	-	-	-	-	-	-	0.8
Hg	mg/l	0.0001	0.0001	0.0001		-	-	-	-	-	-	-	-	-	-	0.0001
K	mg/l	17	1	3		-	-	-	-	-	-	-	-	-	-	2
Mg	mg/l	12	1	1		-	-	-	-	-	-	-	-	-	-	1
Mn	mg/l	0.06	0.02	0.02		-	-	-	-	-	-	-	-	-	-	0.02
Mo	mg/l	0.002	0.01	0.01		-	-	-	-	-	-	-	-	-	-	0.011
Na	mg/l	30	16	15		-	-	-	-	-	-	-	-	-	-	16
Ni	mg/l	0.005	0.001	0.002		-	-	-	-	-	-	-	-	-	-	0.002
P	mg/l	1	1	1		-	-	-	-	-	-	-	-	-	-	1
Pb	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Sb	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Se	mg/l	0.01	0.01	0.01		-	-	-	-	-	-	-	-	-	-	0.01
Si	mg/l	1	3	5		-	-	-	-	-	-	-	-	-	-	3.965
Sn	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
SO_4	mg/l	113	6	8		-	-	-	-	-	-	-	-	-	-	7
Sr	mg/l	0.09	0.002	0.003		-	-	-	-	-	-	-	-	-	-	0.003
Th	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Tl	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
U	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Zn	mg/l	0.005	0.005	0.005		-	-	-	-	-	-	-	-	-	-	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-5: Leachate assay results for the Barbara column leach tests: NAF4

Parameters		Sample #17920 - NAF4														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	593	552	561	552	556	554	558	552	556	561	560	563	561	566	558
pH	-	7.9	7.1	7.3	7.4	7.4	7.6	7.5	7.5	7.4	7.4	7.6	7.5	7.5	7.6	7.4
EC	µS/cm	531	649	616	611	776	795	784	769	711	689	655	550	530	530	667
Alkalinity	mg/l	32	20	24	19	21	23	28	25	24	26	30	30	29	28	25
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.07	0.02	0.04	0.01	0.02	0.02	0.02	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.02
As	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
B	mg/l	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Ba	mg/l	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.03	0.02	0.02	0.02	0.02
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	57	150	170	144	162	165	217	167	103	147	160	131	122	146
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	30	34	27	14	6	3	2	1	1	1	1	1	1	9
Co	mg/l	0.001	0.001	0.001	0.002	0.0	0.002	0.003	0.005	0.004	0.002	0.003	0.003	0.002	0.002	0.002
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.005	0.009	0.02	0.02	0.02	0.026	0.026	0.036	0.026	0.021	0.023	0.017	0.014	0.019	0.021
F	mg/l	0.3	0.3	0.6	0.6	0.6	0.8	0.5	0.1	0.4	0.3	0.4	0.4	0.4	0.3	0.4
Fe	mg/l	0.05	0.05	0.11	0.05	0.06	0.05	0.05	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.06
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	17	30	24	22	22	22	25	23	14	18	18	17	16	21
Mg	mg/l	12	22	38	40	35	37	36	42	28	14	22	22	19	18	29
Mn	mg/l	0.06	0.07	0.1	0.2	0.2	0.21	0.21	0.38	0.26	0.13	0.23	0.19	0.13	0.13	0.19
Mo	mg/l	0.002	0.004	0.003	0.004	0.003	0.003	0.002	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.002
Na	mg/l	30	32	37	32	21	15	9	7	4	2	2	1	1	1	13
Ni	mg/l	0.005	0.001	0.002	0.001	0.001	0.001	0.001	0.002	0.003	0.001	0.002	0.002	0.001	0.001	0.001
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	0.6	0.5	1.0	2.5	0.9	0.9	1.1	1.0	1.0	0.7	1.0	1	1	1	1.0
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	224	482	615	533	551	531	628	499	244	443	434	365	331	452
Sr	mg/l	0.09	0.11	0.19	0.21	0.15	0.16	0.14	0.17	0.14	0.07	0.11	0.10	0.08	0.08	0.13
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-6: Leachate assay results for the Barbara column leach tests: ROM1

Parameters		Sample #16997 - ROM1														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	603	499	503	499	495	500	510	521	525	528	536	540	550	553	520
pH	-	8.0	8.0	7.8	7.7	7.3	7.3	7.4	7.5	7.6	7.5	7.6	7.6	7.5	7.7	7.6
EC	µS/cm	136	131	185	183	158	162	169	141	156	155	149	138	129	128	153
Alkalinity	mg/l	34	30	25	22	20	24	25	23	25	24	26	24	25	24	24
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.1	0.7	2	0.5	0.4	0.7	1	0.6	0.9	0.9	1.0	0.7	0.8	0.71	0.86
As	mg/l	0.001	0.005	0.006	0.005	0.004	0.006	0.006	0.004	0.004	0.004	0.003	0.004	0.003	0.003	0.004
B	mg/l	0.05	0.05	0.3	0.2	0.09	0.3	0.1	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.10
Ba	mg/l	0.03	0.02	0.04	0.03	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.03
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	2	4	6	5	5	3	3	3	2	3	2	2	3	3
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	3	2	2	1	3	1	1	1	1	1	1	1	1	1
Co	mg/l	0.001	0.002	0.005	0.002	0.001	0.003	0.004	0.004	0.006	0.008	0.006	0.005	0.007	0.007	0.005
Cr	mg/l	0.001	0.001	0.003	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.002	0.002	0.004	0.001	0.002
Cu	mg/l	0.005	0.4	0.6	0.3	0.1	0.4	0.5	0.5	0.8	1.0	0.8	0.6	1.0	0.8	0.6
F	mg/l	0.3	2	2	1	1	1	0.7	0.5	0.8	0.5	0.1	0.3	0.3	0.3	0.8
Fe	mg/l	0.05	1	3	0.6	0.5	0.9	1.5	0.8	1.2	1.1	1.4	0.9	1.1	0.96	1.1
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	3	4	4	4	5	3	3	3	3	3	3	3	3	3
Mg	mg/l	12	2	4	6	5	5	3	2	3	2	3	2	3	3	3
Mn	mg/l	0.06	0.04	0.05	0.02	0.01	0.03	0.04	0.05	0.06	0.08	0.07	0.05	0.07	0.07	0.05
Mo	mg/l	0.002	0.02	0.01	0.01	0.009	0.006	0.004	0.003	0.004	0.002	0.001	0.001	0.001	0.001	0.005
Na	mg/l	30	18	24	24	18	16	13	10	10	8	7	6	6	6	13
Ni	mg/l	0.005	0.001	0.003	0.001	0.001	0.002	0.002	0.001	0.002	0.002	0.003	0.001	0.004	0.002	0.002
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	1	5	6	6	6	7	14	5	5	6	4	4	4	4	6
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	22	62	58	44	31	32	16	12	8	5	4	4	4	23
Sr	mg/l	0.09	0.008	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

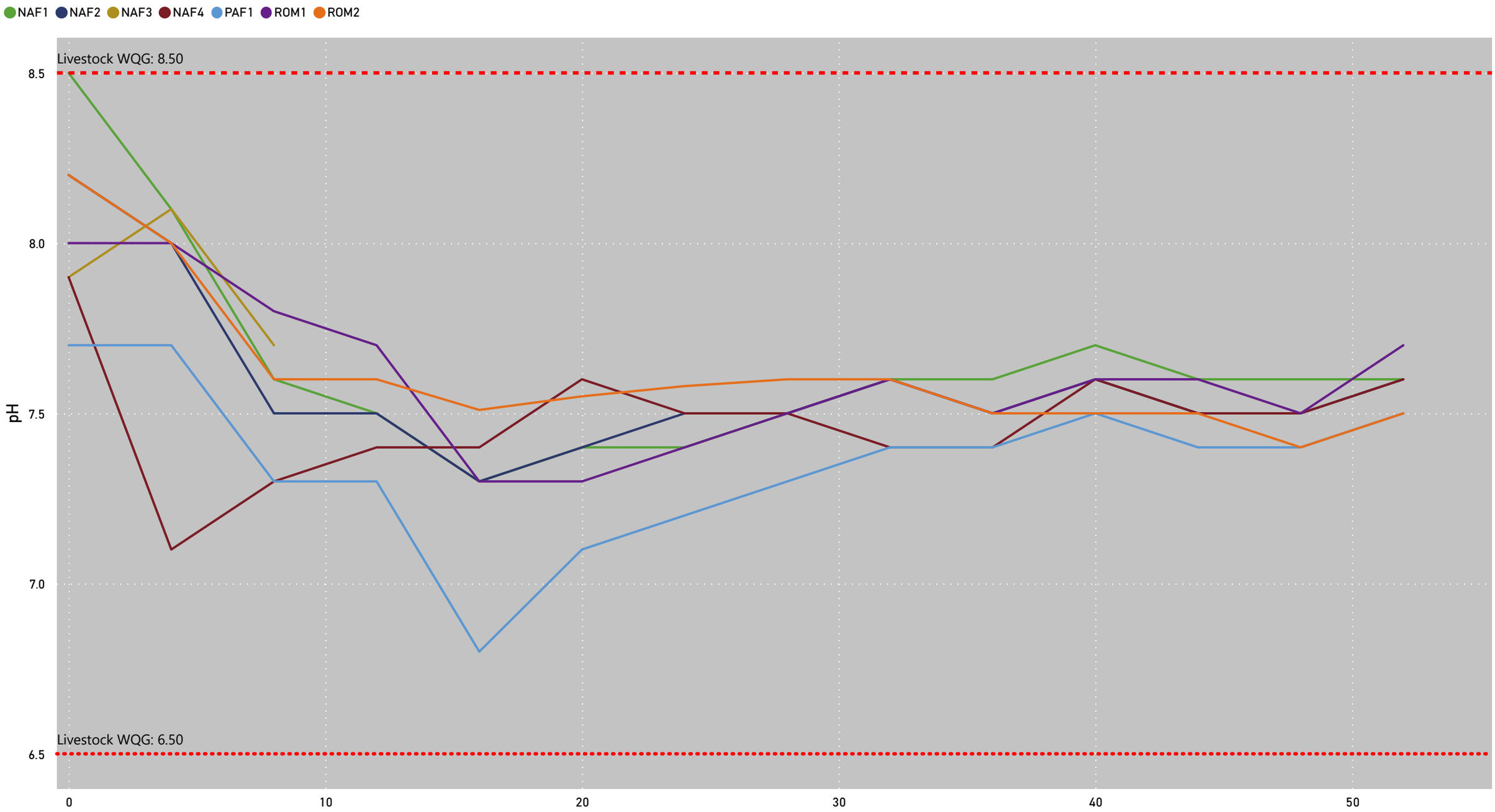
Underline indicates that the concentration is less than the limit of detection

APPENDIX A-7: Leachate assay results for the Barbara column leach tests: ROM2

Parameters		Sample #16998 - ROM2														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	611	509	502	497	508	510	516	525	521	525	531	540	545	551	522
pH	-	8.2	8.0	7.6	7.6	7.51	7.55	7.58	7.6	7.6	7.5	7.5	7.5	7.4	7.5	7.6
EC	µS/cm	278	318	348	342	330	339	341	275	286	288	280	255	225	221	296
Alkalinity	mg/l	68	51	40	37	37	32	30	28	33	30	31	29	28	32	34
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.1	0.8	2.0	0.2	0.3	0.3	0.4	0.2	0.3	0.6	0.5	0.4	0.6	0.3	0.5
As	mg/l	0.001	0.006	0.006	0.003	0.003	0.003	0.004	0.003	0.003	0.004	0.003	0.003	0.002	0.002	0.003
B	mg/l	0.05	0.05	0.2	0.1	0.06	0.07	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.07
Ba	mg/l	0.03	0.03	0.04	0.03	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.03
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	5	7	12	12	10	9	8	10	6	7	6	6	7	8
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	3	3	1	1	1	1	1	1	1	1	1	1	1	1
Co	mg/l	0.001	0.004	0.004	0.001	0.001	0.001	0.001	0.001	0.002	0.005	0.004	0.003	0.006	0.003	0.003
Cr	mg/l	0.001	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.005	0.5	0.5	0.1	0.1	0.2	0.2	0.2	0.2	0.6	0.5	0.3	0.7	0.3	0.3
F	mg/l	0.3	3	2	2	1.4	1.3	1.0	0.8	1.2	0.7	0.1	0.4	0.4	0.4	1.1
Fe	mg/l	0.05	1	2	0.3	0.3	0.4	0.4	0.3	0.3	0.6	0.7	0.5	0.7	0.5	0.6
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	5	8	7	8	9	7	5	6	5	4	5	4	4	6
Mg	mg/l	12	5	8	10	12	10	8	7	8	5	6	5	5	5	7
Mn	mg/l	0.06	0.04	0.03	0.006	0.002	0.01	0.01	0.01	0.012	0.04	0.03	0.02	0.05	0.022	0.021
Mo	mg/l	0.002	0.01	0.01	0.008	0.007	0.005	0.003	0.003	0.004	0.002	0.001	0.001	0.001	0.001	0.005
Na	mg/l	30	47	45	41	34	27	24	19	20	13	12	10	8	8	24
Ni	mg/l	0.005	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	0.6	6	6	5	5	5	17	4	4	5	3	4	3	4	5.463
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	79	120	121	115	77	88	63	55	25	19	15	13	20	62
Sr	mg/l	0.09	0.02	0.04	0.05	0.04	0.03	0.04	0.03	0.04	0.02	0.03	0.03	0.02	0.03	0.031
Th	mg/l	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

L.2 Kinetic column leach test results versus livestock drinking water quality guidelines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NAF3
NAF4
PAF1
ROM1
ROM2
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Livestock WQG: 6.50
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20
30
40
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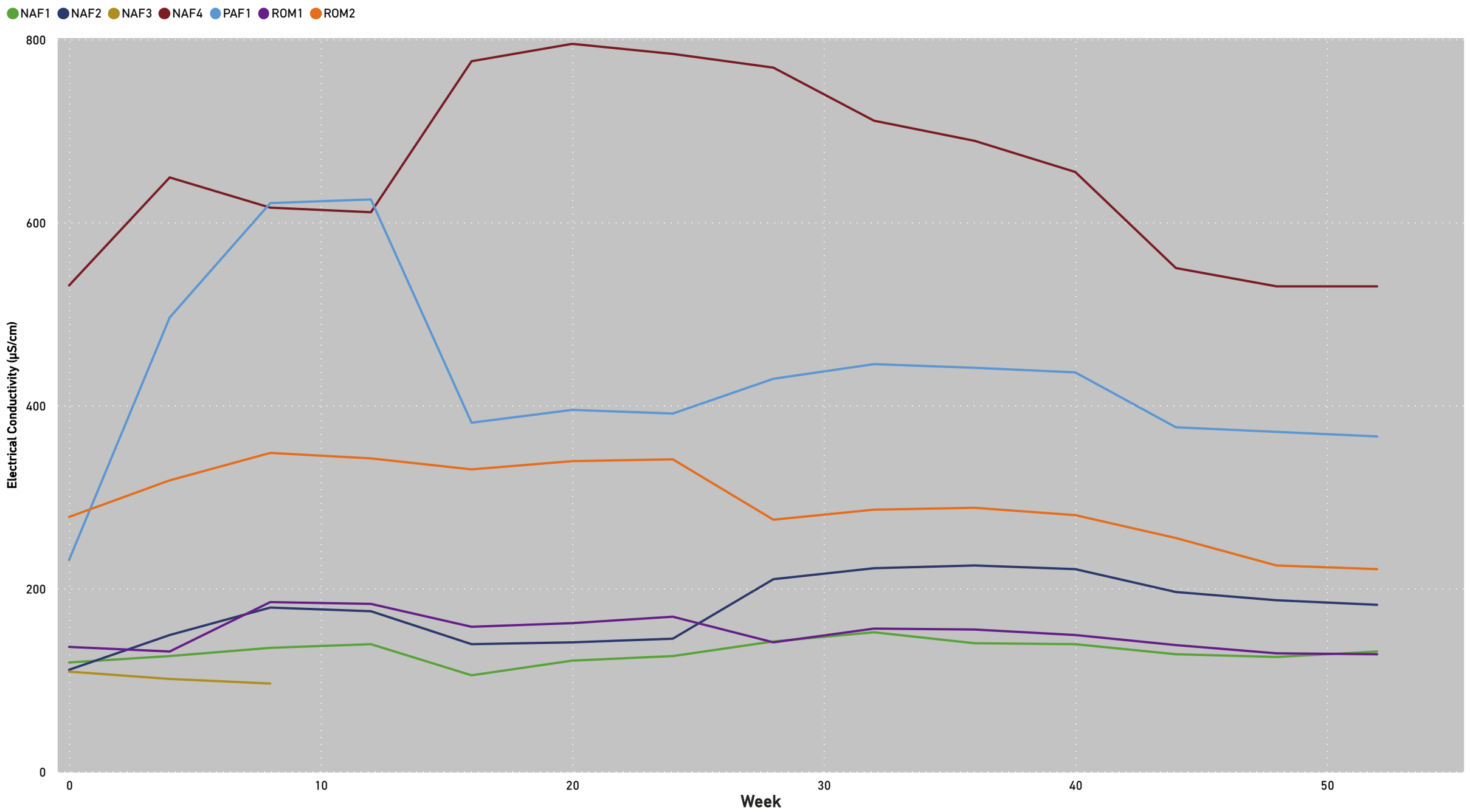
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NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
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400
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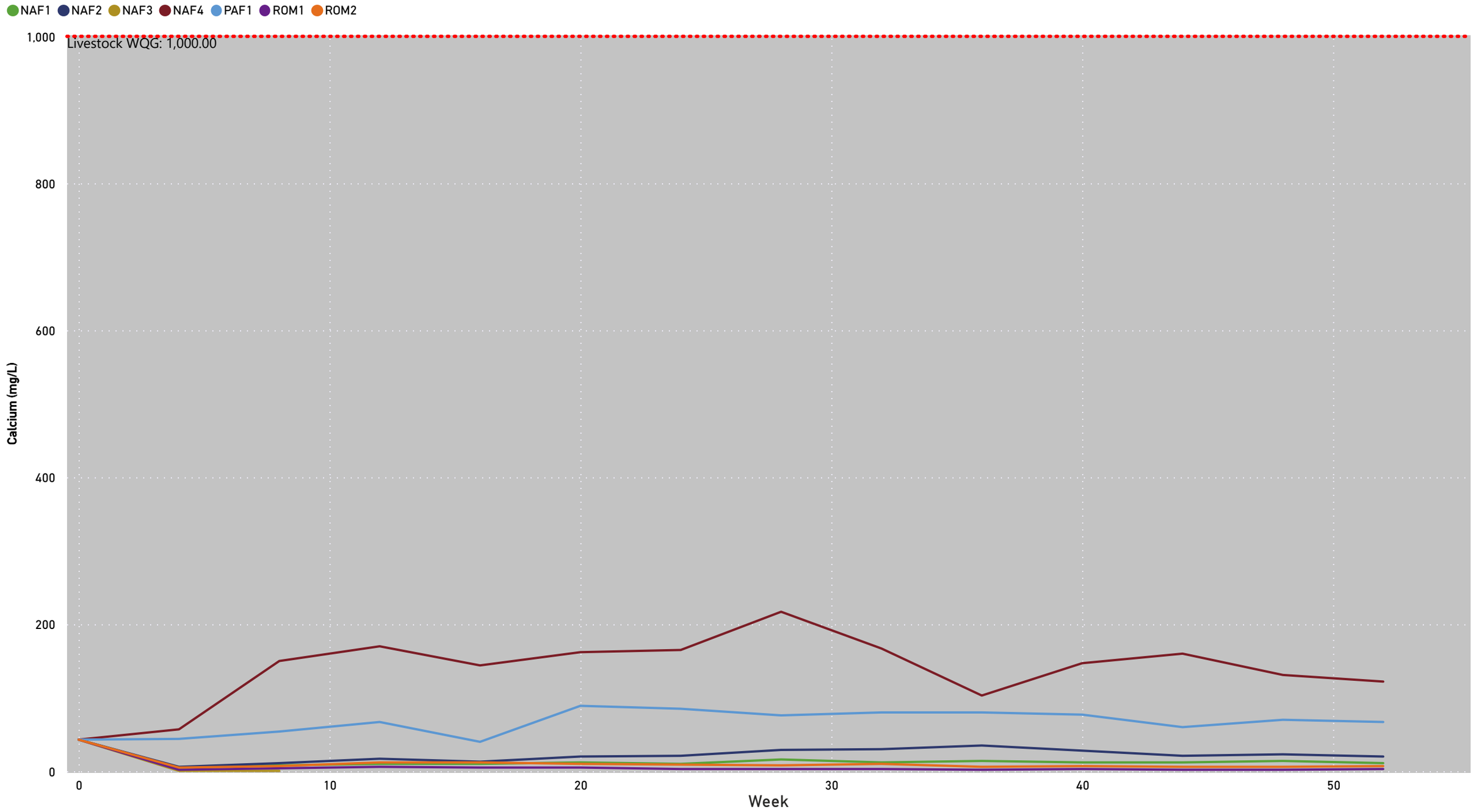
20
30
40
50
Week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NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG: 1,000.00
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600
400
200
0
Calcium (mg/L)
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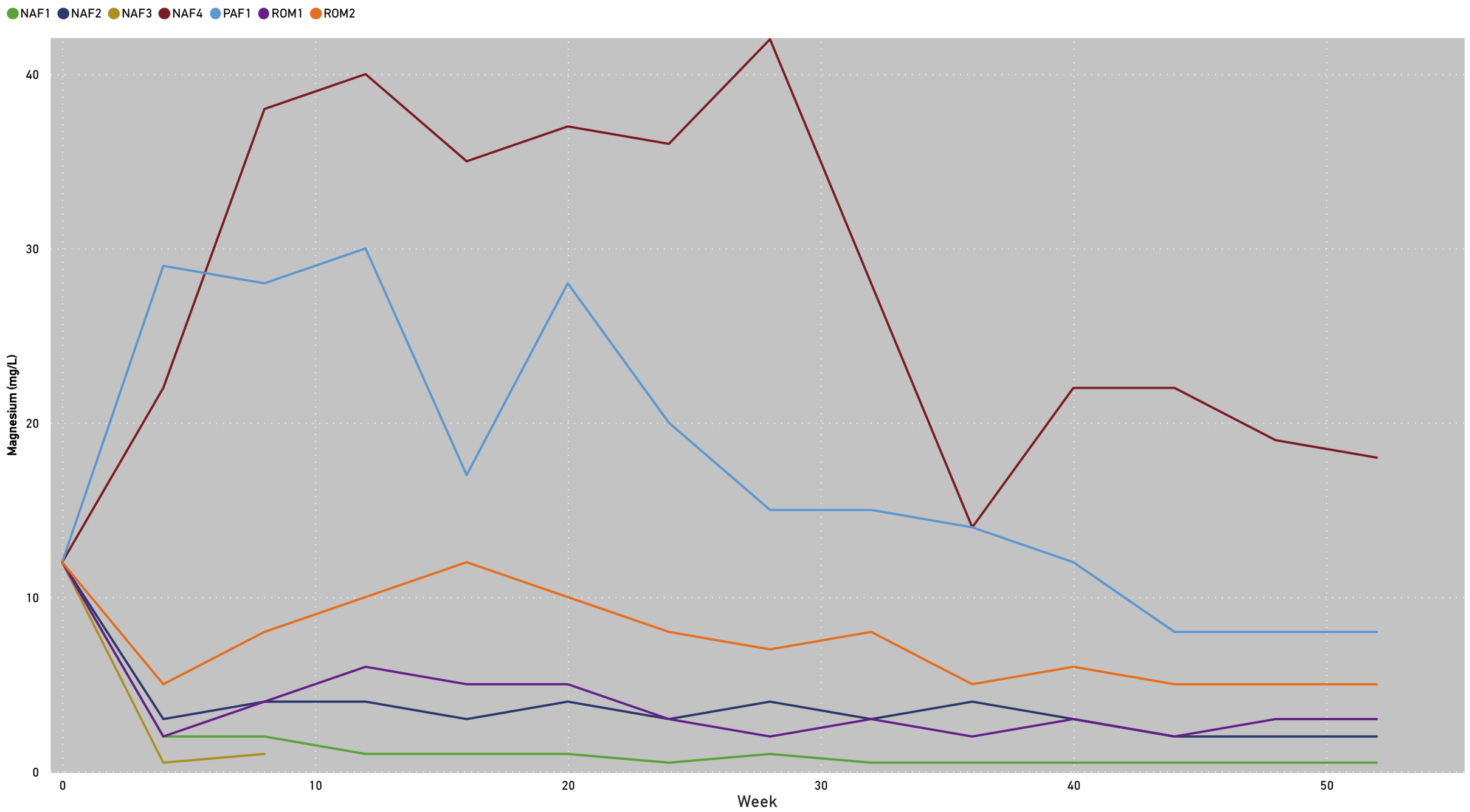
10
20
30
40
50
Week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NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
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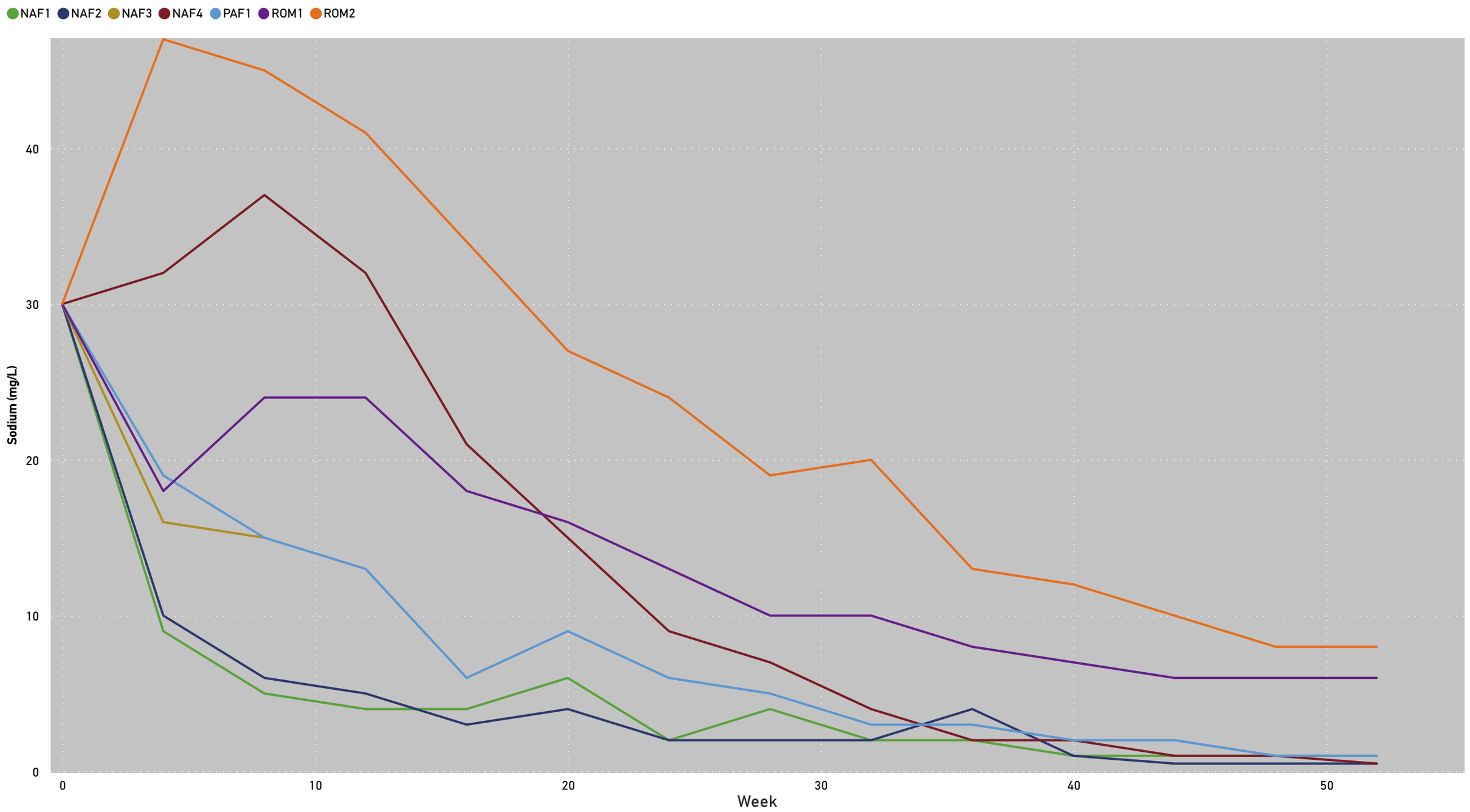
10
20
30
40
50
Week


NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Sodium (mg/L)
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30
40
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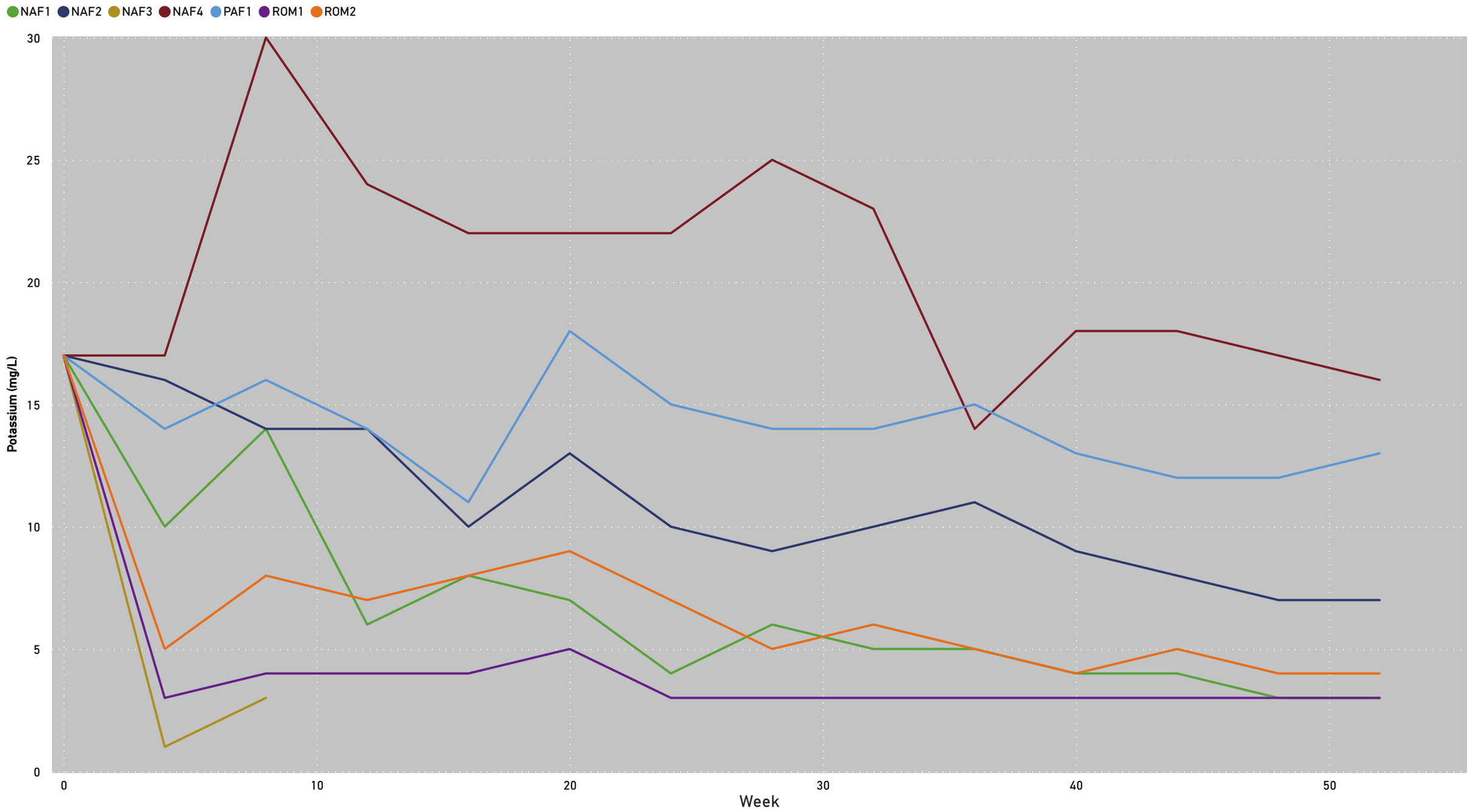
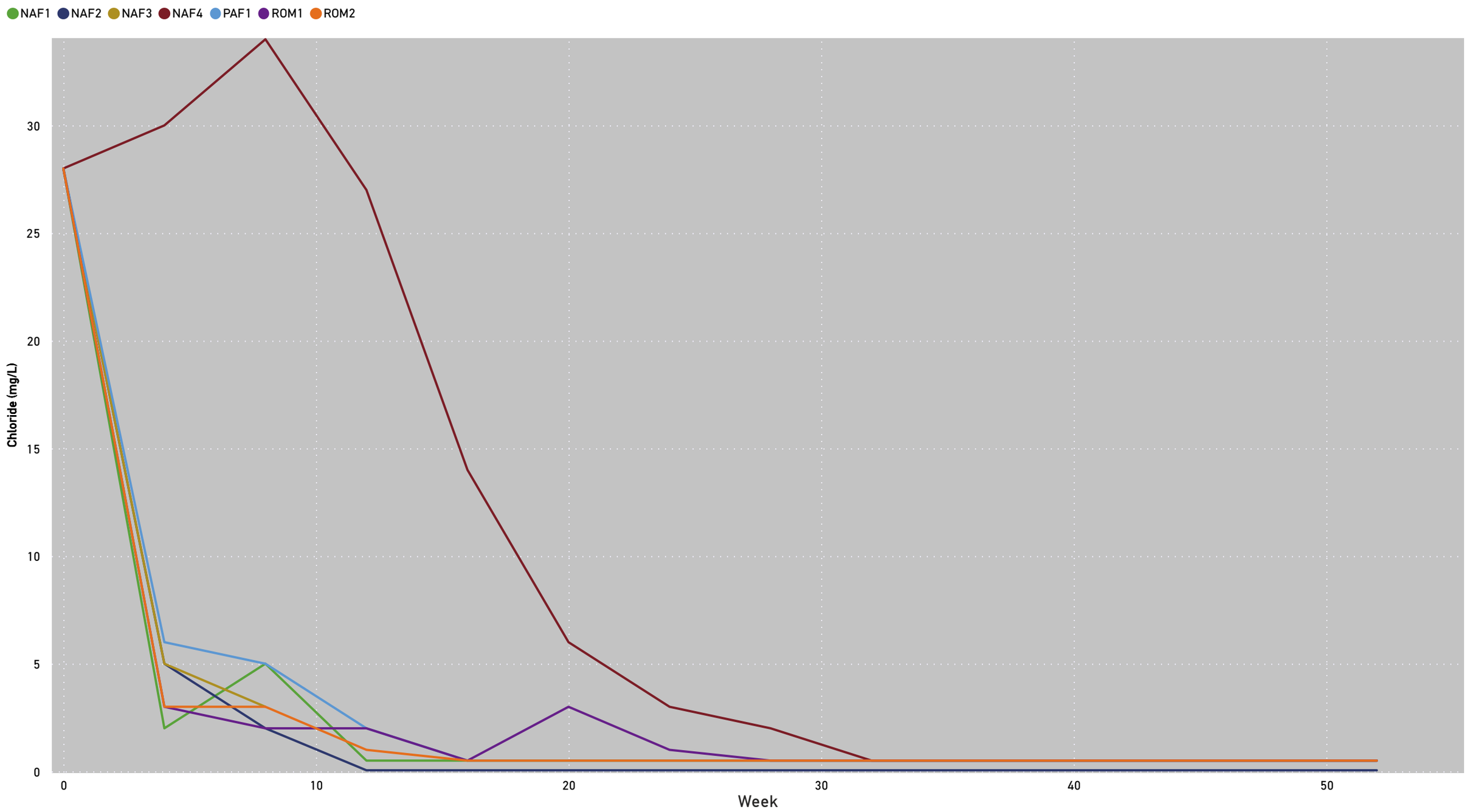
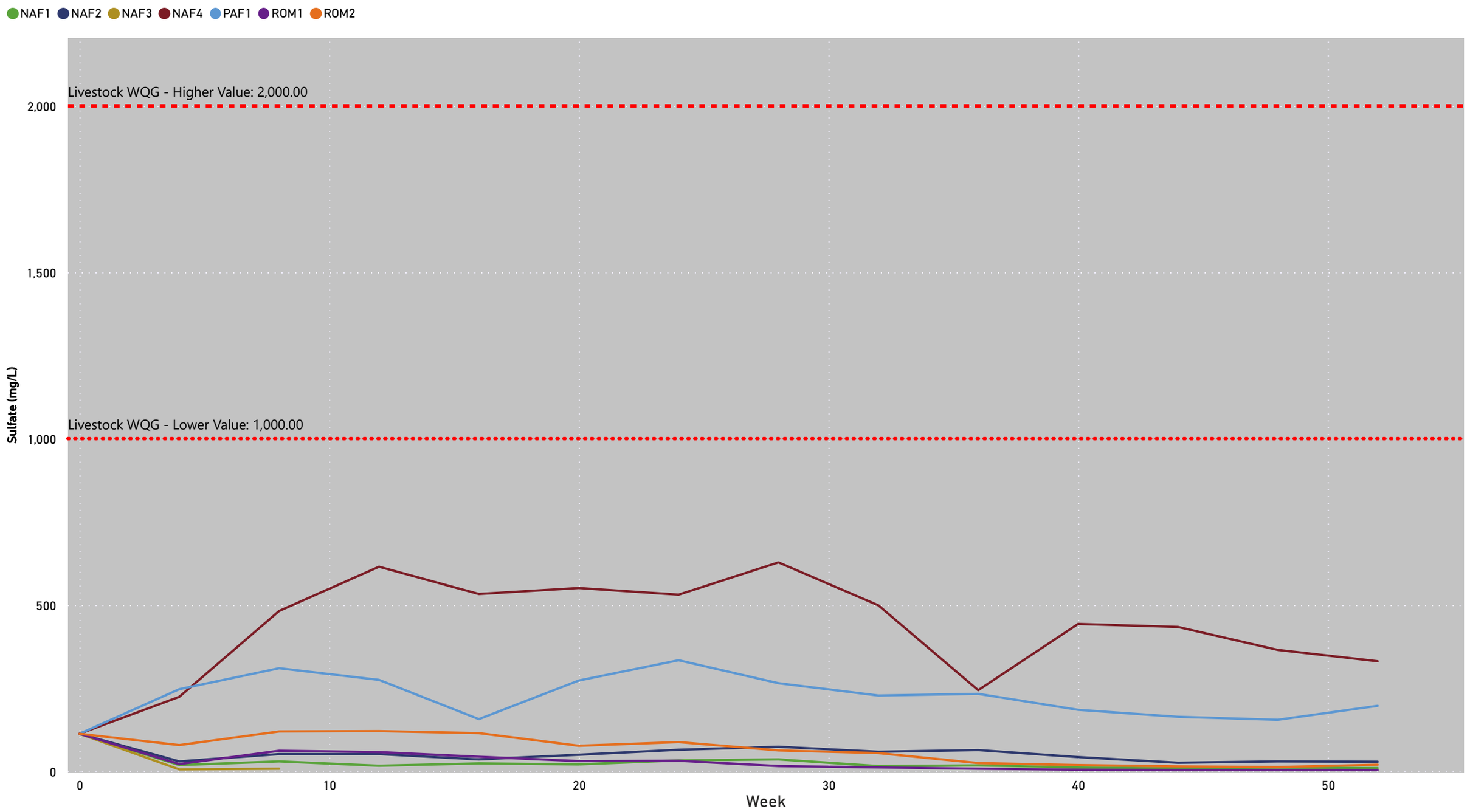
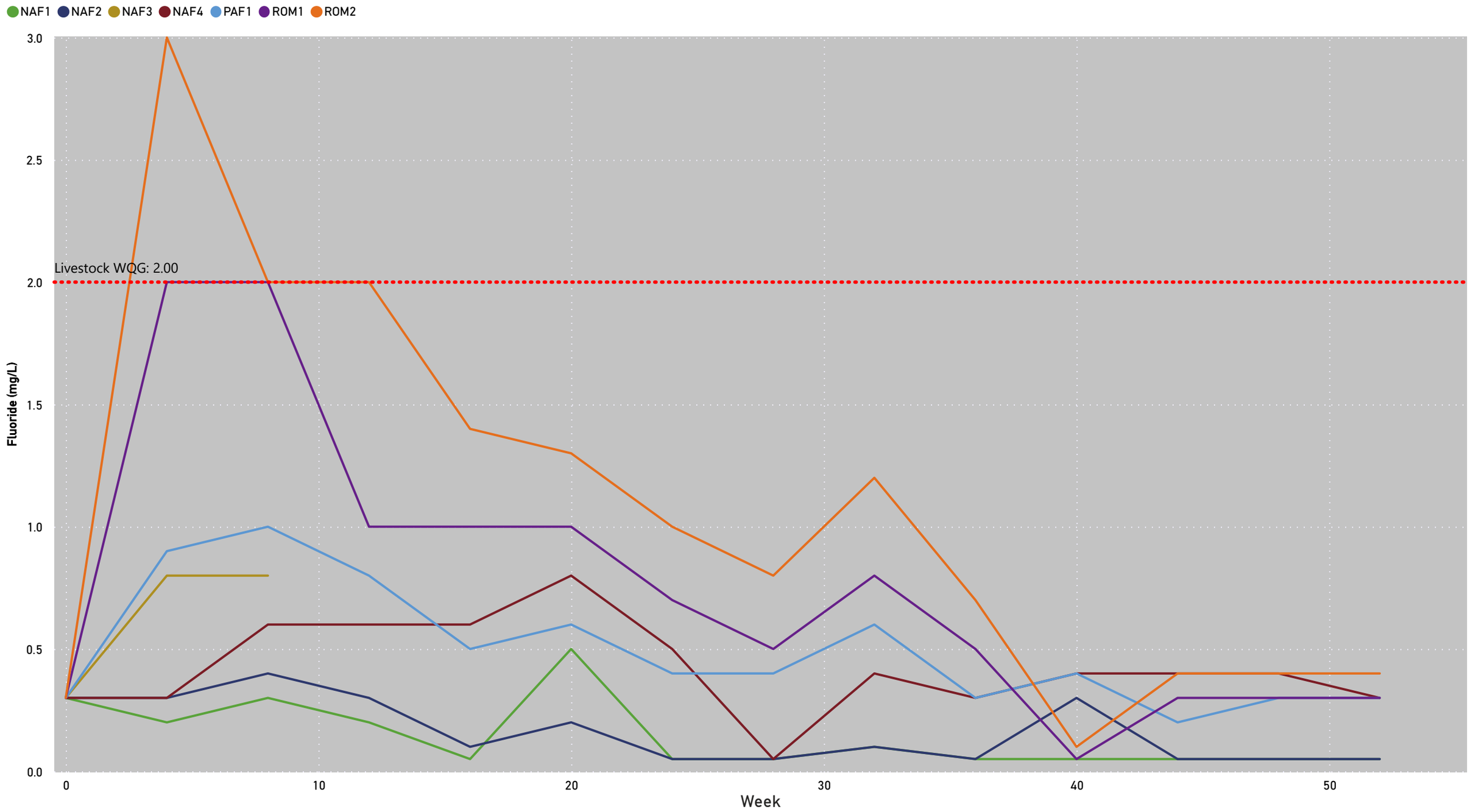
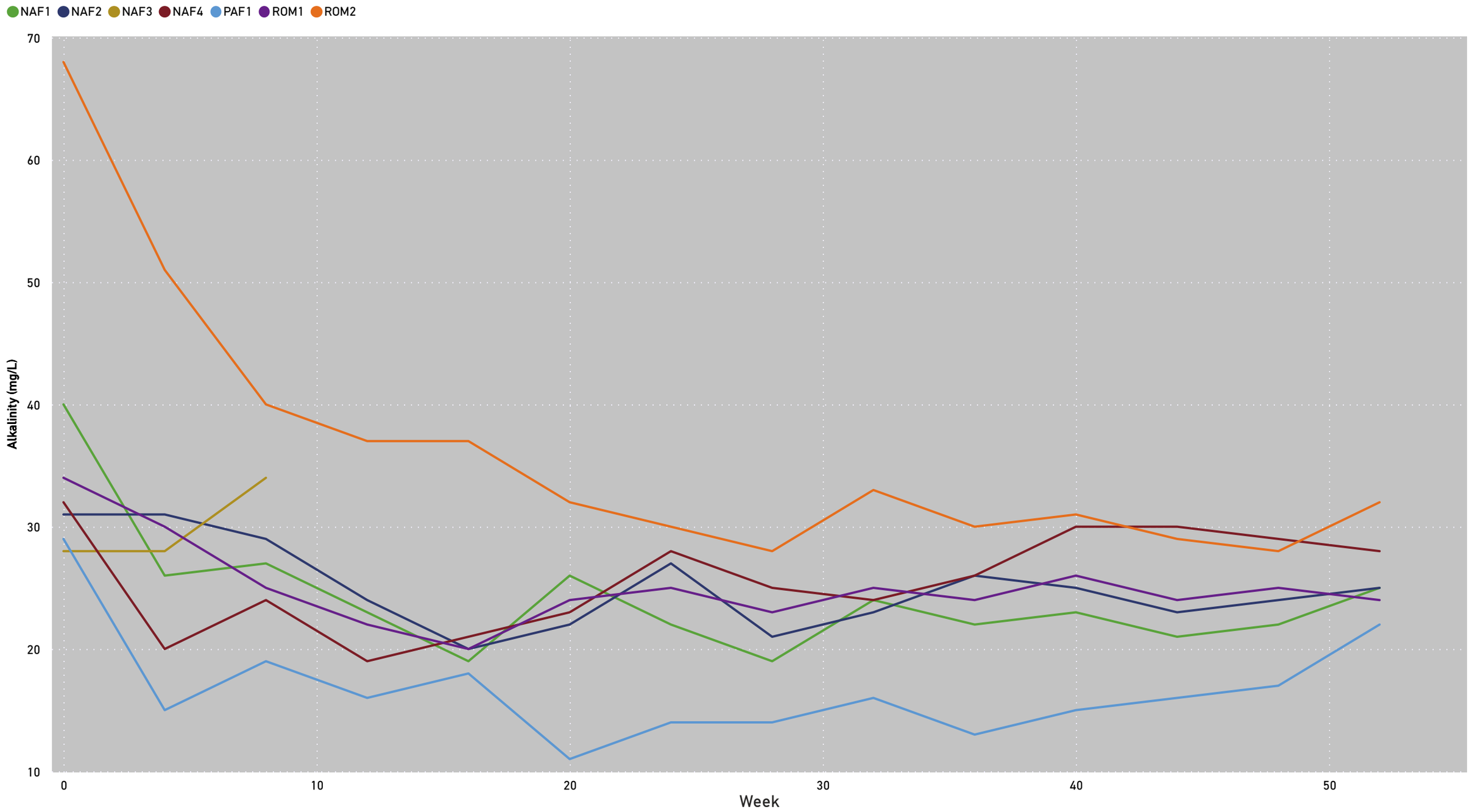
20
30
40
50
Week

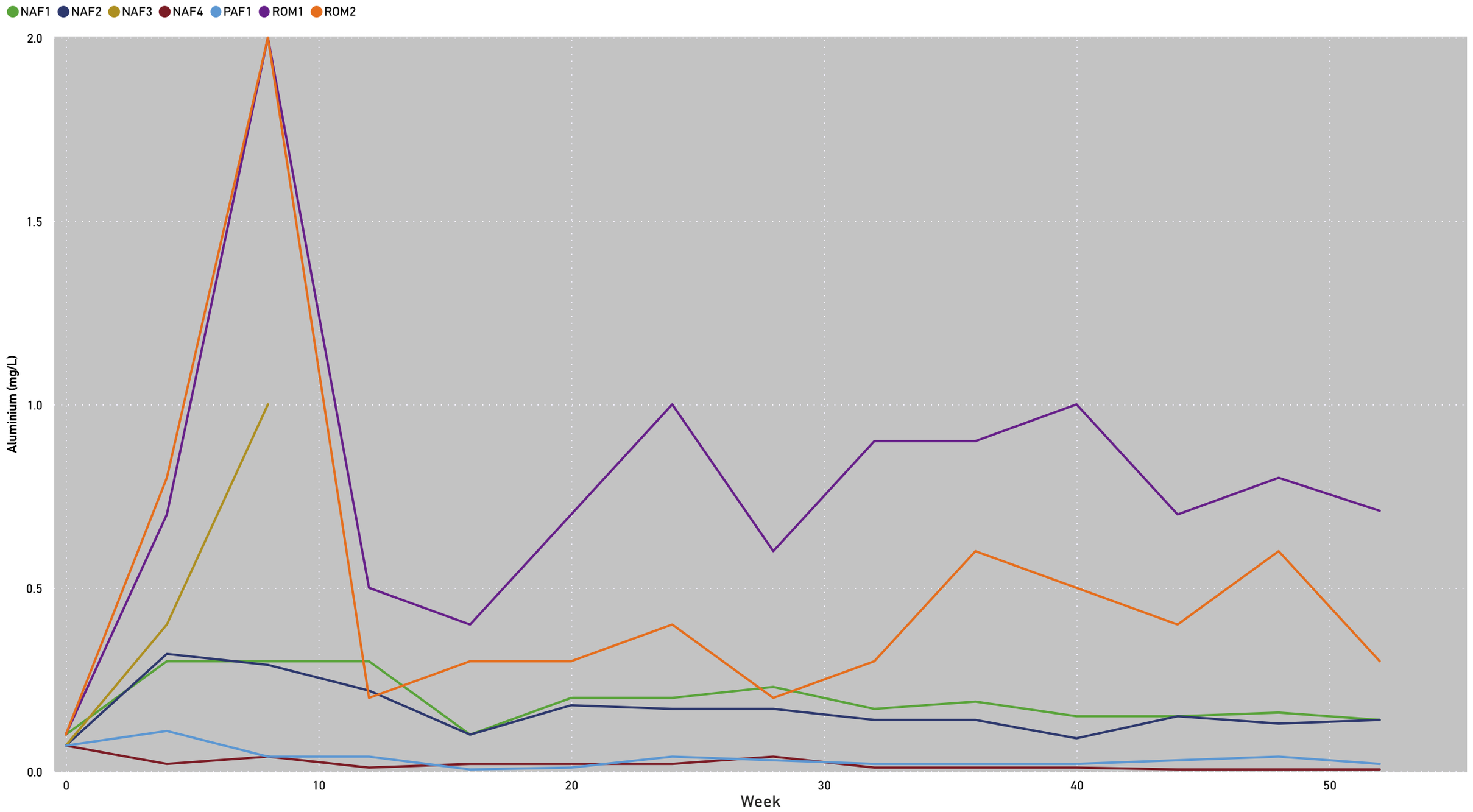

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Potassium (mg/L)
30
25
20
15
10
5
0
0
10
20
30
40
50
Week

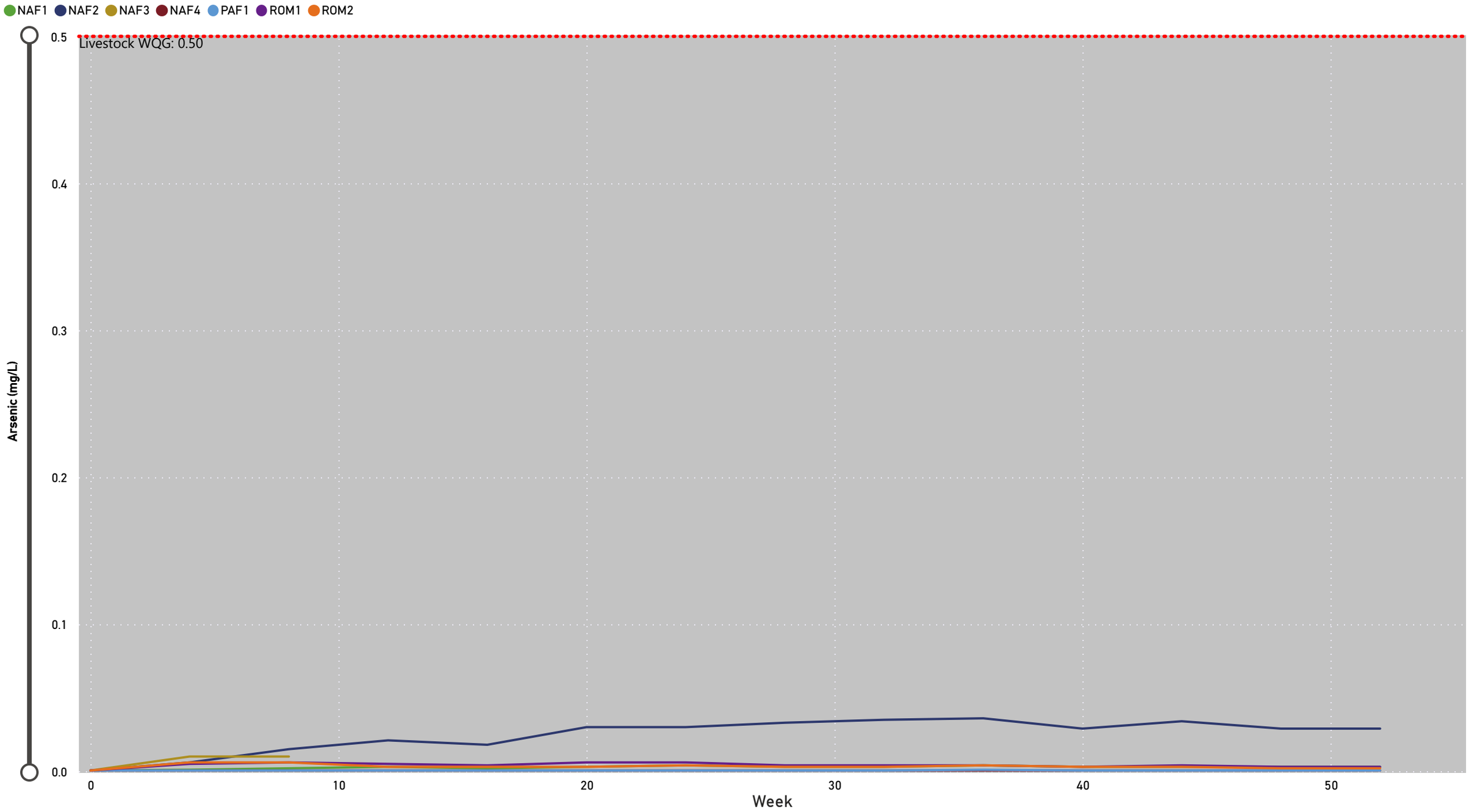

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Chloride (mg/L)
0
5
10
15
20
25
30
0
10
20
30
40
50
Week

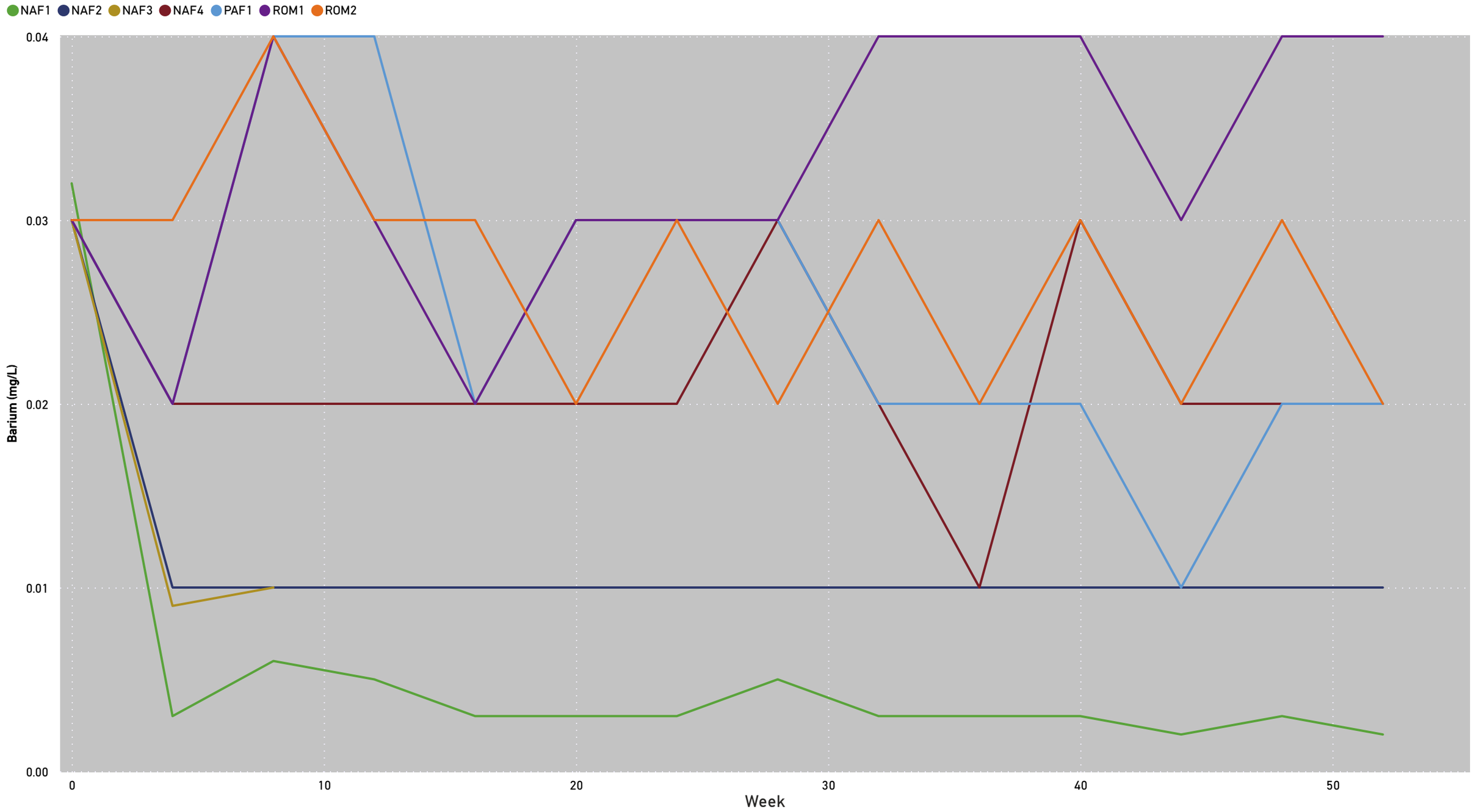

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG - Higher Value: 2,000.00
Livestock WQG - Lower Value: 1,000.00
Sulfate (mg/L)
2,000
1,500
1,000
500
0
0
10
20
30
40
50
Week

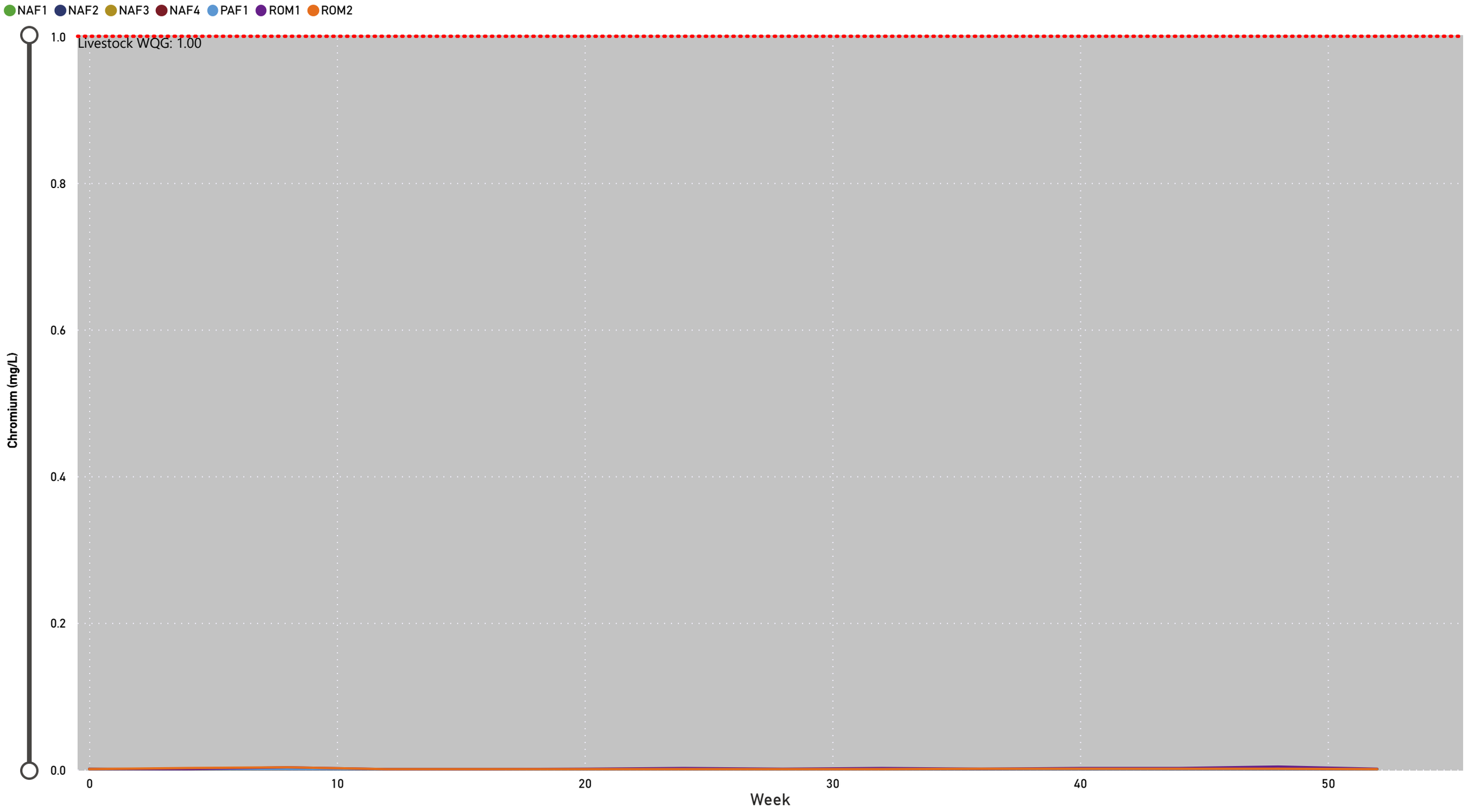

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG: 2.00
Fluoride (mg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
Week

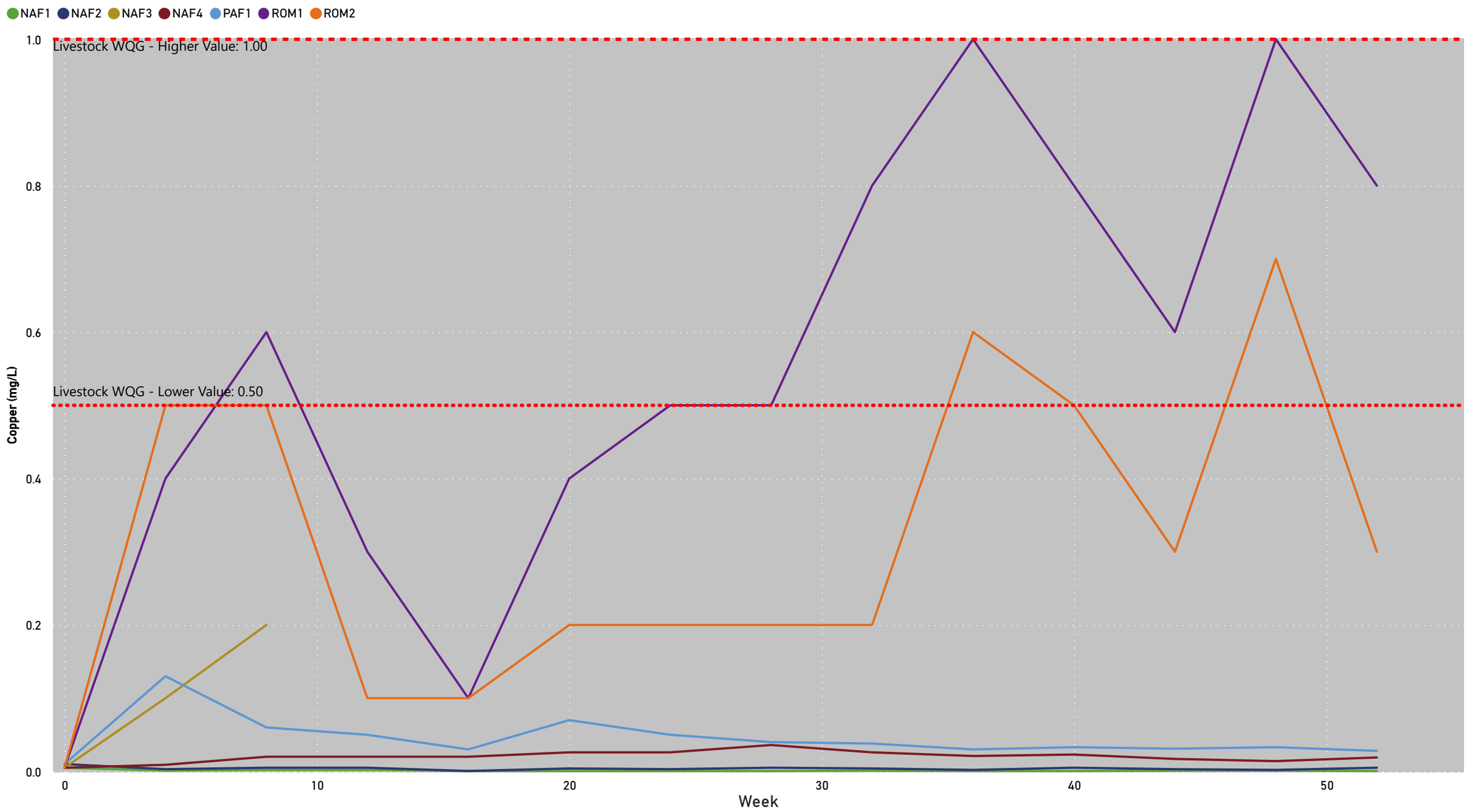

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Alkalinity (mg/L)
70
60
50
40
30
20
10
0
10
20
30
40
50
Week

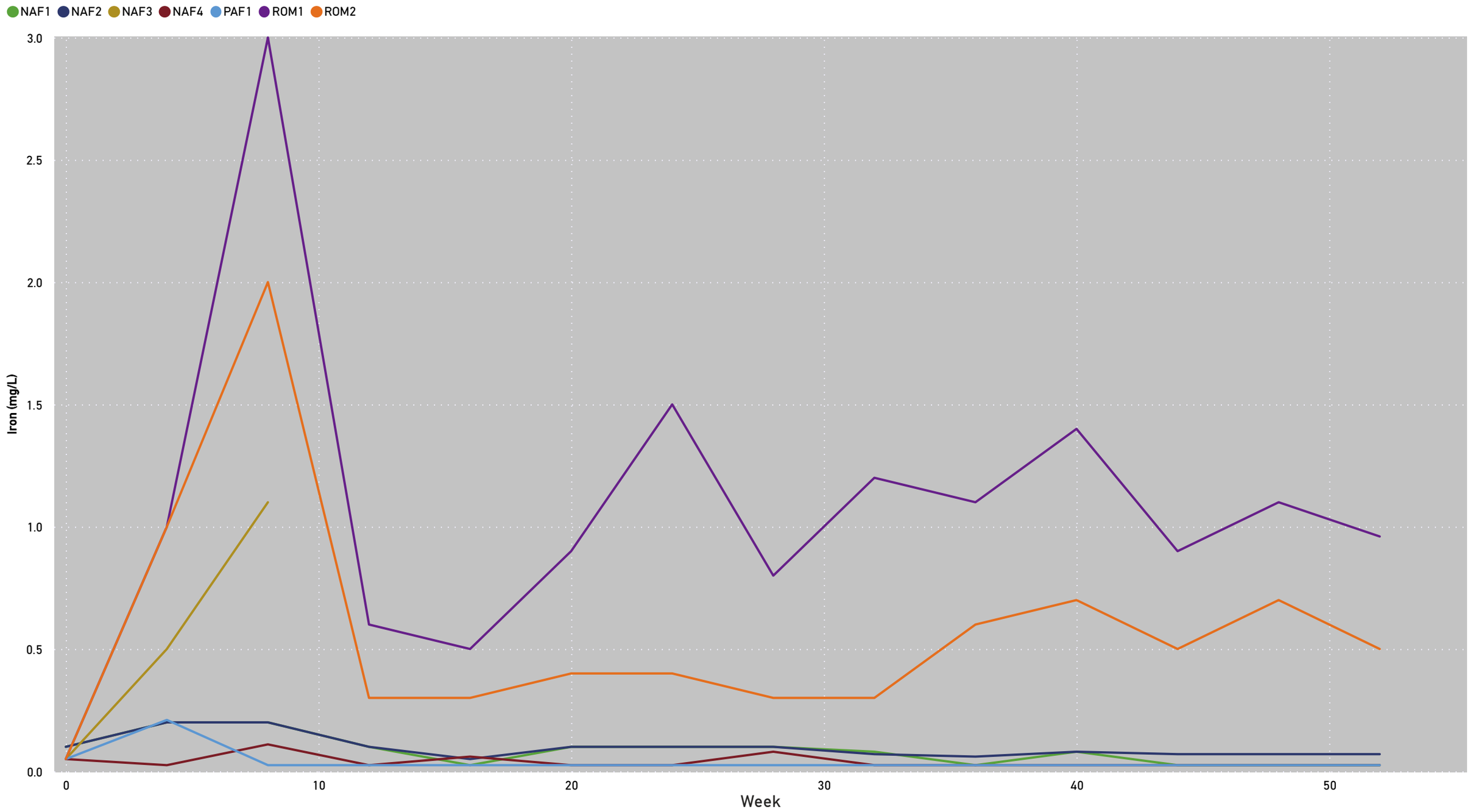

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Aluminium (mg/L)
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
Week

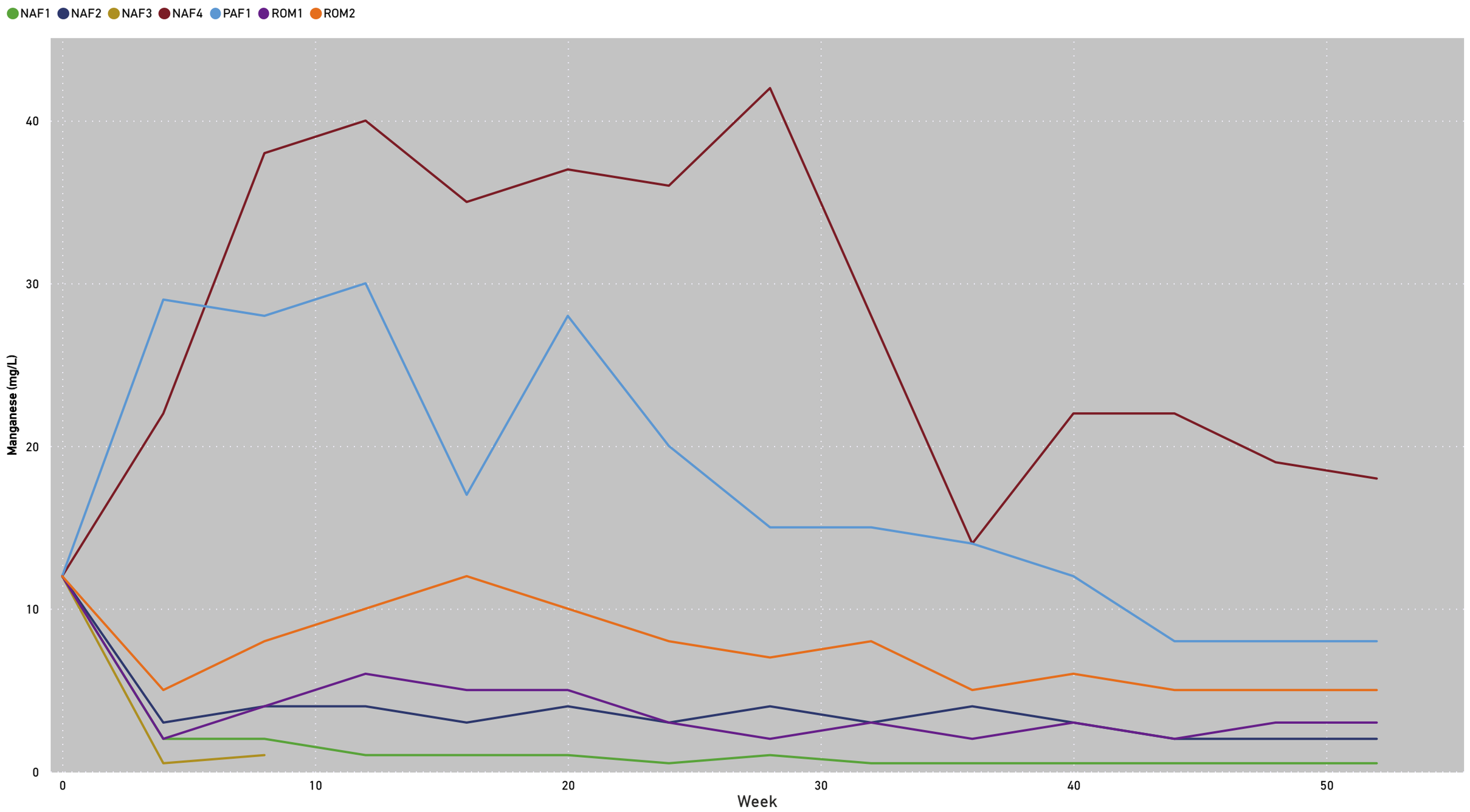

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG: 0.50
Arsenic (mg/L)
0.5
0.4
0.3
0.2
0.1
0.0
0
10
20
30
40
50
Week

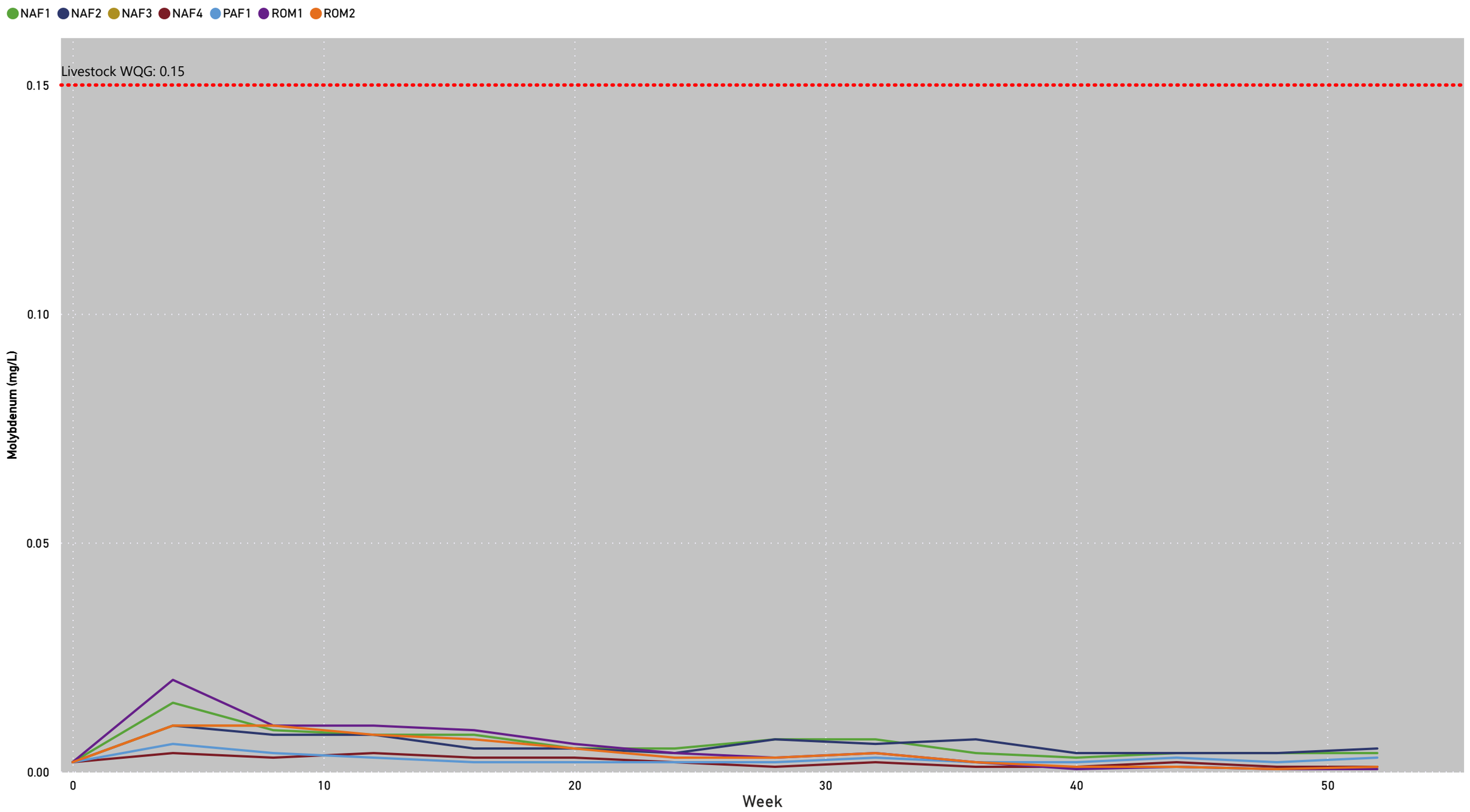

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
0.04
0.03
0.02
0.01
0.00
Barium (mg/L)
0
10
20
30
40
50
Week

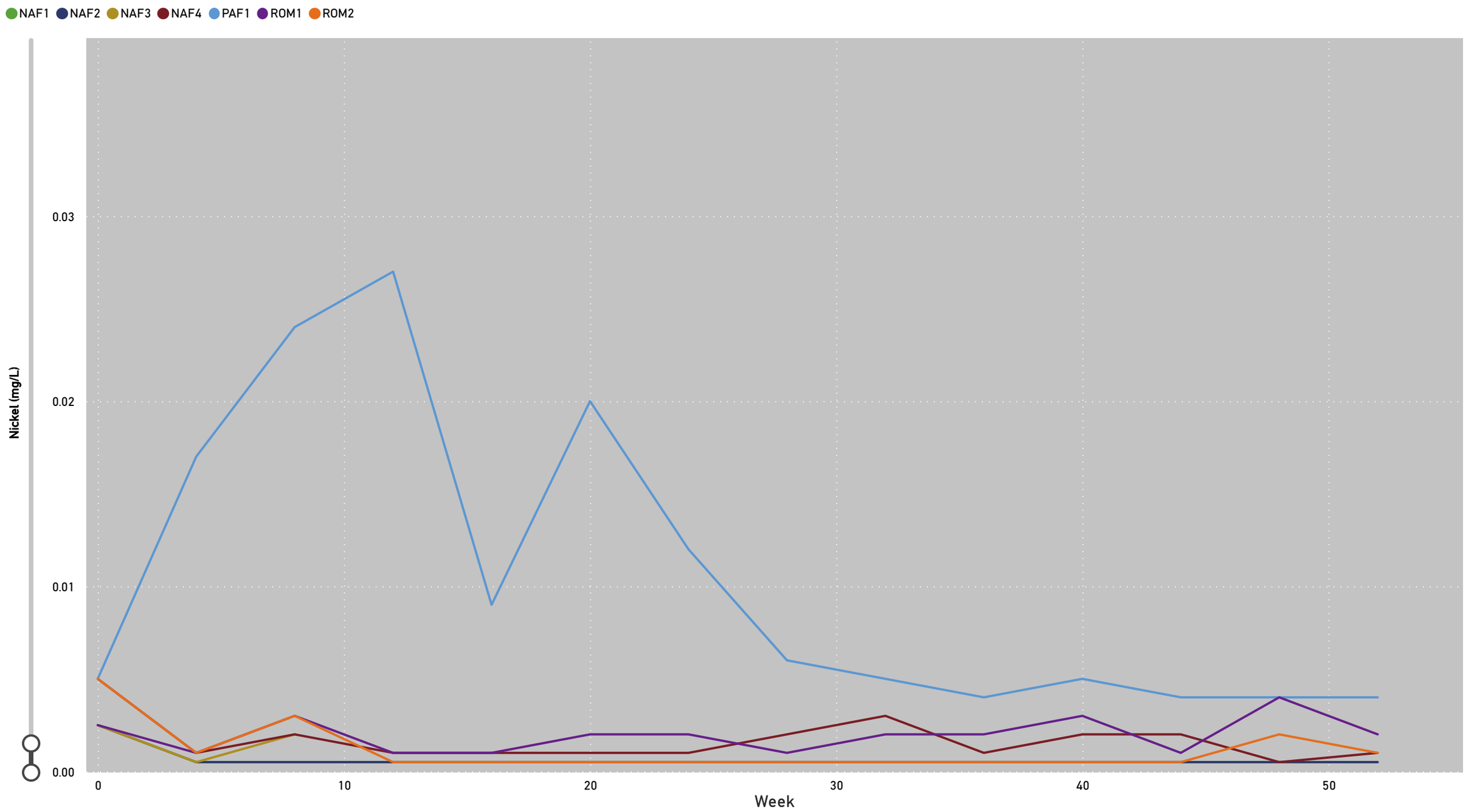

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG: 1.00
Chromium (mg/L)
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
Week

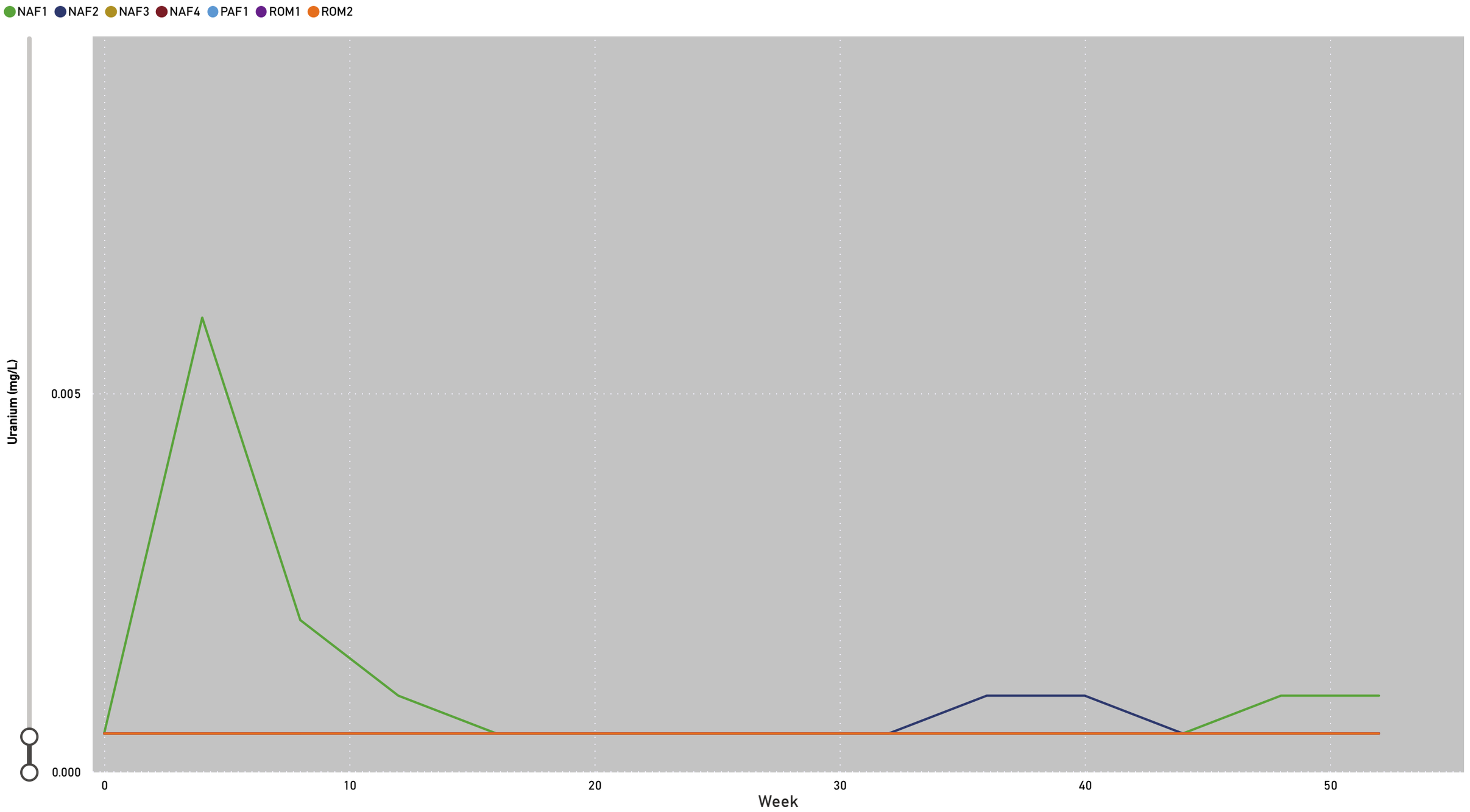

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG - Higher Value: 1.00
Livestock WQG - Lower Value: 0.50
Copper (mg/L)
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
Week

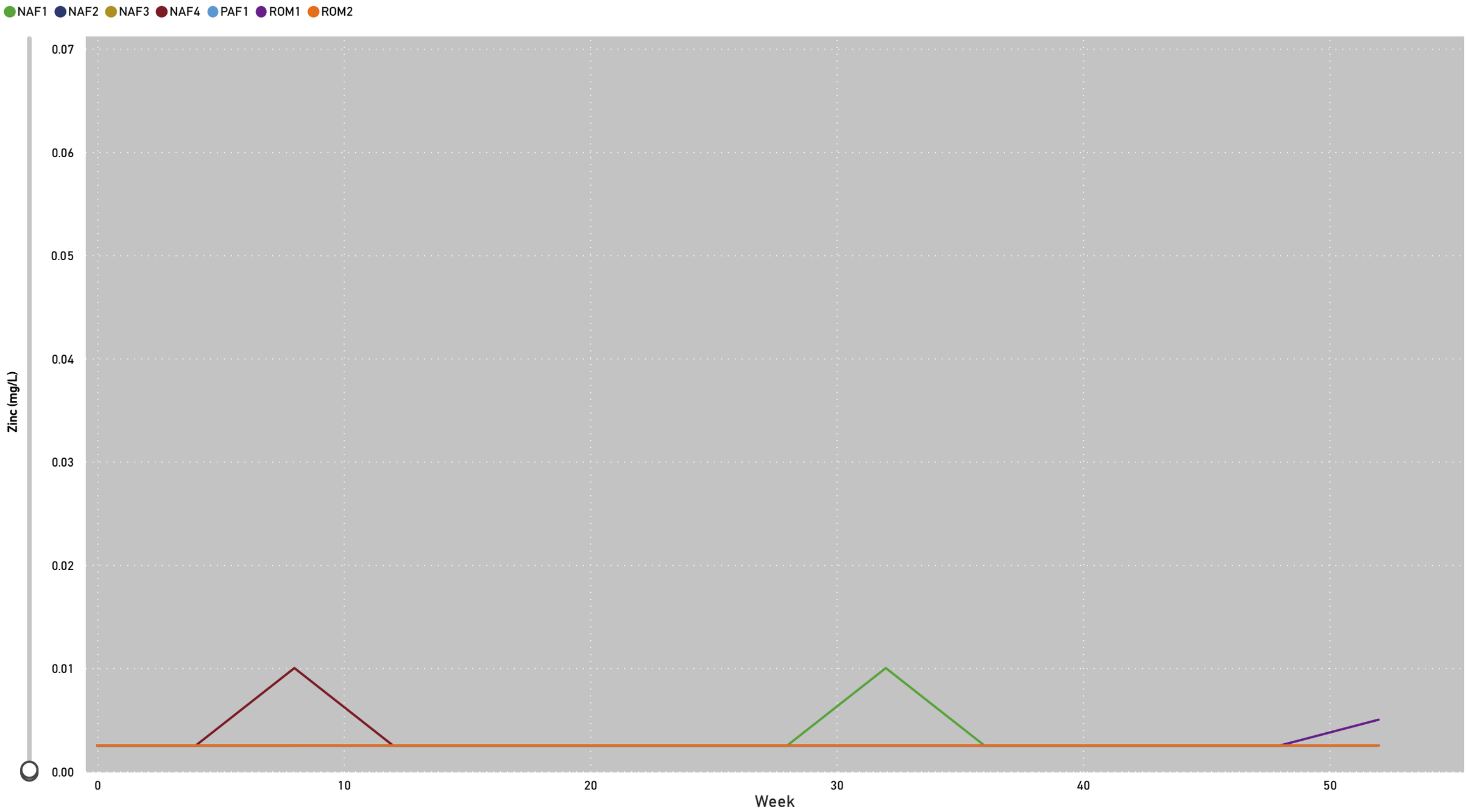

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Iron (mg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
Week


NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Manganese (mg/L)
0
10
20
30
40
0
10
20
30
40
50
Week


NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Livestock WQG: 0.15
0.15
0.10
0.05
0.00
Molybdenum (mg/L)
0
10
20
30
40
50
Week


NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Nickel (mg/L)
0.03
0.02
0.01
0.00
0
10
20
30
40
50
Week

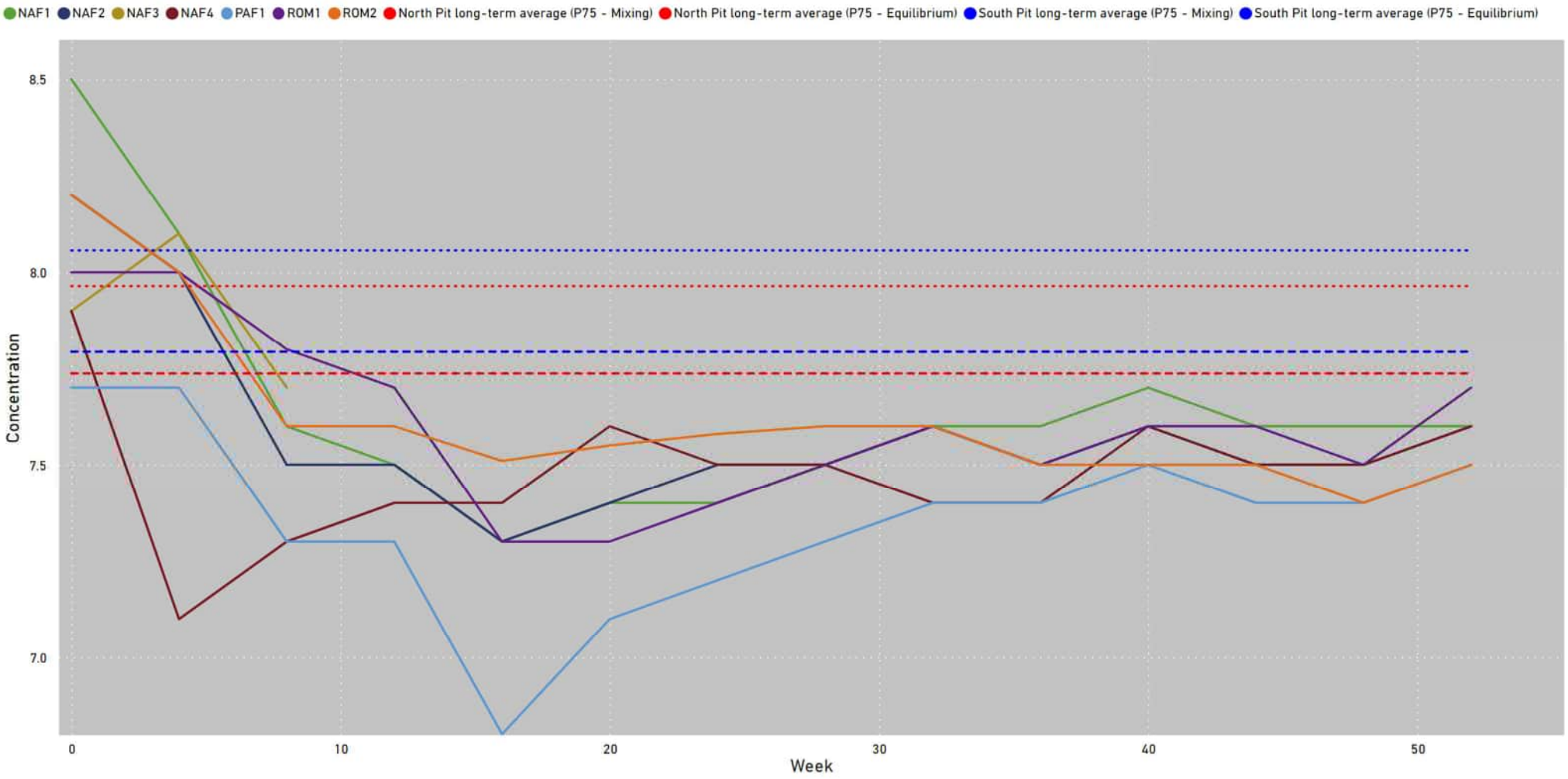

NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Uranium (mg/L)
0.005
0.000
0
10
20
30
40
50
Week


NAF1
NAF2
NAF3
NAF4
PAF1
ROM1
ROM2
Zinc (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
10
20
30
40
50
Week

L.3 Kinetic column leach test results versus open pit final void water quality

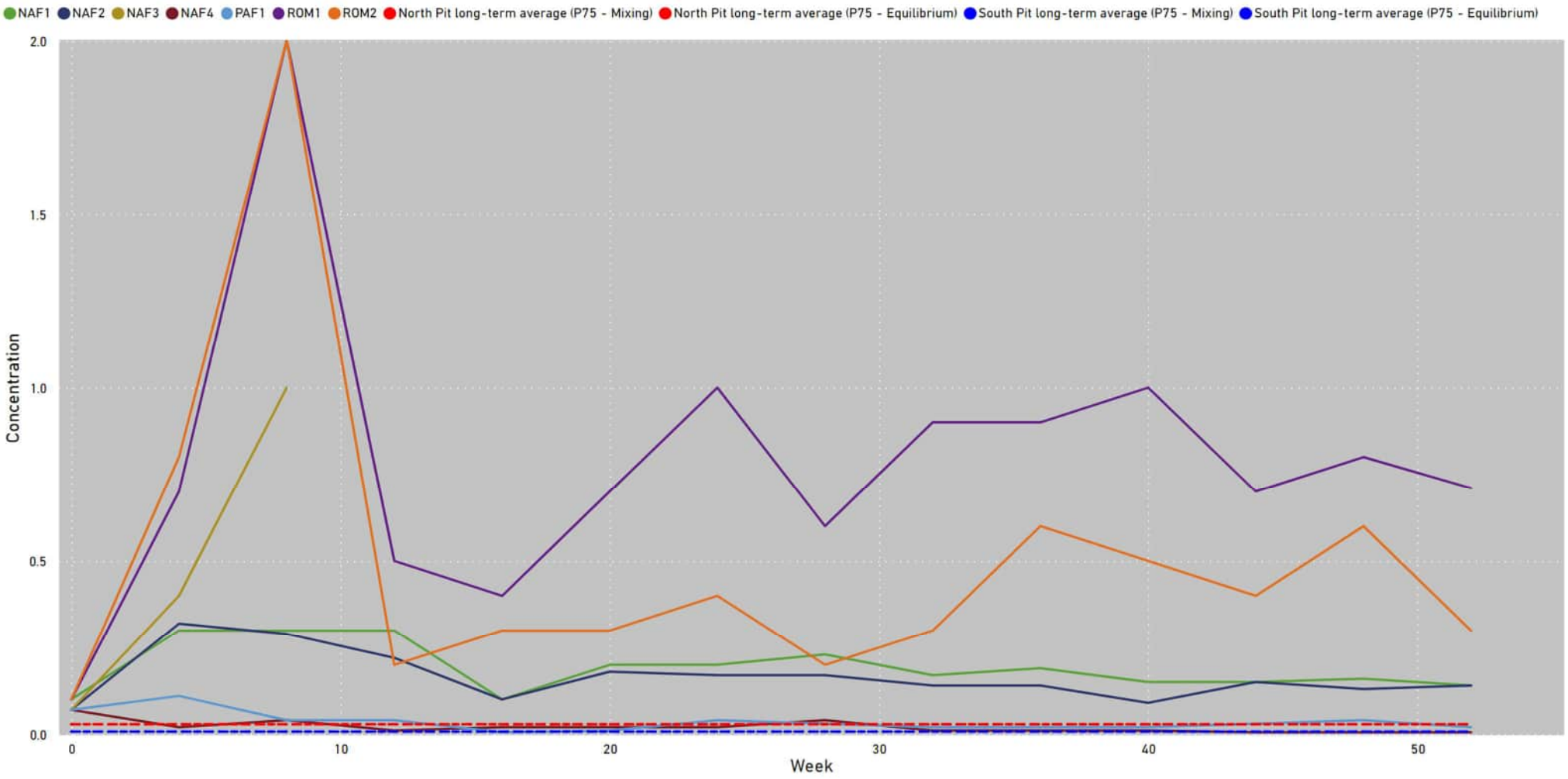
Parameter (Units)

pH (mg/L)



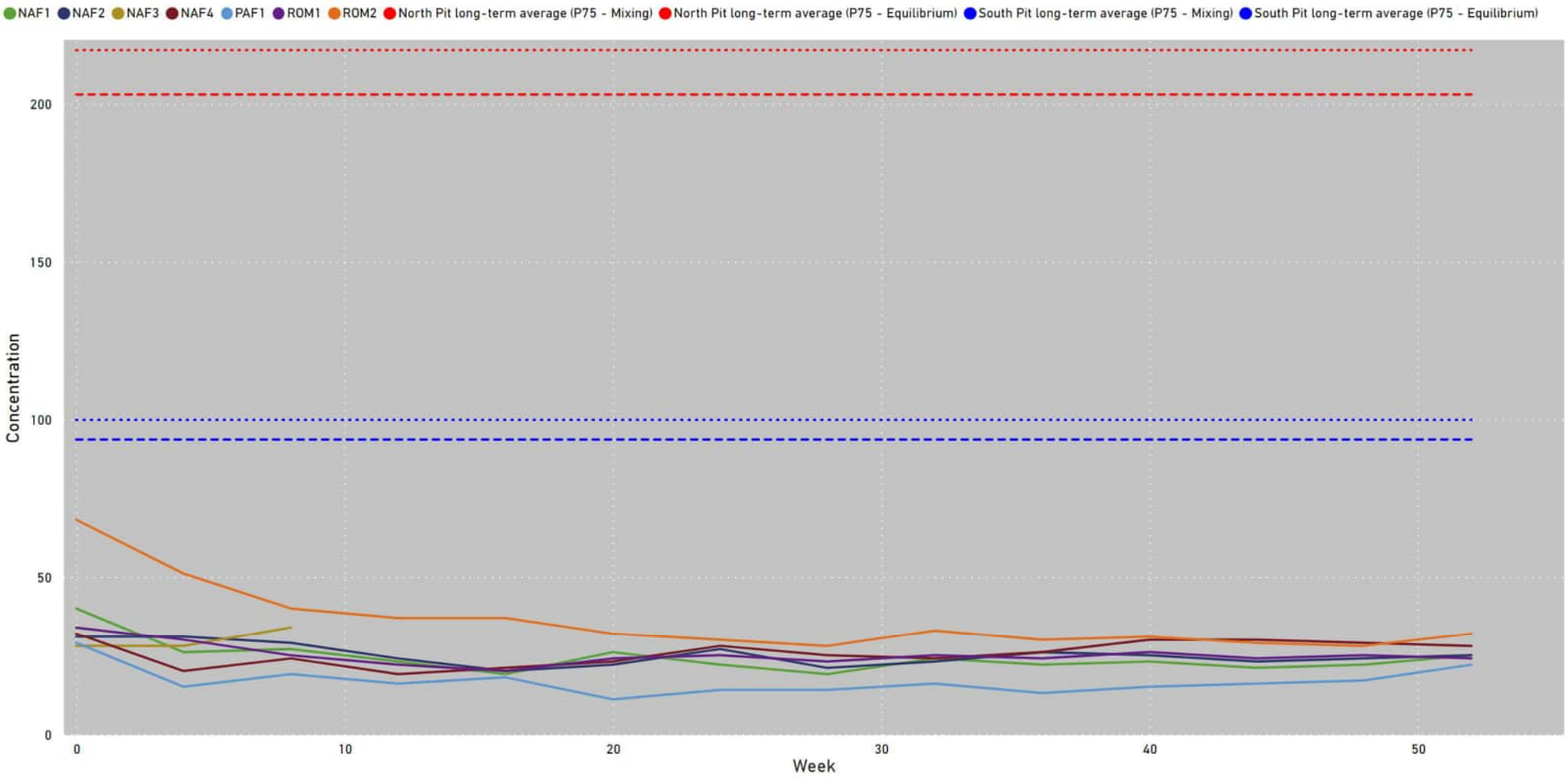
Parameter (Units)

Al (mg/L)



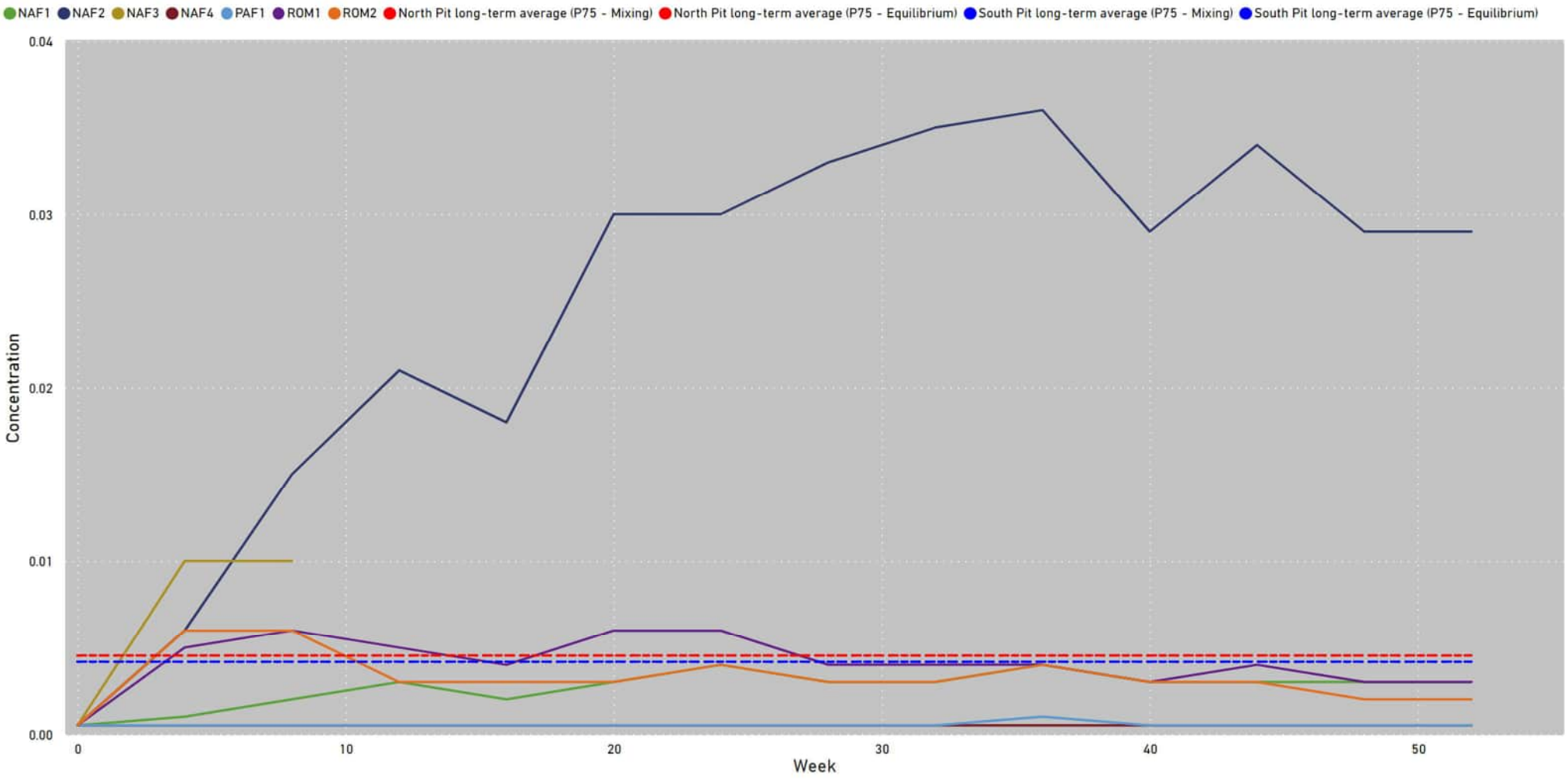
Parameter (Units)

Alkalinity (mg/L)



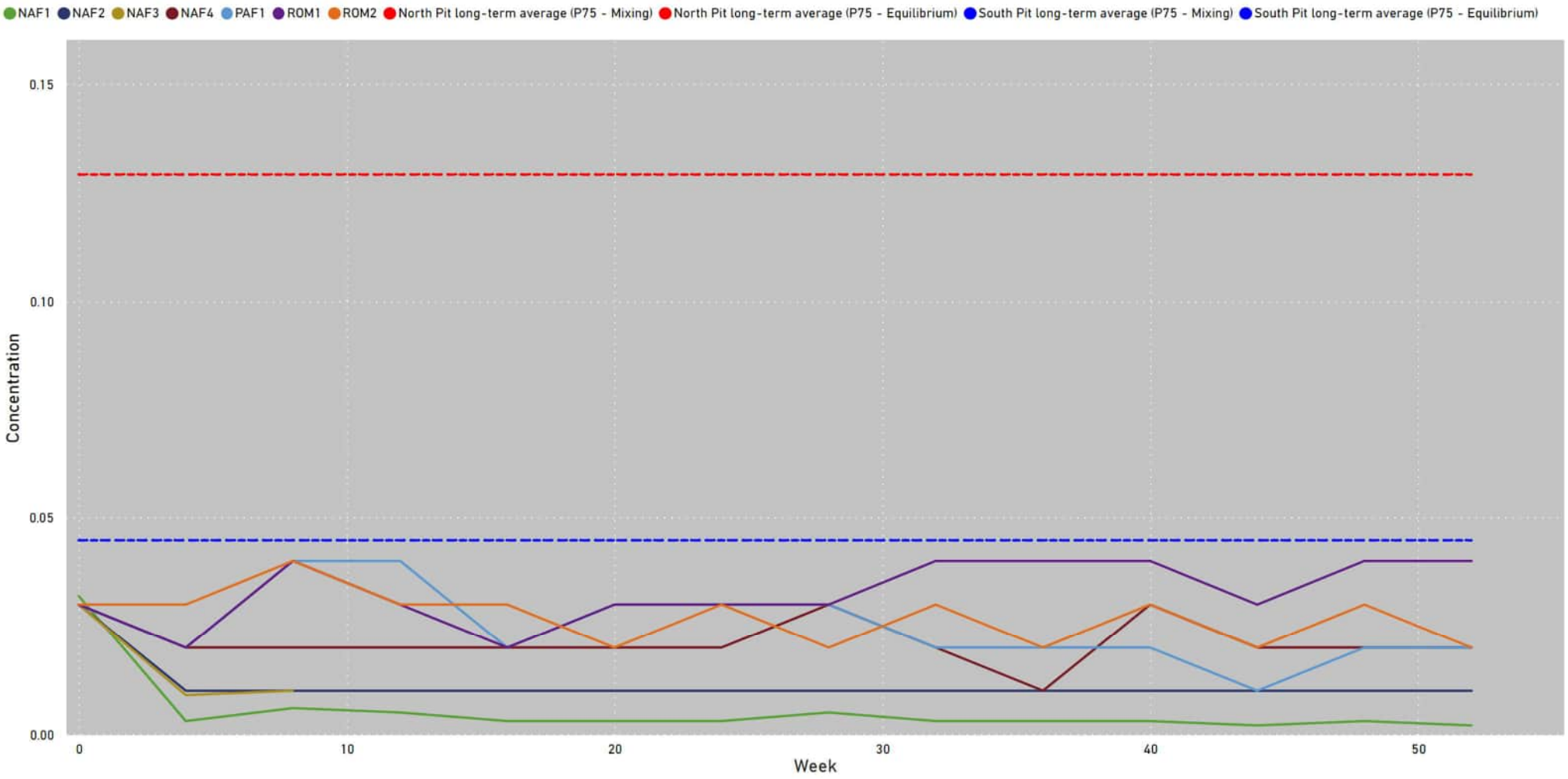
Parameter (Units)

As (mg/L)



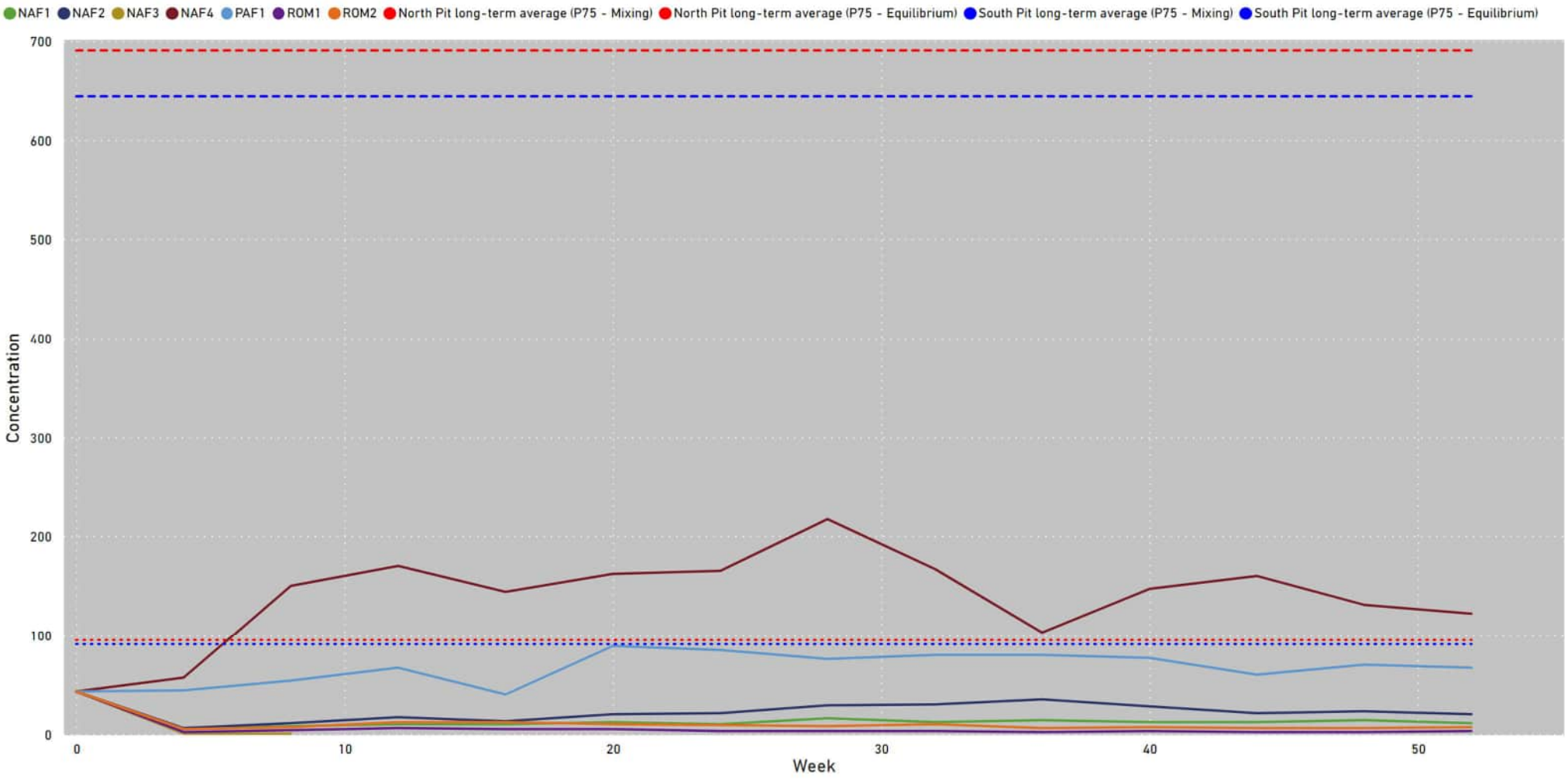
Parameter (Units)

Ba (mg/L)



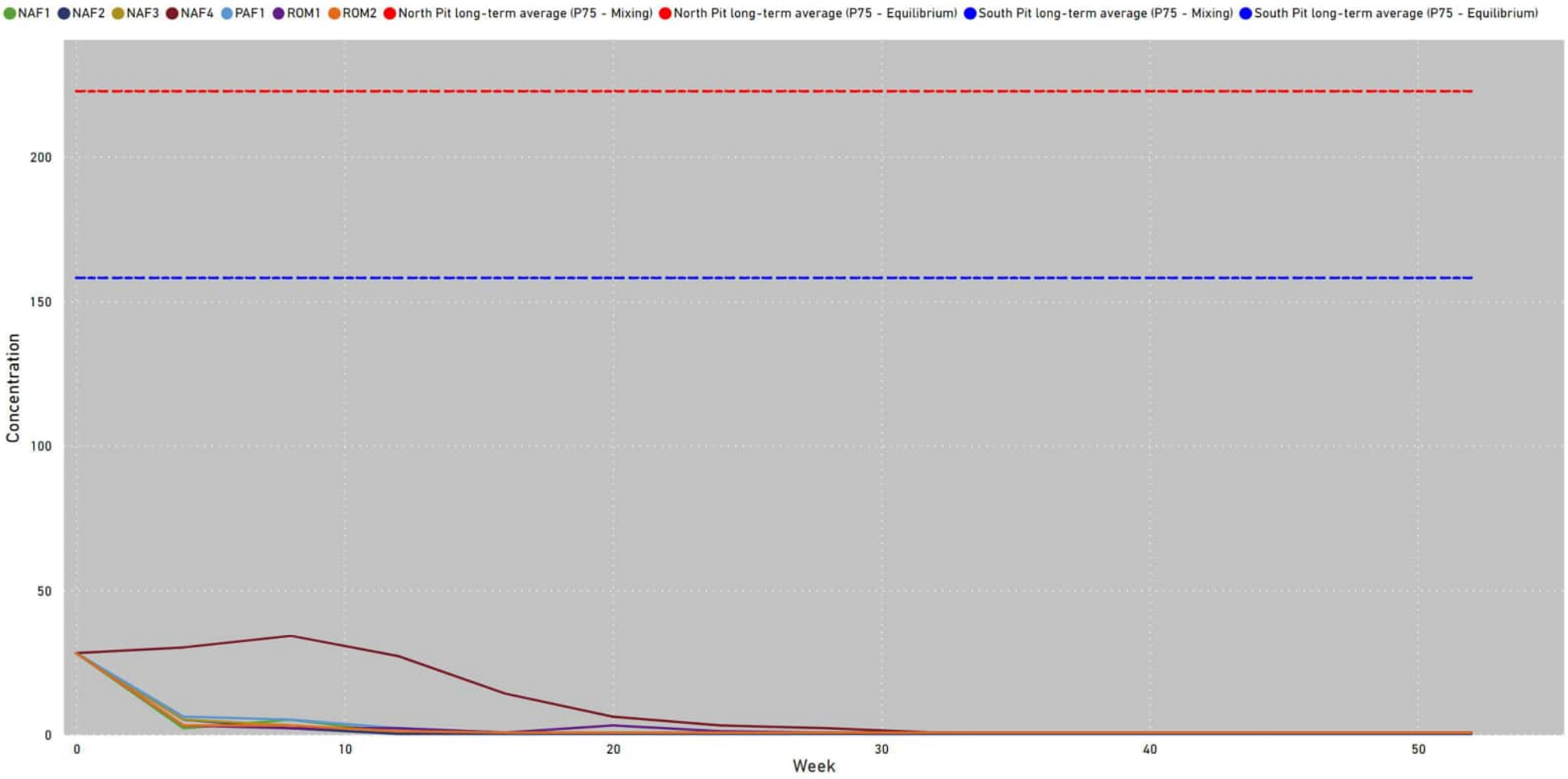
Parameter (Units)

Ca (mg/L)



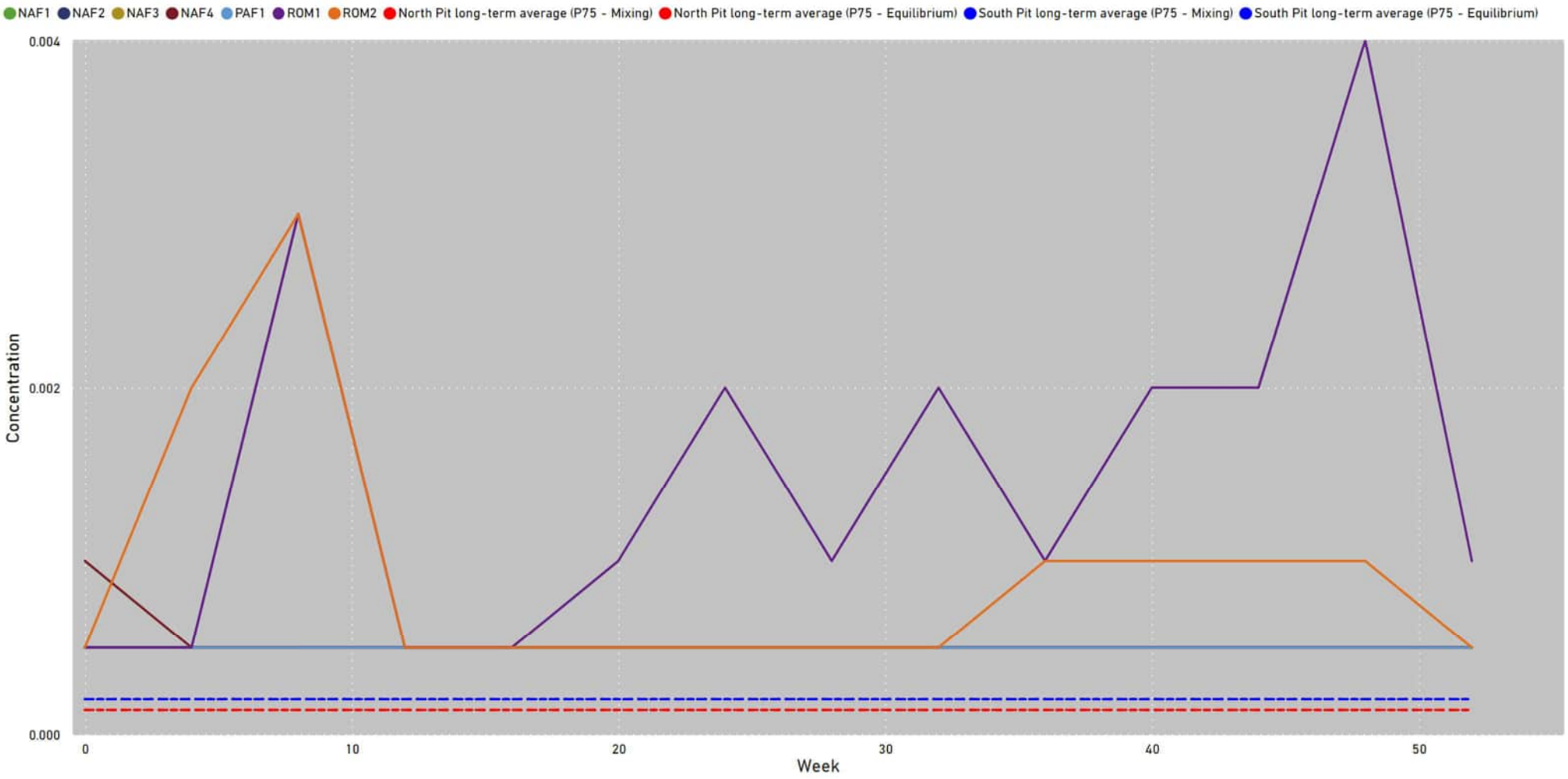
Parameter (Units)

Cl (mg/L)



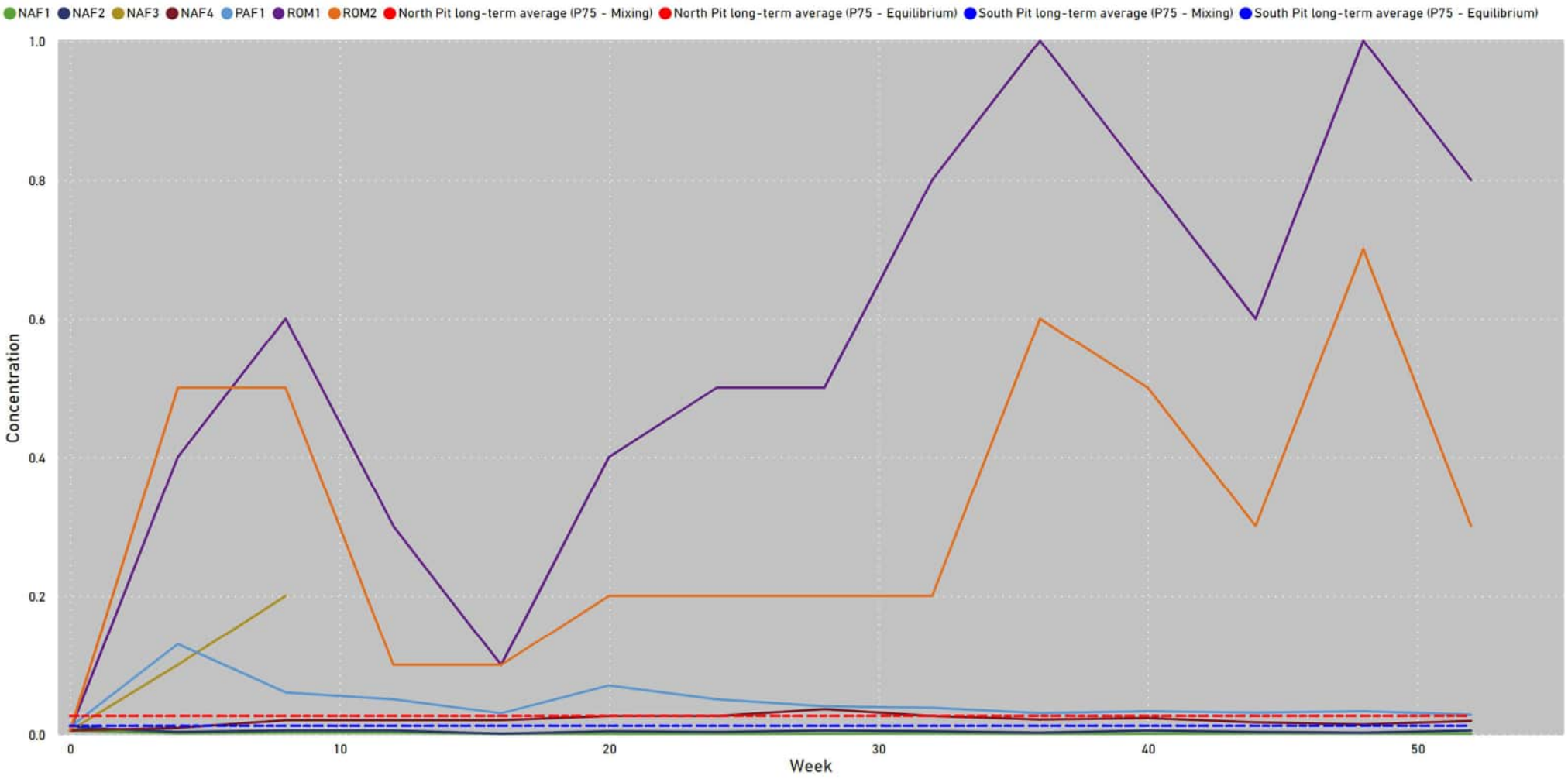
Parameter (Units)

Cr (mg/L)



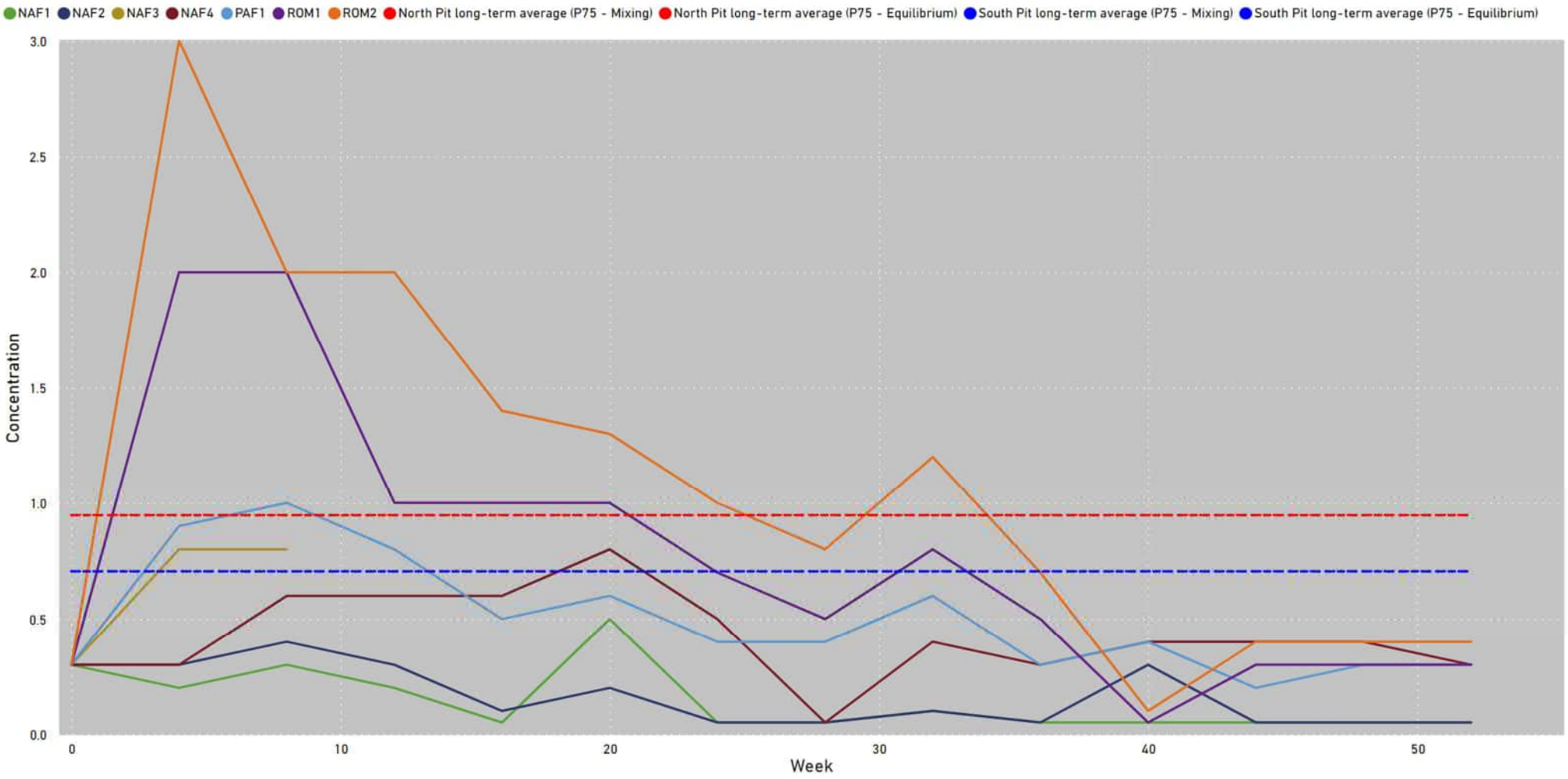
Parameter (Units)

Cu (mg/L)



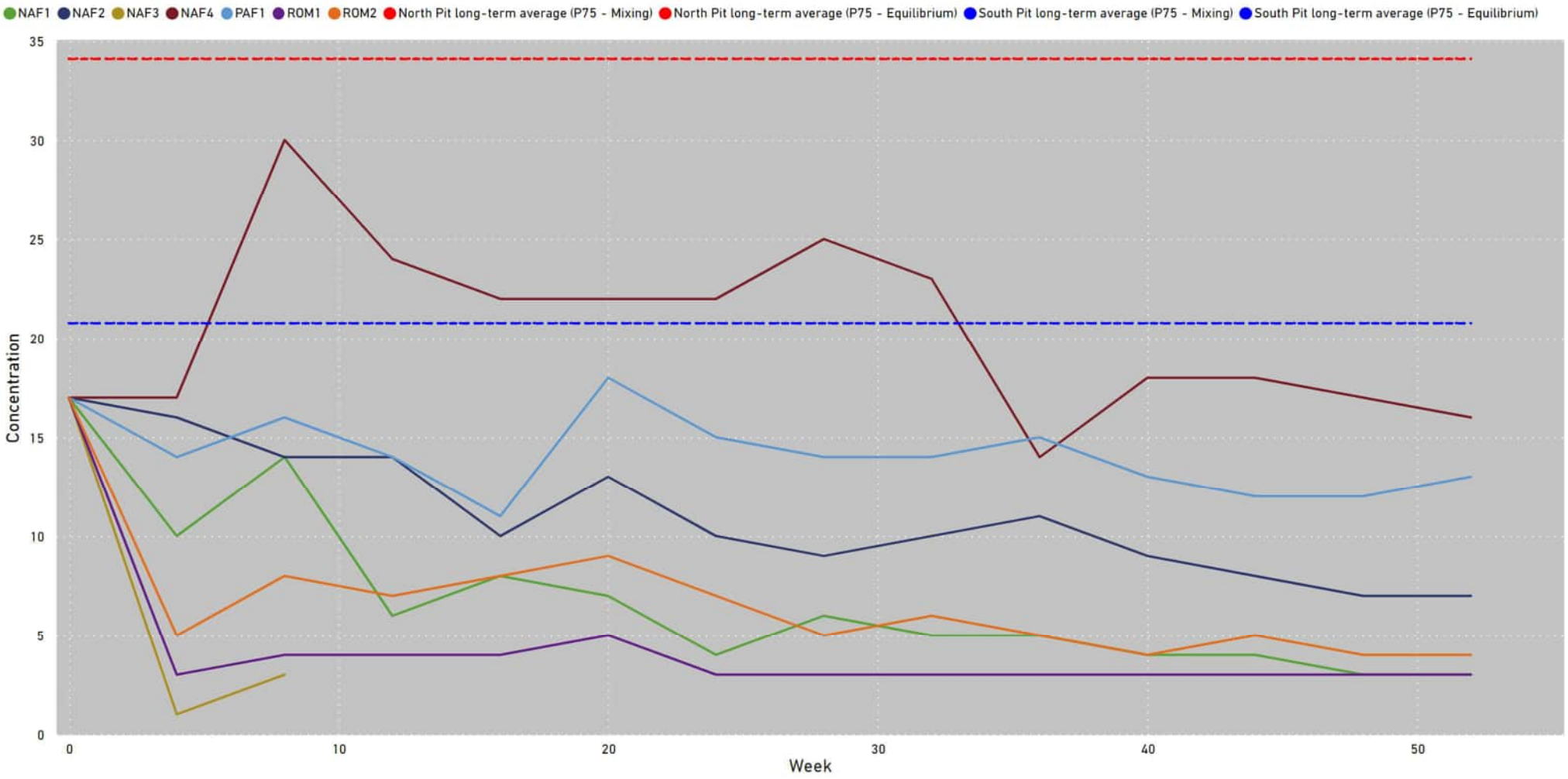
Parameter (Units)

F (mg/L)



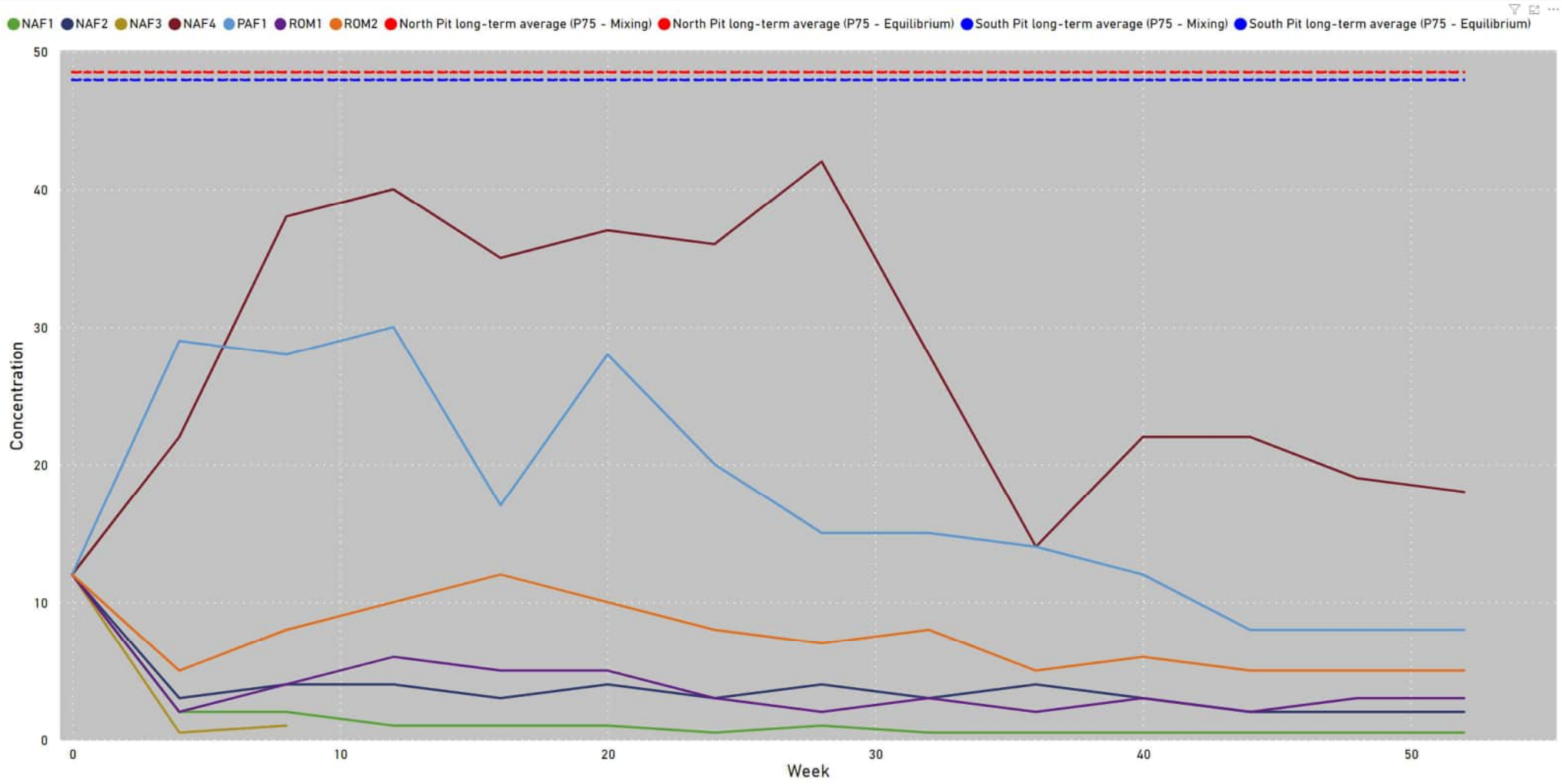
Parameter (Units)

K (mg/L)



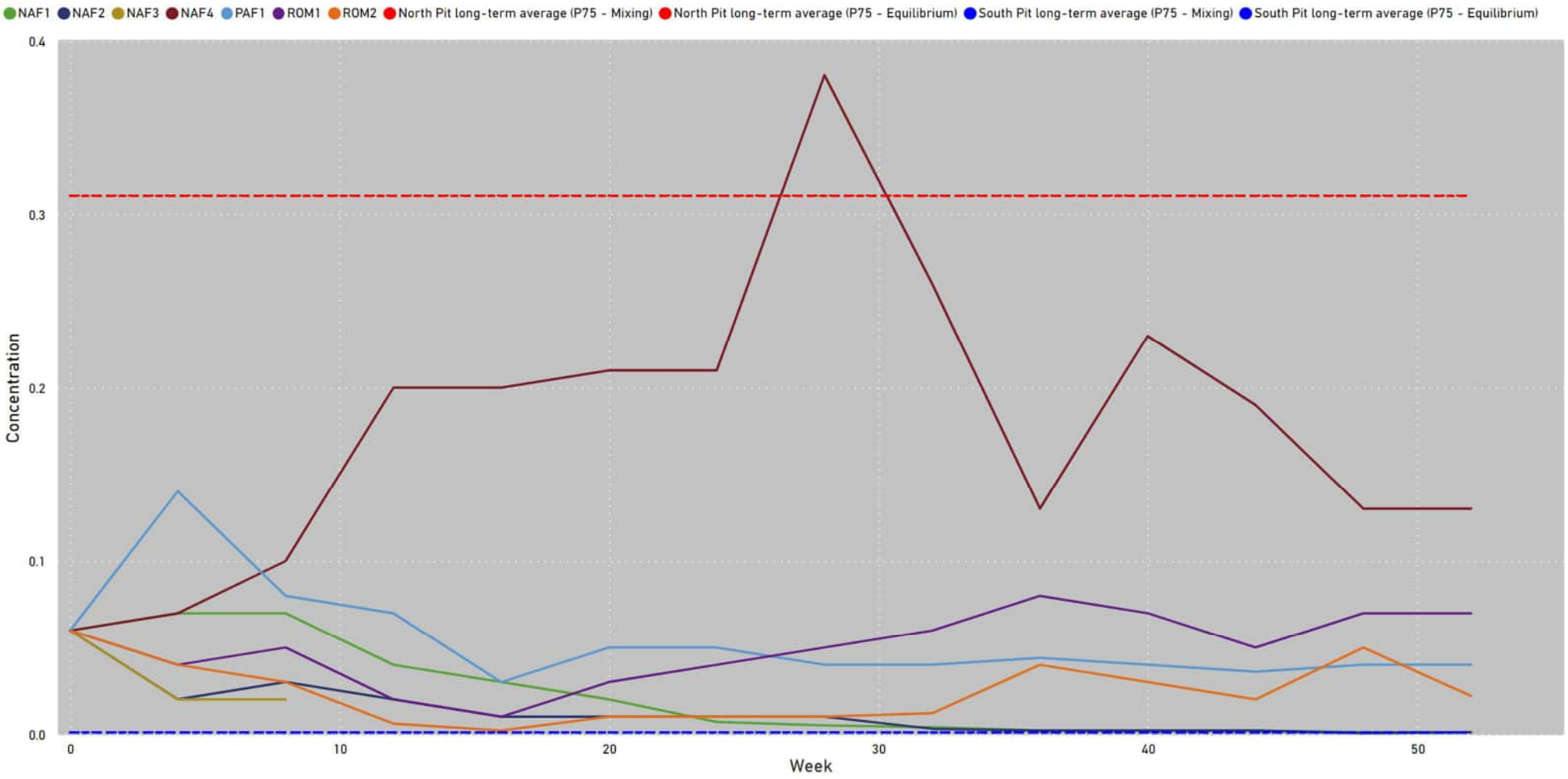
Parameter (Units)

Mg (mg/L)



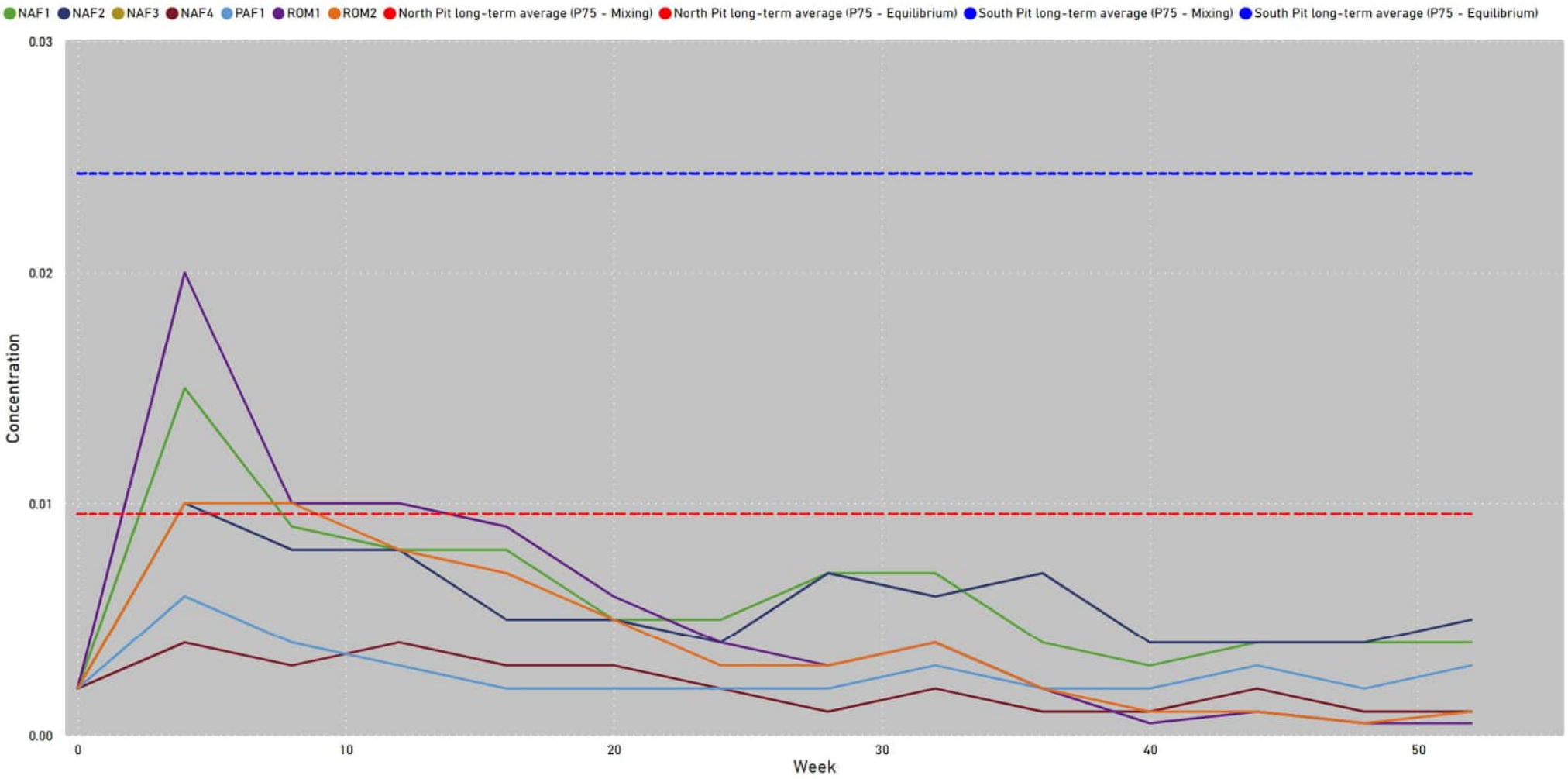
Parameter (Units)

Mn (mg/L)



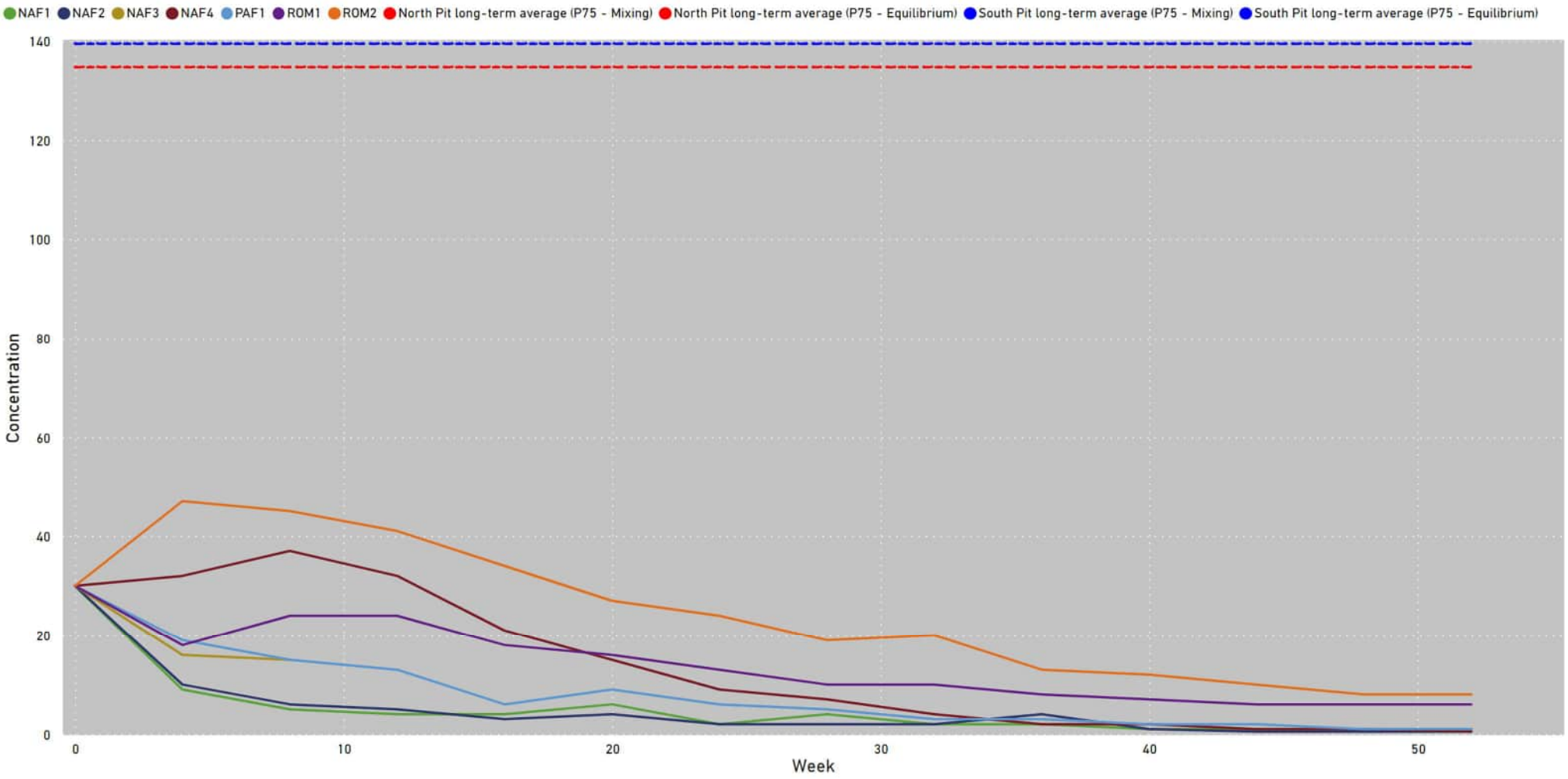
Parameter (Units)

Mo (mg/L)



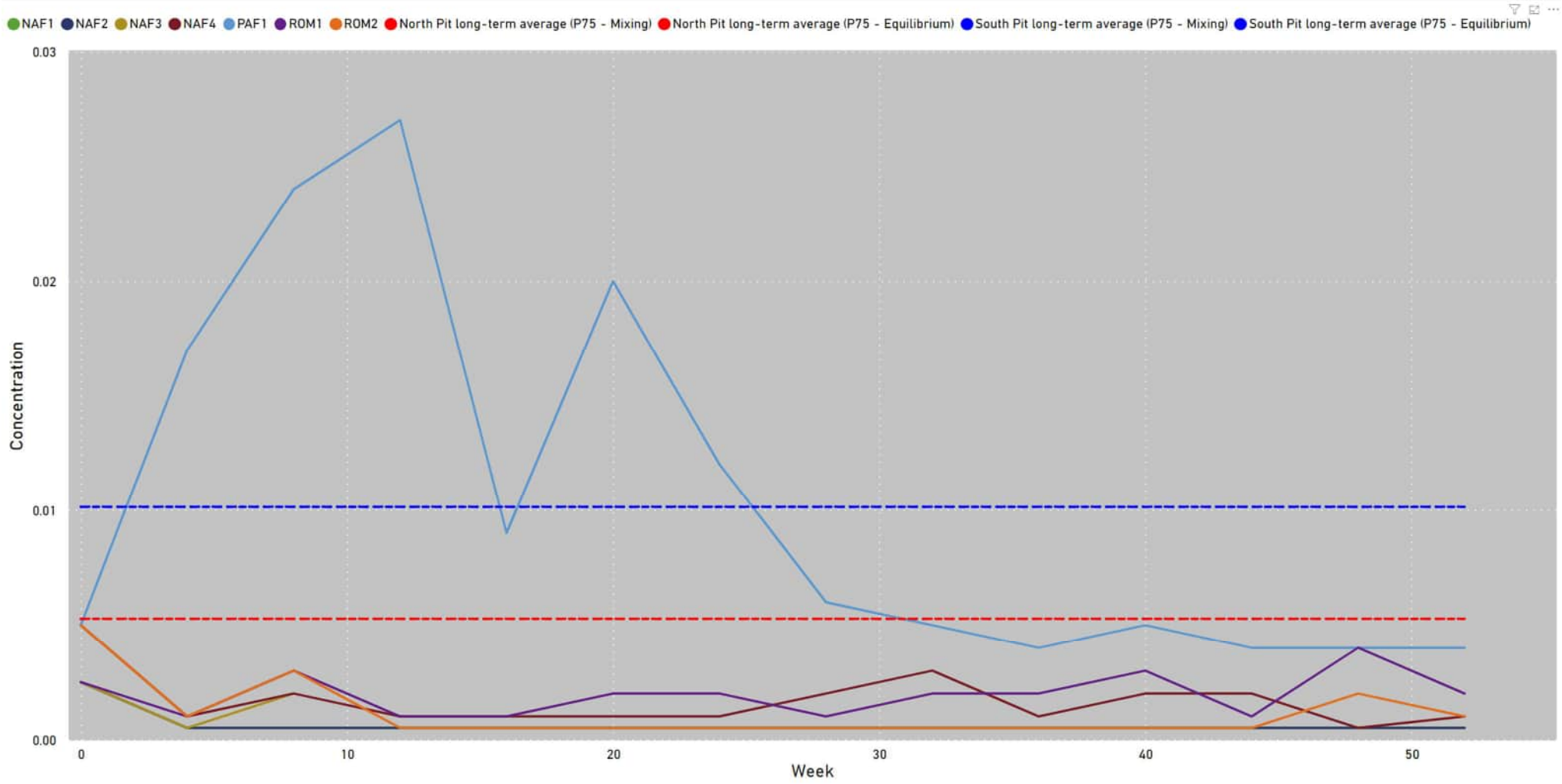
Parameter (Units)

Na (mg/L)



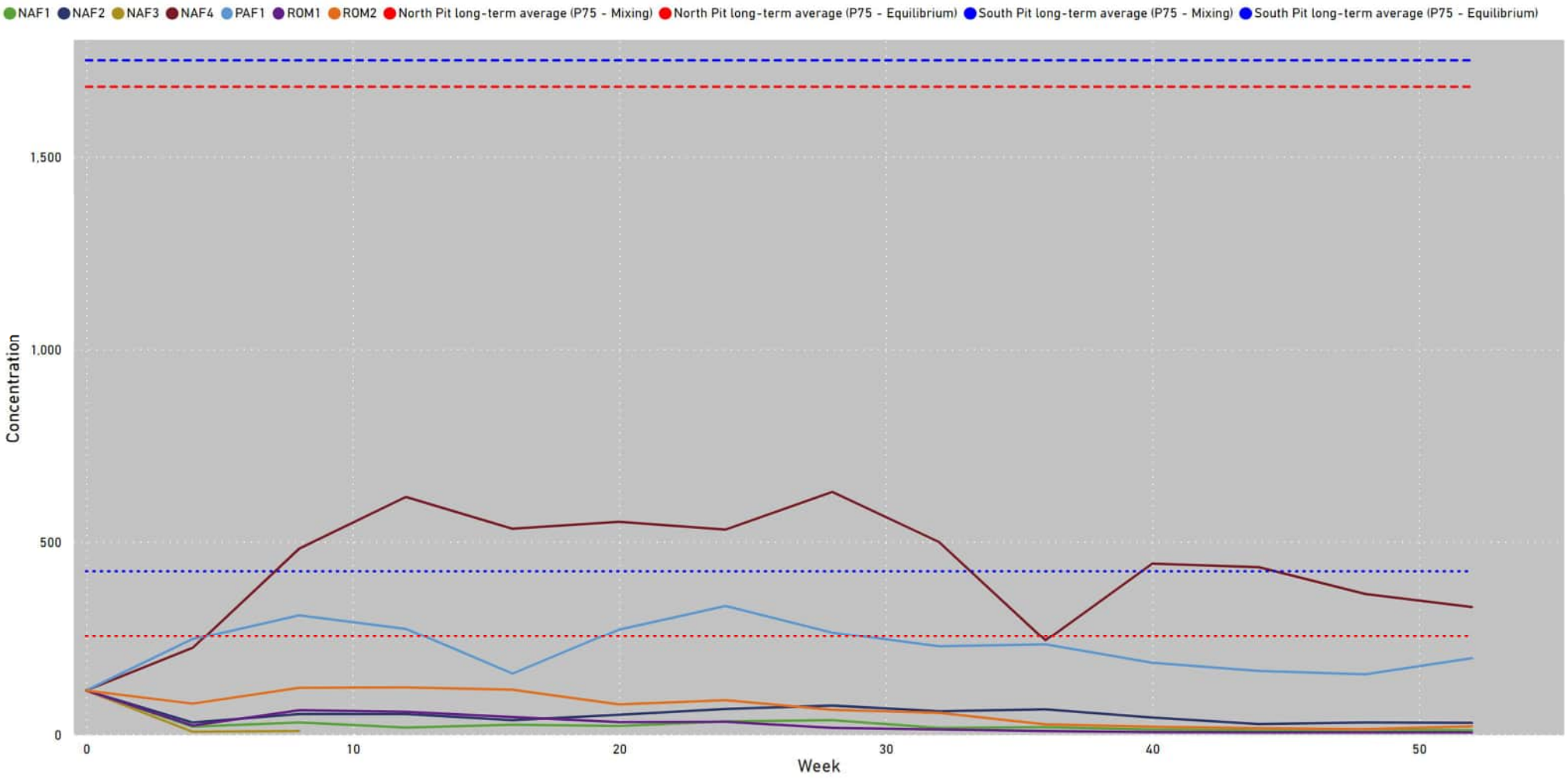
Parameter (Units)

Ni (mg/L)



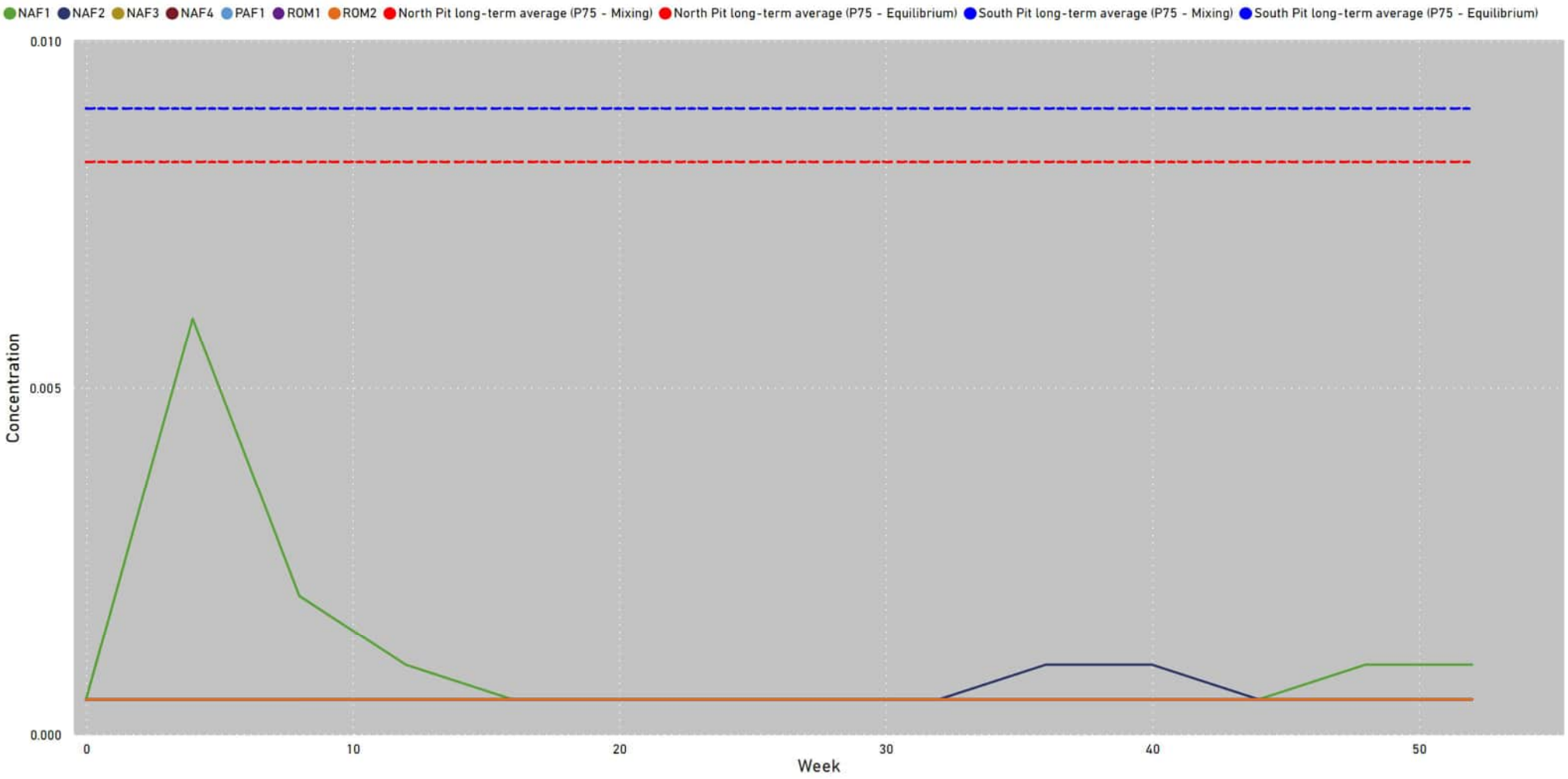
Parameter (Units)

SO4 (mg/L)



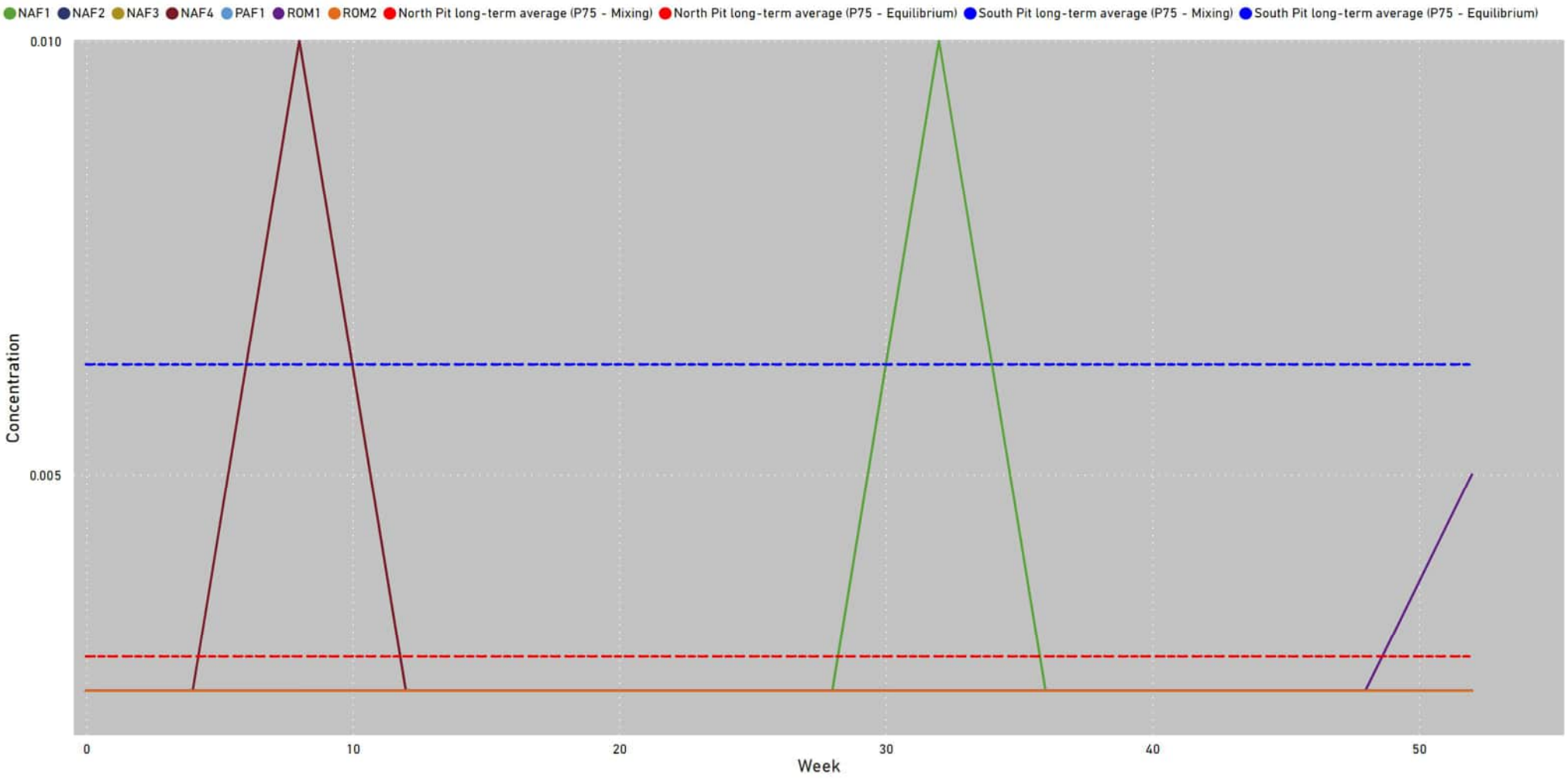
Parameter (Units)

U (mg/L)



Parameter (Units)

Zn (mg/L)



Technical Memorandum

WMV Environmental Pty Ltd
PO Box 597
Cannon Hill QLD 4170

From:	Willy Van Vaerenbergh
To:	Gemma Brown, Principal Environment & Mine Closure Planning
Cc:	David Eason, Senior Environment & Community Advisor
Date:	30 May 2024
Project:	J23011 – BCP UG EA Amendment and PRCP
Re:	Groundwater impact assessment – sensitivity/uncertainty analysis and long-term water quality

1 Introduction

1.1 Barbara Copper Project

The Barbara Copper Project (BCP or the Project) is a former open-cut copper and gold mine located within Mining Lease (ML) ML90241. BCP is authorised under Environmental Authority (EA) EPML02840015 for resource activities relevant to mining metals (copper, lead, silver, zinc, gold and iron ore). The Project is an open-cut copper mine that has extracted approximately 772,000 tonnes of ore. The mine operated from June 2019 until March 2021 and was placed in care and maintenance in April 2021.

Aeris Resources Limited (Aeris Resources, the proponent) plans to extract a significant copper-gold resource that remains under the South Pit through underground (UG) mining. Round Oak Minerals Pty Limited (Round Oak Minerals), wholly owned by Aeris Resources, is the EA holder.

1.2 EA amendment application

On 4 April 2024, Round Oak Minerals submitted to the Department of Environment, Science and Innovation (DESI) an amendment application for an environmental authority and a PRCP schedule. This submission included a Groundwater Technical Report (WMV Environmental, March 2024).

On 18 April 2024, DESI provided Round Oak Minerals with a "*Not properly made amendment application*" notice. The notice was issued because the application was missing information required by sections 226, 226A and 226B of the *Environmental Protection Act 1994* (EP Act). Attachment 1 of the notice details the specific issues.

Table 1 presents the issues in the notice addressed by WMV Environmental in this technical memo.

Table 1 Reasons for 'not properly made' application addressed in this technical memo

Legislative requirement under the EP Act	Reason	Action (s)
Section 226A(1)(f)(iii) The amendment application must include an assessment of the likely impact of the proposed amendment on the environmental values, including a description of the risk and likely magnitude of impacts on the environmental values.	The application did not provide a description of the risk and likely magnitude of impacts on the environmental values: • A risk assessment of impacts from underground mining, including drawdown impacts and blind stopes, to terrestrial groundwater dependent ecosystems (GDEs) has not been provided.	Provide a risk assessment of impacts from underground mining, including drawdown impacts and blind stopes, to terrestrial GDEs.
Section 226B An amendment application for a PRCP schedule must be accompanied by an amended rehabilitation planning part that complies with section 126C in relation to the proposed amendment. Section 126C(1)(e) A proposed PRC plan must for each proposed PMLU for land, state the proposed methods or techniques for rehabilitating the land to a stable condition in a way that supports the rehabilitation milestones under the proposed PRCP schedule.	The application must, for each proposed post-mining land use for land, state the applicant's proposed methods or techniques for rehabilitating the land to a stable condition in a way that supports the rehabilitation milestones under the proposed PRCP schedule: • South Pit currently has a post mine land use (PMLU) of water storage. The applicant has not provided information detailing how the proposed amendment, of commencing underground mining under South Pit, will continue to achieve this PMLU. - The Groundwater Technical Report (J23011-RP01 - BCP UG EA (Final v2.00) provides void water quality modelling for 25 years. This timeframe is not considered sufficient to demonstrate that the PMLU can sustain a post-mine land use of water storage in the long term. - Appendix E Memorandum: Barbara Total Carbon Assays provided within the supporting document notes that further samples are recommended and that pulp samples are awaiting further tests. Therefore, the veracity of the water quality modelling to demonstrate the PMLU can be achieved is unclear due to the possible lack of waste rock data its potential interactions with groundwater following deposition in the underground workings.	Provide void water modelling that demonstrates that the PMLU can sustain a post-mine land use of water storage in the long term that supports the rehabilitation milestones. Discuss proposed amendments to timeframes within the PRCP Schedule, including proposed methods or techniques for rehabilitating the land to a stable condition in a way that supports the rehabilitation milestones. Provide justified management practices that will be implemented to make the reduced timeframes realistic and attainable.

Legislative requirement under the EP Act	Reason	Action (s)
	As the amendments to timeframes within the PRCP Schedule have not been discussed within the supporting documents, the applicant has not stated proposed methods or techniques for rehabilitating the land to a stable condition in a way that supports the rehabilitation milestones. Additionally, the applicant did not provide any justification that management practices will be implemented to make the reduced timeframes realistic and attainable.	

Further communication with DESI identified additional concerns regarding "*the lack of sensitivity analyses being conducted on the groundwater models. Understanding the potential variation in model output/s based on the varied input/s would assist with the decision making. This can be achieved by considering a range of realistic scenarios (both during the past and current predictions)*".

1.3 Structure of technical memorandum

This technical memo has been structured to address DESI's issues and concerns and includes the following Sections:

- Appendix A: Discussion on analytical vs numerical groundwater models, as summarised in Section 2
- Appendix B: Sensitivity analysis on analytical models, as summarised in Section 3
- Section 4: Assessment of impacts on terrestrial GDEs
- Section 5: Long-term final void water quality

The Groundwater Technical Report (WMV Environmental, March 2024), included in the EA amendment application and the BCP UG PRCP application, provides a detailed description of BCP's environmental settings (including geology and hydrogeology), the environmental monitoring results, a hydrogeological conceptual model and a detailed groundwater impact assessment. This memo must be considered in conjunction with this Groundwater Technical Report.

2 Analytical vs numerical groundwater models

The assessment of the final void hydrogeology and groundwater impact assessment, as described in the Groundwater Technical Report, was based on:

- final void water balance modelling (ATC William, 2023ba, ATC Williams, 2024)
- water quality modelling of the open pits and WRD Sediment Dam undertaken by ATC Williams (ATC William, 2023b) with further interpretation of the data by WMV Environmental (2023)
- underground workings final void water quality modelling.

The groundwater impact assessment required groundwater modelling either to provide input data for water balance and water quality models or to allow direct assessment of potential impacts.

WMV Environmental's approach to groundwater modelling included the initial development of analytical models instead of 3D numerical groundwater models. This approach and its justification are discussed in detail in Appendix A.

Given the fact that groundwater at BCP is primarily associated with the orebody itself, the relative impermeability (i.e. low hydraulic conductivity) of the aquifers and the short duration of the underground mining (i.e. four years), analytical models are considered appropriate for the initial assessment of groundwater impact assessment.

3 Sensitivity analysis on analytical models

3.1 Introduction

Sensitivity analyses on the analytical model results have been undertaken in response to DESI's comments. Appendix B provides a detailed discussion of the approach and outcomes of the sensitivity analyses.

With respect to the sensitivity/uncertainty analyses of the analytical models, the following needs to be considered:

- The analytical model used to assess the potential impacts of mining on groundwater-dependent ecosystems calculates the level and extent of drawdown around open pits and voids. The horizontal hydraulic conductivity is the only model parameter on which a sensitivity analysis can be undertaken.
- The analytical model used to calculate groundwater inflows into the open pits/voids provides input into the water balance and quality models. Model input parameters for sensitivity analysis include rainfall recharge and horizontal and vertical hydraulic conductivity. An additional input parameter is the radius of influence, which the previous analytical model calculates.
- Input parameters for the water quality models include the water balance volumes, calculated through the Goldsim water balance models, and analyte concentrations of rainfall, runoff and groundwater inflow. As the analyte concentrations are based on literature values (for rainfall) or actual observed concentrations (e.g. 95th percentile of analysis data for surface water and groundwater), no sensitivity/uncertainty analysis is undertaken on the water quality input data.

Sensitivity/uncertainty analyses have been undertaken on two key input parameters of the analytical models, i.e. the horizontal hydraulic conductivity and the rainfall recharge to groundwater. The hydraulic conductivity has been changed by an order of magnitude, whilst the rainfall recharge coefficient has been changed by a factor of five, resulting in nine different sensitivity scenarios.

3.2 Sensitivity/uncertainty analysis of drawdown radius of influence

With respect to the sensitivity analysis:

- Void geometry is calculated from Aeris's actual and planned void dimensions. No sensitivity analysis is undertaken on this parameter.
- Drawdown in the void has been calculated as the difference between the regional, pre-mining groundwater level and the base of the void during and post-mining.
- The value of saturated hydraulic conductivity was obtained from site investigations undertaken in 2013. Sensitivity analyses have been undertaken on this parameter.

As the rainfall recharge coefficient is not a parameter in Sichardt's equation, only three scenarios have been considered. The sensitivity analysis results are discussed in Appendix B.1.4. As per Sichardt's equation, the higher the horizontal hydraulic conductivity, the larger the drawdown. It is noted that the calculated radii are considered conservative and overestimate the actual radius of influence.

Overall, the potential radius of influence would be much less than the empirically calculated radius and remain within the ML boundaries. Gauging of existing groundwater monitoring bores (BAWB01 to BAWB07, BAWBR01 to BAWBR03) does not show a significant impact of open-cut mining on groundwater levels.

The sensitivity analysis indicates that uncertainty in the hydraulic parameters does not affect the conclusions regarding the potential impact on terrestrial GDEs (Section 4).

3.3 Sensitivity/uncertainty analysis of groundwater inflows into voids

The analytical models calculating groundwater inflows into the voids are based on the model by Marinelli and Nicolli. The key parameters in the Marinelli and Niccoli model are the void geometry, the radius of influence, the rainfall recharge rate, the hydraulic and vertical conductivities, the pre-mining saturated thickness above the base of the void and the depth of water in the void.

With respect to the sensitivity analysis:

- Void geometry is calculated from Aeris's actual and planned void dimensions. No sensitivity analysis was undertaken on this parameter.
- The value of hydraulic conductivity was obtained from site investigations undertaken in 2013. Sensitivity analyses have been undertaken on this parameter.
- As the vertical hydraulic conductivity was set at 10% of the horizontal conductivity, no additional sensitivity analysis was undertaken on this parameter.
- A sensitivity analysis of rainfall recharge has been undertaken.
- The radius of influence has been calculated using Sichardt's equation. This model uses the hydraulic conductivity value. The two analytical models have been linked so that the sensitivity analysis on hydraulic conductivity filters through to the sensitivity analysis on the radius of influence.

The sensitivity analysis results are discussed in Appendix B.1.5. The sensitivity analysis results show that groundwater inflows under Scenarios 7, 8 and 9 (i.e. with a horizontal hydraulic conductivity of 2.29 10^{-07} m/s) are more significant than under the other scenarios, mainly due to the increased horizontal conductivity. This increased conductivity has a two-fold and double effect, i.e. increasing the radius of influence (which affects the Zone 1 flow calculations) and the flow in Zone 2 calculations. The modelled groundwater inflows under these three scenarios are considered unrealistic. Whilst there are no specific measurements of groundwater inflow into the open pits or pit dewatering pumping rates, visual observations by site personnel during mining did not support the calculated groundwater inflows.

The results show that the groundwater inflow rates adopted in the Goldsim water balance models are generally at the upper end of the inflows under scenarios 4 and 6, whilst inflows under scenarios 1 and 3 are generally lower than the Goldsim water balance model groundwater inflows.

3.4 Impact of uncertainty on analytical modelling results

The sensitivity analyses show that the groundwater inflows used in the water balance and quality models are in the upper ranges of the realistic scenarios. Sensitivity analyses indicate that this groundwater inflow may be at a lesser rate than currently adopted.

The impact of the uncertainty regarding groundwater inflow rates (i.e. lower than currently adopted) is considered minimal as:

- Lower groundwater inflow rates would result in a slightly longer recovery time of groundwater levels in the open pits and underground voids.
- The underground void will be filled with water by 2023, i.e. 7 years after the commencement of underground mining. Slower groundwater inflow rates may increase this period, but not to the extent that it will affect the final water quality in the underground voids. Water quality in the underground voids depends largely on the groundwater quality, which does not change with the duration of inflow into the underground voids.
- Groundwater inflow is a minor component of total inflow (i.e. <10%) in the North and South Pits. Surface water runoff and direct rainfall are the major inflow components. A reduction in groundwater inflow rates would not significantly alter the water balance modelling results of the pits and, therefore, not significantly affect the results of the water quality modelling.
- There is no groundwater inflow into the WRD Sediment Dam.

4 Assessment of impacts on terrestrial GDEs

The above sensitivity analyses on the radius of drawdown influence around the open pits and underground void indicate that, under worst-case scenario 7, the maximum drawdown extent would be as follows:

- North pit: ±90m
- South pit: ±275m
- Underground voids: ±480m

It is noted that the drawdown extent would reduce with time post-mining as water levels in the open pits and underground void recover. In addition, the actual radius of influence would be less than the empirically calculated radius and remain within the ML boundaries. Gauging of existing groundwater monitoring bores (BAWB01 to BAWB07, BAWBR01 to BAWBR03) does not show a significant impact of open-cut mining on groundwater levels.

Publicly available data from the BOM indicates that the nearest mapped terrestrial GDEs are outside the maximum drawdown extent, as shown in Figure 1. The terrestrial GDEs nearest to the voids are "low potential GDEs". Based on the modelled drawdown extents, the proposed underground mining operations will not pose a risk to the identified terrestrial GDEs.

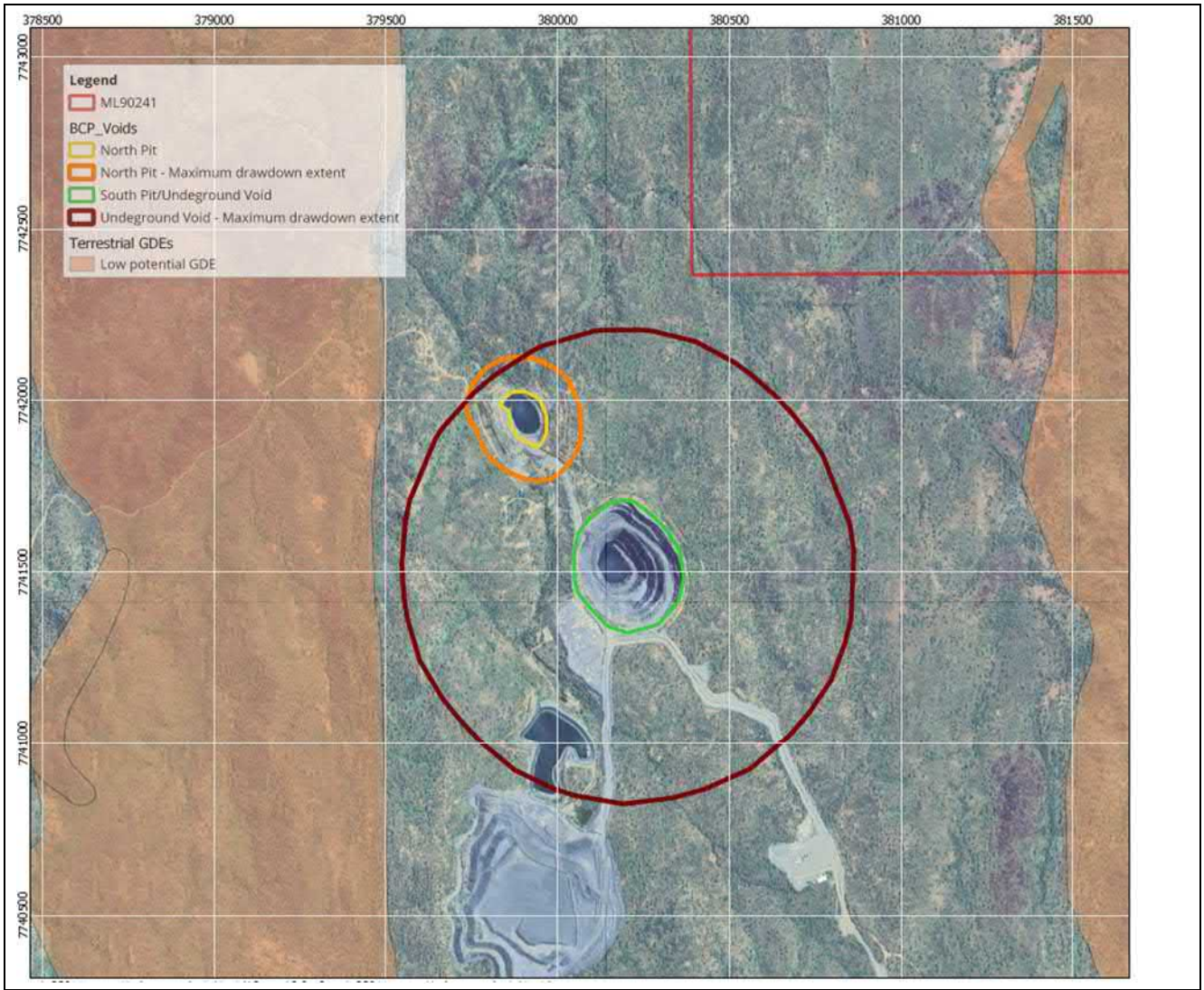


Figure 1 Location of terrestrial GDEs and maximum drawdown extent

5 Long-term final void water quality

5.1 Updated Goldsim Water Balance Model

To assist with assessing the long-term water quality in the final voids, the existing Goldsim Water Balance Model (WBM), developed by ATC Williams, was extended to 200 years.

The results of the long-term WBM can be summarised as follows:

- The average water level in the South Pit at the end of the 200-year simulation is 292m AHD, reaching a maximum elevation of 299m AHD (35.3 m below the crest) (Figure 2).
- The average water level in North Pit at the end of the 200-year simulation is 302m AHD, reaching a maximum elevation of 307.6 m AHD (8.4 m below the crest) (Figure 3).
- The water level in the WRD sediment dam reaches an average elevation of 332 m AHD, spilling on average once every 30 years (Figure 4).

It is noted that the climate data used in the original WBM (130 years) was extended by repeating the data of the last 30 years to cover 200 years. The extended period was wetter than the previous 130-year period, accounting for the rare spills of the WRD sediment dam.

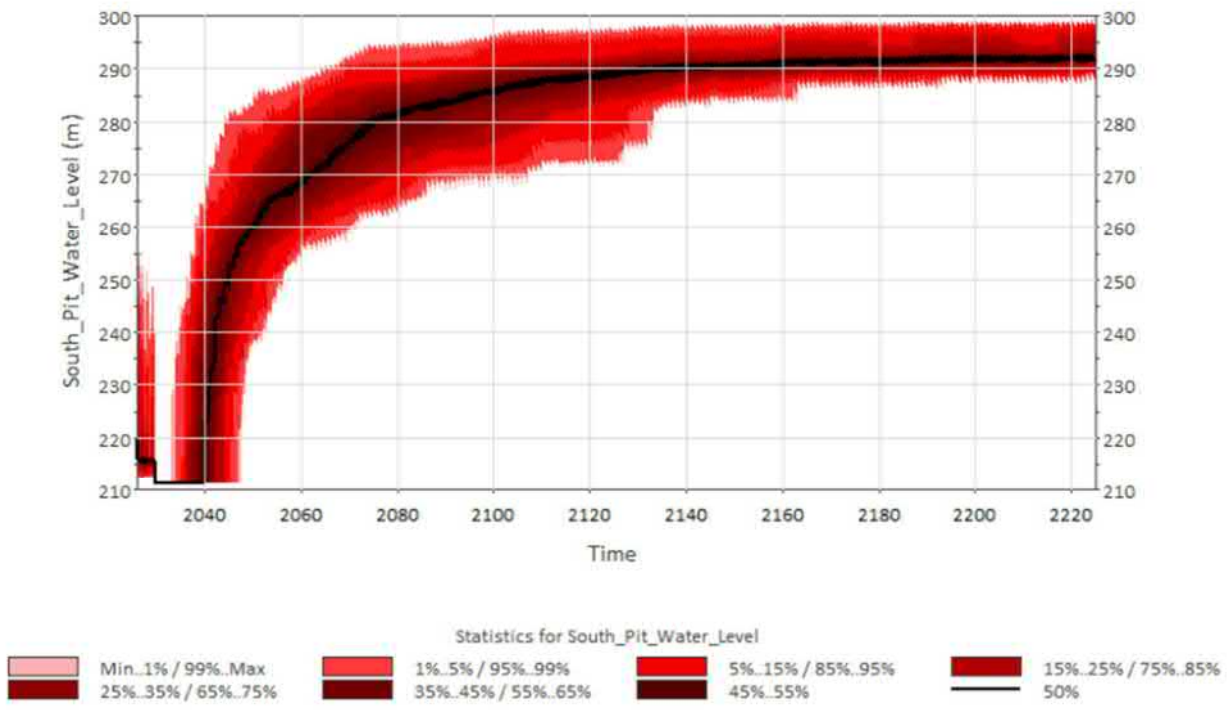


Figure 2 Long-term (200 yrs) South Pit water levels

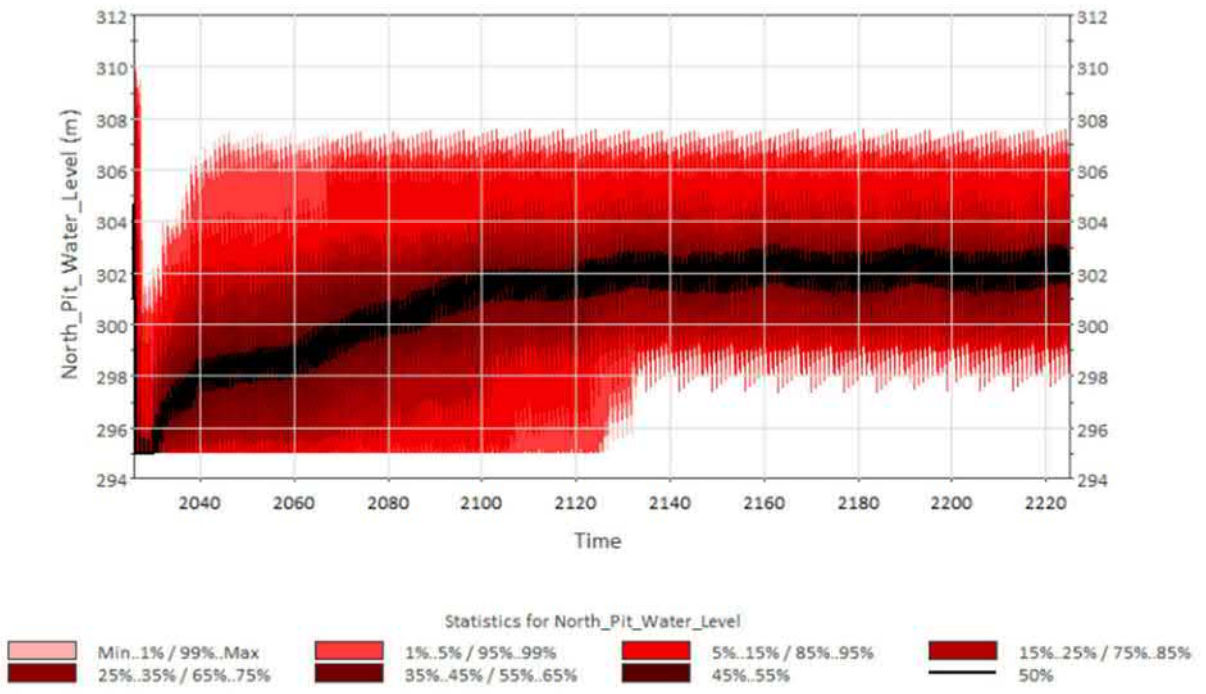


Figure 3 Long-term (200 yrs) North Pit water levels

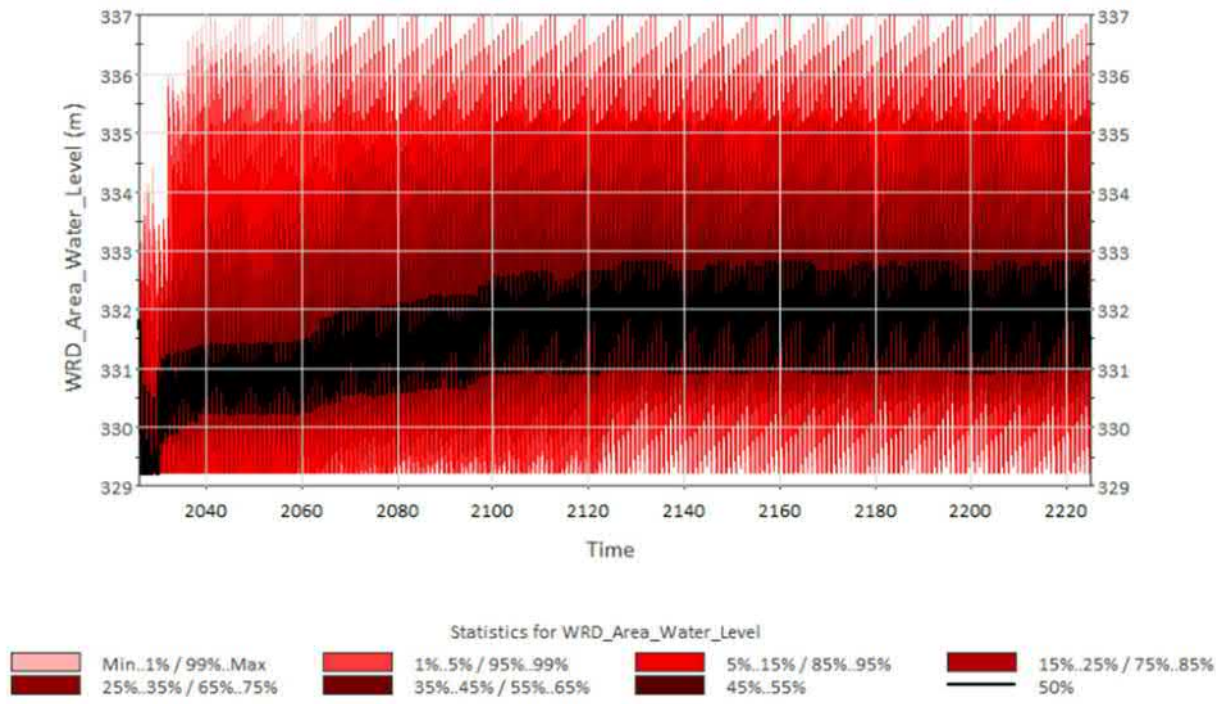


Figure 4 Long-term (200 yrs) WRD Sediment Dam water levels

5.2 Underground void long-term water quality

To assess the long-term water quality in the underground void, the 200-year WBM was used to simulate the underground void water balance under five (5) climate scenarios representing the 5%, 25%, 50%, 75% and 100% rainfall and evaporation time series, as follows:

- Rainfall and evaporation time series/scenarios representing the 5th, 25th, 50th, 75th and 100th percentile (a.k.a. the P05, P25, P50, P75 and P100 scenarios) were generated using the probabilistic 200-year WBM developed by ATC Williams.
- ATC Williams ran the 200-year WBM model in a deterministic mode for each scenario to obtain detailed water balance volumes (i.e. inflows, storages and outflows) for the underground workings.
- A mixing model was developed for each scenario, using the water balance volumes and water quality characteristics of the different components to calculate the long-term water quality in the underground workings.

As the input analyte concentrations are based on literature values (for rainfall) or actual observed concentrations (e.g. 95th percentile of analysis data for surface water and groundwater), no sensitivity/uncertainty analysis is undertaken on the water quality input data.

Appendix C presents time series graphs of analyte concentrations in the underground void for each climate scenario. The time series of the modelled results indicate the following:

- Initial water quality is determined by the water quality of the water transferred into the UG voids (i.e. initial transfer of water from the North Pit, transfers from the WRD Sediment Dam and semi-regular transfers of water from the South Pit).
- Mid- to long-term water quality is governed by the mixing of the transferred water with groundwater inflow.
- Water quality in the underground void reaches long-term stability after approximately 16 years.

The results indicate that long-term stability in underground void water quality is reached after ±2041 when the underground void is completely filled with groundwater. Table 2 presents the long-term water quality compared against the ANZECC Livestock Water Quality Guidelines and the PRCP schedule PRCP EPML02840015 – Water quality limits for North and South Pits and WRD Sediment Dam. The results show that long-term water quality within the UG workings remains below these guideline values.

The results of the mixing modelling indicate that groundwater quality in the UG voids remains below the relevant water quality guidelines values (livestock watering and PRCP criteria for voids) and that the underground workings are suitable for a livestock watering PLMU.

Table 2 Modelled long-term UG workings final void water quality concentrations (mg/L)

Analyte	Guideline values	P05	P25	P50	P75	P100
Aluminium	5 (1)	0.0424	0.0503	0.0437	0.0503	0.0484
Arsenic	0.5 (1)(2)	0.0028	0.0026	0.0028	0.0026	0.0027
Barium	-	0.1838	0.1796	0.1846	0.1821	0.1868
Boron	5 (1)	0.0709	0.0829	0.0728	0.0811	0.0773
Cadmium	0.01 (1)(2)	0.0033	0.0040	0.0032	0.0043	0.0041

Analyte	Guideline values	P05	P25	P50	P75	P100
Calcium	500 (2) 1000 (1)	69.4	71.0	68.7	65.1	61.6
Chloride	-	55.4	50.8	54.7	49.5	50.5
Chromium	1 (1)	0.0081	0.0071	0.0080	0.0075	0.0081
Cobalt	1 (1)	0.0040	0.0037	0.0040	0.0038	0.0040
Copper	1 (1)(2)	0.0479	0.0516	0.0475	0.0541	0.0532
Fluoride	2 (1)(2)	0.7568	0.7868	0.7599	0.7639	0.7480
Lead	0.1 (1)(2)	0.0204	0.0251	0.0202	0.0269	0.0254
Magnesium	150 (2) 2000 (1)	47.2	44.5	46.3	41.0	40.1
Manganese	1 (2)	0.0390	0.0478	0.0388	0.0510	0.0483
Molybdenum		0.0069	0.0064	0.0065	0.0050	0.0042
Nickel	1 (1)	0.0057	0.0055	0.0057	0.0055	0.0057
Potassium	-	39.0529	35.6874	38.8327	36.2957	38.0237
Selenium		0.0067	0.0059	0.0061	0.0031	0.0016
Sodium	-	181.7	177.9	180.4	170.1	167.9
Sulfate	2,000 (1)	127.4	119.4	119.2	83.4	63.5
Total Dissolved Solids	5,000 (1)(2)	648.7	628.0	640.7	589.0	576.4
Uranium	0.2 (1)	0.0069	0.0070	0.0069	0.0068	0.0067
Vanadium	ND (1)	0.0013	0.0016	0.0014	0.0016	0.0015
Zinc	20 (1)(2)	0.0937	0.1138	0.0943	0.1190	0.1132

(1) ANZECC 2000 Livestock (beef cattle) drinking water quality guidelines

(2) PRCP schedule PRCP EPML02840015 – Tabe 5: Water quality limits for North and South Pits and WRD Sediment Dam

5.3 Open pits long-term water quality

5.3.1 Introduction

In 2023 and as part of the preparation of the PRCP for the BCP Project, ATC Williams developed water quality models (WQMs) for the North Pit, South Pit and WRD Sediment Dam by linking the output of the Goldsim WBM with a PHREEQC (USGS, ver. 3.6.2.15100) geochemical model. It is noted that these WQMs did not include the proposed underground workings. However, the results of these WQMs are still considered relevant and representative.

Given the complexity of linking the Goldsim probabilistic output to PHREEQC, three different water balance scenarios were evaluated, corresponding with the following Goldsim™ WBM stochastical results:

- The median climatic conditions that correspond with an occurrence probability of 50% (i.e. 50th percentile or P50).
- Interquartile climatic conditions that correspond with 25th percentile (occurrence probability of 75% or P75) and 75th percentile (occurrence probability of 25% or P25) climatic conditions.

Higher probabilities were not considered since increased rainfall, groundwater discharge into the pit void, and lower evaporation rates would result in improved water quality and represent a lower risk to the downstream environment or closure condition.

With respect to the geochemical process, the modelling included speciation equilibrium modelling, i.e. the precipitation/dissolution of minerals from/into solution when the different water types are mixed. In the first instance, only the mineral phase considered was gypsum, whereby gypsum precipitation could occur if calcium and sulphate concentrations in the mixed water were sufficiently elevated. This model is denoted as the "equilibrium" model.

5.3.2 Validity of the 2023 water quality models

The timeframe of the 2023 water balance and quality models was 58 years (i.e. from mid-2022 to early-2080). The modelling results are discussed in the report "*Barbara Copper Project Progressive Rehabilitation and Closure Plan. Water Quality Assessment of North Pit, South Pit and WRD Sediment Dam*" (WMV Environmental, March 2023) that was included in the 2023 PRCP submission and are summarised in the report "*Barbara Copper Project UG EA Amendment. Groundwater Technical Report*" (WMV Environmental, March 2024) that was included in the BP Underground Workings EA Amendment Application. Appendix D presents the 2023 water quality modelling results for the open pits and WRD sediment dam.

The water levels in the South Pit, North Pit and WRD Sediment Dam for each climate scenario obtained from the long-term (200 yrs) water balance model are presented in Figure 5, Figure 6 and Figure 7, respectively. The modelling results indicate that for most climate scenarios, the water levels in the open pits and WRD sediment dam reach long-term stability (i.e. water levels only influenced by the interaction between rainfall and evaporation) after ±50 years (i.e. by 2075-2080).

Including the underground void in the recent model does not affect the long-term water balance and water quality in the North Pit, South Pit and WRD Sediment Dam. The only interaction between the South Pit and the underground void consists of dewatering the pit to gain access to the underground void. Once the underground mining is complete, such dewatering is no longer required, and the water levels in the South Pit will recover, as per the original 2023 water balance/quality models.

The results of the 2023 water quality model are considered relevant and representative of the post-underground mining operations given that:

- the long-term water balance modelling results indicate stabilisation of water levels in the open pits and sediment dam after ±50 years
- the underground mining only has a minor impact on the mid- to long-term water levels in the open pits and WRD sediment dam
- the 2023 water quality model demonstrates that water quality in the pits and sediment dam remains below the ANZECC livestock drinking water guidelines.

The 2023 water quality modelling indicates that the modelled solute concentrations at all times and for both models (i.e. mixing and equilibrium models) remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.

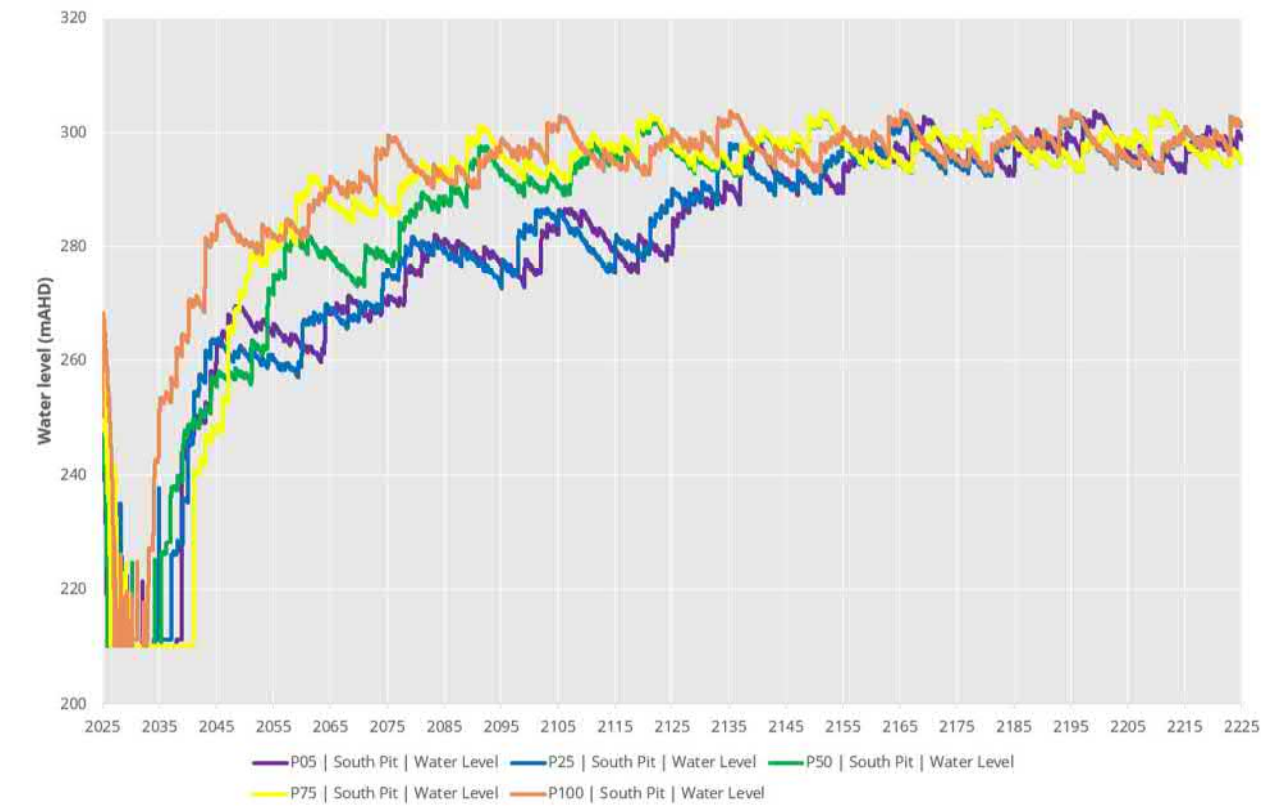


Figure 5 Long-term (200 yrs) South Pit water levels (5 climate scenarios)

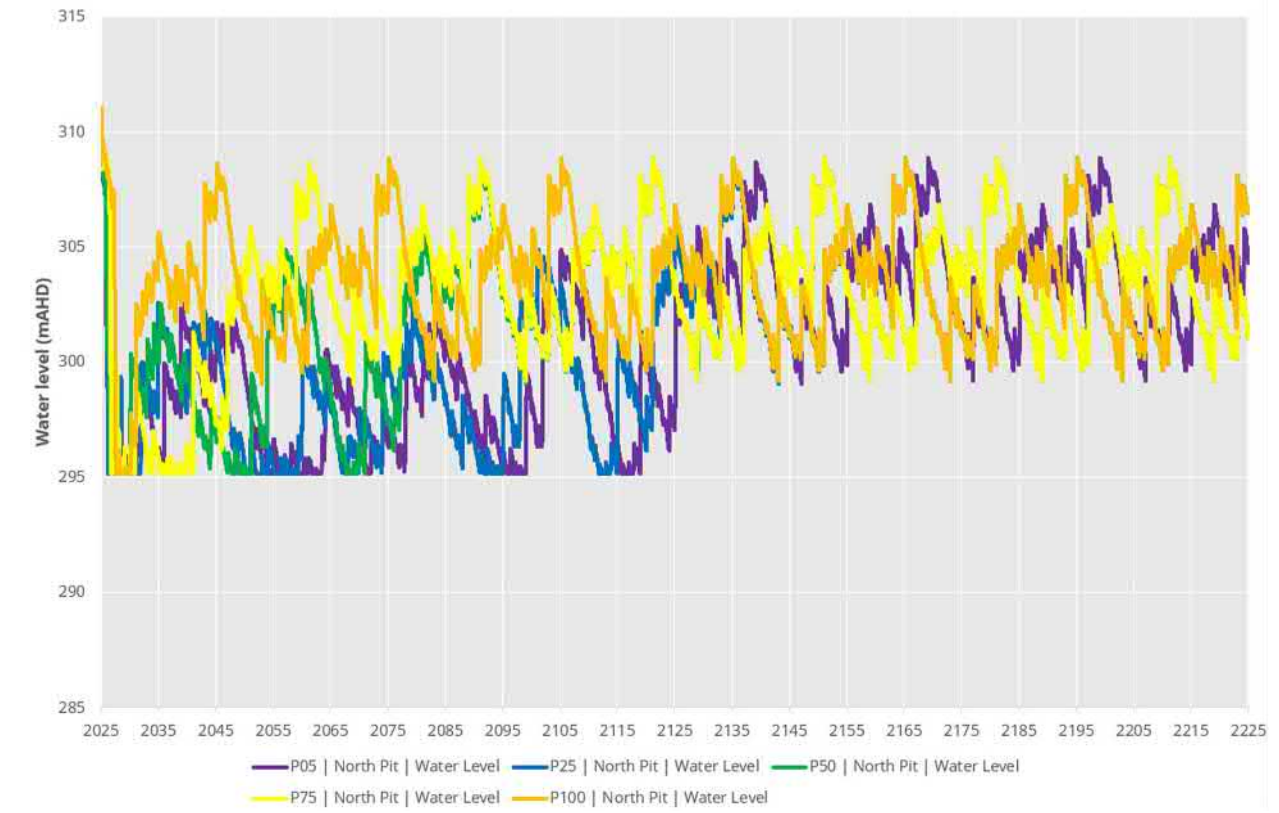


Figure 6 Long-term (200 yrs) North Pit water levels (5 climate scenarios)

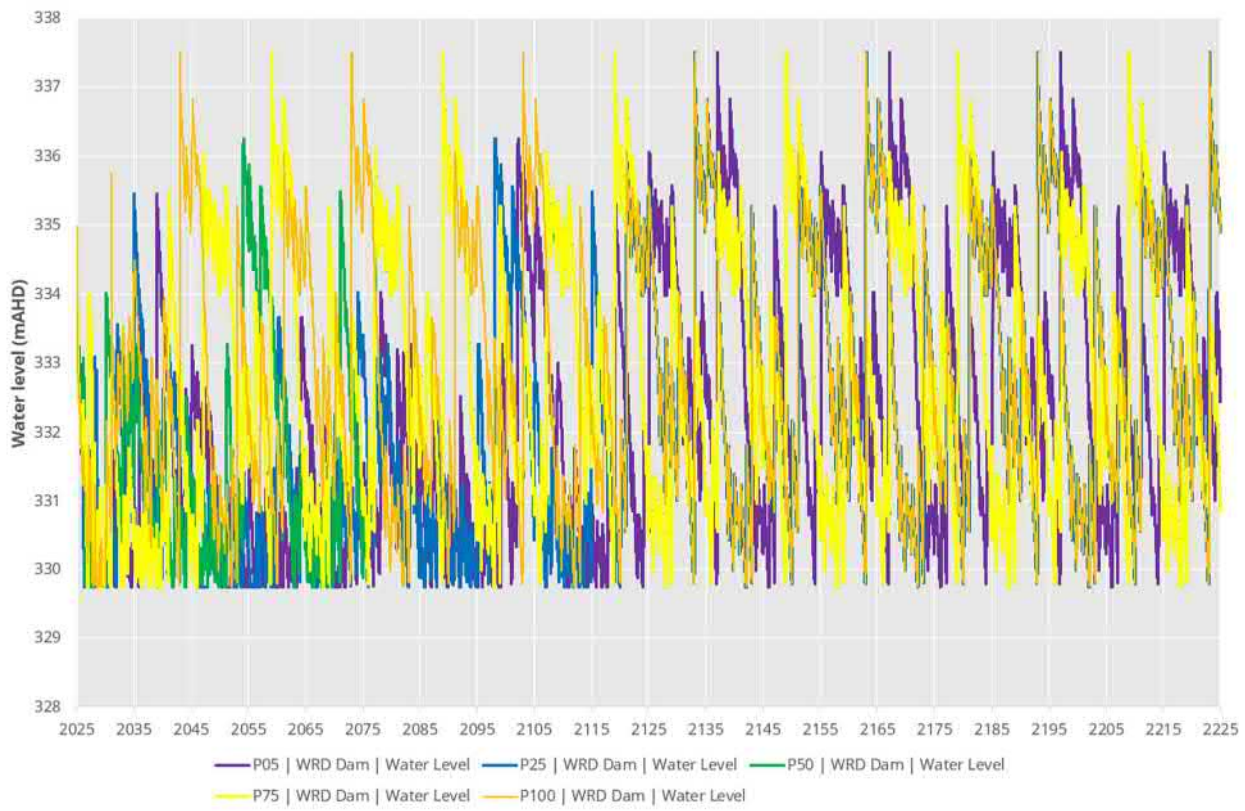


Figure 7 Long-term (200 yrs) WRD Sediment Dam water levels (5 climate scenarios)

5.3.3 Statistical extrapolation of water quality results

The 2023 modelled water quality results (Appendix D.2) indicate that the analyte concentrations in the open pits and sediment dam generally stabilise after 55 years, with water quality determined by the interaction between rainfall, runoff and evaporation. This is demonstrated by the asymptotic flattening of the water quality time series.

Statistical extrapolation/curve fitting of the 2023 modelling results and trends was undertaken to assess the long-term (i.e. 200-yrs) water quality. As the water quality modelling results of the P25 scenario (i.e. 75% percentile), statistical curve fitting was applied to this data.

Appendix D.3 presents the results of the statistical curve fitting for the North Pit, South Pit and WRD Sediment Dam. The curve-fitting equations were used to extrapolate the water quality results from 55 years to 200 years (i.e. from 21,080 to 73,049 days). Table 3 presents the extrapolated results, together with the ANZECC Livestock Water Quality Guidelines and the PRCP schedule PRCP EPML02840015 – Water quality limits for North and South Pits and WRD Sediment Dam.

Table 3 Extraplated long-term (200-yrs) final void water quality concentrations (mg/L)

Analyte	Guideline values	Extrapolated concentration after 200 years		
		North Pit	South Pit	WRD Sediment Dam
Calcium	500 (2) 1000 (1)	192.8	108.0	5.4
Magnesium	150 (2) 2000 (1)	114.2	67.2	2.4
Sodium	-	308.2	208.1	37.9
Potassium	-	80.9	25.3	1.6

Analyte	Guideline values	Extrapolated concentration after 200 years		
		North Pit	South Pit	WRD Sediment Dam
Sulfate	2,000 (1)	298.3	507.5	25.3
Chloride	-	755.0	270.8	5.9
Fluoride	2 (1)(2)	1.2	0.8	0.06
Aluminium	5 (1)	0.0793	0.0091	<LOR
Arsenic	0.5 (1)(2)	0.0127	0.0043	0.0002
Barium	-	0.3421	0.0668	<LOR
Chromium	1 (1)	0.0005	0.0004	<LOR
Copper	1 (1)(2)	0.0423	0.0149	0.0005
Manganese	1 (2)	1.0261	0.0019	<LOR
Molybdenum	0.15 (1)	0.0148	0.0256	0.0025
Nickel	1 (1)	0.0060	0.041	0.0004
Total Dissolved Solids	5,000 (1)(2)	2179	1430	49.7
Uranium	0.2 (1)	0.0203	0.0123	0.003
Zinc	20 (1)(2)	0.0096	0.0130	<LOR
pH	6.5 - 8.5	7.849	8.03	8.35

(1) ANZECC 2000 Livestock (beef cattle) drinking water quality guidelines

(2) PRCP schedule PRCP EPML02840015 – Tabe 5: Water quality limits for North and South Pits and WRD Sediment Dam

The long-term (200-yrs) water quality levels remain below the adopted guidelines.

5.3.4 Conclusions

Long-term water quality in the pits and voids is determined by climatic conditions and geochemical reactions and tends to stabilise. The net flow balance between rainfall runoff plus groundwater inflow and evaporation determines short-term variations.

Based on the WQM results, the North Pit, South Pit and WRD Sediment Dam are considered suitable as PMLUs for livestock watering.

6 References

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WMV Environmental. (March 2024). *Barbara Copper Project UG EA Amendment. Groundwater Technical Report.* Prepared for Aeris Resources Limited.

7 Limitations

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Appendix A Analytical models versus numerical models

A.1 Analytical model justification

A.1.1 Introduction

The assessment of the final void hydrogeology and groundwater impact assessment, as described in the Groundwater Technical Report, was based on:

- final void water balance modelling (ATC William, 2023ba, ATC Williams, 2024)
- water quality modelling of the open pits and WRD Sediment Dam undertaken by ATC Williams (ATC William, 2023b) with further interpretation of the data by WMV Environmental (2023)
- underground workings final void water quality modelling.

The final void hydrogeology and groundwater impact assessment included the following:

1. An assessment of the extent and level of drawdown from the open pits and proposed underground mining and potential impacts on surface water bodies.
1. An assessment of the level of groundwater inflow into the open pits and underground workings as input into the water balance model.
2. An assessment of final void water quality and impacts on environmental values.
3. An assessment of final underground workings water quality and impacts on environmental values.
4. An open pits stratification assessment

Items 1 to 4 required groundwater modelling either to provide input data for water balance and water quality models or to allow direct assessment of potential impacts.

WMV Environmental's approach to groundwater modelling included the initial development of analytical models instead of 3D numerical groundwater models. This approach was based on the following considerations:

- The hydrogeological conceptual model developed for BCP forms the basis for the analytical models. Any numerical groundwater model would be based on the same conceptual model.
- Groundwater models can be simple, like one-dimensional analytical solutions, spreadsheet models or very sophisticated three-dimensional models. It is recommended to start with a simple model as long as the model concept satisfies the modelling objectives, and then the model complexity can be increased (Hill, 2006).
- Analytical models are based on the same scientific equations and calculations as numerical models but include some simplifications (e.g. steady-state models only). The analytical models represent the open pits and underground workings as large-diameter wells with a radius and depth representative of the final void volume and depth during the different stages of mining/dewatering.
- A complex, 3D numerical model does not guarantee better results or predictions than analytical models. Analytical models can be applied relatively quickly to assess groundwater impacts at a high level. If the risks to the receiving environment, as determined through the analytical models, are low/negligible and manageable, it is not necessary to implement more complex numerical groundwater models.

Given the fact that groundwater at BCP is primarily associated with the orebody itself, the relative impermeability (i.e. low hydraulic conductivity) of the aquifers and the short duration of the underground mining (i.e. four years), analytical models are considered appropriate for the initial assessment of groundwater impact assessment.

The analytical models have been used to assess groundwater impacts under steady-state conditions. Steady-state models are generally used when the long-term average state of a groundwater system is to be known, while transient groundwater models are useful when one needs to observe the system in a short time. The groundwater impact assessment aims to assess potential long-term risks over time frames from 25 to 200 years after closure. Therefore, steady-state analytical models are considered appropriate.

A.1.2 References to the use of analytical models

Several documents refer to the use of analytical models.

The guideline "*Quantifying the volume of associated water taken under a mining lease or mineral development licence*" (State of Queensland. Department of Natural Resources, Mines and Energy., October 2020) was prepared under the *Mineral Resources Act 1989* and *Mineral Resources Regulation 2013* to assist mining tenure holders to measure, estimate and report the volume of associated water taken.

The three approved methods under section 31A(2)(b) of the Regulation that can be used to estimate and quantify associated water taken during mining operations or after mine closure are:

- water balance calculations
- numerical groundwater models
- analytical groundwater models.

The guideline recognises that:

> *Using an analytical groundwater model is most suited to simple mine situations to overcome the data requirements and costs associated with numerical groundwater models. The analytical solutions, specifically developed to estimate the fluxes of associated water to mines, described by Marinelli and Niccoli (2000), Powers et al (2007) and Hazel (2009) are in common usage for estimating groundwater flow to mines.*
>
> *....*
>
> *These analytical groundwater solutions have many simplifying assumptions, commonly including steady state conditions and uniform aquifer properties. It is noted that natural hydrogeological systems include complexities that may violate the simplifying assumptions of analytical models. For that reason, care is needed when choosing to use an analytical method because they can potentially provide relatively low accuracy estimates.*

The *Australian Groundwater Modelling Guidelines* (Barnett et al, 2012) provide some information on the use of analytical versus numerical models, as follows:

- An analytical model makes simplifying assumptions (e.g. properties of the aquifer are considered to be constant in space and time) to enable a solution of a given problem, e.g. the level of groundwater inflow into the open pits and underground workings.
- Numerical models are usually solved by a computer and are usually more computationally demanding than analytical models.
- Analytical and numerical models can each be beneficial, depending on the objectives of a particular project.
- Guiding Principle 11.8: Analytical solutions should be used to develop an understanding of the nature of surface water–groundwater interaction prior to regional scale numerical modelling, or in parallel with such modelling as a way of checking the numerical modelling.

The report "*Hydrological and geochemical processes and closure options for below water table open pit mines*" (Cook, et al., 2021) discusses the use of analytical versus numerical models. The report acknowledges that several analytical models have been specifically developed to estimate the volumes of groundwater required to be pumped to dewater large mines and the extent of drawdown (e.g., Marinelli and Niccoli, 2000; Thiess).

A.2 Sichardt's equation for radius of influence

A "radius of influence" is defined as the maximum distance at which drawdown can be detected with the usual measure devices in the field (Dragoni, 1999). Empirical, analytical formulas can be used to calculate the radius of influence around a void that can be represented by a large diameter pumping well.

The radius of influence, R, can be estimated using Sichardt's equation (Powers, 1992) as follows:

$$R = 3000\,(H - h)\sqrt{K_{sat}} + r_0$$

with: R = radius of influence [m]

H = groundwater level at extent of drawdown (i.e. regional groundwater level) [mAHD]

h = water level in the void [mAHD]

s = (H – h) = drawdown in the void

K_{sat} = saturated hydraulic conductivity [m/s]

r_o = equivalent well radius, calculated taking into consideration the void geometry as

$$r_0 = \sqrt{\frac{a \times b}{\pi}}$$ with a= average height of the void; b = average width of the void

A.3 Marinelli and Niccoli equation for groundwater inflow

Plate 1 presents the conceptual model used by the analytical equations of Marinelli and Niccoli to calculate the groundwater inflow into a mine pit.

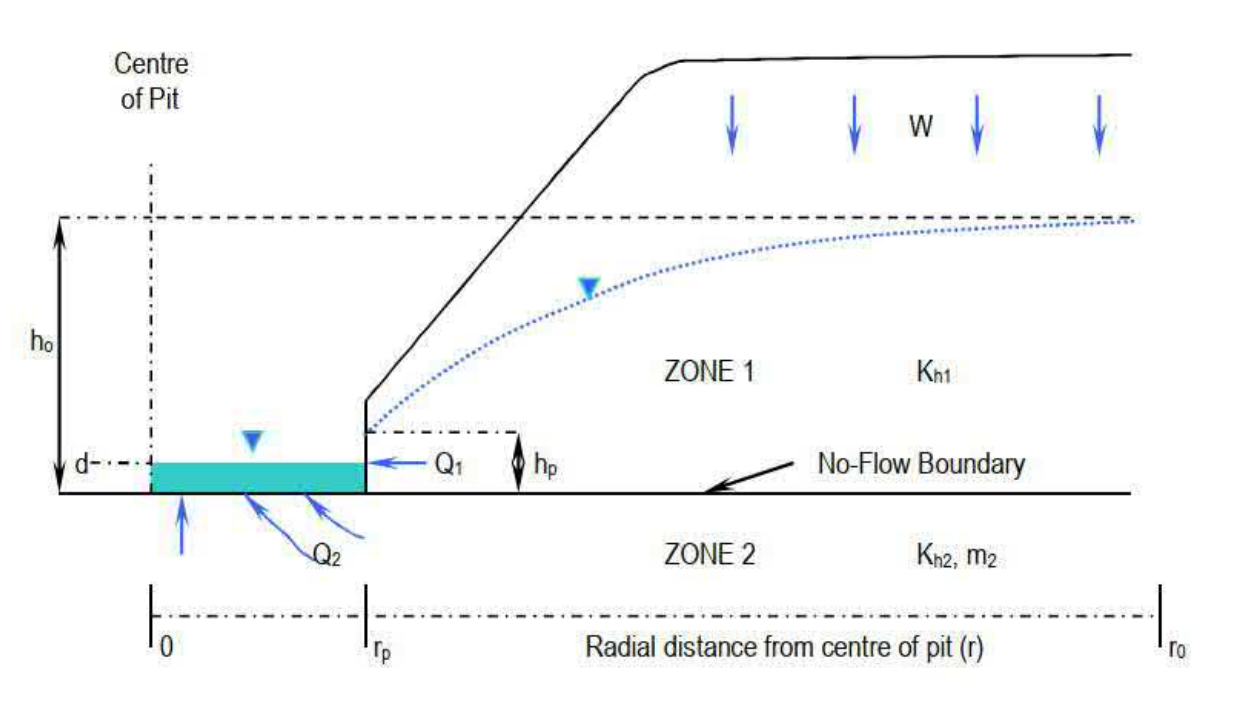


Plate 1 Mine pit inflow conceptual model (Marinelli & Niccoli, 2000)

With Marinelli and Niccoli's method, groundwater flow into a mine pit/underground works is divided into two zones, with Zone 1 representing lateral flow through the pit/underground workings walls and Zone 2 the inflows from the base of the pit/underground working. Table A.1 presents the equations and assumptions used to calculate the groundwater inflows from each zone.

Table A.1 Groundwater inflow into mine pit equations and assumptions

Zone 1	Zone 2
Inflow Equations	
$Q_1 = W \pi (r_0^2 - r_p^2)$	$Q_2 = 4 r_p \left(\frac{K_{h2}}{m_2}\right) (h_0 - d)$ $m_2 = \sqrt{\frac{K_{h2}}{m_2}}$
Q_1 = volumetric flow rate from Zone 1 W = recharge flux r_0 = radius of influence r_p = effective pit radius	Q_2 = volumetric flow rate from Zone 2 K_{h2} = horizontal hydraulic conductivity K_{v2} = vertical hydraulic conductivity m_2 = anisotropy parameter h_0 = pre-mining saturated thickness above base of Zone 1 d = depth of water in pit
Assumptions	

Zone 1	Zone 2
• Pit walls are approximated as a circular cylinder. • Groundwater flow is horizontal and the Dupuit-Forchheimer approximation can be used to account for changes in saturated thickness due to depression of the water table. • The static (pre-mining) water table is approximately horizontal. • Uniform distributed recharge occurs across the site as a result of surface infiltration from rainfall. • All recharge within the radius of influence (cone of depression), of the pit is assumed to be captured by the pit. • Groundwater flow toward the pit is axially symmetric. • The aquifer is infinite in extent (i.e. the cone of depression does not encounter any zero recharge boundaries).	• Hydraulic head is initially uniform (hydrostatic) throughout Zone 2. Initial head is equal to the elevation of the initial water table in Zone 1. • The disk sink has a constant hydraulic head equal to the elevation of the pit lake water surface. If the pit is completely dewatered, the disk sink head is equal to elevation of the pit bottom. • Flow to the disk sink is three-dimensional and axially symmetric. • Materials within Zone 2 are anisotropic, and the principal coordinate directions for hydraulic conductivity are horizontal and vertical.

Appendix B Sensitivity/uncertainty analysis

B.1 Approach to sensitivity/uncertainty analyses

B.1.1 Introduction

Table B.1 presents the analytical models/equations used for the groundwater impact assessment and the parameters/variables used in the analytical equations.

The main groundwater-related calculations that are used directly for the impact assessment or feed into other models are:

- calculations of the extent and level of drawdown (i.e. radius of influence) during and post-mining to:
  - assess potential impacts on GDEs
  - provide input into groundwater inflow into voids calculations
- calculations of groundwater inflows into open pits and underground voids to provide input into water balance model calculations.

The results of the water balance models provide the inputs for the water quality models.

Table B.2 presents the values of the parameters adopted in the analytical models/equations.

Table B.1 Analytical models/equations and input parameters/variables

Purpose	Extent and level of drawdown around voids	Groundwater inflow into voids	BCP Water Balance Model	Final void water quality model – Pits and Sediment Dam	Underground void water quality model	PAF disposal to underground voids
Analytical model /equations	Sichardt's equation	Marinelli & Nicolli, 2000	ATC Williams Goldsim WBMs (2023 and 2024)	ATCW 2023 PHREEQC model, linked to WBMs	ATCW Goldsim WBM (2024) + Mixing model	PHREEQC mass balance/mixing model
Calculations						
Calculated Parameters	Radius of drawdown influence	Groundwater inflow by depth	BCP water balance	Open pit and sediment dam long-term water quality	Long-term BCP water balance + underground void water quality	Long-term underground void water quality
Input Parameters						
Water balance volumes	✗	✗	Calculated	✓	Calculated	✓
Groundwater inflow	✗	Calculated	✓	✗	✓	✗
Rainfall recharge to groundwater	✗	✓	✗	✗	✗	✗
Radius of influence	Calculated	✓	✗	✗	✗	✗
Equivalent void radius	✓	✓	✗	✗	✗	✗
Horizontal hydraulic conductivity	✓	✓	✗	✗	✗	✗
Vertical hydraulic conductivity	✗	✓	✗	✗	✗	✗
Pre-mining groundwater levels/ saturated thickness	✓	✓	✗	✗	✗	✗
Water level/volume in void	✓	✓	✗	✗	✗	✓
Water quality (input)	✗	✗	✗	✓	✓	✓
Water quality (output)	✗	✗	✗	Calculated	Calculated	Calculated

✓: required as input parameter ✗: not required as input parameter

Table B.2 Analytical models/equations input parameter values

Parameter	Adopted value	North Pit	South Pit	Underground Void	Source/ comments
Rainfall recharge to groundwater	0.000025 m/day	NA	NA	NA	Assumed 2% of long-term annual rainfall in Mt Isa (461 mm/year)
Radius of influence – open pits	NA	100m	200m	NA	Based on the distance from the centre of the north pit to groundwater bore BAWB04, considered to represent the actual extent of the cone of depression due to mining.
Radius of influence – underground void	NA	NA	NA	100m	Based on the distance from the centre of the north pit to groundwater bore BAWB04, considered to represent the actual extent of the cone of depression due to mining.
Equivalent void radius	NA	Calculated	Calculated	Calculated	Calculated from open pits and underground void dimensions.
Horizontal hydraulic conductivity	2.29 10^{-08} m/s or 0.00198 m/day	NA	NA	NA	Based on 2013/2014 site investigations Assumed to decrease with depth.
Vertical hydraulic conductivity	0.00020 m/day	NA	NA	NA	10% of horizontal hydraulic conductivity
Pre-mining groundwater levels/ saturated thickness					
Water level/volume in void	NA	Calculated	Calculated	Calculated	Calculated based on void geometry, initial water storage volume and net water balance (i.e. difference between inflow and outflow as determined through the WBM).
Water quality (input)					

The input parameter values are considered appropriate and are, to the extent possible, based on existing data and information. The analytical modelling undertaken to date is described in detail in the Groundwater Technical Report (WMV Environmental, March 2024).

Sensitivity/uncertainty analyses were not undertaken, as it was considered that steady-state analytical models are generally conservative. Steady-state models do not take into account limitations and constraints associated with specific yield and storativity of the aquifer or with physical boundary conditions.

As mentioned above, DESI raised a concern regarding "*the lack of sensitivity analyses being conducted on the groundwater models. Understanding the potential variation in model output/s based on the varied input/s would assist with the decision making. This can be achieved by considering a range of realistic scenarios (both during the past and current predictions)*".

To address DESI's concerns, the results of sensitivity analyses on the analytical models are presented in this technical memo.

B.1.2 Sensitivity/uncertainty analysis for analytical models

As detailed in the Australian Groundwater Modelling Guidelines (Barnett et al, 2012) :

> *Guiding Principle 5.5: Sensitivity analysis should be performed to compare model outputs with different sets of reasonable parameter estimates, both during the period of calibration (the past) and during predictions (in the future).*

Section 5.5 of the Australian Groundwater Modelling Guidelines provides more detail regarding sensitivity analyses and their relationship with uncertainty analyses. However, it must be noted that the description and proposed approach relate to 2-D or 3-D numerical calibrated groundwater models. As part of the calibration or predictive stage, model parameters can be changed either manually or through specialised software (e.g. PEST) to assess the influence of the parameter changes on the model calibration or predictions.

With respect to the sensitivity/uncertainty analyses of the analytical models, the following needs to be considered:

- The analytical model used to assess the potential impacts of mining on groundwater-dependent ecosystems calculates the level and extent of drawdown around open pits and voids. The horizontal hydraulic conductivity is the only model parameter on which a sensitivity analysis can be undertaken.
- The analytical model used to calculate groundwater inflows into the open pits/voids provides input into the water balance and quality models. Model input parameters for sensitivity analysis include rainfall recharge and horizontal and vertical hydraulic conductivity. An additional input parameter is the radius of influence, which the previous analytical model calculates.
- Input parameters for the water quality models include the water balance volumes, calculated through the Goldsim water balance models, and analyte concentrations of rainfall, runoff and groundwater inflow. As the analyte concentrations are based on literature values (for rainfall) or actual observed concentrations (e.g. 95th percentile of analysis data for surface water and groundwater), no sensitivity/uncertainty analysis is undertaken on the water quality input data.

Given that the output of the first analytical model (i.e. the extent and level of drawdown) provides an input into the second analytical model (i.e. calculation of groundwater inflow into open pits and voids), a combined sensitivity/uncertainty analysis has been undertaken.

B.1.3 Sensitivity/uncertainty analysis scenarios

Sensitivity/uncertainty analyses have been undertaken on two key input parameters of the analytical models, i.e. the horizontal hydraulic conductivity and the rainfall recharge to groundwater. The hydraulic conductivity has been changed by an order of magnitude, whilst the rainfall recharge coefficient has been changed by a factor of five. Table B.3 shows the parameter values adopted for the nine sensitivity analysis scenarios.

Table B.3 Sensitivity analysis scenarios and parameter values

	Horizontal hydraulic conductivity (m/s)		
Rainfall Recharge Coefficient (% of annual rainfall)	2.29×10^{-09}	2.29×10^{-08}	2.29×10^{-07}
0.4%	Scenario 1	Scenario 4	Scenario 7
2%	Scenario 2	Scenario 5	Scenario 8
10%	Scenario 3	Scenario 6	Scenario 9

It is noted that Scenario 5, highlighted in the above table, comprises the base scenario and parameters currently used in the analytical modelling described in the Groundwater Technical Report (WMV Environmental, March 2024).

B.1.4 Sensitivity/uncertainty analysis of drawdown radius of influence

A "radius of influence" is defined as the maximum distance at which drawdown can be detected with the usual measure devices in the field (Dragoni, 1999). Empirical, analytical formulas can be used to calculate the radius of influence around a void that can be represented by a large diameter pumping well.

The radius of influence, R, can be estimated using Sichardt's equation, as further detailed in Appendix A.1. The key parameters in Sichardt's equation are the void geometry, the drawdown in the void and the saturated hydraulic conductivity.

With respect to the sensitivity analysis:

- Void geometry is calculated from Aeris's actual and planned void dimensions. No sensitivity analysis is undertaken on this parameter.
- Drawdown in the void has been calculated as the difference between the regional, pre-mining groundwater level and the base of the void during and post mining.
- The value of saturated hydraulic conductivity was obtained from site investigations undertaken in 2013. Sensitivity analyses have been undertaken on this parameter.

As the rainfall recharge coefficient is not a parameter in Sichardt's equation, only three scenarios have been considered, i.e. Scenario 1, Scenario 4 and Scenario 7.

Sensitivity analysis results

Figure B.1, Figure B.2 and Figure B.3 show the modelled radius of drawdown influence (i.e. maximum extent) under the three adopted scenarios for the North Pit, South Pit and Underground Void, respectively.

As per Sichardt's equation, the higher the horizontal hydraulic conductivity, the larger the extent of drawdown. It is noted that the calculated radii are considered conservative and an overestimate of the actual radius of influence as:

- The empirical equations apply to "steady-state" (i.e. indefinite time) conditions only, without consideration of the temporal influence of storativity within the aquifers.
- The equations do not consider the decrease in saturated hydraulic conductivity with depth or the potential presence of boundary conditions (e.g. faults, lithological barriers).

Overall, the potential radius of influence would be much less than the empirically calculated radius and remain within the ML boundaries. Gauging of existing groundwater monitoring bores (BAWB01 to BAWB07, BAWBR01 to BAWBR03) does not show a significant impact of open-cut mining on groundwater levels.

Whilst the uncertainty in the horizontal hydraulic conductivity may affect the confidence in the analytical model results, this would only be the case for scenario 7, which was modelled with a hydraulic conductivity of 2.29×10^{-07} m/s. The modelled radii of influence under Scenario 7 are significantly larger than under Scenario 1 and Scenario 4. This uncertainty would filter through into the groundwater inflow calculations. However, the uncertainty does not affect the conclusions regarding the potential impact on terrestrial GDEs (Section 4).

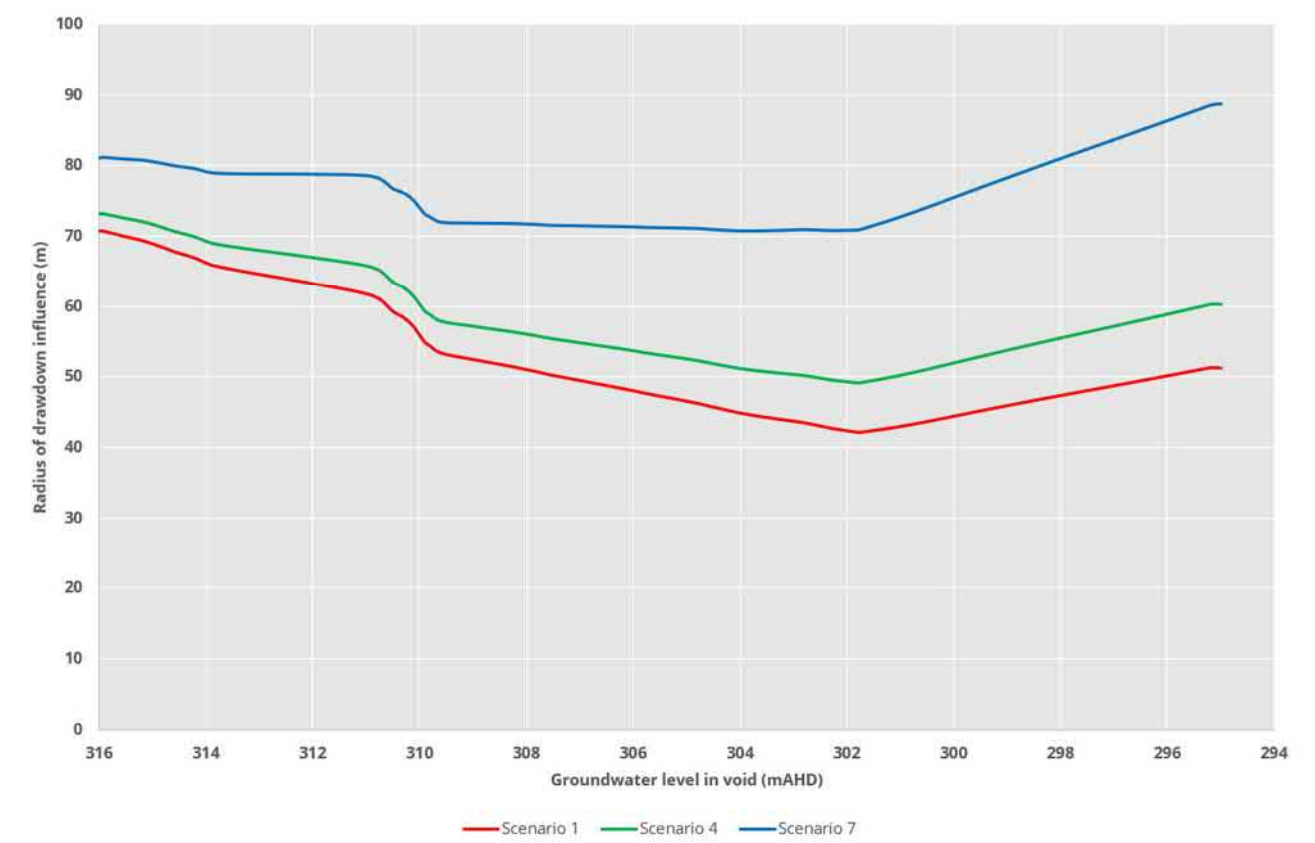


Figure B.1 North Pit radius of drawdown influence

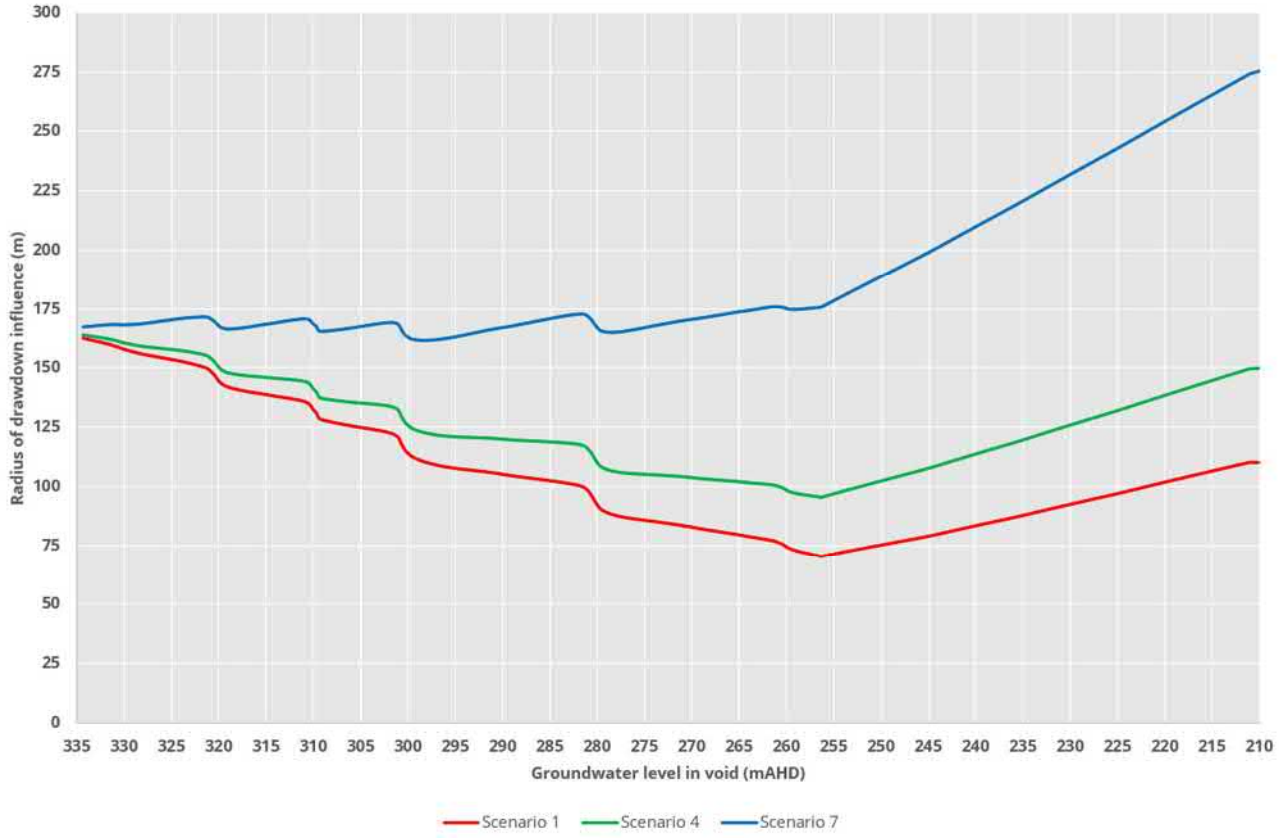


Figure B.2 South Pit radius of drawdown influence

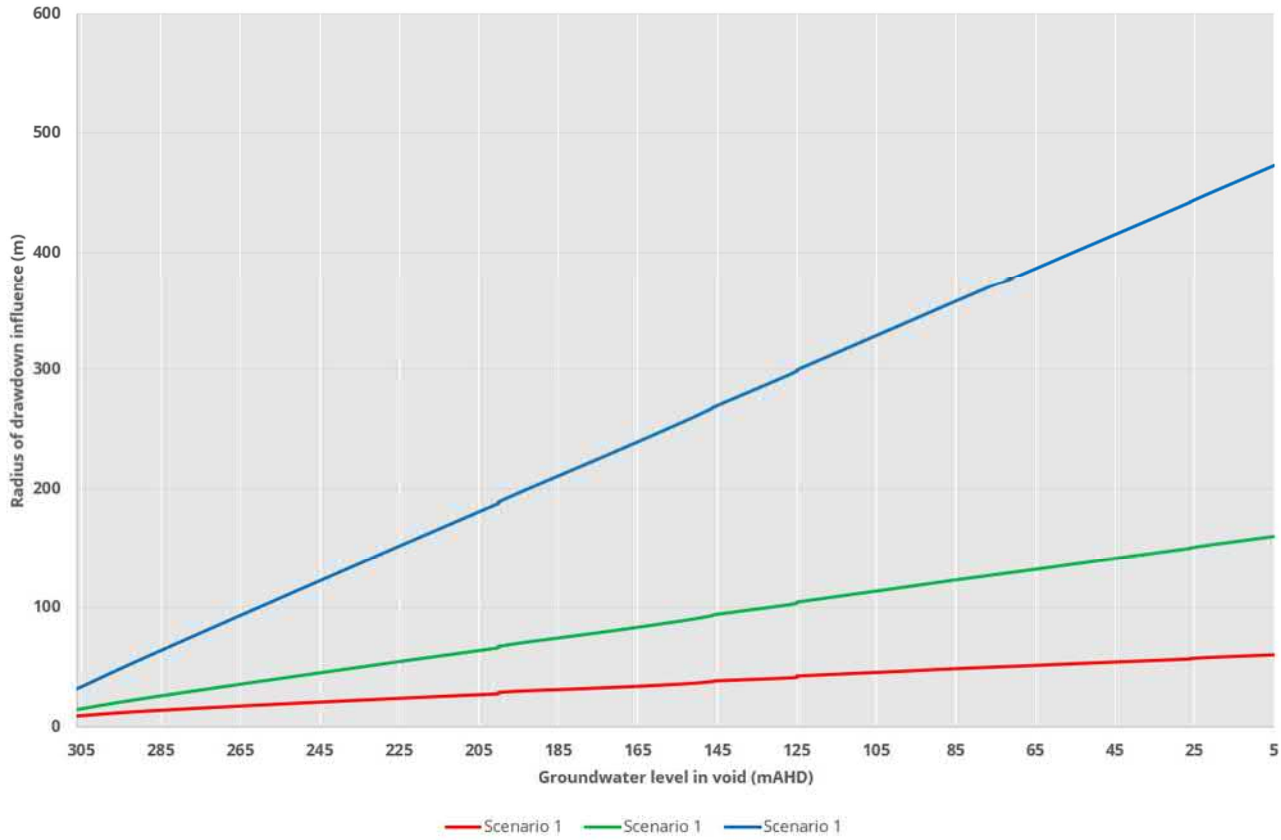


Figure B.3 Underground Void radius of drawdown influence

B.1.5 Sensitivity/uncertainty analysis of groundwater inflows into voids

The analytical models calculating groundwater inflows into the voids are based on the model by Marinelli and Nicolli. Appendix A.3 provides an overview of the Marinelli and Nicolli model.

The key parameters in the Marinelli and Niccoli model are the void geometry, the radius of influence, the rainfall recharge rate, the hydraulic and vertical conductivities, the pre-mining saturated thickness above the base of the void and the depth of water in the void.

With respect to the sensitivity analysis:

- Void geometry is calculated from Aeris's actual and planned void dimensions. No sensitivity analysis was undertaken on this parameter.
- The value of hydraulic conductivity was obtained from site investigations undertaken in 2013. Sensitivity analyses have been undertaken on this parameter.
- As the vertical hydraulic conductivity was set at 10% of the horizontal conductivity, no additional sensitivity analysis was undertaken on this parameter.
- A sensitivity analysis of rainfall recharge has been undertaken.
- Radius of influence has been calculated using Sichardt's equation. This model uses the hydraulic conductivity value. The two analytical models have been linked so that the sensitivity analysis on hydraulic conductivity filters through to the sensitivity analysis on the radius of influence.
- Pre-mining saturated thickness above the base of the void was calculated as the difference between the regional, pre-mining groundwater level and the base of the void during and post mining. No sensitivity analysis was undertaken on this parameter.
- Depth of water in the void was calculated from the void geometry. During mining, the voids are dewatered, and the depth of water has been set at 0 metres. Post-mining, water levels in the void are allowed to recover, and the depth of water has been calculated as the difference between the void level and the base of the void.

The nine scenarios presented in Table B.3 have been considered during the sensitivity analysis.

Sensitivity analysis results

Appendix B.2 includes the results of the sensitivity analysis calculations, with Appendix B.4 presenting examples of the calculations. Appendix B.3 presents graphs of the calculated groundwater inflows into the voids during (i.e. during dewatering) and post (i.e. during recovery) mining.

The sensitivity analysis results show that groundwater inflows under Scenarios 7, 8 and 9 (i.e. with horizontal hydraulic conductivity of 2.29 10^{-07} m/s) are more significant than under the other scenarios, mainly due to the increased horizontal conductivity. This increased conductivity has a two-fold and double effect, i.e. increasing the radius of influence (which affects the Zone 1 flow calculations) and the flow in Zone 2 calculations. The modelled groundwater inflows under these three scenarios are considered unrealistic. Whilst there are no specific measurements of groundwater inflow into the open pits or pit dewatering pumping rates, visual observations by site personnel during mining did not support the calculated groundwater inflows.

Figure B.4, Figure B.5 and Figure B.6 present the calculated inflows under Scenario 1, 3, 4 and 6 together with the groundwater inflow rates adopted in the Goldsim water balance models for the North Pit, South Pit and Underground Void, respectively.

The results show that the groundwater inflow rates adopted in the Goldsim water balance models are generally at the upper end of the inflows under scenarios 4 and 6, whilst inflows under scenarios 1 and 3 are generally lower than the Goldsim water balance model groundwater inflows.

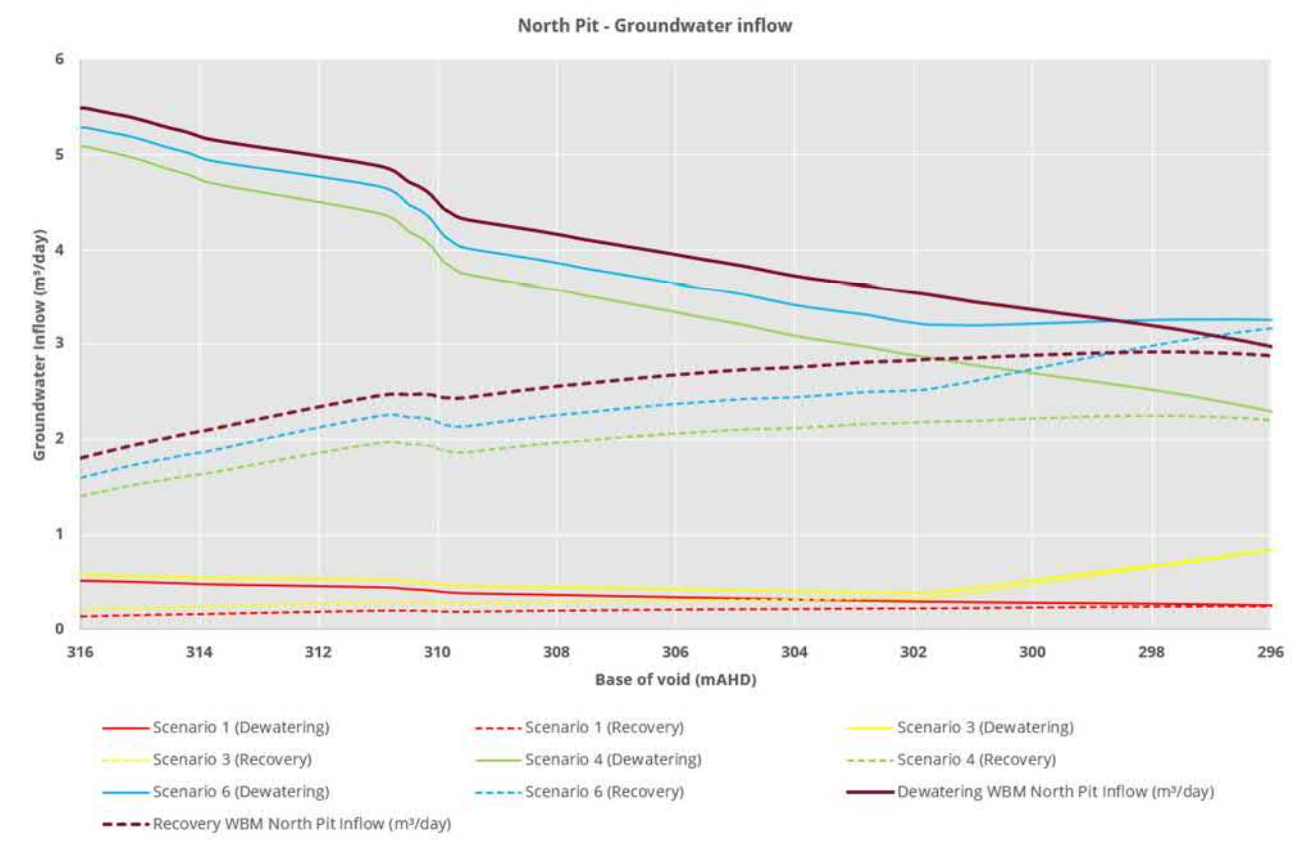


Figure B.4 North Pit groundwater inflows (Scenario 1, 3, 4 and 6 and Goldsim WBM)

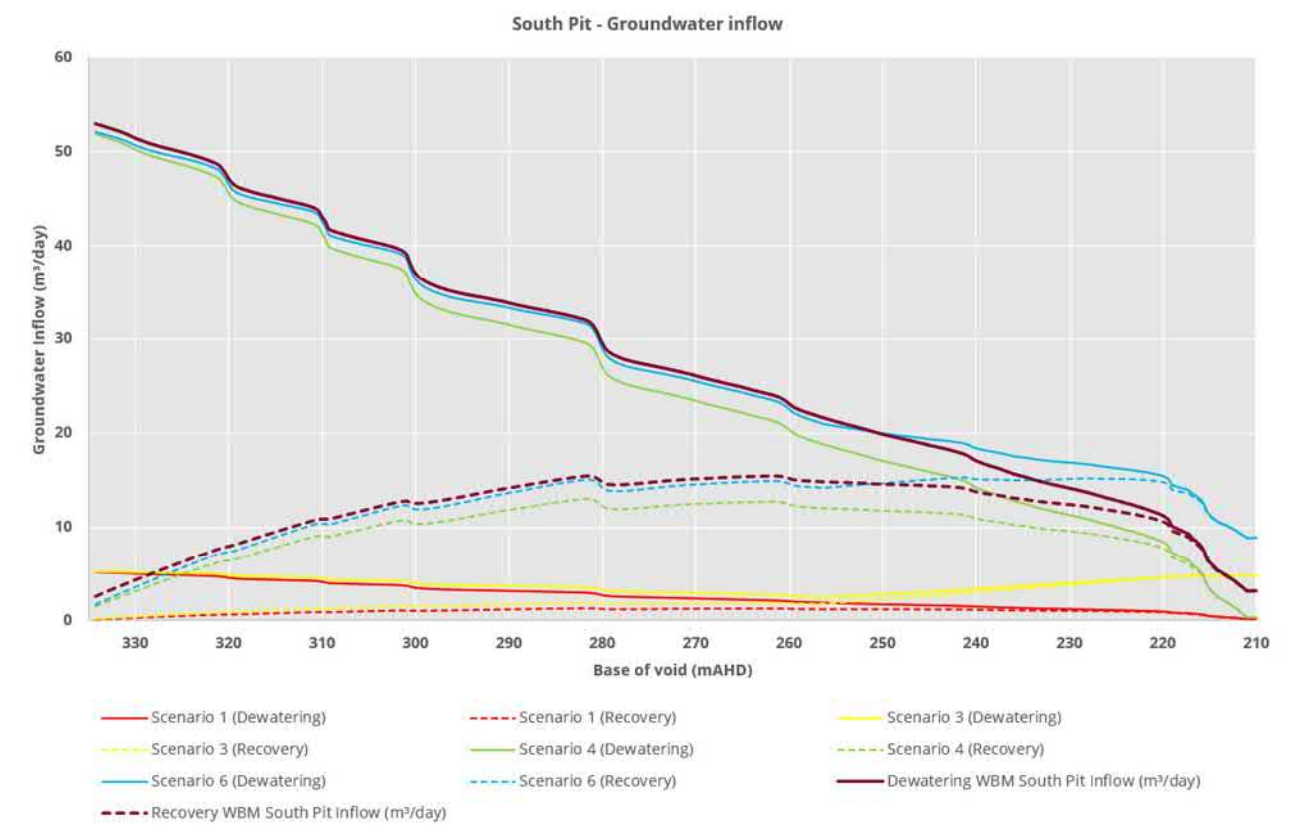


Figure B.5 South Pit groundwater inflows (Scenario 1, 3, 4 and 6 and Goldsim WBM)

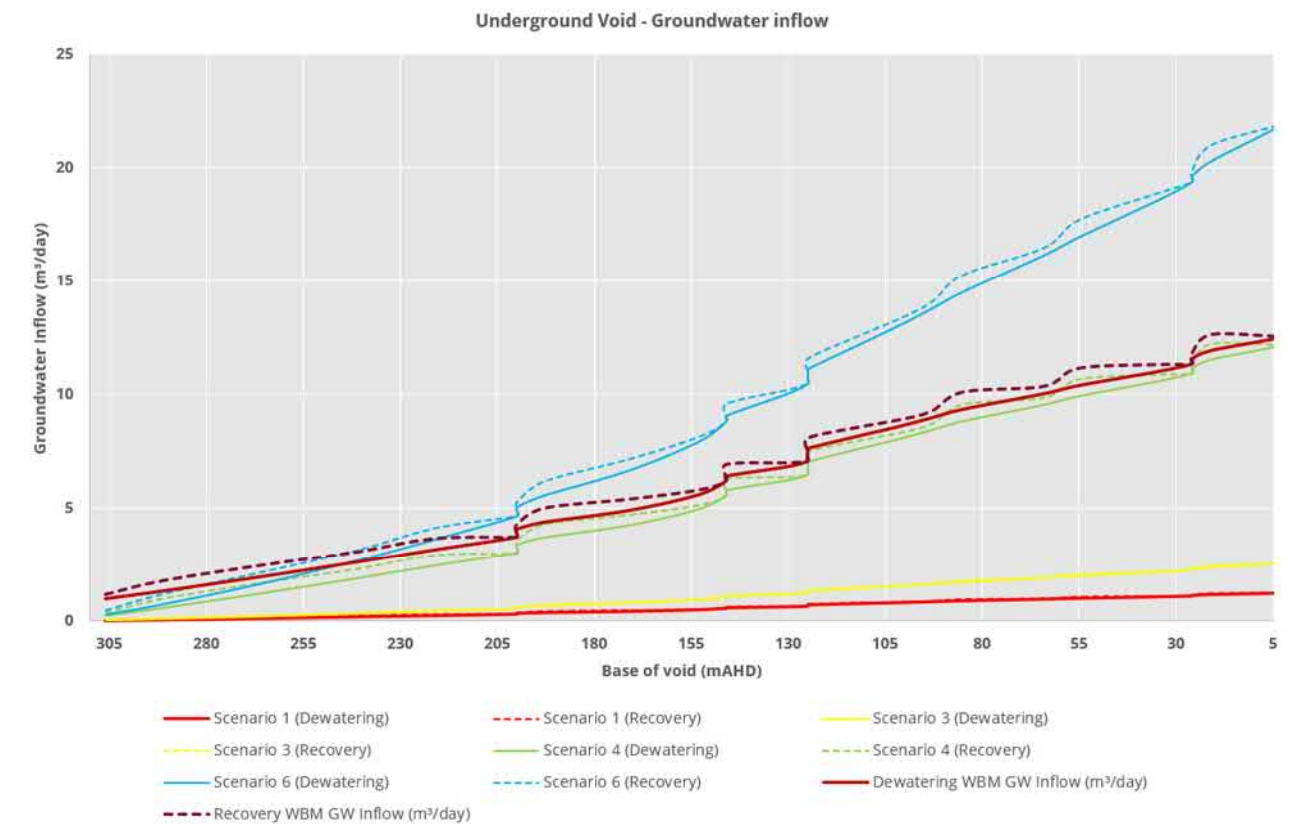


Figure B.6 Underground Void groundwater inflows (Scenario 1, 3, 4 and 6 and Goldsim WBM)

B.2 Sensitivity analyses results

Stage	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)
316	70.746	70.746	70.746	70.746	70.746	70.746	73.229	73.229	73.229	73.229	73.229	73.229	81.082	81.082	81.082
315.95	70.753	70.753	70.753	70.753	70.753	70.753	73.252	73.252	73.252	73.252	73.252	73.252	81.154	81.154	81.154
315.9	70.704	70.704	70.704	70.704	70.704	70.704	73.219	73.219	73.219	73.219	73.219	73.219	81.170	81.170	81.170
315.8	70.518	70.518	70.518	70.518	70.518	70.518	73.063	73.063	73.063	73.063	73.063	73.063	81.112	81.112	81.112
315.7	70.332	70.332	70.332	70.332	70.332	70.332	72.909	72.909	72.909	72.909	72.909	72.909	81.056	81.056	81.056
315.6	70.136	70.136	70.136	70.136	70.136	70.136	72.743	72.743	72.743	72.743	72.743	72.743	80.989	80.989	80.989
315.5	69.949	69.949	69.949	69.949	69.949	69.949	72.587	72.587	72.587	72.587	72.587	72.587	80.931	80.931	80.931
315.4	69.776	69.776	69.776	69.776	69.776	69.776	72.446	72.446	72.446	72.446	72.446	72.446	80.888	80.888	80.888
315.3	69.611	69.611	69.611	69.611	69.611	69.611	72.311	72.311	72.311	72.311	72.311	72.311	80.852	80.852	80.852
315.2	69.415	69.415	69.415	69.415	69.415	69.415	72.146	72.146	72.146	72.146	72.146	72.146	80.785	80.785	80.785
315.1	69.197	69.197	69.197	69.197	69.197	69.197	71.960	71.960	71.960	71.960	71.960	71.960	80.696	80.696	80.696
315	68.947	68.947	68.947	68.947	68.947	68.947	71.741	71.741	71.741	71.741	71.741	71.741	80.576	80.576	80.576
314.9	68.688	68.688	68.688	68.688	68.688	68.688	71.513	71.513	71.513	71.513	71.513	71.513	80.446	80.446	80.446
314.8	68.414	68.414	68.414	68.414	68.414	68.414	71.270	71.270	71.270	71.270	71.270	71.270	80.301	80.301	80.301
314.7	68.128	68.128	68.128	68.128	68.128	68.128	71.015	71.015	71.015	71.015	71.015	71.015	80.145	80.145	80.145
314.6	67.852	67.852	67.852	67.852	67.852	67.852	70.770	70.770	70.770	70.770	70.770	70.770	79.998	79.998	79.998
314.5	67.605	67.605	67.605	67.605	67.605	67.605	70.554	70.554	70.554	70.554	70.554	70.554	79.880	79.880	79.880
314.4	67.391	67.391	67.391	67.391	67.391	67.391	70.371	70.371	70.371	70.371	70.371	70.371	79.795	79.795	79.795
314.3	67.166	67.166	67.166	67.166	67.166	67.166	70.177	70.177	70.177	70.177	70.177	70.177	79.699	79.699	79.699
314.2	66.909	66.909	66.909	66.909	66.909	66.909	69.951	69.951	69.951	69.951	69.951	69.951	79.571	79.571	79.571
314.1	66.591	66.591	66.591	66.591	66.591	66.591	69.664	69.664	69.664	69.664	69.664	69.664	79.382	79.382	79.382
314	66.236	66.236	66.236	66.236	66.236	66.236	69.340	69.340	69.340	69.340	69.340	69.340	79.157	79.157	79.157
313.9	65.944	65.944	65.944	65.944	65.944	65.944	69.080	69.080	69.080	69.080	69.080	69.080	78.994	78.994	78.994
313.8	65.759	65.759	65.759	65.759	65.759	65.759	68.926	68.926	68.926	68.926	68.926	68.926	78.938	78.938	78.938
313.7	65.594	65.594	65.594	65.594	65.594	65.594	68.792	68.792	68.792	68.792	68.792	68.792	78.903	78.903	78.903
313.6	65.437	65.437	65.437	65.437	65.437	65.437	68.666	68.666	68.666	68.666	68.666	68.666	78.875	78.875	78.875
313.5	65.296	65.296	65.296	65.296	65.296	65.296	68.555	68.555	68.555	68.555	68.555	68.555	78.862	78.862	78.862
313.4	65.156	65.156	65.156	65.156	65.156	65.156	68.446	68.446	68.446	68.446	68.446	68.446	78.852	78.852	78.852
313.3	65.016	65.016	65.016	65.016	65.016	65.016	68.338	68.338	68.338	68.338	68.338	68.338	78.841	78.841	78.841
313.2	64.878	64.878	64.878	64.878	64.878	64.878	68.231	68.231	68.231	68.231	68.231	68.231	78.832	78.832	78.832
313.1	64.743	64.743	64.743	64.743	64.743	64.743	68.127	68.127	68.127	68.127	68.127	68.127	78.827	78.827	78.827
313	64.609	64.609	64.609	64.609	64.609	64.609	68.024	68.024	68.024	68.024	68.024	68.024	78.822	78.822	78.822
312.9	64.484	64.484	64.484	64.484	64.484	64.484	67.930	67.930	67.930	67.930	67.930	67.930	78.826	78.826	78.826
312.8	64.349	64.349	64.349	64.349	64.349	64.349	67.826	67.826	67.826	67.826	67.826	67.826	78.820	78.820	78.820
312.7	64.227	64.227	64.227	64.227	64.227	64.227	67.735	67.735	67.735	67.735	67.735	67.735	78.827	78.827	78.827
312.6	64.091	64.091	64.091	64.091	64.091	64.091	67.630	67.630	67.630	67.630	67.630	67.630	78.821	78.821	78.821
312.5	63.965	63.965	63.965	63.965	63.965	63.965	67.535	67.535	67.535	67.535	67.535	67.535	78.824	78.824	78.824
312.4	63.827	63.827	63.827	63.827	63.827	63.827	67.428	67.428	67.428	67.428	67.428	67.428	78.815	78.815	78.815
312.3	63.699	63.699	63.699	63.699	63.699	63.699	67.331	67.331	67.331	67.331	67.331	67.331	78.816	78.816	78.816
312.2	63.567	63.567	63.567	63.567	63.567	63.567	67.230	67.230	67.230	67.230	67.230	67.230	78.813	78.813	78.813
312.1	63.427	63.427	63.427	63.427	63.427	63.427	67.121	67.121	67.121	67.121	67.121	67.121	78.803	78.803	78.803
312	63.286	63.286	63.286	63.286	63.286	63.286	67.011	67.011	67.011	67.011	67.011	67.011	78.791	78.791	78.791
311.9	63.148	63.148	63.148	63.148	63.148	63.148	66.904	66.904	66.904	66.904	66.904	66.904	78.782	78.782	78.782
311.8	63.008	63.008	63.008	63.008	63.008	63.008	66.795	66.795	66.795	66.795	66.795	66.795	78.771	78.771	78.771
311.7	62.868	62.868	62.868	62.868	62.868	62.868	66.686	66.686	66.686	66.686	66.686	66.686	78.760	78.760	78.760
311.6	62.731	62.731	62.731	62.731	62.731	62.731	66.580	66.580	66.580	66.580	66.580	66.580	78.753	78.753	78.753

Stage	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)
311.5	62.591	62.591	62.591	62.591	62.591	62.591	66.471	66.471	66.471	66.471	66.471	66.471	78.742	78.742	78.742
311.4	62.454	62.454	62.454	62.454	62.454	62.454	66.365	66.365	66.365	66.365	66.365	66.365	78.734	78.734	78.734
311.3	62.301	62.301	62.301	62.301	62.301	62.301	66.243	66.243	66.243	66.243	66.243	66.243	78.710	78.710	78.710
311.2	62.141	62.141	62.141	62.141	62.141	62.141	66.115	66.115	66.115	66.115	66.115	66.115	78.680	78.680	78.680
311.1	61.981	61.981	61.981	61.981	61.981	61.981	65.986	65.986	65.986	65.986	65.986	65.986	78.649	78.649	78.649
311	61.805	61.805	61.805	61.805	61.805	61.805	65.840	65.840	65.840	65.840	65.840	65.840	78.602	78.602	78.602
310.9	61.590	61.590	61.590	61.590	61.590	61.590	65.656	65.656	65.656	65.656	65.656	65.656	78.516	78.516	78.516
310.8	61.266	61.266	61.266	61.266	61.266	61.266	65.363	65.363	65.363	65.363	65.363	65.363	78.321	78.321	78.321
310.7	60.800	60.800	60.800	60.800	60.800	60.800	64.928	64.928	64.928	64.928	64.928	64.928	77.984	77.984	77.984
310.6	60.059	60.059	60.059	60.059	60.059	60.059	64.219	64.219	64.219	64.219	64.219	64.219	77.373	77.373	77.373
310.5	59.299	59.299	59.299	59.299	59.299	59.299	63.490	63.490	63.490	63.490	63.490	63.490	76.742	76.742	76.742
310.4	58.865	58.865	58.865	58.865	58.865	58.865	63.087	63.087	63.087	63.087	63.087	63.087	76.437	76.437	76.437
310.3	58.434	58.434	58.434	58.434	58.434	58.434	62.686	62.686	62.686	62.686	62.686	62.686	76.135	76.135	76.135
310.2	57.839	57.839	57.839	57.839	57.839	57.839	62.123	62.123	62.123	62.123	62.123	62.123	75.669	75.669	75.669
310.1	57.043	57.043	57.043	57.043	57.043	57.043	61.357	61.357	61.357	61.357	61.357	61.357	75.002	75.002	75.002
310	55.970	55.970	55.970	55.970	55.970	55.970	60.316	60.316	60.316	60.316	60.316	60.316	74.059	74.059	74.059
309.9	54.945	54.945	54.945	54.945	54.945	54.945	59.322	59.322	59.322	59.322	59.322	59.322	73.163	73.163	73.163
309.8	54.391	54.391	54.391	54.391	54.391	54.391	58.799	58.799	58.799	58.799	58.799	58.799	72.739	72.739	72.739
309.7	53.772	53.772	53.772	53.772	53.772	53.772	58.211	58.211	58.211	58.211	58.211	58.211	72.249	72.249	72.249
309.6	53.418	53.418	53.418	53.418	53.418	53.418	57.888	57.888	57.888	57.888	57.888	57.888	72.023	72.023	72.023
309.5	53.201	53.201	53.201	53.201	53.201	53.201	57.702	57.702	57.702	57.702	57.702	57.702	71.936	71.936	71.936
309.4	53.049	53.049	53.049	53.049	53.049	53.049	57.582	57.582	57.582	57.582	57.582	57.582	71.914	71.914	71.914
309.3	52.909	52.909	52.909	52.909	52.909	52.909	57.472	57.472	57.472	57.472	57.472	57.472	71.902	71.902	71.902
309.2	52.774	52.774	52.774	52.774	52.774	52.774	57.368	57.368	57.368	57.368	57.368	57.368	71.896	71.896	71.896
309.1	52.643	52.643	52.643	52.643	52.643	52.643	57.268	57.268	57.268	57.268	57.268	57.268	71.894	71.894	71.894
309	52.500	52.500	52.500	52.500	52.500	52.500	57.156	57.156	57.156	57.156	57.156	57.156	71.881	71.881	71.881
308.9	52.366	52.366	52.366	52.366	52.366	52.366	57.054	57.054	57.054	57.054	57.054	57.054	71.876	71.876	71.876
308.8	52.227	52.227	52.227	52.227	52.227	52.227	56.946	56.946	56.946	56.946	56.946	56.946	71.866	71.866	71.866
308.7	52.083	52.083	52.083	52.083	52.083	52.083	56.832	56.832	56.832	56.832	56.832	56.832	71.852	71.852	71.852
308.6	51.950	51.950	51.950	51.950	51.950	51.950	56.730	56.730	56.730	56.730	56.730	56.730	71.847	71.847	71.847
308.5	51.817	51.817	51.817	51.817	51.817	51.817	56.628	56.628	56.628	56.628	56.628	56.628	71.843	71.843	71.843
308.4	51.680	51.680	51.680	51.680	51.680	51.680	56.522	56.522	56.522	56.522	56.522	56.522	71.836	71.836	71.836
308.3	51.537	51.537	51.537	51.537	51.537	51.537	56.411	56.411	56.411	56.411	56.411	56.411	71.822	71.822	71.822
308.2	51.392	51.392	51.392	51.392	51.392	51.392	56.297	56.297	56.297	56.297	56.297	56.297	71.806	71.806	71.806
308.1	51.232	51.232	51.232	51.232	51.232	51.232	56.168	56.168	56.168	56.168	56.168	56.168	71.776	71.776	71.776
308	51.078	51.078	51.078	51.078	51.078	51.078	56.045	56.045	56.045	56.045	56.045	56.045	71.751	71.751	71.751
307.9	50.922	50.922	50.922	50.922	50.922	50.922	55.920	55.920	55.920	55.920	55.920	55.920	71.725	71.725	71.725
307.8	50.764	50.764	50.764	50.764	50.764	50.764	55.793	55.793	55.793	55.793	55.793	55.793	71.695	71.695	71.695
307.7	50.575	50.575	50.575	50.575	50.575	50.575	55.635	55.635	55.635	55.635	55.635	55.635	71.636	71.636	71.636
307.6	50.404	50.404	50.404	50.404	50.404	50.404	55.495	55.495	55.495	55.495	55.495	55.495	71.594	71.594	71.594
307.5	50.247	50.247	50.247	50.247	50.247	50.247	55.369	55.369	55.369	55.369	55.369	55.369	71.566	71.566	71.566
307.4	50.110	50.110	50.110	50.110	50.110	50.110	55.263	55.263	55.263	55.263	55.263	55.263	71.558	71.558	71.558
307.3	49.963	49.963	49.963	49.963	49.963	49.963	55.147	55.147	55.147	55.147	55.147	55.147	71.540	71.540	71.540
307.2	49.823	49.823	49.823	49.823	49.823	49.823	55.038	55.038	55.038	55.038	55.038	55.038	71.529	71.529	71.529
307.1	49.682	49.682	49.682	49.682	49.682	49.682	54.929	54.929	54.929	54.929	54.929	54.929	71.518	71.518	71.518
307	49.537	49.537	49.537	49.537	49.537	49.537	54.814	54.814	54.814	54.814	54.814	54.814	71.502	71.502	71.502

Stage	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)
306.9	49.399	49.399	49.399	49.399	49.399	49.399	54.708	54.708	54.708	54.708	54.708	54.708	71.494	71.494	71.494
306.8	49.247	49.247	49.247	49.247	49.247	49.247	54.586	54.586	54.586	54.586	54.586	54.586	71.470	71.470	71.470
306.7	49.103	49.103	49.103	49.103	49.103	49.103	54.474	54.474	54.474	54.474	54.474	54.474	71.456	71.456	71.456
306.6	48.967	48.967	48.967	48.967	48.967	48.967	54.368	54.368	54.368	54.368	54.368	54.368	71.449	71.449	71.449
306.5	48.822	48.822	48.822	48.822	48.822	48.822	54.254	54.254	54.254	54.254	54.254	54.254	71.433	71.433	71.433
306.4	48.677	48.677	48.677	48.677	48.677	48.677	54.140	54.140	54.140	54.140	54.140	54.140	71.417	71.417	71.417
306.3	48.537	48.537	48.537	48.537	48.537	48.537	54.032	54.032	54.032	54.032	54.032	54.032	71.407	71.407	71.407
306.2	48.393	48.393	48.393	48.393	48.393	48.393	53.918	53.918	53.918	53.918	53.918	53.918	71.391	71.391	71.391
306.1	48.243	48.243	48.243	48.243	48.243	48.243	53.799	53.799	53.799	53.799	53.799	53.799	71.371	71.371	71.371
306	48.092	48.092	48.092	48.092	48.092	48.092	53.680	53.680	53.680	53.680	53.680	53.680	71.349	71.349	71.349
305.9	47.934	47.934	47.934	47.934	47.934	47.934	53.552	53.552	53.552	53.552	53.552	53.552	71.320	71.320	71.320
305.8	47.770	47.770	47.770	47.770	47.770	47.770	53.419	53.419	53.419	53.419	53.419	53.419	71.285	71.285	71.285
305.7	47.626	47.626	47.626	47.626	47.626	47.626	53.307	53.307	53.307	53.307	53.307	53.307	71.270	71.270	71.270
305.6	47.472	47.472	47.472	47.472	47.472	47.472	53.184	53.184	53.184	53.184	53.184	53.184	71.246	71.246	71.246
305.5	47.334	47.334	47.334	47.334	47.334	47.334	53.076	53.076	53.076	53.076	53.076	53.076	71.237	71.237	71.237
305.4	47.190	47.190	47.190	47.190	47.190	47.190	52.964	52.964	52.964	52.964	52.964	52.964	71.222	71.222	71.222
305.3	47.055	47.055	47.055	47.055	47.055	47.055	52.860	52.860	52.860	52.860	52.860	52.860	71.216	71.216	71.216
305.2	46.910	46.910	46.910	46.910	46.910	46.910	52.745	52.745	52.745	52.745	52.745	52.745	71.200	71.200	71.200
305.1	46.765	46.765	46.765	46.765	46.765	46.765	52.632	52.632	52.632	52.632	52.632	52.632	71.184	71.184	71.184
305	46.616	46.616	46.616	46.616	46.616	46.616	52.514	52.514	52.514	52.514	52.514	52.514	71.165	71.165	71.165
304.9	46.471	46.471	46.471	46.471	46.471	46.471	52.400	52.400	52.400	52.400	52.400	52.400	71.149	71.149	71.149
304.8	46.321	46.321	46.321	46.321	46.321	46.321	52.281	52.281	52.281	52.281	52.281	52.281	71.128	71.128	71.128
304.7	46.142	46.142	46.142	46.142	46.142	46.142	52.133	52.133	52.133	52.133	52.133	52.133	71.079	71.079	71.079
304.6	45.957	45.957	45.957	45.957	45.957	45.957	51.980	51.980	51.980	51.980	51.980	51.980	71.023	71.023	71.023
304.5	45.784	45.784	45.784	45.784	45.784	45.784	51.838	51.838	51.838	51.838	51.838	51.838	70.979	70.979	70.979
304.4	45.610	45.610	45.610	45.610	45.610	45.610	51.694	51.694	51.694	51.694	51.694	51.694	70.934	70.934	70.934
304.3	45.436	45.436	45.436	45.436	45.436	45.436	51.551	51.551	51.551	51.551	51.551	51.551	70.889	70.889	70.889
304.2	45.266	45.266	45.266	45.266	45.266	45.266	51.412	51.412	51.412	51.412	51.412	51.412	70.849	70.849	70.849
304.1	45.102	45.102	45.102	45.102	45.102	45.102	51.279	51.279	51.279	51.279	51.279	51.279	70.814	70.814	70.814
304	44.946	44.946	44.946	44.946	44.946	44.946	51.154	51.154	51.154	51.154	51.154	51.154	70.787	70.787	70.787
303.9	44.814	44.814	44.814	44.814	44.814	44.814	51.053	51.053	51.053	51.053	51.053	51.053	70.784	70.784	70.784
303.8	44.679	44.679	44.679	44.679	44.679	44.679	50.950	50.950	50.950	50.950	50.950	50.950	70.779	70.779	70.779
303.7	44.550	44.550	44.550	44.550	44.550	44.550	50.852	50.852	50.852	50.852	50.852	50.852	70.779	70.779	70.779
303.6	44.434	44.434	44.434	44.434	44.434	44.434	50.767	50.767	50.767	50.767	50.767	50.767	70.792	70.792	70.792
303.5	44.325	44.325	44.325	44.325	44.325	44.325	50.689	50.689	50.689	50.689	50.689	50.689	70.812	70.812	70.812
303.4	44.212	44.212	44.212	44.212	44.212	44.212	50.607	50.607	50.607	50.607	50.607	50.607	70.829	70.829	70.829
303.3	44.106	44.106	44.106	44.106	44.106	44.106	50.531	50.531	50.531	50.531	50.531	50.531	70.851	70.851	70.851
303.2	43.996	43.996	43.996	43.996	43.996	43.996	50.453	50.453	50.453	50.453	50.453	50.453	70.871	70.871	70.871
303.1	43.895	43.895	43.895	43.895	43.895	43.895	50.382	50.382	50.382	50.382	50.382	50.382	70.899	70.899	70.899
303	43.795	43.795	43.795	43.795	43.795	43.795	50.314	50.314	50.314	50.314	50.314	50.314	70.928	70.928	70.928
302.9	43.691	43.691	43.691	43.691	43.691	43.691	50.241	50.241	50.241	50.241	50.241	50.241	70.954	70.954	70.954
302.8	43.577	43.577	43.577	43.577	43.577	43.577	50.158	50.158	50.158	50.158	50.158	50.158	70.969	70.969	70.969
302.7	43.423	43.423	43.423	43.423	43.423	43.423	50.035	50.035	50.035	50.035	50.035	50.035	70.944	70.944	70.944
302.6	43.278	43.278	43.278	43.278	43.278	43.278	49.921	49.921	49.921	49.921	49.921	49.921	70.928	70.928	70.928
302.5	43.115	43.115	43.115	43.115	43.115	43.115	49.789	49.789	49.789	49.789	49.789	49.789	70.894	70.894	70.894
302.4	42.956	42.956	42.956	42.956	42.956	42.956	49.661	49.661	49.661	49.661	49.661	49.661	70.864	70.864	70.864

Stage	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)
302.3	42.800	42.800	42.800	42.800	42.800	42.800	49.536	49.536	49.536	49.536	49.536	49.536	70.837	70.837	70.837
302.2	42.675	42.675	42.675	42.675	42.675	42.675	49.442	49.442	49.442	49.442	49.442	49.442	70.842	70.842	70.842
302.1	42.562	42.562	42.562	42.562	42.562	42.562	49.360	49.360	49.360	49.360	49.360	49.360	70.858	70.858	70.858
302	42.442	42.442	42.442	42.442	42.442	42.442	49.272	49.272	49.272	49.272	49.272	49.272	70.868	70.868	70.868
301.9	42.341	42.341	42.341	42.341	42.341	42.341	49.202	49.202	49.202	49.202	49.202	49.202	70.896	70.896	70.896
301.8	42.222	42.222	42.222	42.222	42.222	42.222	49.113	49.113	49.113	49.113	49.113	49.113	70.906	70.906	70.906
301.7	42.272	42.272	42.272	42.272	42.272	42.272	49.194	49.194	49.194	49.194	49.194	49.194	71.085	71.085	71.085
301.6	42.376	42.376	42.376	42.376	42.376	42.376	49.329	49.329	49.329	49.329	49.329	49.329	71.318	71.318	71.318
301.5	42.480	42.480	42.480	42.480	42.480	42.480	49.464	49.464	49.464	49.464	49.464	49.464	71.551	71.551	71.551
301.4	42.585	42.585	42.585	42.585	42.585	42.585	49.600	49.600	49.600	49.600	49.600	49.600	71.785	71.785	71.785
301.3	42.693	42.693	42.693	42.693	42.693	42.693	49.740	49.740	49.740	49.740	49.740	49.740	72.023	72.023	72.023
301.2	42.805	42.805	42.805	42.805	42.805	42.805	49.882	49.882	49.882	49.882	49.882	49.882	72.264	72.264	72.264
301.1	42.921	42.921	42.921	42.921	42.921	42.921	50.030	50.030	50.030	50.030	50.030	50.030	72.509	72.509	72.509
301	43.046	43.046	43.046	43.046	43.046	43.046	50.186	50.186	50.186	50.186	50.186	50.186	72.763	72.763	72.763
300.9	43.177	43.177	43.177	43.177	43.177	43.177	50.348	50.348	50.348	50.348	50.348	50.348	73.024	73.024	73.024
300.8	43.313	43.313	43.313	43.313	43.313	43.313	50.514	50.514	50.514	50.514	50.514	50.514	73.288	73.288	73.288
300.7	43.451	43.451	43.451	43.451	43.451	43.451	50.684	50.684	50.684	50.684	50.684	50.684	73.556	73.556	73.556
300.6	43.591	43.591	43.591	43.591	43.591	43.591	50.855	50.855	50.855	50.855	50.855	50.855	73.825	73.825	73.825
300.5	43.734	43.734	43.734	43.734	43.734	43.734	51.029	51.029	51.029	51.029	51.029	51.029	74.097	74.097	74.097
300.4	43.882	43.882	43.882	43.882	43.882	43.882	51.208	51.208	51.208	51.208	51.208	51.208	74.375	74.375	74.375
300.3	44.034	44.034	44.034	44.034	44.034	44.034	51.391	51.391	51.391	51.391	51.391	51.391	74.656	74.656	74.656
300.2	44.187	44.187	44.187	44.187	44.187	44.187	51.575	51.575	51.575	51.575	51.575	51.575	74.938	74.938	74.938
300.1	44.340	44.340	44.340	44.340	44.340	44.340	51.759	51.759	51.759	51.759	51.759	51.759	75.220	75.220	75.220
300	44.493	44.493	44.493	44.493	44.493	44.493	51.943	51.943	51.943	51.943	51.943	51.943	75.502	75.502	75.502
299.9	44.645	44.645	44.645	44.645	44.645	44.645	52.126	52.126	52.126	52.126	52.126	52.126	75.784	75.784	75.784
299.8	44.797	44.797	44.797	44.797	44.797	44.797	52.309	52.309	52.309	52.309	52.309	52.309	76.065	76.065	76.065
299.7	44.948	44.948	44.948	44.948	44.948	44.948	52.491	52.491	52.491	52.491	52.491	52.491	76.345	76.345	76.345
299.6	45.099	45.099	45.099	45.099	45.099	45.099	52.673	52.673	52.673	52.673	52.673	52.673	76.625	76.625	76.625
299.5	45.248	45.248	45.248	45.248	45.248	45.248	52.854	52.854	52.854	52.854	52.854	52.854	76.904	76.904	76.904
299.4	45.397	45.397	45.397	45.397	45.397	45.397	53.034	53.034	53.034	53.034	53.034	53.034	77.182	77.182	77.182
299.3	45.546	45.546	45.546	45.546	45.546	45.546	53.213	53.213	53.213	53.213	53.213	53.213	77.460	77.460	77.460
299.2	45.694	45.694	45.694	45.694	45.694	45.694	53.392	53.392	53.392	53.392	53.392	53.392	77.737	77.737	77.737
299.1	45.841	45.841	45.841	45.841	45.841	45.841	53.570	53.570	53.570	53.570	53.570	53.570	78.013	78.013	78.013
299	45.987	45.987	45.987	45.987	45.987	45.987	53.748	53.748	53.748	53.748	53.748	53.748	78.288	78.288	78.288
298.9	46.133	46.133	46.133	46.133	46.133	46.133	53.924	53.924	53.924	53.924	53.924	53.924	78.563	78.563	78.563
298.8	46.278	46.278	46.278	46.278	46.278	46.278	54.101	54.101	54.101	54.101	54.101	54.101	78.838	78.838	78.838
298.7	46.422	46.422	46.422	46.422	46.422	46.422	54.276	54.276	54.276	54.276	54.276	54.276	79.111	79.111	79.111
298.6	46.566	46.566	46.566	46.566	46.566	46.566	54.451	54.451	54.451	54.451	54.451	54.451	79.384	79.384	79.384
298.5	46.709	46.709	46.709	46.709	46.709	46.709	54.625	54.625	54.625	54.625	54.625	54.625	79.657	79.657	79.657
298.4	46.852	46.852	46.852	46.852	46.852	46.852	54.799	54.799	54.799	54.799	54.799	54.799	79.929	79.929	79.929
298.3	46.994	46.994	46.994	46.994	46.994	46.994	54.972	54.972	54.972	54.972	54.972	54.972	80.200	80.200	80.200
298.2	47.135	47.135	47.135	47.135	47.135	47.135	55.144	55.144	55.144	55.144	55.144	55.144	80.470	80.470	80.470
298.1	47.276	47.276	47.276	47.276	47.276	47.276	55.316	55.316	55.316	55.316	55.316	55.316	80.740	80.740	80.740
298	47.416	47.416	47.416	47.416	47.416	47.416	55.487	55.487	55.487	55.487	55.487	55.487	81.009	81.009	81.009
297.9	47.555	47.555	47.555	47.555	47.555	47.555	55.657	55.657	55.657	55.657	55.657	55.657	81.278	81.278	81.278
297.8	47.694	47.694	47.694	47.694	47.694	47.694	55.827	55.827	55.827	55.827	55.827	55.827	81.546	81.546	81.546

Stage	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)
297.7	47.833	47.833	47.833	47.833	47.833	47.833	55.997	55.997	55.997	55.997	55.997	55.997	81.814	81.814	81.814
297.6	47.971	47.971	47.971	47.971	47.971	47.971	56.166	56.166	56.166	56.166	56.166	56.166	82.081	82.081	82.081
297.5	48.109	48.109	48.109	48.109	48.109	48.109	56.335	56.335	56.335	56.335	56.335	56.335	82.348	82.348	82.348
297.4	48.246	48.246	48.246	48.246	48.246	48.246	56.503	56.503	56.503	56.503	56.503	56.503	82.614	82.614	82.614
297.3	48.383	48.383	48.383	48.383	48.383	48.383	56.671	56.671	56.671	56.671	56.671	56.671	82.880	82.880	82.880
297.2	48.519	48.519	48.519	48.519	48.519	48.519	56.838	56.838	56.838	56.838	56.838	56.838	83.146	83.146	83.146
297.1	48.656	48.656	48.656	48.656	48.656	48.656	57.006	57.006	57.006	57.006	57.006	57.006	83.412	83.412	83.412
297	48.794	48.794	48.794	48.794	48.794	48.794	57.175	57.175	57.175	57.175	57.175	57.175	83.679	83.679	83.679
296.9	48.933	48.933	48.933	48.933	48.933	48.933	57.345	57.345	57.345	57.345	57.345	57.345	83.947	83.947	83.947
296.8	49.072	49.072	49.072	49.072	49.072	49.072	57.516	57.516	57.516	57.516	57.516	57.516	84.216	84.216	84.216
296.7	49.212	49.212	49.212	49.212	49.212	49.212	57.686	57.686	57.686	57.686	57.686	57.686	84.485	84.485	84.485
296.6	49.352	49.352	49.352	49.352	49.352	49.352	57.857	57.857	57.857	57.857	57.857	57.857	84.754	84.754	84.754
296.5	49.491	49.491	49.491	49.491	49.491	49.491	58.028	58.028	58.028	58.028	58.028	58.028	85.023	85.023	85.023
296.4	49.632	49.632	49.632	49.632	49.632	49.632	58.199	58.199	58.199	58.199	58.199	58.199	85.292	85.292	85.292
296.3	49.773	49.773	49.773	49.773	49.773	49.773	58.371	58.371	58.371	58.371	58.371	58.371	85.562	85.562	85.562
296.2	49.914	49.914	49.914	49.914	49.914	49.914	58.544	58.544	58.544	58.544	58.544	58.544	85.833	85.833	85.833
296.1	50.056	50.056	50.056	50.056	50.056	50.056	58.716	58.716	58.716	58.716	58.716	58.716	86.104	86.104	86.104
296	50.198	50.198	50.198	50.198	50.198	50.198	58.889	58.889	58.889	58.889	58.889	58.889	86.375	86.375	86.375
295.9	50.340	50.340	50.340	50.340	50.340	50.340	59.063	59.063	59.063	59.063	59.063	59.063	86.647	86.647	86.647
295.8	50.482	50.482	50.482	50.482	50.482	50.482	59.236	59.236	59.236	59.236	59.236	59.236	86.918	86.918	86.918
295.7	50.624	50.624	50.624	50.624	50.624	50.624	59.409	59.409	59.409	59.409	59.409	59.409	87.189	87.189	87.189
295.6	50.766	50.766	50.766	50.766	50.766	50.766	59.582	59.582	59.582	59.582	59.582	59.582	87.460	87.460	87.460
295.5	50.907	50.907	50.907	50.907	50.907	50.907	59.754	59.754	59.754	59.754	59.754	59.754	87.731	87.731	87.731
295.4	51.049	51.049	51.049	51.049	51.049	51.049	59.927	59.927	59.927	59.927	59.927	59.927	88.002	88.002	88.002
295.3	51.190	51.190	51.190	51.190	51.190	51.190	60.099	60.099	60.099	60.099	60.099	60.099	88.272	88.272	88.272
295.2	51.331	51.331	51.331	51.331	51.331	51.331	60.271	60.271	60.271	60.271	60.271	60.271	88.542	88.542	88.542
295.1	51.354	51.354	51.354	51.354	51.354	51.354	60.326	60.326	60.326	60.326	60.326	60.326	88.695	88.695	88.695
295	51.261	51.261	51.261	51.261	51.261	51.261	60.264	60.264	60.264	60.264	60.264	60.264	88.731	88.731	88.731

Stage	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
316	81.082	81.082	81.082	0.511	0.142	0.521	0.152	0.573	0.203	5.094	1.402	5.127	1.435	5.292	1.599
315.95	81.154	81.154	81.154	0.511	0.143	0.521	0.153	0.573	0.205	5.094	1.410	5.128	1.444	5.293	1.609
315.9	81.170	81.170	81.170	0.511	0.144	0.521	0.154	0.573	0.206	5.090	1.418	5.124	1.451	5.290	1.618
315.8	81.112	81.112	81.112	0.509	0.145	0.520	0.155	0.572	0.208	5.076	1.431	5.109	1.465	5.278	1.633
315.7	81.056	81.056	81.056	0.508	0.146	0.518	0.157	0.571	0.210	5.061	1.445	5.095	1.479	5.265	1.649
315.6	80.989	80.989	80.989	0.506	0.148	0.517	0.158	0.570	0.211	5.046	1.458	5.080	1.492	5.252	1.663
315.5	80.931	80.931	80.931	0.505	0.149	0.516	0.160	0.569	0.213	5.031	1.471	5.066	1.505	5.239	1.678
315.4	80.888	80.888	80.888	0.504	0.150	0.514	0.161	0.569	0.215	5.018	1.484	5.053	1.519	5.227	1.694
315.3	80.852	80.852	80.852	0.502	0.152	0.513	0.163	0.568	0.217	5.005	1.497	5.040	1.533	5.216	1.709
315.2	80.785	80.785	80.785	0.501	0.153	0.512	0.164	0.567	0.219	4.989	1.510	5.025	1.545	5.203	1.723
315.1	80.696	80.696	80.696	0.499	0.154	0.510	0.165	0.566	0.221	4.972	1.522	5.008	1.558	5.188	1.737
315	80.576	80.576	80.576	0.497	0.155	0.508	0.166	0.564	0.222	4.953	1.533	4.989	1.569	5.170	1.750
314.9	80.446	80.446	80.446	0.495	0.156	0.507	0.168	0.563	0.224	4.933	1.544	4.970	1.580	5.152	1.762
314.8	80.301	80.301	80.301	0.493	0.157	0.505	0.169	0.561	0.225	4.912	1.554	4.949	1.591	5.132	1.774
314.7	80.145	80.145	80.145	0.491	0.158	0.502	0.170	0.560	0.227	4.890	1.564	4.927	1.601	5.112	1.785
314.6	79.998	79.998	79.998	0.489	0.159	0.500	0.171	0.558	0.228	4.869	1.574	4.906	1.611	5.092	1.797
314.5	79.880	79.880	79.880	0.487	0.160	0.499	0.172	0.557	0.230	4.850	1.584	4.888	1.622	5.075	1.809
314.4	79.795	79.795	79.795	0.485	0.162	0.497	0.173	0.555	0.232	4.834	1.595	4.871	1.633	5.060	1.822
314.3	79.699	79.699	79.699	0.484	0.163	0.495	0.174	0.554	0.233	4.816	1.606	4.854	1.644	5.044	1.834
314.2	79.571	79.571	79.571	0.482	0.164	0.493	0.175	0.553	0.235	4.796	1.616	4.835	1.654	5.026	1.846
314.1	79.382	79.382	79.382	0.479	0.164	0.491	0.176	0.551	0.236	4.772	1.624	4.811	1.663	5.003	1.855
314	79.157	79.157	79.157	0.477	0.165	0.488	0.177	0.548	0.237	4.745	1.631	4.784	1.670	4.977	1.863
313.9	78.994	78.994	78.994	0.474	0.166	0.486	0.178	0.546	0.238	4.723	1.640	4.762	1.679	4.956	1.873
313.8	78.938	78.938	78.938	0.473	0.167	0.485	0.179	0.545	0.240	4.708	1.651	4.748	1.690	4.943	1.886
313.7	78.903	78.903	78.903	0.472	0.168	0.484	0.180	0.545	0.241	4.695	1.663	4.735	1.702	4.932	1.899
313.6	78.875	78.875	78.875	0.470	0.170	0.483	0.182	0.544	0.243	4.683	1.674	4.723	1.714	4.921	1.913
313.5	78.862	78.862	78.862	0.469	0.171	0.482	0.183	0.543	0.245	4.672	1.686	4.712	1.726	4.912	1.927
313.4	78.852	78.852	78.852	0.468	0.172	0.481	0.184	0.543	0.247	4.660	1.698	4.701	1.739	4.902	1.940
313.3	78.841	78.841	78.841	0.467	0.173	0.480	0.186	0.542	0.248	4.649	1.710	4.690	1.751	4.893	1.954
313.2	78.832	78.832	78.832	0.466	0.174	0.479	0.187	0.542	0.250	4.638	1.722	4.679	1.763	4.884	1.968
313.1	78.827	78.827	78.827	0.465	0.176	0.478	0.188	0.541	0.252	4.627	1.734	4.669	1.775	4.875	1.981
313	78.822	78.822	78.822	0.464	0.177	0.477	0.190	0.541	0.253	4.617	1.746	4.658	1.787	4.866	1.995
312.9	78.826	78.826	78.826	0.463	0.178	0.476	0.191	0.540	0.255	4.606	1.758	4.648	1.799	4.858	2.009
312.8	78.820	78.820	78.820	0.462	0.179	0.475	0.192	0.540	0.257	4.596	1.769	4.638	1.811	4.848	2.022
312.7	78.827	78.827	78.827	0.461	0.180	0.474	0.193	0.539	0.259	4.586	1.781	4.628	1.824	4.840	2.036
312.6	78.821	78.821	78.821	0.460	0.181	0.473	0.195	0.539	0.260	4.575	1.793	4.618	1.835	4.831	2.049
312.5	78.824	78.824	78.824	0.459	0.183	0.472	0.196	0.538	0.262	4.565	1.804	4.608	1.847	4.823	2.062
312.4	78.815	78.815	78.815	0.458	0.184	0.471	0.197	0.538	0.264	4.554	1.815	4.597	1.859	4.814	2.075
312.3	78.816	78.816	78.816	0.457	0.185	0.470	0.198	0.537	0.265	4.543	1.827	4.587	1.871	4.805	2.089
312.2	78.813	78.813	78.813	0.456	0.186	0.469	0.200	0.536	0.267	4.533	1.838	4.576	1.882	4.796	2.102
312.1	78.803	78.803	78.803	0.454	0.187	0.468	0.201	0.536	0.269	4.521	1.849	4.566	1.893	4.787	2.114
312	78.791	78.791	78.791	0.453	0.188	0.467	0.202	0.535	0.270	4.510	1.860	4.555	1.904	4.777	2.127
311.9	78.782	78.782	78.782	0.452	0.189	0.466	0.203	0.535	0.272	4.499	1.871	4.544	1.916	4.768	2.139
311.8	78.771	78.771	78.771	0.451	0.190	0.465	0.204	0.534	0.273	4.488	1.882	4.533	1.927	4.758	2.152
311.7	78.760	78.760	78.760	0.450	0.192	0.464	0.205	0.533	0.275	4.477	1.892	4.522	1.938	4.748	2.164
311.6	78.753	78.753	78.753	0.449	0.193	0.463	0.207	0.533	0.277	4.466	1.903	4.511	1.948	4.739	2.176

Stage	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
311.5	78.742	78.742	78.742	0.448	0.194	0.462	0.208	0.532	0.278	4.454	1.913	4.500	1.959	4.729	2.189
311.4	78.734	78.734	78.734	0.447	0.195	0.461	0.209	0.532	0.280	4.443	1.924	4.490	1.970	4.720	2.201
311.3	78.710	78.710	78.710	0.446	0.196	0.460	0.210	0.531	0.281	4.431	1.934	4.478	1.980	4.710	2.212
311.2	78.680	78.680	78.680	0.444	0.197	0.459	0.211	0.530	0.282	4.419	1.943	4.465	1.990	4.698	2.223
311.1	78.649	78.649	78.649	0.443	0.198	0.457	0.212	0.529	0.284	4.406	1.953	4.453	2.000	4.687	2.234
311	78.602	78.602	78.602	0.442	0.199	0.456	0.213	0.528	0.285	4.392	1.962	4.439	2.009	4.675	2.245
310.9	78.516	78.516	78.516	0.440	0.199	0.454	0.214	0.527	0.286	4.375	1.969	4.423	2.017	4.659	2.253
310.8	78.321	78.321	78.321	0.438	0.200	0.452	0.214	0.525	0.287	4.351	1.973	4.398	2.021	4.635	2.258
310.7	77.984	77.984	77.984	0.434	0.200	0.448	0.214	0.521	0.287	4.315	1.972	4.363	2.020	4.600	2.257
310.6	77.373	77.373	77.373	0.428	0.199	0.443	0.213	0.515	0.285	4.260	1.961	4.308	2.009	4.544	2.245
310.5	76.742	76.742	76.742	0.423	0.197	0.437	0.212	0.509	0.284	4.204	1.950	4.251	1.997	4.486	2.232
310.4	76.437	76.437	76.437	0.419	0.197	0.434	0.212	0.506	0.283	4.171	1.949	4.218	1.996	4.453	2.231
310.3	76.135	76.135	76.135	0.416	0.197	0.431	0.212	0.502	0.283	4.138	1.948	4.185	1.995	4.421	2.230
310.2	75.669	75.669	75.669	0.412	0.196	0.426	0.211	0.498	0.282	4.094	1.941	4.141	1.988	4.375	2.222
310.1	75.002	75.002	75.002	0.406	0.195	0.420	0.209	0.491	0.280	4.034	1.927	4.081	1.973	4.314	2.206
310	74.059	74.059	74.059	0.398	0.193	0.412	0.207	0.482	0.277	3.955	1.902	4.001	1.948	4.232	2.179
309.9	73.163	73.163	73.163	0.390	0.190	0.404	0.204	0.473	0.273	3.879	1.879	3.924	1.925	4.153	2.153
309.8	72.739	72.739	72.739	0.386	0.190	0.400	0.203	0.469	0.272	3.837	1.872	3.883	1.917	4.110	2.145
309.7	72.249	72.249	72.249	0.381	0.189	0.395	0.202	0.464	0.271	3.791	1.862	3.836	1.908	4.063	2.134
309.6	72.023	72.023	72.023	0.379	0.188	0.392	0.202	0.461	0.271	3.764	1.862	3.809	1.907	4.036	2.134
309.5	71.936	71.936	71.936	0.377	0.189	0.391	0.203	0.460	0.272	3.747	1.866	3.793	1.912	4.020	2.139
309.4	71.914	71.914	71.914	0.376	0.190	0.390	0.203	0.459	0.273	3.735	1.873	3.781	1.919	4.009	2.147
309.3	71.902	71.902	71.902	0.375	0.190	0.389	0.204	0.458	0.274	3.724	1.880	3.770	1.926	3.999	2.156
309.2	71.896	71.896	71.896	0.374	0.191	0.388	0.205	0.457	0.275	3.713	1.888	3.759	1.934	3.989	2.164
309.1	71.894	71.894	71.894	0.373	0.192	0.387	0.206	0.457	0.276	3.702	1.895	3.749	1.941	3.980	2.173
309	71.881	71.881	71.881	0.371	0.193	0.386	0.207	0.456	0.277	3.691	1.902	3.737	1.948	3.970	2.181
308.9	71.876	71.876	71.876	0.370	0.193	0.384	0.207	0.455	0.278	3.680	1.909	3.727	1.955	3.960	2.189
308.8	71.866	71.866	71.866	0.369	0.194	0.383	0.208	0.454	0.279	3.669	1.915	3.716	1.962	3.950	2.197
308.7	71.852	71.852	71.852	0.368	0.195	0.382	0.209	0.453	0.280	3.657	1.922	3.704	1.969	3.940	2.204
308.6	71.847	71.847	71.847	0.367	0.195	0.381	0.210	0.453	0.281	3.647	1.929	3.694	1.976	3.930	2.212
308.5	71.843	71.843	71.843	0.366	0.196	0.380	0.210	0.452	0.282	3.636	1.936	3.683	1.983	3.921	2.220
308.4	71.836	71.836	71.836	0.365	0.197	0.379	0.211	0.451	0.283	3.625	1.942	3.673	1.990	3.911	2.228
308.3	71.822	71.822	71.822	0.364	0.197	0.378	0.212	0.450	0.284	3.614	1.948	3.661	1.996	3.900	2.235
308.2	71.806	71.806	71.806	0.363	0.198	0.377	0.212	0.449	0.285	3.602	1.954	3.650	2.002	3.890	2.243
308.1	71.776	71.776	71.776	0.361	0.198	0.376	0.213	0.448	0.286	3.589	1.960	3.637	2.008	3.878	2.249
308	71.751	71.751	71.751	0.360	0.199	0.375	0.214	0.448	0.286	3.577	1.965	3.625	2.014	3.867	2.255
307.9	71.725	71.725	71.725	0.359	0.200	0.374	0.214	0.447	0.287	3.565	1.971	3.613	2.019	3.856	2.262
307.8	71.695	71.695	71.695	0.358	0.200	0.372	0.215	0.446	0.288	3.552	1.976	3.601	2.025	3.844	2.268
307.7	71.636	71.636	71.636	0.356	0.200	0.371	0.215	0.444	0.289	3.537	1.980	3.586	2.029	3.830	2.273
307.6	71.594	71.594	71.594	0.355	0.201	0.370	0.216	0.443	0.289	3.524	1.984	3.573	2.033	3.817	2.278
307.5	71.566	71.566	71.566	0.354	0.201	0.368	0.216	0.442	0.290	3.511	1.989	3.560	2.039	3.806	2.284
307.4	71.558	71.558	71.558	0.352	0.202	0.367	0.217	0.441	0.291	3.500	1.995	3.549	2.044	3.796	2.291
307.3	71.540	71.540	71.540	0.351	0.203	0.366	0.217	0.440	0.292	3.488	2.000	3.538	2.050	3.785	2.297
307.2	71.529	71.529	71.529	0.350	0.203	0.365	0.218	0.440	0.292	3.477	2.006	3.527	2.055	3.775	2.303
307.1	71.518	71.518	71.518	0.349	0.204	0.364	0.219	0.439	0.293	3.466	2.011	3.516	2.061	3.765	2.310
307	71.502	71.502	71.502	0.348	0.204	0.363	0.219	0.438	0.294	3.454	2.016	3.504	2.066	3.754	2.316

Stage	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
306.9	71.494	71.494	71.494	0.347	0.205	0.362	0.220	0.437	0.295	3.443	2.022	3.493	2.072	3.744	2.322
306.8	71.470	71.470	71.470	0.346	0.205	0.361	0.220	0.436	0.295	3.431	2.026	3.481	2.076	3.733	2.328
306.7	71.456	71.456	71.456	0.344	0.206	0.360	0.221	0.435	0.296	3.420	2.031	3.470	2.081	3.722	2.334
306.6	71.449	71.449	71.449	0.343	0.206	0.359	0.221	0.434	0.297	3.409	2.036	3.459	2.087	3.712	2.340
306.5	71.433	71.433	71.433	0.342	0.207	0.357	0.222	0.433	0.298	3.397	2.041	3.448	2.092	3.701	2.345
306.4	71.417	71.417	71.417	0.341	0.207	0.356	0.222	0.432	0.298	3.385	2.046	3.436	2.096	3.691	2.351
306.3	71.407	71.407	71.407	0.340	0.208	0.355	0.223	0.431	0.299	3.374	2.050	3.425	2.101	3.680	2.356
306.2	71.391	71.391	71.391	0.339	0.208	0.354	0.223	0.431	0.300	3.363	2.055	3.414	2.106	3.670	2.362
306.1	71.371	71.371	71.371	0.338	0.208	0.353	0.224	0.430	0.300	3.351	2.059	3.402	2.110	3.658	2.367
306	71.349	71.349	71.349	0.336	0.209	0.352	0.224	0.429	0.301	3.339	2.063	3.390	2.114	3.647	2.372
305.9	71.320	71.320	71.320	0.335	0.209	0.351	0.225	0.427	0.302	3.326	2.067	3.378	2.118	3.635	2.376
305.8	71.285	71.285	71.285	0.334	0.210	0.349	0.225	0.426	0.302	3.313	2.070	3.365	2.121	3.623	2.380
305.7	71.270	71.270	71.270	0.333	0.210	0.348	0.225	0.425	0.303	3.301	2.074	3.353	2.126	3.613	2.385
305.6	71.246	71.246	71.246	0.331	0.210	0.347	0.226	0.424	0.303	3.289	2.077	3.341	2.129	3.601	2.389
305.5	71.237	71.237	71.237	0.330	0.211	0.346	0.226	0.423	0.304	3.278	2.082	3.330	2.134	3.591	2.394
305.4	71.222	71.222	71.222	0.329	0.211	0.345	0.227	0.423	0.304	3.267	2.085	3.319	2.138	3.580	2.399
305.3	71.216	71.216	71.216	0.328	0.212	0.344	0.227	0.422	0.305	3.256	2.090	3.308	2.142	3.570	2.404
305.2	71.200	71.200	71.200	0.327	0.212	0.343	0.228	0.421	0.306	3.244	2.093	3.297	2.146	3.559	2.408
305.1	71.184	71.184	71.184	0.326	0.212	0.341	0.228	0.420	0.306	3.232	2.097	3.285	2.150	3.548	2.413
305	71.165	71.165	71.165	0.325	0.213	0.340	0.228	0.419	0.307	3.221	2.100	3.273	2.153	3.537	2.417
304.9	71.149	71.149	71.149	0.323	0.213	0.339	0.229	0.418	0.307	3.209	2.104	3.262	2.156	3.526	2.421
304.8	71.128	71.128	71.128	0.322	0.213	0.338	0.229	0.417	0.308	3.197	2.107	3.250	2.160	3.515	2.425
304.7	71.079	71.079	71.079	0.321	0.213	0.337	0.229	0.415	0.308	3.183	2.108	3.236	2.161	3.502	2.427
304.6	71.023	71.023	71.023	0.319	0.214	0.335	0.229	0.414	0.308	3.168	2.109	3.221	2.163	3.488	2.429
304.5	70.979	70.979	70.979	0.318	0.214	0.334	0.229	0.413	0.308	3.155	2.111	3.208	2.164	3.474	2.431
304.4	70.934	70.934	70.934	0.317	0.214	0.332	0.230	0.411	0.309	3.141	2.113	3.194	2.166	3.461	2.433
304.3	70.889	70.889	70.889	0.315	0.214	0.331	0.230	0.410	0.309	3.127	2.114	3.181	2.168	3.448	2.435
304.2	70.849	70.849	70.849	0.314	0.214	0.330	0.230	0.409	0.309	3.114	2.116	3.167	2.169	3.435	2.437
304.1	70.814	70.814	70.814	0.313	0.214	0.329	0.230	0.408	0.309	3.101	2.117	3.154	2.171	3.422	2.439
304	70.787	70.787	70.787	0.311	0.215	0.327	0.230	0.407	0.310	3.088	2.119	3.142	2.173	3.411	2.442
303.9	70.784	70.784	70.784	0.310	0.215	0.326	0.231	0.406	0.310	3.078	2.123	3.131	2.176	3.401	2.446
303.8	70.779	70.779	70.779	0.309	0.215	0.325	0.231	0.405	0.311	3.067	2.126	3.121	2.180	3.391	2.450
303.7	70.779	70.779	70.779	0.308	0.216	0.324	0.231	0.404	0.311	3.056	2.129	3.110	2.183	3.381	2.454
303.6	70.792	70.792	70.792	0.307	0.216	0.323	0.232	0.403	0.312	3.047	2.133	3.101	2.187	3.372	2.458
303.5	70.812	70.812	70.812	0.306	0.216	0.322	0.232	0.403	0.312	3.038	2.137	3.092	2.191	3.364	2.463
303.4	70.829	70.829	70.829	0.305	0.217	0.322	0.233	0.402	0.313	3.028	2.141	3.083	2.195	3.356	2.468
303.3	70.851	70.851	70.851	0.305	0.217	0.321	0.233	0.401	0.314	3.020	2.145	3.074	2.199	3.348	2.473
303.2	70.871	70.871	70.871	0.304	0.218	0.320	0.234	0.400	0.314	3.011	2.149	3.065	2.203	3.340	2.478
303.1	70.899	70.899	70.899	0.303	0.218	0.319	0.234	0.400	0.315	3.002	2.153	3.057	2.208	3.332	2.483
303	70.928	70.928	70.928	0.302	0.218	0.318	0.235	0.399	0.315	2.994	2.157	3.049	2.212	3.325	2.488
302.9	70.954	70.954	70.954	0.301	0.219	0.317	0.235	0.399	0.316	2.985	2.161	3.041	2.216	3.317	2.493
302.8	70.969	70.969	70.969	0.300	0.219	0.317	0.235	0.398	0.317	2.976	2.164	3.031	2.220	3.308	2.497
302.7	70.944	70.944	70.944	0.299	0.219	0.315	0.236	0.397	0.317	2.964	2.166	3.019	2.221	3.297	2.499
302.6	70.928	70.928	70.928	0.298	0.219	0.314	0.236	0.396	0.317	2.952	2.167	3.008	2.223	3.286	2.501
302.5	70.894	70.894	70.894	0.297	0.219	0.313	0.236	0.394	0.317	2.939	2.168	2.995	2.223	3.273	2.502
302.4	70.864	70.864	70.864	0.295	0.220	0.312	0.236	0.393	0.317	2.926	2.168	2.982	2.224	3.261	2.503

Stage	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
302.3	70.837	70.837	70.837	0.294	0.220	0.310	0.236	0.392	0.317	2.914	2.169	2.970	2.225	3.249	2.504
302.2	70.842	70.842	70.842	0.293	0.220	0.309	0.236	0.391	0.318	2.904	2.172	2.960	2.227	3.239	2.507
302.1	70.858	70.858	70.858	0.292	0.220	0.309	0.237	0.390	0.318	2.895	2.174	2.951	2.231	3.231	2.511
302	70.868	70.868	70.868	0.291	0.220	0.308	0.237	0.390	0.319	2.885	2.177	2.941	2.233	3.222	2.514
301.9	70.896	70.896	70.896	0.290	0.221	0.307	0.237	0.389	0.319	2.876	2.180	2.933	2.237	3.214	2.518
301.8	70.906	70.906	70.906	0.289	0.221	0.306	0.237	0.388	0.320	2.867	2.183	2.923	2.239	3.205	2.521
301.7	71.085	71.085	71.085	0.289	0.221	0.306	0.239	0.393	0.326	2.857	2.185	2.914	2.243	3.202	2.531
301.6	71.318	71.318	71.318	0.288	0.222	0.307	0.241	0.400	0.334	2.847	2.187	2.906	2.247	3.202	2.542
301.5	71.551	71.551	71.551	0.287	0.222	0.307	0.242	0.407	0.342	2.836	2.189	2.897	2.249	3.200	2.553
301.4	71.785	71.785	71.785	0.286	0.223	0.308	0.244	0.414	0.351	2.825	2.190	2.888	2.253	3.199	2.564
301.3	72.023	72.023	72.023	0.286	0.223	0.308	0.246	0.421	0.359	2.815	2.192	2.879	2.256	3.199	2.576
301.2	72.264	72.264	72.264	0.285	0.224	0.309	0.248	0.428	0.367	2.804	2.193	2.870	2.259	3.198	2.587
301.1	72.509	72.509	72.509	0.284	0.224	0.309	0.249	0.436	0.376	2.792	2.193	2.859	2.260	3.196	2.597
301	72.763	72.763	72.763	0.283	0.224	0.310	0.251	0.444	0.385	2.782	2.195	2.851	2.264	3.196	2.609
300.9	73.024	73.024	73.024	0.283	0.225	0.311	0.253	0.451	0.394	2.773	2.197	2.844	2.268	3.197	2.621
300.8	73.288	73.288	73.288	0.282	0.226	0.311	0.255	0.459	0.402	2.765	2.200	2.837	2.273	3.199	2.634
300.7	73.556	73.556	73.556	0.281	0.226	0.312	0.257	0.466	0.411	2.757	2.203	2.830	2.277	3.200	2.647
300.6	73.825	73.825	73.825	0.281	0.227	0.313	0.259	0.473	0.419	2.749	2.206	2.824	2.282	3.202	2.660
300.5	74.097	74.097	74.097	0.280	0.227	0.314	0.261	0.481	0.428	2.740	2.209	2.817	2.286	3.204	2.673
300.4	74.375	74.375	74.375	0.280	0.228	0.315	0.263	0.489	0.437	2.731	2.211	2.810	2.290	3.205	2.686
300.3	74.656	74.656	74.656	0.279	0.228	0.316	0.265	0.497	0.446	2.722	2.213	2.803	2.294	3.208	2.699
300.2	74.938	74.938	74.938	0.279	0.229	0.316	0.267	0.505	0.456	2.713	2.215	2.796	2.298	3.209	2.711
300.1	75.220	75.220	75.220	0.278	0.229	0.317	0.269	0.513	0.465	2.705	2.218	2.790	2.302	3.212	2.725
300	75.502	75.502	75.502	0.278	0.230	0.318	0.271	0.521	0.474	2.697	2.220	2.783	2.306	3.214	2.738
299.9	75.784	75.784	75.784	0.277	0.231	0.319	0.273	0.529	0.483	2.688	2.223	2.776	2.311	3.216	2.751
299.8	76.065	76.065	76.065	0.277	0.231	0.320	0.275	0.538	0.492	2.679	2.224	2.769	2.314	3.218	2.763
299.7	76.345	76.345	76.345	0.276	0.232	0.321	0.277	0.545	0.501	2.671	2.227	2.763	2.318	3.220	2.776
299.6	76.625	76.625	76.625	0.275	0.232	0.322	0.278	0.554	0.510	2.662	2.228	2.755	2.321	3.222	2.788
299.5	76.904	76.904	76.904	0.275	0.233	0.323	0.280	0.562	0.519	2.653	2.230	2.748	2.325	3.224	2.801
299.4	77.182	77.182	77.182	0.274	0.233	0.324	0.282	0.570	0.528	2.644	2.232	2.741	2.329	3.226	2.813
299.3	77.460	77.460	77.460	0.274	0.234	0.324	0.284	0.577	0.537	2.637	2.234	2.735	2.333	3.229	2.826
299.2	77.737	77.737	77.737	0.273	0.234	0.325	0.286	0.585	0.546	2.628	2.236	2.729	2.336	3.231	2.839
299.1	78.013	78.013	78.013	0.273	0.235	0.326	0.288	0.593	0.555	2.620	2.238	2.722	2.340	3.233	2.851
299	78.288	78.288	78.288	0.272	0.235	0.327	0.290	0.601	0.564	2.612	2.240	2.716	2.344	3.235	2.863
298.9	78.563	78.563	78.563	0.272	0.236	0.328	0.292	0.609	0.573	2.603	2.241	2.709	2.347	3.237	2.875
298.8	78.838	78.838	78.838	0.271	0.236	0.329	0.294	0.617	0.582	2.594	2.242	2.701	2.350	3.239	2.887
298.7	79.111	79.111	79.111	0.271	0.236	0.330	0.295	0.625	0.591	2.585	2.244	2.694	2.353	3.241	2.899
298.6	79.384	79.384	79.384	0.270	0.237	0.330	0.297	0.633	0.600	2.576	2.244	2.687	2.355	3.242	2.911
298.5	79.657	79.657	79.657	0.269	0.237	0.331	0.299	0.641	0.609	2.567	2.245	2.680	2.358	3.244	2.922
298.4	79.929	79.929	79.929	0.269	0.238	0.332	0.301	0.649	0.617	2.558	2.246	2.673	2.361	3.246	2.934
298.3	80.200	80.200	80.200	0.268	0.238	0.333	0.303	0.656	0.626	2.550	2.248	2.666	2.364	3.248	2.946
298.2	80.470	80.470	80.470	0.268	0.238	0.334	0.304	0.664	0.635	2.541	2.249	2.659	2.367	3.249	2.957
298.1	80.740	80.740	80.740	0.267	0.239	0.335	0.306	0.672	0.644	2.532	2.249	2.652	2.369	3.251	2.968
298	81.009	81.009	81.009	0.266	0.239	0.335	0.308	0.680	0.653	2.522	2.249	2.644	2.370	3.252	2.979
297.9	81.278	81.278	81.278	0.266	0.239	0.336	0.310	0.688	0.661	2.513	2.249	2.636	2.373	3.254	2.990
297.8	81.546	81.546	81.546	0.265	0.240	0.337	0.312	0.696	0.671	2.503	2.249	2.628	2.374	3.254	3.000

Stage	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
297.7	81.814	81.814	81.814	0.264	0.240	0.338	0.313	0.704	0.679	2.494	2.249	2.621	2.376	3.256	3.011
297.6	82.081	82.081	82.081	0.264	0.240	0.338	0.315	0.712	0.688	2.484	2.249	2.613	2.378	3.257	3.022
297.5	82.348	82.348	82.348	0.263	0.241	0.339	0.317	0.720	0.697	2.474	2.248	2.604	2.379	3.258	3.032
297.4	82.614	82.614	82.614	0.262	0.241	0.340	0.318	0.728	0.706	2.462	2.246	2.595	2.379	3.258	3.041
297.3	82.880	82.880	82.880	0.262	0.241	0.341	0.320	0.736	0.716	2.451	2.244	2.585	2.378	3.257	3.050
297.2	83.146	83.146	83.146	0.261	0.241	0.341	0.322	0.745	0.725	2.440	2.242	2.576	2.379	3.258	3.060
297.1	83.412	83.412	83.412	0.260	0.241	0.342	0.323	0.753	0.734	2.428	2.239	2.566	2.378	3.257	3.069
297	83.679	83.679	83.679	0.259	0.241	0.343	0.325	0.761	0.743	2.417	2.238	2.557	2.378	3.258	3.078
296.9	83.947	83.947	83.947	0.258	0.241	0.344	0.327	0.770	0.753	2.405	2.235	2.547	2.377	3.257	3.087
296.8	84.216	84.216	84.216	0.258	0.241	0.344	0.328	0.778	0.762	2.395	2.233	2.539	2.377	3.258	3.096
296.7	84.485	84.485	84.485	0.257	0.242	0.345	0.330	0.786	0.771	2.384	2.231	2.529	2.377	3.258	3.106
296.6	84.754	84.754	84.754	0.256	0.242	0.346	0.331	0.795	0.780	2.372	2.228	2.520	2.376	3.258	3.114
296.5	85.023	85.023	85.023	0.255	0.242	0.346	0.333	0.803	0.790	2.360	2.225	2.510	2.375	3.258	3.123
296.4	85.292	85.292	85.292	0.254	0.242	0.347	0.335	0.812	0.799	2.347	2.221	2.499	2.372	3.257	3.131
296.3	85.562	85.562	85.562	0.253	0.241	0.348	0.336	0.821	0.809	2.334	2.216	2.488	2.370	3.256	3.138
296.2	85.833	85.833	85.833	0.252	0.241	0.349	0.338	0.830	0.819	2.322	2.212	2.477	2.368	3.255	3.146
296.1	86.104	86.104	86.104	0.251	0.241	0.349	0.339	0.839	0.829	2.308	2.207	2.466	2.365	3.254	3.153
296	86.375	86.375	86.375	0.250	0.241	0.350	0.341	0.848	0.838	2.294	2.202	2.454	2.362	3.253	3.160
295.9	86.647	86.647	86.647	0.249	0.241	0.350	0.342	0.857	0.849	2.279	2.194	2.441	2.356	3.250	3.166
295.8	86.918	86.918	86.918	0.248	0.240	0.351	0.343	0.867	0.859	2.261	2.185	2.425	2.349	3.246	3.170
295.7	87.189	87.189	87.189	0.246	0.240	0.351	0.345	0.877	0.870	2.242	2.174	2.408	2.341	3.241	3.173
295.6	87.460	87.460	87.460	0.245	0.239	0.352	0.346	0.888	0.882	2.221	2.161	2.390	2.330	3.234	3.175
295.5	87.731	87.731	87.731	0.243	0.238	0.352	0.347	0.899	0.894	2.196	2.145	2.368	2.316	3.226	3.174
295.4	88.002	88.002	88.002	0.240	0.235	0.352	0.348	0.913	0.909	2.160	2.117	2.335	2.291	3.209	3.165
295.3	88.272	88.272	88.272	0.234	0.230	0.350	0.347	0.933	0.930	2.091	2.056	2.271	2.236	3.169	3.133
295.2	88.542	88.542	88.542	0.217	0.215	0.343	0.341	0.975	0.973	1.902	1.877	2.092	2.066	3.040	3.015
295.1	88.695	88.695	88.695	0.183	0.182	0.325	0.323	1.032	1.030	1.532	1.516	1.737	1.721	2.761	2.746
295	88.731	88.731	88.731	0.122	0.121	0.281	0.280	1.075	1.074	0.876	0.870	1.098	1.093	2.211	2.205

North Pit Sensitivity Analysis Results

Stage	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	Mining - WBM North Pit Inflow (m³/day)	Recovery - WBM North Pit Inflow (m³/day)
316	50.889	13.962	50.998	14.072	51.548	14.621	5.495	1.803
315.95	50.889	14.049	50.999	14.160	51.552	14.713	5.495	1.811
315.9	50.848	14.125	50.959	14.236	51.516	14.793	5.492	1.820
315.8	50.701	14.258	50.814	14.371	51.376	14.933	5.479	1.835
315.7	50.556	14.391	50.669	14.504	51.237	15.072	5.467	1.850
315.6	50.402	14.520	50.516	14.634	51.090	15.208	5.454	1.866
315.5	50.255	14.650	50.371	14.766	50.951	15.345	5.441	1.881
315.4	50.119	14.782	50.236	14.899	50.822	15.484	5.430	1.896
315.3	49.988	14.914	50.106	15.033	50.697	15.624	5.419	1.911
315.2	49.834	15.039	49.953	15.159	50.551	15.756	5.405	1.926
315.1	49.665	15.159	49.786	15.279	50.388	15.882	5.391	1.940
315	49.472	15.269	49.594	15.391	50.201	15.999	5.374	1.954
314.9	49.272	15.377	49.395	15.499	50.008	16.112	5.357	1.968
314.8	49.062	15.479	49.186	15.603	49.804	16.221	5.339	1.981
314.7	48.843	15.577	48.967	15.702	49.590	16.325	5.321	1.994
314.6	48.631	15.676	48.756	15.802	49.384	16.430	5.303	2.007
314.5	48.440	15.781	48.567	15.908	49.199	16.540	5.286	2.020
314.4	48.273	15.892	48.401	16.020	49.039	16.658	5.272	2.034
314.3	48.099	16.000	48.228	16.128	48.871	16.771	5.257	2.047
314.2	47.901	16.098	48.030	16.227	48.678	16.875	5.240	2.060
314.1	47.658	16.180	47.788	16.310	48.441	16.962	5.219	2.071
314	47.388	16.250	47.519	16.382	48.175	17.038	5.196	2.082
313.9	47.165	16.335	47.297	16.468	47.957	17.128	5.177	2.094
313.8	47.019	16.446	47.152	16.579	47.818	17.245	5.164	2.107
313.7	46.889	16.561	47.023	16.695	47.694	17.367	5.153	2.120
313.6	46.764	16.677	46.899	16.813	47.576	17.490	5.142	2.133
313.5	46.650	16.797	46.786	16.933	47.469	17.616	5.132	2.147
313.4	46.537	16.916	46.675	17.053	47.363	17.742	5.123	2.160
313.3	46.425	17.034	46.564	17.173	47.258	17.867	5.113	2.174
313.2	46.314	17.152	46.454	17.292	47.154	17.991	5.103	2.187
313.1	46.205	17.270	46.346	17.411	47.052	18.116	5.094	2.200
313	46.097	17.388	46.239	17.530	46.950	18.241	5.084	2.214
312.9	45.995	17.507	46.139	17.650	46.856	18.367	5.076	2.227
312.8	45.887	17.623	46.031	17.767	46.754	18.490	5.066	2.240
312.7	45.787	17.741	45.933	17.887	46.661	18.615	5.058	2.253
312.6	45.678	17.855	45.825	18.002	46.559	18.736	5.048	2.266
312.5	45.576	17.972	45.723	18.120	46.463	18.859	5.039	2.279
312.4	45.465	18.084	45.614	18.233	46.359	18.978	5.030	2.292
312.3	45.361	18.198	45.511	18.348	46.262	19.099	5.021	2.304
312.2	45.254	18.310	45.405	18.461	46.162	19.218	5.011	2.317
312.1	45.142	18.419	45.294	18.572	46.056	19.334	5.002	2.329
312	45.028	18.527	45.182	18.681	45.949	19.448	4.992	2.342
311.9	44.917	18.636	45.072	18.790	45.845	19.563	4.982	2.354
311.8	44.805	18.742	44.960	18.898	45.739	19.677	4.972	2.366
311.7	44.692	18.848	44.848	19.005	45.632	19.789	4.963	2.378
311.6	44.582	18.955	44.740	19.113	45.529	19.902	4.953	2.390

Stage	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	Mining - WBM North Pit Inflow (m^3/day)	Recovery - WBM North Pit Inflow (m^3/day)
311.5	44.469	19.059	44.628	19.218	45.423	20.013	4.943	2.402
311.4	44.359	19.164	44.519	19.324	45.319	20.124	4.934	2.414
311.3	44.236	19.263	44.398	19.424	45.203	20.229	4.923	2.426
311.2	44.110	19.359	44.272	19.521	45.083	20.331	4.912	2.437
311.1	43.983	19.453	44.146	19.617	44.962	20.432	4.901	2.448
311	43.843	19.542	44.008	19.706	44.828	20.527	4.889	2.459
310.9	43.676	19.617	43.841	19.782	44.666	20.607	4.874	2.468
310.8	43.429	19.655	43.595	19.821	44.423	20.649	4.853	2.475
310.7	43.078	19.644	43.244	19.810	44.073	20.639	4.822	2.479
310.6	42.526	19.538	42.692	19.703	43.519	20.531	4.774	2.475
310.5	41.960	19.422	42.125	19.587	42.950	20.412	4.724	2.470
310.4	41.632	19.412	41.798	19.578	42.624	20.404	4.696	2.474
310.3	41.307	19.402	41.472	19.568	42.300	20.396	4.667	2.477
310.2	40.862	19.333	41.027	19.499	41.854	20.326	4.628	2.475
310.1	40.269	19.191	40.434	19.355	41.258	20.179	4.576	2.468
310	39.474	18.947	39.638	19.111	40.454	19.927	4.506	2.453
309.9	38.715	18.715	38.877	18.877	39.687	19.688	4.439	2.439
309.8	38.299	18.646	38.461	18.808	39.271	19.617	4.402	2.437
309.7	37.836	18.550	37.998	18.712	38.806	19.520	4.361	2.432
309.6	37.567	18.547	37.729	18.709	38.538	19.518	4.337	2.435
309.5	37.398	18.591	37.561	18.754	38.374	19.567	4.322	2.441
309.4	37.277	18.659	37.441	18.822	38.258	19.640	4.311	2.449
309.3	37.164	18.730	37.329	18.894	38.151	19.716	4.301	2.458
309.2	37.055	18.802	37.220	18.967	38.047	19.794	4.291	2.466
309.1	36.949	18.875	37.115	19.041	37.946	19.872	4.282	2.474
309	36.835	18.942	37.002	19.109	37.837	19.945	4.272	2.482
308.9	36.727	19.012	36.895	19.180	37.735	20.020	4.262	2.491
308.8	36.615	19.080	36.784	19.249	37.628	20.093	4.252	2.499
308.7	36.499	19.145	36.669	19.314	37.518	20.163	4.242	2.506
308.6	36.391	19.213	36.562	19.383	37.415	20.237	4.232	2.514
308.5	36.284	19.280	36.455	19.452	37.313	20.310	4.222	2.522
308.4	36.173	19.346	36.346	19.518	37.208	20.380	4.213	2.530
308.3	36.059	19.408	36.232	19.581	37.099	20.448	4.202	2.537
308.2	35.943	19.468	36.117	19.642	36.987	20.513	4.192	2.545
308.1	35.816	19.522	35.991	19.697	36.865	20.572	4.181	2.551
308	35.693	19.578	35.868	19.753	36.747	20.632	4.170	2.558
307.9	35.569	19.631	35.745	19.808	36.628	20.691	4.158	2.565
307.8	35.442	19.683	35.620	19.860	36.507	20.747	4.147	2.571
307.7	35.294	19.722	35.472	19.900	36.363	20.790	4.134	2.577
307.6	35.159	19.767	35.338	19.945	36.232	20.840	4.122	2.583
307.5	35.034	19.816	35.214	19.996	36.112	20.894	4.111	2.589
307.4	34.923	19.873	35.104	20.054	36.006	20.956	4.101	2.596
307.3	34.805	19.925	34.987	20.107	35.893	21.013	4.090	2.602
307.2	34.693	19.980	34.875	20.162	35.785	21.072	4.080	2.609
307.1	34.580	20.033	34.763	20.216	35.678	21.131	4.070	2.615
307	34.464	20.084	34.647	20.267	35.566	21.186	4.059	2.621

North Pit Sensitivity Analysis Results

Stage	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	Mining - WBM North Pit Inflow (m³/day)	Recovery - WBM North Pit Inflow (m³/day)
306.9	34.353	20.137	34.537	20.321	35.460	21.244	4.049	2.628
306.8	34.231	20.182	34.416	20.368	35.343	21.295	4.038	2.634
306.7	34.116	20.231	34.302	20.418	35.233	21.348	4.028	2.640
306.6	34.006	20.283	34.193	20.470	35.128	21.405	4.018	2.646
306.5	33.889	20.329	34.077	20.517	35.016	21.456	4.008	2.652
306.4	33.773	20.375	33.962	20.564	34.905	21.507	3.997	2.657
306.3	33.661	20.423	33.850	20.612	34.797	21.559	3.987	2.663
306.2	33.545	20.467	33.735	20.657	34.686	21.608	3.977	2.669
306.1	33.425	20.508	33.616	20.699	34.571	21.654	3.966	2.674
306	33.305	20.549	33.496	20.740	34.455	21.699	3.955	2.679
305.9	33.179	20.585	33.371	20.777	34.333	21.739	3.944	2.684
305.8	33.048	20.617	33.242	20.810	34.207	21.776	3.932	2.689
305.7	32.933	20.658	33.127	20.852	34.097	21.821	3.921	2.694
305.6	32.810	20.693	33.005	20.888	33.978	21.861	3.910	2.699
305.5	32.699	20.735	32.894	20.930	33.871	21.907	3.900	2.704
305.4	32.583	20.773	32.780	20.969	33.761	21.950	3.890	2.709
305.3	32.475	20.815	32.672	21.012	33.657	21.997	3.880	2.714
305.2	32.358	20.851	32.556	21.049	33.545	22.037	3.869	2.719
305.1	32.242	20.886	32.440	21.085	33.433	22.077	3.859	2.723
305	32.123	20.919	32.322	21.119	33.318	22.115	3.848	2.728
304.9	32.006	20.953	32.206	21.153	33.206	22.153	3.837	2.732
304.8	31.887	20.984	32.087	21.184	33.091	22.188	3.827	2.736
304.7	31.746	21.000	31.947	21.201	32.954	22.208	3.814	2.739
304.6	31.600	21.012	31.802	21.214	32.812	22.223	3.801	2.742
304.5	31.464	21.028	31.666	21.231	32.679	22.244	3.788	2.745
304.4	31.326	21.044	31.529	21.247	32.545	22.263	3.776	2.748
304.3	31.188	21.058	31.392	21.262	32.411	22.280	3.763	2.750
304.2	31.054	21.073	31.258	21.278	32.280	22.300	3.751	2.753
304.1	30.923	21.091	31.128	21.296	32.154	22.321	3.739	2.756
304	30.799	21.111	31.005	21.317	32.033	22.346	3.728	2.759
303.9	30.692	21.143	30.899	21.350	31.931	22.382	3.718	2.763
303.8	30.584	21.173	30.791	21.380	31.827	22.417	3.708	2.767
303.7	30.479	21.205	30.687	21.413	31.727	22.453	3.699	2.771
303.6	30.384	21.243	30.593	21.452	31.637	22.496	3.690	2.776
303.5	30.294	21.284	30.504	21.493	31.552	22.541	3.682	2.781
303.4	30.201	21.322	30.412	21.532	31.464	22.584	3.673	2.785
303.3	30.113	21.363	30.324	21.574	31.381	22.630	3.665	2.790
303.2	30.022	21.401	30.235	21.613	31.295	22.674	3.657	2.795
303.1	29.938	21.444	30.151	21.656	31.216	22.721	3.649	2.800
303	29.855	21.486	30.069	21.700	31.138	22.769	3.642	2.805
302.9	29.769	21.526	29.984	21.741	31.057	22.814	3.634	2.810
302.8	29.675	21.560	29.891	21.775	30.968	22.853	3.625	2.814
302.7	29.553	21.572	29.769	21.788	30.849	22.868	3.614	2.816
302.6	29.436	21.588	29.653	21.804	30.737	22.888	3.603	2.819
302.5	29.306	21.593	29.524	21.810	30.611	22.897	3.592	2.820
302.4	29.180	21.599	29.398	21.817	30.488	22.907	3.580	2.822

Stage	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	Mining - WBM North Pit Inflow (m^3/day)	Recovery - WBM North Pit Inflow (m^3/day)
302.3	29.056	21.607	29.274	21.825	30.367	22.918	3.569	2.824
302.2	28.954	21.630	29.173	21.850	30.270	22.946	3.559	2.827
302.1	28.861	21.660	29.081	21.880	30.182	22.980	3.551	2.831
302	28.764	21.685	28.984	21.906	30.089	23.010	3.542	2.834
301.9	28.679	21.719	28.901	21.941	30.010	23.050	3.534	2.838
301.8	28.582	21.743	28.804	21.966	29.917	23.078	3.525	2.841
301.7	28.480	21.763	28.704	21.988	29.828	23.112	3.516	2.844
301.6	28.379	21.784	28.607	22.011	29.744	23.149	3.507	2.847
301.5	28.265	21.793	28.496	22.023	29.648	23.175	3.496	2.849
301.4	28.155	21.804	28.388	22.038	29.555	23.204	3.486	2.851
301.3	28.051	21.820	28.287	22.056	29.468	23.237	3.476	2.853
301.2	27.941	21.830	28.180	22.069	29.375	23.264	3.466	2.855
301.1	27.809	21.822	28.052	22.065	29.263	23.276	3.454	2.855
301	27.706	21.836	27.951	22.082	29.178	23.308	3.444	2.858
300.9	27.614	21.859	27.863	22.107	29.104	23.348	3.436	2.860
300.8	27.528	21.884	27.779	22.136	29.036	23.392	3.428	2.864
300.7	27.444	21.912	27.698	22.166	28.970	23.438	3.420	2.867
300.6	27.361	21.939	27.619	22.197	28.906	23.484	3.413	2.870
300.5	27.269	21.959	27.530	22.219	28.833	23.522	3.404	2.873
300.4	27.176	21.976	27.439	22.240	28.758	23.559	3.395	2.875
300.3	27.088	21.998	27.355	22.265	28.690	23.601	3.387	2.878
300.2	26.992	22.013	27.263	22.284	28.614	23.635	3.378	2.880
300.1	26.909	22.037	27.182	22.310	28.550	23.678	3.371	2.883
300	26.819	22.055	27.096	22.332	28.480	23.717	3.362	2.886
299.9	26.733	22.076	27.013	22.356	28.413	23.756	3.354	2.889
299.8	26.637	22.088	26.920	22.371	28.337	23.788	3.345	2.890
299.7	26.554	22.110	26.841	22.397	28.274	23.830	3.338	2.893
299.6	26.456	22.119	26.746	22.409	28.196	23.859	3.328	2.895
299.5	26.362	22.131	26.655	22.424	28.122	23.890	3.320	2.897
299.4	26.276	22.148	26.573	22.445	28.055	23.928	3.312	2.899
299.3	26.195	22.170	26.495	22.470	27.994	23.969	3.304	2.902
299.2	26.108	22.185	26.411	22.489	27.927	24.004	3.296	2.904
299.1	26.020	22.200	26.327	22.506	27.858	24.038	3.288	2.906
299	25.935	22.215	26.244	22.525	27.792	24.073	3.280	2.908
298.9	25.843	22.225	26.156	22.538	27.721	24.103	3.271	2.910
298.8	25.750	22.234	26.067	22.550	27.648	24.131	3.263	2.911
298.7	25.659	22.243	25.979	22.562	27.577	24.160	3.254	2.913
298.6	25.563	22.247	25.886	22.570	27.501	24.184	3.245	2.914
298.5	25.467	22.250	25.793	22.577	27.424	24.208	3.236	2.915
298.4	25.378	22.259	25.708	22.589	27.355	24.237	3.228	2.916
298.3	25.292	22.270	25.625	22.603	27.289	24.267	3.220	2.918
298.2	25.199	22.274	25.535	22.610	27.215	24.291	3.211	2.919
298.1	25.105	22.277	25.445	22.617	27.142	24.314	3.203	2.920
298	25.000	22.270	25.343	22.612	27.057	24.327	3.193	2.920
297.9	24.908	22.273	25.254	22.619	26.985	24.350	3.184	2.921
297.8	24.801	22.262	25.150	22.611	26.898	24.359	3.174	2.920

North Pit Sensitivity Analysis Results

Stage	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	Mining - WBM North Pit Inflow (m^3/day)	Recovery - WBM North Pit Inflow (m^3/day)
297.7	24.706	22.261	25.059	22.614	26.823	24.378	3.165	2.921
297.6	24.607	22.256	24.964	22.613	26.745	24.394	3.156	2.921
297.5	24.500	22.243	24.860	22.602	26.658	24.401	3.146	2.920
297.4	24.383	22.220	24.746	22.583	26.562	24.399	3.135	2.919
297.3	24.263	22.193	24.629	22.560	26.463	24.393	3.124	2.917
297.2	24.153	22.176	24.524	22.546	26.374	24.396	3.114	2.916
297.1	24.028	22.143	24.402	22.516	26.270	24.385	3.102	2.913
297	23.914	22.119	24.291	22.496	26.177	24.382	3.091	2.912
296.9	23.794	22.090	24.175	22.470	26.078	24.374	3.080	2.910
296.8	23.683	22.067	24.067	22.451	25.988	24.372	3.070	2.908
296.7	23.569	22.041	23.956	22.429	25.895	24.367	3.059	2.906
296.6	23.452	22.013	23.843	22.404	25.799	24.360	3.048	2.904
296.5	23.327	21.974	23.722	22.369	25.696	24.343	3.036	2.901
296.4	23.193	21.928	23.592	22.327	25.584	24.319	3.024	2.897
296.3	23.060	21.881	23.463	22.283	25.473	24.294	3.011	2.893
296.2	22.928	21.834	23.334	22.239	25.363	24.268	2.999	2.889
296.1	22.791	21.781	23.200	22.190	25.248	24.238	2.986	2.885
296	22.648	21.722	23.061	22.135	25.128	24.201	2.973	2.880
295.9	22.488	21.644	22.905	22.061	24.990	24.147	2.957	2.873
295.8	22.307	21.547	22.728	21.968	24.833	24.073	2.941	2.864
295.7	22.108	21.430	22.533	21.855	24.659	23.981	2.922	2.854
295.6	21.892	21.295	22.321	21.725	24.468	23.871	2.902	2.842
295.5	21.643	21.127	22.077	21.560	24.244	23.728	2.878	2.827
295.4	21.273	20.838	21.711	21.276	23.903	23.469	2.843	2.800
295.3	20.577	20.226	21.022	20.671	23.246	22.896	2.778	2.743
295.2	18.659	18.405	19.116	18.862	21.400	21.146	2.597	2.572
295.1	14.921	14.769	15.395	15.243	17.762	17.610	2.241	2.226
295	8.323	8.266	8.814	8.758	11.274	11.217	1.604	1.598

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
334.30	162.58	162.58	162.58	162.58	162.58	162.58	163.73	163.73	163.73	163.73	163.73	163.73	167.36	167.36	167.36	167.36	167.36	167.36	5.19	0.15	5.20	0.16	5.26	0.22	51.91	1.51	51.94	1.54	52.11	1.72
334.20	162.48	162.48	162.48	162.48	162.48	162.48	163.66	163.66	163.66	163.66	163.66	163.66	167.39	167.39	167.39	167.39	167.39	167.39	5.19	0.16	5.20	0.17	5.26	0.22	51.87	1.55	51.91	1.58	52.08	1.76
334.10	162.39	162.39	162.39	162.39	162.39	162.39	163.60	163.60	163.60	163.60	163.60	163.60	167.43	167.43	167.43	167.43	167.43	167.43	5.19	0.16	5.20	0.17	5.25	0.23	51.84	1.59	51.87	1.63	52.06	1.81
334.00	162.29	162.29	162.29	162.29	162.29	162.29	163.54	163.54	163.54	163.54	163.54	163.54	167.46	167.46	167.46	167.46	167.46	167.46	5.18	0.16	5.19	0.18	5.25	0.24	51.80	1.63	51.84	1.67	52.03	1.85
333.90	162.20	162.20	162.20	162.20	162.20	162.20	163.47	163.47	163.47	163.47	163.47	163.47	167.50	167.50	167.50	167.50	167.50	167.50	5.18	0.17	5.19	0.18	5.25	0.24	51.77	1.67	51.81	1.71	52.00	1.90
333.80	162.11	162.11	162.11	162.11	162.11	162.11	163.42	163.42	163.42	163.42	163.42	163.42	167.54	167.54	167.54	167.54	167.54	167.54	5.18	0.17	5.19	0.19	5.25	0.25	51.74	1.71	51.77	1.75	51.97	1.94
333.70	162.03	162.03	162.03	162.03	162.03	162.03	163.36	163.36	163.36	163.36	163.36	163.36	167.58	167.58	167.58	167.58	167.58	167.58	5.17	0.18	5.19	0.19	5.25	0.25	51.70	1.75	51.74	1.79	51.94	1.99
333.60	161.94	161.94	161.94	161.94	161.94	161.94	163.30	163.30	163.30	163.30	163.30	163.30	167.62	167.62	167.62	167.62	167.62	167.62	5.17	0.18	5.18	0.19	5.25	0.26	51.67	1.79	51.71	1.83	51.92	2.03
333.50	161.85	161.85	161.85	161.85	161.85	161.85	163.25	163.25	163.25	163.25	163.25	163.25	167.66	167.66	167.66	167.66	167.66	167.66	5.17	0.18	5.18	0.20	5.25	0.26	51.64	1.83	51.68	1.87	51.89	2.08
333.40	161.76	161.76	161.76	161.76	161.76	161.76	163.18	163.18	163.18	163.18	163.18	163.18	167.70	167.70	167.70	167.70	167.70	167.70	5.16	0.19	5.18	0.20	5.24	0.27	51.60	1.87	51.65	1.91	51.86	2.12
333.30	161.67	161.67	161.67	161.67	161.67	161.67	163.12	163.12	163.12	163.12	163.12	163.12	167.74	167.74	167.74	167.74	167.74	167.74	5.16	0.19	5.17	0.21	5.24	0.28	51.57	1.90	51.61	1.95	51.83	2.17
333.20	161.57	161.57	161.57	161.57	161.57	161.57	163.06	163.06	163.06	163.06	163.06	163.06	167.77	167.77	167.77	167.77	167.77	167.77	5.16	0.20	5.17	0.21	5.24	0.28	51.54	1.94	51.58	1.99	51.80	2.21
333.10	161.48	161.48	161.48	161.48	161.48	161.48	163.00	163.00	163.00	163.00	163.00	163.00	167.81	167.81	167.81	167.81	167.81	167.81	5.15	0.20	5.17	0.22	5.24	0.29	51.50	1.98	51.55	2.03	51.77	2.26
333.00	161.38	161.38	161.38	161.38	161.38	161.38	162.94	162.94	162.94	162.94	162.94	162.94	167.84	167.84	167.84	167.84	167.84	167.84	5.15	0.20	5.16	0.22	5.24	0.29	51.47	2.02	51.51	2.07	51.75	2.30
332.90	161.29	161.29	161.29	161.29	161.29	161.29	162.87	162.87	162.87	162.87	162.87	162.87	167.88	167.88	167.88	167.88	167.88	167.88	5.15	0.21	5.16	0.22	5.24	0.30	51.43	2.06	51.48	2.11	51.72	2.35
332.80	161.20	161.20	161.20	161.20	161.20	161.20	162.81	162.81	162.81	162.81	162.81	162.81	167.91	167.91	167.91	167.91	167.91	167.91	5.14	0.21	5.16	0.23	5.23	0.30	51.40	2.10	51.45	2.15	51.69	2.39
332.70	161.11	161.11	161.11	161.11	161.11	161.11	162.75	162.75	162.75	162.75	162.75	162.75	167.95	167.95	167.95	167.95	167.95	167.95	5.14	0.22	5.15	0.23	5.23	0.31	51.36	2.14	51.41	2.19	51.66	2.44
332.60	161.01	161.01	161.01	161.01	161.01	161.01	162.69	162.69	162.69	162.69	162.69	162.69	167.99	167.99	167.99	167.99	167.99	167.99	5.14	0.22	5.15	0.24	5.23	0.32	51.33	2.18	51.38	2.23	51.63	2.48
332.50	160.92	160.92	160.92	160.92	160.92	160.92	162.63	162.63	162.63	162.63	162.63	162.63	168.03	168.03	168.03	168.03	168.03	168.03	5.13	0.22	5.15	0.24	5.23	0.32	51.30	2.22	51.35	2.27	51.60	2.52
332.40	160.83	160.83	160.83	160.83	160.83	160.83	162.57	162.57	162.57	162.57	162.57	162.57	168.07	168.07	168.07	168.07	168.07	168.07	5.13	0.23	5.15	0.24	5.23	0.33	51.26	2.26	51.32	2.31	51.58	2.57
332.30	160.74	160.74	160.74	160.74	160.74	160.74	162.51	162.51	162.51	162.51	162.51	162.51	168.10	168.10	168.10	168.10	168.10	168.10	5.13	0.23	5.14	0.25	5.23	0.33	51.23	2.29	51.28	2.35	51.55	2.61
332.20	160.64	160.64	160.64	160.64	160.64	160.64	162.44	162.44	162.44	162.44	162.44	162.44	168.14	168.14	168.14	168.14	168.14	168.14	5.12	0.24	5.14	0.25	5.22	0.34	51.19	2.33	51.25	2.39	51.52	2.66
332.10	160.55	160.55	160.55	160.55	160.55	160.55	162.38	162.38	162.38	162.38	162.38	162.38	168.17	168.17	168.17	168.17	168.17	168.17	5.12	0.24	5.14	0.26	5.22	0.34	51.16	2.37	51.21	2.43	51.49	2.70
332.00	160.45	160.45	160.45	160.45	160.45	160.45	162.31	162.31	162.31	162.31	162.31	162.31	168.20	168.20	168.20	168.20	168.20	168.20	5.12	0.24	5.13	0.26	5.22	0.35	51.12	2.41	51.18	2.47	51.46	2.74
331.90	160.35	160.35	160.35	160.35	160.35	160.35	162.25	162.25	162.25	162.25	162.25	162.25	168.23	168.23	168.23	168.23	168.23	168.23	5.11	0.25	5.13	0.27	5.22	0.35	51.09	2.45	51.14	2.51	51.43	2.79
331.80	160.25	160.25	160.25	160.25	160.25	160.25	162.18	162.18	162.18	162.18	162.18	162.18	168.26	168.26	168.26	168.26	168.26	168.26	5.11	0.25	5.13	0.27	5.22	0.36	51.05	2.49	51.11	2.54	51.40	2.83
331.70	160.15	160.15	160.15	160.15	160.15	160.15	162.11	162.11	162.11	162.11	162.11	162.11	168.29	168.29	168.29	168.29	168.29	168.29	5.10	0.26	5.12	0.27	5.21	0.37	51.01	2.53	51.07	2.58	51.36	2.88
331.60	160.04	160.04	160.04	160.04	160.04	160.04	162.03	162.03	162.03	162.03	162.03	162.03	168.31	168.31	168.31	168.31	168.31	168.31	5.10	0.26	5.12	0.28	5.21	0.37	50.98	2.56	51.03	2.62	51.33	2.92
331.50	159.93	159.93	159.93	159.93	159.93	159.93	161.94	161.94	161.94	161.94	161.94	161.94	168.33	168.33	168.33	168.33	168.33	168.33	5.10	0.26	5.12	0.28	5.21	0.38	50.93	2.60	50.99	2.66	51.29	2.96
331.40	159.81	159.81	159.81	159.81	159.81	159.81	161.86	161.86	161.86	161.86	161.86	161.86	168.34	168.34	168.34	168.34	168.34	168.34	5.09	0.27	5.11	0.29	5.21	0.38	50.89	2.64	50.95	2.70	51.26	3.01
331.30	159.69	159.69	159.69	159.69	159.69	159.69	161.77	161.77	161.77	161.77	161.77	161.77	168.35	168.35	168.35	168.35	168.35	168.35	5.09	0.27	5.11	0.29	5.20	0.39	50.85	2.68	50.91	2.74	51.22	3.05
331.20	159.57	159.57	159.57	159.57	159.57	159.57	161.69	161.69	161.69	161.69	161.69	161.69	168.36	168.36	168.36	168.36	168.36	168.36	5.08	0.27	5.10	0.29	5.20	0.39	50.81	2.71	50.87	2.78	51.18	3.09
331.10	159.46	159.46	159.46	159.46	159.46	159.46	161.60	161.60	161.60	161.60	161.60	161.60	168.37	168.37	168.37	168.37	168.37	168.37	5.08	0.28	5.10	0.30	5.20	0.40	50.77	2.75	50.83	2.82	51.15	3.13
331.00	159.34	159.34	159.34	159.34	159.34	159.34	161.52	161.52	161.52	161.52	161.52	161.52	168.39	168.39	168.39	168.39	168.39	168.39	5.08	0.28	5.10	0.30	5.20	0.40	50.73	2.79	50.79	2.85	51.11	3.18
330.90	159.22	159.22	159.22	159.22	159.22	159.22	161.43	161.43	161.43	161.43	161.43	161.43	168.40	168.40	168.40	168.40	168.40	168.40	5.07	0.29	5.09	0.31	5.19	0.41	50.68	2.83	50.75	2.89	51.07	3.22
330.80	159.09	159.09	159.09	159.09	159.09	159.09	161.33	161.33	161.33	161.33	161.33	161.33	168.40	168.40	168.40	168.40	168.40	168.40	5.07	0.29	5.09	0.31	5.19	0.41	50.64	2.86	50.70	2.93	51.03	3.26
330.70	158.94	158.94	158.94	158.94	158.94	158.94	161.20	161.20	161.20	161.20	161.20	161.20	168.37	168.37	168.37	168.37	168.37	168.37	5.06	0.29	5.08	0.31	5.19	0.42	50.58	2.90	50.65	2.97	50.98	3.30
330.60	158.78	158.78	158.78	158.78	158.78	158.78	161.08	161.08	161.08	161.08	161.08	161.08	168.34	168.34	168.34	168.34	168.34	168.34	5.06	0.30	5.08	0.32	5.18	0.43	50.53	2.94	50.60	3.01	50.94	3.35
330.50	158.64	158.64	158.64	158.64	158.64	158.64	160.96	160.96	160.96	160.96	160.96	160.96	168.33	168.33	168.33	168.33	168.33	168.33	5.05	0.30	5.07	0.32	5.18	0.43	50.48	2.97	50.55	3.04	50.89	3.39
330.40	158.49	158.49	158.49	158.49	158.49	158.49	160.85	160.85	160.85	160.85	160.85	160.85	168.31	168.31	168.31	168.31	168.31	168.31	5.05	0.30	5.07	0.33	5.18	0.44	50.43	3.01	50.50	3.08	50.84	3.43
330.30	158.33	158.33	158.33	158.33	158.33	158.33	160.72	160.72	160.72	160.72	160.72	160.72	168.27	168.27	168.27	168.27	168.27	168.27	5.04	0.31	5.06	0.33	5.17	0.44	50.37	3.05	50.44	3.12	50.79	3.47
330.20	158.18	158.18	158.18	158.18	158.18	158.18	160.60	160.60	160.60	160.60	160.60	160.60	168.26	168.26	168.26	168.26	168.26	168.26	5.04	0.31	5.06	0.33	5.17	0.45	50.32	3.08	50.39	3.16	50.75	3.51
330.10	158.04	158.04	158.04	158.04	158.04	158.04	160.49	160.49	160.49	160.49	160.49	160.49	168.25	168.25	168.25	168.25	168.25	168.25	5.03	0.32	5.05	0.34	5.17	0.45	50.27	3.12	50.34	3.19	50.70	3.55
330.00	157.92	157.92	157.92	157.92	157.92	157.92	160.40	160.40	160.40	160.40	160.40	160.40	168.26	168.26	168.26	168.26	168.26	168.26	5.03	0.32	5.05	0.34	5.16	0.46	50.23	3.16	50.30	3.23	50.66	3.60
329.90	157.80	157.80	157.80	157.80	157.80	157.80	160.32	160.32	160.32	160.32	160.32	160.32	168.27	168.27	168.27	168.27	168.27	168.27	5.02	0.32	5.05	0.35	5.16	0.46	50.18	3.19	50.26	3.27	50.63	3.64
329.80	157.69	157.69	157.69	157.69	157.69	157.69	160.23	160.23	160.23	160.23	160.23	160.23	168.28	168.28	168.28	168.28	168.28	168.28	5.02	0.33	5.04	0.35	5.16	0.47	50.14	3.23	50.22	3.31	50.59	3.68
329.70	157.58	157.58	157.58	157.58	157.58	157.58	160.15	160.15	160.15	160.15	160.15	160.15	168.30	168.30	168.30	168.30	168.30	168.30	5.01	0.33	5.04	0.35	5.16	0.47	50.10	3.27	50.18	3.34	50.56	3.72
329.60	157.46	157.46	157.46	157.46	157.46	157.46	160.07	160.07	160.07	160.07	160.07	160.07	168.32	168.32	168.32	168.32	168.32	168.32	5.01	0.33	5.03	0.36	5.15	0.48	50.06	3.30	50.14	3.38	50.52	3.76
329.50	157.35	157.35	157.35	157.35	157.35	157.35	159.99	159.99	159.99	159.99	159.99	159.99	168.33	168.33	168.33	168.33	168.33	168.33	5.01	0.34	5.03	0.36	5.15	0.48	50.02	3.34	50.10	3.42	50.49	3.81
329.40	157.23	157.23	157.23	157.23	157.23	157.23	159.90	159.90	159.90	159.90	159.90	159.90	168.35	168.35	168.35	168.35	168.35	168.35	5.00	0.34	5.03	0.37	5.15	0.49	49.98	3.38	50.06	3.46	50.45	3.85
329.30	157.12	157.12	157.12	157.12	157.12	157.12	159.82	159.82	159.82	159.82	159.82	159.82	168.36	168.36	168.36	168.36	168.36	168.36	5.00	0.35	5.02	0.37	5.15	0.49	49.94	3.41	50.02	3.49	50.41	3.89
329.20	157.01	157.01	157.01	157.01	157.01	157.01	159.74	159.74	159.74	159.74	159.74	159.74	168.38	168.38	168.38	168.38	168.38	168.38	4.99	0.35	5.02	0.37	5.14	0.50	49.90	3.45	49.98	3.53	50.38	3.93
329.10	156.90	156.90	156.90	156.90	156.90	156.90	159.66	159.66	159.66	159.66	159.66	159.66	168.40	168.40	168.40	168.40	168.40	168.40	4.99	0.35	5.02	0.38	5.14	0.51	49.86	3.49	49.94	3.57	50.34	3.97
329.00	156.79	156.79	156.79	156.79	156.79	156.79	159.58	159.58	159.58	159.58	159.58	159.58	168.42	168.42	168.42	168.42	168.42	168.42	4.99	0.36	5.01	0.38	5.14	0.51	49.82	3.52	49.90	3.60	50.31	4.01
328.90	156.68	156.68	156.68	156.68	156.68	156.68	159.50	159.50	159.50	159.50	159.50	159.50	168.44	168.44	168.44	168.44	168.44	168.44	4.98	0.36	5.01	0.39	5.14	0.52	49.78	3.56	49.86	3.64	50.28	4.05
328.80	156.57	156.57	156.57	156.57	156.57	156.57	159.43	159.43	159.43	159.43	159.43	159.43	168.46	168.46	168.46	168.46	168.46	168.46	4.98	0.36	5.00	0.39	5.14	0.52	49.74	3.60	49.83	3.68	50.24	4.10
328.70	156.47	156.47	156.47	156.47	156.47	156.47	159.36	159.36	159.36	159.36	159.36	159.36	168.49	168.49	168.49	168.49	168.49	168.49	4.97	0.37	5.00	0.39	5.13	0.53	49.70	3.63	49.79	3.72	50.21	4.14
328.60	156.37	156.37	156.37	156.37	156.37	156.37	159.29	159.29	159.29	159.29	159.29	159.29	168.52	168.52	168.52	168.52	168.52	168.52	4.97	0.37	5.00	0.40	5.13	0.53	49.67	3.67	49.75	3.75	50.18	4.18
328.50	156.28	156.28	156.28	156.28	156.28	156.28	159.22	159.22	159.22	159.22	159.22	159.22	168.55	168.55	168.55	168.55	168.55	168.55	4.97	0.38	4.99	0.40	5.13	0.54	49.63	3.70	49.72	3.79	50.15	4.22
328.40	156.18	156.18	156.18	156.18	156.18	156.18	159.16	159.16	159.16	159.16	159.16	159.16	168.59	168.59	168.59	168.59	168.59	168.59	4.96	0.38	4.99	0.41	5.13	0.54	49.60	3.74	49.69	3.83	50.12	4.26
328.30	156.09	156.09	156.09	156.09	156.09	156.09	159.10	159.10	159.10	159.10	159.10	159.10	168.63	168.63	168.63	168.63	168.63	168.63	4.96	0.38	4.99	0.41	5.13	0.55	49.57	3.78	49.65	3.87	50.09	4.30
328.20	156.00	156.00	156.00	156.00	156.00	156.00	159.05	159.05	159.05	159.05	159.05	159.05	168.67	168.67	168.67	168.67	168.67	168.67	4.96	0.39	4.99	0.41	5.12	0.55	49.53	3.81	49.62	3.90	50.06	4.35
328.10	155.92	155.92	155.92	155.92	155.92	155.92	158.99	158.99	158.99	158.99	158.99	158.99	168.71	168.71	168.71	168.71	168.71	168.71	4.95	0.39	4.98	0.42	5.12	0.56	49.50	3.85	49.59	3.94	50.04	4.39
328.00	155.83	155.83	155.83	155.83	155.83	155.83	158.93	158.93	158.93	158.93	158.93	158.93	168.75	168.75	168.75	168.75	168.75	168.75	4.95	0.39	4.98	0.42	5.12	0.56	49.47	3.89	49.56	3.98	50.01	4.43
327.90	155.75	155.75	155.75	155.75	155.75	155.75	158.88	158.88	158.88	158.88	158.88	158.88	168.80	168.80	168.80	168.80	168.80	168.80	4.95	0.40	4.98	0.43	5.12	0.57	49.44	3.92	49.53	4.01	49.98	4.47
327.80	155.66	155.66	155.66	155.66	155.66	155.66	158.83	158.83	158.83	158.83	158.83	158.83	168.84	168.84	168.84	168.84	168.84	168.84	4.95	0.40	4.97	0.43	5.12	0.57	49.41	3.96	49.50	4.05	49.96	4.51
327.70	155.58	155.58	155.58	155.58	155.58	155.58	158.78	158.78	158.78	158.78	158.78	158.78	168.89	168.89	168.89	168.89	168.89	168.89	4.94	0.40	4.97	0.43	5.12	0.58	49.38	4.00	49.47	4.09	49.93	4.55
327.60	155.50	155.50	155.50	155.50	155.50	155.50	158.73	158.73	158.73	158.73	158.73	158.73	168.94	168.94	168.94	168.94	168.94	168.94	4.94	0.41	4.97	0.44	5.12	0.58	49.35	4.03	49.44	4.13	49.91	4.59
327.50	155.43	155.43	155.43	155.43	155.43	155.43	158.69	158.69	158.69	158.69	158.69	158.69	168.99	168.99	168.99	168.99	168.99	168.99	4.94	0.41	4.97	0.44	5.11	0.59	49.32	4.07	49.41	4.16	49.89	4.64
327.40	155.35	155.35	155.35	155.35	155.35	155.35	158.64	158.64	158.64	158.64	158.64	158.64	169.05	169.05	169.05	169.05	169.05	169.05	4.93	0.42	4.96	0.45	5.11	0.59	49.29	4.10	49.38	4.20	49.86	4.68
327.30	155.27	155.27	155.27	155.27	155.27	155.27	158.60	158.60	158.60	158.60	158.60	158.60	169.10	169.10	169.10	169.10	169.10	169.10	4.93	0.42	4.96	0.45	5.11	0.60	49.26	4.14	49.36	4.24	49.84	4.72
327.20	155.20	155.20	155.20	155.20	155.20	155.20	158.55	158.55	158.55	158.55	158.55	158.55	169.15	169.15	169.15	169.15	169.15	169.15	4.93	0.42	4.96	0.45	5.11	0.61	49.23	4.18	49.33	4.27	49.81	4.76
327.10	155.12	155.12	155.12	155.12	155.12	155.12	158.51	158.51	158.51	158.51	158.51	158.51	169.21	169.21	169.21	169.21	169.21	169.21	4.93	0.43	4.96	0.46	5.11	0.61	49.20	4.21	49.30	4.31	49.79	4.80
327.00	155.05	155.05	155.05	155.05	155.05	155.05	158.46	158.46	158.46	158.46	158.46	158.46	169.26	169.26	169.26	169.26	169.26	169.26	4.92	0.43	4.95	0.46	5.11	0.62	49.17	4.25	49.27	4.35	49.77	4.84
326.90	154.98	154.98	154.98	154.98	154.98	154.98	158.42	158.42	158.42	158.42	158.42	158.42	169.32	169.32	169.32	169.32	169.32	169.32	4.92	0.43	4.95	0.47	5.11	0.62	49.15	4.29	49.25	4.39	49.75	4.88
326.80	154.90	154.90	154.90	154.90	154.90	154.90	158.38	158.38	158.38	158.38	158.38	158.38	169.37	169.37	169.37	169.37	169.37	169.37	4.92	0.44	4.95	0.47	5.11	0.63	49.12	4.32	49.22	4.42	49.72	4.93
326.70	154.83	154.83	154.83	154.83	154.83	154.83	158.34	158.34	158.34	158.34	158.34	158.34	169.43	169.43	169.43	169.43	169.43	169.43	4.91	0.44	4.95	0.47	5.10	0.63	49.09	4.36	49.19	4.46	49.70	4.97
326.60	154.76	154.76	154.76	154.76	154.76	154.76	158.29	158.29	158.29	158.29	158.29	158.29	169.49	169.49	169.49	169.49	169.49	169.49	4.91	0.44	4.94	0.48	5.10	0.64	49.06	4.39	49.17	4.50	49.68	5.01
326.50	154.68	154.68	154.68	154.68	154.68	154.68	158.25	158.25	158.25	158.25	158.25	158.25	169.54	169.54	169.54	169.54	169.54	169.54	4.91	0.45	4.94	0.48	5.10	0.64	49.04	4.43	49.14	4.53	49.66	5.05
326.40	154.61	154.61	154.61	154.61	154.61	154.61	158.21	158.21	158.21	158.21	158.21	158.21	169.60	169.60	169.60	169.60	169.60	169.60	4.91	0.45	4.94	0.48	5.10	0.65	49.01	4.47	49.11	4.57	49.63	5.09
326.30	154.54	154.54	154.54	154.54	154.54	154.54	158.17	158.17	158.17	158.17	158.17	158.17	169.66	169.66	169.66	169.66	169.66	169.66	4.90	0.46	4.94	0.49	5.10	0.65	48.

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
324.10	152.91	152.91	152.91	152.91	152.91	152.91	157.23	157.23	157.23	157.23	157.23	157.23	170.87	170.87	170.87	170.87	170.87	170.87	4.84	0.53	4.88	0.57	5.07	0.77	48.36	5.28	48.49	5.40	49.10	6.02
324.00	152.83	152.83	152.83	152.83	152.83	152.83	157.17	157.17	157.17	157.17	157.17	157.17	170.92	170.92	170.92	170.92	170.92	170.92	4.84	0.54	4.88	0.58	5.07	0.77	48.33	5.32	48.46	5.44	49.08	6.06
323.90	152.74	152.74	152.74	152.74	152.74	152.74	157.12	157.12	157.12	157.12	157.12	157.12	170.96	170.96	170.96	170.96	170.96	170.96	4.84	0.54	4.88	0.58	5.07	0.78	48.30	5.35	48.42	5.47	49.05	6.10
323.80	152.66	152.66	152.66	152.66	152.66	152.66	157.07	157.07	157.07	157.07	157.07	157.07	171.00	171.00	171.00	171.00	171.00	171.00	4.83	0.55	4.87	0.58	5.07	0.78	48.27	5.38	48.39	5.51	49.02	6.14
323.70	152.57	152.57	152.57	152.57	152.57	152.57	157.01	157.01	157.01	157.01	157.01	157.01	171.05	171.05	171.05	171.05	171.05	171.05	4.83	0.55	4.87	0.59	5.07	0.79	48.24	5.42	48.36	5.55	49.00	6.18
323.60	152.48	152.48	152.48	152.48	152.48	152.48	156.95	156.95	156.95	156.95	156.95	156.95	171.09	171.09	171.09	171.09	171.09	171.09	4.83	0.55	4.87	0.59	5.07	0.79	48.20	5.45	48.33	5.58	48.97	6.22
323.50	152.39	152.39	152.39	152.39	152.39	152.39	156.89	156.89	156.89	156.89	156.89	156.89	171.13	171.13	171.13	171.13	171.13	171.13	4.82	0.56	4.86	0.60	5.06	0.80	48.17	5.49	48.30	5.62	48.94	6.26
323.40	152.30	152.30	152.30	152.30	152.30	152.30	156.84	156.84	156.84	156.84	156.84	156.84	171.17	171.17	171.17	171.17	171.17	171.17	4.82	0.56	4.86	0.60	5.06	0.80	48.14	5.52	48.27	5.65	48.91	6.30
323.30	152.21	152.21	152.21	152.21	152.21	152.21	156.78	156.78	156.78	156.78	156.78	156.78	171.21	171.21	171.21	171.21	171.21	171.21	4.82	0.56	4.86	0.60	5.06	0.81	48.10	5.55	48.23	5.68	48.88	6.33
323.20	152.12	152.12	152.12	152.12	152.12	152.12	156.72	156.72	156.72	156.72	156.72	156.72	171.24	171.24	171.24	171.24	171.24	171.24	4.81	0.57	4.85	0.61	5.06	0.81	48.07	5.59	48.20	5.72	48.86	6.37
323.10	152.03	152.03	152.03	152.03	152.03	152.03	156.65	156.65	156.65	156.65	156.65	156.65	171.28	171.28	171.28	171.28	171.28	171.28	4.81	0.57	4.85	0.61	5.06	0.82	48.04	5.62	48.17	5.75	48.83	6.41
323.00	151.93	151.93	151.93	151.93	151.93	151.93	156.59	156.59	156.59	156.59	156.59	156.59	171.31	171.31	171.31	171.31	171.31	171.31	4.81	0.57	4.85	0.61	5.05	0.82	48.00	5.66	48.13	5.79	48.80	6.45
322.90	151.84	151.84	151.84	151.84	151.84	151.84	156.52	156.52	156.52	156.52	156.52	156.52	171.35	171.35	171.35	171.35	171.35	171.35	4.80	0.58	4.85	0.62	5.05	0.82	47.97	5.69	48.10	5.82	48.77	6.49
322.80	151.74	151.74	151.74	151.74	151.74	151.74	156.45	156.45	156.45	156.45	156.45	156.45	171.37	171.37	171.37	171.37	171.37	171.37	4.80	0.58	4.84	0.62	5.05	0.83	47.93	5.72	48.06	5.86	48.73	6.53
322.70	151.63	151.63	151.63	151.63	151.63	151.63	156.38	156.38	156.38	156.38	156.38	156.38	171.40	171.40	171.40	171.40	171.40	171.40	4.80	0.58	4.84	0.62	5.05	0.83	47.89	5.76	48.02	5.89	48.70	6.56
322.60	151.52	151.52	151.52	151.52	151.52	151.52	156.30	156.30	156.30	156.30	156.30	156.30	171.42	171.42	171.42	171.42	171.42	171.42	4.79	0.59	4.83	0.63	5.05	0.84	47.85	5.79	47.99	5.92	48.66	6.60
322.50	151.41	151.41	151.41	151.41	151.41	151.41	156.22	156.22	156.22	156.22	156.22	156.22	171.43	171.43	171.43	171.43	171.43	171.43	4.79	0.59	4.83	0.63	5.04	0.84	47.81	5.82	47.95	5.96	48.63	6.64
322.40	151.30	151.30	151.30	151.30	151.30	151.30	156.14	156.14	156.14	156.14	156.14	156.14	171.46	171.46	171.46	171.46	171.46	171.46	4.78	0.59	4.83	0.64	5.04	0.85	47.77	5.85	47.91	5.99	48.60	6.68
322.30	151.19	151.19	151.19	151.19	151.19	151.19	156.07	156.07	156.07	156.07	156.07	156.07	171.48	171.48	171.48	171.48	171.48	171.48	4.78	0.60	4.82	0.64	5.04	0.85	47.73	5.89	47.87	6.02	48.56	6.71
322.20	151.09	151.09	151.09	151.09	151.09	151.09	155.99	155.99	155.99	155.99	155.99	155.99	171.50	171.50	171.50	171.50	171.50	171.50	4.78	0.60	4.82	0.64	5.04	0.86	47.70	5.92	47.83	6.06	48.53	6.75
322.10	150.98	150.98	150.98	150.98	150.98	150.98	155.92	155.92	155.92	155.92	155.92	155.92	171.53	171.53	171.53	171.53	171.53	171.53	4.77	0.60	4.82	0.65	5.03	0.86	47.66	5.95	47.80	6.09	48.50	6.79
322.00	150.88	150.88	150.88	150.88	150.88	150.88	155.84	155.84	155.84	155.84	155.84	155.84	171.55	171.55	171.55	171.55	171.55	171.55	4.77	0.61	4.81	0.65	5.03	0.87	47.62	5.98	47.76	6.13	48.46	6.83
321.90	150.77	150.77	150.77	150.77	150.77	150.77	155.76	155.76	155.76	155.76	155.76	155.76	171.57	171.57	171.57	171.57	171.57	171.57	4.77	0.61	4.81	0.65	5.03	0.87	47.58	6.02	47.72	6.16	48.43	6.86
321.80	150.65	150.65	150.65	150.65	150.65	150.65	155.68	155.68	155.68	155.68	155.68	155.68	171.58	171.58	171.58	171.58	171.58	171.58	4.76	0.61	4.81	0.66	5.03	0.88	47.54	6.05	47.68	6.19	48.39	6.90
321.70	150.53	150.53	150.53	150.53	150.53	150.53	155.59	155.59	155.59	155.59	155.59	155.59	171.59	171.59	171.59	171.59	171.59	171.59	4.76	0.62	4.80	0.66	5.02	0.88	47.49	6.08	47.64	6.22	48.35	6.94
321.60	150.40	150.40	150.40	150.40	150.40	150.40	155.49	155.49	155.49	155.49	155.49	155.49	171.59	171.59	171.59	171.59	171.59	171.59	4.75	0.62	4.80	0.66	5.02	0.89	47.45	6.11	47.59	6.26	48.31	6.97
321.50	150.26	150.26	150.26	150.26	150.26	150.26	155.39	155.39	155.39	155.39	155.39	155.39	171.58	171.58	171.58	171.58	171.58	171.58	4.75	0.62	4.79	0.67	5.02	0.89	47.40	6.14	47.55	6.29	48.27	7.01
321.40	150.12	150.12	150.12	150.12	150.12	150.12	155.27	155.27	155.27	155.27	155.27	155.27	171.57	171.57	171.57	171.57	171.57	171.57	4.74	0.63	4.79	0.67	5.01	0.90	47.35	6.17	47.49	6.32	48.22	7.04
321.30	149.96	149.96	149.96	149.96	149.96	149.96	155.15	155.15	155.15	155.15	155.15	155.15	171.54	171.54	171.54	171.54	171.54	171.54	4.74	0.63	4.78	0.67	5.01	0.90	47.30	6.20	47.44	6.35	48.17	7.08
321.20	149.79	149.79	149.79	149.79	149.79	149.79	155.01	155.01	155.01	155.01	155.01	155.01	171.50	171.50	171.50	171.50	171.50	171.50	4.73	0.63	4.78	0.68	5.00	0.90	47.24	6.23	47.38	6.38	48.12	7.11
321.10	149.60	149.60	149.60	149.60	149.60	149.60	154.84	154.84	154.84	154.84	154.84	154.84	171.43	171.43	171.43	171.43	171.43	171.43	4.72	0.63	4.77	0.68	5.00	0.91	47.17	6.26	47.32	6.41	48.05	7.14
321.00	149.33	149.33	149.33	149.33	149.33	149.33	154.61	154.61	154.61	154.61	154.61	154.61	171.30	171.30	171.30	171.30	171.30	171.30	4.72	0.64	4.76	0.68	4.99	0.91	47.08	6.29	47.23	6.43	47.97	7.17
320.90	148.93	148.93	148.93	148.93	148.93	148.93	154.24	154.24	154.24	154.24	154.24	154.24	171.03	171.03	171.03	171.03	171.03	171.03	4.70	0.64	4.75	0.68	4.98	0.91	46.95	6.31	47.10	6.45	47.84	7.19
320.80	148.59	148.59	148.59	148.59	148.59	148.59	153.93	153.93	153.93	153.93	153.93	153.93	170.82	170.82	170.82	170.82	170.82	170.82	4.69	0.64	4.74	0.69	4.97	0.92	46.83	6.33	46.98	6.48	47.73	7.22
320.70	148.16	148.16	148.16	148.16	148.16	148.16	153.53	153.53	153.53	153.53	153.53	153.53	170.51	170.51	170.51	170.51	170.51	170.51	4.68	0.64	4.72	0.69	4.95	0.92	46.69	6.34	46.84	6.49	47.59	7.24
320.60	147.78	147.78	147.78	147.78	147.78	147.78	153.18	153.18	153.18	153.18	153.18	153.18	170.26	170.26	170.26	170.26	170.26	170.26	4.66	0.64	4.71	0.69	4.94	0.92	46.57	6.36	46.72	6.51	47.46	7.26
320.50	147.40	147.40	147.40	147.40	147.40	147.40	152.83	152.83	152.83	152.83	152.83	152.83	170.01	170.01	170.01	170.01	170.01	170.01	4.65	0.65	4.70	0.69	4.93	0.93	46.44	6.38	46.59	6.53	47.34	7.28
320.40	146.91	146.91	146.91	146.91	146.91	146.91	152.38	152.38	152.38	152.38	152.38	152.38	169.65	169.65	169.65	169.65	169.65	169.65	4.64	0.65	4.68	0.69	4.92	0.93	46.28	6.40	46.43	6.55	47.18	7.30
320.30	146.36	146.36	146.36	146.36	146.36	146.36	151.86	151.86	151.86	151.86	151.86	151.86	169.23	169.23	169.23	169.23	169.23	169.23	4.62	0.65	4.66	0.70	4.90	0.93	46.10	6.41	46.25	6.56	47.00	7.31
320.20	145.73	145.73	145.73	145.73	145.73	145.73	151.26	151.26	151.26	151.26	151.26	151.26	168.73	168.73	168.73	168.73	168.73	168.73	4.60	0.65	4.64	0.70	4.88	0.93	45.89	6.42	46.04	6.57	46.80	7.32
320.10	145.23	145.23	145.23	145.23	145.23	145.23	150.78	150.78	150.78	150.78	150.78	150.78	168.36	168.36	168.36	168.36	168.36	168.36	4.58	0.65	4.63	0.70	4.86	0.93	45.73	6.43	45.88	6.58	46.63	7.34
320.00	144.72	144.72	144.72	144.72	144.72	144.72	150.30	150.30	150.30	150.30	150.30	150.30	167.97	167.97	167.97	167.97	167.97	167.97	4.56	0.65	4.61	0.70	4.85	0.93	45.56	6.44	45.71	6.59	46.47	7.35
319.90	144.29	144.29	144.29	144.29	144.29	144.29	149.91	149.91	149.91	149.91	149.91	149.91	167.68	167.68	167.68	167.68	167.68	167.68	4.55	0.65	4.60	0.70	4.83	0.94	45.42	6.46	45.57	6.61	46.33	7.37
319.80	143.85	143.85	143.85	143.85	143.85	143.85	149.50	149.50	149.50	149.50	149.50	149.50	167.37	167.37	167.37	167.37	167.37	167.37	4.54	0.66	4.58	0.70	4.82	0.94	45.27	6.47	45.42	6.62	46.19	7.39
319.70	143.48	143.48	143.48	143.48	143.48	143.48	149.16	149.16	149.16	149.16	149.16	149.16	167.12	167.12	167.12	167.12	167.12	167.12	4.52	0.66	4.57	0.70	4.81	0.94	45.15	6.49	45.30	6.64	46.06	7.41
319.60	143.18	143.18	143.18	143.18	143.18	143.18	148.89	148.89	148.89	148.89	148.89	148.89	166.95	166.95	166.95	166.95	166.95	166.95	4.51	0.66	4.56	0.71	4.80	0.94	45.05	6.51	45.20	6.66	45.97	7.43
319.50	142.93	142.93	142.93	142.93	142.93	142.93	148.68	148.68	148.68	148.68	148.68	148.68	166.84	166.84	166.84	166.84	166.84	166.84	4.50	0.66	4.55	0.71	4.79	0.95	44.96	6.53	45.12	6.69	45.89	7.46
319.40	142.72	142.72	142.72	142.72	142.72	142.72	148.49	148.49	148.49	148.49	148.49	148.49	166.75	166.75	166.75	166.75	166.75	166.75	4.50	0.66	4.55	0.71	4.78	0.95	44.89	6.56	45.04	6.71	45.82	7.49
319.30	142.49	142.49	142.49	142.49	142.49	142.49	148.29	148.29	148.29	148.29	148.29	148.29	166.65	166.65	166.65	166.65	166.65	166.65	4.49	0.67	4.54	0.71	4.78	0.96	44.81	6.58	44.97	6.74	45.74	7.51
319.20	142.26	142.26	142.26	142.26	142.26	142.26	148.10	148.10	148.10	148.10	148.10	148.10	166.55	166.55	166.55	166.55	166.55	166.55	4.48	0.67	4.53	0.72	4.77	0.96	44.74	6.61	44.89	6.76	45.67	7.54
319.10	142.10	142.10	142.10	142.10	142.10	142.10	147.96	147.96	147.96	147.96	147.96	147.96	166.52	166.52	166.52	166.52	166.52	166.52	4.48	0.67	4.52	0.72	4.77	0.96	44.68	6.63	44.83	6.79	45.62	7.57
319.00	141.96	141.96	141.96	141.96	141.96	141.96	147.85	147.85	147.85	147.85	147.85	147.85	166.50	166.50	166.50	166.50	166.50	166.50	4.47	0.67	4.52	0.72	4.76	0.97	44.63	6.66	44.79	6.82	45.57	7.60
318.90	141.82	141.82	141.82	141.82	141.82	141.82	147.75	147.75	147.75	147.75	147.75	147.75	166.50	166.50	166.50	166.50	166.50	166.50	4.47	0.68	4.52	0.73	4.76	0.97	44.58	6.69	44.74	6.85	45.53	7.64
318.80	141.70	141.70	141.70	141.70	141.70	141.70	147.66	147.66	147.66	147.66	147.66	147.66	166.51	166.51	166.51	166.51	166.51	166.51	4.46	0.68	4.51	0.73	4.76	0.97	44.54	6.72	44.70	6.87	45.49	7.67
318.70	141.58	141.58	141.58	141.58	141.58	141.58	147.57	147.57	147.57	147.57	147.57	147.57	166.52	166.52	166.52	166.52	166.52	166.52	4.46	0.68	4.51	0.73	4.75	0.98	44.49	6.74	44.65	6.90	45.45	7.70
318.60	141.47	141.47	141.47	141.47	141.47	141.47	147.49	147.49	147.49	147.49	147.49	147.49	166.54	166.54	166.54	166.54	166.54	166.54	4.45	0.69	4.50	0.74	4.75	0.98	44.46	6.77	44.62	6.93	45.42	7.73
318.50	141.37	141.37	141.37	141.37	141.37	141.37	147.42	147.42	147.42	147.42	147.42	147.42	166.56	166.56	166.56	166.56	166.56	166.56	4.45	0.69	4.50	0.74	4.75	0.99	44.42	6.80	44.58	6.96	45.38	7.77
318.40	141.27	141.27	141.27	141.27	141.27	141.27	147.35	147.35	147.35	147.35	147.35	147.35	166.59	166.59	166.59	166.59	166.59	166.59	4.45	0.69	4.50	0.74	4.75	0.99	44.38	6.83	44.54	6.99	45.35	7.80
318.30	141.17	141.17	141.17	141.17	141.17	141.17	147.28	147.28	147.28	147.28	147.28	147.28	166.62	166.62	166.62	166.62	166.62	166.62	4.44	0.69	4.49	0.74	4.74	1.00	44.35	6.86	44.51	7.02	45.32	7.83
318.20	141.07	141.07	141.07	141.07	141.07	141.07	147.22	147.22	147.22	147.22	147.22	147.22	166.66	166.66	166.66	166.66	166.66	166.66	4.44	0.70	4.49	0.75	4.74	1.00	44.31	6.89	44.47	7.05	45.29	7.87
318.10	140.98	140.98	140.98	140.98	140.98	140.98	147.15	147.15	147.15	147.15	147.15	147.15	166.69	166.69	166.69	166.69	166.69	166.69	4.44	0.70	4.49	0.75	4.74	1.00	44.27	6.92	44.44	7.08	45.26	7.90
318.00	140.88	140.88	140.88	140.88	140.88	140.88	147.09	147.09	147.09	147.09	147.09	147.09	166.72	166.72	166.72	166.72	166.72	166.72	4.43	0.70	4.48	0.75	4.74	1.01	44.24	6.95	44.40	7.11	45.23	7.94
317.90	140.79	140.79	140.79	140.79	140.79	140.79	147.03	147.03	147.03	147.03	147.03	147.03	166.76	166.76	166.76	166.76	166.76	166.76	4.43	0.71	4.48	0.76	4.74	1.01	44.21	6.98	44.37	7.14	45.20	7.97
317.80	140.71	140.71	140.71	140.71	140.71	140.71	146.98	146.98	146.98	146.98	146.98	146.98	166.81	166.81	166.81	166.81	166.81	166.81	4.43	0.71	4.48	0.76	4.73	1.02	44.18	7.01	44.34	7.17	45.17	8.00
317.70	140.63	140.63	140.63	140.63	140.63	140.63	146.93	146.93	146.93	146.93	146.93	146.93	166.85	166.85	166.85	166.85	166.85	166.85	4.42	0.71	4.47	0.76	4.73	1.02	44.14	7.04	44.31	7.20	45.14	8.04
317.60	140.54	140.54	140.54	140.54	140.54	140.54	146.87	146.87	146.87	146.87	146.87	146.87	166.90	166.90	166.90	166.90	166.90	166.90	4.42	0.72	4.47	0.77	4.73	1.03	44.11	7.07	44.28	7.23	45.12	8.07
317.50	140.45	140.45	140.45	140.45	140.45	140.45	146.82	146.82	146.82	146.82	146.82	146.82	166.94	166.94	166.94	166.94	166.94	166.94	4.42	0.72	4.47	0.77	4.73	1.03	44.08	7.10	44.25	7.27	45.09	8.11
317.40	140.38	140.38	140.38	140.38	140.38	140.38	146.77	146.77	146.77	146.77	146.77	146.77	166.99	166.99	166.99	166.99	166.99	166.99	4.41	0.72	4.47	0.77	4.73	1.03	44.05	7.13	44.22	7.30	45.06	8.14
317.30	140.30	140.30	140.30	140.30	140.30	140.30	146.72	146.72	146.72	146.72	146.72	146.72	167.04	167.04	167.04	167.04	167.04	167.04	4.41	0.72	4.46	0.78	4.73	1.04	44.02	7.16	44.19	7.33	45.04	8.17
317.20	140.22	140.22	140.22	140.22	140.22	140.22	146.68	146.68	146.68	146.68	146.68	146.68	167.10	167.10	167.10	167.10	167.10	167.10	4.41	0.73	4.46	0.78	4.72	1.04	43.99	7.19	44.16	7.36	45.01	8.21
317.10	140.15	140.15	140.15	140.15	140.15	140.15	146.64	146.64	146.64	146.64	146.64	146.64	167.15	167.15	167.15	167.15	167.15	167.15	4.41	0.73	4.46	0.78	4.72	1.05	43.97	7.22	44.14	7.39	44.99	8.24
317.00	140.07	140.07	140.07	140.07	140.07	140.07	146.59	146.59	146.59	146.59	146.59	146.59	167.20	167.20	167.20	167.20	167.20	167.20	4.40	0.73	4.46	0.79	4.72	1.05	43.94	7.25	44.11	7.42	44.97	8.28
316.90	140.00	140.00	140.00	140.00	140.00	140.00	146.55	146.55	146.55	146.55	146.55	146.55	167.26	167.26	167.26	167.26	167.26	167.26	4.40	0.74	4.45	0.79	4.72	1.06	43.91	7.28	44.08	7.45	44.94	8.31
316.80	139.93	139.93	139.93	139.93	139.93	139.93	146.51	146.51	146.51	146.51	146.51	146.51	167.32	167.32	167.32	167.32	167.32	167.32	4.40	0.74	4.45	0.79	4.72	1.06	43.88	7.31	44.05	7.48	44.92	8.34
316.70	139.86	139.86	139.86	139.86	139.86	139.86	146.47	146.47	146.47	146.47	146.47	146.47	167.38	167.38	167.38	167.38	167.38	167.38	4.39	0.74	4.45	0.80	4.72	1.06	43.86	7.34	44.03	7.51	44.90	8.38
316.60	139.79	139.79	139.79	139.79	139.79	139.79	146.44	146.44	146.44	146.44	146.44	146.44	167.44	167.44	167.44	167.44	167.44	167.44	4.39	0.75	4.45	0.80	4.72	1.07	43.83	7.37	44.00	7.54	44.88	8.41
316.50	139.73	139.73	139.73	139.73	139.73	139.73	146.40	146.40	146.40	146.40	146.40	146.40	167.51	167.51	167.51	167.51	167.51	167.51	4.39	0.75	4.44	0.80	4.71	1.07	43.81	7.40	43.98	7.57	44.86	8.45
316.40	139.67	139.67	139.67	139.67	139.67	139.67	146.37	146.37	146.37	146.37	146.37	146.37	167.58	167.58	167.58	167.58	167.58	167.58	4.39	0.75	4.44	0.81	4.71	1.08	43.78	7.43	43.96	7.60	44.84	8.48
316.30	139.61	139.61	139.61	139.61	139.61	139.61	146.34	146.34	146.34	146.34	146.34	146.34	167.64	167.64	167.64	167.64	167.64	167.64	4.38	0.75	4.44	0.81	4.71	1.08	43.76	7.46	43.93	7.63	44.82	8.52
316.20	139.55	139.55	139.55	139.55	139.55	139.55	146.31	146.31	146.31	146.31	146.31	146.31	167.71	167.71	167.71	167.71	167.71	167.71	4.38	0.76	4.44	0.81	4.71	1.09	43.73	7.49	43.91	7.66	44.80	8.55
316.10	139.49	139.49	139.49	139.49	139.49	139.49	146.28	146.28	146.28	146.28	146.28	146.28	167.78	167.78	167.78	167.78	167.78	167.78	4.38	0.76	4.44	0.82	4.71	1.09	43.

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)
313.90	138.01	138.01	138.01	138.01	138.01	138.01	145.49	145.49	145.49	145.49	145.49	145.49	169.14	169.14	169.14	169.14	169.14	169.14	4.32	0.83	4.38	0.89	4.68	1.19	43.14	8.16	43.33	8.36	44.31	9.33
313.80	137.94	137.94	137.94	137.94	137.94	137.94	145.45	145.45	145.45	145.45	145.45	145.45	169.21	169.21	169.21	169.21	169.21	169.21	4.32	0.83	4.38	0.89	4.68	1.19	43.11	8.19	43.31	8.39	44.28	9.36
313.70	137.88	137.88	137.88	137.88	137.88	137.88	145.42	145.42	145.42	145.42	145.42	145.42	169.28	169.28	169.28	169.28	169.28	169.28	4.32	0.83	4.38	0.89	4.68	1.19	43.09	8.22	43.28	8.42	44.26	9.40
313.60	137.82	137.82	137.82	137.82	137.82	137.82	145.39	145.39	145.39	145.39	145.39	145.39	169.34	169.34	169.34	169.34	169.34	169.34	4.32	0.84	4.38	0.90	4.68	1.20	43.06	8.25	43.26	8.45	44.25	9.43
313.50	137.76	137.76	137.76	137.76	137.76	137.76	145.36	145.36	145.36	145.36	145.36	145.36	169.41	169.41	169.41	169.41	169.41	169.41	4.31	0.84	4.38	0.90	4.68	1.20	43.04	8.28	43.24	8.48	44.23	9.46
313.40	137.70	137.70	137.70	137.70	137.70	137.70	145.33	145.33	145.33	145.33	145.33	145.33	169.48	169.48	169.48	169.48	169.48	169.48	4.31	0.84	4.37	0.90	4.68	1.21	43.02	8.31	43.21	8.51	44.21	9.50
313.30	137.64	137.64	137.64	137.64	137.64	137.64	145.30	145.30	145.30	145.30	145.30	145.30	169.55	169.55	169.55	169.55	169.55	169.55	4.31	0.84	4.37	0.91	4.68	1.21	42.99	8.34	43.19	8.54	44.19	9.53
313.20	137.58	137.58	137.58	137.58	137.58	137.58	145.28	145.28	145.28	145.28	145.28	145.28	169.62	169.62	169.62	169.62	169.62	169.62	4.31	0.85	4.37	0.91	4.68	1.22	42.97	8.37	43.17	8.57	44.17	9.57
313.10	137.52	137.52	137.52	137.52	137.52	137.52	145.25	145.25	145.25	145.25	145.25	145.25	169.69	169.69	169.69	169.69	169.69	169.69	4.31	0.85	4.37	0.91	4.67	1.22	42.95	8.40	43.15	8.60	44.15	9.60
313.00	137.46	137.46	137.46	137.46	137.46	137.46	145.22	145.22	145.22	145.22	145.22	145.22	169.76	169.76	169.76	169.76	169.76	169.76	4.30	0.85	4.36	0.91	4.67	1.22	42.92	8.43	43.12	8.63	44.13	9.63
312.90	137.39	137.39	137.39	137.39	137.39	137.39	145.18	145.18	145.18	145.18	145.18	145.18	169.82	169.82	169.82	169.82	169.82	169.82	4.30	0.86	4.36	0.92	4.67	1.23	42.90	8.45	43.10	8.66	44.11	9.67
312.80	137.33	137.33	137.33	137.33	137.33	137.33	145.15	145.15	145.15	145.15	145.15	145.15	169.89	169.89	169.89	169.89	169.89	169.89	4.30	0.86	4.36	0.92	4.67	1.23	42.87	8.48	43.07	8.69	44.09	9.70
312.70	137.26	137.26	137.26	137.26	137.26	137.26	145.11	145.11	145.11	145.11	145.11	145.11	169.95	169.95	169.95	169.95	169.95	169.95	4.30	0.86	4.36	0.92	4.67	1.24	42.85	8.51	43.05	8.72	44.07	9.73
312.60	137.20	137.20	137.20	137.20	137.20	137.20	145.08	145.08	145.08	145.08	145.08	145.08	170.02	170.02	170.02	170.02	170.02	170.02	4.29	0.86	4.36	0.93	4.67	1.24	42.82	8.54	43.03	8.74	44.05	9.76
312.50	137.13	137.13	137.13	137.13	137.13	137.13	145.05	145.05	145.05	145.05	145.05	145.05	170.08	170.08	170.08	170.08	170.08	170.08	4.29	0.87	4.35	0.93	4.67	1.24	42.80	8.57	43.00	8.77	44.03	9.80
312.40	137.07	137.07	137.07	137.07	137.07	137.07	145.02	145.02	145.02	145.02	145.02	145.02	170.15	170.15	170.15	170.15	170.15	170.15	4.29	0.87	4.35	0.93	4.67	1.25	42.77	8.60	42.98	8.80	44.00	9.83
312.30	137.00	137.00	137.00	137.00	137.00	137.00	144.98	144.98	144.98	144.98	144.98	144.98	170.21	170.21	170.21	170.21	170.21	170.21	4.29	0.87	4.35	0.94	4.67	1.25	42.75	8.63	42.95	8.83	43.98	9.86
312.20	136.93	136.93	136.93	136.93	136.93	136.93	144.94	144.94	144.94	144.94	144.94	144.94	170.26	170.26	170.26	170.26	170.26	170.26	4.28	0.88	4.35	0.94	4.66	1.26	42.72	8.65	42.92	8.86	43.96	9.89
312.10	136.86	136.86	136.86	136.86	136.86	136.86	144.90	144.90	144.90	144.90	144.90	144.90	170.32	170.32	170.32	170.32	170.32	170.32	4.28	0.88	4.34	0.94	4.66	1.26	42.69	8.68	42.90	8.89	43.94	9.93
312.00	136.78	136.78	136.78	136.78	136.78	136.78	144.85	144.85	144.85	144.85	144.85	144.85	170.38	170.38	170.38	170.38	170.38	170.38	4.28	0.88	4.34	0.95	4.66	1.27	42.66	8.71	42.87	8.92	43.91	9.96
311.90	136.71	136.71	136.71	136.71	136.71	136.71	144.81	144.81	144.81	144.81	144.81	144.81	170.44	170.44	170.44	170.44	170.44	170.44	4.27	0.88	4.34	0.95	4.66	1.27	42.64	8.74	42.84	8.95	43.89	9.99
311.80	136.64	136.64	136.64	136.64	136.64	136.64	144.77	144.77	144.77	144.77	144.77	144.77	170.49	170.49	170.49	170.49	170.49	170.49	4.27	0.89	4.34	0.95	4.66	1.27	42.61	8.77	42.82	8.97	43.86	10.02
311.70	136.56	136.56	136.56	136.56	136.56	136.56	144.72	144.72	144.72	144.72	144.72	144.72	170.54	170.54	170.54	170.54	170.54	170.54	4.27	0.89	4.33	0.95	4.66	1.28	42.58	8.79	42.79	9.00	43.84	10.05
311.60	136.48	136.48	136.48	136.48	136.48	136.48	144.67	144.67	144.67	144.67	144.67	144.67	170.59	170.59	170.59	170.59	170.59	170.59	4.27	0.89	4.33	0.96	4.65	1.28	42.55	8.82	42.76	9.03	43.81	10.09
311.50	136.40	136.40	136.40	136.40	136.40	136.40	144.63	144.63	144.63	144.63	144.63	144.63	170.64	170.64	170.64	170.64	170.64	170.64	4.26	0.90	4.33	0.96	4.65	1.29	42.52	8.85	42.73	9.06	43.79	10.12
311.40	136.32	136.32	136.32	136.32	136.32	136.32	144.57	144.57	144.57	144.57	144.57	144.57	170.68	170.68	170.68	170.68	170.68	170.68	4.26	0.90	4.32	0.96	4.65	1.29	42.49	8.87	42.70	9.09	43.76	10.15
311.30	136.23	136.23	136.23	136.23	136.23	136.23	144.52	144.52	144.52	144.52	144.52	144.52	170.73	170.73	170.73	170.73	170.73	170.73	4.26	0.90	4.32	0.97	4.65	1.29	42.46	8.90	42.67	9.11	43.73	10.18
311.20	136.14	136.14	136.14	136.14	136.14	136.14	144.45	144.45	144.45	144.45	144.45	144.45	170.76	170.76	170.76	170.76	170.76	170.76	4.25	0.90	4.32	0.97	4.65	1.30	42.42	8.93	42.63	9.14	43.70	10.21
311.10	136.02	136.02	136.02	136.02	136.02	136.02	144.37	144.37	144.37	144.37	144.37	144.37	170.77	170.77	170.77	170.77	170.77	170.77	4.25	0.91	4.31	0.97	4.64	1.30	42.38	8.95	42.59	9.16	43.66	10.24
311.00	135.89	135.89	135.89	135.89	135.89	135.89	144.28	144.28	144.28	144.28	144.28	144.28	170.78	170.78	170.78	170.78	170.78	170.78	4.24	0.91	4.31	0.97	4.64	1.30	42.33	8.97	42.55	9.19	43.62	10.26
310.90	135.78	135.78	135.78	135.78	135.78	135.78	144.19	144.19	144.19	144.19	144.19	144.19	170.79	170.79	170.79	170.79	170.79	170.79	4.24	0.91	4.31	0.98	4.64	1.31	42.29	9.00	42.51	9.21	43.59	10.29
310.80	135.63	135.63	135.63	135.63	135.63	135.63	144.08	144.08	144.08	144.08	144.08	144.08	170.78	170.78	170.78	170.78	170.78	170.78	4.24	0.91	4.30	0.98	4.63	1.31	42.24	9.02	42.46	9.24	43.54	10.32
310.70	135.47	135.47	135.47	135.47	135.47	135.47	143.95	143.95	143.95	143.95	143.95	143.95	170.75	170.75	170.75	170.75	170.75	170.75	4.23	0.92	4.30	0.98	4.63	1.31	42.19	9.04	42.40	9.26	43.49	10.34
310.60	135.31	135.31	135.31	135.31	135.31	135.31	143.81	143.81	143.81	143.81	143.81	143.81	170.71	170.71	170.71	170.71	170.71	170.71	4.22	0.92	4.29	0.98	4.62	1.32	42.13	9.06	42.34	9.28	43.43	10.37
310.50	135.09	135.09	135.09	135.09	135.09	135.09	143.63	143.63	143.63	143.63	143.63	143.63	170.63	170.63	170.63	170.63	170.63	170.63	4.22	0.92	4.28	0.99	4.62	1.32	42.06	9.08	42.27	9.30	43.36	10.39
310.40	134.75	134.75	134.75	134.75	134.75	134.75	143.32	143.32	143.32	143.32	143.32	143.32	170.41	170.41	170.41	170.41	170.41	170.41	4.21	0.92	4.27	0.99	4.61	1.32	41.94	9.09	42.16	9.31	43.25	10.40
310.30	134.34	134.34	134.34	134.34	134.34	134.34	142.94	142.94	142.94	142.94	142.94	142.94	170.13	170.13	170.13	170.13	170.13	170.13	4.19	0.92	4.26	0.99	4.59	1.32	41.80	9.09	42.02	9.31	43.11	10.40
310.20	133.80	133.80	133.80	133.80	133.80	133.80	142.43	142.43	142.43	142.43	142.43	142.43	169.72	169.72	169.72	169.72	169.72	169.72	4.17	0.92	4.24	0.99	4.57	1.32	41.63	9.09	41.85	9.30	42.94	10.39
310.10	133.12	133.12	133.12	133.12	133.12	133.12	141.78	141.78	141.78	141.78	141.78	141.78	169.17	169.17	169.17	169.17	169.17	169.17	4.15	0.92	4.22	0.98	4.55	1.32	41.40	9.07	41.62	9.29	42.71	10.38
310.00	132.60	132.60	132.60	132.60	132.60	132.60	141.29	141.29	141.29	141.29	141.29	141.29	168.78	168.78	168.78	168.78	168.78	168.78	4.13	0.92	4.20	0.98	4.53	1.32	41.23	9.06	41.45	9.28	42.54	10.37
309.90	132.08	132.08	132.08	132.08	132.08	132.08	140.81	140.81	140.81	140.81	140.81	140.81	168.39	168.39	168.39	168.39	168.39	168.39	4.12	0.92	4.18	0.98	4.52	1.32	41.06	9.06	41.28	9.28	42.37	10.37
309.80	131.69	131.69	131.69	131.69	131.69	131.69	140.44	140.44	140.44	140.44	140.44	140.44	168.12	168.12	168.12	168.12	168.12	168.12	4.10	0.92	4.17	0.98	4.50	1.32	40.93	9.06	41.15	9.28	42.24	10.37
309.70	131.27	131.27	131.27	131.27	131.27	131.27	140.06	140.06	140.06	140.06	140.06	140.06	167.84	167.84	167.84	167.84	167.84	167.84	4.09	0.92	4.16	0.98	4.49	1.32	40.79	9.06	41.01	9.28	42.10	10.37
309.60	130.64	130.64	130.64	130.64	130.64	130.64	139.45	139.45	139.45	139.45	139.45	139.45	167.33	167.33	167.33	167.33	167.33	167.33	4.07	0.92	4.14	0.98	4.47	1.32	40.59	9.05	40.80	9.27	41.89	10.36
309.50	129.71	129.71	129.71	129.71	129.71	129.71	138.56	138.56	138.56	138.56	138.56	138.56	166.53	166.53	166.53	166.53	166.53	166.53	4.04	0.91	4.11	0.98	4.44	1.31	40.28	9.01	40.50	9.23	41.59	10.32
309.40	128.85	128.85	128.85	128.85	128.85	128.85	137.73	137.73	137.73	137.73	137.73	137.73	165.80	165.80	165.80	165.80	165.80	165.80	4.01	0.91	4.08	0.98	4.41	1.31	40.00	8.98	40.22	9.20	41.30	10.28
309.30	128.55	128.55	128.55	128.55	128.55	128.55	137.45	137.45	137.45	137.45	137.45	137.45	165.63	165.63	165.63	165.63	165.63	165.63	4.00	0.91	4.07	0.98	4.40	1.31	39.90	8.99	40.12	9.21	41.20	10.29
309.20	128.30	128.30	128.30	128.30	128.30	128.30	137.24	137.24	137.24	137.24	137.24	137.24	165.51	165.51	165.51	165.51	165.51	165.51	3.99	0.91	4.06	0.98	4.39	1.31	39.82	9.00	40.04	9.22	41.12	10.31
309.10	128.14	128.14	128.14	128.14	128.14	128.14	137.12	137.12	137.12	137.12	137.12	137.12	165.48	165.48	165.48	165.48	165.48	165.48	3.99	0.91	4.05	0.98	4.39	1.31	39.76	9.02	39.98	9.24	41.07	10.33
309.00	128.03	128.03	128.03	128.03	128.03	128.03	137.03	137.03	137.03	137.03	137.03	137.03	165.50	165.50	165.50	165.50	165.50	165.50	3.98	0.92	4.05	0.98	4.38	1.32	39.72	9.04	39.94	9.26	41.03	10.35
308.90	127.92	127.92	127.92	127.92	127.92	127.92	136.95	136.95	136.95	136.95	136.95	136.95	165.52	165.52	165.52	165.52	165.52	165.52	3.98	0.92	4.05	0.98	4.38	1.32	39.68	9.07	39.90	9.29	41.00	10.38
308.80	127.82	127.82	127.82	127.82	127.82	127.82	136.88	136.88	136.88	136.88	136.88	136.88	165.54	165.54	165.54	165.54	165.54	165.54	3.98	0.92	4.04	0.99	4.38	1.32	39.65	9.09	39.87	9.31	40.96	10.40
308.70	127.71	127.71	127.71	127.71	127.71	127.71	136.81	136.81	136.81	136.81	136.81	136.81	165.57	165.57	165.57	165.57	165.57	165.57	3.97	0.92	4.04	0.99	4.37	1.32	39.61	9.11	39.83	9.33	40.93	10.43
308.60	127.61	127.61	127.61	127.61	127.61	127.61	136.74	136.74	136.74	136.74	136.74	136.74	165.60	165.60	165.60	165.60	165.60	165.60	3.97	0.92	4.04	0.99	4.37	1.33	39.57	9.13	39.79	9.35	40.89	10.46
308.50	127.52	127.52	127.52	127.52	127.52	127.52	136.68	136.68	136.68	136.68	136.68	136.68	165.63	165.63	165.63	165.63	165.63	165.63	3.97	0.93	4.03	0.99	4.37	1.33	39.54	9.16	39.76	9.38	40.86	10.48
308.40	127.43	127.43	127.43	127.43	127.43	127.43	136.62	136.62	136.62	136.62	136.62	136.62	165.68	165.68	165.68	165.68	165.68	165.68	3.96	0.93	4.03	1.00	4.37	1.34	39.51	9.18	39.73	9.40	40.84	10.51
308.30	127.35	127.35	127.35	127.35	127.35	127.35	136.57	136.57	136.57	136.57	136.57	136.57	165.72	165.72	165.72	165.72	165.72	165.72	3.96	0.93	4.03	1.00	4.37	1.34	39.47	9.20	39.70	9.43	40.81	10.54
308.20	127.26	127.26	127.26	127.26	127.26	127.26	136.51	136.51	136.51	136.51	136.51	136.51	165.77	165.77	165.77	165.77	165.77	165.77	3.96	0.93	4.02	1.00	4.36	1.34	39.44	9.23	39.67	9.45	40.78	10.57
308.10	127.18	127.18	127.18	127.18	127.18	127.18	136.46	136.46	136.46	136.46	136.46	136.46	165.81	165.81	165.81	165.81	165.81	165.81	3.95	0.94	4.02	1.00	4.36	1.35	39.41	9.25	39.64	9.48	40.75	10.59
308.00	127.10	127.10	127.10	127.10	127.10	127.10	136.41	136.41	136.41	136.41	136.41	136.41	165.86	165.86	165.86	165.86	165.86	165.86	3.95	0.94	4.02	1.01	4.36	1.35	39.38	9.28	39.61	9.50	40.73	10.62
307.90	127.02	127.02	127.02	127.02	127.02	127.02	136.36	136.36	136.36	136.36	136.36	136.36	165.91	165.91	165.91	165.91	165.91	165.91	3.95	0.94	4.02	1.01	4.36	1.35	39.35	9.30	39.57	9.52	40.70	10.65
307.80	126.93	126.93	126.93	126.93	126.93	126.93	136.30	136.30	136.30	136.30	136.30	136.30	165.95	165.95	165.95	165.95	165.95	165.95	3.94	0.94	4.01	1.01	4.36	1.36	39.32	9.32	39.54	9.55	40.67	10.67
307.70	126.84	126.84	126.84	126.84	126.84	126.84	136.25	136.25	136.25	136.25	136.25	136.25	165.99	165.99	165.99	165.99	165.99	165.99	3.94	0.95	4.01	1.01	4.35	1.36	39.29	9.35	39.51	9.57	40.64	10.70
307.60	126.76	126.76	126.76	126.76	126.76	126.76	136.20	136.20	136.20	136.20	136.20	136.20	166.04	166.04	166.04	166.04	166.04	166.04	3.94	0.95	4.01	1.02	4.35	1.36	39.25	9.37	39.48	9.60	40.61	10.73
307.50	126.68	126.68	126.68	126.68	126.68	126.68	136.15	136.15	136.15	136.15	136.15	136.15	166.09	166.09	166.09	166.09	166.09	166.09	3.93	0.95	4.00	1.02	4.35	1.37	39.22	9.39	39.45	9.62	40.59	10.76
307.40	126.60	126.60	126.60	126.60	126.60	126.60	136.10	136.10	136.10	136.10	136.10	136.10	166.14	166.14	166.14	166.14	166.14	166.14	3.93	0.95	4.00	1.02	4.35	1.37	39.20	9.42	39.42	9.64	40.56	10.78
307.30	126.53	126.53	126.53	126.53	126.53	126.53	136.06	136.06	136.06	136.06	136.06	136.06	166.20	166.20	166.20	166.20	166.20	166.20	3.93	0.96	4.00	1.03	4.35	1.37	39.17	9.44	39.40	9.67	40.54	10.81
307.20	126.45	126.45	126.45	126.45	126.45	126.45	136.01	136.01	136.01	136.01	136.01	136.01	166.25	166.25	166.25	166.25	166.25	166.25	3.93	0.96	4.00	1.03	4.34	1.38	39.14	9.46	39.37	9.69	40.51	10.84
307.10	126.38	126.38	126.38	126.38	126.38	126.38	135.97	135.97	135.97	135.97	135.97	135.97	166.30	166.30	166.30	166.30	166.30	166.30	3.92	0.96	3.99	1.03	4.34	1.38	39.11	9.49	39.34	9.72	40.49	10.87
307.00	126.30	126.30	126.30	126.30	126.30	126.30	135.92	135.92	135.92	135.92	135.92	135.92	166.35	166.35	166.35	166.35	166.35	166.35	3.92	0.96	3.99	1.03	4.34	1.38	39.08	9.51	39.31	9.74	40.46	10.89
306.90	126.21	126.21	126.21	126.21	126.21	126.21	135.87	135.87	135.87	135.87	135.87	135.87	166.40	166.40	166.40	166.40	166.40	166.40	3.92	0.97	3.99	1.04	4.34	1.39	39.05	9.53	39.28	9.76	40.43	10.92
306.80	126.14	126.14	126.14	126.14	126.14	126.14	135.82	135.82	135.82	135.82	135.82	135.82	166.45	166.45	166.45	166.45	166.45	166.45	3.91	0.97	3.98	1.04	4.34	1.39	39.02	9.56	39.25	9.79	40.41	10.95
306.70	126.06	126.06	126.06	126.06	126.06	126.06	135.78	135.78	135.78	135.78	135.78	135.78	166.50	166.50	166.50	166.50	166.50	166.50	3.91	0.97	3.98	1.04	4.33	1.39	38.99	9.58	39.22	9.81	40.38	10.97
306.60	125.99	125.99	125.99	125.99	125.99	125.99	135.73	135.73	135.73	135.73	135.73	135.73	166.56	166.56	166.56	166.56	166.56	166.56	3.91	0.97	3.98	1.04	4.33	1.40	38.96	9.60	39.20	9.84	40.36	11.00
306.50	125.91	125.91	125.91	125.91	125.91	125.91	135.69	135.69	135.69	135.69	135.69	135.69	166.61	166.61	166.61	166.61	166.61	166.61	3.91	0.97	3.98	1.05	4.33	1.40	38.93	9.63	39.17	9.86	40.34	11.03
306.40	125.84	125.84	125.84	125.84	125.84	125.84	135.65	135.65	135.65	135.65	135.65	135.65	166.67	166.67	166.67	166.67	166.67	166.67	3.90	0.98	3.97	1.05	4.33	1.40	38.91	9.65	39.14	9.89	40.31	11.06
306.30	125.77	125.77	125.77	125.77	125.77	125.77	135.61	135.61	135.61	135.61	135.61	135.61	166.73	166.73	166.73	166.73	166.73	166.73	3.90	0.98	3.97	1.05	4.33	1.41	38.88	9.68	39.11	9.91	40.29	11.08
306.20	125.70	125.70	125.70	125.70	125.70	125.70	135.57	135.57	135.57	135.57	135.57	135.57	166.78	166.78	166.78	166.78	166.78	166.78	3.90	0.98	3.97	1.05	4.33	1.41	38.85	9.70	39.09	9.93	40.26	11.11
306.10	125.62	125.62	125.62	125.62	125.62	125.62	135.52	135.52	135.52	135.52	135.52	135.52	166.84	166.84	166.84	166.84	166.84	166.84	3.89	0.98	3.97	1.06	4.32	1.41	38.82	9.72	39.06	9.96	40.24	11.14
306.00	125.55	125.55	125.55	125.55	125.55	125.55	135.48	135.48	135.48	135.48	135.48	135.48	166.89	166.89	166.89	166.89	166.89	166.89	3.89	0.99	3.96	1.06	4.32	1.42	38.80	9.75	39.03	9.98	40.22	11.17
305.90	125.48	125.48	125.48	125.48	125.48	125.48	135.44	135.44	135.44	135.44	135.44	135.44	166.95	166.95	166.95	166.95	166.95	166.95	3.89	0.99	3.96	1.06	4.32	1.42	38.77	9.77	39.01	10.01	40.19	11.19

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
303.70	124.05	124.05	124.05	124.05	124.05	124.05	134.70	134.70	134.70	134.70	134.70	134.70	168.37	168.37	168.37	168.37	168.37	168.37	3.83	1.04	3.91	1.12	4.29	1.50	38.21	10.29	38.46	10.54	39.72	11.79
303.60	123.98	123.98	123.98	123.98	123.98	123.98	134.66	134.66	134.66	134.66	134.66	134.66	168.43	168.43	168.43	168.43	168.43	168.43	3.83	1.04	3.91	1.12	4.29	1.50	38.19	10.31	38.44	10.56	39.70	11.82
303.50	123.91	123.91	123.91	123.91	123.91	123.91	134.62	134.62	134.62	134.62	134.62	134.62	168.49	168.49	168.49	168.49	168.49	168.49	3.83	1.05	3.91	1.12	4.29	1.50	38.16	10.33	38.41	10.59	39.67	11.85
303.40	123.84	123.84	123.84	123.84	123.84	123.84	134.58	134.58	134.58	134.58	134.58	134.58	168.55	168.55	168.55	168.55	168.55	168.55	3.83	1.05	3.90	1.13	4.29	1.51	38.13	10.36	38.39	10.61	39.65	11.87
303.30	123.77	123.77	123.77	123.77	123.77	123.77	134.55	134.55	134.55	134.55	134.55	134.55	168.61	168.61	168.61	168.61	168.61	168.61	3.82	1.05	3.90	1.13	4.28	1.51	38.11	10.38	38.36	10.63	39.63	11.90
303.20	123.71	123.71	123.71	123.71	123.71	123.71	134.51	134.51	134.51	134.51	134.51	134.51	168.67	168.67	168.67	168.67	168.67	168.67	3.82	1.05	3.90	1.13	4.28	1.51	38.08	10.40	38.34	10.66	39.60	11.93
303.10	123.63	123.63	123.63	123.63	123.63	123.63	134.46	134.46	134.46	134.46	134.46	134.46	168.72	168.72	168.72	168.72	168.72	168.72	3.82	1.06	3.90	1.13	4.28	1.52	38.05	10.42	38.31	10.68	39.58	11.95
303.00	123.55	123.55	123.55	123.55	123.55	123.55	134.41	134.41	134.41	134.41	134.41	134.41	168.77	168.77	168.77	168.77	168.77	168.77	3.82	1.06	3.89	1.13	4.28	1.52	38.02	10.45	38.28	10.70	39.55	11.98
302.90	123.48	123.48	123.48	123.48	123.48	123.48	134.37	134.37	134.37	134.37	134.37	134.37	168.83	168.83	168.83	168.83	168.83	168.83	3.81	1.06	3.89	1.14	4.28	1.52	37.99	10.47	38.25	10.72	39.53	12.00
302.80	123.40	123.40	123.40	123.40	123.40	123.40	134.33	134.33	134.33	134.33	134.33	134.33	168.88	168.88	168.88	168.88	168.88	168.88	3.81	1.06	3.89	1.14	4.27	1.53	37.97	10.49	38.22	10.75	39.50	12.03
302.70	123.33	123.33	123.33	123.33	123.33	123.33	134.28	134.28	134.28	134.28	134.28	134.28	168.94	168.94	168.94	168.94	168.94	168.94	3.81	1.06	3.88	1.14	4.27	1.53	37.94	10.51	38.19	10.77	39.48	12.05
302.60	123.25	123.25	123.25	123.25	123.25	123.25	134.24	134.24	134.24	134.24	134.24	134.24	168.99	168.99	168.99	168.99	168.99	168.99	3.80	1.07	3.88	1.14	4.27	1.53	37.91	10.53	38.17	10.79	39.45	12.08
302.50	123.17	123.17	123.17	123.17	123.17	123.17	134.19	134.19	134.19	134.19	134.19	134.19	169.04	169.04	169.04	169.04	169.04	169.04	3.80	1.07	3.88	1.15	4.27	1.54	37.88	10.56	38.14	10.81	39.43	12.10
302.40	123.08	123.08	123.08	123.08	123.08	123.08	134.13	134.13	134.13	134.13	134.13	134.13	169.08	169.08	169.08	169.08	169.08	169.08	3.80	1.07	3.88	1.15	4.27	1.54	37.85	10.58	38.10	10.83	39.40	12.13
302.30	122.99	122.99	122.99	122.99	122.99	122.99	134.07	134.07	134.07	134.07	134.07	134.07	169.11	169.11	169.11	169.11	169.11	169.11	3.79	1.07	3.87	1.15	4.26	1.54	37.81	10.60	38.07	10.85	39.37	12.15
302.20	122.89	122.89	122.89	122.89	122.89	122.89	134.00	134.00	134.00	134.00	134.00	134.00	169.15	169.15	169.15	169.15	169.15	169.15	3.79	1.07	3.87	1.15	4.26	1.55	37.78	10.62	38.04	10.87	39.33	12.17
302.10	122.80	122.80	122.80	122.80	122.80	122.80	133.94	133.94	133.94	133.94	133.94	133.94	169.18	169.18	169.18	169.18	169.18	169.18	3.79	1.08	3.87	1.16	4.26	1.55	37.74	10.63	38.00	10.90	39.30	12.20
302.00	122.69	122.69	122.69	122.69	122.69	122.69	133.87	133.87	133.87	133.87	133.87	133.87	169.21	169.21	169.21	169.21	169.21	169.21	3.78	1.08	3.86	1.16	4.26	1.55	37.70	10.65	37.96	10.91	39.27	12.22
301.90	122.58	122.58	122.58	122.58	122.58	122.58	133.78	133.78	133.78	133.78	133.78	133.78	169.22	169.22	169.22	169.22	169.22	169.22	3.78	1.08	3.86	1.16	4.25	1.55	37.66	10.67	37.92	10.93	39.23	12.24
301.80	122.45	122.45	122.45	122.45	122.45	122.45	133.69	133.69	133.69	133.69	133.69	133.69	169.23	169.23	169.23	169.23	169.23	169.23	3.78	1.08	3.85	1.16	4.25	1.56	37.62	10.69	37.88	10.95	39.19	12.26
301.70	122.32	122.32	122.32	122.32	122.32	122.32	133.59	133.59	133.59	133.59	133.59	133.59	169.22	169.22	169.22	169.22	169.22	169.22	3.77	1.08	3.85	1.16	4.25	1.56	37.57	10.70	37.83	10.97	39.14	12.28
301.60	122.18	122.18	122.18	122.18	122.18	122.18	133.48	133.48	133.48	133.48	133.48	133.48	169.21	169.21	169.21	169.21	169.21	169.21	3.77	1.09	3.84	1.16	4.24	1.56	37.52	10.72	37.78	10.98	39.10	12.30
301.50	122.02	122.02	122.02	122.02	122.02	122.02	133.35	133.35	133.35	133.35	133.35	133.35	169.18	169.18	169.18	169.18	169.18	169.18	3.76	1.09	3.84	1.17	4.24	1.56	37.46	10.73	37.73	11.00	39.04	12.31
301.40	121.83	121.83	121.83	121.83	121.83	121.83	133.19	133.19	133.19	133.19	133.19	133.19	169.12	169.12	169.12	169.12	169.12	169.12	3.75	1.09	3.83	1.17	4.23	1.56	37.40	10.74	37.66	11.01	38.98	12.33
301.30	121.58	121.58	121.58	121.58	121.58	121.58	132.98	132.98	132.98	132.98	132.98	132.98	169.00	169.00	169.00	169.00	169.00	169.00	3.74	1.09	3.82	1.17	4.22	1.57	37.32	10.75	37.58	11.01	38.90	12.33
301.20	121.35	121.35	121.35	121.35	121.35	121.35	132.78	132.78	132.78	132.78	132.78	132.78	168.90	168.90	168.90	168.90	168.90	168.90	3.74	1.09	3.82	1.17	4.21	1.57	37.24	10.76	37.50	11.02	38.82	12.34
301.10	121.07	121.07	121.07	121.07	121.07	121.07	132.53	132.53	132.53	132.53	132.53	132.53	168.75	168.75	168.75	168.75	168.75	168.75	3.73	1.09	3.81	1.17	4.21	1.57	37.14	10.76	37.41	11.02	38.73	12.34
301.00	120.72	120.72	120.72	120.72	120.72	120.72	132.21	132.21	132.21	132.21	132.21	132.21	168.53	168.53	168.53	168.53	168.53	168.53	3.72	1.09	3.80	1.17	4.19	1.57	37.03	10.75	37.29	11.02	38.61	12.34
300.90	120.20	120.20	120.20	120.20	120.20	120.20	131.71	131.71	131.71	131.71	131.71	131.71	168.13	168.13	168.13	168.13	168.13	168.13	3.70	1.09	3.78	1.17	4.18	1.56	36.85	10.73	37.12	11.00	38.44	12.31
300.80	119.38	119.38	119.38	119.38	119.38	119.38	130.92	130.92	130.92	130.92	130.92	130.92	167.44	167.44	167.44	167.44	167.44	167.44	3.67	1.08	3.75	1.16	4.15	1.56	36.59	10.68	36.85	10.95	38.16	12.26
300.70	118.25	118.25	118.25	118.25	118.25	118.25	129.83	129.83	129.83	129.83	129.83	129.83	166.44	166.44	166.44	166.44	166.44	166.44	3.64	1.07	3.71	1.15	4.11	1.54	36.22	10.60	36.48	10.86	37.79	12.17
300.60	117.47	117.47	117.47	117.47	117.47	117.47	129.08	129.08	129.08	129.08	129.08	129.08	165.79	165.79	165.79	165.79	165.79	165.79	3.61	1.07	3.69	1.15	4.08	1.54	35.97	10.56	36.23	10.82	37.53	12.12
300.50	116.81	116.81	116.81	116.81	116.81	116.81	128.45	128.45	128.45	128.45	128.45	128.45	165.26	165.26	165.26	165.26	165.26	165.26	3.59	1.07	3.67	1.14	4.06	1.53	35.75	10.52	36.01	10.78	37.31	12.08
300.40	116.12	116.12	116.12	116.12	116.12	116.12	127.79	127.79	127.79	127.79	127.79	127.79	164.70	164.70	164.70	164.70	164.70	164.70	3.57	1.06	3.64	1.14	4.03	1.53	35.52	10.48	35.78	10.74	37.08	12.03
300.30	115.43	115.43	115.43	115.43	115.43	115.43	127.14	127.14	127.14	127.14	127.14	127.14	164.14	164.14	164.14	164.14	164.14	164.14	3.54	1.06	3.62	1.13	4.01	1.52	35.30	10.45	35.56	10.70	36.85	11.99
300.20	114.88	114.88	114.88	114.88	114.88	114.88	126.62	126.62	126.62	126.62	126.62	126.62	163.72	163.72	163.72	163.72	163.72	163.72	3.52	1.05	3.60	1.13	3.99	1.52	35.12	10.42	35.38	10.68	36.66	11.96
300.10	114.46	114.46	114.46	114.46	114.46	114.46	126.22	126.22	126.22	126.22	126.22	126.22	163.43	163.43	163.43	163.43	163.43	163.43	3.51	1.05	3.59	1.13	3.97	1.52	34.98	10.40	35.23	10.66	36.52	11.95
300.00	114.08	114.08	114.08	114.08	114.08	114.08	125.87	125.87	125.87	125.87	125.87	125.87	163.17	163.17	163.17	163.17	163.17	163.17	3.50	1.05	3.58	1.13	3.96	1.52	34.85	10.39	35.11	10.65	36.39	11.94
299.90	113.72	113.72	113.72	113.72	113.72	113.72	125.55	125.55	125.55	125.55	125.55	125.55	162.95	162.95	162.95	162.95	162.95	162.95	3.49	1.05	3.56	1.13	3.95	1.51	34.73	10.39	34.99	10.64	36.27	11.93
299.80	113.39	113.39	113.39	113.39	113.39	113.39	125.25	125.25	125.25	125.25	125.25	125.25	162.75	162.75	162.75	162.75	162.75	162.75	3.48	1.05	3.55	1.13	3.94	1.51	34.62	10.38	34.88	10.64	36.16	11.92
299.70	113.03	113.03	113.03	113.03	113.03	113.03	124.92	124.92	124.92	124.92	124.92	124.92	162.52	162.52	162.52	162.52	162.52	162.52	3.46	1.05	3.54	1.13	3.93	1.51	34.50	10.37	34.76	10.63	36.04	11.91
299.60	112.73	112.73	112.73	112.73	112.73	112.73	124.65	124.65	124.65	124.65	124.65	124.65	162.34	162.34	162.34	162.34	162.34	162.34	3.45	1.05	3.53	1.13	3.91	1.51	34.40	10.37	34.66	10.62	35.94	11.91
299.50	112.46	112.46	112.46	112.46	112.46	112.46	124.41	124.41	124.41	124.41	124.41	124.41	162.21	162.21	162.21	162.21	162.21	162.21	3.44	1.05	3.52	1.13	3.91	1.51	34.31	10.37	34.57	10.62	35.85	11.91
299.40	112.26	112.26	112.26	112.26	112.26	112.26	124.24	124.24	124.24	124.24	124.24	124.24	162.13	162.13	162.13	162.13	162.13	162.13	3.44	1.05	3.51	1.13	3.90	1.51	34.24	10.37	34.50	10.63	35.78	11.92
299.30	112.07	112.07	112.07	112.07	112.07	112.07	124.08	124.08	124.08	124.08	124.08	124.08	162.07	162.07	162.07	162.07	162.07	162.07	3.43	1.05	3.51	1.13	3.89	1.51	34.18	10.38	34.43	10.64	35.72	11.92
299.20	111.87	111.87	111.87	111.87	111.87	111.87	123.91	123.91	123.91	123.91	123.91	123.91	162.00	162.00	162.00	162.00	162.00	162.00	3.42	1.05	3.50	1.13	3.89	1.51	34.11	10.39	34.36	10.64	35.65	11.93
299.10	111.68	111.68	111.68	111.68	111.68	111.68	123.75	123.75	123.75	123.75	123.75	123.75	161.94	161.94	161.94	161.94	161.94	161.94	3.42	1.05	3.49	1.13	3.88	1.52	34.04	10.39	34.30	10.65	35.59	11.94
299.00	111.49	111.49	111.49	111.49	111.49	111.49	123.60	123.60	123.60	123.60	123.60	123.60	161.88	161.88	161.88	161.88	161.88	161.88	3.41	1.05	3.49	1.13	3.87	1.52	33.98	10.40	34.24	10.66	35.53	11.95
298.90	111.33	111.33	111.33	111.33	111.33	111.33	123.46	123.46	123.46	123.46	123.46	123.46	161.85	161.85	161.85	161.85	161.85	161.85	3.40	1.05	3.48	1.13	3.87	1.52	33.92	10.41	34.18	10.67	35.47	11.96
298.80	111.16	111.16	111.16	111.16	111.16	111.16	123.33	123.33	123.33	123.33	123.33	123.33	161.81	161.81	161.81	161.81	161.81	161.81	3.40	1.05	3.48	1.13	3.86	1.52	33.86	10.42	34.12	10.68	35.41	11.97
298.70	111.00	111.00	111.00	111.00	111.00	111.00	123.20	123.20	123.20	123.20	123.20	123.20	161.78	161.78	161.78	161.78	161.78	161.78	3.39	1.06	3.47	1.13	3.86	1.52	33.81	10.43	34.07	10.69	35.36	11.98
298.60	110.86	110.86	110.86	110.86	110.86	110.86	123.09	123.09	123.09	123.09	123.09	123.09	161.76	161.76	161.76	161.76	161.76	161.76	3.39	1.06	3.47	1.13	3.85	1.52	33.76	10.44	34.02	10.70	35.31	11.99
298.50	110.71	110.71	110.71	110.71	110.71	110.71	122.97	122.97	122.97	122.97	122.97	122.97	161.75	161.75	161.75	161.75	161.75	161.75	3.38	1.06	3.46	1.14	3.85	1.52	33.70	10.45	33.96	10.71	35.26	12.01
298.40	110.56	110.56	110.56	110.56	110.56	110.56	122.85	122.85	122.85	122.85	122.85	122.85	161.73	161.73	161.73	161.73	161.73	161.73	3.38	1.06	3.46	1.14	3.84	1.53	33.65	10.46	33.91	10.72	35.21	12.02
298.30	110.42	110.42	110.42	110.42	110.42	110.42	122.75	122.75	122.75	122.75	122.75	122.75	161.72	161.72	161.72	161.72	161.72	161.72	3.37	1.06	3.45	1.14	3.84	1.53	33.60	10.47	33.86	10.73	35.17	12.03
298.20	110.29	110.29	110.29	110.29	110.29	110.29	122.65	122.65	122.65	122.65	122.65	122.65	161.72	161.72	161.72	161.72	161.72	161.72	3.37	1.06	3.45	1.14	3.84	1.53	33.56	10.48	33.82	10.74	35.12	12.05
298.10	110.17	110.17	110.17	110.17	110.17	110.17	122.56	122.56	122.56	122.56	122.56	122.56	161.73	161.73	161.73	161.73	161.73	161.73	3.36	1.06	3.44	1.14	3.83	1.53	33.51	10.50	33.78	10.76	35.08	12.06
298.00	110.06	110.06	110.06	110.06	110.06	110.06	122.47	122.47	122.47	122.47	122.47	122.47	161.74	161.74	161.74	161.74	161.74	161.74	3.36	1.06	3.44	1.14	3.83	1.53	33.47	10.51	33.73	10.77	35.04	12.08
297.90	109.94	109.94	109.94	109.94	109.94	109.94	122.39	122.39	122.39	122.39	122.39	122.39	161.76	161.76	161.76	161.76	161.76	161.76	3.36	1.07	3.43	1.14	3.83	1.53	33.43	10.52	33.69	10.78	35.00	12.09
297.80	109.83	109.83	109.83	109.83	109.83	109.83	122.31	122.31	122.31	122.31	122.31	122.31	161.77	161.77	161.77	161.77	161.77	161.77	3.35	1.07	3.43	1.14	3.82	1.54	33.39	10.54	33.65	10.80	34.97	12.11
297.70	109.72	109.72	109.72	109.72	109.72	109.72	122.23	122.23	122.23	122.23	122.23	122.23	161.79	161.79	161.79	161.79	161.79	161.79	3.35	1.07	3.43	1.15	3.82	1.54	33.35	10.55	33.62	10.81	34.93	12.13
297.60	109.62	109.62	109.62	109.62	109.62	109.62	122.16	122.16	122.16	122.16	122.16	122.16	161.82	161.82	161.82	161.82	161.82	161.82	3.34	1.07	3.42	1.15	3.82	1.54	33.31	10.56	33.58	10.83	34.89	12.14
297.50	109.52	109.52	109.52	109.52	109.52	109.52	122.09	122.09	122.09	122.09	122.09	122.09	161.85	161.85	161.85	161.85	161.85	161.85	3.34	1.07	3.42	1.15	3.81	1.54	33.28	10.58	33.54	10.84	34.86	12.16
297.40	109.42	109.42	109.42	109.42	109.42	109.42	122.02	122.02	122.02	122.02	122.02	122.02	161.87	161.87	161.87	161.87	161.87	161.87	3.34	1.07	3.42	1.15	3.81	1.55	33.24	10.59	33.50	10.86	34.82	12.18
297.30	109.31	109.31	109.31	109.31	109.31	109.31	121.95	121.95	121.95	121.95	121.95	121.95	161.90	161.90	161.90	161.90	161.90	161.90	3.33	1.07	3.41	1.15	3.81	1.55	33.20	10.61	33.47	10.87	34.79	12.19
297.20	109.21	109.21	109.21	109.21	109.21	109.21	121.88	121.88	121.88	121.88	121.88	121.88	161.93	161.93	161.93	161.93	161.93	161.93	3.33	1.08	3.41	1.15	3.80	1.55	33.17	10.62	33.43	10.88	34.76	12.21
297.10	109.12	109.12	109.12	109.12	109.12	109.12	121.81	121.81	121.81	121.81	121.81	121.81	161.96	161.96	161.96	161.96	161.96	161.96	3.33	1.08	3.41	1.16	3.80	1.55	33.13	10.63	33.40	10.90	34.72	12.23
297.00	109.02	109.02	109.02	109.02	109.02	109.02	121.75	121.75	121.75	121.75	121.75	121.75	161.99	161.99	161.99	161.99	161.99	161.99	3.32	1.08	3.40	1.16	3.80	1.55	33.10	10.65	33.36	10.91	34.69	12.24
296.90	108.92	108.92	108.92	108.92	108.92	108.92	121.68	121.68	121.68	121.68	121.68	121.68	162.03	162.03	162.03	162.03	162.03	162.03	3.32	1.08	3.40	1.16	3.80	1.56	33.06	10.66	33.33	10.93	34.66	12.26
296.80	108.82	108.82	108.82	108.82	108.82	108.82	121.61	121.61	121.61	121.61	121.61	121.61	162.05	162.05	162.05	162.05	162.05	162.05	3.32	1.08	3.39	1.16	3.79	1.56	33.02	10.68	33.29	10.94	34.62	12.28
296.70	108.73	108.73	108.73	108.73	108.73	108.73	121.55	121.55	121.55	121.55	121.55	121.55	162.09	162.09	162.09	162.09	162.09	162.09	3.31	1.08	3.39	1.16	3.79	1.56	32.99	10.69	33.26	10.96	34.59	12.29
296.60	108.65	108.65	108.65	108.65	108.65	108.65	121.50	121.50	121.50	121.50	121.50	121.50	162.14	162.14	162.14	162.14	162.14	162.14	3.31	1.08	3.39	1.16	3.79	1.56	32.96	10.71	33.23	10.98	34.57	12.31
296.50	108.57	108.57	108.57	108.57	108.57	108.57	121.46	121.46	121.46	121.46	121.46	121.46	162.20	162.20	162.20	162.20	162.20	162.20	3.31	1.09	3.39	1.17	3.79	1.57	32.93	10.73	33.20	10.99	34.54	12.33
296.40	108.50	108.50	108.50	108.50	108.50	108.50	121.41	121.41	121.41	121.41	121.41	121.41	162.25	162.25	162.25	162.25	162.25	162.25	3.30	1.09	3.38	1.17	3.78	1.57	32.90	10.74	33.17	11.01	34.51	12.35
296.30	108.43	108.43	108.43	108.43	108.43	108.43	121.38	121.38	121.38	121.38	121.38	121.38	162.31	162.31	162.31	162.31	162.31	162.31	3.30	1.09	3.38	1.17	3.78	1.57	32.88	10.76	33.14	11.03	34.49	12.37
296.20	108.36	108.36	108.36	108.36	108.36	108.36	121.34	121.34	121.34	121.34	121.34	121.34	162.37	162.37	162.37	162.37	162.37	162.37	3.30	1.09	3.38	1.17	3.78	1.57	32.85	10.78	33.12	11.05	34.47	12.39
296.10	108.30	108.30	108.30	108.30	108.30	108.30	121.30	121.30	121.30	121.30	121.30	121.30	162.43	162.43	162.43	162.43	162.43	162.43	3.30	1.09	3.38	1.17	3.78	1.58	32.82	10.79	33.09	11.06	34.44	12.41
296.00	108.23	108.23	108.23	108.23	108.23	108.23	121.27	121.27	121.27	121.27	121.27	121.27	162.49	162.49	162.49	162.49	162.49	162.49	3.29	1.09	3.37	1.17	3.78	1.58	32.80	10.81	33.07	11.08	34.42	12.43
295.90	108.16	108.16	108.16	108.16	108.16	108.16	121.23	121.23	121.23	121.23	121.23	121.23	162.56	162.56	162.56	162.56	162.56	162.56	3.29	1.10	3.37	1.18	3.77	1.58	32.77	10.83	33.04	11.10	34.40	12.45
295.80	108.10	108.10	108.10	108.10	108.10	108.10	121.20	121.20	121.20	121.20	121.20	121.20	162.62	162.62	162.62	162.62	162.62	162.62	3.29	1.10	3.37	1.18	3.77	1.58	32.75	10.84	33.02	11.12	34.38	12.47
295.70	108.03	108.03	108.03	108.03	108.03	108.03	121.16	121.16	121.16	121.16	121.16	121.16	162.68	162.68	162.68	162.68	162.68	162.68	3.29	1.10	3.37	1.18	3.77	1.59	32.

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
293.50	106.88	106.88	106.88	106.88	106.88	106.88	120.70	120.70	120.70	120.70	120.70	120.70	164.38	164.38	164.38	164.38	164.38	164.38	3.24	1.14	3.32	1.22	3.74	1.64	32.26	11.26	32.54	11.55	33.96	12.97
293.40	106.84	106.84	106.84	106.84	106.84	106.84	120.68	120.68	120.68	120.68	120.68	120.68	164.47	164.47	164.47	164.47	164.47	164.47	3.24	1.14	3.32	1.23	3.74	1.65	32.24	11.28	32.52	11.57	33.94	12.99
293.30	106.79	106.79	106.79	106.79	106.79	106.79	120.67	120.67	120.67	120.67	120.67	120.67	164.55	164.55	164.55	164.55	164.55	164.55	3.24	1.14	3.32	1.23	3.74	1.65	32.22	11.30	32.50	11.59	33.93	13.01
293.20	106.75	106.75	106.75	106.75	106.75	106.75	120.65	120.65	120.65	120.65	120.65	120.65	164.63	164.63	164.63	164.63	164.63	164.63	3.23	1.15	3.32	1.23	3.74	1.65	32.20	11.32	32.48	11.60	33.91	13.03
293.10	106.70	106.70	106.70	106.70	106.70	106.70	120.64	120.64	120.64	120.64	120.64	120.64	164.72	164.72	164.72	164.72	164.72	164.72	3.23	1.15	3.32	1.23	3.74	1.66	32.18	11.34	32.47	11.62	33.89	13.05
293.00	106.66	106.66	106.66	106.66	106.66	106.66	120.63	120.63	120.63	120.63	120.63	120.63	164.80	164.80	164.80	164.80	164.80	164.80	3.23	1.15	3.31	1.23	3.74	1.66	32.16	11.36	32.45	11.64	33.88	13.07
292.90	106.61	106.61	106.61	106.61	106.61	106.61	120.61	120.61	120.61	120.61	120.61	120.61	164.89	164.89	164.89	164.89	164.89	164.89	3.23	1.15	3.31	1.24	3.74	1.66	32.14	11.37	32.43	11.66	33.86	13.10
292.80	106.57	106.57	106.57	106.57	106.57	106.57	120.60	120.60	120.60	120.60	120.60	120.60	164.97	164.97	164.97	164.97	164.97	164.97	3.23	1.15	3.31	1.24	3.74	1.66	32.12	11.39	32.41	11.68	33.85	13.12
292.70	106.53	106.53	106.53	106.53	106.53	106.53	120.59	120.59	120.59	120.59	120.59	120.59	165.06	165.06	165.06	165.06	165.06	165.06	3.22	1.16	3.31	1.24	3.74	1.67	32.11	11.41	32.39	11.70	33.83	13.14
292.60	106.48	106.48	106.48	106.48	106.48	106.48	120.57	120.57	120.57	120.57	120.57	120.57	165.14	165.14	165.14	165.14	165.14	165.14	3.22	1.16	3.31	1.24	3.74	1.67	32.09	11.43	32.37	11.72	33.82	13.16
292.50	106.43	106.43	106.43	106.43	106.43	106.43	120.56	120.56	120.56	120.56	120.56	120.56	165.22	165.22	165.22	165.22	165.22	165.22	3.22	1.16	3.31	1.24	3.73	1.67	32.07	11.45	32.36	11.74	33.80	13.18
292.40	106.38	106.38	106.38	106.38	106.38	106.38	120.54	120.54	120.54	120.54	120.54	120.54	165.30	165.30	165.30	165.30	165.30	165.30	3.22	1.16	3.30	1.25	3.73	1.68	32.05	11.47	32.34	11.76	33.78	13.20
292.30	106.34	106.34	106.34	106.34	106.34	106.34	120.52	120.52	120.52	120.52	120.52	120.52	165.38	165.38	165.38	165.38	165.38	165.38	3.22	1.16	3.30	1.25	3.73	1.68	32.03	11.48	32.32	11.77	33.77	13.23
292.20	106.29	106.29	106.29	106.29	106.29	106.29	120.51	120.51	120.51	120.51	120.51	120.51	165.47	165.47	165.47	165.47	165.47	165.47	3.22	1.16	3.30	1.25	3.73	1.68	32.01	11.50	32.30	11.79	33.75	13.25
292.10	106.25	106.25	106.25	106.25	106.25	106.25	120.50	120.50	120.50	120.50	120.50	120.50	165.55	165.55	165.55	165.55	165.55	165.55	3.21	1.17	3.30	1.25	3.73	1.68	31.99	11.52	32.28	11.81	33.74	13.27
292.00	106.20	106.20	106.20	106.20	106.20	106.20	120.48	120.48	120.48	120.48	120.48	120.48	165.64	165.64	165.64	165.64	165.64	165.64	3.21	1.17	3.30	1.25	3.73	1.69	31.97	11.54	32.26	11.83	33.72	13.29
291.90	106.15	106.15	106.15	106.15	106.15	106.15	120.46	120.46	120.46	120.46	120.46	120.46	165.72	165.72	165.72	165.72	165.72	165.72	3.21	1.17	3.30	1.26	3.73	1.69	31.95	11.56	32.24	11.85	33.70	13.31
291.80	106.10	106.10	106.10	106.10	106.10	106.10	120.44	120.44	120.44	120.44	120.44	120.44	165.79	165.79	165.79	165.79	165.79	165.79	3.21	1.17	3.29	1.26	3.73	1.69	31.93	11.57	32.22	11.87	33.68	13.33
291.70	106.05	106.05	106.05	106.05	106.05	106.05	120.42	120.42	120.42	120.42	120.42	120.42	165.87	165.87	165.87	165.87	165.87	165.87	3.21	1.17	3.29	1.26	3.73	1.69	31.91	11.59	32.20	11.88	33.67	13.35
291.60	106.00	106.00	106.00	106.00	106.00	106.00	120.40	120.40	120.40	120.40	120.40	120.40	165.95	165.95	165.95	165.95	165.95	165.95	3.20	1.18	3.29	1.26	3.72	1.70	31.89	11.61	32.18	11.90	33.65	13.37
291.50	105.95	105.95	105.95	105.95	105.95	105.95	120.38	120.38	120.38	120.38	120.38	120.38	166.03	166.03	166.03	166.03	166.03	166.03	3.20	1.18	3.29	1.26	3.72	1.70	31.87	11.63	32.16	11.92	33.63	13.39
291.40	105.90	105.90	105.90	105.90	105.90	105.90	120.36	120.36	120.36	120.36	120.36	120.36	166.11	166.11	166.11	166.11	166.11	166.11	3.20	1.18	3.29	1.27	3.72	1.70	31.85	11.64	32.14	11.94	33.61	13.41
291.30	105.84	105.84	105.84	105.84	105.84	105.84	120.33	120.33	120.33	120.33	120.33	120.33	166.18	166.18	166.18	166.18	166.18	166.18	3.20	1.18	3.28	1.27	3.72	1.70	31.82	11.66	32.12	11.96	33.59	13.43
291.20	105.78	105.78	105.78	105.78	105.78	105.78	120.31	120.31	120.31	120.31	120.31	120.31	166.25	166.25	166.25	166.25	166.25	166.25	3.19	1.18	3.28	1.27	3.72	1.71	31.80	11.68	32.10	11.97	33.58	13.45
291.10	105.73	105.73	105.73	105.73	105.73	105.73	120.29	120.29	120.29	120.29	120.29	120.29	166.33	166.33	166.33	166.33	166.33	166.33	3.19	1.18	3.28	1.27	3.72	1.71	31.78	11.69	32.08	11.99	33.56	13.47
291.00	105.68	105.68	105.68	105.68	105.68	105.68	120.27	120.27	120.27	120.27	120.27	120.27	166.41	166.41	166.41	166.41	166.41	166.41	3.19	1.19	3.28	1.27	3.72	1.71	31.76	11.71	32.06	12.01	33.54	13.49
290.90	105.63	105.63	105.63	105.63	105.63	105.63	120.25	120.25	120.25	120.25	120.25	120.25	166.48	166.48	166.48	166.48	166.48	166.48	3.19	1.19	3.28	1.28	3.71	1.71	31.74	11.73	32.03	12.03	33.52	13.51
290.80	105.57	105.57	105.57	105.57	105.57	105.57	120.22	120.22	120.22	120.22	120.22	120.22	166.55	166.55	166.55	166.55	166.55	166.55	3.19	1.19	3.27	1.28	3.71	1.72	31.71	11.74	32.01	12.04	33.50	13.53
290.70	105.51	105.51	105.51	105.51	105.51	105.51	120.20	120.20	120.20	120.20	120.20	120.20	166.63	166.63	166.63	166.63	166.63	166.63	3.18	1.19	3.27	1.28	3.71	1.72	31.69	11.76	31.99	12.06	33.48	13.55
290.60	105.45	105.45	105.45	105.45	105.45	105.45	120.17	120.17	120.17	120.17	120.17	120.17	166.70	166.70	166.70	166.70	166.70	166.70	3.18	1.19	3.27	1.28	3.71	1.72	31.67	11.78	31.97	12.08	33.46	13.57
290.50	105.39	105.39	105.39	105.39	105.39	105.39	120.14	120.14	120.14	120.14	120.14	120.14	166.76	166.76	166.76	166.76	166.76	166.76	3.18	1.19	3.27	1.28	3.71	1.72	31.64	11.79	31.94	12.09	33.44	13.59
290.40	105.33	105.33	105.33	105.33	105.33	105.33	120.10	120.10	120.10	120.10	120.10	120.10	166.83	166.83	166.83	166.83	166.83	166.83	3.18	1.20	3.26	1.28	3.71	1.73	31.62	11.81	31.92	12.11	33.42	13.61
290.30	105.26	105.26	105.26	105.26	105.26	105.26	120.07	120.07	120.07	120.07	120.07	120.07	166.90	166.90	166.90	166.90	166.90	166.90	3.17	1.20	3.26	1.29	3.71	1.73	31.59	11.82	31.89	12.12	33.40	13.63
290.20	105.19	105.19	105.19	105.19	105.19	105.19	120.03	120.03	120.03	120.03	120.03	120.03	166.95	166.95	166.95	166.95	166.95	166.95	3.17	1.20	3.26	1.29	3.70	1.73	31.57	11.84	31.87	12.14	33.37	13.64
290.10	105.13	105.13	105.13	105.13	105.13	105.13	120.00	120.00	120.00	120.00	120.00	120.00	167.02	167.02	167.02	167.02	167.02	167.02	3.17	1.20	3.26	1.29	3.70	1.73	31.54	11.85	31.84	12.15	33.35	13.66
290.00	105.06	105.06	105.06	105.06	105.06	105.06	119.96	119.96	119.96	119.96	119.96	119.96	167.08	167.08	167.08	167.08	167.08	167.08	3.17	1.20	3.26	1.29	3.70	1.74	31.52	11.87	31.82	12.17	33.33	13.68
289.90	105.00	105.00	105.00	105.00	105.00	105.00	119.93	119.93	119.93	119.93	119.93	119.93	167.14	167.14	167.14	167.14	167.14	167.14	3.16	1.20	3.25	1.29	3.70	1.74	31.49	11.88	31.79	12.19	33.30	13.70
289.80	104.93	104.93	104.93	104.93	104.93	104.93	119.89	119.89	119.89	119.89	119.89	119.89	167.20	167.20	167.20	167.20	167.20	167.20	3.16	1.20	3.25	1.29	3.70	1.74	31.46	11.90	31.77	12.20	33.28	13.71
289.70	104.86	104.86	104.86	104.86	104.86	104.86	119.85	119.85	119.85	119.85	119.85	119.85	167.27	167.27	167.27	167.27	167.27	167.27	3.16	1.21	3.25	1.30	3.69	1.74	31.44	11.91	31.74	12.22	33.26	13.73
289.60	104.80	104.80	104.80	104.80	104.80	104.80	119.82	119.82	119.82	119.82	119.82	119.82	167.33	167.33	167.33	167.33	167.33	167.33	3.16	1.21	3.25	1.30	3.69	1.74	31.41	11.93	31.72	12.23	33.23	13.75
289.50	104.73	104.73	104.73	104.73	104.73	104.73	119.79	119.79	119.79	119.79	119.79	119.79	167.40	167.40	167.40	167.40	167.40	167.40	3.15	1.21	3.24	1.30	3.69	1.75	31.39	11.94	31.69	12.25	33.21	13.77
289.40	104.67	104.67	104.67	104.67	104.67	104.67	119.75	119.75	119.75	119.75	119.75	119.75	167.46	167.46	167.46	167.46	167.46	167.46	3.15	1.21	3.24	1.30	3.69	1.75	31.36	11.96	31.67	12.26	33.19	13.79
289.30	104.60	104.60	104.60	104.60	104.60	104.60	119.72	119.72	119.72	119.72	119.72	119.72	167.53	167.53	167.53	167.53	167.53	167.53	3.15	1.21	3.24	1.30	3.69	1.75	31.34	11.97	31.64	12.28	33.17	13.80
289.20	104.55	104.55	104.55	104.55	104.55	104.55	119.69	119.69	119.69	119.69	119.69	119.69	167.60	167.60	167.60	167.60	167.60	167.60	3.15	1.21	3.24	1.30	3.69	1.75	31.31	11.99	31.62	12.29	33.15	13.82
289.10	104.49	104.49	104.49	104.49	104.49	104.49	119.67	119.67	119.67	119.67	119.67	119.67	167.67	167.67	167.67	167.67	167.67	167.67	3.14	1.22	3.23	1.31	3.68	1.76	31.29	12.00	31.60	12.31	33.13	13.84
289.00	104.43	104.43	104.43	104.43	104.43	104.43	119.64	119.64	119.64	119.64	119.64	119.64	167.74	167.74	167.74	167.74	167.74	167.74	3.14	1.22	3.23	1.31	3.68	1.76	31.27	12.02	31.57	12.33	33.11	13.86
288.90	104.37	104.37	104.37	104.37	104.37	104.37	119.61	119.61	119.61	119.61	119.61	119.61	167.81	167.81	167.81	167.81	167.81	167.81	3.14	1.22	3.23	1.31	3.68	1.76	31.24	12.04	31.55	12.34	33.09	13.88
288.80	104.31	104.31	104.31	104.31	104.31	104.31	119.58	119.58	119.58	119.58	119.58	119.58	167.88	167.88	167.88	167.88	167.88	167.88	3.14	1.22	3.23	1.31	3.68	1.76	31.22	12.05	31.53	12.36	33.07	13.90
288.70	104.25	104.25	104.25	104.25	104.25	104.25	119.56	119.56	119.56	119.56	119.56	119.56	167.95	167.95	167.95	167.95	167.95	167.95	3.13	1.22	3.23	1.31	3.68	1.76	31.20	12.07	31.51	12.37	33.05	13.91
288.60	104.20	104.20	104.20	104.20	104.20	104.20	119.53	119.53	119.53	119.53	119.53	119.53	168.02	168.02	168.02	168.02	168.02	168.02	3.13	1.22	3.22	1.31	3.68	1.77	31.18	12.08	31.48	12.39	33.03	13.93
288.50	104.14	104.14	104.14	104.14	104.14	104.14	119.51	119.51	119.51	119.51	119.51	119.51	168.10	168.10	168.10	168.10	168.10	168.10	3.13	1.22	3.22	1.32	3.67	1.77	31.15	12.10	31.46	12.41	33.01	13.95
288.40	104.09	104.09	104.09	104.09	104.09	104.09	119.49	119.49	119.49	119.49	119.49	119.49	168.18	168.18	168.18	168.18	168.18	168.18	3.13	1.23	3.22	1.32	3.67	1.77	31.13	12.11	31.44	12.42	32.99	13.97
288.30	104.04	104.04	104.04	104.04	104.04	104.04	119.47	119.47	119.47	119.47	119.47	119.47	168.26	168.26	168.26	168.26	168.26	168.26	3.13	1.23	3.22	1.32	3.67	1.77	31.11	12.13	31.42	12.44	32.97	13.99
288.20	103.99	103.99	103.99	103.99	103.99	103.99	119.45	119.45	119.45	119.45	119.45	119.45	168.33	168.33	168.33	168.33	168.33	168.33	3.12	1.23	3.22	1.32	3.67	1.78	31.09	12.15	31.40	12.46	32.95	14.01
288.10	103.94	103.94	103.94	103.94	103.94	103.94	119.43	119.43	119.43	119.43	119.43	119.43	168.41	168.41	168.41	168.41	168.41	168.41	3.12	1.23	3.21	1.32	3.67	1.78	31.07	12.16	31.38	12.47	32.94	14.03
288.00	103.89	103.89	103.89	103.89	103.89	103.89	119.41	119.41	119.41	119.41	119.41	119.41	168.49	168.49	168.49	168.49	168.49	168.49	3.12	1.23	3.21	1.32	3.67	1.78	31.05	12.18	31.36	12.49	32.92	14.05
287.90	103.84	103.84	103.84	103.84	103.84	103.84	119.39	119.39	119.39	119.39	119.39	119.39	168.57	168.57	168.57	168.57	168.57	168.57	3.12	1.23	3.21	1.33	3.67	1.78	31.03	12.20	31.34	12.51	32.90	14.07
287.80	103.79	103.79	103.79	103.79	103.79	103.79	119.37	119.37	119.37	119.37	119.37	119.37	168.65	168.65	168.65	168.65	168.65	168.65	3.12	1.24	3.21	1.33	3.67	1.79	31.01	12.21	31.32	12.52	32.88	14.09
287.70	103.74	103.74	103.74	103.74	103.74	103.74	119.35	119.35	119.35	119.35	119.35	119.35	168.73	168.73	168.73	168.73	168.73	168.73	3.11	1.24	3.21	1.33	3.66	1.79	30.99	12.23	31.30	12.54	32.87	14.11
287.60	103.69	103.69	103.69	103.69	103.69	103.69	119.34	119.34	119.34	119.34	119.34	119.34	168.81	168.81	168.81	168.81	168.81	168.81	3.11	1.24	3.20	1.33	3.66	1.79	30.97	12.25	31.28	12.56	32.85	14.13
287.50	103.64	103.64	103.64	103.64	103.64	103.64	119.32	119.32	119.32	119.32	119.32	119.32	168.89	168.89	168.89	168.89	168.89	168.89	3.11	1.24	3.20	1.33	3.66	1.79	30.95	12.26	31.26	12.58	32.83	14.15
287.40	103.59	103.59	103.59	103.59	103.59	103.59	119.30	119.30	119.30	119.30	119.30	119.30	168.97	168.97	168.97	168.97	168.97	168.97	3.11	1.24	3.20	1.34	3.66	1.80	30.93	12.28	31.24	12.59	32.82	14.16
287.30	103.54	103.54	103.54	103.54	103.54	103.54	119.28	119.28	119.28	119.28	119.28	119.28	169.05	169.05	169.05	169.05	169.05	169.05	3.11	1.24	3.20	1.34	3.66	1.80	30.91	12.29	31.22	12.61	32.80	14.18
287.20	103.49	103.49	103.49	103.49	103.49	103.49	119.25	119.25	119.25	119.25	119.25	119.25	169.12	169.12	169.12	169.12	169.12	169.12	3.10	1.25	3.20	1.34	3.66	1.80	30.89	12.31	31.20	12.62	32.78	14.20
287.10	103.43	103.43	103.43	103.43	103.43	103.43	119.23	119.23	119.23	119.23	119.23	119.23	169.20	169.20	169.20	169.20	169.20	169.20	3.10	1.25	3.19	1.34	3.66	1.80	30.86	12.32	31.18	12.64	32.76	14.22
287.00	103.38	103.38	103.38	103.38	103.38	103.38	119.22	119.22	119.22	119.22	119.22	119.22	169.28	169.28	169.28	169.28	169.28	169.28	3.10	1.25	3.19	1.34	3.66	1.81	30.84	12.34	31.16	12.66	32.74	14.24
286.90	103.34	103.34	103.34	103.34	103.34	103.34	119.20	119.20	119.20	119.20	119.20	119.20	169.36	169.36	169.36	169.36	169.36	169.36	3.10	1.25	3.19	1.34	3.65	1.81	30.82	12.36	31.14	12.67	32.73	14.26
286.80	103.29	103.29	103.29	103.29	103.29	103.29	119.18	119.18	119.18	119.18	119.18	119.18	169.44	169.44	169.44	169.44	169.44	169.44	3.10	1.25	3.19	1.35	3.65	1.81	30.80	12.37	31.12	12.69	32.71	14.28
286.70	103.24	103.24	103.24	103.24	103.24	103.24	119.17	119.17	119.17	119.17	119.17	119.17	169.53	169.53	169.53	169.53	169.53	169.53	3.09	1.25	3.19	1.35	3.65	1.81	30.79	12.39	31.10	12.71	32.69	14.30
286.60	103.20	103.20	103.20	103.20	103.20	103.20	119.15	119.15	119.15	119.15	119.15	119.15	169.61	169.61	169.61	169.61	169.61	169.61	3.09	1.26	3.19	1.35	3.65	1.82	30.77	12.41	31.08	12.72	32.68	14.32
286.50	103.15	103.15	103.15	103.15	103.15	103.15	119.14	119.14	119.14	119.14	119.14	119.14	169.69	169.69	169.69	169.69	169.69	169.69	3.09	1.26	3.18	1.35	3.65	1.82	30.75	12.42	31.07	12.74	32.66	14.34
286.40	103.10	103.10	103.10	103.10	103.10	103.10	119.12	119.12	119.12	119.12	119.12	119.12	169.77	169.77	169.77	169.77	169.77	169.77	3.09	1.26	3.18	1.35	3.65	1.82	30.73	12.44	31.05	12.76	32.64	14.35
286.30	103.05	103.05	103.05	103.05	103.05	103.05	119.10	119.10	119.10	119.10	119.10	119.10	169.85	169.85	169.85	169.85	169.85	169.85	3.09	1.26	3.18	1.35	3.65	1.82	30.71	12.45	31.03	12.77	32.63	14.37
286.20	103.00	103.00	103.00	103.00	103.00	103.00	119.08	119.08	119.08	119.08	119.08	119.08	169.93	169.93	169.93	169.93	169.93	169.93	3.08	1.26	3.18	1.36	3.65	1.82	30.69	12.47	31.01	12.79	32.61	14.39
286.10	102.95	102.95	102.95	102.95	102.95	102.95	119.06	119.06	119.06	119.06	119.06	119.06	170.01	170.01	170.01	170.01	170.01	170.01	3.08	1.26	3.18	1.36	3.65	1.83	30.67	12.48	30.99	12.81	32.59	14.41
286.00	102.90	102.90	102.90	102.90	102.90	102.90	119.04	119.04	119.04	119.04	119.04	119.04	170.09	170.09	170.09	170.09	170.09	170.09	3.08	1.27	3.17	1.36	3.64	1.83	30.64	12.50	30.97	12.82	32.57	14.43
285.90	102.85	102.85	102.85	102.85	102.85	102.85	119.02	119.02	119.02	119.02	119.02	119.02	170.16	170.16	170.16	170.16	170.16	170.16	3.08	1.27	3.17	1.36	3.64	1.83	30.62	12.52	30.94	12.84	32.55	14.45
285.80	102.80	102.80	102.80	102.80	102.80	102.80	119.00	119.00	119.00	119.00	119.00	119.00	170.24	170.24	170.24	170.24	170.24	170.24	3.08	1.27	3.17	1.36	3.64	1.83	30.60	12.53	30.92	12.85	32.54	14.47
285.70	102.74	102.74	102.74	102.74	102.74	102.74	118.98	118.98	118.98	118.98	118.98	118.98	170.32	170.32	170.32	170.32	170.32	170.32	3.07	1.27	3.17	1.36	3.64	1.84	30.58	12.55	30.90	12.87	32.52	14.48
285.60	102.69	102.69	102.69	102.69	102.69	102.69	118.96	118.96	118.96	118.96	118.96	118.96	170.39	170.39	170.39	170.39	170.39	170.39	3.07	1.27	3.17	1.37	3.64	1.84	30.56	12.56	30.88	12.88	32.50	14.50
285.50	102.64	102.64	102.64	102.64	102.64	102.64	118.93	118.93	118.93	118.93	118.93	118.93	170.47	170.47	170.47	170.47	170.47	170.47	3.07	1.27	3.16	1.37	3.64	1.84	30.

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
283.30	101.39	101.39	101.39	101.39	101.39	101.39	118.37	118.37	118.37	118.37	118.37	118.37	172.07	172.07	172.07	172.07	172.07	172.07	3.02	1.30	3.12	1.40	3.60	1.89	30.04	12.89	30.37	13.22	32.04	14.89
283.20	101.33	101.33	101.33	101.33	101.33	101.33	118.34	118.34	118.34	118.34	118.34	118.34	172.13	172.13	172.13	172.13	172.13	172.13	3.02	1.31	3.11	1.40	3.60	1.89	30.01	12.90	30.35	13.24	32.02	14.91
283.10	101.25	101.25	101.25	101.25	101.25	101.25	118.30	118.30	118.30	118.30	118.30	118.30	172.19	172.19	172.19	172.19	172.19	172.19	3.01	1.31	3.11	1.40	3.60	1.89	29.99	12.91	30.32	13.25	32.00	14.92
283.00	101.18	101.18	101.18	101.18	101.18	101.18	118.25	118.25	118.25	118.25	118.25	118.25	172.24	172.24	172.24	172.24	172.24	172.24	3.01	1.31	3.11	1.41	3.60	1.89	29.96	12.92	30.29	13.26	31.97	14.94
282.90	101.11	101.11	101.11	101.11	101.11	101.11	118.22	118.22	118.22	118.22	118.22	118.22	172.30	172.30	172.30	172.30	172.30	172.30	3.01	1.31	3.11	1.41	3.59	1.90	29.93	12.94	30.27	13.27	31.95	14.95
282.80	101.04	101.04	101.04	101.04	101.04	101.04	118.18	118.18	118.18	118.18	118.18	118.18	172.36	172.36	172.36	172.36	172.36	172.36	3.01	1.31	3.10	1.41	3.59	1.90	29.91	12.95	30.24	13.28	31.92	14.96
282.70	100.97	100.97	100.97	100.97	100.97	100.97	118.13	118.13	118.13	118.13	118.13	118.13	172.42	172.42	172.42	172.42	172.42	172.42	3.00	1.31	3.10	1.41	3.59	1.90	29.88	12.96	30.21	13.30	31.90	14.98
282.60	100.89	100.89	100.89	100.89	100.89	100.89	118.09	118.09	118.09	118.09	118.09	118.09	172.47	172.47	172.47	172.47	172.47	172.47	3.00	1.31	3.10	1.41	3.59	1.90	29.85	12.97	30.19	13.31	31.87	14.99
282.50	100.82	100.82	100.82	100.82	100.82	100.82	118.05	118.05	118.05	118.05	118.05	118.05	172.53	172.53	172.53	172.53	172.53	172.53	3.00	1.31	3.10	1.41	3.59	1.90	29.82	12.98	30.16	13.32	31.84	15.01
282.40	100.74	100.74	100.74	100.74	100.74	100.74	118.00	118.00	118.00	118.00	118.00	118.00	172.58	172.58	172.58	172.58	172.58	172.58	3.00	1.32	3.09	1.41	3.58	1.90	29.79	12.99	30.13	13.33	31.82	15.02
282.30	100.67	100.67	100.67	100.67	100.67	100.67	117.96	117.96	117.96	117.96	117.96	117.96	172.64	172.64	172.64	172.64	172.64	172.64	2.99	1.32	3.09	1.41	3.58	1.91	29.76	13.00	30.10	13.34	31.79	15.03
282.20	100.59	100.59	100.59	100.59	100.59	100.59	117.91	117.91	117.91	117.91	117.91	117.91	172.69	172.69	172.69	172.69	172.69	172.69	2.99	1.32	3.09	1.42	3.58	1.91	29.73	13.01	30.07	13.35	31.77	15.05
282.10	100.51	100.51	100.51	100.51	100.51	100.51	117.86	117.86	117.86	117.86	117.86	117.86	172.73	172.73	172.73	172.73	172.73	172.73	2.99	1.32	3.08	1.42	3.58	1.91	29.70	13.02	30.04	13.36	31.74	15.06
282.00	100.42	100.42	100.42	100.42	100.42	100.42	117.80	117.80	117.80	117.80	117.80	117.80	172.77	172.77	172.77	172.77	172.77	172.77	2.98	1.32	3.08	1.42	3.57	1.91	29.67	13.03	30.01	13.37	31.70	15.07
281.90	100.32	100.32	100.32	100.32	100.32	100.32	117.73	117.73	117.73	117.73	117.73	117.73	172.80	172.80	172.80	172.80	172.80	172.80	2.98	1.32	3.08	1.42	3.57	1.91	29.63	13.04	29.97	13.38	31.67	15.08
281.80	100.21	100.21	100.21	100.21	100.21	100.21	117.65	117.65	117.65	117.65	117.65	117.65	172.82	172.82	172.82	172.82	172.82	172.82	2.98	1.32	3.07	1.42	3.57	1.91	29.59	13.04	29.93	13.38	31.63	15.08
281.70	100.09	100.09	100.09	100.09	100.09	100.09	117.57	117.57	117.57	117.57	117.57	117.57	172.83	172.83	172.83	172.83	172.83	172.83	2.97	1.32	3.07	1.42	3.56	1.91	29.55	13.05	29.89	13.39	31.59	15.09
281.60	99.97	99.97	99.97	99.97	99.97	99.97	117.47	117.47	117.47	117.47	117.47	117.47	172.84	172.84	172.84	172.84	172.84	172.84	2.97	1.32	3.07	1.42	3.56	1.91	29.51	13.05	29.85	13.39	31.55	15.09
281.50	99.82	99.82	99.82	99.82	99.82	99.82	117.35	117.35	117.35	117.35	117.35	117.35	172.82	172.82	172.82	172.82	172.82	172.82	2.96	1.32	3.06	1.42	3.55	1.91	29.45	13.05	29.79	13.39	31.50	15.10
281.40	99.66	99.66	99.66	99.66	99.66	99.66	117.23	117.23	117.23	117.23	117.23	117.23	172.79	172.79	172.79	172.79	172.79	172.79	2.96	1.32	3.05	1.42	3.55	1.91	29.40	13.05	29.74	13.39	31.44	15.09
281.30	99.43	99.43	99.43	99.43	99.43	99.43	117.03	117.03	117.03	117.03	117.03	117.03	172.69	172.69	172.69	172.69	172.69	172.69	2.95	1.32	3.05	1.42	3.54	1.91	29.32	13.04	29.66	13.38	31.36	15.08
281.20	99.11	99.11	99.11	99.11	99.11	99.11	116.74	116.74	116.74	116.74	116.74	116.74	172.50	172.50	172.50	172.50	172.50	172.50	2.94	1.32	3.04	1.42	3.53	1.91	29.21	13.01	29.55	13.35	31.25	15.05
281.10	98.79	98.79	98.79	98.79	98.79	98.79	116.46	116.46	116.46	116.46	116.46	116.46	172.31	172.31	172.31	172.31	172.31	172.31	2.93	1.32	3.03	1.41	3.52	1.90	29.11	12.99	29.45	13.33	31.15	15.03
281.00	98.42	98.42	98.42	98.42	98.42	98.42	116.11	116.11	116.11	116.11	116.11	116.11	172.06	172.06	172.06	172.06	172.06	172.06	2.91	1.31	3.01	1.41	3.50	1.90	28.98	12.96	29.32	13.30	31.02	14.99
280.90	97.97	97.97	97.97	97.97	97.97	97.97	115.69	115.69	115.69	115.69	115.69	115.69	171.74	171.74	171.74	171.74	171.74	171.74	2.90	1.31	3.00	1.40	3.49	1.89	28.83	12.91	29.17	13.25	30.86	14.94
280.80	97.47	97.47	97.47	97.47	97.47	97.47	115.22	115.22	115.22	115.22	115.22	115.22	171.37	171.37	171.37	171.37	171.37	171.37	2.88	1.30	2.98	1.40	3.47	1.89	28.67	12.86	29.01	13.20	30.69	14.88
280.70	96.90	96.90	96.90	96.90	96.90	96.90	114.69	114.69	114.69	114.69	114.69	114.69	170.94	170.94	170.94	170.94	170.94	170.94	2.86	1.30	2.96	1.39	3.45	1.88	28.48	12.80	28.82	13.14	30.50	14.82
280.60	96.41	96.41	96.41	96.41	96.41	96.41	114.23	114.23	114.23	114.23	114.23	114.23	170.57	170.57	170.57	170.57	170.57	170.57	2.85	1.29	2.94	1.39	3.43	1.87	28.32	12.75	28.65	13.08	30.33	14.76
280.50	95.76	95.76	95.76	95.76	95.76	95.76	113.60	113.60	113.60	113.60	113.60	113.60	170.05	170.05	170.05	170.05	170.05	170.05	2.83	1.28	2.92	1.38	3.40	1.86	28.11	12.68	28.44	13.01	30.11	14.67
280.40	95.01	95.01	95.01	95.01	95.01	95.01	112.89	112.89	112.89	112.89	112.89	112.89	169.44	169.44	169.44	169.44	169.44	169.44	2.80	1.27	2.90	1.37	3.37	1.85	27.86	12.59	28.19	12.92	29.85	14.58
280.30	94.24	94.24	94.24	94.24	94.24	94.24	112.15	112.15	112.15	112.15	112.15	112.15	168.79	168.79	168.79	168.79	168.79	168.79	2.78	1.26	2.87	1.36	3.34	1.83	27.61	12.49	27.94	12.82	29.59	14.47
280.20	93.57	93.57	93.57	93.57	93.57	93.57	111.52	111.52	111.52	111.52	111.52	111.52	168.26	168.26	168.26	168.26	168.26	168.26	2.75	1.26	2.85	1.35	3.32	1.82	27.39	12.42	27.72	12.75	29.36	14.38
280.10	92.95	92.95	92.95	92.95	92.95	92.95	110.93	110.93	110.93	110.93	110.93	110.93	167.76	167.76	167.76	167.76	167.76	167.76	2.73	1.25	2.83	1.34	3.30	1.81	27.19	12.35	27.52	12.67	29.15	14.30
280.00	92.34	92.34	92.34	92.34	92.34	92.34	110.34	110.34	110.34	110.34	110.34	110.34	167.28	167.28	167.28	167.28	167.28	167.28	2.71	1.24	2.81	1.34	3.27	1.80	26.99	12.28	27.31	12.60	28.94	14.23
279.90	91.82	91.82	91.82	91.82	91.82	91.82	109.86	109.86	109.86	109.86	109.86	109.86	166.89	166.89	166.89	166.89	166.89	166.89	2.70	1.24	2.79	1.33	3.25	1.79	26.82	12.22	27.14	12.54	28.76	14.16
279.80	91.28	91.28	91.28	91.28	91.28	91.28	109.35	109.35	109.35	109.35	109.35	109.35	166.48	166.48	166.48	166.48	166.48	166.48	2.68	1.23	2.77	1.32	3.23	1.79	26.64	12.16	26.96	12.48	28.57	14.09
279.70	90.70	90.70	90.70	90.70	90.70	90.70	108.80	108.80	108.80	108.80	108.80	108.80	166.03	166.03	166.03	166.03	166.03	166.03	2.66	1.22	2.75	1.32	3.21	1.78	26.45	12.09	26.77	12.41	28.38	14.02
279.60	90.36	90.36	90.36	90.36	90.36	90.36	108.49	108.49	108.49	108.49	108.49	108.49	165.81	165.81	165.81	165.81	165.81	165.81	2.65	1.22	2.74	1.31	3.20	1.77	26.33	12.06	26.65	12.38	28.26	13.98
279.50	90.02	90.02	90.02	90.02	90.02	90.02	108.18	108.18	108.18	108.18	108.18	108.18	165.61	165.61	165.61	165.61	165.61	165.61	2.64	1.22	2.73	1.31	3.19	1.77	26.22	12.03	26.54	12.35	28.14	13.95
279.40	89.79	89.79	89.79	89.79	89.79	89.79	107.98	107.98	107.98	107.98	107.98	107.98	165.50	165.50	165.50	165.50	165.50	165.50	2.63	1.22	2.72	1.31	3.18	1.76	26.14	12.01	26.46	12.33	28.06	13.93
279.30	89.57	89.57	89.57	89.57	89.57	89.57	107.80	107.80	107.80	107.80	107.80	107.80	165.42	165.42	165.42	165.42	165.42	165.42	2.62	1.21	2.71	1.31	3.17	1.76	26.07	12.00	26.39	12.32	27.99	13.92
279.20	89.38	89.38	89.38	89.38	89.38	89.38	107.63	107.63	107.63	107.63	107.63	107.63	165.35	165.35	165.35	165.35	165.35	165.35	2.61	1.21	2.71	1.31	3.16	1.76	26.00	11.99	26.32	12.31	27.92	13.91
279.10	89.19	89.19	89.19	89.19	89.19	89.19	107.47	107.47	107.47	107.47	107.47	107.47	165.29	165.29	165.29	165.29	165.29	165.29	2.61	1.21	2.70	1.30	3.16	1.76	25.94	11.98	26.26	12.30	27.85	13.90
279.00	89.00	89.00	89.00	89.00	89.00	89.00	107.32	107.32	107.32	107.32	107.32	107.32	165.24	165.24	165.24	165.24	165.24	165.24	2.60	1.21	2.69	1.30	3.15	1.76	25.87	11.97	26.19	12.29	27.79	13.89
278.90	88.83	88.83	88.83	88.83	88.83	88.83	107.18	107.18	107.18	107.18	107.18	107.18	165.19	165.19	165.19	165.19	165.19	165.19	2.60	1.21	2.69	1.30	3.14	1.76	25.81	11.96	26.13	12.28	27.73	13.88
278.80	88.66	88.66	88.66	88.66	88.66	88.66	107.03	107.03	107.03	107.03	107.03	107.03	165.15	165.15	165.15	165.15	165.15	165.15	2.59	1.21	2.68	1.30	3.14	1.76	25.75	11.96	26.07	12.28	27.67	13.87
278.70	88.51	88.51	88.51	88.51	88.51	88.51	106.91	106.91	106.91	106.91	106.91	106.91	165.13	165.13	165.13	165.13	165.13	165.13	2.58	1.21	2.68	1.30	3.13	1.76	25.70	11.95	26.02	12.27	27.62	13.87
278.60	88.36	88.36	88.36	88.36	88.36	88.36	106.80	106.80	106.80	106.80	106.80	106.80	165.11	165.11	165.11	165.11	165.11	165.11	2.58	1.21	2.67	1.30	3.13	1.76	25.65	11.95	25.97	12.27	27.57	13.87
278.50	88.24	88.24	88.24	88.24	88.24	88.24	106.71	106.71	106.71	106.71	106.71	106.71	165.11	165.11	165.11	165.11	165.11	165.11	2.58	1.21	2.67	1.30	3.12	1.76	25.60	11.95	25.92	12.27	27.52	13.86
278.40	88.11	88.11	88.11	88.11	88.11	88.11	106.61	106.61	106.61	106.61	106.61	106.61	165.12	165.12	165.12	165.12	165.12	165.12	2.57	1.21	2.66	1.30	3.12	1.76	25.56	11.95	25.88	12.27	27.48	13.87
278.30	87.99	87.99	87.99	87.99	87.99	87.99	106.52	106.52	106.52	106.52	106.52	106.52	165.13	165.13	165.13	165.13	165.13	165.13	2.57	1.21	2.66	1.30	3.11	1.76	25.51	11.95	25.83	12.27	27.43	13.87
278.20	87.88	87.88	87.88	87.88	87.88	87.88	106.44	106.44	106.44	106.44	106.44	106.44	165.14	165.14	165.14	165.14	165.14	165.14	2.56	1.21	2.65	1.30	3.11	1.76	25.47	11.95	25.79	12.27	27.39	13.87
278.10	87.76	87.76	87.76	87.76	87.76	87.76	106.35	106.35	106.35	106.35	106.35	106.35	165.15	165.15	165.15	165.15	165.15	165.15	2.56	1.21	2.65	1.30	3.10	1.76	25.43	11.95	25.75	12.27	27.35	13.87
278.00	87.64	87.64	87.64	87.64	87.64	87.64	106.27	106.27	106.27	106.27	106.27	106.27	165.17	165.17	165.17	165.17	165.17	165.17	2.55	1.21	2.64	1.30	3.10	1.76	25.39	11.95	25.71	12.27	27.31	13.87
277.90	87.54	87.54	87.54	87.54	87.54	87.54	106.20	106.20	106.20	106.20	106.20	106.20	165.19	165.19	165.19	165.19	165.19	165.19	2.55	1.21	2.64	1.30	3.10	1.76	25.35	11.95	25.67	12.27	27.28	13.87
277.80	87.43	87.43	87.43	87.43	87.43	87.43	106.12	106.12	106.12	106.12	106.12	106.12	165.22	165.22	165.22	165.22	165.22	165.22	2.55	1.21	2.64	1.30	3.09	1.76	25.31	11.95	25.63	12.27	27.24	13.88
277.70	87.33	87.33	87.33	87.33	87.33	87.33	106.05	106.05	106.05	106.05	106.05	106.05	165.24	165.24	165.24	165.24	165.24	165.24	2.54	1.21	2.63	1.30	3.09	1.76	25.28	11.95	25.60	12.27	27.20	13.88
277.60	87.24	87.24	87.24	87.24	87.24	87.24	105.99	105.99	105.99	105.99	105.99	105.99	165.28	165.28	165.28	165.28	165.28	165.28	2.54	1.21	2.63	1.30	3.09	1.76	25.24	11.96	25.56	12.28	27.17	13.88
277.50	87.16	87.16	87.16	87.16	87.16	87.16	105.94	105.94	105.94	105.94	105.94	105.94	165.33	165.33	165.33	165.33	165.33	165.33	2.54	1.21	2.63	1.30	3.08	1.76	25.21	11.96	25.53	12.28	27.14	13.89
277.40	87.08	87.08	87.08	87.08	87.08	87.08	105.89	105.89	105.89	105.89	105.89	105.89	165.38	165.38	165.38	165.38	165.38	165.38	2.53	1.21	2.62	1.30	3.08	1.76	25.18	11.97	25.50	12.29	27.11	13.90
277.30	86.99	86.99	86.99	86.99	86.99	86.99	105.84	105.84	105.84	105.84	105.84	105.84	165.42	165.42	165.42	165.42	165.42	165.42	2.53	1.21	2.62	1.30	3.08	1.76	25.15	11.97	25.47	12.29	27.08	13.91
277.20	86.92	86.92	86.92	86.92	86.92	86.92	105.79	105.79	105.79	105.79	105.79	105.79	165.47	165.47	165.47	165.47	165.47	165.47	2.53	1.21	2.62	1.30	3.08	1.76	25.12	11.98	25.44	12.30	27.06	13.91
277.10	86.84	86.84	86.84	86.84	86.84	86.84	105.75	105.75	105.75	105.75	105.75	105.75	165.53	165.53	165.53	165.53	165.53	165.53	2.52	1.21	2.62	1.30	3.07	1.76	25.09	11.98	25.42	12.31	27.03	13.92
277.00	86.78	86.78	86.78	86.78	86.78	86.78	105.71	105.71	105.71	105.71	105.71	105.71	165.59	165.59	165.59	165.59	165.59	165.59	2.52	1.21	2.61	1.31	3.07	1.76	25.07	11.99	25.39	12.31	27.00	13.93
276.90	86.71	86.71	86.71	86.71	86.71	86.71	105.68	105.68	105.68	105.68	105.68	105.68	165.65	165.65	165.65	165.65	165.65	165.65	2.52	1.21	2.61	1.31	3.07	1.76	25.04	12.00	25.36	12.32	26.98	13.94
276.80	86.63	86.63	86.63	86.63	86.63	86.63	105.63	105.63	105.63	105.63	105.63	105.63	165.71	165.71	165.71	165.71	165.71	165.71	2.52	1.22	2.61	1.31	3.07	1.77	25.01	12.00	25.34	12.33	26.95	13.95
276.70	86.57	86.57	86.57	86.57	86.57	86.57	105.60	105.60	105.60	105.60	105.60	105.60	165.77	165.77	165.77	165.77	165.77	165.77	2.51	1.22	2.61	1.31	3.06	1.77	24.99	12.01	25.31	12.34	26.93	13.96
276.60	86.51	86.51	86.51	86.51	86.51	86.51	105.57	105.57	105.57	105.57	105.57	105.57	165.84	165.84	165.84	165.84	165.84	165.84	2.51	1.22	2.60	1.31	3.06	1.77	24.96	12.02	25.29	12.34	26.91	13.97
276.50	86.45	86.45	86.45	86.45	86.45	86.45	105.54	105.54	105.54	105.54	105.54	105.54	165.91	165.91	165.91	165.91	165.91	165.91	2.51	1.22	2.60	1.31	3.06	1.77	24.94	12.03	25.26	12.35	26.89	13.98
276.40	86.39	86.39	86.39	86.39	86.39	86.39	105.51	105.51	105.51	105.51	105.51	105.51	165.98	165.98	165.98	165.98	165.98	165.98	2.51	1.22	2.60	1.31	3.06	1.77	24.92	12.04	25.24	12.36	26.87	13.99
276.30	86.33	86.33	86.33	86.33	86.33	86.33	105.49	105.49	105.49	105.49	105.49	105.49	166.05	166.05	166.05	166.05	166.05	166.05	2.50	1.22	2.60	1.31	3.06	1.77	24.89	12.04	25.22	12.37	26.85	14.00
276.20	86.28	86.28	86.28	86.28	86.28	86.28	105.46	105.46	105.46	105.46	105.46	105.46	166.13	166.13	166.13	166.13	166.13	166.13	2.50	1.22	2.59	1.31	3.06	1.77	24.87	12.05	25.20	12.38	26.83	14.01
276.10	86.22	86.22	86.22	86.22	86.22	86.22	105.44	105.44	105.44	105.44	105.44	105.44	166.20	166.20	166.20	166.20	166.20	166.20	2.50	1.22	2.59	1.31	3.05	1.77	24.85	12.06	25.18	12.39	26.81	14.02
276.00	86.17	86.17	86.17	86.17	86.17	86.17	105.41	105.41	105.41	105.41	105.41	105.41	166.28	166.28	166.28	166.28	166.28	166.28	2.50	1.22	2.59	1.31	3.05	1.78	24.83	12.07	25.15	12.40	26.79	14.03
275.90	86.11	86.11	86.11	86.11	86.11	86.11	105.39	105.39	105.39	105.39	105.39	105.39	166.35	166.35	166.35	166.35	166.35	166.35	2.50	1.22	2.59	1.32	3.05	1.78	24.81	12.08	25.13	12.41	26.77	14.04
275.80	86.06	86.06	86.06	86.06	86.06	86.06	105.37	105.37	105.37	105.37	105.37	105.37	166.42	166.42	166.42	166.42	166.42	166.42	2.49	1.22	2.59	1.32	3.05	1.78	24.78	12.09	25.11	12.42	26.75	14.05
275.70	86.00	86.00	86.00	86.00	86.00	86.00	105.34	105.34	105.34	105.34	105.34	105.34	166.50	166.50	166.50	166.50	166.50	166.50	2.49	1.22	2.58	1.32	3.05	1.78	24.76	12.10	25.09	12.42	26.73	14.06
275.60	85.95	85.95	85.95	85.95	85.95	85.95	105.32	105.32	105.32	105.32	105.32	105.32	166.57	166.57	166.57	166.57	166.57	166.57	2.49	1.23	2.58	1.32	3.04	1.78	24.74	12.11	25.07	12.43	26.71	14.07
275.50	85.89	85.89	85.89	85.89	85.89	85.89	105.30	105.30	105.30	105.30	105.30	105.30	166.65	166.65	166.65	166.65	166.65	166.65	2.49	1.23	2.58	1.32	3.04	1.78	24.72	12.11	25.05	12.44	26.69	14.08
275.40	85.84	85.84	85.84	85.84	85.84	85.84	105.28	105.28	105.28	105.28	105.28	105.28	166.73	166.73	166.73	166.73	166.73	166.73	2.48	1.23	2.58	1.32	3.04	1.78	24.70	12.12	25.02	12.45	26.67	14.09
275.30	85.79	85.79	85.79	85.79	85.79	85.79	105.25	105.25	105.25	105.25	105.25	105.25	166.80	166.80	166.80	166.80	166.80	166.80	2.48	1.23	2.58	1.32	3.04	1.79	24.

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)
273.10	84.64	84.64	84.64	84.64	84.64	84.64	104.79	104.79	104.79	104.79	104.79	104.79	168.49	168.49	168.49	168.49	168.49	168.49	2.44	1.25	2.53	1.34	3.00	1.81	24.21	12.32	24.54	12.66	26.23	14.34
273.00	84.58	84.58	84.58	84.58	84.58	84.58	104.76	104.76	104.76	104.76	104.76	104.76	168.56	168.56	168.56	168.56	168.56	168.56	2.43	1.25	2.53	1.34	3.00	1.82	24.18	12.33	24.52	12.66	26.21	14.35
272.90	84.52	84.52	84.52	84.52	84.52	84.52	104.73	104.73	104.73	104.73	104.73	104.73	168.63	168.63	168.63	168.63	168.63	168.63	2.43	1.25	2.53	1.34	3.00	1.82	24.16	12.33	24.50	12.67	26.18	14.36
272.80	84.46	84.46	84.46	84.46	84.46	84.46	104.70	104.70	104.70	104.70	104.70	104.70	168.70	168.70	168.70	168.70	168.70	168.70	2.43	1.25	2.52	1.34	3.00	1.82	24.14	12.34	24.47	12.68	26.16	14.37
272.70	84.40	84.40	84.40	84.40	84.40	84.40	104.67	104.67	104.67	104.67	104.67	104.67	168.77	168.77	168.77	168.77	168.77	168.77	2.43	1.25	2.52	1.34	3.00	1.82	24.11	12.35	24.45	12.68	26.14	14.38
272.60	84.35	84.35	84.35	84.35	84.35	84.35	104.65	104.65	104.65	104.65	104.65	104.65	168.85	168.85	168.85	168.85	168.85	168.85	2.42	1.25	2.52	1.35	2.99	1.82	24.09	12.35	24.43	12.69	26.12	14.38
272.50	84.29	84.29	84.29	84.29	84.29	84.29	104.62	104.62	104.62	104.62	104.62	104.62	168.92	168.92	168.92	168.92	168.92	168.92	2.42	1.25	2.52	1.35	2.99	1.82	24.07	12.36	24.41	12.70	26.10	14.39
272.40	84.23	84.23	84.23	84.23	84.23	84.23	104.60	104.60	104.60	104.60	104.60	104.60	168.99	168.99	168.99	168.99	168.99	168.99	2.42	1.25	2.51	1.35	2.99	1.82	24.04	12.37	24.38	12.71	26.08	14.40
272.30	84.18	84.18	84.18	84.18	84.18	84.18	104.57	104.57	104.57	104.57	104.57	104.57	169.06	169.06	169.06	169.06	169.06	169.06	2.42	1.25	2.51	1.35	2.99	1.82	24.02	12.37	24.36	12.71	26.06	14.41
272.20	84.12	84.12	84.12	84.12	84.12	84.12	104.54	104.54	104.54	104.54	104.54	104.54	169.14	169.14	169.14	169.14	169.14	169.14	2.42	1.25	2.51	1.35	2.99	1.82	24.00	12.38	24.34	12.72	26.04	14.42
272.10	84.06	84.06	84.06	84.06	84.06	84.06	104.52	104.52	104.52	104.52	104.52	104.52	169.21	169.21	169.21	169.21	169.21	169.21	2.41	1.25	2.51	1.35	2.98	1.83	23.98	12.39	24.32	12.73	26.02	14.43
272.00	84.00	84.00	84.00	84.00	84.00	84.00	104.49	104.49	104.49	104.49	104.49	104.49	169.28	169.28	169.28	169.28	169.28	169.28	2.41	1.25	2.51	1.35	2.98	1.83	23.95	12.40	24.29	12.74	26.00	14.44
271.90	83.95	83.95	83.95	83.95	83.95	83.95	104.47	104.47	104.47	104.47	104.47	104.47	169.35	169.35	169.35	169.35	169.35	169.35	2.41	1.26	2.50	1.35	2.98	1.83	23.93	12.40	24.27	12.74	25.98	14.45
271.80	83.89	83.89	83.89	83.89	83.89	83.89	104.44	104.44	104.44	104.44	104.44	104.44	169.42	169.42	169.42	169.42	169.42	169.42	2.41	1.26	2.50	1.35	2.98	1.83	23.91	12.41	24.25	12.75	25.96	14.46
271.70	83.83	83.83	83.83	83.83	83.83	83.83	104.42	104.42	104.42	104.42	104.42	104.42	169.50	169.50	169.50	169.50	169.50	169.50	2.40	1.26	2.50	1.35	2.98	1.83	23.89	12.42	24.23	12.76	25.94	14.47
271.60	83.78	83.78	83.78	83.78	83.78	83.78	104.39	104.39	104.39	104.39	104.39	104.39	169.57	169.57	169.57	169.57	169.57	169.57	2.40	1.26	2.50	1.35	2.98	1.83	23.86	12.42	24.21	12.77	25.91	14.47
271.50	83.72	83.72	83.72	83.72	83.72	83.72	104.36	104.36	104.36	104.36	104.36	104.36	169.64	169.64	169.64	169.64	169.64	169.64	2.40	1.26	2.50	1.35	2.97	1.83	23.84	12.43	24.18	12.77	25.89	14.48
271.40	83.66	83.66	83.66	83.66	83.66	83.66	104.33	104.33	104.33	104.33	104.33	104.33	169.71	169.71	169.71	169.71	169.71	169.71	2.40	1.26	2.49	1.35	2.97	1.83	23.82	12.44	24.16	12.78	25.87	14.49
271.30	83.60	83.60	83.60	83.60	83.60	83.60	104.30	104.30	104.30	104.30	104.30	104.30	169.78	169.78	169.78	169.78	169.78	169.78	2.39	1.26	2.49	1.36	2.97	1.83	23.79	12.44	24.13	12.78	25.85	14.50
271.20	83.53	83.53	83.53	83.53	83.53	83.53	104.27	104.27	104.27	104.27	104.27	104.27	169.84	169.84	169.84	169.84	169.84	169.84	2.39	1.26	2.49	1.36	2.97	1.84	23.77	12.45	24.11	12.79	25.83	14.51
271.10	83.47	83.47	83.47	83.47	83.47	83.47	104.24	104.24	104.24	104.24	104.24	104.24	169.91	169.91	169.91	169.91	169.91	169.91	2.39	1.26	2.49	1.36	2.97	1.84	23.74	12.45	24.08	12.80	25.80	14.51
271.00	83.40	83.40	83.40	83.40	83.40	83.40	104.20	104.20	104.20	104.20	104.20	104.20	169.97	169.97	169.97	169.97	169.97	169.97	2.39	1.26	2.48	1.36	2.96	1.84	23.71	12.46	24.06	12.80	25.78	14.52
270.90	83.33	83.33	83.33	83.33	83.33	83.33	104.16	104.16	104.16	104.16	104.16	104.16	170.03	170.03	170.03	170.03	170.03	170.03	2.38	1.26	2.48	1.36	2.96	1.84	23.69	12.46	24.03	12.81	25.75	14.53
270.80	83.27	83.27	83.27	83.27	83.27	83.27	104.13	104.13	104.13	104.13	104.13	104.13	170.10	170.10	170.10	170.10	170.10	170.10	2.38	1.26	2.48	1.36	2.96	1.84	23.66	12.47	24.01	12.81	25.73	14.53
270.70	83.21	83.21	83.21	83.21	83.21	83.21	104.10	104.10	104.10	104.10	104.10	104.10	170.16	170.16	170.16	170.16	170.16	170.16	2.38	1.26	2.48	1.36	2.96	1.84	23.64	12.47	23.98	12.82	25.71	14.54
270.60	83.14	83.14	83.14	83.14	83.14	83.14	104.06	104.06	104.06	104.06	104.06	104.06	170.22	170.22	170.22	170.22	170.22	170.22	2.38	1.26	2.47	1.36	2.95	1.84	23.61	12.48	23.96	12.82	25.68	14.55
270.50	83.07	83.07	83.07	83.07	83.07	83.07	104.02	104.02	104.02	104.02	104.02	104.02	170.28	170.28	170.28	170.28	170.28	170.28	2.37	1.26	2.47	1.36	2.95	1.84	23.59	12.48	23.93	12.83	25.66	14.55
270.40	83.00	83.00	83.00	83.00	83.00	83.00	103.99	103.99	103.99	103.99	103.99	103.99	170.35	170.35	170.35	170.35	170.35	170.35	2.37	1.26	2.47	1.36	2.95	1.84	23.56	12.49	23.91	12.83	25.63	14.56
270.30	82.93	82.93	82.93	82.93	82.93	82.93	103.95	103.95	103.95	103.95	103.95	103.95	170.40	170.40	170.40	170.40	170.40	170.40	2.37	1.26	2.47	1.36	2.95	1.84	23.53	12.49	23.88	12.84	25.61	14.57
270.20	82.86	82.86	82.86	82.86	82.86	82.86	103.91	103.91	103.91	103.91	103.91	103.91	170.46	170.46	170.46	170.46	170.46	170.46	2.37	1.26	2.46	1.36	2.94	1.84	23.51	12.49	23.85	12.84	25.58	14.57
270.10	82.78	82.78	82.78	82.78	82.78	82.78	103.85	103.85	103.85	103.85	103.85	103.85	170.51	170.51	170.51	170.51	170.51	170.51	2.36	1.27	2.46	1.36	2.94	1.84	23.47	12.50	23.82	12.84	25.55	14.57
270.00	82.70	82.70	82.70	82.70	82.70	82.70	103.81	103.81	103.81	103.81	103.81	103.81	170.56	170.56	170.56	170.56	170.56	170.56	2.36	1.27	2.46	1.36	2.94	1.84	23.45	12.50	23.79	12.85	25.53	14.58
269.90	82.63	82.63	82.63	82.63	82.63	82.63	103.77	103.77	103.77	103.77	103.77	103.77	170.62	170.62	170.62	170.62	170.62	170.62	2.36	1.27	2.45	1.36	2.94	1.84	23.42	12.50	23.76	12.85	25.50	14.58
269.80	82.55	82.55	82.55	82.55	82.55	82.55	103.72	103.72	103.72	103.72	103.72	103.72	170.67	170.67	170.67	170.67	170.67	170.67	2.35	1.27	2.45	1.36	2.93	1.85	23.39	12.51	23.74	12.85	25.47	14.59
269.70	82.48	82.48	82.48	82.48	82.48	82.48	103.68	103.68	103.68	103.68	103.68	103.68	170.72	170.72	170.72	170.72	170.72	170.72	2.35	1.27	2.45	1.36	2.93	1.85	23.36	12.51	23.71	12.86	25.44	14.59
269.60	82.40	82.40	82.40	82.40	82.40	82.40	103.64	103.64	103.64	103.64	103.64	103.64	170.78	170.78	170.78	170.78	170.78	170.78	2.35	1.27	2.45	1.36	2.93	1.85	23.33	12.51	23.68	12.86	25.42	14.60
269.50	82.33	82.33	82.33	82.33	82.33	82.33	103.59	103.59	103.59	103.59	103.59	103.59	170.83	170.83	170.83	170.83	170.83	170.83	2.35	1.27	2.44	1.36	2.93	1.85	23.30	12.52	23.65	12.86	25.39	14.60
269.40	82.25	82.25	82.25	82.25	82.25	82.25	103.55	103.55	103.55	103.55	103.55	103.55	170.89	170.89	170.89	170.89	170.89	170.89	2.34	1.27	2.44	1.36	2.92	1.85	23.28	12.52	23.62	12.87	25.36	14.61
269.30	82.18	82.18	82.18	82.18	82.18	82.18	103.51	103.51	103.51	103.51	103.51	103.51	170.94	170.94	170.94	170.94	170.94	170.94	2.34	1.27	2.44	1.36	2.92	1.85	23.25	12.52	23.60	12.87	25.34	14.61
269.20	82.11	82.11	82.11	82.11	82.11	82.11	103.47	103.47	103.47	103.47	103.47	103.47	171.00	171.00	171.00	171.00	171.00	171.00	2.34	1.27	2.43	1.36	2.92	1.85	23.22	12.52	23.57	12.87	25.31	14.61
269.10	82.04	82.04	82.04	82.04	82.04	82.04	103.42	103.42	103.42	103.42	103.42	103.42	171.06	171.06	171.06	171.06	171.06	171.06	2.33	1.27	2.43	1.37	2.92	1.85	23.19	12.53	23.54	12.88	25.28	14.62
269.00	81.97	81.97	81.97	81.97	81.97	81.97	103.39	103.39	103.39	103.39	103.39	103.39	171.12	171.12	171.12	171.12	171.12	171.12	2.33	1.27	2.43	1.37	2.91	1.85	23.17	12.53	23.51	12.88	25.26	14.62
268.90	81.90	81.90	81.90	81.90	81.90	81.90	103.35	103.35	103.35	103.35	103.35	103.35	171.18	171.18	171.18	171.18	171.18	171.18	2.33	1.27	2.43	1.37	2.91	1.85	23.14	12.53	23.49	12.88	25.23	14.63
268.80	81.82	81.82	81.82	81.82	81.82	81.82	103.31	103.31	103.31	103.31	103.31	103.31	171.24	171.24	171.24	171.24	171.24	171.24	2.33	1.27	2.42	1.37	2.91	1.85	23.11	12.54	23.46	12.89	25.21	14.63
268.70	81.76	81.76	81.76	81.76	81.76	81.76	103.27	103.27	103.27	103.27	103.27	103.27	171.30	171.30	171.30	171.30	171.30	171.30	2.32	1.27	2.42	1.37	2.91	1.85	23.08	12.54	23.43	12.89	25.18	14.64
268.60	81.69	81.69	81.69	81.69	81.69	81.69	103.23	103.23	103.23	103.23	103.23	103.23	171.36	171.36	171.36	171.36	171.36	171.36	2.32	1.27	2.42	1.37	2.90	1.85	23.06	12.55	23.41	12.90	25.16	14.65
268.50	81.63	81.63	81.63	81.63	81.63	81.63	103.20	103.20	103.20	103.20	103.20	103.20	171.42	171.42	171.42	171.42	171.42	171.42	2.32	1.27	2.42	1.37	2.90	1.85	23.03	12.55	23.38	12.90	25.13	14.65
268.40	81.56	81.56	81.56	81.56	81.56	81.56	103.17	103.17	103.17	103.17	103.17	103.17	171.49	171.49	171.49	171.49	171.49	171.49	2.32	1.27	2.41	1.37	2.90	1.85	23.01	12.55	23.36	12.90	25.11	14.66
268.30	81.50	81.50	81.50	81.50	81.50	81.50	103.13	103.13	103.13	103.13	103.13	103.13	171.55	171.55	171.55	171.55	171.55	171.55	2.31	1.27	2.41	1.37	2.90	1.85	22.98	12.56	23.33	12.91	25.09	14.66
268.20	81.43	81.43	81.43	81.43	81.43	81.43	103.10	103.10	103.10	103.10	103.10	103.10	171.62	171.62	171.62	171.62	171.62	171.62	2.31	1.27	2.41	1.37	2.89	1.86	22.96	12.56	23.31	12.91	25.06	14.67
268.10	81.37	81.37	81.37	81.37	81.37	81.37	103.07	103.07	103.07	103.07	103.07	103.07	171.68	171.68	171.68	171.68	171.68	171.68	2.31	1.27	2.41	1.37	2.89	1.86	22.93	12.57	23.28	12.92	25.04	14.67
268.00	81.30	81.30	81.30	81.30	81.30	81.30	103.03	103.03	103.03	103.03	103.03	103.03	171.75	171.75	171.75	171.75	171.75	171.75	2.31	1.27	2.40	1.37	2.89	1.86	22.91	12.57	23.26	12.92	25.02	14.68
267.90	81.24	81.24	81.24	81.24	81.24	81.24	103.00	103.00	103.00	103.00	103.00	103.00	171.82	171.82	171.82	171.82	171.82	171.82	2.30	1.27	2.40	1.37	2.89	1.86	22.88	12.58	23.24	12.93	25.00	14.69
267.80	81.18	81.18	81.18	81.18	81.18	81.18	102.97	102.97	102.97	102.97	102.97	102.97	171.88	171.88	171.88	171.88	171.88	171.88	2.30	1.27	2.40	1.37	2.89	1.86	22.86	12.58	23.21	12.93	24.97	14.69
267.70	81.12	81.12	81.12	81.12	81.12	81.12	102.94	102.94	102.94	102.94	102.94	102.94	171.95	171.95	171.95	171.95	171.95	171.95	2.30	1.27	2.40	1.37	2.88	1.86	22.83	12.58	23.19	12.94	24.95	14.70
267.60	81.06	81.06	81.06	81.06	81.06	81.06	102.91	102.91	102.91	102.91	102.91	102.91	172.02	172.02	172.02	172.02	172.02	172.02	2.30	1.27	2.39	1.37	2.88	1.86	22.81	12.59	23.16	12.94	24.93	14.71
267.50	81.00	81.00	81.00	81.00	81.00	81.00	102.88	102.88	102.88	102.88	102.88	102.88	172.09	172.09	172.09	172.09	172.09	172.09	2.29	1.27	2.39	1.37	2.88	1.86	22.79	12.59	23.14	12.95	24.90	14.71
267.40	80.94	80.94	80.94	80.94	80.94	80.94	102.85	102.85	102.85	102.85	102.85	102.85	172.16	172.16	172.16	172.16	172.16	172.16	2.29	1.28	2.39	1.37	2.88	1.86	22.76	12.60	23.12	12.95	24.88	14.72
267.30	80.88	80.88	80.88	80.88	80.88	80.88	102.82	102.82	102.82	102.82	102.82	102.82	172.22	172.22	172.22	172.22	172.22	172.22	2.29	1.28	2.39	1.37	2.88	1.86	22.74	12.60	23.09	12.96	24.86	14.72
267.20	80.81	80.81	80.81	80.81	80.81	80.81	102.79	102.79	102.79	102.79	102.79	102.79	172.29	172.29	172.29	172.29	172.29	172.29	2.29	1.28	2.38	1.37	2.87	1.86	22.71	12.61	23.07	12.96	24.84	14.73
267.10	80.74	80.74	80.74	80.74	80.74	80.74	102.75	102.75	102.75	102.75	102.75	102.75	172.35	172.35	172.35	172.35	172.35	172.35	2.28	1.28	2.38	1.37	2.87	1.86	22.69	12.61	23.04	12.96	24.81	14.73
267.00	80.67	80.67	80.67	80.67	80.67	80.67	102.71	102.71	102.71	102.71	102.71	102.71	172.41	172.41	172.41	172.41	172.41	172.41	2.28	1.28	2.38	1.37	2.87	1.86	22.66	12.61	23.02	12.97	24.79	14.74
266.90	80.61	80.61	80.61	80.61	80.61	80.61	102.68	102.68	102.68	102.68	102.68	102.68	172.48	172.48	172.48	172.48	172.48	172.48	2.28	1.28	2.38	1.38	2.87	1.86	22.64	12.62	22.99	12.97	24.76	14.74
266.80	80.55	80.55	80.55	80.55	80.55	80.55	102.65	102.65	102.65	102.65	102.65	102.65	172.54	172.54	172.54	172.54	172.54	172.54	2.28	1.28	2.37	1.38	2.86	1.87	22.61	12.62	22.97	12.98	24.74	14.75
266.70	80.49	80.49	80.49	80.49	80.49	80.49	102.62	102.62	102.62	102.62	102.62	102.62	172.61	172.61	172.61	172.61	172.61	172.61	2.27	1.28	2.37	1.38	2.86	1.87	22.59	12.63	22.94	12.98	24.72	14.76
266.60	80.43	80.43	80.43	80.43	80.43	80.43	102.60	102.60	102.60	102.60	102.60	102.60	172.69	172.69	172.69	172.69	172.69	172.69	2.27	1.28	2.37	1.38	2.86	1.87	22.57	12.63	22.92	12.99	24.70	14.76
266.50	80.38	80.38	80.38	80.38	80.38	80.38	102.57	102.57	102.57	102.57	102.57	102.57	172.76	172.76	172.76	172.76	172.76	172.76	2.27	1.28	2.37	1.38	2.86	1.87	22.54	12.64	22.90	12.99	24.68	14.77
266.40	80.32	80.32	80.32	80.32	80.32	80.32	102.55	102.55	102.55	102.55	102.55	102.55	172.83	172.83	172.83	172.83	172.83	172.83	2.27	1.28	2.37	1.38	2.86	1.87	22.52	12.64	22.88	13.00	24.66	14.78
266.30	80.27	80.27	80.27	80.27	80.27	80.27	102.52	102.52	102.52	102.52	102.52	102.52	172.91	172.91	172.91	172.91	172.91	172.91	2.27	1.28	2.36	1.38	2.85	1.87	22.50	12.65	22.85	13.00	24.64	14.78
266.20	80.21	80.21	80.21	80.21	80.21	80.21	102.50	102.50	102.50	102.50	102.50	102.50	172.98	172.98	172.98	172.98	172.98	172.98	2.26	1.28	2.36	1.38	2.85	1.87	22.48	12.65	22.83	13.01	24.62	14.79
266.10	80.15	80.15	80.15	80.15	80.15	80.15	102.47	102.47	102.47	102.47	102.47	102.47	173.05	173.05	173.05	173.05	173.05	173.05	2.26	1.28	2.36	1.38	2.85	1.87	22.45	12.65	22.81	13.01	24.59	14.80
266.00	80.08	80.08	80.08	80.08	80.08	80.08	102.43	102.43	102.43	102.43	102.43	102.43	173.11	173.11	173.11	173.11	173.11	173.11	2.26	1.28	2.36	1.38	2.85	1.87	22.42	12.66	22.78	13.01	24.57	14.80
265.90	80.01	80.01	80.01	80.01	80.01	80.01	102.39	102.39	102.39	102.39	102.39	102.39	173.17	173.17	173.17	173.17	173.17	173.17	2.26	1.28	2.35	1.38	2.85	1.87	22.40	12.66	22.76	13.02	24.54	14.80
265.80	79.95	79.95	79.95	79.95	79.95	79.95	102.36	102.36	102.36	102.36	102.36	102.36	173.23	173.23	173.23	173.23	173.23	173.23	2.25	1.28	2.35	1.38	2.84	1.87	22.37	12.66	22.73	13.02	24.52	14.81
265.70	79.89	79.89	79.89	79.89	79.89	79.89	102.33	102.33	102.33	102.33	102.33	102.33	173.30	173.30	173.30	173.30	173.30	173.30	2.25	1.28	2.35	1.38	2.84	1.87	22.35	12.67	22.71	13.02	24.50	14.81
265.60	79.83	79.83	79.83	79.83	79.83	79.83	102.30	102.30	102.30	102.30	102.30	102.30	173.37	173.37	173.37	173.37	173.37	173.37	2.25	1.28	2.35	1.38	2.84	1.87	22.33	12.67	22.69	13.03	24.48	14.82
265.50	79.77	79.77	79.77	79.77	79.77	79.77	102.28	102.28	102.28	102.28	102.28	102.28	173.45	173.45	173.45	173.45	173.45	173.45	2.25	1.28	2.34	1.38	2.84	1.87	22.30	12.68	22.66	13.03	24.46	14.83
265.40	79.71	79.71	79.71	79.71	79.71	79.71	102.25	102.25	102.25	102.25	102.25	102.25	173.52	173.52	173.52	173.52	173.52	173.52	2.24	1.28	2.34	1.38	2.84	1.88	22.28	12.68	22.64	13.04	24.43	14.83
265.30	79.65	79.65	79.65	79.65	79.65	79.65	102.22	102.22	102.22	102.22	102.22	102.22	173.59	173.59	173.59	173.59	173.59	173.59	2.24	1.28	2.34	1.38	2.83	1.88	22.26	12.68	22.62	13.04	24.41	14.84
265.20	79.59	79.59	79.59	79.59	79.59	79.59	102.19	102.19	102.19	102.19	102.19	102.19	173.65	173.65	173.65	173.65	173.65	173.65	2.24	1.28	2.34	1.38	2.83	1.88	22.23	12.69	22.59	13.05	24.39	14.84
265.10	79.52	79.52	79.52	79.52	79.52	79.52	102.15	102.15	102.15	102.15	102.15	102.15	173.71	173.71	173.71	173.71	173.71	173.71	2.24	1.28	2.33	1.38	2.83	1.88	22.20	12.69	22.56	13.05	24.36	14.85

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)
262.90	77.99	77.99	77.99	77.99	77.99	77.99	101.30	101.30	101.30	101.30	101.30	101.30	175.02	175.02	175.02	175.02	175.02	175.02	2.18	1.29	2.28	1.39	2.77	1.88	21.61	12.72	21.98	13.09	23.80	14.91
262.80	77.93	77.93	77.93	77.93	77.93	77.93	101.27	101.27	101.27	101.27	101.27	101.27	175.09	175.09	175.09	175.09	175.09	175.09	2.17	1.29	2.27	1.39	2.77	1.88	21.59	12.73	21.96	13.09	23.78	14.92
262.70	77.87	77.87	77.87	77.87	77.87	77.87	101.24	101.24	101.24	101.24	101.24	101.24	175.16	175.16	175.16	175.16	175.16	175.16	2.17	1.29	2.27	1.39	2.77	1.89	21.57	12.73	21.93	13.09	23.76	14.92
262.60	77.80	77.80	77.80	77.80	77.80	77.80	101.21	101.21	101.21	101.21	101.21	101.21	175.22	175.22	175.22	175.22	175.22	175.22	2.17	1.29	2.27	1.39	2.77	1.89	21.54	12.73	21.91	13.10	23.73	14.92
262.50	77.74	77.74	77.74	77.74	77.74	77.74	101.18	101.18	101.18	101.18	101.18	101.18	175.29	175.29	175.29	175.29	175.29	175.29	2.17	1.29	2.27	1.39	2.76	1.89	21.52	12.73	21.88	13.10	23.71	14.93
262.40	77.68	77.68	77.68	77.68	77.68	77.68	101.14	101.14	101.14	101.14	101.14	101.14	175.36	175.36	175.36	175.36	175.36	175.36	2.16	1.29	2.26	1.39	2.76	1.89	21.49	12.73	21.86	13.10	23.69	14.93
262.30	77.60	77.60	77.60	77.60	77.60	77.60	101.10	101.10	101.10	101.10	101.10	101.10	175.41	175.41	175.41	175.41	175.41	175.41	2.16	1.29	2.26	1.39	2.76	1.89	21.46	12.74	21.83	13.10	23.66	14.93
262.20	77.53	77.53	77.53	77.53	77.53	77.53	101.06	101.06	101.06	101.06	101.06	101.06	175.47	175.47	175.47	175.47	175.47	175.47	2.16	1.29	2.26	1.39	2.76	1.89	21.44	12.74	21.80	13.10	23.64	14.93
262.10	77.46	77.46	77.46	77.46	77.46	77.46	101.02	101.02	101.02	101.02	101.02	101.02	175.53	175.53	175.53	175.53	175.53	175.53	2.16	1.29	2.26	1.39	2.75	1.89	21.41	12.74	21.78	13.10	23.61	14.94
262.00	77.39	77.39	77.39	77.39	77.39	77.39	100.98	100.98	100.98	100.98	100.98	100.98	175.58	175.58	175.58	175.58	175.58	175.58	2.15	1.29	2.25	1.39	2.75	1.89	21.38	12.74	21.75	13.10	23.58	14.94
261.90	77.31	77.31	77.31	77.31	77.31	77.31	100.94	100.94	100.94	100.94	100.94	100.94	175.64	175.64	175.64	175.64	175.64	175.64	2.15	1.29	2.25	1.39	2.75	1.89	21.35	12.74	21.72	13.10	23.56	14.94
261.80	77.24	77.24	77.24	77.24	77.24	77.24	100.89	100.89	100.89	100.89	100.89	100.89	175.69	175.69	175.69	175.69	175.69	175.69	2.15	1.29	2.25	1.39	2.75	1.89	21.32	12.74	21.69	13.10	23.53	14.94
261.70	77.16	77.16	77.16	77.16	77.16	77.16	100.85	100.85	100.85	100.85	100.85	100.85	175.75	175.75	175.75	175.75	175.75	175.75	2.15	1.29	2.25	1.39	2.74	1.89	21.30	12.73	21.66	13.10	23.50	14.94
261.60	77.08	77.08	77.08	77.08	77.08	77.08	100.80	100.80	100.80	100.80	100.80	100.80	175.80	175.80	175.80	175.80	175.80	175.80	2.14	1.29	2.24	1.39	2.74	1.89	21.27	12.73	21.63	13.10	23.47	14.94
261.50	77.00	77.00	77.00	77.00	77.00	77.00	100.75	100.75	100.75	100.75	100.75	100.75	175.85	175.85	175.85	175.85	175.85	175.85	2.14	1.29	2.24	1.39	2.74	1.89	21.24	12.73	21.60	13.10	23.44	14.94
261.40	76.91	76.91	76.91	76.91	76.91	76.91	100.69	100.69	100.69	100.69	100.69	100.69	175.88	175.88	175.88	175.88	175.88	175.88	2.14	1.29	2.24	1.39	2.73	1.89	21.20	12.73	21.57	13.10	23.41	14.94
261.30	76.81	76.81	76.81	76.81	76.81	76.81	100.62	100.62	100.62	100.62	100.62	100.62	175.91	175.91	175.91	175.91	175.91	175.91	2.13	1.29	2.23	1.39	2.73	1.89	21.17	12.72	21.53	13.09	23.37	14.93
261.20	76.70	76.70	76.70	76.70	76.70	76.70	100.54	100.54	100.54	100.54	100.54	100.54	175.93	175.93	175.93	175.93	175.93	175.93	2.13	1.29	2.23	1.39	2.73	1.89	21.12	12.72	21.49	13.08	23.33	14.92
261.10	76.58	76.58	76.58	76.58	76.58	76.58	100.45	100.45	100.45	100.45	100.45	100.45	175.94	175.94	175.94	175.94	175.94	175.94	2.12	1.29	2.22	1.39	2.72	1.88	21.08	12.71	21.45	13.07	23.29	14.91
261.00	76.45	76.45	76.45	76.45	76.45	76.45	100.36	100.36	100.36	100.36	100.36	100.36	175.94	175.94	175.94	175.94	175.94	175.94	2.12	1.29	2.22	1.38	2.72	1.88	21.04	12.70	21.40	13.06	23.24	14.90
260.90	76.31	76.31	76.31	76.31	76.31	76.31	100.24	100.24	100.24	100.24	100.24	100.24	175.93	175.93	175.93	175.93	175.93	175.93	2.11	1.28	2.21	1.38	2.71	1.88	20.99	12.68	21.35	13.05	23.19	14.89
260.80	76.15	76.15	76.15	76.15	76.15	76.15	100.12	100.12	100.12	100.12	100.12	100.12	175.90	175.90	175.90	175.90	175.90	175.90	2.11	1.28	2.21	1.38	2.71	1.88	20.93	12.66	21.30	13.03	23.14	14.87
260.70	75.99	75.99	75.99	75.99	75.99	75.99	99.98	99.98	99.98	99.98	99.98	99.98	175.86	175.86	175.86	175.86	175.86	175.86	2.10	1.28	2.20	1.38	2.70	1.88	20.87	12.65	21.24	13.01	23.08	14.85
260.60	75.81	75.81	75.81	75.81	75.81	75.81	99.83	99.83	99.83	99.83	99.83	99.83	175.81	175.81	175.81	175.81	175.81	175.81	2.10	1.28	2.20	1.38	2.69	1.87	20.81	12.62	21.18	12.99	23.01	14.83
260.50	75.61	75.61	75.61	75.61	75.61	75.61	99.67	99.67	99.67	99.67	99.67	99.67	175.74	175.74	175.74	175.74	175.74	175.74	2.09	1.28	2.19	1.37	2.68	1.87	20.74	12.60	21.11	12.97	22.94	14.80
260.40	75.41	75.41	75.41	75.41	75.41	75.41	99.50	99.50	99.50	99.50	99.50	99.50	175.67	175.67	175.67	175.67	175.67	175.67	2.08	1.27	2.18	1.37	2.68	1.87	20.67	12.57	21.04	12.94	22.87	14.77
260.30	75.20	75.20	75.20	75.20	75.20	75.20	99.32	99.32	99.32	99.32	99.32	99.32	175.60	175.60	175.60	175.60	175.60	175.60	2.08	1.27	2.17	1.37	2.67	1.86	20.60	12.55	20.97	12.91	22.80	14.74
260.20	74.97	74.97	74.97	74.97	74.97	74.97	99.12	99.12	99.12	99.12	99.12	99.12	175.49	175.49	175.49	175.49	175.49	175.49	2.07	1.27	2.17	1.37	2.66	1.86	20.52	12.51	20.89	12.88	22.71	14.71
260.10	74.72	74.72	74.72	74.72	74.72	74.72	98.90	98.90	98.90	98.90	98.90	98.90	175.37	175.37	175.37	175.37	175.37	175.37	2.06	1.26	2.16	1.36	2.65	1.85	20.44	12.48	20.80	12.84	22.63	14.67
260.00	74.46	74.46	74.46	74.46	74.46	74.46	98.67	98.67	98.67	98.67	98.67	98.67	175.24	175.24	175.24	175.24	175.24	175.24	2.05	1.26	2.15	1.36	2.64	1.85	20.35	12.44	20.72	12.80	22.54	14.63
259.90	74.20	74.20	74.20	74.20	74.20	74.20	98.45	98.45	98.45	98.45	98.45	98.45	175.11	175.11	175.11	175.11	175.11	175.11	2.04	1.26	2.14	1.35	2.63	1.84	20.26	12.40	20.63	12.77	22.44	14.58
259.80	73.97	73.97	73.97	73.97	73.97	73.97	98.25	98.25	98.25	98.25	98.25	98.25	175.01	175.01	175.01	175.01	175.01	175.01	2.03	1.25	2.13	1.35	2.62	1.84	20.19	12.37	20.55	12.73	22.36	14.55
259.70	73.74	73.74	73.74	73.74	73.74	73.74	98.04	98.04	98.04	98.04	98.04	98.04	174.91	174.91	174.91	174.91	174.91	174.91	2.03	1.25	2.12	1.35	2.61	1.83	20.11	12.34	20.47	12.70	22.28	14.51
259.60	73.54	73.54	73.54	73.54	73.54	73.54	97.88	97.88	97.88	97.88	97.88	97.88	174.84	174.84	174.84	174.84	174.84	174.84	2.02	1.25	2.12	1.34	2.60	1.83	20.04	12.31	20.40	12.67	22.21	14.48
259.50	73.38	73.38	73.38	73.38	73.38	73.38	97.75	97.75	97.75	97.75	97.75	97.75	174.81	174.81	174.81	174.81	174.81	174.81	2.01	1.24	2.11	1.34	2.60	1.83	19.98	12.29	20.34	12.65	22.15	14.46
259.40	73.24	73.24	73.24	73.24	73.24	73.24	97.63	97.63	97.63	97.63	97.63	97.63	174.79	174.79	174.79	174.79	174.79	174.79	2.01	1.24	2.11	1.34	2.59	1.82	19.93	12.28	20.29	12.64	22.10	14.45
259.30	73.10	73.10	73.10	73.10	73.10	73.10	97.53	97.53	97.53	97.53	97.53	97.53	174.78	174.78	174.78	174.78	174.78	174.78	2.00	1.24	2.10	1.34	2.58	1.82	19.88	12.26	20.24	12.62	22.05	14.43
259.20	72.96	72.96	72.96	72.96	72.96	72.96	97.42	97.42	97.42	97.42	97.42	97.42	174.78	174.78	174.78	174.78	174.78	174.78	2.00	1.24	2.10	1.34	2.58	1.82	19.83	12.25	20.20	12.61	22.00	14.42
259.10	72.83	72.83	72.83	72.83	72.83	72.83	97.33	97.33	97.33	97.33	97.33	97.33	174.78	174.78	174.78	174.78	174.78	174.78	1.99	1.24	2.09	1.34	2.57	1.82	19.79	12.24	20.15	12.60	21.96	14.40
259.00	72.71	72.71	72.71	72.71	72.71	72.71	97.24	97.24	97.24	97.24	97.24	97.24	174.79	174.79	174.79	174.79	174.79	174.79	1.99	1.24	2.09	1.33	2.57	1.82	19.75	12.22	20.11	12.59	21.91	14.39
258.90	72.60	72.60	72.60	72.60	72.60	72.60	97.15	97.15	97.15	97.15	97.15	97.15	174.80	174.80	174.80	174.80	174.80	174.80	1.99	1.24	2.08	1.33	2.56	1.82	19.70	12.21	20.06	12.57	21.87	14.38
258.80	72.48	72.48	72.48	72.48	72.48	72.48	97.07	97.07	97.07	97.07	97.07	97.07	174.81	174.81	174.81	174.81	174.81	174.81	1.98	1.24	2.08	1.33	2.56	1.81	19.66	12.20	20.02	12.56	21.83	14.37
258.70	72.37	72.37	72.37	72.37	72.37	72.37	96.99	96.99	96.99	96.99	96.99	96.99	174.83	174.83	174.83	174.83	174.83	174.83	1.98	1.23	2.07	1.33	2.56	1.81	19.62	12.19	19.98	12.56	21.79	14.36
258.60	72.26	72.26	72.26	72.26	72.26	72.26	96.91	96.91	96.91	96.91	96.91	96.91	174.85	174.85	174.85	174.85	174.85	174.85	1.97	1.23	2.07	1.33	2.55	1.81	19.58	12.19	19.94	12.55	21.75	14.35
258.50	72.16	72.16	72.16	72.16	72.16	72.16	96.83	96.83	96.83	96.83	96.83	96.83	174.88	174.88	174.88	174.88	174.88	174.88	1.97	1.23	2.07	1.33	2.55	1.81	19.54	12.18	19.90	12.54	21.71	14.34
258.40	72.06	72.06	72.06	72.06	72.06	72.06	96.77	96.77	96.77	96.77	96.77	96.77	174.90	174.90	174.90	174.90	174.90	174.90	1.97	1.23	2.06	1.33	2.54	1.81	19.51	12.17	19.87	12.53	21.67	14.34
258.30	71.96	71.96	71.96	71.96	71.96	71.96	96.70	96.70	96.70	96.70	96.70	96.70	174.94	174.94	174.94	174.94	174.94	174.94	1.96	1.23	2.06	1.33	2.54	1.81	19.47	12.16	19.83	12.52	21.64	14.33
258.20	71.87	71.87	71.87	71.87	71.87	71.87	96.64	96.64	96.64	96.64	96.64	96.64	174.98	174.98	174.98	174.98	174.98	174.98	1.96	1.23	2.06	1.33	2.54	1.81	19.44	12.16	19.80	12.52	21.61	14.32
258.10	71.78	71.78	71.78	71.78	71.78	71.78	96.58	96.58	96.58	96.58	96.58	96.58	175.01	175.01	175.01	175.01	175.01	175.01	1.96	1.23	2.05	1.33	2.53	1.81	19.40	12.15	19.77	12.51	21.57	14.32
258.00	71.69	71.69	71.69	71.69	71.69	71.69	96.52	96.52	96.52	96.52	96.52	96.52	175.05	175.05	175.05	175.05	175.05	175.05	1.95	1.23	2.05	1.33	2.53	1.81	19.37	12.14	19.73	12.51	21.54	14.31
257.90	71.59	71.59	71.59	71.59	71.59	71.59	96.46	96.46	96.46	96.46	96.46	96.46	175.09	175.09	175.09	175.09	175.09	175.09	1.95	1.23	2.04	1.32	2.53	1.81	19.34	12.14	19.70	12.50	21.50	14.31
257.80	71.50	71.50	71.50	71.50	71.50	71.50	96.40	96.40	96.40	96.40	96.40	96.40	175.12	175.12	175.12	175.12	175.12	175.12	1.95	1.23	2.04	1.32	2.52	1.80	19.30	12.13	19.66	12.49	21.47	14.30
257.70	71.41	71.41	71.41	71.41	71.41	71.41	96.34	96.34	96.34	96.34	96.34	96.34	175.16	175.16	175.16	175.16	175.16	175.16	1.94	1.23	2.04	1.32	2.52	1.80	19.27	12.12	19.63	12.49	21.44	14.29
257.60	71.33	71.33	71.33	71.33	71.33	71.33	96.28	96.28	96.28	96.28	96.28	96.28	175.21	175.21	175.21	175.21	175.21	175.21	1.94	1.23	2.03	1.32	2.52	1.80	19.24	12.12	19.60	12.48	21.41	14.29
257.50	71.24	71.24	71.24	71.24	71.24	71.24	96.23	96.23	96.23	96.23	96.23	96.23	175.25	175.25	175.25	175.25	175.25	175.25	1.94	1.23	2.03	1.32	2.51	1.80	19.20	12.11	19.57	12.48	21.38	14.29
257.40	71.15	71.15	71.15	71.15	71.15	71.15	96.17	96.17	96.17	96.17	96.17	96.17	175.29	175.29	175.29	175.29	175.29	175.29	1.93	1.23	2.03	1.32	2.51	1.80	19.17	12.11	19.53	12.47	21.34	14.28
257.30	71.05	71.05	71.05	71.05	71.05	71.05	96.10	96.10	96.10	96.10	96.10	96.10	175.32	175.32	175.32	175.32	175.32	175.32	1.93	1.22	2.02	1.32	2.50	1.80	19.13	12.10	19.50	12.46	21.30	14.27
257.20	70.95	70.95	70.95	70.95	70.95	70.95	96.03	96.03	96.03	96.03	96.03	96.03	175.35	175.35	175.35	175.35	175.35	175.35	1.92	1.22	2.02	1.32	2.50	1.80	19.10	12.09	19.46	12.45	21.27	14.26
257.10	70.86	70.86	70.86	70.86	70.86	70.86	95.98	95.98	95.98	95.98	95.98	95.98	175.39	175.39	175.39	175.39	175.39	175.39	1.92	1.22	2.02	1.32	2.50	1.80	19.07	12.09	19.43	12.45	21.24	14.26
257.00	70.78	70.78	70.78	70.78	70.78	70.78	95.93	95.93	95.93	95.93	95.93	95.93	175.44	175.44	175.44	175.44	175.44	175.44	1.92	1.22	2.01	1.32	2.49	1.80	19.03	12.08	19.40	12.44	21.21	14.25
256.90	70.70	70.70	70.70	70.70	70.70	70.70	95.87	95.87	95.87	95.87	95.87	95.87	175.49	175.49	175.49	175.49	175.49	175.49	1.92	1.22	2.01	1.32	2.49	1.80	19.00	12.08	19.37	12.44	21.18	14.25
256.80	70.61	70.61	70.61	70.61	70.61	70.61	95.82	95.82	95.82	95.82	95.82	95.82	175.53	175.53	175.53	175.53	175.53	175.53	1.91	1.22	2.01	1.32	2.49	1.80	18.97	12.07	19.33	12.43	21.15	14.25
256.70	70.53	70.53	70.53	70.53	70.53	70.53	95.76	95.76	95.76	95.76	95.76	95.76	175.57	175.57	175.57	175.57	175.57	175.57	1.91	1.22	2.00	1.32	2.48	1.80	18.94	12.07	19.30	12.43	21.11	14.24
256.60	70.43	70.43	70.43	70.43	70.43	70.43	95.70	95.70	95.70	95.70	95.70	95.70	175.61	175.61	175.61	175.61	175.61	175.61	1.91	1.22	2.00	1.32	2.48	1.80	18.90	12.06	19.27	12.42	21.08	14.23
256.50	70.34	70.34	70.34	70.34	70.34	70.34	95.64	95.64	95.64	95.64	95.64	95.64	175.65	175.65	175.65	175.65	175.65	175.65	1.90	1.22	2.00	1.32	2.48	1.79	18.87	12.05	19.23	12.41	21.05	14.23
256.40	70.26	70.26	70.26	70.26	70.26	70.26	95.59	95.59	95.59	95.59	95.59	95.59	175.69	175.69	175.69	175.69	175.69	175.69	1.90	1.22	1.99	1.32	2.47	1.79	18.84	12.05	19.20	12.41	21.01	14.22
256.30	70.17	70.17	70.17	70.17	70.17	70.17	95.53	95.53	95.53	95.53	95.53	95.53	175.73	175.73	175.73	175.73	175.73	175.73	1.90	1.22	1.99	1.31	2.47	1.79	18.81	12.04	19.17	12.40	20.98	14.21
256.20	70.21	70.21	70.21	70.21	70.21	70.21	95.60	95.60	95.60	95.60	95.60	95.60	175.90	175.90	175.90	175.90	175.90	175.90	1.89	1.22	1.99	1.32	2.47	1.80	18.78	12.04	19.14	12.40	20.96	14.22
256.10	70.29	70.29	70.29	70.29	70.29	70.29	95.72	95.72	95.72	95.72	95.72	95.72	176.11	176.11	176.11	176.11	176.11	176.11	1.89	1.22	1.99	1.32	2.48	1.81	18.75	12.03	19.11	12.40	20.95	14.23
256.00	70.37	70.37	70.37	70.37	70.37	70.37	95.83	95.83	95.83	95.83	95.83	95.83	176.32	176.32	176.32	176.32	176.32	176.32	1.89	1.22	1.99	1.32	2.49	1.82	18.72	12.03	19.09	12.40	20.93	14.24
255.90	70.45	70.45	70.45	70.45	70.45	70.45	95.94	95.94	95.94	95.94	95.94	95.94	176.53	176.53	176.53	176.53	176.53	176.53	1.89	1.22	1.99	1.32	2.49	1.82	18.69	12.03	19.06	12.40	20.91	14.25
255.80	70.53	70.53	70.53	70.53	70.53	70.53	96.05	96.05	96.05	96.05	96.05	96.05	176.74	176.74	176.74	176.74	176.74	176.74	1.88	1.22	1.99	1.32	2.50	1.83	18.67	12.02	19.04	12.40	20.90	14.26
255.70	70.61	70.61	70.61	70.61	70.61	70.61	96.16	96.16	96.16	96.16	96.16	96.16	176.95	176.95	176.95	176.95	176.95	176.95	1.88	1.22	1.98	1.32	2.50	1.84	18.64	12.02	19.01	12.39	20.88	14.27
255.60	70.69	70.69	70.69	70.69	70.69	70.69	96.27	96.27	96.27	96.27	96.27	96.27	177.16	177.16	177.16	177.16	177.16	177.16	1.88	1.22	1.98	1.32	2.51	1.85	18.61	12.02	18.99	12.39	20.87	14.27
255.50	70.77	70.77	70.77	70.77	70.77	70.77	96.38	96.38	96.38	96.38	96.38	96.38	177.37	177.37	177.37	177.37	177.37	177.37	1.88	1.22	1.98	1.32	2.51	1.86	18.58	12.01	18.96	12.39	20.85	14.28
255.40	70.85	70.85	70.85	70.85	70.85	70.85	96.49	96.49	96.49	96.49	96.49	96.49	177.58	177.58	177.58	177.58	177.58	177.58	1.87	1.22	1.98	1.33	2.52	1.87	18.55	12.01	18.93	12.39	20.83	14.29
255.30	70.93	70.93	70.93	70.93	70.93	70.93	96.60	96.60	96.60	96.60	96.60	96.60	177.78	177.78	177.78	177.78	177.78	177.78	1.87	1.22	1.98	1.33	2.53	1.87	18.52	12.00	18.90	12.39	20.82	14.30
255.20	71.01	71.01	71.01	71.01	71.01	71.01	96.71	96.71	96.71	96.71	96.71	96.71	177.99	177.99	177.99	177.99	177.99	177.99	1.87	1.22	1.98	1.33	2.53	1.88	18.49	12.00	18.88	12.38	20.80	14.31
255.10	71.09	71.09	71.09	71.09	71.09	71.09	96.82	96.82	96.82	96.82	96.82	96.82	178.20	178.20	178.20	178.20	178.20	178.20	1.86	1.22	1.98	1.33	2.54	1.89	18.46	11.99	18.85	12.38	20.78	14.31
255.00	71.17	71.17	71.17	71.17	71.17	71.17	96.93	96.93	96.93	96.93	96.93	96.93	178.41	178.41	178.41	178.41	178.41	178.41	1.86	1.22	1.98	1.33	2.54	1.90	18.43	11.99	18.82	12.38	20.76	14.32
254.90	71.25	71.25	71.25	71.25	71.25	71.25	97.04	97.04	97.04	97.04	97.04	97.04	178.62	178.62	178.62	178.62	178.62	178.62	1.86	1.22	1.97	1.33	2.55	1.91	18.40	11.99	18.79	12.38	20.75	14.33

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
252.70	72.97	72.97	72.97	72.97	72.97	72.97	99.45	99.45	99.45	99.45	99.45	99.45	183.18	183.18	183.18	183.18	183.18	183.18	1.81	1.22	1.95	1.36	2.67	2.08	17.82	11.92	18.26	12.35	20.43	14.52
252.60	73.05	73.05	73.05	73.05	73.05	73.05	99.56	99.56	99.56	99.56	99.56	99.56	183.39	183.39	183.39	183.39	183.39	183.39	1.80	1.22	1.95	1.36	2.68	2.09	17.80	11.91	18.23	12.35	20.41	14.53
252.50	73.13	73.13	73.13	73.13	73.13	73.13	99.67	99.67	99.67	99.67	99.67	99.67	183.60	183.60	183.60	183.60	183.60	183.60	1.80	1.22	1.95	1.36	2.68	2.10	17.76	11.91	18.20	12.34	20.39	14.53
252.40	73.20	73.20	73.20	73.20	73.20	73.20	99.78	99.78	99.78	99.78	99.78	99.78	183.80	183.80	183.80	183.80	183.80	183.80	1.80	1.22	1.95	1.36	2.69	2.10	17.74	11.90	18.17	12.34	20.37	14.54
252.30	73.28	73.28	73.28	73.28	73.28	73.28	99.88	99.88	99.88	99.88	99.88	99.88	184.01	184.01	184.01	184.01	184.01	184.01	1.80	1.22	1.95	1.36	2.69	2.11	17.71	11.89	18.15	12.34	20.36	14.54
252.20	73.36	73.36	73.36	73.36	73.36	73.36	99.99	99.99	99.99	99.99	99.99	99.99	184.22	184.22	184.22	184.22	184.22	184.22	1.79	1.22	1.95	1.37	2.70	2.12	17.68	11.89	18.12	12.33	20.34	14.55
252.10	73.43	73.43	73.43	73.43	73.43	73.43	100.10	100.10	100.10	100.10	100.10	100.10	184.42	184.42	184.42	184.42	184.42	184.42	1.79	1.22	1.94	1.37	2.70	2.13	17.65	11.89	18.10	12.33	20.33	14.56
252.00	73.51	73.51	73.51	73.51	73.51	73.51	100.21	100.21	100.21	100.21	100.21	100.21	184.63	184.63	184.63	184.63	184.63	184.63	1.79	1.22	1.94	1.37	2.71	2.13	17.63	11.88	18.08	12.33	20.31	14.57
251.90	73.59	73.59	73.59	73.59	73.59	73.59	100.31	100.31	100.31	100.31	100.31	100.31	184.83	184.83	184.83	184.83	184.83	184.83	1.79	1.22	1.94	1.37	2.71	2.14	17.60	11.88	18.05	12.33	20.30	14.58
251.80	73.66	73.66	73.66	73.66	73.66	73.66	100.42	100.42	100.42	100.42	100.42	100.42	185.04	185.04	185.04	185.04	185.04	185.04	1.78	1.22	1.94	1.37	2.72	2.15	17.57	11.87	18.02	12.33	20.28	14.58
251.70	73.74	73.74	73.74	73.74	73.74	73.74	100.53	100.53	100.53	100.53	100.53	100.53	185.24	185.24	185.24	185.24	185.24	185.24	1.78	1.21	1.94	1.37	2.73	2.16	17.54	11.87	18.00	12.32	20.26	14.59
251.60	73.82	73.82	73.82	73.82	73.82	73.82	100.64	100.64	100.64	100.64	100.64	100.64	185.45	185.45	185.45	185.45	185.45	185.45	1.78	1.21	1.94	1.37	2.73	2.17	17.51	11.86	17.97	12.32	20.24	14.59
251.50	73.89	73.89	73.89	73.89	73.89	73.89	100.74	100.74	100.74	100.74	100.74	100.74	185.66	185.66	185.66	185.66	185.66	185.66	1.78	1.21	1.94	1.37	2.74	2.17	17.48	11.85	17.94	12.31	20.23	14.60
251.40	73.97	73.97	73.97	73.97	73.97	73.97	100.85	100.85	100.85	100.85	100.85	100.85	185.86	185.86	185.86	185.86	185.86	185.86	1.77	1.21	1.94	1.37	2.74	2.18	17.45	11.85	17.91	12.31	20.21	14.61
251.30	74.04	74.04	74.04	74.04	74.04	74.04	100.96	100.96	100.96	100.96	100.96	100.96	186.07	186.07	186.07	186.07	186.07	186.07	1.77	1.21	1.93	1.38	2.75	2.19	17.42	11.84	17.89	12.30	20.19	14.61
251.20	74.12	74.12	74.12	74.12	74.12	74.12	101.06	101.06	101.06	101.06	101.06	101.06	186.27	186.27	186.27	186.27	186.27	186.27	1.77	1.21	1.93	1.38	2.75	2.20	17.39	11.84	17.86	12.30	20.18	14.62
251.10	74.20	74.20	74.20	74.20	74.20	74.20	101.17	101.17	101.17	101.17	101.17	101.17	186.48	186.48	186.48	186.48	186.48	186.48	1.77	1.21	1.93	1.38	2.76	2.20	17.36	11.83	17.83	12.29	20.16	14.62
251.00	74.27	74.27	74.27	74.27	74.27	74.27	101.28	101.28	101.28	101.28	101.28	101.28	186.68	186.68	186.68	186.68	186.68	186.68	1.76	1.21	1.93	1.38	2.76	2.21	17.33	11.82	17.80	12.29	20.14	14.63
250.90	74.35	74.35	74.35	74.35	74.35	74.35	101.39	101.39	101.39	101.39	101.39	101.39	186.89	186.89	186.89	186.89	186.89	186.89	1.76	1.21	1.93	1.38	2.77	2.22	17.30	11.81	17.77	12.28	20.12	14.63
250.80	74.42	74.42	74.42	74.42	74.42	74.42	101.49	101.49	101.49	101.49	101.49	101.49	187.09	187.09	187.09	187.09	187.09	187.09	1.76	1.21	1.93	1.38	2.77	2.23	17.27	11.81	17.74	12.28	20.10	14.64
250.70	74.50	74.50	74.50	74.50	74.50	74.50	101.60	101.60	101.60	101.60	101.60	101.60	187.30	187.30	187.30	187.30	187.30	187.30	1.76	1.21	1.93	1.38	2.78	2.24	17.24	11.80	17.72	12.28	20.09	14.64
250.60	74.57	74.57	74.57	74.57	74.57	74.57	101.70	101.70	101.70	101.70	101.70	101.70	187.50	187.50	187.50	187.50	187.50	187.50	1.75	1.21	1.92	1.38	2.79	2.24	17.22	11.80	17.69	12.27	20.07	14.65
250.50	74.65	74.65	74.65	74.65	74.65	74.65	101.81	101.81	101.81	101.81	101.81	101.81	187.70	187.70	187.70	187.70	187.70	187.70	1.75	1.21	1.92	1.38	2.79	2.25	17.19	11.79	17.67	12.27	20.05	14.66
250.40	74.72	74.72	74.72	74.72	74.72	74.72	101.92	101.92	101.92	101.92	101.92	101.92	187.91	187.91	187.91	187.91	187.91	187.91	1.75	1.21	1.92	1.39	2.80	2.26	17.16	11.79	17.64	12.27	20.04	14.66
250.30	74.80	74.80	74.80	74.80	74.80	74.80	102.02	102.02	102.02	102.02	102.02	102.02	188.11	188.11	188.11	188.11	188.11	188.11	1.75	1.21	1.92	1.39	2.80	2.27	17.14	11.78	17.62	12.26	20.03	14.67
250.20	74.87	74.87	74.87	74.87	74.87	74.87	102.13	102.13	102.13	102.13	102.13	102.13	188.32	188.32	188.32	188.32	188.32	188.32	1.74	1.21	1.92	1.39	2.81	2.27	17.11	11.78	17.59	12.26	20.01	14.68
250.10	74.95	74.95	74.95	74.95	74.95	74.95	102.24	102.24	102.24	102.24	102.24	102.24	188.52	188.52	188.52	188.52	188.52	188.52	1.74	1.21	1.92	1.39	2.81	2.28	17.09	11.77	17.57	12.26	20.00	14.69
250.00	75.02	75.02	75.02	75.02	75.02	75.02	102.34	102.34	102.34	102.34	102.34	102.34	188.73	188.73	188.73	188.73	188.73	188.73	1.74	1.21	1.92	1.39	2.82	2.29	17.06	11.77	17.55	12.26	19.98	14.69
249.90	75.10	75.10	75.10	75.10	75.10	75.10	102.45	102.45	102.45	102.45	102.45	102.45	188.93	188.93	188.93	188.93	188.93	188.93	1.74	1.21	1.92	1.39	2.82	2.30	17.04	11.77	17.52	12.26	19.97	14.70
249.80	75.17	75.17	75.17	75.17	75.17	75.17	102.55	102.55	102.55	102.55	102.55	102.55	189.13	189.13	189.13	189.13	189.13	189.13	1.73	1.21	1.92	1.39	2.83	2.30	17.01	11.76	17.50	12.25	19.96	14.71
249.70	75.25	75.25	75.25	75.25	75.25	75.25	102.66	102.66	102.66	102.66	102.66	102.66	189.34	189.34	189.34	189.34	189.34	189.34	1.73	1.21	1.92	1.39	2.83	2.31	16.99	11.76	17.48	12.25	19.94	14.72
249.60	75.32	75.32	75.32	75.32	75.32	75.32	102.77	102.77	102.77	102.77	102.77	102.77	189.54	189.54	189.54	189.54	189.54	189.54	1.73	1.21	1.91	1.39	2.84	2.32	16.96	11.76	17.46	12.25	19.93	14.73
249.50	75.40	75.40	75.40	75.40	75.40	75.40	102.87	102.87	102.87	102.87	102.87	102.87	189.75	189.75	189.75	189.75	189.75	189.75	1.73	1.21	1.91	1.40	2.84	2.32	16.94	11.75	17.44	12.25	19.92	14.73
249.40	75.47	75.47	75.47	75.47	75.47	75.47	102.98	102.98	102.98	102.98	102.98	102.98	189.95	189.95	189.95	189.95	189.95	189.95	1.73	1.21	1.91	1.40	2.85	2.33	16.92	11.75	17.42	12.25	19.91	14.74
249.30	75.55	75.55	75.55	75.55	75.55	75.55	103.08	103.08	103.08	103.08	103.08	103.08	190.15	190.15	190.15	190.15	190.15	190.15	1.72	1.21	1.91	1.40	2.85	2.34	16.90	11.75	17.40	12.25	19.90	14.75
249.20	75.62	75.62	75.62	75.62	75.62	75.62	103.19	103.19	103.19	103.19	103.19	103.19	190.36	190.36	190.36	190.36	190.36	190.36	1.72	1.21	1.91	1.40	2.86	2.35	16.87	11.75	17.37	12.25	19.89	14.76
249.10	75.70	75.70	75.70	75.70	75.70	75.70	103.29	103.29	103.29	103.29	103.29	103.29	190.56	190.56	190.56	190.56	190.56	190.56	1.72	1.21	1.91	1.40	2.86	2.35	16.85	11.74	17.35	12.25	19.87	14.77
249.00	75.77	75.77	75.77	75.77	75.77	75.77	103.40	103.40	103.40	103.40	103.40	103.40	190.76	190.76	190.76	190.76	190.76	190.76	1.72	1.21	1.91	1.40	2.87	2.36	16.82	11.74	17.33	12.25	19.86	14.78
248.90	75.85	75.85	75.85	75.85	75.85	75.85	103.50	103.50	103.50	103.50	103.50	103.50	190.97	190.97	190.97	190.97	190.97	190.97	1.72	1.21	1.91	1.40	2.87	2.37	16.80	11.74	17.31	12.24	19.85	14.78
248.80	75.92	75.92	75.92	75.92	75.92	75.92	103.61	103.61	103.61	103.61	103.61	103.61	191.17	191.17	191.17	191.17	191.17	191.17	1.71	1.21	1.91	1.40	2.88	2.38	16.78	11.73	17.29	12.24	19.84	14.79
248.70	75.99	75.99	75.99	75.99	75.99	75.99	103.72	103.72	103.72	103.72	103.72	103.72	191.38	191.38	191.38	191.38	191.38	191.38	1.71	1.21	1.91	1.40	2.88	2.38	16.75	11.73	17.27	12.24	19.83	14.80
248.60	76.07	76.07	76.07	76.07	76.07	76.07	103.82	103.82	103.82	103.82	103.82	103.82	191.58	191.58	191.58	191.58	191.58	191.58	1.71	1.21	1.91	1.41	2.89	2.39	16.73	11.73	17.25	12.24	19.81	14.81
248.50	76.14	76.14	76.14	76.14	76.14	76.14	103.93	103.93	103.93	103.93	103.93	103.93	191.78	191.78	191.78	191.78	191.78	191.78	1.71	1.21	1.91	1.41	2.89	2.40	16.71	11.73	17.23	12.24	19.81	14.82
248.40	76.22	76.22	76.22	76.22	76.22	76.22	104.03	104.03	104.03	104.03	104.03	104.03	191.99	191.99	191.99	191.99	191.99	191.99	1.71	1.21	1.90	1.41	2.90	2.40	16.69	11.73	17.21	12.24	19.80	14.83
248.30	76.29	76.29	76.29	76.29	76.29	76.29	104.14	104.14	104.14	104.14	104.14	104.14	192.19	192.19	192.19	192.19	192.19	192.19	1.70	1.21	1.90	1.41	2.91	2.41	16.67	11.72	17.19	12.24	19.78	14.84
248.20	76.37	76.37	76.37	76.37	76.37	76.37	104.24	104.24	104.24	104.24	104.24	104.24	192.39	192.39	192.39	192.39	192.39	192.39	1.70	1.21	1.90	1.41	2.91	2.42	16.65	11.72	17.17	12.24	19.77	14.85
248.10	76.44	76.44	76.44	76.44	76.44	76.44	104.35	104.35	104.35	104.35	104.35	104.35	192.60	192.60	192.60	192.60	192.60	192.60	1.70	1.21	1.90	1.41	2.92	2.42	16.62	11.72	17.14	12.24	19.76	14.85
248.00	76.51	76.51	76.51	76.51	76.51	76.51	104.45	104.45	104.45	104.45	104.45	104.45	192.80	192.80	192.80	192.80	192.80	192.80	1.70	1.21	1.90	1.41	2.92	2.43	16.60	11.71	17.12	12.24	19.75	14.86
247.90	76.59	76.59	76.59	76.59	76.59	76.59	104.56	104.56	104.56	104.56	104.56	104.56	193.00	193.00	193.00	193.00	193.00	193.00	1.70	1.21	1.90	1.41	2.93	2.44	16.58	11.71	17.10	12.24	19.74	14.87
247.80	76.66	76.66	76.66	76.66	76.66	76.66	104.66	104.66	104.66	104.66	104.66	104.66	193.21	193.21	193.21	193.21	193.21	193.21	1.69	1.21	1.90	1.42	2.93	2.45	16.56	11.71	17.08	12.24	19.73	14.88
247.70	76.74	76.74	76.74	76.74	76.74	76.74	104.77	104.77	104.77	104.77	104.77	104.77	193.41	193.41	193.41	193.41	193.41	193.41	1.69	1.21	1.90	1.42	2.94	2.45	16.53	11.71	17.06	12.24	19.72	14.89
247.60	76.81	76.81	76.81	76.81	76.81	76.81	104.87	104.87	104.87	104.87	104.87	104.87	193.61	193.61	193.61	193.61	193.61	193.61	1.69	1.21	1.90	1.42	2.94	2.46	16.51	11.70	17.04	12.23	19.70	14.90
247.50	76.89	76.89	76.89	76.89	76.89	76.89	104.98	104.98	104.98	104.98	104.98	104.98	193.82	193.82	193.82	193.82	193.82	193.82	1.69	1.21	1.90	1.42	2.95	2.47	16.49	11.70	17.02	12.23	19.69	14.90
247.40	76.96	76.96	76.96	76.96	76.96	76.96	105.09	105.09	105.09	105.09	105.09	105.09	194.02	194.02	194.02	194.02	194.02	194.02	1.69	1.21	1.90	1.42	2.95	2.47	16.46	11.69	17.00	12.23	19.68	14.91
247.30	77.04	77.04	77.04	77.04	77.04	77.04	105.19	105.19	105.19	105.19	105.19	105.19	194.23	194.23	194.23	194.23	194.23	194.23	1.68	1.21	1.90	1.42	2.96	2.48	16.44	11.69	16.98	12.23	19.67	14.92
247.20	77.11	77.11	77.11	77.11	77.11	77.11	105.30	105.30	105.30	105.30	105.30	105.30	194.43	194.43	194.43	194.43	194.43	194.43	1.68	1.21	1.89	1.42	2.96	2.49	16.42	11.69	16.96	12.23	19.65	14.93
247.10	77.18	77.18	77.18	77.18	77.18	77.18	105.40	105.40	105.40	105.40	105.40	105.40	194.63	194.63	194.63	194.63	194.63	194.63	1.68	1.21	1.89	1.42	2.97	2.50	16.39	11.68	16.94	12.23	19.64	14.93
247.00	77.26	77.26	77.26	77.26	77.26	77.26	105.51	105.51	105.51	105.51	105.51	105.51	194.84	194.84	194.84	194.84	194.84	194.84	1.68	1.21	1.89	1.42	2.97	2.50	16.37	11.68	16.92	12.23	19.63	14.94
246.90	77.33	77.33	77.33	77.33	77.33	77.33	105.61	105.61	105.61	105.61	105.61	105.61	195.04	195.04	195.04	195.04	195.04	195.04	1.68	1.21	1.89	1.43	2.98	2.51	16.35	11.68	16.89	12.22	19.62	14.95
246.80	77.41	77.41	77.41	77.41	77.41	77.41	105.72	105.72	105.72	105.72	105.72	105.72	195.24	195.24	195.24	195.24	195.24	195.24	1.67	1.21	1.89	1.43	2.98	2.52	16.33	11.68	16.88	12.22	19.61	14.96
246.70	77.48	77.48	77.48	77.48	77.48	77.48	105.83	105.83	105.83	105.83	105.83	105.83	195.45	195.45	195.45	195.45	195.45	195.45	1.67	1.21	1.89	1.43	2.99	2.52	16.31	11.67	16.86	12.22	19.60	14.97
246.60	77.56	77.56	77.56	77.56	77.56	77.56	105.93	105.93	105.93	105.93	105.93	105.93	195.65	195.65	195.65	195.65	195.65	195.65	1.67	1.21	1.89	1.43	2.99	2.53	16.28	11.67	16.83	12.22	19.59	14.98
246.50	77.63	77.63	77.63	77.63	77.63	77.63	106.04	106.04	106.04	106.04	106.04	106.04	195.86	195.86	195.86	195.86	195.86	195.86	1.67	1.21	1.89	1.43	3.00	2.54	16.26	11.67	16.81	12.22	19.58	14.98
246.40	77.71	77.71	77.71	77.71	77.71	77.71	106.14	106.14	106.14	106.14	106.14	106.14	196.06	196.06	196.06	196.06	196.06	196.06	1.67	1.21	1.89	1.43	3.00	2.55	16.23	11.66	16.79	12.22	19.56	14.99
246.30	77.78	77.78	77.78	77.78	77.78	77.78	106.25	106.25	106.25	106.25	106.25	106.25	196.27	196.27	196.27	196.27	196.27	196.27	1.66	1.21	1.89	1.43	3.01	2.55	16.21	11.65	16.77	12.21	19.55	15.00
246.20	77.86	77.86	77.86	77.86	77.86	77.86	106.36	106.36	106.36	106.36	106.36	106.36	196.47	196.47	196.47	196.47	196.47	196.47	1.66	1.21	1.89	1.43	3.01	2.56	16.18	11.65	16.74	12.21	19.54	15.00
246.10	77.94	77.94	77.94	77.94	77.94	77.94	106.46	106.46	106.46	106.46	106.46	106.46	196.68	196.68	196.68	196.68	196.68	196.68	1.66	1.21	1.89	1.43	3.02	2.57	16.16	11.65	16.72	12.21	19.52	15.01
246.00	78.01	78.01	78.01	78.01	78.01	78.01	106.57	106.57	106.57	106.57	106.57	106.57	196.88	196.88	196.88	196.88	196.88	196.88	1.66	1.21	1.88	1.44	3.02	2.57	16.14	11.64	16.70	12.20	19.51	15.02
245.90	78.09	78.09	78.09	78.09	78.09	78.09	106.68	106.68	106.68	106.68	106.68	106.68	197.09	197.09	197.09	197.09	197.09	197.09	1.65	1.21	1.88	1.44	3.03	2.58	16.12	11.64	16.68	12.20	19.50	15.03
245.80	78.16	78.16	78.16	78.16	78.16	78.16	106.78	106.78	106.78	106.78	106.78	106.78	197.29	197.29	197.29	197.29	197.29	197.29	1.65	1.21	1.88	1.44	3.03	2.59	16.09	11.63	16.66	12.20	19.49	15.03
245.70	78.24	78.24	78.24	78.24	78.24	78.24	106.89	106.89	106.89	106.89	106.89	106.89	197.50	197.50	197.50	197.50	197.50	197.50	1.65	1.21	1.88	1.44	3.04	2.60	16.07	11.63	16.64	12.20	19.48	15.04
245.60	78.32	78.32	78.32	78.32	78.32	78.32	107.00	107.00	107.00	107.00	107.00	107.00	197.70	197.70	197.70	197.70	197.70	197.70	1.65	1.21	1.88	1.44	3.05	2.60	16.05	11.63	16.62	12.20	19.47	15.05
245.50	78.39	78.39	78.39	78.39	78.39	78.39	107.11	107.11	107.11	107.11	107.11	107.11	197.91	197.91	197.91	197.91	197.91	197.91	1.65	1.21	1.88	1.44	3.05	2.61	16.02	11.62	16.59	12.19	19.45	15.05
245.40	78.47	78.47	78.47	78.47	78.47	78.47	107.22	107.22	107.22	107.22	107.22	107.22	198.12	198.12	198.12	198.12	198.12	198.12	1.64	1.21	1.88	1.44	3.06	2.62	15.99	11.61	16.56	12.19	19.44	15.06
245.30	78.55	78.55	78.55	78.55	78.55	78.55	107.33	107.33	107.33	107.33	107.33	107.33	198.32	198.32	198.32	198.32	198.32	198.32	1.64	1.20	1.88	1.44	3.06	2.63	15.96	11.60	16.54	12.18	19.42	15.06
245.20	78.63	78.63	78.63	78.63	78.63	78.63	107.43	107.43	107.43	107.43	107.43	107.43	198.53	198.53	198.53	198.53	198.53	198.53	1.64	1.20	1.88	1.44	3.07	2.63	15.94	11.60	16.51	12.18	19.41	15.07
245.10	78.71	78.71	78.71	78.71	78.71	78.71	107.54	107.54	107.54	107.54	107.54	107.54	198.74	198.74	198.74	198.74	198.74	198.74	1.64	1.20	1.88	1.44	3.07	2.64	15.91	11.59	16.49	12.17	19.39	15.07
245.00	78.79	78.79	78.79	78.79	78.79	78.79	107.65	107.65	107.65	107.65	107.65	107.65	198.95	198.95	198.95	198.95	198.95	198.95	1.63	1.20	1.87	1.44	3.08	2.65	15.89	11.58	16.47	12.17	19.38	15.08
244.90	78.87	78.87	78.87	78.87	78.87	78.87	107.77	107.77	107.77	107.77	107.77	107.77	199.16	199.16	199.16	199.16	199.16	199.16	1.63	1.20	1.87	1.45	3.08	2.66	15.86	11.58	16.45	12.16	19.37	15.09
244.80	78.95	78.95	78.95	78.95	78.95	78.95	107.88	107.88	107.88	107.88	107.88	107.88	199.37	199.37	199.37	199.37	199.37	199.37	1.63	1.20	1.87	1.45	3.09	2.66	15.84	11.58	16.43	12.16	19.36	15.09
244.70	79.03	79.03	79.03	79.03	79.03	79.03	107.99	107.99	107.99	107.99	107.99	107.99	199.58	199.58	199.58	199.58	199.58	199.58	1.63	1.20	1.87	1.45	3.10	2.67	15.

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
242.50	81.00	81.00	81.00	81.00	81.00	81.00	110.64	110.64	110.64	110.64	110.64	110.64	204.39	204.39	204.39	204.39	204.39	204.39	1.58	1.20	1.86	1.47	3.23	2.85	15.30	11.46	15.93	12.09	19.11	15.27
242.40	81.09	81.09	81.09	81.09	81.09	81.09	110.76	110.76	110.76	110.76	110.76	110.76	204.61	204.61	204.61	204.61	204.61	204.61	1.58	1.20	1.86	1.47	3.24	2.85	15.27	11.45	15.91	12.08	19.09	15.27
242.30	81.18	81.18	81.18	81.18	81.18	81.18	110.88	110.88	110.88	110.88	110.88	110.88	204.83	204.83	204.83	204.83	204.83	204.83	1.58	1.20	1.86	1.47	3.24	2.86	15.24	11.44	15.88	12.08	19.08	15.28
242.20	81.27	81.27	81.27	81.27	81.27	81.27	111.01	111.01	111.01	111.01	111.01	111.01	205.05	205.05	205.05	205.05	205.05	205.05	1.58	1.20	1.85	1.48	3.25	2.87	15.22	11.44	15.86	12.08	19.07	15.29
242.10	81.36	81.36	81.36	81.36	81.36	81.36	111.13	111.13	111.13	111.13	111.13	111.13	205.27	205.27	205.27	205.27	205.27	205.27	1.57	1.20	1.85	1.48	3.26	2.88	15.20	11.43	15.84	12.07	19.06	15.29
242.00	81.45	81.45	81.45	81.45	81.45	81.45	111.25	111.25	111.25	111.25	111.25	111.25	205.48	205.48	205.48	205.48	205.48	205.48	1.57	1.20	1.85	1.48	3.26	2.89	15.17	11.42	15.82	12.07	19.05	15.30
241.90	81.54	81.54	81.54	81.54	81.54	81.54	111.37	111.37	111.37	111.37	111.37	111.37	205.70	205.70	205.70	205.70	205.70	205.70	1.57	1.20	1.85	1.48	3.27	2.89	15.14	11.41	15.79	12.06	19.03	15.30
241.80	81.63	81.63	81.63	81.63	81.63	81.63	111.49	111.49	111.49	111.49	111.49	111.49	205.92	205.92	205.92	205.92	205.92	205.92	1.57	1.19	1.85	1.48	3.27	2.90	15.11	11.40	15.76	12.05	19.02	15.30
241.70	81.72	81.72	81.72	81.72	81.72	81.72	111.61	111.61	111.61	111.61	111.61	111.61	206.14	206.14	206.14	206.14	206.14	206.14	1.56	1.19	1.85	1.48	3.28	2.91	15.08	11.39	15.73	12.04	18.99	15.30
241.60	81.81	81.81	81.81	81.81	81.81	81.81	111.73	111.73	111.73	111.73	111.73	111.73	206.36	206.36	206.36	206.36	206.36	206.36	1.56	1.19	1.85	1.48	3.29	2.92	15.04	11.37	15.70	12.03	18.98	15.31
241.50	81.90	81.90	81.90	81.90	81.90	81.90	111.85	111.85	111.85	111.85	111.85	111.85	206.58	206.58	206.58	206.58	206.58	206.58	1.56	1.19	1.85	1.48	3.29	2.93	15.01	11.36	15.67	12.02	18.96	15.31
241.40	81.99	81.99	81.99	81.99	81.99	81.99	111.97	111.97	111.97	111.97	111.97	111.97	206.80	206.80	206.80	206.80	206.80	206.80	1.55	1.19	1.84	1.48	3.30	2.94	14.98	11.35	15.64	12.01	18.94	15.31
241.30	82.07	82.07	82.07	82.07	82.07	82.07	112.09	112.09	112.09	112.09	112.09	112.09	207.02	207.02	207.02	207.02	207.02	207.02	1.55	1.19	1.84	1.48	3.31	2.94	14.94	11.33	15.61	12.00	18.92	15.31
241.20	82.16	82.16	82.16	82.16	82.16	82.16	112.21	112.21	112.21	112.21	112.21	112.21	207.23	207.23	207.23	207.23	207.23	207.23	1.55	1.19	1.84	1.48	3.31	2.95	14.90	11.31	15.57	11.98	18.89	15.30
241.10	82.25	82.25	82.25	82.25	82.25	82.25	112.33	112.33	112.33	112.33	112.33	112.33	207.45	207.45	207.45	207.45	207.45	207.45	1.54	1.19	1.84	1.48	3.32	2.96	14.86	11.29	15.52	11.96	18.86	15.30
241.00	82.34	82.34	82.34	82.34	82.34	82.34	112.45	112.45	112.45	112.45	112.45	112.45	207.67	207.67	207.67	207.67	207.67	207.67	1.54	1.18	1.84	1.48	3.33	2.97	14.81	11.27	15.48	11.94	18.83	15.29
240.90	82.43	82.43	82.43	82.43	82.43	82.43	112.57	112.57	112.57	112.57	112.57	112.57	207.89	207.89	207.89	207.89	207.89	207.89	1.53	1.18	1.83	1.48	3.33	2.98	14.76	11.24	15.43	11.91	18.80	15.28
240.80	82.52	82.52	82.52	82.52	82.52	82.52	112.69	112.69	112.69	112.69	112.69	112.69	208.11	208.11	208.11	208.11	208.11	208.11	1.53	1.18	1.83	1.48	3.34	2.99	14.70	11.21	15.38	11.88	18.76	15.26
240.70	82.61	82.61	82.61	82.61	82.61	82.61	112.81	112.81	112.81	112.81	112.81	112.81	208.33	208.33	208.33	208.33	208.33	208.33	1.52	1.18	1.83	1.48	3.34	3.00	14.64	11.18	15.32	11.85	18.71	15.25
240.60	82.70	82.70	82.70	82.70	82.70	82.70	112.93	112.93	112.93	112.93	112.93	112.93	208.54	208.54	208.54	208.54	208.54	208.54	1.52	1.17	1.82	1.48	3.35	3.01	14.57	11.13	15.25	11.81	18.66	15.22
240.50	82.79	82.79	82.79	82.79	82.79	82.79	113.05	113.05	113.05	113.05	113.05	113.05	208.76	208.76	208.76	208.76	208.76	208.76	1.51	1.17	1.82	1.48	3.36	3.02	14.50	11.09	15.19	11.78	18.61	15.20
240.40	82.87	82.87	82.87	82.87	82.87	82.87	113.17	113.17	113.17	113.17	113.17	113.17	208.98	208.98	208.98	208.98	208.98	208.98	1.50	1.17	1.81	1.48	3.36	3.03	14.44	11.06	15.13	11.74	18.57	15.18
240.30	82.96	82.96	82.96	82.96	82.96	82.96	113.29	113.29	113.29	113.29	113.29	113.29	209.20	209.20	209.20	209.20	209.20	209.20	1.50	1.16	1.81	1.47	3.37	3.03	14.38	11.02	15.07	11.71	18.52	15.16
240.20	83.05	83.05	83.05	83.05	83.05	83.05	113.41	113.41	113.41	113.41	113.41	113.41	209.41	209.41	209.41	209.41	209.41	209.41	1.49	1.16	1.81	1.47	3.38	3.04	14.33	10.99	15.02	11.68	18.48	15.15
240.10	83.14	83.14	83.14	83.14	83.14	83.14	113.53	113.53	113.53	113.53	113.53	113.53	209.63	209.63	209.63	209.63	209.63	209.63	1.49	1.16	1.80	1.47	3.38	3.05	14.28	10.96	14.97	11.66	18.45	15.13
240.00	83.23	83.23	83.23	83.23	83.23	83.23	113.65	113.65	113.65	113.65	113.65	113.65	209.85	209.85	209.85	209.85	209.85	209.85	1.48	1.16	1.80	1.47	3.39	3.06	14.23	10.94	14.93	11.64	18.42	15.12
239.90	83.32	83.32	83.32	83.32	83.32	83.32	113.77	113.77	113.77	113.77	113.77	113.77	210.07	210.07	210.07	210.07	210.07	210.07	1.48	1.15	1.80	1.47	3.40	3.07	14.19	10.92	14.89	11.62	18.39	15.12
239.80	83.40	83.40	83.40	83.40	83.40	83.40	113.89	113.89	113.89	113.89	113.89	113.89	210.28	210.28	210.28	210.28	210.28	210.28	1.48	1.15	1.80	1.47	3.40	3.08	14.14	10.89	14.85	11.60	18.36	15.11
239.70	83.49	83.49	83.49	83.49	83.49	83.49	114.01	114.01	114.01	114.01	114.01	114.01	210.50	210.50	210.50	210.50	210.50	210.50	1.47	1.15	1.80	1.47	3.41	3.09	14.10	10.87	14.81	11.58	18.33	15.11
239.60	83.58	83.58	83.58	83.58	83.58	83.58	114.12	114.12	114.12	114.12	114.12	114.12	210.72	210.72	210.72	210.72	210.72	210.72	1.47	1.15	1.79	1.47	3.41	3.09	14.06	10.86	14.77	11.56	18.31	15.10
239.50	83.67	83.67	83.67	83.67	83.67	83.67	114.24	114.24	114.24	114.24	114.24	114.24	210.93	210.93	210.93	210.93	210.93	210.93	1.47	1.15	1.79	1.47	3.42	3.10	14.03	10.84	14.74	11.55	18.29	15.10
239.40	83.75	83.75	83.75	83.75	83.75	83.75	114.36	114.36	114.36	114.36	114.36	114.36	211.15	211.15	211.15	211.15	211.15	211.15	1.46	1.15	1.79	1.47	3.43	3.11	13.99	10.82	14.70	11.53	18.26	15.09
239.30	83.84	83.84	83.84	83.84	83.84	83.84	114.48	114.48	114.48	114.48	114.48	114.48	211.37	211.37	211.37	211.37	211.37	211.37	1.46	1.14	1.79	1.47	3.43	3.12	13.95	10.80	14.67	11.52	18.24	15.09
239.20	83.93	83.93	83.93	83.93	83.93	83.93	114.60	114.60	114.60	114.60	114.60	114.60	211.58	211.58	211.58	211.58	211.58	211.58	1.46	1.14	1.79	1.47	3.44	3.13	13.92	10.79	14.63	11.50	18.22	15.09
239.10	84.02	84.02	84.02	84.02	84.02	84.02	114.72	114.72	114.72	114.72	114.72	114.72	211.80	211.80	211.80	211.80	211.80	211.80	1.45	1.14	1.78	1.47	3.44	3.13	13.88	10.77	14.60	11.49	18.20	15.08
239.00	84.10	84.10	84.10	84.10	84.10	84.10	114.84	114.84	114.84	114.84	114.84	114.84	212.02	212.02	212.02	212.02	212.02	212.02	1.45	1.14	1.78	1.47	3.45	3.14	13.84	10.75	14.57	11.47	18.17	15.08
238.90	84.19	84.19	84.19	84.19	84.19	84.19	114.95	114.95	114.95	114.95	114.95	114.95	212.23	212.23	212.23	212.23	212.23	212.23	1.45	1.14	1.78	1.47	3.46	3.15	13.81	10.74	14.54	11.46	18.15	15.08
238.80	84.28	84.28	84.28	84.28	84.28	84.28	115.07	115.07	115.07	115.07	115.07	115.07	212.45	212.45	212.45	212.45	212.45	212.45	1.44	1.14	1.78	1.47	3.46	3.16	13.78	10.72	14.50	11.45	18.14	15.08
238.70	84.37	84.37	84.37	84.37	84.37	84.37	115.19	115.19	115.19	115.19	115.19	115.19	212.67	212.67	212.67	212.67	212.67	212.67	1.44	1.14	1.78	1.47	3.47	3.17	13.74	10.71	14.47	11.44	18.12	15.08
238.60	84.45	84.45	84.45	84.45	84.45	84.45	115.31	115.31	115.31	115.31	115.31	115.31	212.88	212.88	212.88	212.88	212.88	212.88	1.44	1.14	1.78	1.48	3.47	3.17	13.71	10.69	14.44	11.42	18.10	15.08
238.50	84.54	84.54	84.54	84.54	84.54	84.54	115.43	115.43	115.43	115.43	115.43	115.43	213.10	213.10	213.10	213.10	213.10	213.10	1.44	1.13	1.78	1.48	3.48	3.18	13.68	10.68	14.42	11.41	18.08	15.08
238.40	84.63	84.63	84.63	84.63	84.63	84.63	115.54	115.54	115.54	115.54	115.54	115.54	213.32	213.32	213.32	213.32	213.32	213.32	1.43	1.13	1.77	1.48	3.49	3.19	13.65	10.67	14.39	11.40	18.06	15.08
238.30	84.71	84.71	84.71	84.71	84.71	84.71	115.66	115.66	115.66	115.66	115.66	115.66	213.53	213.53	213.53	213.53	213.53	213.53	1.43	1.13	1.77	1.48	3.49	3.20	13.62	10.66	14.36	11.39	18.05	15.08
238.20	84.80	84.80	84.80	84.80	84.80	84.80	115.78	115.78	115.78	115.78	115.78	115.78	213.75	213.75	213.75	213.75	213.75	213.75	1.43	1.13	1.77	1.48	3.50	3.20	13.60	10.64	14.34	11.38	18.03	15.08
238.10	84.89	84.89	84.89	84.89	84.89	84.89	115.90	115.90	115.90	115.90	115.90	115.90	213.96	213.96	213.96	213.96	213.96	213.96	1.42	1.13	1.77	1.48	3.50	3.21	13.56	10.63	14.30	11.37	18.01	15.08
238.00	84.97	84.97	84.97	84.97	84.97	84.97	116.02	116.02	116.02	116.02	116.02	116.02	214.18	214.18	214.18	214.18	214.18	214.18	1.42	1.13	1.77	1.48	3.51	3.22	13.53	10.62	14.28	11.36	18.00	15.08
237.90	85.06	85.06	85.06	85.06	85.06	85.06	116.13	116.13	116.13	116.13	116.13	116.13	214.40	214.40	214.40	214.40	214.40	214.40	1.42	1.13	1.77	1.48	3.52	3.23	13.50	10.60	14.25	11.35	17.98	15.08
237.80	85.15	85.15	85.15	85.15	85.15	85.15	116.25	116.25	116.25	116.25	116.25	116.25	214.61	214.61	214.61	214.61	214.61	214.61	1.42	1.13	1.77	1.48	3.52	3.23	13.47	10.59	14.22	11.34	17.97	15.08
237.70	85.23	85.23	85.23	85.23	85.23	85.23	116.37	116.37	116.37	116.37	116.37	116.37	214.83	214.83	214.83	214.83	214.83	214.83	1.41	1.13	1.77	1.48	3.53	3.24	13.45	10.58	14.20	11.33	17.95	15.08
237.60	85.32	85.32	85.32	85.32	85.32	85.32	116.49	116.49	116.49	116.49	116.49	116.49	215.04	215.04	215.04	215.04	215.04	215.04	1.41	1.13	1.76	1.48	3.53	3.25	13.41	10.57	14.17	11.32	17.93	15.08
237.50	85.41	85.41	85.41	85.41	85.41	85.41	116.60	116.60	116.60	116.60	116.60	116.60	215.26	215.26	215.26	215.26	215.26	215.26	1.41	1.12	1.76	1.48	3.54	3.26	13.37	10.54	14.13	11.30	17.91	15.08
237.40	85.49	85.49	85.49	85.49	85.49	85.49	116.72	116.72	116.72	116.72	116.72	116.72	215.47	215.47	215.47	215.47	215.47	215.47	1.40	1.12	1.76	1.48	3.55	3.26	13.34	10.53	14.10	11.28	17.89	15.07
237.30	85.58	85.58	85.58	85.58	85.58	85.58	116.84	116.84	116.84	116.84	116.84	116.84	215.69	215.69	215.69	215.69	215.69	215.69	1.40	1.12	1.76	1.48	3.55	3.27	13.31	10.51	14.07	11.27	17.87	15.07
237.20	85.67	85.67	85.67	85.67	85.67	85.67	116.96	116.96	116.96	116.96	116.96	116.96	215.90	215.90	215.90	215.90	215.90	215.90	1.40	1.12	1.76	1.48	3.56	3.28	13.27	10.49	14.03	11.26	17.85	15.07
237.10	85.75	85.75	85.75	85.75	85.75	85.75	117.07	117.07	117.07	117.07	117.07	117.07	216.12	216.12	216.12	216.12	216.12	216.12	1.39	1.12	1.76	1.48	3.56	3.29	13.24	10.48	14.00	11.24	17.82	15.07
237.00	85.84	85.84	85.84	85.84	85.84	85.84	117.19	117.19	117.19	117.19	117.19	117.19	216.34	216.34	216.34	216.34	216.34	216.34	1.39	1.12	1.75	1.48	3.57	3.30	13.20	10.46	13.97	11.23	17.80	15.06
236.90	85.92	85.92	85.92	85.92	85.92	85.92	117.31	117.31	117.31	117.31	117.31	117.31	216.55	216.55	216.55	216.55	216.55	216.55	1.39	1.12	1.75	1.48	3.58	3.30	13.16	10.44	13.93	11.21	17.78	15.06
236.80	86.01	86.01	86.01	86.01	86.01	86.01	117.42	117.42	117.42	117.42	117.42	117.42	216.77	216.77	216.77	216.77	216.77	216.77	1.38	1.11	1.75	1.48	3.58	3.31	13.12	10.42	13.89	11.19	17.75	15.05
236.70	86.10	86.10	86.10	86.10	86.10	86.10	117.54	117.54	117.54	117.54	117.54	117.54	216.98	216.98	216.98	216.98	216.98	216.98	1.38	1.11	1.75	1.48	3.59	3.32	13.09	10.40	13.86	11.17	17.73	15.05
236.60	86.18	86.18	86.18	86.18	86.18	86.18	117.66	117.66	117.66	117.66	117.66	117.66	217.20	217.20	217.20	217.20	217.20	217.20	1.38	1.11	1.75	1.48	3.59	3.33	13.05	10.38	13.83	11.16	17.71	15.04
236.50	86.27	86.27	86.27	86.27	86.27	86.27	117.78	117.78	117.78	117.78	117.78	117.78	217.41	217.41	217.41	217.41	217.41	217.41	1.37	1.11	1.75	1.48	3.60	3.33	13.02	10.36	13.79	11.14	17.69	15.04
236.40	86.35	86.35	86.35	86.35	86.35	86.35	117.89	117.89	117.89	117.89	117.89	117.89	217.63	217.63	217.63	217.63	217.63	217.63	1.37	1.11	1.74	1.48	3.60	3.34	12.98	10.34	13.76	11.12	17.66	15.03
236.30	86.44	86.44	86.44	86.44	86.44	86.44	118.01	118.01	118.01	118.01	118.01	118.01	217.84	217.84	217.84	217.84	217.84	217.84	1.37	1.11	1.74	1.48	3.61	3.35	12.94	10.32	13.72	11.11	17.64	15.02
236.20	86.53	86.53	86.53	86.53	86.53	86.53	118.13	118.13	118.13	118.13	118.13	118.13	218.06	218.06	218.06	218.06	218.06	218.06	1.36	1.10	1.74	1.48	3.62	3.36	12.90	10.30	13.69	11.09	17.62	15.02
236.10	86.61	86.61	86.61	86.61	86.61	86.61	118.24	118.24	118.24	118.24	118.24	118.24	218.27	218.27	218.27	218.27	218.27	218.27	1.36	1.10	1.74	1.48	3.62	3.36	12.87	10.29	13.66	11.07	17.60	15.02
236.00	86.70	86.70	86.70	86.70	86.70	86.70	118.36	118.36	118.36	118.36	118.36	118.36	218.49	218.49	218.49	218.49	218.49	218.49	1.36	1.10	1.74	1.48	3.63	3.37	12.83	10.27	13.62	11.06	17.58	15.01
235.90	86.78	86.78	86.78	86.78	86.78	86.78	118.48	118.48	118.48	118.48	118.48	118.48	218.70	218.70	218.70	218.70	218.70	218.70	1.36	1.10	1.74	1.48	3.63	3.38	12.80	10.25	13.59	11.05	17.56	15.01
235.80	86.87	86.87	86.87	86.87	86.87	86.87	118.60	118.60	118.60	118.60	118.60	118.60	218.92	218.92	218.92	218.92	218.92	218.92	1.35	1.10	1.73	1.48	3.64	3.39	12.77	10.24	13.57	11.04	17.54	15.01
235.70	86.96	86.96	86.96	86.96	86.96	86.96	118.71	118.71	118.71	118.71	118.71	118.71	219.13	219.13	219.13	219.13	219.13	219.13	1.35	1.10	1.73	1.48	3.65	3.39	12.74	10.23	13.54	11.03	17.53	15.01
235.60	87.05	87.05	87.05	87.05	87.05	87.05	118.83	118.83	118.83	118.83	118.83	118.83	219.35	219.35	219.35	219.35	219.35	219.35	1.35	1.10	1.73	1.48	3.65	3.40	12.72	10.22	13.52	11.02	17.52	15.01
235.50	87.14	87.14	87.14	87.14	87.14	87.14	118.95	118.95	118.95	118.95	118.95	118.95	219.57	219.57	219.57	219.57	219.57	219.57	1.35	1.10	1.73	1.48	3.66	3.41	12.69	10.21	13.50	11.01	17.50	15.02
235.40	87.23	87.23	87.23	87.23	87.23	87.23	119.08	119.08	119.08	119.08	119.08	119.08	219.79	219.79	219.79	219.79	219.79	219.79	1.34	1.10	1.73	1.48	3.66	3.42	12.67	10.20	13.47	11.00	17.49	15.02
235.30	87.32	87.32	87.32	87.32	87.32	87.32	119.20	119.20	119.20	119.20	119.20	119.20	220.01	220.01	220.01	220.01	220.01	220.01	1.34	1.10	1.73	1.48	3.67	3.42	12.64	10.19	13.45	10.99	17.48	15.02
235.20	87.41	87.41	87.41	87.41	87.41	87.41	119.32	119.32	119.32	119.32	119.32	119.32	220.23	220.23	220.23	220.23	220.23	220.23	1.34	1.09	1.73	1.48	3.68	3.43	12.62	10.18	13.43	10.99	17.47	15.03
235.10	87.50	87.50	87.50	87.50	87.50	87.50	119.44	119.44	119.44	119.44	119.44	119.44	220.45	220.45	220.45	220.45	220.45	220.45	1.34	1.09	1.73	1.49	3.68	3.44	12.60	10.17	13.41	10.98	17.46	15.03
235.00	87.59	87.59	87.59	87.59	87.59	87.59	119.57	119.57	119.57	119.57	119.57	119.57	220.68	220.68	220.68	220.68	220.68	220.68	1.33	1.09	1.73	1.49	3.69	3.45	12.57	10.16	13.38	10.97	17.45	15.03
234.90	87.69	87.69	87.69	87.69	87.69	87.69	119.69	119.69	119.69	119.69	119.69	119.69	220.90	220.90	220.90	220.90	220.90	220.90	1.33	1.09	1.73	1.49	3.70	3.46	12.54	10.14	13.36	10.96	17.43	15.04
234.80	87.78	87.78	87.78	87.78	87.78	87.78	119.82	119.82	119.82	119.82	119.82	119.82	221.12	221.12	221.12	221.12	221.12	221.12	1.33	1.09	1.73	1.49	3.70	3.46	12.51	10.13	13.33	10.95	17.42	15.04
234.70	87.88	87.88	87.88	87.88	87.88	87.88	119.94	119.94	119.94	119.94	119.94	119.94	221.35	221.35	221.35	221.35	221.35	221.35	1.33	1.09	1.72	1.49	3.71	3.47	12.48	10.12	13.30	10.94	17.40	15.04
234.60	87.97	87.97	87.97	87.97	87.97	87.97	120.07	120.07	120.07	120.07	120.07	120.07	221.57	221.57	221.57	221.57	221.57	221.57	1.32	1.09	1.72	1.49	3.72	3.48	12.45	10.10	13.28	10.93	17.39	15.04
234.50	88.07	88.07	88.07	88.07	88.07	88.07	120.20	120.20	120.20	120.20	120.20	120.20	221.80	221.80	221.80	221.80	221.80	221.80	1.32	1.09	1.72	1.49	3.72	3.49	12.

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)
232.30	90.16	90.16	90.16	90.16	90.16	90.16	122.97	122.97	122.97	122.97	122.97	122.97	226.73	226.73	226.73	226.73	226.73	226.73	1.27	1.07	1.70	1.50	3.87	3.66	11.83	9.81	12.71	10.69	17.09	15.07
232.20	90.25	90.25	90.25	90.25	90.25	90.25	123.10	123.10	123.10	123.10	123.10	123.10	226.95	226.95	226.95	226.95	226.95	226.95	1.27	1.07	1.70	1.50	3.87	3.67	11.80	9.80	12.68	10.67	17.08	15.07
232.10	90.35	90.35	90.35	90.35	90.35	90.35	123.22	123.22	123.22	123.22	123.22	123.22	227.18	227.18	227.18	227.18	227.18	227.18	1.26	1.07	1.70	1.50	3.88	3.68	11.77	9.78	12.66	10.66	17.06	15.07
232.00	90.44	90.44	90.44	90.44	90.44	90.44	123.35	123.35	123.35	123.35	123.35	123.35	227.40	227.40	227.40	227.40	227.40	227.40	1.26	1.06	1.70	1.50	3.88	3.69	11.75	9.77	12.63	10.66	17.05	15.07
231.90	90.54	90.54	90.54	90.54	90.54	90.54	123.47	123.47	123.47	123.47	123.47	123.47	227.62	227.62	227.62	227.62	227.62	227.62	1.26	1.06	1.70	1.50	3.89	3.69	11.73	9.76	12.62	10.65	17.05	15.08
231.80	90.63	90.63	90.63	90.63	90.63	90.63	123.60	123.60	123.60	123.60	123.60	123.60	227.85	227.85	227.85	227.85	227.85	227.85	1.26	1.06	1.70	1.50	3.90	3.70	11.71	9.76	12.60	10.64	17.04	15.08
231.70	90.72	90.72	90.72	90.72	90.72	90.72	123.72	123.72	123.72	123.72	123.72	123.72	228.07	228.07	228.07	228.07	228.07	228.07	1.26	1.06	1.70	1.50	3.90	3.71	11.69	9.75	12.58	10.64	17.03	15.09
231.60	90.82	90.82	90.82	90.82	90.82	90.82	123.85	123.85	123.85	123.85	123.85	123.85	228.29	228.29	228.29	228.29	228.29	228.29	1.25	1.06	1.70	1.50	3.91	3.72	11.66	9.73	12.56	10.63	17.02	15.09
231.50	90.91	90.91	90.91	90.91	90.91	90.91	123.97	123.97	123.97	123.97	123.97	123.97	228.51	228.51	228.51	228.51	228.51	228.51	1.25	1.06	1.70	1.51	3.92	3.73	11.64	9.72	12.53	10.62	17.01	15.09
231.40	91.00	91.00	91.00	91.00	91.00	91.00	124.09	124.09	124.09	124.09	124.09	124.09	228.74	228.74	228.74	228.74	228.74	228.74	1.25	1.06	1.70	1.51	3.92	3.73	11.62	9.71	12.51	10.61	17.00	15.10
231.30	91.10	91.10	91.10	91.10	91.10	91.10	124.22	124.22	124.22	124.22	124.22	124.22	228.96	228.96	228.96	228.96	228.96	228.96	1.25	1.06	1.70	1.51	3.93	3.74	11.59	9.70	12.49	10.60	16.99	15.10
231.20	91.19	91.19	91.19	91.19	91.19	91.19	124.34	124.34	124.34	124.34	124.34	124.34	229.18	229.18	229.18	229.18	229.18	229.18	1.25	1.06	1.69	1.51	3.94	3.75	11.57	9.70	12.47	10.60	16.98	15.11
231.10	91.28	91.28	91.28	91.28	91.28	91.28	124.47	124.47	124.47	124.47	124.47	124.47	229.40	229.40	229.40	229.40	229.40	229.40	1.24	1.06	1.69	1.51	3.94	3.76	11.55	9.69	12.45	10.59	16.98	15.11
231.00	91.37	91.37	91.37	91.37	91.37	91.37	124.59	124.59	124.59	124.59	124.59	124.59	229.62	229.62	229.62	229.62	229.62	229.62	1.24	1.06	1.69	1.51	3.95	3.76	11.53	9.68	12.44	10.58	16.97	15.12
230.90	91.47	91.47	91.47	91.47	91.47	91.47	124.71	124.71	124.71	124.71	124.71	124.71	229.85	229.85	229.85	229.85	229.85	229.85	1.24	1.06	1.69	1.51	3.96	3.77	11.51	9.67	12.42	10.58	16.96	15.12
230.80	91.56	91.56	91.56	91.56	91.56	91.56	124.84	124.84	124.84	124.84	124.84	124.84	230.07	230.07	230.07	230.07	230.07	230.07	1.24	1.06	1.69	1.51	3.96	3.78	11.49	9.66	12.40	10.57	16.95	15.12
230.70	91.65	91.65	91.65	91.65	91.65	91.65	124.96	124.96	124.96	124.96	124.96	124.96	230.29	230.29	230.29	230.29	230.29	230.29	1.24	1.06	1.69	1.51	3.97	3.79	11.46	9.65	12.38	10.56	16.94	15.13
230.60	91.74	91.74	91.74	91.74	91.74	91.74	125.08	125.08	125.08	125.08	125.08	125.08	230.51	230.51	230.51	230.51	230.51	230.51	1.24	1.06	1.69	1.51	3.97	3.79	11.44	9.64	12.36	10.55	16.93	15.13
230.50	91.84	91.84	91.84	91.84	91.84	91.84	125.21	125.21	125.21	125.21	125.21	125.21	230.73	230.73	230.73	230.73	230.73	230.73	1.23	1.05	1.69	1.51	3.98	3.80	11.42	9.63	12.34	10.55	16.93	15.14
230.40	91.93	91.93	91.93	91.93	91.93	91.93	125.33	125.33	125.33	125.33	125.33	125.33	230.95	230.95	230.95	230.95	230.95	230.95	1.23	1.05	1.69	1.51	3.99	3.81	11.40	9.62	12.32	10.54	16.92	15.14
230.30	92.02	92.02	92.02	92.02	92.02	92.02	125.45	125.45	125.45	125.45	125.45	125.45	231.18	231.18	231.18	231.18	231.18	231.18	1.23	1.05	1.69	1.51	3.99	3.82	11.38	9.61	12.30	10.53	16.91	15.14
230.20	92.11	92.11	92.11	92.11	92.11	92.11	125.58	125.58	125.58	125.58	125.58	125.58	231.40	231.40	231.40	231.40	231.40	231.40	1.23	1.05	1.69	1.51	4.00	3.83	11.35	9.60	12.28	10.53	16.90	15.15
230.10	92.21	92.21	92.21	92.21	92.21	92.21	125.70	125.70	125.70	125.70	125.70	125.70	231.62	231.62	231.62	231.62	231.62	231.62	1.23	1.05	1.69	1.52	4.01	3.83	11.33	9.59	12.26	10.52	16.89	15.15
230.00	92.30	92.30	92.30	92.30	92.30	92.30	125.82	125.82	125.82	125.82	125.82	125.82	231.84	231.84	231.84	231.84	231.84	231.84	1.22	1.05	1.69	1.52	4.01	3.84	11.31	9.58	12.24	10.51	16.89	15.16
229.90	92.39	92.39	92.39	92.39	92.39	92.39	125.95	125.95	125.95	125.95	125.95	125.95	232.06	232.06	232.06	232.06	232.06	232.06	1.22	1.05	1.69	1.52	4.02	3.85	11.29	9.57	12.22	10.51	16.88	15.16
229.80	92.48	92.48	92.48	92.48	92.48	92.48	126.07	126.07	126.07	126.07	126.07	126.07	232.28	232.28	232.28	232.28	232.28	232.28	1.22	1.05	1.69	1.52	4.03	3.86	11.27	9.57	12.20	10.50	16.87	15.17
229.70	92.57	92.57	92.57	92.57	92.57	92.57	126.19	126.19	126.19	126.19	126.19	126.19	232.50	232.50	232.50	232.50	232.50	232.50	1.22	1.05	1.69	1.52	4.03	3.86	11.25	9.56	12.18	10.49	16.86	15.17
229.60	92.66	92.66	92.66	92.66	92.66	92.66	126.31	126.31	126.31	126.31	126.31	126.31	232.72	232.72	232.72	232.72	232.72	232.72	1.22	1.05	1.69	1.52	4.04	3.87	11.23	9.55	12.17	10.48	16.86	15.18
229.50	92.76	92.76	92.76	92.76	92.76	92.76	126.44	126.44	126.44	126.44	126.44	126.44	232.94	232.94	232.94	232.94	232.94	232.94	1.22	1.05	1.69	1.52	4.05	3.88	11.21	9.54	12.15	10.48	16.85	15.18
229.40	92.85	92.85	92.85	92.85	92.85	92.85	126.56	126.56	126.56	126.56	126.56	126.56	233.16	233.16	233.16	233.16	233.16	233.16	1.21	1.05	1.69	1.52	4.05	3.89	11.18	9.53	12.12	10.47	16.84	15.18
229.30	92.94	92.94	92.94	92.94	92.94	92.94	126.68	126.68	126.68	126.68	126.68	126.68	233.38	233.38	233.38	233.38	233.38	233.38	1.21	1.05	1.69	1.52	4.06	3.89	11.16	9.51	12.10	10.46	16.83	15.18
229.20	93.03	93.03	93.03	93.03	93.03	93.03	126.80	126.80	126.80	126.80	126.80	126.80	233.60	233.60	233.60	233.60	233.60	233.60	1.21	1.05	1.68	1.52	4.06	3.90	11.13	9.50	12.08	10.45	16.82	15.18
229.10	93.12	93.12	93.12	93.12	93.12	93.12	126.93	126.93	126.93	126.93	126.93	126.93	233.83	233.83	233.83	233.83	233.83	233.83	1.21	1.04	1.68	1.52	4.07	3.91	11.11	9.49	12.06	10.44	16.81	15.19
229.00	93.21	93.21	93.21	93.21	93.21	93.21	127.05	127.05	127.05	127.05	127.05	127.05	234.05	234.05	234.05	234.05	234.05	234.05	1.20	1.04	1.68	1.52	4.08	3.92	11.09	9.48	12.04	10.43	16.80	15.19
228.90	93.30	93.30	93.30	93.30	93.30	93.30	127.17	127.17	127.17	127.17	127.17	127.17	234.27	234.27	234.27	234.27	234.27	234.27	1.20	1.04	1.68	1.52	4.08	3.92	11.06	9.47	12.02	10.42	16.79	15.19
228.80	93.39	93.39	93.39	93.39	93.39	93.39	127.29	127.29	127.29	127.29	127.29	127.29	234.49	234.49	234.49	234.49	234.49	234.49	1.20	1.04	1.68	1.52	4.09	3.93	11.04	9.46	12.00	10.41	16.78	15.19
228.70	93.48	93.48	93.48	93.48	93.48	93.48	127.41	127.41	127.41	127.41	127.41	127.41	234.71	234.71	234.71	234.71	234.71	234.71	1.20	1.04	1.68	1.52	4.10	3.94	11.02	9.44	11.97	10.40	16.77	15.20
228.60	93.57	93.57	93.57	93.57	93.57	93.57	127.53	127.53	127.53	127.53	127.53	127.53	234.93	234.93	234.93	234.93	234.93	234.93	1.20	1.04	1.68	1.52	4.10	3.95	10.99	9.43	11.95	10.39	16.76	15.20
228.50	93.66	93.66	93.66	93.66	93.66	93.66	127.66	127.66	127.66	127.66	127.66	127.66	235.15	235.15	235.15	235.15	235.15	235.15	1.19	1.04	1.68	1.53	4.11	3.95	10.97	9.42	11.93	10.38	16.75	15.20
228.40	93.76	93.76	93.76	93.76	93.76	93.76	127.78	127.78	127.78	127.78	127.78	127.78	235.36	235.36	235.36	235.36	235.36	235.36	1.19	1.04	1.68	1.53	4.11	3.96	10.95	9.41	11.91	10.37	16.74	15.20
228.30	93.85	93.85	93.85	93.85	93.85	93.85	127.90	127.90	127.90	127.90	127.90	127.90	235.58	235.58	235.58	235.58	235.58	235.58	1.19	1.04	1.68	1.53	4.12	3.97	10.92	9.40	11.89	10.36	16.73	15.20
228.20	93.94	93.94	93.94	93.94	93.94	93.94	128.02	128.02	128.02	128.02	128.02	128.02	235.80	235.80	235.80	235.80	235.80	235.80	1.19	1.04	1.68	1.53	4.13	3.98	10.90	9.38	11.87	10.35	16.72	15.21
228.10	94.03	94.03	94.03	94.03	94.03	94.03	128.14	128.14	128.14	128.14	128.14	128.14	236.02	236.02	236.02	236.02	236.02	236.02	1.19	1.04	1.68	1.53	4.13	3.98	10.87	9.37	11.84	10.34	16.71	15.21
228.00	94.12	94.12	94.12	94.12	94.12	94.12	128.26	128.26	128.26	128.26	128.26	128.26	236.24	236.24	236.24	236.24	236.24	236.24	1.18	1.03	1.68	1.53	4.14	3.99	10.85	9.36	11.82	10.33	16.70	15.21
227.90	94.21	94.21	94.21	94.21	94.21	94.21	128.38	128.38	128.38	128.38	128.38	128.38	236.46	236.46	236.46	236.46	236.46	236.46	1.18	1.03	1.68	1.53	4.15	4.00	10.82	9.35	11.80	10.32	16.69	15.21
227.80	94.30	94.30	94.30	94.30	94.30	94.30	128.50	128.50	128.50	128.50	128.50	128.50	236.68	236.68	236.68	236.68	236.68	236.68	1.18	1.03	1.67	1.53	4.15	4.01	10.80	9.33	11.78	10.31	16.68	15.21
227.70	94.39	94.39	94.39	94.39	94.39	94.39	128.63	128.63	128.63	128.63	128.63	128.63	236.90	236.90	236.90	236.90	236.90	236.90	1.18	1.03	1.67	1.53	4.16	4.01	10.78	9.32	11.76	10.30	16.67	15.21
227.60	94.48	94.48	94.48	94.48	94.48	94.48	128.75	128.75	128.75	128.75	128.75	128.75	237.12	237.12	237.12	237.12	237.12	237.12	1.17	1.03	1.67	1.53	4.17	4.02	10.75	9.31	11.73	10.29	16.65	15.21
227.50	94.57	94.57	94.57	94.57	94.57	94.57	128.87	128.87	128.87	128.87	128.87	128.87	237.34	237.34	237.34	237.34	237.34	237.34	1.17	1.03	1.67	1.53	4.17	4.03	10.71	9.28	11.70	10.27	16.63	15.20
227.40	94.66	94.66	94.66	94.66	94.66	94.66	128.99	128.99	128.99	128.99	128.99	128.99	237.56	237.56	237.56	237.56	237.56	237.56	1.17	1.03	1.67	1.53	4.18	4.04	10.68	9.26	11.67	10.25	16.61	15.20
227.30	94.75	94.75	94.75	94.75	94.75	94.75	129.11	129.11	129.11	129.11	129.11	129.11	237.78	237.78	237.78	237.78	237.78	237.78	1.17	1.03	1.67	1.53	4.18	4.04	10.65	9.25	11.64	10.24	16.60	15.19
227.20	94.84	94.84	94.84	94.84	94.84	94.84	129.23	129.23	129.23	129.23	129.23	129.23	238.00	238.00	238.00	238.00	238.00	238.00	1.16	1.02	1.67	1.53	4.19	4.05	10.62	9.23	11.61	10.22	16.58	15.19
227.10	94.93	94.93	94.93	94.93	94.93	94.93	129.35	129.35	129.35	129.35	129.35	129.35	238.21	238.21	238.21	238.21	238.21	238.21	1.16	1.02	1.67	1.53	4.20	4.06	10.59	9.21	11.59	10.21	16.57	15.19
227.00	95.01	95.01	95.01	95.01	95.01	95.01	129.47	129.47	129.47	129.47	129.47	129.47	238.43	238.43	238.43	238.43	238.43	238.43	1.16	1.02	1.67	1.53	4.20	4.07	10.56	9.19	11.56	10.19	16.55	15.18
226.90	95.10	95.10	95.10	95.10	95.10	95.10	129.59	129.59	129.59	129.59	129.59	129.59	238.65	238.65	238.65	238.65	238.65	238.65	1.16	1.02	1.66	1.53	4.21	4.07	10.53	9.18	11.53	10.18	16.54	15.18
226.80	95.19	95.19	95.19	95.19	95.19	95.19	129.71	129.71	129.71	129.71	129.71	129.71	238.87	238.87	238.87	238.87	238.87	238.87	1.15	1.02	1.66	1.53	4.21	4.08	10.51	9.16	11.51	10.17	16.52	15.18
226.70	95.28	95.28	95.28	95.28	95.28	95.28	129.83	129.83	129.83	129.83	129.83	129.83	239.09	239.09	239.09	239.09	239.09	239.09	1.15	1.02	1.66	1.53	4.22	4.09	10.48	9.15	11.48	10.15	16.51	15.18
226.60	95.37	95.37	95.37	95.37	95.37	95.37	129.95	129.95	129.95	129.95	129.95	129.95	239.31	239.31	239.31	239.31	239.31	239.31	1.15	1.02	1.66	1.53	4.23	4.09	10.45	9.13	11.46	10.14	16.50	15.18
226.50	95.46	95.46	95.46	95.46	95.46	95.46	130.07	130.07	130.07	130.07	130.07	130.07	239.53	239.53	239.53	239.53	239.53	239.53	1.15	1.01	1.66	1.53	4.23	4.10	10.42	9.11	11.43	10.12	16.48	15.17
226.40	95.55	95.55	95.55	95.55	95.55	95.55	130.19	130.19	130.19	130.19	130.19	130.19	239.75	239.75	239.75	239.75	239.75	239.75	1.14	1.01	1.66	1.53	4.24	4.11	10.39	9.10	11.41	10.11	16.47	15.17
226.30	95.64	95.64	95.64	95.64	95.64	95.64	130.32	130.32	130.32	130.32	130.32	130.32	239.96	239.96	239.96	239.96	239.96	239.96	1.14	1.01	1.66	1.53	4.25	4.12	10.37	9.08	11.38	10.10	16.45	15.17
226.20	95.73	95.73	95.73	95.73	95.73	95.73	130.44	130.44	130.44	130.44	130.44	130.44	240.18	240.18	240.18	240.18	240.18	240.18	1.14	1.01	1.66	1.53	4.25	4.12	10.34	9.06	11.35	10.08	16.44	15.17
226.10	95.82	95.82	95.82	95.82	95.82	95.82	130.56	130.56	130.56	130.56	130.56	130.56	240.40	240.40	240.40	240.40	240.40	240.40	1.14	1.01	1.66	1.53	4.26	4.13	10.31	9.04	11.33	10.06	16.42	15.16
226.00	95.91	95.91	95.91	95.91	95.91	95.91	130.68	130.68	130.68	130.68	130.68	130.68	240.62	240.62	240.62	240.62	240.62	240.62	1.13	1.01	1.65	1.53	4.26	4.14	10.28	9.03	11.30	10.05	16.41	15.16
225.90	96.00	96.00	96.00	96.00	96.00	96.00	130.80	130.80	130.80	130.80	130.80	130.80	240.84	240.84	240.84	240.84	240.84	240.84	1.13	1.01	1.65	1.53	4.27	4.15	10.26	9.02	11.28	10.04	16.40	15.16
225.80	96.09	96.09	96.09	96.09	96.09	96.09	130.92	130.92	130.92	130.92	130.92	130.92	241.06	241.06	241.06	241.06	241.06	241.06	1.13	1.01	1.65	1.53	4.28	4.15	10.23	9.00	11.26	10.03	16.39	15.16
225.70	96.18	96.18	96.18	96.18	96.18	96.18	131.04	131.04	131.04	131.04	131.04	131.04	241.28	241.28	241.28	241.28	241.28	241.28	1.13	1.00	1.65	1.53	4.28	4.16	10.21	8.99	11.24	10.02	16.38	15.16
225.60	96.27	96.27	96.27	96.27	96.27	96.27	131.16	131.16	131.16	131.16	131.16	131.16	241.50	241.50	241.50	241.50	241.50	241.50	1.12	1.00	1.65	1.53	4.29	4.17	10.18	8.98	11.21	10.01	16.37	15.16
225.50	96.36	96.36	96.36	96.36	96.36	96.36	131.28	131.28	131.28	131.28	131.28	131.28	241.72	241.72	241.72	241.72	241.72	241.72	1.12	1.00	1.65	1.53	4.30	4.18	10.16	8.96	11.19	9.99	16.36	15.16
225.40	96.45	96.45	96.45	96.45	96.45	96.45	131.40	131.40	131.40	131.40	131.40	131.40	241.94	241.94	241.94	241.94	241.94	241.94	1.12	1.00	1.65	1.53	4.30	4.18	10.13	8.94	11.16	9.98	16.34	15.16
225.30	96.54	96.54	96.54	96.54	96.54	96.54	131.53	131.53	131.53	131.53	131.53	131.53	242.16	242.16	242.16	242.16	242.16	242.16	1.12	1.00	1.65	1.53	4.31	4.19	10.10	8.93	11.14	9.97	16.33	15.16
225.20	96.63	96.63	96.63	96.63	96.63	96.63	131.65	131.65	131.65	131.65	131.65	131.65	242.38	242.38	242.38	242.38	242.38	242.38	1.11	1.00	1.65	1.53	4.31	4.20	10.07	8.91	11.12	9.95	16.32	15.16
225.10	96.73	96.73	96.73	96.73	96.73	96.73	131.77	131.77	131.77	131.77	131.77	131.77	242.60	242.60	242.60	242.60	242.60	242.60	1.11	1.00	1.65	1.53	4.32	4.21	10.05	8.90	11.09	9.94	16.31	15.15
225.00	96.82	96.82	96.82	96.82	96.82	96.82	131.90	131.90	131.90	131.90	131.90	131.90	242.82	242.82	242.82	242.82	242.82	242.82	1.11	1.00	1.65	1.53	4.33	4.21	10.02	8.88	11.07	9.92	16.29	15.15
224.90	96.91	96.91	96.91	96.91	96.91	96.91	132.02	132.02	132.02	132.02	132.02	132.02	243.05	243.05	243.05	243.05	243.05	243.05	1.11	0.99	1.65	1.53	4.33	4.22	9.99	8.86	11.04	9.91	16.28	15.15
224.80	97.01	97.01	97.01	97.01	97.01	97.01	132.15	132.15	132.15	132.15	132.15	132.15	243.27	243.27	243.27	243.27	243.27	243.27	1.11	0.99	1.64	1.53	4.34	4.23	9.97	8.85	11.02	9.90	16.27	15.15
224.70	97.10	97.10	97.10	97.10	97.10	97.10	132.27	132.27	132.27	132.27	132.27	132.27	243.49	243.49	243.49	243.49	243.49	243.49	1.10	0.99	1.64	1.53	4.35	4.24	9.94	8.83	11.00	9.89	16.26	15.15
224.60	97.20	97.20	97.20	97.20	97.20	97.20	132.40	132.40	132.40	132.40	132.40	132.40	243.72	243.72	243.72	243.72	243.72	243.72	1.10	0.99	1.64	1.53	4.35	4.24	9.92	8.82	10.97	9.87	16.25	15.15
224.50	97.30	97.30	97.30	97.30	97.30	97.30	132.53	132.53	132.53	132.53	132.53	132.53	243.94	243.94	243.94	243.94	243.94	243.94	1.10	0.99	1.64	1.53	4.36	4.25	9.89	8.80	10.95	9.86	16.24	15.15
224.40	97.39	97.39	97.39	97.39	97.39	97.39	132.66	132.66	132.66	132.66	132.66	132.66	244.17	244.17	244.17	244.17	244.17	244.17	1.10	0.99	1.64	1.53	4.37	4.26	9.87	8.79	10.93	9.85	16.23	15.15
224.30	97.49	97.49	97.49	97.49	97.49	97.49	132.78	132.78	132.78	132.78	132.78	132.78	244.40	244.40	244.40	244.40	244.40	244.40	1.09	0.99	1.64	1.53	4.37	4.27	9.84	8.77	10.90	9.83	16.21	15.15

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
222.10	99.64	99.64	99.64	99.64	99.64	99.64	135.62	135.62	135.62	135.62	135.62	135.62	249.39	249.39	249.39	249.39	249.39	249.39	1.04	0.95	1.62	1.53	4.52	4.44	9.20	8.36	10.32	9.48	15.91	15.07
222.00	99.74	99.74	99.74	99.74	99.74	99.74	135.75	135.75	135.75	135.75	135.75	135.75	249.62	249.62	249.62	249.62	249.62	249.62	1.03	0.95	1.62	1.53	4.53	4.45	9.17	8.34	10.29	9.46	15.89	15.06
221.90	99.83	99.83	99.83	99.83	99.83	99.83	135.87	135.87	135.87	135.87	135.87	135.87	249.84	249.84	249.84	249.84	249.84	249.84	1.03	0.95	1.62	1.53	4.54	4.45	9.14	8.32	10.26	9.44	15.88	15.06
221.80	99.93	99.93	99.93	99.93	99.93	99.93	136.00	136.00	136.00	136.00	136.00	136.00	250.07	250.07	250.07	250.07	250.07	250.07	1.03	0.95	1.61	1.53	4.54	4.46	9.11	8.30	10.23	9.42	15.86	15.05
221.70	100.03	100.03	100.03	100.03	100.03	100.03	136.13	136.13	136.13	136.13	136.13	136.13	250.30	250.30	250.30	250.30	250.30	250.30	1.03	0.95	1.61	1.53	4.55	4.47	9.08	8.27	10.20	9.40	15.85	15.05
221.60	100.13	100.13	100.13	100.13	100.13	100.13	136.26	136.26	136.26	136.26	136.26	136.26	250.52	250.52	250.52	250.52	250.52	250.52	1.02	0.94	1.61	1.53	4.56	4.48	9.03	8.24	10.16	9.37	15.82	15.03
221.50	100.22	100.22	100.22	100.22	100.22	100.22	136.39	136.39	136.39	136.39	136.39	136.39	250.75	250.75	250.75	250.75	250.75	250.75	1.02	0.94	1.61	1.53	4.56	4.49	8.99	8.21	10.13	9.35	15.80	15.02
221.40	100.32	100.32	100.32	100.32	100.32	100.32	136.52	136.52	136.52	136.52	136.52	136.52	250.97	250.97	250.97	250.97	250.97	250.97	1.02	0.94	1.61	1.53	4.57	4.49	8.96	8.19	10.09	9.32	15.78	15.01
221.30	100.42	100.42	100.42	100.42	100.42	100.42	136.64	136.64	136.64	136.64	136.64	136.64	251.20	251.20	251.20	251.20	251.20	251.20	1.01	0.94	1.61	1.53	4.58	4.50	8.92	8.16	10.06	9.30	15.76	15.00
221.20	100.51	100.51	100.51	100.51	100.51	100.51	136.77	136.77	136.77	136.77	136.77	136.77	251.43	251.43	251.43	251.43	251.43	251.43	1.01	0.93	1.60	1.53	4.58	4.51	8.89	8.14	10.03	9.28	15.74	14.99
221.10	100.61	100.61	100.61	100.61	100.61	100.61	136.90	136.90	136.90	136.90	136.90	136.90	251.65	251.65	251.65	251.65	251.65	251.65	1.01	0.93	1.60	1.53	4.59	4.52	8.85	8.11	10.00	9.25	15.72	14.98
221.00	100.71	100.71	100.71	100.71	100.71	100.71	137.03	137.03	137.03	137.03	137.03	137.03	251.88	251.88	251.88	251.88	251.88	251.88	1.00	0.93	1.60	1.53	4.60	4.52	8.82	8.08	9.96	9.23	15.70	14.97
220.90	100.81	100.81	100.81	100.81	100.81	100.81	137.16	137.16	137.16	137.16	137.16	137.16	252.10	252.10	252.10	252.10	252.10	252.10	1.00	0.93	1.60	1.53	4.60	4.53	8.78	8.06	9.93	9.21	15.68	14.96
220.80	100.90	100.90	100.90	100.90	100.90	100.90	137.28	137.28	137.28	137.28	137.28	137.28	252.33	252.33	252.33	252.33	252.33	252.33	1.00	0.92	1.60	1.53	4.61	4.54	8.74	8.03	9.89	9.18	15.65	14.94
220.70	101.00	101.00	101.00	101.00	101.00	101.00	137.41	137.41	137.41	137.41	137.41	137.41	252.56	252.56	252.56	252.56	252.56	252.56	0.99	0.92	1.60	1.53	4.61	4.54	8.70	8.00	9.85	9.15	15.63	14.93
220.60	101.09	101.09	101.09	101.09	101.09	101.09	137.54	137.54	137.54	137.54	137.54	137.54	252.78	252.78	252.78	252.78	252.78	252.78	0.99	0.92	1.59	1.53	4.62	4.55	8.66	7.97	9.82	9.13	15.61	14.92
220.50	101.19	101.19	101.19	101.19	101.19	101.19	137.67	137.67	137.67	137.67	137.67	137.67	253.01	253.01	253.01	253.01	253.01	253.01	0.99	0.92	1.59	1.52	4.63	4.56	8.63	7.95	9.79	9.11	15.59	14.91
220.40	101.29	101.29	101.29	101.29	101.29	101.29	137.79	137.79	137.79	137.79	137.79	137.79	253.23	253.23	253.23	253.23	253.23	253.23	0.98	0.91	1.59	1.52	4.63	4.57	8.59	7.92	9.75	9.08	15.57	14.89
220.30	101.38	101.38	101.38	101.38	101.38	101.38	137.92	137.92	137.92	137.92	137.92	137.92	253.46	253.46	253.46	253.46	253.46	253.46	0.98	0.91	1.59	1.52	4.64	4.57	8.55	7.89	9.71	9.05	15.54	14.88
220.20	101.48	101.48	101.48	101.48	101.48	101.48	138.05	138.05	138.05	138.05	138.05	138.05	253.68	253.68	253.68	253.68	253.68	253.68	0.97	0.91	1.59	1.52	4.65	4.58	8.51	7.85	9.67	9.02	15.51	14.86
220.10	101.58	101.58	101.58	101.58	101.58	101.58	138.17	138.17	138.17	138.17	138.17	138.17	253.91	253.91	253.91	253.91	253.91	253.91	0.97	0.91	1.58	1.52	4.65	4.59	8.46	7.81	9.63	8.99	15.48	14.84
220.00	101.67	101.67	101.67	101.67	101.67	101.67	138.30	138.30	138.30	138.30	138.30	138.30	254.13	254.13	254.13	254.13	254.13	254.13	0.96	0.90	1.58	1.52	4.66	4.60	8.40	7.77	9.58	8.95	15.45	14.81
219.90	101.77	101.77	101.77	101.77	101.77	101.77	138.43	138.43	138.43	138.43	138.43	138.43	254.36	254.36	254.36	254.36	254.36	254.36	0.96	0.90	1.58	1.52	4.66	4.60	8.35	7.73	9.53	8.91	15.41	14.79
219.80	101.86	101.86	101.86	101.86	101.86	101.86	138.56	138.56	138.56	138.56	138.56	138.56	254.58	254.58	254.58	254.58	254.58	254.58	0.95	0.89	1.57	1.51	4.67	4.61	8.30	7.69	9.48	8.87	15.37	14.76
219.70	101.96	101.96	101.96	101.96	101.96	101.96	138.68	138.68	138.68	138.68	138.68	138.68	254.81	254.81	254.81	254.81	254.81	254.81	0.95	0.89	1.57	1.51	4.67	4.61	8.23	7.63	9.41	8.81	15.32	14.72
219.60	102.06	102.06	102.06	102.06	102.06	102.06	138.81	138.81	138.81	138.81	138.81	138.81	255.03	255.03	255.03	255.03	255.03	255.03	0.94	0.88	1.56	1.51	4.68	4.62	8.15	7.56	9.33	8.75	15.26	14.67
219.50	102.15	102.15	102.15	102.15	102.15	102.15	138.94	138.94	138.94	138.94	138.94	138.94	255.26	255.26	255.26	255.26	255.26	255.26	0.93	0.88	1.56	1.50	4.68	4.63	8.07	7.50	9.26	8.69	15.20	14.63
219.40	102.25	102.25	102.25	102.25	102.25	102.25	139.06	139.06	139.06	139.06	139.06	139.06	255.48	255.48	255.48	255.48	255.48	255.48	0.92	0.87	1.55	1.50	4.69	4.63	7.97	7.41	9.16	8.60	15.12	14.56
219.30	102.34	102.34	102.34	102.34	102.34	102.34	139.19	139.19	139.19	139.19	139.19	139.19	255.71	255.71	255.71	255.71	255.71	255.71	0.91	0.85	1.54	1.48	4.69	4.63	7.81	7.27	9.01	8.46	14.98	14.44
219.20	102.44	102.44	102.44	102.44	102.44	102.44	139.31	139.31	139.31	139.31	139.31	139.31	255.93	255.93	255.93	255.93	255.93	255.93	0.88	0.83	1.51	1.46	4.68	4.63	7.53	7.01	8.73	8.21	14.72	14.21
219.10	102.53	102.53	102.53	102.53	102.53	102.53	139.44	139.44	139.44	139.44	139.44	139.44	256.16	256.16	256.16	256.16	256.16	256.16	0.86	0.81	1.50	1.45	4.68	4.63	7.34	6.84	8.54	8.05	14.56	14.06
219.00	102.63	102.63	102.63	102.63	102.63	102.63	139.57	139.57	139.57	139.57	139.57	139.57	256.38	256.38	256.38	256.38	256.38	256.38	0.86	0.81	1.49	1.45	4.69	4.64	7.26	6.77	8.47	7.98	14.50	14.01
218.90	102.72	102.72	102.72	102.72	102.72	102.72	139.69	139.69	139.69	139.69	139.69	139.69	256.61	256.61	256.61	256.61	256.61	256.61	0.85	0.80	1.49	1.44	4.69	4.65	7.21	6.73	8.42	7.94	14.46	13.99
218.80	102.82	102.82	102.82	102.82	102.82	102.82	139.82	139.82	139.82	139.82	139.82	139.82	256.83	256.83	256.83	256.83	256.83	256.83	0.85	0.80	1.49	1.44	4.70	4.65	7.16	6.69	8.37	7.90	14.43	13.96
218.70	102.91	102.91	102.91	102.91	102.91	102.91	139.95	139.95	139.95	139.95	139.95	139.95	257.05	257.05	257.05	257.05	257.05	257.05	0.84	0.80	1.49	1.44	4.70	4.66	7.12	6.66	8.33	7.87	14.41	13.94
218.60	103.01	103.01	103.01	103.01	103.01	103.01	140.07	140.07	140.07	140.07	140.07	140.07	257.28	257.28	257.28	257.28	257.28	257.28	0.84	0.79	1.48	1.44	4.71	4.66	7.07	6.62	8.29	7.83	14.37	13.92
218.50	103.10	103.10	103.10	103.10	103.10	103.10	140.20	140.20	140.20	140.20	140.20	140.20	257.50	257.50	257.50	257.50	257.50	257.50	0.83	0.79	1.48	1.44	4.71	4.67	7.02	6.57	8.24	7.79	14.34	13.89
218.40	103.20	103.20	103.20	103.20	103.20	103.20	140.32	140.32	140.32	140.32	140.32	140.32	257.73	257.73	257.73	257.73	257.73	257.73	0.83	0.78	1.48	1.43	4.72	4.68	6.97	6.53	8.19	7.75	14.30	13.87
218.30	103.29	103.29	103.29	103.29	103.29	103.29	140.45	140.45	140.45	140.45	140.45	140.45	257.95	257.95	257.95	257.95	257.95	257.95	0.82	0.78	1.47	1.43	4.73	4.68	6.91	6.49	8.14	7.71	14.27	13.84
218.20	103.39	103.39	103.39	103.39	103.39	103.39	140.57	140.57	140.57	140.57	140.57	140.57	258.17	258.17	258.17	258.17	258.17	258.17	0.82	0.78	1.47	1.43	4.73	4.69	6.87	6.45	8.10	7.68	14.24	13.82
218.10	103.48	103.48	103.48	103.48	103.48	103.48	140.70	140.70	140.70	140.70	140.70	140.70	258.40	258.40	258.40	258.40	258.40	258.40	0.82	0.77	1.47	1.43	4.74	4.70	6.83	6.42	8.06	7.65	14.21	13.80
218.00	103.57	103.57	103.57	103.57	103.57	103.57	140.82	140.82	140.82	140.82	140.82	140.82	258.62	258.62	258.62	258.62	258.62	258.62	0.81	0.77	1.47	1.43	4.74	4.70	6.78	6.38	8.02	7.61	14.18	13.78
217.90	103.67	103.67	103.67	103.67	103.67	103.67	140.95	140.95	140.95	140.95	140.95	140.95	258.84	258.84	258.84	258.84	258.84	258.84	0.81	0.77	1.46	1.42	4.75	4.71	6.74	6.34	7.97	7.58	14.15	13.76
217.80	103.76	103.76	103.76	103.76	103.76	103.76	141.07	141.07	141.07	141.07	141.07	141.07	259.07	259.07	259.07	259.07	259.07	259.07	0.80	0.76	1.46	1.42	4.75	4.71	6.69	6.31	7.93	7.54	14.12	13.73
217.70	103.86	103.86	103.86	103.86	103.86	103.86	141.20	141.20	141.20	141.20	141.20	141.20	259.29	259.29	259.29	259.29	259.29	259.29	0.80	0.76	1.46	1.42	4.76	4.72	6.65	6.27	7.89	7.51	14.09	13.71
217.60	103.95	103.95	103.95	103.95	103.95	103.95	141.33	141.33	141.33	141.33	141.33	141.33	259.51	259.51	259.51	259.51	259.51	259.51	0.79	0.76	1.46	1.42	4.76	4.73	6.60	6.23	7.85	7.47	14.06	13.69
217.50	104.04	104.04	104.04	104.04	104.04	104.04	141.45	141.45	141.45	141.45	141.45	141.45	259.74	259.74	259.74	259.74	259.74	259.74	0.79	0.75	1.45	1.42	4.77	4.73	6.56	6.19	7.80	7.44	14.03	13.67
217.40	104.14	104.14	104.14	104.14	104.14	104.14	141.58	141.58	141.58	141.58	141.58	141.58	259.96	259.96	259.96	259.96	259.96	259.96	0.79	0.75	1.45	1.41	4.77	4.74	6.50	6.15	7.75	7.40	14.00	13.64
217.30	104.23	104.23	104.23	104.23	104.23	104.23	141.70	141.70	141.70	141.70	141.70	141.70	260.18	260.18	260.18	260.18	260.18	260.18	0.78	0.75	1.45	1.41	4.78	4.74	6.45	6.10	7.70	7.35	13.96	13.61
217.20	104.33	104.33	104.33	104.33	104.33	104.33	141.82	141.82	141.82	141.82	141.82	141.82	260.41	260.41	260.41	260.41	260.41	260.41	0.77	0.74	1.44	1.41	4.78	4.75	6.38	6.04	7.63	7.29	13.90	13.57
217.10	104.42	104.42	104.42	104.42	104.42	104.42	141.95	141.95	141.95	141.95	141.95	141.95	260.63	260.63	260.63	260.63	260.63	260.63	0.77	0.73	1.44	1.40	4.79	4.75	6.29	5.96	7.55	7.22	13.84	13.50
217.00	104.51	104.51	104.51	104.51	104.51	104.51	142.07	142.07	142.07	142.07	142.07	142.07	260.85	260.85	260.85	260.85	260.85	260.85	0.75	0.72	1.42	1.39	4.79	4.75	6.15	5.83	7.41	7.10	13.71	13.40
216.90	104.61	104.61	104.61	104.61	104.61	104.61	142.20	142.20	142.20	142.20	142.20	142.20	261.08	261.08	261.08	261.08	261.08	261.08	0.74	0.71	1.41	1.38	4.79	4.76	6.03	5.72	7.29	6.99	13.61	13.30
216.80	104.70	104.70	104.70	104.70	104.70	104.70	142.32	142.32	142.32	142.32	142.32	142.32	261.30	261.30	261.30	261.30	261.30	261.30	0.73	0.70	1.41	1.38	4.79	4.76	5.94	5.64	7.21	6.91	13.54	13.24
216.70	104.79	104.79	104.79	104.79	104.79	104.79	142.45	142.45	142.45	142.45	142.45	142.45	261.52	261.52	261.52	261.52	261.52	261.52	0.72	0.69	1.40	1.37	4.79	4.76	5.85	5.57	7.12	6.84	13.47	13.18
216.60	104.89	104.89	104.89	104.89	104.89	104.89	142.57	142.57	142.57	142.57	142.57	142.57	261.74	261.74	261.74	261.74	261.74	261.74	0.72	0.69	1.40	1.37	4.80	4.77	5.77	5.49	7.04	6.76	13.41	13.13
216.50	104.98	104.98	104.98	104.98	104.98	104.98	142.70	142.70	142.70	142.70	142.70	142.70	261.97	261.97	261.97	261.97	261.97	261.97	0.71	0.68	1.39	1.36	4.80	4.77	5.70	5.43	6.98	6.70	13.35	13.08
216.40	105.07	105.07	105.07	105.07	105.07	105.07	142.82	142.82	142.82	142.82	142.82	142.82	262.19	262.19	262.19	262.19	262.19	262.19	0.70	0.67	1.38	1.36	4.80	4.78	5.62	5.36	6.90	6.64	13.29	13.02
216.30	105.17	105.17	105.17	105.17	105.17	105.17	142.95	142.95	142.95	142.95	142.95	142.95	262.41	262.41	262.41	262.41	262.41	262.41	0.69	0.67	1.38	1.35	4.81	4.78	5.54	5.28	6.82	6.56	13.22	12.97
216.20	105.26	105.26	105.26	105.26	105.26	105.26	143.07	143.07	143.07	143.07	143.07	143.07	262.63	262.63	262.63	262.63	262.63	262.63	0.69	0.66	1.37	1.35	4.81	4.78	5.45	5.21	6.74	6.49	13.15	12.91
216.10	105.35	105.35	105.35	105.35	105.35	105.35	143.19	143.19	143.19	143.19	143.19	143.19	262.86	262.86	262.86	262.86	262.86	262.86	0.68	0.65	1.37	1.34	4.81	4.79	5.36	5.12	6.65	6.41	13.08	12.84
216.00	105.45	105.45	105.45	105.45	105.45	105.45	143.32	143.32	143.32	143.32	143.32	143.32	263.08	263.08	263.08	263.08	263.08	263.08	0.67	0.64	1.36	1.33	4.81	4.79	5.25	5.02	6.54	6.31	12.99	12.76
215.90	105.54	105.54	105.54	105.54	105.54	105.54	143.44	143.44	143.44	143.44	143.44	143.44	263.30	263.30	263.30	263.30	263.30	263.30	0.65	0.63	1.35	1.32	4.81	4.79	5.12	4.90	6.41	6.19	12.87	12.65
215.80	105.63	105.63	105.63	105.63	105.63	105.63	143.57	143.57	143.57	143.57	143.57	143.57	263.52	263.52	263.52	263.52	263.52	263.52	0.64	0.62	1.33	1.31	4.81	4.79	4.97	4.76	6.27	6.06	12.74	12.53
215.70	105.73	105.73	105.73	105.73	105.73	105.73	143.69	143.69	143.69	143.69	143.69	143.69	263.75	263.75	263.75	263.75	263.75	263.75	0.62	0.60	1.32	1.30	4.81	4.79	4.81	4.61	6.10	5.91	12.60	12.40
215.60	105.82	105.82	105.82	105.82	105.82	105.82	143.82	143.82	143.82	143.82	143.82	143.82	263.97	263.97	263.97	263.97	263.97	263.97	0.60	0.58	1.30	1.28	4.80	4.78	4.58	4.40	5.88	5.70	12.39	12.21
215.50	105.91	105.91	105.91	105.91	105.91	105.91	143.94	143.94	143.94	143.94	143.94	143.94	264.19	264.19	264.19	264.19	264.19	264.19	0.58	0.56	1.28	1.26	4.79	4.77	4.33	4.15	5.63	5.46	12.16	11.99
215.40	106.01	106.01	106.01	106.01	106.01	106.01	144.07	144.07	144.07	144.07	144.07	144.07	264.41	264.41	264.41	264.41	264.41	264.41	0.55	0.54	1.26	1.24	4.78	4.77	4.11	3.95	5.42	5.26	11.96	11.80
215.30	106.10	106.10	106.10	106.10	106.10	106.10	144.19	144.19	144.19	144.19	144.19	144.19	264.64	264.64	264.64	264.64	264.64	264.64	0.53	0.52	1.24	1.23	4.77	4.76	3.90	3.76	5.21	5.07	11.77	11.63
215.20	106.19	106.19	106.19	106.19	106.19	106.19	144.31	144.31	144.31	144.31	144.31	144.31	264.86	264.86	264.86	264.86	264.86	264.86	0.51	0.50	1.22	1.21	4.77	4.75	3.68	3.54	4.99	4.86	11.57	11.43
215.10	106.29	106.29	106.29	106.29	106.29	106.29	144.44	144.44	144.44	144.44	144.44	144.44	265.08	265.08	265.08	265.08	265.08	265.08	0.50	0.48	1.21	1.19	4.76	4.75	3.51	3.38	4.82	4.70	11.41	11.29
215.00	106.38	106.38	106.38	106.38	106.38	106.38	144.56	144.56	144.56	144.56	144.56	144.56	265.30	265.30	265.30	265.30	265.30	265.30	0.48	0.47	1.20	1.18	4.76	4.75	3.39	3.27	4.71	4.59	11.31	11.19
214.90	106.47	106.47	106.47	106.47	106.47	106.47	144.69	144.69	144.69	144.69	144.69	144.69	265.53	265.53	265.53	265.53	265.53	265.53	0.47	0.46	1.19	1.18	4.76	4.75	3.29	3.18	4.62	4.50	11.23	11.12
214.80	106.57	106.57	106.57	106.57	106.57	106.57	144.81	144.81	144.81	144.81	144.81	144.81	265.75	265.75	265.75	265.75	265.75	265.75	0.46	0.45	1.18	1.17	4.76	4.75	3.19	3.08	4.52	4.41	11.15	11.04
214.70	106.66	106.66	106.66	106.66	106.66	106.66	144.94	144.94	144.94	144.94	144.94	144.94	265.97	265.97	265.97	265.97	265.97	265.97	0.45	0.44	1.17	1.16	4.76	4.75	3.07	2.97	4.40	4.30	11.05	10.95
214.60	106.75	106.75	106.75	106.75	106.75	106.75	145.06	145.06	145.06	145.06	145.06	145.06	266.19	266.19	266.19	266.19	266.19	266.19	0.44	0.43	1.16	1.15	4.76	4.75	2.96	2.86	4.29	4.19	10.95	10.85
214.50	106.85	106.85	106.85	106.85	106.85	106.85	145.18	145.18	145.18	145.18	145.18	145.18	266.42	266.42	266.42	266.42	266.42	266.42	0.43	0.43	1.16	1.15	4.76	4.75	2.88	2.79	4.21	4.12	10.88	10.79
214.40	106.94	106.94	106.94	106.94	106.94	106.94	145.31	145.31	145.31	145.31	145.31	145.31	266.64	266.64	266.64	266.64	266.64	266.64	0.43	0.42	1.15	1.14	4.76	4.75	2.80	2.71	4.13	4.05	10.82	10.73
214.30	107.03	107.03	107.03	107.03	107.03	107.03	145.43	145.43	145.43	145.43	145.43	145.43	266.86	266.86	266.86	266.86	266.86	266.86	0.42	0.41	1.14	1.13	4.76	4.75	2.69	2.61	4.03	3.95	10.73	10.65
214.20	107.13	107.13	107.13	107.13	107.13	107.13	145.56	145.56	145.56	145.56	145.56	145.56	267.08	267.08	267.08	267.08	267.08	267.08	0.40	0.40	1.13	1.12	4.76	4.75	2.57	2.50	3.91	3.84	10.62	10.55
214.10	107.22	107.22	107.22	107.22	107.22	107.22	145.68	145.68	145.68	145.68	145.68	145.68	267.31	267.31	267.31	267.31	267.31	267.31	0.40	0.39	1.13	1.12	4.76	4.75	2.

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Pit Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
211.90	109.27	109.27	109.27	109.27	109.27	109.27	148.42	148.42	148.42	148.42	148.42	148.42	272.20	272.20	272.20	272.20	272.20	272.20	0.26	0.26	1.02	1.02	4.81	4.80	1.05	1.04	2.45	2.44	9.44	9.43
211.80	109.36	109.36	109.36	109.36	109.36	109.36	148.54	148.54	148.54	148.54	148.54	148.54	272.42	272.42	272.42	272.42	272.42	272.42	0.25	0.25	1.01	1.01	4.81	4.81	0.97	0.96	2.37	2.36	9.37	9.36
211.70	109.46	109.46	109.46	109.46	109.46	109.46	148.66	148.66	148.66	148.66	148.66	148.66	272.64	272.64	272.64	272.64	272.64	272.64	0.24	0.24	1.00	1.00	4.81	4.81	0.89	0.89	2.30	2.29	9.31	9.30
211.60	109.55	109.55	109.55	109.55	109.55	109.55	148.79	148.79	148.79	148.79	148.79	148.79	272.87	272.87	272.87	272.87	272.87	272.87	0.24	0.24	1.00	1.00	4.81	4.81	0.81	0.81	2.22	2.21	9.25	9.24
211.50	109.64	109.64	109.64	109.64	109.64	109.64	148.91	148.91	148.91	148.91	148.91	148.91	273.09	273.09	273.09	273.09	273.09	273.09	0.23	0.23	0.99	0.99	4.81	4.81	0.74	0.73	2.14	2.14	9.18	9.18
211.40	109.74	109.74	109.74	109.74	109.74	109.74	149.03	149.03	149.03	149.03	149.03	149.03	273.31	273.31	273.31	273.31	273.31	273.31	0.22	0.22	0.99	0.99	4.81	4.81	0.66	0.65	2.07	2.06	9.12	9.11
211.30	109.83	109.83	109.83	109.83	109.83	109.83	149.16	149.16	149.16	149.16	149.16	149.16	273.53	273.53	273.53	273.53	273.53	273.53	0.21	0.21	0.98	0.98	4.81	4.81	0.58	0.58	1.99	1.99	9.05	9.05
211.20	109.92	109.92	109.92	109.92	109.92	109.92	149.28	149.28	149.28	149.28	149.28	149.28	273.75	273.75	273.75	273.75	273.75	273.75	0.21	0.21	0.97	0.97	4.81	4.81	0.50	0.50	1.91	1.91	8.99	8.98
211.10	110.01	110.01	110.01	110.01	110.01	110.01	149.41	149.41	149.41	149.41	149.41	149.41	273.97	273.97	273.97	273.97	273.97	273.97	0.20	0.20	0.97	0.97	4.81	4.81	0.41	0.41	1.83	1.83	8.91	8.91
211.04	110.11	110.11	110.11	110.11	110.11	110.11	149.53	149.53	149.53	149.53	149.53	149.53	274.16	274.16	274.16	274.16	274.16	274.16	0.19	0.19	0.96	0.96	4.81	4.81	0.35	0.35	1.77	1.77	8.87	8.87
210.04	110.00	110.00	110.00	110.00	110.00	110.00	149.73	149.73	149.73	149.73	149.73	149.73	275.34	275.34	275.34	275.34	275.34	275.34	0.19	0.19	0.96	0.96	4.80	4.80	0.36	0.36	1.78	1.78	8.90	8.90

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	Dewatering WBM South Pit Inflow (m³/day)	Recovery WBM South Pit Inflow (m³/day)
334.30	518.99	15.03	519.11	15.14	519.66	15.70	52.99	2.59
334.20	518.65	15.43	518.76	15.54	519.33	16.11	52.96	2.63
334.10	518.31	15.82	518.43	15.94	519.01	16.53	52.92	2.68
334.00	517.95	16.22	518.07	16.34	518.67	16.94	52.89	2.72
333.90	517.61	16.61	517.73	16.74	518.35	17.35	52.86	2.76
333.80	517.29	17.01	517.41	17.13	518.04	17.76	52.83	2.80
333.70	516.96	17.40	517.09	17.53	517.73	18.18	52.80	2.84
333.60	516.63	17.80	516.76	17.93	517.42	18.59	52.77	2.89
333.50	516.30	18.19	516.44	18.32	517.11	19.00	52.74	2.93
333.40	515.96	18.58	516.10	18.72	516.79	19.41	52.71	2.97
333.30	515.62	18.97	515.76	19.11	516.46	19.82	52.68	3.01
333.20	515.28	19.36	515.42	19.51	516.14	20.23	52.64	3.05
333.10	514.93	19.75	515.07	19.90	515.81	20.63	52.61	3.09
333.00	514.58	20.14	514.73	20.29	515.48	21.04	52.58	3.14
332.90	514.23	20.53	514.38	20.68	515.14	21.45	52.55	3.18
332.80	513.89	20.92	514.05	21.08	514.82	21.85	52.52	3.22
332.70	513.56	21.31	513.72	21.47	514.51	22.26	52.49	3.26
332.60	513.22	21.70	513.38	21.86	514.19	22.67	52.45	3.30
332.50	512.88	22.08	513.04	22.25	513.86	23.07	52.42	3.34
332.40	512.54	22.47	512.71	22.64	513.55	23.47	52.39	3.38
332.30	512.20	22.86	512.37	23.03	513.22	23.88	52.36	3.43
332.20	511.85	23.24	512.03	23.41	512.89	24.28	52.33	3.47
332.10	511.50	23.63	511.68	23.80	512.56	24.68	52.30	3.51
332.00	511.14	24.01	511.32	24.19	512.21	25.08	52.26	3.55
331.90	510.78	24.39	510.96	24.57	511.87	25.49	52.23	3.59
331.80	510.42	24.77	510.60	24.96	511.53	25.88	52.20	3.63
331.70	510.04	25.16	510.23	25.34	511.17	26.28	52.16	3.67
331.60	509.65	25.54	509.84	25.73	510.80	26.68	52.13	3.71
331.50	509.24	25.91	509.43	26.11	510.40	27.08	52.09	3.75
331.40	508.82	26.29	509.01	26.49	510.00	27.47	52.05	3.80
331.30	508.39	26.67	508.59	26.87	509.59	27.86	52.01	3.84
331.20	507.98	27.04	508.18	27.24	509.19	28.26	51.97	3.88
331.10	507.55	27.42	507.76	27.62	508.79	28.65	51.93	3.92
331.00	507.14	27.79	507.35	28.00	508.39	29.04	51.89	3.96
330.90	506.71	28.16	506.93	28.38	507.98	29.43	51.85	4.00
330.80	506.25	28.53	506.46	28.75	507.54	29.82	51.81	4.04
330.70	505.70	28.90	505.92	29.12	507.00	30.20	51.76	4.08
330.60	505.16	29.26	505.38	29.48	506.48	30.58	51.71	4.12
330.50	504.65	29.63	504.88	29.85	505.99	30.97	51.66	4.16
330.40	504.15	29.99	504.37	30.22	505.50	31.35	51.62	4.20
330.30	503.57	30.35	503.80	30.58	504.94	31.73	51.56	4.24
330.20	503.05	30.72	503.28	30.95	504.44	32.10	51.52	4.28
330.10	502.57	31.08	502.80	31.32	503.97	32.49	51.47	4.32
330.00	502.14	31.45	502.37	31.68	503.56	32.87	51.43	4.36
329.90	501.71	31.81	501.95	32.05	503.15	33.25	51.39	4.40
329.80	501.30	32.18	501.54	32.42	502.76	33.64	51.35	4.44
329.70	500.90	32.55	501.14	32.79	502.37	34.02	51.32	4.48
329.60	500.49	32.91	500.74	33.16	501.98	34.40	51.28	4.52
329.50	500.08	33.28	500.33	33.53	501.59	34.78	51.24	4.56
329.40	499.67	33.64	499.92	33.89	501.19	35.17	51.20	4.60
329.30	499.26	34.00	499.51	34.26	500.80	35.55	51.17	4.64
329.20	498.86	34.37	499.12	34.63	500.42	35.93	51.13	4.68
329.10	498.46	34.73	498.72	34.99	500.04	36.31	51.09	4.72
329.00	498.06	35.09	498.33	35.36	499.66	36.69	51.05	4.76
328.90	497.66	35.45	497.93	35.72	499.27	37.06	51.02	4.80
328.80	497.27	35.81	497.55	36.09	498.90	37.44	50.98	4.84
328.70	496.90	36.18	497.17	36.45	498.55	37.82	50.95	4.88
328.60	496.54	36.54	496.81	36.82	498.20	38.20	50.91	4.91
328.50	496.19	36.90	496.47	37.18	497.87	38.58	50.88	4.95
328.40	495.85	37.26	496.13	37.55	497.54	38.96	50.85	4.99
328.30	495.51	37.63	495.80	37.91	497.23	39.34	50.82	5.03
328.20	495.18	37.99	495.47	38.28	496.91	39.72	50.79	5.07
328.10	494.85	38.35	495.15	38.64	496.60	40.10	50.76	5.11
328.00	494.53	38.71	494.83	39.01	496.30	40.48	50.73	5.15
327.90	494.22	39.08	494.52	39.37	496.00	40.86	50.70	5.19
327.80	493.91	39.44	494.21	39.74	495.71	41.24	50.67	5.22
327.70	493.61	39.80	493.91	40.10	495.43	41.62	50.64	5.26
327.60	493.31	40.16	493.62	40.47	495.15	42.00	50.62	5.30
327.50	493.02	40.52	493.33	40.83	494.87	42.38	50.59	5.34
327.40	492.72	40.89	493.04	41.20	494.60	42.76	50.56	5.38
327.30	492.44	41.25	492.75	41.56	494.33	43.14	50.53	5.42
327.20	492.15	41.61	492.47	41.93	494.06	43.52	50.51	5.45
327.10	491.87	41.97	492.19	42.29	493.79	43.89	50.48	5.49
327.00	491.58	42.33	491.91	42.65	493.52	44.27	50.46	5.53
326.90	491.30	42.69	491.63	43.02	493.26	44.65	50.43	5.57
326.80	491.02	43.05	491.35	43.38	492.99	45.03	50.40	5.61
326.70	490.74	43.41	491.07	43.74	492.73	45.40	50.38	5.64
326.60	490.46	43.77	490.80	44.11	492.47	45.78	50.35	5.68
326.50	490.19	44.13	490.53	44.47	492.22	46.16	50.33	5.72
326.40	489.91	44.49	490.25	44.83	491.96	46.53	50.30	5.76
326.30	489.64	44.85	489.99	45.19	491.70	46.91	50.28	5.80
326.20	489.37	45.21	489.72	45.55	491.46	47.29	50.25	5.83
326.10	489.10	45.56	489.45	45.91	491.20	47.66	50.23	5.87
326.00	488.83	45.92	489.18	46.27	490.94	48.04	50.20	5.91
325.90	488.56	46.28	488.92	46.63	490.69	48.41	50.18	5.95
325.80	488.29	46.63	488.65	46.99	490.44	48.78	50.15	5.98
325.70	488.01	46.99	488.37	47.35	490.18	49.16	50.12	6.02
325.60	487.74	47.34	488.10	47.71	489.92	49.53	50.10	6.06
325.50	487.47	47.70	487.83	48.07	489.67	49.90	50.07	6.10
325.40	487.19	48.05	487.56	48.42	489.41	50.27	50.05	6.13
325.30	486.91	48.41	487.28	48.78	489.15	50.65	50.02	6.17
325.20	486.63	48.76	487.01	49.14	488.89	51.02	50.00	6.21
325.10	486.35	49.11	486.73	49.49	488.63	51.39	49.97	6.25
325.00	486.07	49.47	486.45	49.85	488.36	51.76	49.94	6.28
324.90	485.79	49.82	486.18	50.20	488.10	52.13	49.92	6.32
324.80	485.51	50.17	485.90	50.56	487.83	52.49	49.89	6.36
324.70	485.22	50.52	485.61	50.91	487.57	52.86	49.87	6.40
324.60	484.94	50.87	485.33	51.26	487.30	53.23	49.84	6.43
324.50	484.65	51.22	485.04	51.61	487.02	53.59	49.81	6.47
324.40	484.35	51.57	484.75	51.96	486.74	53.96	49.79	6.51
324.30	484.05	51.91	484.45	52.31	486.46	54.32	49.76	6.54
324.20	483.74	52.26	484.14	52.66	486.16	54.69	49.73	6.58

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	Dewatering WBM South Pit Inflow (m^3/day)	Recovery WBM South Pit Inflow (m^3/day)
324.10	483.42	52.60	483.83	53.01	485.87	55.05	49.70	6.62
324.00	483.11	52.95	483.52	53.36	485.57	55.41	49.67	6.65
323.90	482.79	53.29	483.20	53.70	485.27	55.77	49.64	6.69
323.80	482.47	53.63	482.89	54.05	484.97	56.13	49.61	6.73
323.70	482.15	53.97	482.57	54.39	484.67	56.49	49.58	6.76
323.60	481.82	54.31	482.24	54.74	484.35	56.85	49.55	6.80
323.50	481.49	54.65	481.92	55.08	484.04	57.20	49.52	6.84
323.40	481.16	54.99	481.59	55.42	483.72	57.56	49.49	6.87
323.30	480.82	55.33	481.26	55.76	483.41	57.91	49.46	6.91
323.20	480.49	55.67	480.92	56.10	483.09	58.27	49.43	6.94
323.10	480.14	56.00	480.57	56.44	482.76	58.62	49.39	6.98
323.00	479.79	56.34	480.23	56.78	482.42	58.97	49.36	7.02
322.90	479.44	56.67	479.88	57.11	482.09	59.32	49.33	7.05
322.80	479.07	57.00	479.51	57.45	481.73	59.67	49.29	7.09
322.70	478.68	57.33	479.12	57.78	481.36	60.02	49.26	7.12
322.60	478.28	57.66	478.73	58.11	480.98	60.36	49.22	7.16
322.50	477.88	57.98	478.33	58.44	480.60	60.70	49.18	7.20
322.40	477.49	58.31	477.95	58.77	480.23	61.04	49.15	7.23
322.30	477.10	58.64	477.56	59.09	479.86	61.39	49.11	7.27
322.20	476.72	58.96	477.19	59.42	479.49	61.73	49.08	7.30
322.10	476.34	59.29	476.81	59.75	479.13	62.07	49.04	7.34
322.00	475.96	59.61	476.42	60.08	478.76	62.41	49.01	7.37
321.90	475.56	59.94	476.03	60.40	478.37	62.75	48.97	7.41
321.80	475.14	60.25	475.61	60.73	477.97	63.09	48.93	7.44
321.70	474.71	60.57	475.18	61.05	477.56	63.42	48.89	7.48
321.60	474.25	60.88	474.73	61.36	477.12	63.75	48.85	7.51
321.50	473.77	61.19	474.25	61.67	476.65	64.08	48.80	7.55
321.40	473.26	61.50	473.74	61.98	476.16	64.40	48.76	7.58
321.30	472.71	61.80	473.20	62.28	475.63	64.71	48.71	7.61
321.20	472.12	62.09	472.61	62.58	475.05	65.02	48.65	7.65
321.10	471.45	62.37	471.94	62.86	474.39	65.31	48.59	7.68
321.00	470.56	62.62	471.05	63.11	473.51	65.58	48.51	7.71
320.90	469.23	62.81	469.72	63.30	472.19	65.78	48.38	7.74
320.80	468.09	63.02	468.59	63.52	471.08	66.01	48.28	7.77
320.70	466.66	63.20	467.16	63.70	469.65	66.19	48.14	7.80
320.60	465.41	63.39	465.91	63.89	468.41	66.39	48.03	7.83
320.50	464.14	63.58	464.64	64.08	467.15	66.60	47.91	7.85
320.40	462.54	63.73	463.04	64.23	465.56	66.75	47.76	7.88
320.30	460.73	63.84	461.23	64.34	463.76	66.87	47.59	7.90
320.20	458.67	63.91	459.18	64.42	461.71	66.95	47.40	7.93
320.10	457.00	64.04	457.51	64.54	460.04	67.08	47.25	7.95
320.00	455.32	64.16	455.82	64.66	458.37	67.21	47.09	7.97
319.90	453.91	64.31	454.42	64.82	456.97	67.37	46.96	8.00
319.80	452.46	64.46	452.97	64.97	455.53	67.53	46.82	8.02
319.70	451.21	64.64	451.73	65.15	454.30	67.72	46.71	8.05
319.60	450.21	64.85	450.73	65.36	453.30	67.94	46.62	8.08
319.50	449.38	65.08	449.90	65.60	452.49	68.19	46.54	8.11
319.40	448.64	65.32	449.16	65.84	451.76	68.44	46.47	8.14
319.30	447.87	65.56	448.39	66.08	451.00	68.69	46.40	8.17
319.20	447.10	65.80	447.62	66.32	450.24	68.94	46.33	8.20
319.10	446.51	66.06	447.04	66.59	449.68	69.22	46.27	8.23
319.00	446.02	66.34	446.55	66.87	449.20	69.51	46.22	8.26
318.90	445.56	66.62	446.09	67.15	448.75	69.81	46.18	8.29
318.80	445.11	66.90	445.64	67.43	448.32	70.11	46.14	8.32
318.70	444.69	67.18	445.22	67.72	447.91	70.41	46.10	8.35
318.60	444.29	67.47	444.83	68.01	447.53	70.71	46.06	8.38
318.50	443.91	67.76	444.46	68.30	447.17	71.01	46.03	8.41
318.40	443.54	68.05	444.09	68.60	446.81	71.32	45.99	8.44
318.30	443.19	68.34	443.73	68.89	446.47	71.63	45.96	8.48
318.20	442.83	68.64	443.38	69.19	446.13	71.94	45.93	8.51
318.10	442.48	68.93	443.03	69.48	445.79	72.24	45.89	8.54
318.00	442.13	69.22	442.69	69.77	445.47	72.55	45.86	8.57
317.90	441.80	69.51	442.36	70.07	445.15	72.86	45.83	8.60
317.80	441.48	69.81	442.05	70.37	444.85	73.17	45.80	8.63
317.70	441.17	70.10	441.73	70.67	444.55	73.49	45.77	8.67
317.60	440.85	70.40	441.42	70.97	444.25	73.80	45.74	8.70
317.50	440.53	70.69	441.10	71.26	443.95	74.11	45.71	8.73
317.40	440.24	70.99	440.81	71.56	443.67	74.42	45.69	8.76
317.30	439.94	71.29	440.52	71.86	443.39	74.73	45.66	8.79
317.20	439.66	71.58	440.23	72.16	443.12	75.05	45.63	8.82
317.10	439.37	71.88	439.95	72.46	442.85	75.36	45.60	8.86
317.00	439.08	72.18	439.66	72.76	442.57	75.67	45.58	8.89
316.90	438.79	72.47	439.38	73.06	442.30	75.98	45.55	8.92
316.80	438.53	72.77	439.12	73.36	442.06	76.30	45.53	8.95
316.70	438.27	73.07	438.86	73.66	441.81	76.62	45.50	8.98
316.60	438.01	73.37	438.60	73.97	441.57	76.93	45.48	9.01
316.50	437.76	73.67	438.36	74.27	441.34	77.25	45.45	9.05
316.40	437.52	73.98	438.12	74.57	441.11	77.57	45.43	9.08
316.30	437.28	74.28	437.88	74.88	440.88	77.89	45.41	9.11
316.20	437.04	74.58	437.64	75.18	440.66	78.20	45.39	9.14
316.10	436.80	74.88	437.41	75.49	440.44	78.52	45.36	9.17
316.00	436.55	75.18	437.16	75.79	440.21	78.84	45.34	9.20
315.90	436.30	75.48	436.92	76.09	439.98	79.15	45.32	9.23
315.80	436.06	75.78	436.68	76.39	439.75	79.47	45.29	9.27
315.70	435.82	76.08	436.43	76.69	439.52	79.78	45.27	9.30
315.60	435.56	76.37	436.18	76.99	439.29	80.10	45.25	9.33
315.50	435.30	76.67	435.93	77.29	439.04	80.41	45.22	9.36
315.40	435.04	76.96	435.66	77.59	438.80	80.72	45.20	9.39
315.30	434.78	77.26	435.41	77.89	438.56	81.03	45.18	9.42
315.20	434.54	77.55	435.17	78.19	438.33	81.34	45.15	9.45
315.10	434.29	77.85	434.93	78.48	438.10	81.66	45.13	9.49
315.00	434.04	78.14	434.67	78.78	437.86	81.97	45.11	9.52
314.90	433.76	78.43	434.40	79.07	437.60	82.27	45.08	9.55
314.80	433.47	78.72	434.12	79.36	437.33	82.58	45.05	9.58
314.70	433.20	79.01	433.85	79.65	437.07	82.88	45.03	9.61
314.60	432.92	79.30	433.57	79.94	436.81	83.19	45.00	9.64
314.50	432.62	79.58	433.27	80.23	436.53	83.49	44.97	9.67
314.40	432.36	79.87	433.01	80.52	436.28	83.79	44.95	9.70
314.30	432.09	80.16	432.75	80.82	436.03	84.10	44.92	9.73
314.20	431.82	80.45	432.48	81.11	435.78	84.40	44.90	9.76
314.10	431.57	80.74	432.23	81.40	435.54	84.71	44.87	9.79
314.00	431.31	81.03	431.97	81.69	435.30	85.01	44.85	9.82

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	Dewatering WBM South Pit Inflow (m³/day)	Recovery WBM South Pit Inflow (m³/day)
313.90	431.06	81.32	431.73	81.99	435.06	85.32	44.83	9.85
313.80	430.81	81.61	431.48	82.28	434.83	85.63	44.80	9.88
313.70	430.57	81.90	431.24	82.57	434.60	85.93	44.78	9.91
313.60	430.33	82.19	431.00	82.87	434.38	86.24	44.76	9.94
313.50	430.08	82.48	430.76	83.16	434.15	86.55	44.74	9.98
313.40	429.84	82.77	430.52	83.45	433.93	86.85	44.71	10.01
313.30	429.61	83.06	430.29	83.74	433.71	87.16	44.69	10.04
313.20	429.38	83.35	430.07	84.04	433.50	87.47	44.67	10.07
313.10	429.14	83.64	429.83	84.33	433.28	87.78	44.65	10.10
313.00	428.89	83.93	429.59	84.62	433.04	88.08	44.62	10.13
312.90	428.64	84.22	429.33	84.91	432.81	88.38	44.60	10.16
312.80	428.39	84.50	429.09	85.20	432.57	88.69	44.58	10.19
312.70	428.13	84.79	428.83	85.49	432.33	88.99	44.55	10.22
312.60	427.89	85.07	428.59	85.78	432.10	89.29	44.53	10.25
312.50	427.64	85.36	428.34	86.06	431.87	89.59	44.51	10.28
312.40	427.39	85.64	428.10	86.35	431.64	89.89	44.48	10.31
312.30	427.11	85.92	427.83	86.63	431.38	90.19	44.46	10.34
312.20	426.84	86.20	427.55	86.91	431.12	90.48	44.43	10.37
312.10	426.57	86.48	427.29	87.20	430.87	90.78	44.41	10.40
312.00	426.29	86.76	427.01	87.48	430.60	91.07	44.38	10.43
311.90	426.01	87.03	426.73	87.76	430.34	91.36	44.35	10.46
311.80	425.73	87.31	426.45	88.03	430.07	91.66	44.33	10.49
311.70	425.42	87.58	426.15	88.31	429.78	91.94	44.30	10.51
311.60	425.13	87.85	425.86	88.58	429.51	92.23	44.27	10.54
311.50	424.83	88.12	425.56	88.85	429.22	92.52	44.24	10.57
311.40	424.52	88.39	425.25	89.12	428.93	92.80	44.21	10.60
311.30	424.20	88.66	424.94	89.39	428.63	93.08	44.19	10.63
311.20	423.85	88.91	424.59	89.65	428.29	93.35	44.15	10.66
311.10	423.42	89.15	424.16	89.90	427.87	93.61	44.11	10.69
311.00	422.99	89.39	423.73	90.14	427.46	93.87	44.07	10.71
310.90	422.57	89.64	423.31	90.38	427.05	94.12	44.03	10.74
310.80	422.05	89.86	422.80	90.61	426.55	94.36	43.98	10.76
310.70	421.50	90.07	422.25	90.82	426.01	94.58	43.93	10.79
310.60	420.92	90.28	421.68	91.03	425.45	94.80	43.88	10.81
310.50	420.20	90.45	420.95	91.21	424.73	94.99	43.81	10.84
310.40	419.05	90.53	419.80	91.29	423.59	95.08	43.70	10.85
310.30	417.69	90.56	418.45	91.32	422.25	95.12	43.58	10.86
310.20	415.92	90.51	416.68	91.27	420.48	95.06	43.41	10.87
310.10	413.69	90.35	414.45	91.10	418.25	94.90	43.20	10.87
310.00	411.98	90.29	412.74	91.05	416.53	94.85	43.04	10.87
309.90	410.28	90.24	411.04	91.00	414.83	94.80	42.88	10.88
309.80	408.96	90.27	409.72	91.03	413.52	94.83	42.76	10.89
309.70	407.58	90.29	408.34	91.05	412.15	94.85	42.63	10.90
309.60	405.51	90.14	406.27	90.91	410.07	94.71	42.44	10.90
309.50	402.49	89.79	403.25	90.55	407.05	94.34	42.15	10.88
309.40	399.70	89.48	400.45	90.24	404.24	94.02	41.89	10.87
309.30	398.67	89.56	399.43	90.32	403.22	94.11	41.79	10.88
309.20	397.85	89.69	398.61	90.45	402.41	94.25	41.72	10.90
309.10	397.29	89.87	398.06	90.64	401.87	94.45	41.66	10.92
309.00	396.87	90.09	397.64	90.85	401.46	94.68	41.62	10.95
308.90	396.48	90.31	397.25	91.08	401.09	94.91	41.59	10.97
308.80	396.11	90.53	396.87	91.30	400.72	95.15	41.55	11.00
308.70	395.74	90.76	396.51	91.53	400.37	95.39	41.52	11.02
308.60	395.37	90.98	396.14	91.76	400.01	95.63	41.48	11.05
308.50	395.02	91.21	395.80	91.99	399.68	95.87	41.45	11.07
308.40	394.69	91.45	395.47	92.23	399.37	96.12	41.42	11.10
308.30	394.38	91.68	395.16	92.47	399.07	96.37	41.39	11.12
308.20	394.07	91.92	394.85	92.70	398.77	96.62	41.36	11.15
308.10	393.76	92.15	394.54	92.94	398.48	96.88	41.33	11.17
308.00	393.45	92.39	394.24	93.18	398.19	97.13	41.30	11.20
307.90	393.14	92.63	393.93	93.42	397.89	97.38	41.27	11.22
307.80	392.81	92.86	393.61	93.65	397.58	97.62	41.24	11.25
307.70	392.49	93.09	393.29	93.88	397.27	97.87	41.21	11.27
307.60	392.18	93.32	392.98	94.12	396.97	98.11	41.18	11.30
307.50	391.88	93.56	392.68	94.36	396.69	98.37	41.16	11.32
307.40	391.60	93.79	392.40	94.60	396.42	98.62	41.13	11.35
307.30	391.31	94.03	392.11	94.84	396.15	98.87	41.10	11.37
307.20	391.02	94.27	391.83	95.08	395.88	99.12	41.07	11.40
307.10	390.73	94.50	391.54	95.32	395.60	99.37	41.05	11.42
307.00	390.43	94.74	391.24	95.55	395.31	99.62	41.02	11.45
306.90	390.11	94.97	390.93	95.78	395.01	99.87	40.99	11.47
306.80	389.82	95.20	390.64	96.02	394.74	100.12	40.96	11.50
306.70	389.54	95.43	390.36	96.26	394.47	100.37	40.93	11.52
306.60	389.25	95.67	390.07	96.49	394.19	100.61	40.91	11.55
306.50	388.97	95.91	389.80	96.73	393.93	100.87	40.88	11.57
306.40	388.70	96.14	389.53	96.97	393.68	101.12	40.86	11.60
306.30	388.42	96.38	389.25	97.21	393.41	101.37	40.83	11.63
306.20	388.14	96.61	388.97	97.45	393.14	101.62	40.80	11.65
306.10	387.85	96.84	388.69	97.68	392.88	101.87	40.78	11.68
306.00	387.58	97.08	388.42	97.92	392.62	102.12	40.75	11.70
305.90	387.30	97.31	388.14	98.15	392.35	102.36	40.72	11.73
305.80	387.03	97.55	387.87	98.39	392.09	102.61	40.70	11.75
305.70	386.75	97.78	387.60	98.63	391.84	102.86	40.67	11.78
305.60	386.49	98.01	387.34	98.86	391.59	103.11	40.65	11.80
305.50	386.23	98.25	387.08	99.10	391.34	103.36	40.62	11.83
305.40	385.97	98.49	386.82	99.34	391.10	103.62	40.60	11.85
305.30	385.72	98.73	386.58	99.58	390.87	103.87	40.58	11.88
305.20	385.48	98.97	386.34	99.83	390.64	104.13	40.55	11.90
305.10	385.24	99.20	386.10	100.07	390.41	104.38	40.53	11.93
305.00	384.99	99.44	385.86	100.31	390.19	104.64	40.51	11.95
304.90	384.75	99.68	385.62	100.55	389.96	104.89	40.48	11.98
304.80	384.50	99.92	385.37	100.79	389.72	105.14	40.46	12.00
304.70	384.25	100.15	385.13	101.03	389.49	105.39	40.44	12.03
304.60	384.00	100.39	384.88	101.27	389.26	105.64	40.41	12.05
304.50	383.75	100.62	384.63	101.50	389.02	105.89	40.39	12.08
304.40	383.50	100.86	384.38	101.74	388.78	106.14	40.37	12.10
304.30	383.25	101.09	384.13	101.98	388.55	106.39	40.34	12.13
304.20	383.00	101.33	383.89	102.21	388.32	106.64	40.32	12.15
304.10	382.76	101.56	383.65	102.45	388.09	106.89	40.30	12.18
304.00	382.51	101.80	383.40	102.69	387.86	107.14	40.27	12.20
303.90	382.24	102.02	383.14	102.92	387.60	107.39	40.25	12.23
303.80	381.99	102.25	382.88	103.15	387.36	107.63	40.22	12.25

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	Dewatering WBM South Pit Inflow (m³/day)	Recovery WBM South Pit Inflow (m³/day)
303.70	381.73	102.48	382.63	103.38	387.12	107.88	40.20	12.27
303.60	381.46	102.71	382.36	103.61	386.87	108.12	40.17	12.30
303.50	381.19	102.94	382.10	103.84	386.62	108.36	40.15	12.32
303.40	380.94	103.17	381.84	104.07	386.37	108.60	40.12	12.35
303.30	380.67	103.39	381.58	104.30	386.12	108.84	40.10	12.37
303.20	380.40	103.62	381.32	104.53	385.87	109.09	40.07	12.39
303.10	380.11	103.84	381.03	104.75	385.60	109.32	40.05	12.42
303.00	379.81	104.05	380.73	104.97	385.31	109.55	40.02	12.44
302.90	379.53	104.27	380.45	105.19	385.05	109.78	39.99	12.47
302.80	379.25	104.49	380.17	105.41	384.78	110.02	39.96	12.49
302.70	378.97	104.71	379.89	105.63	384.51	110.25	39.94	12.51
302.60	378.68	104.92	379.60	105.85	384.24	110.48	39.91	12.54
302.50	378.38	105.14	379.31	106.07	383.95	110.71	39.88	12.56
302.40	378.04	105.34	378.97	106.27	383.63	110.93	39.85	12.58
302.30	377.69	105.54	378.63	106.47	383.29	111.14	39.82	12.60
302.20	377.35	105.74	378.28	106.67	382.96	111.35	39.79	12.62
302.10	376.99	105.93	377.93	106.87	382.62	111.56	39.75	12.65
302.00	376.62	106.12	377.56	107.06	382.26	111.77	39.72	12.67
301.90	376.20	106.30	377.15	107.24	381.86	111.96	39.68	12.69
301.80	375.76	106.47	376.71	107.41	381.43	112.14	39.64	12.71
301.70	375.29	106.63	376.23	107.58	380.97	112.31	39.59	12.73
301.60	374.78	106.78	375.73	107.73	380.48	112.47	39.54	12.74
301.50	374.22	106.91	375.18	107.86	379.93	112.62	39.49	12.76
301.40	373.59	107.02	374.55	107.98	379.31	112.74	39.43	12.77
301.30	372.75	107.07	373.70	108.03	378.47	112.80	39.35	12.78
301.20	371.96	107.14	372.91	108.09	377.69	112.87	39.28	12.80
301.10	371.02	107.16	371.97	108.11	376.76	112.90	39.19	12.80
301.00	369.86	107.11	370.82	108.07	375.60	112.86	39.08	12.80
300.90	368.13	106.90	369.08	107.85	373.87	112.64	38.92	12.79
300.80	365.45	106.41	366.40	107.36	371.17	112.13	38.66	12.76
300.70	361.79	105.62	362.73	106.57	367.48	111.32	38.32	12.70
300.60	359.24	105.16	360.19	106.11	364.92	110.85	38.08	12.67
300.50	357.09	104.81	358.03	105.76	362.76	110.49	37.87	12.65
300.40	354.84	104.43	355.78	105.37	360.50	110.09	37.66	12.62
300.30	352.59	104.04	353.53	104.98	358.24	109.70	37.45	12.59
300.20	350.78	103.78	351.72	104.73	356.43	109.43	37.28	12.58
300.10	349.37	103.64	350.31	104.58	355.02	109.29	37.14	12.57
300.00	348.10	103.54	349.04	104.48	353.75	109.18	37.02	12.57
299.90	346.92	103.46	347.86	104.40	352.57	109.11	36.91	12.57
299.80	345.81	103.40	346.76	104.34	351.47	109.05	36.81	12.57
299.70	344.62	103.31	345.56	104.25	350.28	108.97	36.70	12.56
299.60	343.60	103.27	344.54	104.22	349.26	108.93	36.60	12.57
299.50	342.71	103.27	343.65	104.22	348.37	108.94	36.51	12.57
299.40	342.01	103.33	342.95	104.28	347.68	109.00	36.45	12.58
299.30	341.35	103.40	342.30	104.35	347.03	109.08	36.39	12.59
299.20	340.66	103.46	341.61	104.40	346.35	109.15	36.32	12.60
299.10	340.01	103.53	340.97	104.48	345.72	109.23	36.26	12.61
299.00	339.38	103.60	340.33	104.55	345.09	109.31	36.20	12.62
298.90	338.79	103.69	339.75	104.64	344.52	109.41	36.14	12.63
298.80	338.21	103.77	339.17	104.73	343.94	109.50	36.09	12.64
298.70	337.67	103.87	338.63	104.83	343.41	109.61	36.04	12.66
298.60	337.15	103.97	338.11	104.93	342.91	109.73	35.99	12.67
298.50	336.64	104.08	337.60	105.04	342.40	109.84	35.94	12.68
298.40	336.11	104.18	337.08	105.14	341.89	109.95	35.89	12.70
298.30	335.63	104.29	336.59	105.26	341.41	110.08	35.84	12.71
298.20	335.17	104.41	336.13	105.38	340.96	110.21	35.80	12.72
298.10	334.74	104.54	335.71	105.51	340.55	110.35	35.76	12.74
298.00	334.32	104.67	335.29	105.64	340.14	110.49	35.72	12.75
297.90	333.91	104.80	334.88	105.78	339.74	110.64	35.68	12.77
297.80	333.51	104.94	334.48	105.91	339.35	110.78	35.64	12.78
297.70	333.12	105.08	334.09	106.05	338.97	110.93	35.60	12.80
297.60	332.73	105.22	333.71	106.19	338.60	111.08	35.57	12.82
297.50	332.36	105.36	333.34	106.34	338.24	111.24	35.53	12.83
297.40	331.99	105.50	332.97	106.48	337.88	111.39	35.50	12.85
297.30	331.62	105.64	332.60	106.63	337.53	111.55	35.46	12.86
297.20	331.25	105.78	332.24	106.77	337.17	111.70	35.43	12.88
297.10	330.89	105.93	331.88	106.92	336.83	111.86	35.39	12.90
297.00	330.54	106.07	331.53	107.06	336.49	112.02	35.36	12.91
296.90	330.19	106.22	331.18	107.21	336.14	112.18	35.33	12.93
296.80	329.81	106.35	330.80	107.35	335.78	112.32	35.29	12.94
296.70	329.48	106.51	330.48	107.50	335.47	112.49	35.26	12.96
296.60	329.18	106.67	330.18	107.67	335.18	112.66	35.23	12.98
296.50	328.89	106.83	329.89	107.83	334.90	112.84	35.20	13.00
296.40	328.61	107.00	329.61	108.00	334.63	113.02	35.18	13.01
296.30	328.34	107.17	329.34	108.17	334.37	113.20	35.15	13.03
296.20	328.08	107.34	329.09	108.35	334.13	113.39	35.13	13.05
296.10	327.82	107.51	328.83	108.52	333.88	113.57	35.10	13.07
296.00	327.55	107.68	328.56	108.69	333.63	113.76	35.08	13.09
295.90	327.29	107.85	328.31	108.86	333.38	113.94	35.05	13.11
295.80	327.04	108.02	328.06	109.04	333.15	114.13	35.03	13.12
295.70	326.78	108.19	327.80	109.21	332.91	114.31	35.00	13.14
295.60	326.53	108.36	327.55	109.39	332.67	114.50	34.98	13.16
295.50	326.28	108.54	327.30	109.56	332.43	114.69	34.95	13.18
295.40	326.03	108.71	327.06	109.74	332.20	114.87	34.93	13.20
295.30	325.78	108.88	326.81	109.91	331.96	115.06	34.91	13.22
295.20	325.55	109.06	326.58	110.09	331.74	115.25	34.88	13.24
295.10	325.32	109.23	326.35	110.27	331.52	115.44	34.86	13.25
295.00	325.08	109.41	326.12	110.45	331.30	115.63	34.84	13.27
294.90	324.86	109.59	325.90	110.63	331.10	115.82	34.82	13.29
294.80	324.65	109.77	325.69	110.81	330.90	116.02	34.80	13.31
294.70	324.44	109.95	325.48	111.00	330.70	116.22	34.78	13.33
294.60	324.23	110.14	325.28	111.18	330.51	116.42	34.76	13.35
294.50	324.03	110.32	325.08	111.37	330.32	116.62	34.74	13.37
294.40	323.83	110.51	324.88	111.56	330.14	116.82	34.72	13.39
294.30	323.63	110.69	324.69	111.75	329.96	117.02	34.70	13.41
294.20	323.43	110.88	324.49	111.93	329.77	117.22	34.68	13.43
294.10	323.23	111.06	324.29	112.12	329.58	117.42	34.66	13.45
294.00	323.03	111.25	324.09	112.31	329.40	117.62	34.64	13.47
293.90	322.85	111.44	323.91	112.50	329.23	117.82	34.63	13.49
293.80	322.67	111.63	323.73	112.69	329.07	118.03	34.61	13.51
293.70	322.49	111.82	323.56	112.88	328.90	118.23	34.59	13.53
293.60	322.31	112.01	323.38	113.08	328.74	118.44	34.58	13.55

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	Dewatering WBM South Pit Inflow (m^3/day)	Recovery WBM South Pit Inflow (m^3/day)
293.50	322.11	112.19	323.19	113.26	328.56	118.64	34.56	13.57
293.40	321.93	112.38	323.00	113.45	328.39	118.84	34.54	13.58
293.30	321.73	112.56	322.81	113.64	328.21	119.04	34.52	13.60
293.20	321.54	112.75	322.62	113.83	328.03	119.24	34.50	13.62
293.10	321.35	112.93	322.44	114.02	327.86	119.44	34.48	13.64
293.00	321.17	113.12	322.25	114.20	327.69	119.64	34.47	13.66
292.90	320.98	113.30	322.06	114.39	327.51	119.84	34.45	13.68
292.80	320.79	113.49	321.88	114.58	327.34	120.04	34.43	13.70
292.70	320.60	113.67	321.70	114.77	327.17	120.24	34.41	13.72
292.60	320.41	113.85	321.51	114.95	326.99	120.44	34.40	13.74
292.50	320.22	114.04	321.32	115.13	326.81	120.63	34.38	13.76
292.40	320.02	114.21	321.12	115.32	326.63	120.83	34.36	13.78
292.30	319.82	114.39	320.93	115.50	326.45	121.02	34.34	13.80
292.20	319.63	114.58	320.74	115.68	326.27	121.22	34.32	13.82
292.10	319.44	114.76	320.55	115.87	326.10	121.41	34.30	13.83
292.00	319.25	114.94	320.36	116.05	325.92	121.61	34.28	13.85
291.90	319.04	115.12	320.16	116.23	325.73	121.80	34.26	13.87
291.80	318.83	115.29	319.94	116.40	325.53	121.99	34.24	13.89
291.70	318.62	115.46	319.74	116.58	325.33	122.18	34.22	13.91
291.60	318.41	115.63	319.53	116.76	325.14	122.36	34.20	13.93
291.50	318.20	115.81	319.33	116.93	324.95	122.55	34.18	13.94
291.40	318.00	115.98	319.13	117.11	324.76	122.74	34.17	13.96
291.30	317.76	116.15	318.89	117.27	324.54	122.92	34.14	13.98
291.20	317.55	116.31	318.68	117.45	324.34	123.10	34.12	14.00
291.10	317.34	116.49	318.47	117.62	324.14	123.29	34.10	14.02
291.00	317.13	116.66	318.26	117.79	323.95	123.48	34.08	14.03
290.90	316.91	116.82	318.04	117.96	323.74	123.66	34.06	14.05
290.80	316.68	116.99	317.82	118.13	323.53	123.84	34.04	14.07
290.70	316.45	117.15	317.60	118.30	323.32	124.02	34.02	14.09
290.60	316.22	117.31	317.36	118.46	323.10	124.19	34.00	14.10
290.50	315.97	117.47	317.12	118.62	322.87	124.36	33.97	14.12
290.40	315.73	117.62	316.88	118.77	322.63	124.53	33.95	14.14
290.30	315.47	117.78	316.63	118.93	322.40	124.70	33.92	14.15
290.20	315.20	117.92	316.36	119.08	322.14	124.86	33.90	14.17
290.10	314.95	118.07	316.10	119.23	321.89	125.02	33.87	14.19
290.00	314.70	118.23	315.86	119.39	321.66	125.19	33.85	14.20
289.90	314.43	118.37	315.60	119.53	321.41	125.35	33.83	14.22
289.80	314.16	118.52	315.33	119.68	321.15	125.51	33.80	14.23
289.70	313.91	118.66	315.07	119.83	320.91	125.67	33.77	14.25
289.60	313.66	118.82	314.83	119.99	320.68	125.84	33.75	14.27
289.50	313.42	118.97	314.59	120.14	320.45	126.00	33.73	14.28
289.40	313.15	119.11	314.33	120.29	320.20	126.16	33.70	14.30
289.30	312.91	119.27	314.08	120.44	319.97	126.33	33.68	14.32
289.20	312.67	119.42	313.85	120.60	319.75	126.50	33.66	14.33
289.10	312.44	119.58	313.62	120.76	319.53	126.67	33.63	14.35
289.00	312.20	119.73	313.39	120.91	319.31	126.83	33.61	14.36
288.90	311.97	119.89	313.16	121.07	319.09	127.01	33.59	14.38
288.80	311.75	120.04	312.93	121.23	318.88	127.18	33.57	14.40
288.70	311.51	120.20	312.70	121.39	318.66	127.34	33.55	14.41
288.60	311.29	120.35	312.48	121.55	318.45	127.52	33.52	14.43
288.50	311.07	120.51	312.27	121.71	318.25	127.69	33.50	14.45
288.40	310.86	120.67	312.06	121.87	318.05	127.87	33.48	14.47
288.30	310.65	120.84	311.85	122.04	317.85	128.04	33.46	14.48
288.20	310.44	121.00	311.64	122.20	317.66	128.22	33.44	14.50
288.10	310.23	121.16	311.43	122.36	317.46	128.39	33.42	14.52
288.00	310.02	121.32	311.23	122.53	317.27	128.57	33.40	14.53
287.90	309.81	121.48	311.02	122.69	317.08	128.75	33.38	14.55
287.80	309.61	121.64	310.83	122.86	316.90	128.93	33.37	14.57
287.70	309.42	121.81	310.63	123.02	316.71	129.10	33.35	14.59
287.60	309.22	121.97	310.43	123.19	316.53	129.28	33.33	14.60
287.50	309.02	122.13	310.24	123.36	316.34	129.46	33.31	14.62
287.40	308.81	122.29	310.03	123.52	316.15	129.63	33.29	14.64
287.30	308.59	122.45	309.81	123.67	315.94	129.80	33.27	14.65
287.20	308.37	122.60	309.60	123.83	315.74	129.97	33.25	14.67
287.10	308.16	122.76	309.39	123.99	315.54	130.15	33.23	14.69
287.00	307.96	122.92	309.19	124.15	315.36	130.32	33.21	14.70
286.90	307.76	123.08	309.00	124.32	315.18	130.50	33.19	14.72
286.80	307.56	123.25	308.80	124.48	314.99	130.68	33.17	14.74
286.70	307.37	123.41	308.61	124.65	314.81	130.85	33.15	14.75
286.60	307.17	123.57	308.42	124.81	314.63	131.03	33.13	14.77
286.50	306.98	123.73	308.22	124.98	314.45	131.21	33.11	14.79
286.40	306.78	123.89	308.03	125.14	314.27	131.38	33.09	14.81
286.30	306.58	124.05	307.83	125.30	314.08	131.55	33.08	14.82
286.20	306.37	124.21	307.63	125.46	313.89	131.73	33.06	14.84
286.10	306.16	124.36	307.42	125.62	313.70	131.90	33.04	14.86
286.00	305.95	124.51	307.21	125.77	313.50	132.06	33.02	14.87
285.90	305.74	124.67	307.00	125.93	313.30	132.23	32.99	14.89
285.80	305.53	124.82	306.79	126.08	313.11	132.40	32.97	14.90
285.70	305.31	124.97	306.58	126.24	312.91	132.57	32.95	14.92
285.60	305.10	125.12	306.37	126.39	312.71	132.73	32.93	14.94
285.50	304.89	125.27	306.16	126.54	312.51	132.90	32.91	14.95
285.40	304.68	125.42	305.95	126.70	312.32	133.06	32.89	14.97
285.30	304.46	125.57	305.73	126.85	312.11	133.23	32.87	14.98
285.20	304.22	125.71	305.50	126.99	311.89	133.38	32.85	15.00
285.10	303.99	125.86	305.28	127.14	311.68	133.54	32.83	15.01
285.00	303.78	126.01	305.07	127.29	311.48	133.71	32.81	15.03
284.90	303.58	126.16	304.86	127.44	311.29	133.87	32.79	15.05
284.80	303.37	126.31	304.65	127.60	311.09	134.04	32.77	15.06
284.70	303.15	126.45	304.44	127.74	310.89	134.20	32.75	15.08
284.60	302.92	126.60	304.22	127.89	310.68	134.36	32.73	15.09
284.50	302.70	126.74	303.99	128.04	310.47	134.51	32.70	15.11
284.40	302.47	126.88	303.77	128.18	310.26	134.67	32.68	15.12
284.30	302.25	127.03	303.55	128.33	310.05	134.83	32.66	15.14
284.20	302.02	127.17	303.32	128.47	309.83	134.98	32.64	15.15
284.10	301.79	127.31	303.09	128.61	309.62	135.14	32.62	15.17
284.00	301.56	127.44	302.87	128.75	309.40	135.29	32.60	15.18
283.90	301.33	127.58	302.64	128.89	309.19	135.44	32.57	15.20
283.80	301.09	127.72	302.41	129.03	308.97	135.59	32.55	15.21
283.70	300.86	127.86	302.18	129.17	308.75	135.74	32.53	15.23
283.60	300.63	127.99	301.95	129.31	308.53	135.89	32.51	15.24
283.50	300.39	128.13	301.71	129.44	308.31	136.04	32.48	15.26
283.40	300.14	128.25	301.46	129.58	308.07	136.18	32.46	15.27

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	Dewatering WBM South Pit Inflow (m^3/day)	Recovery WBM South Pit Inflow (m^3/day)
283.30	299.89	128.38	301.22	129.71	307.84	136.33	32.44	15.29
283.20	299.64	128.51	300.97	129.84	307.60	136.47	32.41	15.30
283.10	299.37	128.63	300.70	129.95	307.34	136.60	32.39	15.31
283.00	299.09	128.74	300.42	130.07	307.08	136.73	32.36	15.32
282.90	298.82	128.86	300.15	130.19	306.82	136.86	32.33	15.34
282.80	298.54	128.97	299.88	130.31	306.56	136.99	32.31	15.35
282.70	298.27	129.09	299.61	130.42	306.29	137.11	32.28	15.36
282.60	297.98	129.20	299.32	130.54	306.03	137.24	32.25	15.37
282.50	297.70	129.31	299.04	130.65	305.75	137.36	32.23	15.39
282.40	297.42	129.42	298.76	130.76	305.48	137.48	32.20	15.40
282.30	297.13	129.52	298.48	130.87	305.21	137.60	32.17	15.41
282.20	296.84	129.63	298.19	130.98	304.94	137.72	32.14	15.42
282.10	296.52	129.72	297.88	131.07	304.63	137.83	32.11	15.43
282.00	296.18	129.81	297.54	131.16	304.30	137.93	32.08	15.44
281.90	295.81	129.88	297.17	131.23	303.95	138.01	32.05	15.45
281.80	295.42	129.93	296.78	131.29	303.56	138.08	32.01	15.46
281.70	295.01	129.98	296.36	131.34	303.16	138.14	31.97	15.47
281.60	294.56	130.02	295.92	131.38	302.73	138.18	31.93	15.47
281.50	294.03	130.01	295.40	131.38	302.21	138.19	31.88	15.47
281.40	293.47	130.00	294.84	131.36	301.65	138.18	31.82	15.47
281.30	292.70	129.88	294.06	131.25	300.88	138.07	31.75	15.47
281.20	291.63	129.64	293.00	131.00	299.82	137.82	31.65	15.45
281.10	290.58	129.40	291.94	130.76	298.76	137.58	31.55	15.43
281.00	289.32	129.06	290.68	130.42	297.49	137.24	31.43	15.40
280.90	287.84	128.63	289.20	129.99	296.00	136.79	31.28	15.36
280.80	286.18	128.11	287.54	129.47	294.34	136.26	31.13	15.32
280.70	284.34	127.51	285.69	128.86	292.47	135.64	30.95	15.27
280.60	282.70	127.00	284.06	128.35	290.82	135.12	30.79	15.22
280.50	280.57	126.26	281.91	127.61	288.66	134.35	30.59	15.16
280.40	278.14	125.38	279.48	126.73	286.21	133.45	30.36	15.08
280.30	275.61	124.46	276.95	125.80	283.64	132.49	30.12	15.00
280.20	273.44	123.69	274.78	125.03	281.45	131.71	29.91	14.93
280.10	271.41	122.98	272.74	124.32	279.40	130.98	29.71	14.87
280.00	269.39	122.28	270.72	123.61	277.36	130.25	29.52	14.81
279.90	267.70	121.72	269.02	123.05	275.65	129.68	29.36	14.76
279.80	265.91	121.12	267.24	122.44	273.85	129.06	29.19	14.71
279.70	264.02	120.46	265.33	121.78	271.93	128.38	29.00	14.65
279.60	262.86	120.14	264.18	121.46	270.77	128.06	28.89	14.62
279.50	261.74	119.83	263.06	121.15	269.65	127.74	28.79	14.60
279.40	260.94	119.67	262.26	120.99	268.85	127.58	28.71	14.58
279.30	260.21	119.54	261.53	120.86	268.12	127.46	28.64	14.57
279.20	259.54	119.44	260.86	120.76	267.46	127.35	28.58	14.56
279.10	258.89	119.34	260.21	120.66	266.82	127.27	28.51	14.56
279.00	258.25	119.25	259.57	120.57	266.18	127.18	28.45	14.55
278.90	257.64	119.17	258.96	120.49	265.58	127.10	28.39	14.55
278.80	257.05	119.09	258.37	120.42	264.99	127.04	28.34	14.54
278.70	256.52	119.05	257.84	120.37	264.46	127.00	28.28	14.54
278.60	256.01	119.02	257.34	120.34	263.97	126.97	28.24	14.54
278.50	255.56	119.00	256.88	120.33	263.52	126.97	28.19	14.54
278.40	255.11	119.00	256.44	120.33	263.09	126.97	28.15	14.54
278.30	254.68	118.99	256.01	120.33	262.66	126.98	28.11	14.54
278.20	254.27	119.00	255.60	120.33	262.26	126.99	28.07	14.54
278.10	253.84	119.00	255.17	120.33	261.84	127.00	28.03	14.54
278.00	253.43	119.01	254.77	120.34	261.44	127.02	27.99	14.55
277.90	253.05	119.03	254.39	120.36	261.08	127.05	27.95	14.55
277.80	252.67	119.05	254.01	120.38	260.71	127.08	27.92	14.55
277.70	252.30	119.06	253.64	120.41	260.34	127.11	27.88	14.56
277.60	251.96	119.10	253.30	120.45	260.01	127.16	27.85	14.56
277.50	251.65	119.15	253.00	120.50	259.72	127.22	27.82	14.57
277.40	251.35	119.21	252.69	120.55	259.42	127.28	27.79	14.57
277.30	251.04	119.26	252.38	120.60	259.13	127.35	27.76	14.58
277.20	250.74	119.31	252.09	120.66	258.84	127.41	27.73	14.59
277.10	250.46	119.37	251.81	120.73	258.58	127.49	27.70	14.59
277.00	250.20	119.45	251.55	120.80	258.33	127.57	27.68	14.60
276.90	249.94	119.52	251.30	120.87	258.08	127.66	27.65	14.61
276.80	249.66	119.58	251.02	120.94	257.81	127.73	27.63	14.62
276.70	249.40	119.65	250.77	121.01	257.57	127.82	27.60	14.63
276.60	249.16	119.73	250.53	121.09	257.34	127.91	27.58	14.63
276.50	248.93	119.81	250.30	121.18	257.12	128.00	27.56	14.64
276.40	248.70	119.90	250.07	121.26	256.90	128.10	27.53	14.65
276.30	248.47	119.98	249.84	121.35	256.68	128.20	27.51	14.66
276.20	248.24	120.06	249.61	121.44	256.47	128.29	27.49	14.67
276.10	248.02	120.15	249.40	121.53	256.27	128.40	27.47	14.68
276.00	247.80	120.24	249.18	121.61	256.06	128.50	27.45	14.69
275.90	247.58	120.32	248.96	121.70	255.85	128.59	27.42	14.70
275.80	247.35	120.41	248.73	121.79	255.64	128.69	27.40	14.71
275.70	247.13	120.49	248.51	121.88	255.43	128.79	27.38	14.72
275.60	246.91	120.58	248.30	121.96	255.22	128.89	27.36	14.73
275.50	246.70	120.67	248.08	122.06	255.02	128.99	27.34	14.74
275.40	246.48	120.76	247.87	122.15	254.82	129.10	27.32	14.75
275.30	246.27	120.85	247.67	122.24	254.63	129.20	27.30	14.76
275.20	246.07	120.94	247.46	122.33	254.43	129.30	27.28	14.77
275.10	245.86	121.03	247.26	122.42	254.24	129.41	27.26	14.78
275.00	245.66	121.12	247.06	122.52	254.05	129.51	27.24	14.79
274.90	245.45	121.21	246.85	122.61	253.86	129.62	27.22	14.80
274.80	245.24	121.30	246.65	122.70	253.67	129.72	27.20	14.81
274.70	245.03	121.39	246.43	122.79	253.46	129.82	27.18	14.81
274.60	244.82	121.47	246.23	122.88	253.27	129.92	27.16	14.82
274.50	244.61	121.56	246.02	122.97	253.07	130.02	27.14	14.83
274.40	244.40	121.65	245.81	123.06	252.88	130.12	27.12	14.84
274.30	244.20	121.74	245.61	123.15	252.69	130.23	27.10	14.85
274.20	244.00	121.83	245.42	123.25	252.50	130.33	27.08	14.86
274.10	243.78	121.91	245.20	123.33	252.30	130.43	27.06	14.87
274.00	243.56	121.99	244.98	123.41	252.09	130.52	27.04	14.88
273.90	243.34	122.07	244.77	123.50	251.89	130.62	27.02	14.89
273.80	243.13	122.16	244.56	123.58	251.69	130.71	27.00	14.90
273.70	242.92	122.24	244.35	123.67	251.49	130.81	26.98	14.91
273.60	242.71	122.32	244.14	123.75	251.29	130.91	26.95	14.92
273.50	242.49	122.40	243.93	123.84	251.09	131.00	26.93	14.93
273.40	242.28	122.49	243.71	123.92	250.89	131.10	26.91	14.93
273.30	242.06	122.56	243.50	124.00	250.68	131.19	26.89	14.94
273.20	241.83	122.64	243.27	124.08	250.47	131.28	26.87	14.95

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	Dewatering WBM South Pit Inflow (m³/day)	Recovery WBM South Pit Inflow (m³/day)
273.10	241.59	122.70	243.03	124.15	250.24	131.36	26.85	14.96
273.00	241.35	122.77	242.79	124.22	250.02	131.44	26.82	14.97
272.90	241.11	122.84	242.56	124.29	249.79	131.52	26.80	14.97
272.80	240.88	122.91	242.32	124.36	249.57	131.60	26.78	14.98
272.70	240.65	122.98	242.10	124.43	249.35	131.68	26.76	14.99
272.60	240.42	123.05	241.87	124.50	249.14	131.77	26.73	15.00
272.50	240.19	123.12	241.65	124.58	248.92	131.85	26.71	15.00
272.40	239.96	123.19	241.42	124.65	248.71	131.94	26.69	15.01
272.30	239.74	123.26	241.20	124.72	248.50	132.02	26.67	15.02
272.20	239.51	123.33	240.97	124.80	248.28	132.11	26.65	15.03
272.10	239.28	123.40	240.74	124.87	248.07	132.19	26.62	15.04
272.00	239.05	123.47	240.52	124.94	247.85	132.27	26.60	15.04
271.90	238.83	123.54	240.30	125.01	247.64	132.36	26.58	15.05
271.80	238.60	123.61	240.07	125.08	247.42	132.44	26.56	15.06
271.70	238.37	123.68	239.85	125.15	247.21	132.52	26.54	15.07
271.60	238.15	123.75	239.63	125.23	247.00	132.61	26.52	15.08
271.50	237.92	123.82	239.40	125.30	246.79	132.68	26.49	15.08
271.40	237.67	123.88	239.15	125.36	246.55	132.76	26.47	15.09
271.30	237.43	123.93	238.91	125.42	246.32	132.83	26.45	15.10
271.20	237.19	123.99	238.67	125.48	246.09	132.90	26.42	15.10
271.10	236.93	124.04	238.41	125.53	245.85	132.96	26.40	15.11
271.00	236.65	124.09	238.14	125.57	245.59	133.02	26.37	15.11
270.90	236.41	124.14	237.90	125.63	245.35	133.08	26.35	15.12
270.80	236.16	124.19	237.65	125.69	245.11	133.15	26.32	15.13
270.70	235.91	124.25	237.40	125.74	244.88	133.22	26.30	15.13
270.60	235.65	124.29	237.14	125.79	244.63	133.27	26.27	15.14
270.50	235.38	124.34	236.88	125.84	244.38	133.33	26.25	15.14
270.40	235.12	124.38	236.62	125.88	244.12	133.39	26.22	15.15
270.30	234.85	124.42	236.35	125.93	243.87	133.44	26.20	15.15
270.20	234.57	124.46	236.07	125.96	243.60	133.49	26.17	15.16
270.10	234.26	124.48	235.77	125.99	243.30	133.52	26.14	15.16
270.00	233.98	124.51	235.49	126.02	243.03	133.57	26.11	15.17
269.90	233.68	124.54	235.20	126.05	242.75	133.60	26.08	15.17
269.80	233.40	124.57	234.91	126.08	242.48	133.65	26.06	15.17
269.70	233.11	124.60	234.63	126.11	242.20	133.69	26.03	15.18
269.60	232.83	124.63	234.35	126.15	241.94	133.73	26.00	15.18
269.50	232.55	124.66	234.07	126.18	241.67	133.78	25.97	15.19
269.40	232.27	124.69	233.79	126.21	241.39	133.82	25.95	15.19
269.30	231.98	124.72	233.51	126.24	241.12	133.86	25.92	15.19
269.20	231.71	124.76	233.24	126.28	240.86	133.91	25.89	15.20
269.10	231.43	124.79	232.96	126.31	240.60	133.95	25.87	15.20
269.00	231.16	124.82	232.69	126.35	240.34	134.00	25.84	15.21
268.90	230.89	124.85	232.42	126.39	240.08	134.04	25.81	15.21
268.80	230.62	124.89	232.15	126.42	239.82	134.09	25.79	15.21
268.70	230.35	124.92	231.89	126.46	239.56	134.14	25.76	15.22
268.60	230.09	124.96	231.63	126.50	239.32	134.19	25.74	15.22
268.50	229.84	125.01	231.38	126.55	239.08	134.25	25.71	15.23
268.40	229.59	125.05	231.13	126.59	238.84	134.30	25.69	15.23
268.30	229.34	125.09	230.88	126.64	238.60	134.36	25.66	15.24
268.20	229.09	125.13	230.63	126.68	238.36	134.41	25.64	15.24
268.10	228.84	125.18	230.39	126.73	238.13	134.47	25.62	15.25
268.00	228.59	125.22	230.14	126.77	237.89	134.52	25.59	15.25
267.90	228.34	125.26	229.90	126.82	237.66	134.58	25.57	15.26
267.80	228.10	125.31	229.66	126.86	237.43	134.64	25.54	15.27
267.70	227.86	125.35	229.41	126.91	237.20	134.69	25.52	15.27
267.60	227.61	125.40	229.17	126.96	236.97	134.75	25.50	15.28
267.50	227.37	125.44	228.93	127.00	236.74	134.81	25.47	15.28
267.40	227.14	125.49	228.70	127.05	236.52	134.87	25.45	15.29
267.30	226.90	125.54	228.46	127.10	236.29	134.93	25.43	15.29
267.20	226.64	125.57	228.21	127.14	236.05	134.97	25.40	15.30
267.10	226.37	125.60	227.94	127.17	235.79	135.02	25.38	15.30
267.00	226.12	125.63	227.69	127.21	235.55	135.06	25.35	15.30
266.90	225.87	125.67	227.44	127.25	235.31	135.12	25.33	15.31
266.80	225.63	125.71	227.20	127.29	235.08	135.17	25.31	15.31
266.70	225.39	125.76	226.97	127.34	234.86	135.23	25.28	15.32
266.60	225.16	125.81	226.74	127.39	234.65	135.29	25.26	15.32
266.50	224.94	125.86	226.52	127.44	234.43	135.35	25.24	15.33
266.40	224.72	125.91	226.30	127.49	234.22	135.42	25.22	15.34
266.30	224.49	125.96	226.08	127.55	234.01	135.48	25.20	15.34
266.20	224.26	126.01	225.85	127.59	233.80	135.54	25.17	15.35
266.10	224.02	126.04	225.61	127.63	233.57	135.59	25.15	15.35
266.00	223.75	126.07	225.34	127.66	233.31	135.63	25.12	15.36
265.90	223.48	126.09	225.08	127.69	233.06	135.67	25.10	15.36
265.80	223.24	126.13	224.84	127.73	232.82	135.72	25.07	15.36
265.70	223.00	126.17	224.60	127.77	232.60	135.77	25.05	15.37
265.60	222.78	126.22	224.38	127.82	232.39	135.83	25.03	15.37
265.50	222.55	126.26	224.15	127.86	232.17	135.89	25.01	15.38
265.40	222.31	126.30	223.92	127.91	231.95	135.94	24.98	15.38
265.30	222.07	126.34	223.68	127.95	231.72	135.99	24.96	15.39
265.20	221.82	126.37	223.43	127.98	231.49	136.03	24.94	15.39
265.10	221.55	126.39	223.16	128.00	231.23	136.07	24.91	15.39
265.00	221.26	126.39	222.87	128.01	230.95	136.08	24.88	15.40
264.90	220.94	126.39	222.56	128.00	230.64	136.09	24.85	15.40
264.80	220.66	126.39	222.27	128.01	230.37	136.11	24.82	15.40
264.70	220.39	126.41	222.01	128.03	230.11	136.14	24.80	15.40
264.60	220.12	126.43	221.74	128.05	229.86	136.17	24.77	15.40
264.50	219.85	126.45	221.48	128.07	229.60	136.20	24.75	15.41
264.40	219.57	126.46	221.20	128.09	229.33	136.22	24.72	15.41
264.30	219.30	126.48	220.93	128.11	229.07	136.25	24.69	15.41
264.20	219.03	126.49	220.66	128.12	228.82	136.28	24.67	15.41
264.10	218.74	126.50	220.37	128.13	228.54	136.29	24.64	15.41
264.00	218.43	126.49	220.07	128.12	228.24	136.30	24.61	15.41
263.90	218.14	126.49	219.78	128.13	227.96	136.31	24.58	15.42
263.80	217.87	126.50	219.51	128.14	227.70	136.34	24.55	15.42
263.70	217.61	126.52	219.25	128.16	227.45	136.37	24.53	15.42
263.60	217.34	126.54	218.98	128.18	227.20	136.39	24.50	15.42
263.50	217.08	126.55	218.72	128.20	226.95	136.42	24.48	15.43
263.40	216.83	126.58	218.48	128.22	226.71	136.46	24.45	15.43
263.30	216.59	126.61	218.24	128.26	226.48	136.50	24.43	15.43
263.20	216.34	126.63	217.99	128.28	226.25	136.54	24.41	15.44
263.10	216.11	126.66	217.76	128.32	226.03	136.58	24.38	15.44
263.00	215.88	126.70	217.54	128.35	225.82	136.63	24.36	15.44

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	Dewatering WBM South Pit Inflow (m³/day)	Recovery WBM South Pit Inflow (m³/day)
262.90	215.65	126.73	217.31	128.39	225.60	136.68	24.34	15.45
262.80	215.41	126.76	217.07	128.42	225.37	136.72	24.32	15.45
262.70	215.16	126.78	216.83	128.45	225.14	136.76	24.29	15.45
262.60	214.92	126.81	216.58	128.47	224.91	136.79	24.27	15.46
262.50	214.68	126.83	216.34	128.50	224.68	136.83	24.25	15.46
262.40	214.42	126.85	216.09	128.52	224.44	136.86	24.22	15.46
262.30	214.15	126.85	215.82	128.52	224.17	136.88	24.19	15.46
262.20	213.88	126.86	215.55	128.53	223.91	136.90	24.17	15.47
262.10	213.59	126.86	215.27	128.53	223.64	136.91	24.14	15.47
262.00	213.32	126.86	214.99	128.54	223.38	136.92	24.11	15.47
261.90	213.04	126.86	214.72	128.54	223.11	136.94	24.09	15.47
261.80	212.75	126.86	214.43	128.54	222.83	136.94	24.06	15.47
261.70	212.46	126.85	214.14	128.53	222.56	136.95	24.03	15.47
261.60	212.17	126.84	213.85	128.53	222.27	136.95	24.00	15.47
261.50	211.86	126.82	213.55	128.51	221.98	136.94	23.97	15.47
261.40	211.52	126.79	213.21	128.48	221.65	136.92	23.94	15.47
261.30	211.15	126.73	212.84	128.42	221.29	136.87	23.90	15.46
261.20	210.75	126.65	212.44	128.34	220.90	136.80	23.86	15.46
261.10	210.33	126.56	212.02	128.26	220.48	136.72	23.82	15.45
261.00	209.87	126.46	211.57	128.15	220.04	136.62	23.78	15.44
260.90	209.37	126.31	211.06	128.01	219.54	136.48	23.73	15.43
260.80	208.82	126.15	210.52	127.84	218.99	136.32	23.68	15.41
260.70	208.24	125.96	209.94	127.66	218.42	136.14	23.62	15.39
260.60	207.61	125.74	209.31	127.44	217.79	135.92	23.56	15.37
260.50	206.94	125.50	208.63	127.19	217.12	135.68	23.50	15.35
260.40	206.25	125.24	207.94	126.93	216.43	135.42	23.43	15.33
260.30	205.54	124.97	207.24	126.67	215.73	135.15	23.36	15.30
260.20	204.74	124.64	206.44	126.34	214.92	134.82	23.28	15.27
260.10	203.89	124.29	205.59	125.98	214.07	134.46	23.20	15.24
260.00	203.03	123.92	204.73	125.62	213.21	134.10	23.12	15.21
259.90	202.16	123.55	203.86	125.24	212.33	133.72	23.03	15.17
259.80	201.37	123.22	203.06	124.92	211.53	133.39	22.96	15.14
259.70	200.58	122.90	202.27	124.59	210.74	133.06	22.88	15.11
259.60	199.90	122.64	201.60	124.33	210.07	132.81	22.81	15.09
259.50	199.34	122.45	201.04	124.15	209.52	132.62	22.76	15.07
259.40	198.83	122.29	200.53	123.99	209.00	132.47	22.71	15.06
259.30	198.34	122.15	200.04	123.84	208.53	132.33	22.66	15.04
259.20	197.86	122.00	199.56	123.70	208.05	132.19	22.62	15.03
259.10	197.41	121.88	199.11	123.58	207.60	132.07	22.57	15.02
259.00	196.97	121.77	198.67	123.47	207.18	131.97	22.53	15.01
258.90	196.55	121.66	198.26	123.36	206.76	131.87	22.49	15.00
258.80	196.14	121.56	197.84	123.26	206.36	131.78	22.45	14.99
258.70	195.75	121.47	197.45	123.17	205.97	131.69	22.41	14.98
258.60	195.35	121.38	197.06	123.08	205.59	131.61	22.37	14.98
258.50	194.96	121.28	196.67	122.99	205.21	131.53	22.34	14.97
258.40	194.60	121.21	196.31	122.92	204.85	131.46	22.30	14.96
258.30	194.25	121.15	195.96	122.86	204.51	131.41	22.27	14.96
258.20	193.91	121.08	195.62	122.80	204.18	131.36	22.23	14.95
258.10	193.57	121.02	195.28	122.74	203.85	131.31	22.20	14.95
258.00	193.23	120.96	194.94	122.68	203.52	131.25	22.17	14.94
257.90	192.89	120.90	194.61	122.62	203.19	131.20	22.13	14.93
257.80	192.55	120.84	194.27	122.55	202.86	131.15	22.10	14.93
257.70	192.21	120.78	193.93	122.50	202.53	131.10	22.07	14.92
257.60	191.90	120.73	193.62	122.45	202.23	131.06	22.04	14.92
257.50	191.58	120.68	193.30	122.40	201.92	131.02	22.01	14.92
257.40	191.23	120.61	192.95	122.33	201.58	130.96	21.97	14.91
257.30	190.86	120.52	192.59	122.25	201.22	130.89	21.94	14.90
257.20	190.51	120.45	192.24	122.18	200.88	130.82	21.90	14.90
257.10	190.19	120.40	191.92	122.13	200.57	130.78	21.87	14.89
257.00	189.88	120.35	191.61	122.08	200.27	130.74	21.84	14.89
256.90	189.57	120.30	191.30	122.03	199.97	130.70	21.81	14.88
256.80	189.25	120.25	190.99	121.98	199.66	130.66	21.78	14.88
256.70	188.92	120.18	190.65	121.92	199.34	130.61	21.75	14.87
256.60	188.57	120.11	190.31	121.85	199.01	130.54	21.71	14.87
256.50	188.25	120.05	189.99	121.79	198.69	130.49	21.68	14.86
256.40	187.92	119.99	189.66	121.73	198.37	130.44	21.65	14.86
256.30	187.59	119.92	189.33	121.67	198.05	130.38	21.62	14.85
256.20	187.29	119.88	189.03	121.63	197.78	130.37	21.59	14.85
256.10	187.00	119.84	188.76	121.60	197.53	130.37	21.56	14.85
256.00	186.73	119.82	188.49	121.57	197.28	130.37	21.53	14.84
255.90	186.45	119.78	188.21	121.54	197.03	130.36	21.51	14.84
255.80	186.16	119.74	187.93	121.51	196.78	130.36	21.48	14.84
255.70	185.88	119.71	187.66	121.48	196.53	130.36	21.45	14.83
255.60	185.61	119.68	187.39	121.46	196.29	130.36	21.43	14.83
255.50	185.32	119.64	187.11	121.42	196.03	130.35	21.40	14.83
255.40	185.01	119.58	186.80	121.37	195.76	130.33	21.37	14.82
255.30	184.71	119.53	186.51	121.33	195.49	130.31	21.34	14.82
255.20	184.41	119.48	186.21	121.28	195.22	130.29	21.31	14.82
255.10	184.11	119.43	185.92	121.24	194.95	130.27	21.28	14.81
255.00	183.82	119.39	185.63	121.20	194.69	130.26	21.25	14.81
254.90	183.52	119.33	185.33	121.15	194.42	130.24	21.22	14.80
254.80	183.24	119.30	185.07	121.12	194.18	130.24	21.19	14.80
254.70	182.97	119.26	184.80	121.09	193.94	130.24	21.17	14.80
254.60	182.70	119.23	184.54	121.07	193.71	130.24	21.14	14.79
254.50	182.44	119.21	184.28	121.05	193.48	130.24	21.12	14.79
254.40	182.18	119.18	184.02	121.02	193.25	130.25	21.09	14.79
254.30	181.90	119.14	183.75	120.99	193.00	130.24	21.06	14.79
254.20	181.62	119.10	183.48	120.95	192.76	130.23	21.04	14.78
254.10	181.36	119.07	183.23	120.93	192.53	130.24	21.01	14.78
254.00	181.10	119.04	182.96	120.90	192.29	130.23	20.98	14.78
253.90	180.81	118.99	182.68	120.86	192.04	130.22	20.96	14.77
253.80	180.54	118.95	182.41	120.83	191.80	130.21	20.93	14.77
253.70	180.27	118.92	182.15	120.80	191.56	130.21	20.90	14.77
253.60	180.01	118.89	181.89	120.77	191.33	130.21	20.88	14.77
253.50	179.75	118.86	181.64	120.75	191.11	130.21	20.85	14.76
253.40	179.48	118.82	181.38	120.72	190.88	130.21	20.83	14.76
253.30	179.22	118.79	181.12	120.69	190.64	130.21	20.80	14.76
253.20	178.96	118.75	180.87	120.66	190.41	130.21	20.78	14.76
253.10	178.70	118.72	180.62	120.64	190.19	130.21	20.75	14.75
253.00	178.44	118.69	180.36	120.61	189.96	130.21	20.73	14.75
252.90	178.16	118.64	180.09	120.57	189.71	130.20	20.70	14.75
252.80	177.90	118.61	179.83	120.54	189.49	130.20	20.67	14.74

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	Dewatering WBM South Pit Inflow (m^3/day)	Recovery WBM South Pit Inflow (m^3/day)
252.70	177.64	118.58	179.58	120.51	189.26	130.19	20.65	14.74
252.60	177.35	118.52	179.29	120.46	189.00	130.17	20.62	14.74
252.50	177.03	118.44	178.98	120.39	188.71	130.13	20.59	14.73
252.40	176.74	118.39	178.69	120.34	188.46	130.10	20.56	14.72
252.30	176.44	118.33	178.40	120.28	188.19	130.07	20.53	14.72
252.20	176.18	118.29	178.14	120.25	187.96	130.07	20.50	14.72
252.10	175.91	118.25	177.88	120.22	187.73	130.06	20.48	14.71
252.00	175.66	118.21	177.63	120.19	187.50	130.06	20.45	14.71
251.90	175.38	118.17	177.36	120.15	187.26	130.04	20.43	14.70
251.80	175.09	118.11	177.07	120.09	187.00	130.02	20.40	14.70
251.70	174.79	118.04	176.78	120.03	186.73	129.98	20.37	14.69
251.60	174.47	117.96	176.46	119.96	186.44	129.94	20.34	14.69
251.50	174.15	117.88	176.15	119.89	186.16	129.89	20.31	14.68
251.40	173.87	117.82	175.87	119.83	185.91	129.87	20.28	14.67
251.30	173.59	117.78	175.60	119.79	185.67	129.85	20.25	14.67
251.20	173.29	117.71	175.31	119.72	185.40	129.81	20.22	14.66
251.10	172.95	117.61	174.98	119.64	185.09	129.75	20.19	14.65
251.00	172.64	117.54	174.67	119.57	184.82	129.71	20.16	14.65
250.90	172.34	117.47	174.38	119.50	184.55	129.68	20.13	14.64
250.80	172.05	117.40	174.09	119.44	184.29	129.64	20.10	14.64
250.70	171.76	117.34	173.80	119.39	184.03	129.61	20.07	14.63
250.60	171.48	117.28	173.53	119.33	183.79	129.59	20.04	14.63
250.50	171.21	117.23	173.26	119.29	183.54	129.57	20.02	14.62
250.40	170.95	117.19	173.01	119.25	183.32	129.56	19.99	14.62
250.30	170.67	117.13	172.74	119.20	183.07	129.53	19.97	14.61
250.20	170.40	117.08	172.47	119.15	182.84	129.52	19.94	14.61
250.10	170.16	117.05	172.24	119.12	182.63	129.51	19.92	14.60
250.00	169.91	117.01	171.99	119.09	182.41	129.51	19.89	14.60
249.90	169.65	116.96	171.74	119.05	182.19	129.50	19.87	14.60
249.80	169.39	116.92	171.49	119.01	181.96	129.48	19.84	14.59
249.70	169.16	116.89	171.25	118.99	181.75	129.48	19.82	14.59
249.60	168.91	116.85	171.02	118.96	181.54	129.48	19.79	14.59
249.50	168.68	116.82	170.79	118.93	181.34	129.48	19.77	14.58
249.40	168.45	116.80	170.57	118.91	181.15	129.49	19.75	14.58
249.30	168.23	116.77	170.35	118.89	180.96	129.50	19.73	14.58
249.20	167.99	116.74	170.11	118.86	180.75	129.50	19.70	14.58
249.10	167.74	116.70	169.88	118.83	180.54	129.49	19.68	14.57
249.00	167.50	116.66	169.64	118.80	180.33	129.49	19.66	14.57
248.90	167.26	116.63	169.41	118.77	180.12	129.48	19.63	14.57
248.80	167.04	116.60	169.18	118.75	179.93	129.49	19.61	14.57
248.70	166.80	116.57	168.96	118.72	179.73	129.49	19.59	14.56
248.60	166.59	116.55	168.75	118.70	179.54	129.50	19.57	14.56
248.50	166.38	116.53	168.54	118.69	179.37	129.52	19.55	14.56
248.40	166.16	116.51	168.33	118.68	179.18	129.53	19.52	14.56
248.30	165.93	116.48	168.11	118.65	178.99	129.53	19.50	14.56
248.20	165.70	116.44	167.88	118.62	178.78	129.53	19.48	14.55
248.10	165.45	116.40	167.64	118.59	178.57	129.52	19.45	14.55
248.00	165.23	116.37	167.42	118.56	178.38	129.52	19.43	14.55
247.90	165.01	116.34	167.21	118.54	178.19	129.53	19.41	14.54
247.80	164.79	116.32	166.99	118.52	178.01	129.54	19.39	14.54
247.70	164.57	116.29	166.78	118.50	177.82	129.54	19.37	14.54
247.60	164.32	116.24	166.53	118.46	177.60	129.53	19.34	14.54
247.50	164.08	116.20	166.30	118.42	177.39	129.52	19.32	14.53
247.40	163.83	116.16	166.06	118.38	177.18	129.51	19.30	14.53
247.30	163.61	116.13	165.84	118.36	176.99	129.51	19.27	14.53
247.20	163.37	116.08	165.60	118.32	176.78	129.50	19.25	14.52
247.10	163.14	116.05	165.39	118.29	176.59	129.50	19.23	14.52
247.00	162.92	116.02	165.17	118.27	176.40	129.50	19.21	14.52
246.90	162.69	115.98	164.94	118.24	176.20	129.50	19.18	14.51
246.80	162.48	115.96	164.74	118.22	176.03	129.51	19.16	14.51
246.70	162.26	115.93	164.52	118.19	175.84	129.51	19.14	14.51
246.60	162.02	115.89	164.29	118.16	175.64	129.50	19.12	14.50
246.50	161.79	115.85	164.06	118.12	175.43	129.49	19.09	14.50
246.40	161.53	115.79	163.81	118.07	175.21	129.47	19.07	14.50
246.30	161.26	115.72	163.55	118.01	174.98	129.44	19.04	14.49
246.20	161.01	115.67	163.30	117.96	174.76	129.42	19.02	14.48
246.10	160.78	115.63	163.08	117.92	174.56	129.41	19.00	14.48
246.00	160.55	115.59	162.85	117.89	174.37	129.40	18.97	14.48
245.90	160.32	115.55	162.63	117.86	174.17	129.40	18.95	14.47
245.80	160.09	115.51	162.40	117.82	173.97	129.39	18.93	14.47
245.70	159.85	115.46	162.17	117.78	173.76	129.37	18.90	14.47
245.60	159.61	115.41	161.93	117.74	173.56	129.36	18.88	14.46
245.50	159.36	115.35	161.69	117.68	173.34	129.34	18.86	14.46
245.40	159.05	115.26	161.39	117.59	173.07	129.27	18.83	14.45
245.30	158.75	115.16	161.09	117.51	172.80	129.22	18.80	14.44
245.20	158.50	115.11	160.85	117.45	172.59	129.19	18.77	14.43
245.10	158.24	115.04	160.60	117.40	172.37	129.17	18.75	14.43
245.00	157.99	114.98	160.35	117.34	172.15	129.14	18.72	14.42
244.90	157.75	114.93	160.11	117.29	171.94	129.12	18.70	14.42
244.80	157.52	114.89	159.89	117.26	171.75	129.11	18.68	14.41
244.70	157.32	114.86	159.70	117.24	171.58	129.12	18.66	14.41
244.60	157.12	114.84	159.50	117.22	171.41	129.13	18.64	14.41
244.50	156.92	114.82	159.31	117.20	171.25	129.15	18.62	14.41
244.40	156.72	114.79	159.11	117.18	171.08	129.16	18.60	14.40
244.30	156.50	114.75	158.90	117.15	170.90	129.15	18.58	14.40
244.20	156.27	114.71	158.67	117.11	170.70	129.14	18.55	14.40
244.10	156.03	114.65	158.44	117.07	170.50	129.13	18.53	14.39
244.00	155.80	114.61	158.22	117.02	170.31	129.11	18.51	14.39
243.90	155.57	114.56	157.99	116.98	170.11	129.10	18.48	14.38
243.80	155.34	114.51	157.77	116.94	169.92	129.09	18.46	14.38
243.70	155.10	114.45	157.53	116.89	169.71	129.07	18.44	14.37
243.60	154.83	114.38	157.28	116.82	169.49	129.04	18.41	14.37
243.50	154.60	114.33	157.05	116.78	169.29	129.02	18.39	14.36
243.40	154.38	114.29	156.84	116.74	169.11	129.02	18.37	14.36
243.30	154.16	114.24	156.62	116.70	168.92	129.01	18.35	14.35
243.20	153.92	114.19	156.39	116.66	168.72	128.99	18.32	14.35
243.10	153.67	114.13	156.15	116.60	168.51	128.96	18.30	14.34
243.00	153.41	114.05	155.89	116.53	168.29	128.92	18.27	14.34
242.90	153.17	113.99	155.65	116.47	168.08	128.90	18.25	14.33
242.80	152.92	113.92	155.41	116.42	167.87	128.87	18.22	14.32
242.70	152.65	113.84	155.14	116.34	167.63	128.83	18.20	14.32
242.60	152.37	113.75	154.87	116.25	167.39	128.77	18.17	14.31

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	Dewatering WBM South Pit Inflow (m^3/day)	Recovery WBM South Pit Inflow (m^3/day)
242.50	152.00	113.60	154.51	116.11	167.06	128.66	18.13	14.29
242.40	151.71	113.50	154.23	116.02	166.81	128.60	18.11	14.28
242.30	151.47	113.44	153.99	115.96	166.61	128.57	18.08	14.28
242.20	151.24	113.38	153.77	115.91	166.41	128.55	18.06	14.27
242.10	150.99	113.32	153.53	115.85	166.20	128.53	18.04	14.27
242.00	150.71	113.22	153.25	115.76	165.95	128.47	18.01	14.26
241.90	150.43	113.13	152.98	115.68	165.72	128.41	17.98	14.25
241.80	150.12	113.01	152.67	115.56	165.44	128.33	17.95	14.24
241.70	149.77	112.86	152.33	115.42	165.13	128.23	17.91	14.22
241.60	149.44	112.74	152.01	115.30	164.84	128.14	17.88	14.21
241.50	149.11	112.61	151.69	115.18	164.55	128.04	17.85	14.20
241.40	148.78	112.47	151.36	115.05	164.25	127.95	17.82	14.19
241.30	148.42	112.32	151.01	114.90	163.94	127.83	17.78	14.17
241.20	148.01	112.12	150.60	114.71	163.56	127.67	17.74	14.15
241.10	147.54	111.88	150.14	114.48	163.14	127.48	17.70	14.13
241.00	147.09	111.66	149.70	114.26	162.72	127.29	17.65	14.11
240.90	146.57	111.37	149.18	113.98	162.24	127.04	17.60	14.08
240.80	145.99	111.05	148.61	113.67	161.71	126.76	17.54	14.05
240.70	145.41	110.72	148.03	113.34	161.16	126.47	17.49	14.02
240.60	144.66	110.27	147.30	112.90	160.46	126.06	17.41	13.97
240.50	143.98	109.86	146.62	112.50	159.82	125.70	17.35	13.94
240.40	143.39	109.52	146.04	112.17	159.27	125.40	17.29	13.90
240.30	142.78	109.17	145.43	111.82	158.70	125.09	17.23	13.87
240.20	142.20	108.84	144.86	111.50	158.16	124.80	17.17	13.84
240.10	141.68	108.55	144.35	111.22	157.69	124.55	17.12	13.81
240.00	141.22	108.31	143.90	110.98	157.27	124.35	17.08	13.79
239.90	140.78	108.08	143.46	110.76	156.86	124.16	17.03	13.76
239.80	140.35	107.86	143.04	110.55	156.47	123.98	16.99	13.74
239.70	139.94	107.66	142.64	110.35	156.10	123.82	16.95	13.72
239.60	139.55	107.47	142.25	110.16	155.75	123.66	16.91	13.70
239.50	139.17	107.28	141.87	109.99	155.40	123.52	16.88	13.69
239.40	138.80	107.10	141.51	109.82	155.07	123.38	16.84	13.67
239.30	138.43	106.93	141.15	109.65	154.74	123.24	16.80	13.65
239.20	138.06	106.75	140.79	109.48	154.41	123.10	16.77	13.64
239.10	137.68	106.56	140.41	109.30	154.07	122.95	16.73	13.62
239.00	137.33	106.40	140.07	109.14	153.76	122.83	16.69	13.60
238.90	136.99	106.24	139.73	108.99	153.46	122.71	16.66	13.59
238.80	136.66	106.09	139.41	108.84	153.16	122.60	16.63	13.57
238.70	136.31	105.93	139.07	108.69	152.86	122.48	16.59	13.56
238.60	136.00	105.79	138.76	108.56	152.58	122.37	16.56	13.54
238.50	135.69	105.66	138.46	108.43	152.31	122.28	16.53	13.53
238.40	135.39	105.53	138.16	108.31	152.05	122.19	16.50	13.52
238.30	135.10	105.41	137.88	108.19	151.79	122.11	16.47	13.51
238.20	134.80	105.29	137.59	108.07	151.54	122.02	16.45	13.49
238.10	134.47	105.13	137.27	107.93	151.25	121.91	16.41	13.48
238.00	134.16	105.00	136.96	107.80	150.97	121.81	16.38	13.47
237.90	133.87	104.87	136.68	107.68	150.72	121.72	16.35	13.45
237.80	133.58	104.75	136.39	107.56	150.46	121.63	16.32	13.44
237.70	133.28	104.62	136.10	107.44	150.21	121.55	16.30	13.43
237.60	132.97	104.48	135.80	107.31	149.94	121.44	16.27	13.42
237.50	132.55	104.26	135.39	107.09	149.56	121.26	16.22	13.39
237.40	132.20	104.08	135.04	106.92	149.24	121.12	16.19	13.38
237.30	131.86	103.92	134.71	106.77	148.95	121.00	16.16	13.36
237.20	131.53	103.76	134.38	106.61	148.65	120.88	16.12	13.35
237.10	131.16	103.57	134.02	106.43	148.32	120.73	16.09	13.33
237.00	130.81	103.40	133.68	106.26	148.01	120.60	16.05	13.31
236.90	130.43	103.20	133.31	106.07	147.67	120.44	16.02	13.29
236.80	130.00	102.96	132.88	105.84	147.28	120.24	15.97	13.27
236.70	129.65	102.79	132.54	105.67	146.97	120.10	15.94	13.25
236.60	129.31	102.62	132.21	105.51	146.67	119.98	15.91	13.24
236.50	128.93	102.42	131.83	105.31	146.32	119.81	15.87	13.22
236.40	128.53	102.20	131.43	105.10	145.96	119.63	15.83	13.19
236.30	128.16	102.00	131.07	104.91	145.63	119.47	15.79	13.18
236.20	127.79	101.81	130.71	104.73	145.30	119.32	15.76	13.16
236.10	127.43	101.62	130.35	104.55	144.98	119.17	15.72	13.14
236.00	127.08	101.44	130.01	104.37	144.67	119.03	15.69	13.12
235.90	126.76	101.29	129.70	104.22	144.39	118.92	15.65	13.11
235.80	126.46	101.15	129.41	104.09	144.13	118.82	15.62	13.09
235.70	126.19	101.03	129.14	103.98	143.89	118.73	15.60	13.08
235.60	125.92	100.91	128.88	103.87	143.67	118.66	15.57	13.07
235.50	125.67	100.81	128.64	103.77	143.46	118.60	15.55	13.06
235.40	125.42	100.70	128.39	103.68	143.24	118.53	15.52	13.05
235.30	125.17	100.60	128.15	103.58	143.03	118.47	15.50	13.04
235.20	124.92	100.50	127.91	103.49	142.83	118.41	15.47	13.03
235.10	124.67	100.40	127.66	103.39	142.62	118.34	15.45	13.02
235.00	124.41	100.28	127.41	103.28	142.39	118.27	15.42	13.01
234.90	124.12	100.14	127.12	103.15	142.14	118.17	15.39	13.00
234.80	123.82	100.01	126.83	103.02	141.89	118.07	15.36	12.98
234.70	123.53	99.87	126.55	102.88	141.63	117.97	15.34	12.97
234.60	123.24	99.73	126.27	102.75	141.39	117.87	15.31	12.96
234.50	122.96	99.60	125.99	102.63	141.14	117.78	15.28	12.94
234.40	122.63	99.42	125.67	102.46	140.85	117.65	15.25	12.93
234.30	122.32	99.27	125.37	102.32	140.59	117.54	15.22	12.91
234.20	122.01	99.12	125.06	102.17	140.32	117.42	15.19	12.90
234.10	121.71	98.97	124.77	102.02	140.06	117.31	15.16	12.88
234.00	121.38	98.79	124.45	101.86	139.77	117.18	15.12	12.86
233.90	121.03	98.60	124.10	101.67	139.46	117.03	15.09	12.85
233.80	120.73	98.45	123.81	101.53	139.20	116.92	15.06	12.83
233.70	120.45	98.32	123.54	101.40	138.96	116.83	15.03	12.82
233.60	120.17	98.18	123.26	101.27	138.72	116.73	15.00	12.80
233.50	119.91	98.06	123.01	101.16	138.50	116.66	14.98	12.79
233.40	119.65	97.94	122.75	101.05	138.28	116.58	14.95	12.78
233.30	119.38	97.81	122.49	100.93	138.05	116.49	14.93	12.77
233.20	119.12	97.69	122.23	100.81	137.83	116.41	14.90	12.76
233.10	118.84	97.56	121.97	100.69	137.60	116.32	14.87	12.74
233.00	118.58	97.44	121.71	100.57	137.37	116.23	14.85	12.73
232.90	118.32	97.32	121.46	100.46	137.16	116.16	14.82	12.72
232.80	118.07	97.21	121.22	100.35	136.95	116.08	14.80	12.71
232.70	117.84	97.11	120.99	100.26	136.76	116.02	14.77	12.70
232.60	117.61	97.01	120.77	100.17	136.57	115.97	14.75	12.69
232.50	117.38	96.91	120.55	100.08	136.38	115.91	14.73	12.68
232.40	117.15	96.82	120.32	99.99	136.19	115.86	14.71	12.67

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	Dewatering WBM South Pit Inflow (m^3/day)	Recovery WBM South Pit Inflow (m^3/day)
232.30	116.92	96.71	120.10	99.89	136.00	115.79	14.68	12.66
232.20	116.62	96.56	119.81	99.74	135.74	115.68	14.65	12.65
232.10	116.34	96.42	119.54	99.61	135.51	115.58	14.63	12.63
232.00	116.10	96.31	119.30	99.51	135.31	115.52	14.60	12.62
231.90	115.89	96.23	119.10	99.43	135.14	115.47	14.58	12.61
231.80	115.67	96.14	118.89	99.35	134.96	115.42	14.56	12.61
231.70	115.44	96.03	118.66	99.25	134.76	115.36	14.54	12.60
231.60	115.20	95.92	118.43	99.15	134.57	115.29	14.51	12.58
231.50	114.97	95.82	118.20	99.05	134.37	115.22	14.49	12.57
231.40	114.73	95.71	117.97	98.95	134.17	115.16	14.47	12.56
231.30	114.49	95.60	117.74	98.85	133.98	115.09	14.44	12.55
231.20	114.28	95.51	117.53	98.76	133.80	115.04	14.42	12.54
231.10	114.06	95.42	117.32	98.68	133.63	114.99	14.40	12.54
231.00	113.84	95.33	117.11	98.59	133.45	114.94	14.38	12.53
230.90	113.63	95.23	116.90	98.51	133.28	114.89	14.36	12.52
230.80	113.40	95.14	116.69	98.42	133.10	114.83	14.33	12.51
230.70	113.17	95.03	116.46	98.32	132.90	114.76	14.31	12.50
230.60	112.94	94.92	116.24	98.22	132.71	114.70	14.29	12.49
230.50	112.72	94.83	116.02	98.13	132.53	114.64	14.27	12.48
230.40	112.50	94.73	115.81	98.04	132.35	114.58	14.24	12.47
230.30	112.28	94.63	115.60	97.95	132.18	114.53	14.22	12.46
230.20	112.07	94.54	115.39	97.86	132.00	114.48	14.20	12.45
230.10	111.85	94.44	115.18	97.77	131.83	114.42	14.18	12.44
230.00	111.63	94.34	114.97	97.68	131.65	114.36	14.16	12.43
229.90	111.42	94.25	114.76	97.59	131.47	114.31	14.14	12.42
229.80	111.20	94.16	114.55	97.51	131.30	114.26	14.12	12.41
229.70	110.99	94.06	114.35	97.42	131.13	114.20	14.10	12.40
229.60	110.77	93.96	114.13	97.33	130.95	114.14	14.07	12.39
229.50	110.55	93.86	113.92	97.24	130.78	114.09	14.05	12.38
229.40	110.31	93.74	113.68	97.12	130.57	114.01	14.03	12.37
229.30	110.05	93.61	113.43	96.99	130.35	113.91	14.00	12.36
229.20	109.80	93.48	113.19	96.87	130.14	113.83	13.98	12.35
229.10	109.57	93.37	112.97	96.77	129.96	113.76	13.96	12.34
229.00	109.34	93.26	112.75	96.67	129.77	113.69	13.93	12.32
228.90	109.10	93.14	112.51	96.55	129.57	113.61	13.91	12.31
228.80	108.86	93.02	112.28	96.44	129.37	113.53	13.88	12.30
228.70	108.62	92.90	112.04	96.32	129.17	113.45	13.86	12.29
228.60	108.38	92.78	111.81	96.21	128.97	113.37	13.84	12.28
228.50	108.14	92.66	111.58	96.10	128.77	113.29	13.81	12.27
228.40	107.90	92.54	111.35	95.98	128.58	113.21	13.79	12.25
228.30	107.66	92.41	111.11	95.87	128.37	113.13	13.77	12.24
228.20	107.40	92.28	110.86	95.74	128.16	113.04	13.74	12.23
228.10	107.15	92.15	110.62	95.61	127.95	112.95	13.72	12.21
228.00	106.90	92.01	110.37	95.49	127.74	112.86	13.69	12.20
227.90	106.65	91.88	110.13	95.36	127.53	112.77	13.67	12.19
227.80	106.42	91.76	109.90	95.25	127.34	112.69	13.64	12.18
227.70	106.18	91.64	109.67	95.13	127.14	112.61	13.62	12.17
227.60	105.91	91.49	109.41	95.00	126.92	112.50	13.59	12.15
227.50	105.53	91.25	109.04	94.76	126.58	112.30	13.55	12.13
227.40	105.20	91.04	108.72	94.56	126.29	112.14	13.52	12.11
227.30	104.90	90.87	108.42	94.39	126.03	112.00	13.49	12.09
227.20	104.58	90.67	108.11	94.20	125.76	111.85	13.46	12.07
227.10	104.30	90.51	107.84	94.04	125.52	111.73	13.43	12.05
227.00	104.00	90.33	107.55	93.87	125.26	111.59	13.40	12.04
226.90	103.71	90.16	107.26	93.71	125.01	111.46	13.37	12.02
226.80	103.44	90.00	106.99	93.56	124.78	111.35	13.35	12.00
226.70	103.15	89.83	106.71	93.40	124.54	111.22	13.32	11.99
226.60	102.87	89.67	106.44	93.24	124.30	111.10	13.29	11.97
226.50	102.58	89.50	106.16	93.08	124.05	110.97	13.26	11.95
226.40	102.29	89.33	105.88	92.91	123.81	110.84	13.23	11.94
226.30	102.02	89.16	105.61	92.76	123.57	110.72	13.21	11.92
226.20	101.72	88.99	105.32	92.59	123.32	110.58	13.18	11.90
226.10	101.41	88.80	105.02	92.40	123.05	110.43	13.15	11.89
226.00	101.15	88.64	104.76	92.26	122.83	110.32	13.12	11.87
225.90	100.91	88.51	104.53	92.13	122.63	110.23	13.10	11.86
225.80	100.68	88.39	104.31	92.02	122.45	110.15	13.07	11.85
225.70	100.43	88.25	104.07	91.88	122.24	110.06	13.05	11.83
225.60	100.17	88.10	103.81	91.74	122.02	109.94	13.02	11.82
225.50	99.90	87.93	103.54	91.58	121.79	109.83	13.00	11.80
225.40	99.61	87.76	103.27	91.42	121.54	109.69	12.97	11.78
225.30	99.33	87.59	103.00	91.26	121.31	109.57	12.94	11.77
225.20	99.07	87.43	102.74	91.10	121.09	109.45	12.91	11.75
225.10	98.79	87.27	102.47	90.95	120.85	109.33	12.89	11.74
225.00	98.50	87.09	102.19	90.78	120.61	109.20	12.86	11.72
224.90	98.23	86.93	101.93	90.62	120.38	109.08	12.83	11.70
224.80	97.99	86.79	101.68	90.48	120.18	108.98	12.81	11.69
224.70	97.73	86.64	101.44	90.34	119.97	108.87	12.78	11.67
224.60	97.47	86.48	101.19	90.20	119.75	108.76	12.76	11.66
224.50	97.21	86.33	100.93	90.05	119.53	108.65	12.73	11.64
224.40	96.95	86.17	100.68	89.90	119.31	108.54	12.70	11.63
224.30	96.67	85.99	100.40	89.73	119.08	108.41	12.68	11.61
224.20	96.34	85.78	100.09	89.52	118.80	108.24	12.64	11.59
224.10	96.00	85.55	99.75	89.30	118.50	108.05	12.61	11.57
224.00	95.68	85.34	99.43	89.09	118.22	107.88	12.58	11.54
223.90	95.44	85.20	99.21	88.97	118.03	107.79	12.56	11.53
223.80	95.21	85.07	98.98	88.84	117.84	107.70	12.53	11.52
223.70	94.96	84.92	98.74	88.70	117.64	107.60	12.51	11.50
223.60	94.72	84.78	98.51	88.57	117.44	107.50	12.48	11.49
223.50	94.48	84.64	98.27	88.43	117.25	107.40	12.46	11.48
223.40	94.23	84.48	98.03	88.29	117.04	107.29	12.43	11.46
223.30	93.93	84.29	97.74	88.10	116.78	107.15	12.41	11.44
223.20	93.59	84.06	97.41	87.88	116.49	106.96	12.37	11.42
223.10	93.28	83.85	97.10	87.68	116.22	106.80	12.34	11.40
223.00	92.95	83.63	96.79	87.47	115.95	106.62	12.31	11.38
222.90	92.63	83.41	96.47	87.25	115.66	106.45	12.28	11.35
222.80	92.29	83.18	96.14	87.03	115.38	106.26	12.24	11.33
222.70	91.98	82.98	95.84	86.83	115.11	106.10	12.21	11.31
222.60	91.67	82.76	95.53	86.62	114.84	105.93	12.18	11.29
222.50	91.35	82.55	95.22	86.41	114.57	105.76	12.15	11.27
222.40	91.05	82.34	94.92	86.22	114.31	105.60	12.12	11.25
222.30	90.76	82.15	94.64	86.04	114.06	105.46	12.09	11.23
222.20	90.46	81.96	94.36	85.85	113.81	105.31	12.06	11.21

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	Dewatering WBM South Pit Inflow (m³/day)	Recovery WBM South Pit Inflow (m³/day)
222.10	90.17	81.76	94.07	85.66	113.57	105.16	12.03	11.19
222.00	89.86	81.55	93.77	85.46	113.31	104.99	12.00	11.17
221.90	89.55	81.33	93.46	85.25	113.03	104.82	11.97	11.15
221.80	89.25	81.13	93.17	85.05	112.78	104.66	11.94	11.13
221.70	88.92	80.91	92.85	84.84	112.50	104.48	11.91	11.11
221.60	88.48	80.57	92.42	84.51	112.10	104.19	11.86	11.07
221.50	88.08	80.28	92.02	84.22	111.75	103.94	11.82	11.04
221.40	87.70	80.00	91.65	83.95	111.42	103.71	11.79	11.02
221.30	87.34	79.74	91.30	83.70	111.10	103.50	11.75	10.99
221.20	86.99	79.49	90.96	83.46	110.80	103.30	11.72	10.97
221.10	86.64	79.23	90.61	83.21	110.49	103.08	11.68	10.94
221.00	86.28	78.98	90.27	82.96	110.18	102.87	11.65	10.92
220.90	85.92	78.71	89.91	82.70	109.86	102.65	11.61	10.89
220.80	85.50	78.39	89.50	82.39	109.49	102.38	11.57	10.86
220.70	85.11	78.10	89.11	82.10	109.14	102.13	11.53	10.83
220.60	84.75	77.83	88.76	81.85	108.83	101.91	11.49	10.80
220.50	84.37	77.56	88.40	81.58	108.50	101.68	11.46	10.78
220.40	83.99	77.27	88.02	81.30	108.16	101.44	11.42	10.75
220.30	83.57	76.95	87.61	80.99	107.79	101.17	11.38	10.72
220.20	83.15	76.62	87.19	80.66	107.41	100.88	11.34	10.68
220.10	82.65	76.23	86.70	80.28	106.96	100.54	11.29	10.64
220.00	82.11	75.80	86.17	79.86	106.47	100.16	11.23	10.60
219.90	81.60	75.39	85.67	79.46	106.01	99.79	11.18	10.56
219.80	81.04	74.93	85.12	79.01	105.49	99.38	11.13	10.52
219.70	80.33	74.34	84.41	78.42	104.83	98.84	11.06	10.46
219.60	79.56	73.69	83.65	77.78	104.10	98.23	10.98	10.39
219.50	78.79	73.04	82.89	77.14	103.39	97.64	10.90	10.33
219.40	77.74	72.12	81.85	76.23	102.38	96.77	10.80	10.24
219.30	76.18	70.74	80.30	74.86	100.88	95.44	10.65	10.10
219.20	73.28	68.11	77.41	72.23	98.04	92.87	10.36	9.84
219.10	71.43	66.44	75.57	70.58	96.24	91.25	10.18	9.68
219.00	70.61	65.73	74.75	69.88	95.47	90.59	10.09	9.61
218.90	70.09	65.31	74.24	69.46	95.00	90.21	10.04	9.56
218.80	69.63	64.93	73.78	69.09	94.58	89.88	10.00	9.53
218.70	69.19	64.57	73.35	68.74	94.18	89.57	9.95	9.49
218.60	68.70	64.17	72.87	68.34	93.74	89.21	9.90	9.45
218.50	68.16	63.72	72.34	67.90	93.25	88.81	9.85	9.41
218.40	67.64	63.29	71.83	67.48	92.78	88.43	9.80	9.36
218.30	67.13	62.87	71.33	67.06	92.32	88.05	9.75	9.32
218.20	66.68	62.49	70.89	66.70	91.91	87.72	9.70	9.29
218.10	66.24	62.13	70.45	66.35	91.52	87.41	9.66	9.25
218.00	65.80	61.77	70.02	65.99	91.13	87.09	9.62	9.21
217.90	65.34	61.39	69.57	65.62	90.71	86.76	9.57	9.18
217.80	64.89	61.01	69.12	65.25	90.30	86.43	9.53	9.14
217.70	64.44	60.64	68.68	64.88	89.90	86.10	9.48	9.10
217.60	63.98	60.26	68.23	64.51	89.49	85.77	9.44	9.06
217.50	63.50	59.86	67.76	64.12	89.06	85.41	9.39	9.02
217.40	62.97	59.41	67.24	63.68	88.57	85.01	9.34	8.98
217.30	62.41	58.92	66.68	63.20	88.05	84.57	9.28	8.93
217.20	61.73	58.34	66.01	62.62	87.43	84.03	9.21	8.87
217.10	60.85	57.55	65.14	61.84	86.60	83.30	9.12	8.79
217.00	59.45	56.27	63.75	60.57	85.24	82.07	8.99	8.67
216.90	58.22	55.16	62.53	59.46	84.06	81.00	8.86	8.56
216.80	57.32	54.35	61.64	58.66	83.21	80.24	8.77	8.48
216.70	56.45	53.57	60.78	57.89	82.39	79.51	8.69	8.40
216.60	55.63	52.83	59.96	57.16	81.62	78.82	8.61	8.33
216.50	54.91	52.19	59.24	56.53	80.94	78.22	8.53	8.26
216.40	54.11	51.47	58.45	55.82	80.19	77.55	8.45	8.19
216.30	53.29	50.73	57.64	55.09	79.42	76.86	8.37	8.12
216.20	52.43	49.96	56.79	54.32	78.61	76.13	8.29	8.04
216.10	51.49	49.10	55.86	53.48	77.72	75.33	8.19	7.96
216.00	50.38	48.09	54.76	52.47	76.66	74.36	8.08	7.85
215.90	49.02	46.82	53.40	51.21	75.34	73.14	7.95	7.73
215.80	47.57	45.48	51.97	49.87	73.95	71.85	7.81	7.60
215.70	45.92	43.93	50.32	48.34	72.34	70.36	7.64	7.44
215.60	43.66	41.81	48.07	46.22	70.13	68.28	7.42	7.23
215.50	41.10	39.39	45.52	43.81	67.63	65.92	7.16	6.99
215.40	38.93	37.35	43.36	41.78	65.51	63.93	6.95	6.79
215.30	36.86	35.39	41.30	39.82	63.49	62.02	6.74	6.59
215.20	34.60	33.24	39.04	37.69	61.28	59.92	6.51	6.38
215.10	32.87	31.61	37.33	36.07	59.60	58.34	6.34	6.22
215.00	31.68	30.50	36.15	34.96	58.46	57.27	6.22	6.11
214.90	30.72	29.60	35.19	34.07	57.55	56.42	6.13	6.02
214.80	29.71	28.65	34.19	33.13	56.59	55.52	6.03	5.92
214.70	28.51	27.51	33.00	32.00	55.43	54.43	5.91	5.81
214.60	27.35	26.42	31.85	30.91	54.32	53.38	5.79	5.70
214.50	26.56	25.67	31.06	30.17	53.57	52.68	5.71	5.62
214.40	25.74	24.90	30.25	29.41	52.80	51.96	5.63	5.55
214.30	24.70	23.91	29.22	28.43	51.80	51.02	5.53	5.45
214.20	23.47	22.74	27.99	27.27	50.62	49.89	5.40	5.33
214.10	22.91	22.22	27.45	26.75	50.11	49.42	5.35	5.28
214.00	22.43	21.77	26.97	26.31	49.68	49.02	5.30	5.23
213.90	21.91	21.29	26.46	25.84	49.21	48.58	5.25	5.19
213.80	21.32	20.72	25.87	25.28	48.65	48.06	5.19	5.13
213.70	20.55	20.00	25.12	24.56	47.94	47.38	5.11	5.06
213.60	19.91	19.39	24.48	23.96	47.34	46.82	5.05	5.00
213.50	19.33	18.84	23.91	23.42	46.81	46.32	4.99	4.94
213.40	18.76	18.30	23.35	22.89	46.29	45.83	4.93	4.89
213.30	18.22	17.78	22.81	22.38	45.79	45.35	4.88	4.84
213.20	17.67	17.26	22.27	21.86	45.29	44.88	4.82	4.78
213.10	17.06	16.68	21.67	21.29	44.72	44.34	4.76	4.72
213.00	16.35	16.00	20.97	20.62	44.06	43.71	4.69	4.66
212.90	15.57	15.25	20.20	19.88	43.33	43.01	4.61	4.58
212.80	14.89	14.59	19.53	19.23	42.69	42.40	4.55	4.52
212.70	14.25	13.98	18.89	18.62	42.10	41.83	4.48	4.45
212.60	13.61	13.36	18.25	18.01	41.50	41.25	4.42	4.39
212.50	12.94	12.72	17.60	17.37	40.89	40.66	4.35	4.33
212.40	12.24	12.04	16.90	16.70	40.23	40.02	4.28	4.26
212.30	11.48	11.30	16.16	15.97	39.52	39.34	4.20	4.19
212.20	10.66	10.50	15.34	15.18	38.75	38.59	4.12	4.11
212.10	9.83	9.69	14.52	14.38	37.96	37.82	4.04	4.03
212.00	9.00	8.88	13.70	13.58	37.18	37.06	3.96	3.94

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Pit Level (mAHD)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	Dewatering WBM South Pit Inflow (m^3/day)	Recovery WBM South Pit Inflow (m^3/day)
211.90	8.18	8.08	12.89	12.79	36.41	36.30	3.87	3.86
211.80	7.38	7.29	12.09	12.01	35.65	35.56	3.79	3.79
211.70	6.60	6.53	11.32	11.25	34.91	34.84	3.72	3.71
211.60	5.82	5.76	10.54	10.49	34.18	34.12	3.64	3.63
211.50	5.02	4.98	9.76	9.71	33.43	33.38	3.56	3.55
211.40	4.23	4.20	8.97	8.94	32.69	32.65	3.48	3.48
211.30	3.44	3.42	8.19	8.17	31.94	31.92	3.40	3.40
211.20	2.63	2.61	7.38	7.37	31.17	31.16	3.32	3.32
211.10	1.76	1.75	6.52	6.52	30.35	30.34	3.23	3.23
211.04	1.19	1.19	5.96	5.96	29.82	29.82	3.17	3.17
210.04	1.20	1.20	6.02	6.02	30.08	30.08	3.17	3.17

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
Open Void Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)
306	8.96279889	8.96279889	8.96279889	8.96279889	8.96279889	8.96279889	14.5503687	14.5503687	14.5503687	14.5503687	14.5503687	14.5503687	32.2198159	32.2198159	32.2198159
291	12.616097	12.616097	12.616097	12.616097	12.616097	12.616097	22.859975	22.859975	22.859975	22.859975	22.859975	22.859975	55.2539615	55.2539615	55.2539615
265	17.3599173	17.3599173	17.3599173	17.3599173	17.3599173	17.3599173	35.6747295	35.6747295	35.6747295	35.6747295	35.6747295	35.6747295	93.5912509	93.5912509	93.5912509
241	21.3313724	21.3313724	21.3313724	21.3313724	21.3313724	21.3313724	47.0962777	47.0962777	47.0962777	47.0962777	47.0962777	47.0962777	128.572062	128.572062	128.572062
221	24.5247077	24.5247077	24.5247077	24.5247077	24.5247077	24.5247077	56.4980238	56.4980238	56.4980238	56.4980238	56.4980238	56.4980238	157.606527	157.606527	157.606527
200	27.681465	27.681465	27.681465	27.681465	27.681465	27.681465	66.1736126	66.1736126	66.1736126	66.1736126	66.1736126	66.1736126	187.896471	187.896471	187.896471
200	28.3471009	28.3471009	28.3471009	28.3471009	28.3471009	28.3471009	66.8392484	66.8392484	66.8392484	66.8392484	66.8392484	66.8392484	188.562107	188.562107	188.562107
200	28.8653524	28.8653524	28.8653524	28.8653524	28.8653524	28.8653524	67.3575	67.3575	67.3575	67.3575	67.3575	67.3575	189.080358	189.080358	189.080358
193	30.2280646	30.2280646	30.2280646	30.2280646	30.2280646	30.2280646	70.8931561	70.8931561	70.8931561	70.8931561	70.8931561	70.8931561	199.487466	199.487466	199.487466
171	33.0947154	33.0947154	33.0947154	33.0947154	33.0947154	33.0947154	80.5890588	80.5890588	80.5890588	80.5890588	80.5890588	80.5890588	230.77936	230.77936	230.77936
153	36.1425165	36.1425165	36.1425165	36.1425165	36.1425165	36.1425165	89.2244297	89.2244297	89.2244297	89.2244297	89.2244297	89.2244297	257.084178	257.084178	257.084178
146	38.0620934	38.0620934	38.0620934	38.0620934	38.0620934	38.0620934	93.3169504	93.3169504	93.3169504	93.3169504	93.3169504	93.3169504	268.04815	268.04815	268.04815
146	38.544988	38.544988	38.544988	38.544988	38.544988	38.544988	93.799845	93.799845	93.799845	93.799845	93.799845	93.799845	268.531045	268.531045	268.531045
130	40.6402323	40.6402323	40.6402323	40.6402323	40.6402323	40.6402323	100.861818	100.861818	100.861818	100.861818	100.861818	100.861818	291.299193	291.299193	291.299193
125	41.50548	41.50548	41.50548	41.50548	41.50548	41.50548	103.279168	103.279168	103.279168	103.279168	103.279168	103.279168	298.624724	298.624724	298.624724
125	41.8504858	41.8504858	41.8504858	41.8504858	41.8504858	41.8504858	103.624174	103.624174	103.624174	103.624174	103.624174	103.624174	298.969729	298.969729	298.969729
125	42.0898482	42.0898482	42.0898482	42.0898482	42.0898482	42.0898482	103.863537	103.863537	103.863537	103.863537	103.863537	103.863537	299.209092	299.209092	299.209092
125	42.452985	42.452985	42.452985	42.452985	42.452985	42.452985	104.226674	104.226674	104.226674	104.226674	104.226674	104.226674	299.572229	299.572229	299.572229
125	42.6583964	42.6583964	42.6583964	42.6583964	42.6583964	42.6583964	104.432085	104.432085	104.432085	104.432085	104.432085	104.432085	299.77764	299.77764	299.77764
112	44.6850264	44.6850264	44.6850264	44.6850264	44.6850264	44.6850264	110.494182	110.494182	110.494182	110.494182	110.494182	110.494182	318.601004	318.601004	318.601004
101	46.355155	46.355155	46.355155	46.355155	46.355155	46.355155	115.578937	115.578937	115.578937	115.578937	115.578937	115.578937	334.483755	334.483755	334.483755
93	47.6379336	47.6379336	47.6379336	47.6379336	47.6379336	47.6379336	119.34508	119.34508	119.34508	119.34508	119.34508	119.34508	346.102985	346.102985	346.102985
85	48.9247838	48.9247838	48.9247838	48.9247838	48.9247838	48.9247838	123.115294	123.115294	123.115294	123.115294	123.115294	123.115294	357.726287	357.726287	357.726287
64	51.8150958	51.8150958	51.8150958	51.8150958	51.8150958	51.8150958	132.524437	132.524437	132.524437	132.524437	132.524437	132.524437	387.749786	387.749786	387.749786
55	53.1551046	53.1551046	53.1551046	53.1551046	53.1551046	53.1551046	136.658231	136.658231	136.658231	136.658231	136.658231	136.658231	400.718303	400.718303	400.718303
34	55.9880063	55.9880063	55.9880063	55.9880063	55.9880063	55.9880063	146.009964	146.009964	146.009964	146.009964	146.009964	146.009964	430.684391	430.684391	430.684391
26	57.1659695	57.1659695	57.1659695	57.1659695	57.1659695	57.1659695	149.671292	149.671292	149.671292	149.671292	149.671292	149.671292	442.198807	442.198807	442.198807
26	57.476853	57.476853	57.476853	57.476853	57.476853	57.476853	149.982175	149.982175	149.982175	149.982175	149.982175	149.982175	442.50969	442.50969	442.50969
21	58.4340867	58.4340867	58.4340867	58.4340867	58.4340867	58.4340867	152.491512	152.491512	152.491512	152.491512	152.491512	152.491512	449.927206	449.927206	449.927206
2	61.0603929	61.0603929	61.0603929	61.0603929	61.0603929	61.0603929	161.015808	161.015808	161.015808	161.015808	161.015808	161.015808	477.102586	477.102586	477.102586
2	61.5661559	61.5661559	61.5661559	61.5661559	61.5661559	61.5661559	161.521571	161.521571	161.521571	161.521571	161.521571	161.521571	477.608349	477.608349	477.608349
2	62.0351398	62.0351398	62.0351398	62.0351398	62.0351398	62.0351398	161.990555	161.990555	161.990555	161.990555	161.990555	161.990555	478.077333	478.077333	478.077333
2	62.4264352	62.4264352	62.4264352	62.4264352	62.4264352	62.4264352	162.381851	162.381851	162.381851	162.381851	162.381851	162.381851	478.468628	478.468628	478.468628
2	62.795871	62.795871	62.795871	62.795871	62.795871	62.795871	162.751287	162.751287	162.751287	162.751287	162.751287	162.751287	478.838064	478.838064	478.838064
2	63.1162996	63.1162996	63.1162996	63.1162996	63.1162996	63.1162996	163.071715	163.071715	163.071715	163.071715	163.071715	163.071715	479.158493	479.158493	479.158493
2	63.2572878	63.2572878	63.2572878	63.2572878	63.2572878	63.2572878	163.212703	163.212703	163.212703	163.212703	163.212703	163.212703	479.299481	479.299481	479.299481
2	63.372808	63.372808	63.372808	63.372808	63.372808	63.372808	163.328224	163.328224	163.328224	163.328224	163.328224	163.328224	479.415001	479.415001	479.415001
2	63.6387232	63.6387232	63.6387232	63.6387232	63.6387232	63.6387232	163.594139	163.594139	163.594139	163.594139	163.594139	163.594139	479.680916	479.680916	479.680916
2	63.9925312	63.9925312	63.9925312	63.9925312	63.9925312	63.9925312	163.947947	163.947947	163.947947	163.947947	163.947947	163.947947	480.034724	480.034724	480.034724
2	64.3810974	64.3810974	64.3810974	64.3810974	64.3810974	64.3810974	164.336513	164.336513	164.336513	164.336513	164.336513	164.336513	480.423291	480.423291	480.423291
2	64.8093193	64.8093193	64.8093193	64.8093193	64.8093193	64.8093193	164.764735	164.764735	164.764735	164.764735	164.764735	164.764735	480.851512	480.851512	480.851512
2	65.2754207	65.2754207	65.2754207	65.2754207	65.2754207	65.2754207	165.230836	165.230836	165.230836	165.230836	165.230836	165.230836	481.317614	481.317614	481.317614
2	65.5002237	65.5002237	65.5002237	65.5002237	65.5002237	65.5002237	165.455639	165.455639	165.455639	165.455639	165.455639	165.455639	481.542417	481.542417	481.542417
2	65.5348032	65.5348032	65.5348032	65.5348032	65.5348032	65.5348032	165.490219	165.490219	165.490219	165.490219	165.490219	165.490219	481.576996	481.576996	481.576996

Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering
Scenario	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
Open Void Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)
2	65.5747114	65.5747114	65.5747114	65.5747114	65.5747114	65.5747114	165.530127	165.530127	165.530127	165.530127	165.530127	165.530127	481.616905	481.616905	481.616905
2	65.59637	65.59637	65.59637	65.59637	65.59637	65.59637	165.551786	165.551786	165.551786	165.551786	165.551786	165.551786	481.638563	481.638563	481.638563
2	65.6570098	65.6570098	65.6570098	65.6570098	65.6570098	65.6570098	165.612425	165.612425	165.612425	165.612425	165.612425	165.612425	481.699203	481.699203	481.699203
2	65.7175056	65.7175056	65.7175056	65.7175056	65.7175056	65.7175056	165.672921	165.672921	165.672921	165.672921	165.672921	165.672921	481.759699	481.759699	481.759699
2	65.7414083	65.7414083	65.7414083	65.7414083	65.7414083	65.7414083	165.696824	165.696824	165.696824	165.696824	165.696824	165.696824	481.783601	481.783601	481.783601
2	65.7887374	65.7887374	65.7887374	65.7887374	65.7887374	65.7887374	165.744153	165.744153	165.744153	165.744153	165.744153	165.744153	481.830931	481.830931	481.830931
2	65.8512682	65.8512682	65.8512682	65.8512682	65.8512682	65.8512682	165.806684	165.806684	165.806684	165.806684	165.806684	165.806684	481.893461	481.893461	481.893461
2	65.8852996	65.8852996	65.8852996	65.8852996	65.8852996	65.8852996	165.840715	165.840715	165.840715	165.840715	165.840715	165.840715	481.927493	481.927493	481.927493
2	66.0414147	66.0414147	66.0414147	66.0414147	66.0414147	66.0414147	165.99683	165.99683	165.99683	165.99683	165.99683	165.99683	482.083608	482.083608	482.083608
2	66.2093234	66.2093234	66.2093234	66.2093234	66.2093234	66.2093234	166.164739	166.164739	166.164739	166.164739	166.164739	166.164739	482.251516	482.251516	482.251516
2	66.4114612	66.4114612	66.4114612	66.4114612	66.4114612	66.4114612	166.366877	166.366877	166.366877	166.366877	166.366877	166.366877	482.453654	482.453654	482.453654
2	66.6352781	66.6352781	66.6352781	66.6352781	66.6352781	66.6352781	166.590694	166.590694	166.590694	166.590694	166.590694	166.590694	482.677471	482.677471	482.677471
2	66.8072354	66.8072354	66.8072354	66.8072354	66.8072354	66.8072354	166.762651	166.762651	166.762651	166.762651	166.762651	166.762651	482.849428	482.849428	482.849428
2	66.8546334	66.8546334	66.8546334	66.8546334	66.8546334	66.8546334	166.810049	166.810049	166.810049	166.810049	166.810049	166.810049	482.896827	482.896827	482.896827

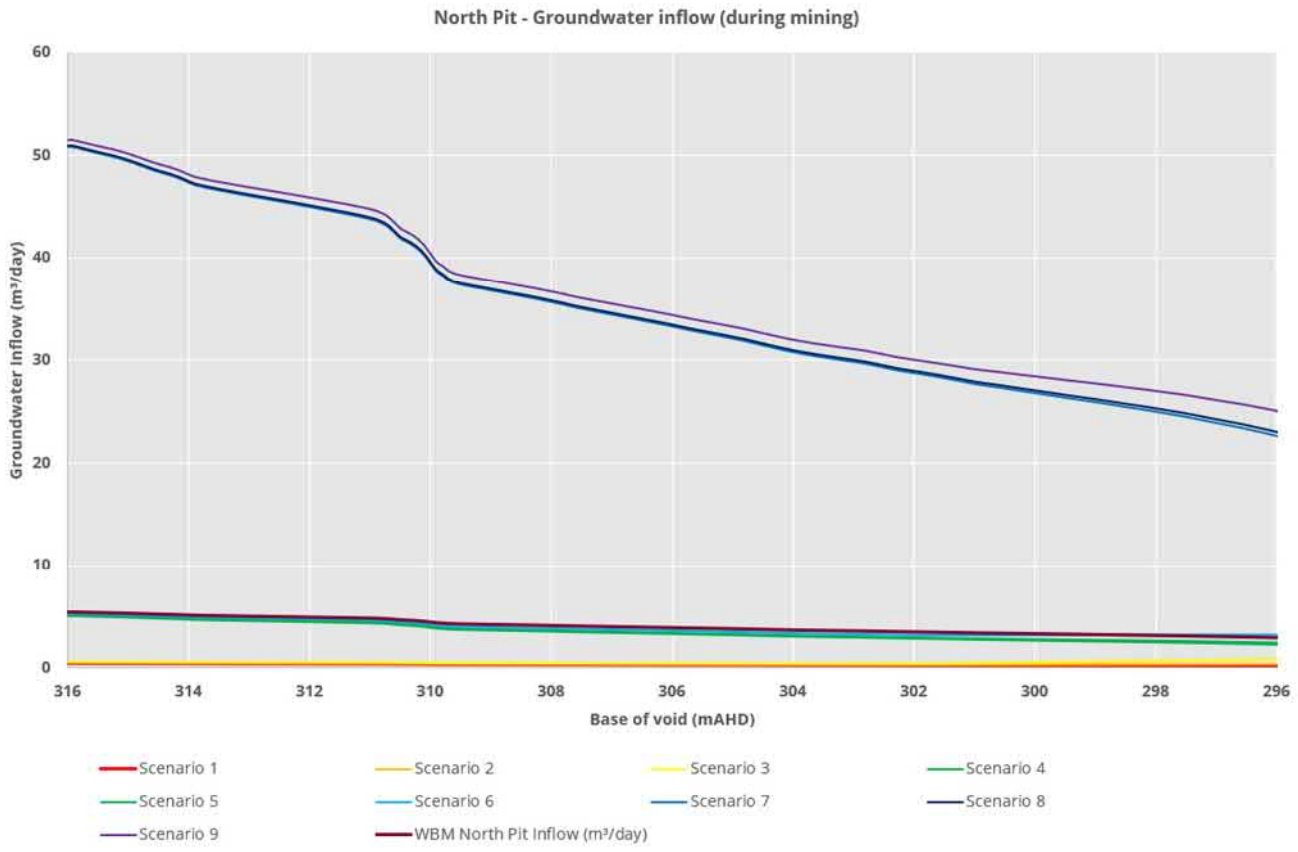
Type	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Void Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
306	32.2198159	32.2198159	32.2198159	0.02276526	0.04098538	0.02636973	0.04458985	0.04439206	0.06261218	0.22162778	0.40382898	0.23357313	0.41577433	0.29329987	0.47550107
291	55.2539615	55.2539615	55.2539615	0.05867346	0.10350425	0.0657648	0.1105956	0.10122152	0.14605232	0.57654697	1.02485491	0.60670992	1.05501786	0.75752467	1.20583261
265	93.5912509	93.5912509	93.5912509	0.12589793	0.17560716	0.14068228	0.19039151	0.21460404	0.26431326	1.24113082	1.73822307	1.31758036	1.81467261	1.69982807	2.19692031
241	128.572062	128.572062	128.572062	0.19198999	0.23681917	0.21578547	0.26061465	0.3347629	0.37959208	1.89434197	2.34263381	2.03006528	2.47835713	2.70868187	3.15697371
221	157.606527	157.606527	157.606527	0.24932944	0.29850056	0.2819568	0.33112792	0.4450936	0.49426471	2.46099903	2.95271016	2.658091	3.14980214	3.64355089	4.13526202
200	187.896471	187.896471	187.896471	0.30734291	0.30734291	0.35018962	0.35018962	0.56442315	0.56442315	3.0343627	3.0343627	3.30656421	3.30656421	4.66757174	4.66757174
200	188.562107	188.562107	188.562107	0.32771792	0.32771792	0.37212441	0.37212441	0.59415688	0.59415688	3.23541659	3.23541659	3.51243113	3.51243113	4.89750382	4.89750382
200	189.080358	189.080358	189.080358	0.34358214	0.36233403	0.38920555	0.40795744	0.61732259	0.63607447	3.391954	3.57947288	3.67271837	3.86023725	5.0765402	5.26405908
193	199.487466	199.487466	199.487466	0.37549017	0.43644071	0.42571979	0.48667033	0.67686787	0.73781841	3.70715034	4.31665575	4.01844094	4.62794635	5.57489394	6.18439936
171	230.77936	230.77936	230.77936	0.43047578	0.47929416	0.49255388	0.54137226	0.8029444	0.85176278	4.2507776	4.73896143	4.65563793	5.14382175	6.67993955	7.16812337
153	257.084178	257.084178	257.084178	0.50317817	0.52301066	0.57797261	0.59780511	0.95194482	0.97177732	4.96911452	5.16743948	5.4663903	5.66471526	7.95276921	8.15109417
146	268.04815	268.04815	268.04815	0.56523883	0.56523883	0.64772383	0.64772383	1.06014883	1.06014883	5.58201347	5.58201347	6.12536426	6.12536426	8.84211822	8.84211822
146	268.531045	268.531045	268.531045	0.58666509	0.63750944	0.67075185	0.7215962	1.09118565	1.14203	5.79351915	6.30196266	6.3418596	6.85030311	9.08356186	9.59200537
130	291.299193	291.299193	291.299193	0.63180199	0.6474741	0.72669922	0.74237133	1.20118536	1.21685747	6.23974981	6.39647086	6.87564152	7.03236257	10.0551001	10.2118211
125	298.624724	298.624724	298.624724	0.65606984	0.65606984	0.7552376	0.7552376	1.25107641	1.25107641	6.4795237	6.4795237	7.14650268	7.14650268	10.4813976	10.4813976
125	298.969729	298.969729	298.969729	0.67322388	0.67322388	0.7736661	0.7736661	1.2758772	1.2758772	6.64887315	6.64887315	7.31983265	7.31983265	10.6746301	10.6746301
125	299.209092	299.209092	299.209092	0.68512532	0.68512532	0.7864521	0.7864521	1.29308602	1.29308602	6.7663666	6.7663666	7.44008811	7.44008811	10.8086956	10.8086956
125	299.572229	299.572229	299.572229	0.70318114	0.70318114	0.80585045	0.80585045	1.31919701	1.31919701	6.94461616	6.94461616	7.62252847	7.62252847	11.01209	11.01209
125	299.77764	299.77764	299.77764	0.71339463	0.75830913	0.81682365	0.86173815	1.33396876	1.37888326	7.04544454	7.49458956	7.72572771	8.17487273	11.1271436	11.5762886
112	318.601004	318.601004	318.601004	0.77031743	0.80880331	0.8846759	0.92316177	1.45646824	1.49495412	7.60795085	7.99280962	8.37064178	8.75550055	12.1840964	12.5689552
101	334.483755	334.483755	334.483755	0.81690243	0.84509778	0.94073091	0.96892626	1.55987328	1.58806863	8.06832484	8.35027831	8.90381162	9.1857651	13.0812456	13.363199
93	346.102985	346.102985	346.102985	0.8550961	0.88357363	0.98632596	1.01480349	1.64247526	1.67095278	8.44573716	8.73051245	9.33714039	9.62191567	13.7941565	14.0789318
85	357.726287	357.726287	357.726287	0.89412312	0.96963604	1.03297958	1.10849251	1.72726189	1.80277482	8.83138385	9.5865131	9.78055909	10.5356883	14.5264353	15.2815646
64	387.749786	387.749786	387.749786	0.96762479	0.99975627	1.12515304	1.15728452	1.91279428	1.94492576	9.55794425	9.87925905	10.6600122	10.981327	16.1703518	16.4916666
55	400.718303	400.718303	400.718303	1.00565001	1.08091123	1.1720089	1.24727012	2.00380335	2.07906456	9.933756	10.6863681	11.1063683	11.8589804	16.9694299	17.7220421
34	430.684391	430.684391	430.684391	1.07401792	1.10236128	1.26030194	1.2886453	2.19172201	2.22006538	10.6096515	10.8930851	11.9503809	12.2338145	18.6540277	18.9374613
26	442.198807	442.198807	442.198807	1.1070287	1.1070287	1.30171289	1.30171289	2.27513383	2.27513383	10.9359256	10.9359256	12.3453221	12.3453221	19.3923043	19.3923043
26	442.50969	442.50969	442.50969	1.13032829	1.14846976	1.32671657	1.34485804	2.30865796	2.32679942	11.1660003	11.3474149	12.5807523	12.7621669	19.6545126	19.8359272
21	449.927206	449.927206	449.927206	1.16828367	1.23836023	1.3712714	1.44134796	2.38621004	2.4562866	11.5409908	12.2417564	13.0034847	13.7042503	20.3159541	21.0167197
2	477.102586	477.102586	477.102586	1.23625887	1.23625887	1.45933526	1.45933526	2.57471721	2.57471721	12.2129779	12.2129779	13.8452985	13.8452985	22.0069016	22.0069016
2	477.608349	477.608349	477.608349	1.27725704	1.27725704	1.50332601	1.50332601	2.63367087	2.63367087	12.617831	12.617831	14.2595631	14.2595631	22.4682237	22.4682237
2	478.077333	478.077333	478.077333	1.315274	1.315274	1.54411866	1.54411866	2.68834192	2.68834192	12.9932434	12.9932434	14.6437033	14.6437033	22.8960029	22.8960029
2	478.468628	478.468628	478.468628	1.34699348	1.34699348	1.57815454	1.57815454	2.73395986	2.73395986	13.3064678	13.3064678	14.9642102	14.9642102	23.2529226	23.2529226
2	478.838064	478.838064	478.838064	1.37694107	1.37694107	1.61028958	1.61028958	2.77703213	2.77703213	13.6021941	13.6021941	15.2668127	15.2668127	23.5899058	23.5899058
2	479.158493	479.158493	479.158493	1.40291608	1.40291608	1.63816221	1.63816221	2.81439287	2.81439287	13.8586912	13.8586912	15.5292742	15.5292742	23.8821891	23.8821891
2	479.299481	479.299481	479.299481	1.41434507	1.41434507	1.65042625	1.65042625	2.83083218	2.83083218	13.9715496	13.9715496	15.644757	15.644757	24.0107939	24.0107939
2	479.415001	479.415001	479.415001	1.42370956	1.42370956	1.660475	1.660475	2.8443022	2.8443022	14.0640214	14.0640214	15.7393792	15.7393792	24.1161681	24.1161681
2	479.680916	479.680916	479.680916	1.44526564	1.44526564	1.68360632	1.68360632	2.87530975	2.87530975	14.2768816	14.2768816	15.9571895	15.9571895	24.358729	24.358729
2	480.034724	480.034724	480.034724	1.47394673	1.47394673	1.71438367	1.71438367	2.91656837	2.91656837	14.5600986	14.5600986	16.2469931	16.2469931	24.6814656	24.6814656
2	480.423291	480.423291	480.423291	1.50544556	1.50544556	1.74818515	1.74818515	2.96188307	2.96188307	14.8711389	14.8711389	16.5652675	16.5652675	25.0359108	25.0359108
2	480.851512	480.851512	480.851512	1.5401592	1.5401592	1.78543698	1.78543698	3.01182587	3.01182587	15.213923	15.213923	16.9160246	16.9160246	25.4265329	25.4265329
2	481.317614	481.317614	481.317614	1.57794369	1.57794369	1.82598484	1.82598484	3.0661906	3.0661906	15.5870292	15.5870292	17.2978097	17.2978097	25.8517125	25.8517125
2	481.542417	481.542417	481.542417	1.59616739	1.59616739	1.84554158	1.84554158	3.09241249	3.09241249	15.7669801	15.7669801	17.4819468	17.4819468	26.0567803	26.0567803
2	481.576996	481.576996	481.576996	1.59897059	1.59897059	1.84854984	1.84854984	3.09644608	3.09644608	15.7946605	15.7946605	17.5102711	17.5102711	26.0883242	26.0883242

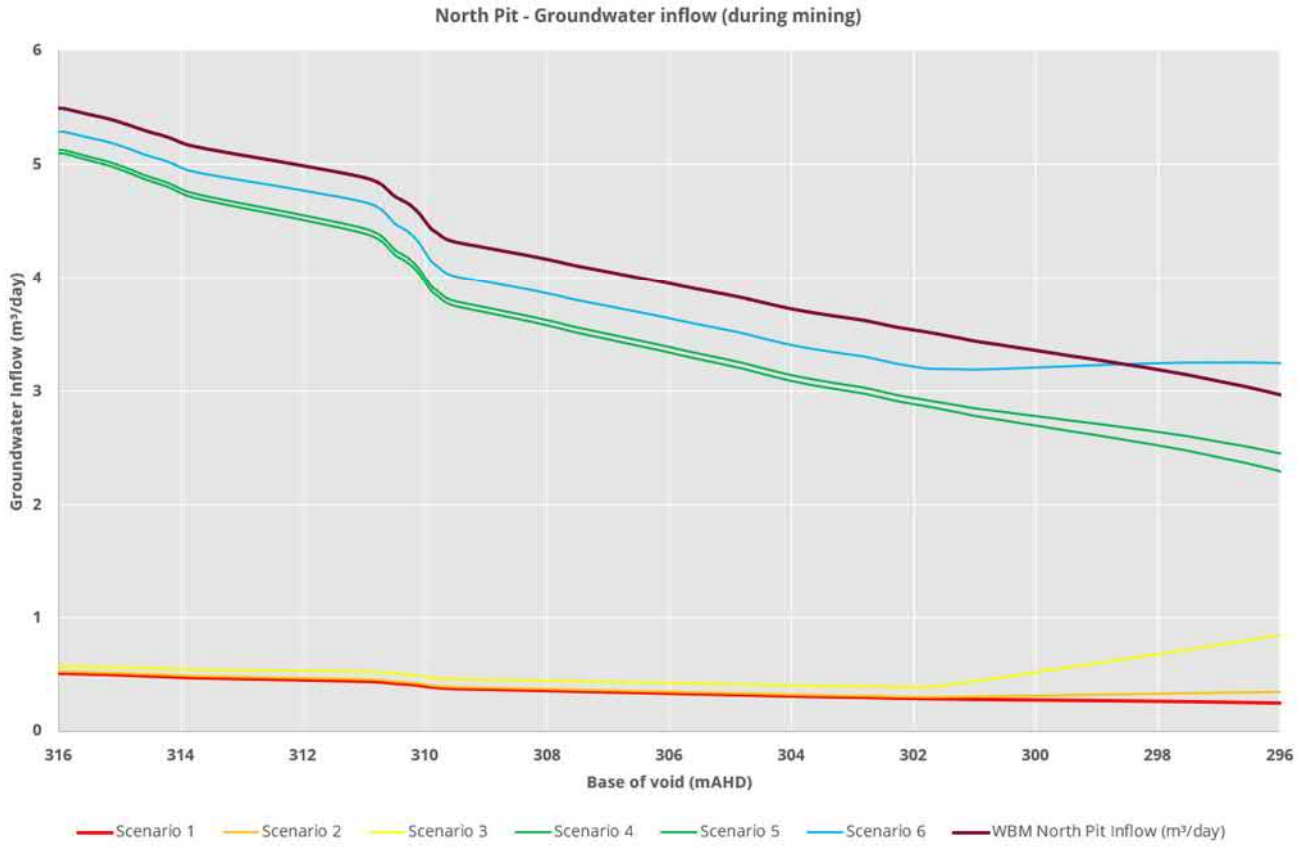
Type	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery
Scenario	8	9	9	1	1	2	2	3	3	4	4	5	5	6	6
Open Void Level (mAHD)	Radius of Influence (m)	Radius of Influence (m)	Radius of Influence (m)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)	GW Inflow (m^3/day)
2	481.616905	481.616905	481.616905	1.60220577	1.60220577	1.85202168	1.85202168	3.10110126	3.10110126	15.8266063	15.8266063	17.5429601	17.5429601	26.1247291	26.1247291
2	481.638563	481.638563	481.638563	1.60396153	1.60396153	1.85390589	1.85390589	3.10362769	3.10362769	15.8439437	15.8439437	17.5607008	17.5607008	26.1444864	26.1444864
2	481.699203	481.699203	481.699203	1.60887732	1.60887732	1.8591813	1.8591813	3.11070123	3.11070123	15.8924848	15.8924848	17.6103711	17.6103711	26.1998029	26.1998029
2	481.759699	481.759699	481.759699	1.61378144	1.61378144	1.86444421	1.86444421	3.11775805	3.11775805	15.9409107	15.9409107	17.6599236	17.6599236	26.2549882	26.2549882
2	481.783601	481.783601	481.783601	1.61571912	1.61571912	1.86652365	1.86652365	3.12054631	3.12054631	15.9600444	15.9600444	17.6795024	17.6795024	26.2767927	26.2767927
2	481.830931	481.830931	481.830931	1.61955588	1.61955588	1.87064112	1.87064112	3.12606732	3.12606732	15.9979306	15.9979306	17.71827	17.71827	26.3199672	26.3199672
2	481.893461	481.893461	481.893461	1.62462498	1.62462498	1.87608109	1.87608109	3.13336169	3.13336169	16.0479854	16.0479854	17.7694894	17.7694894	26.377009	26.377009
2	481.927493	481.927493	481.927493	1.62738375	1.62738375	1.87904172	1.87904172	3.13733156	3.13733156	16.075227	16.075227	17.7973647	17.7973647	26.4080531	26.4080531
2	482.083608	482.083608	482.083608	1.64003932	1.64003932	1.8926233	1.8926233	3.1555432	3.1555432	16.2001945	16.2001945	17.9252396	17.9252396	26.5504647	26.5504647
2	482.251516	482.251516	482.251516	1.65365098	1.65365098	1.90723101	1.90723101	3.17513116	3.17513116	16.3346027	16.3346027	18.0627748	18.0627748	26.7036354	26.7036354
2	482.453654	482.453654	482.453654	1.67003747	1.67003747	1.92481672	1.92481672	3.19871297	3.19871297	16.4964108	16.4964108	18.2283475	18.2283475	26.8880314	26.8880314
2	482.677471	482.677471	482.677471	1.68818144	1.68818144	1.94428868	1.94428868	3.22482485	3.22482485	16.6755727	16.6755727	18.411678	18.411678	27.0922046	27.0922046
2	482.849428	482.849428	482.849428	1.70212138	1.70212138	1.959249	1.959249	3.24488712	3.24488712	16.8132218	16.8132218	18.5525299	18.5525299	27.2490705	27.2490705
2	482.896827	482.896827	482.896827	1.70596376	1.70596376	1.96337266	1.96337266	3.25041716	3.25041716	16.8511631	16.8511631	18.5913541	18.5913541	27.2923088	27.2923088

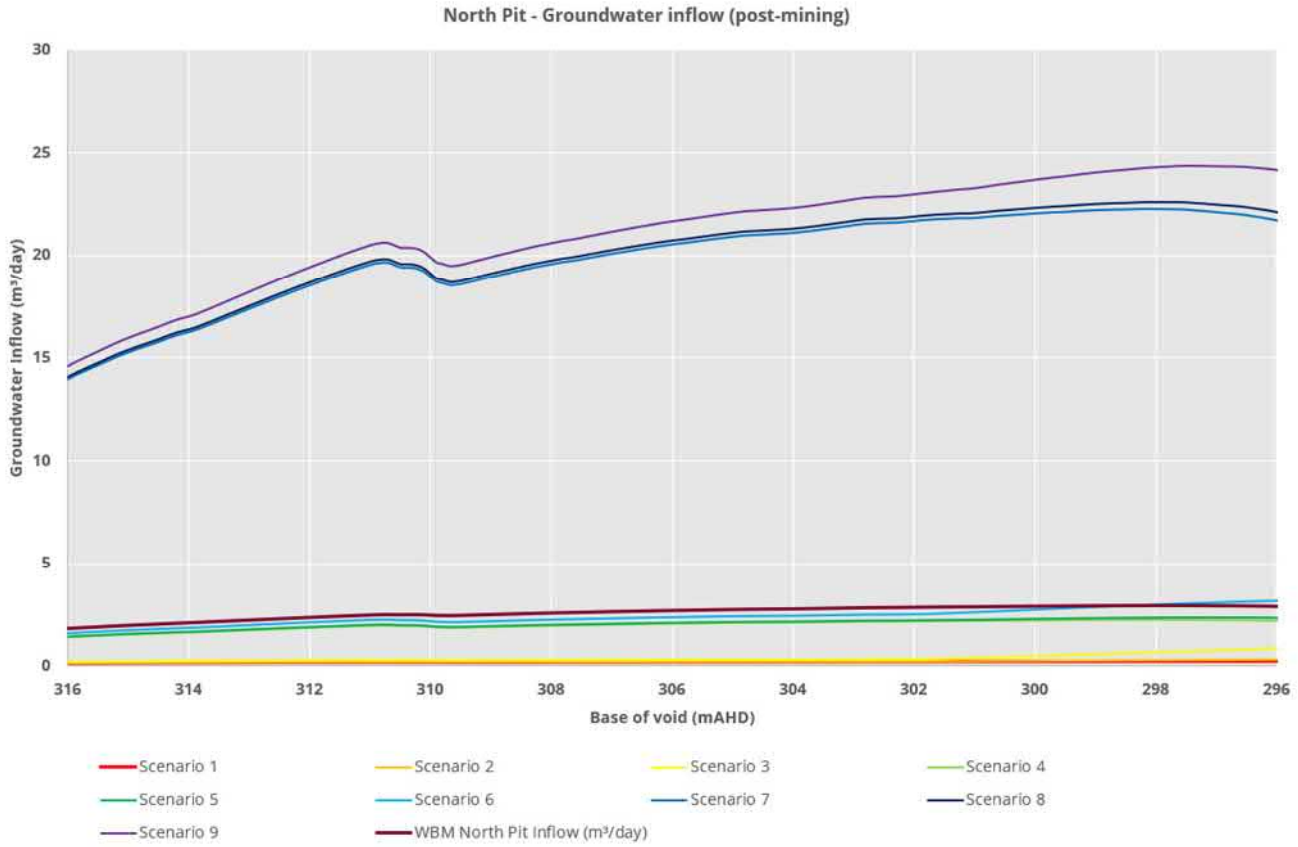
Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Void Level (mAHD)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	Mining - WBM GW Inflow (m³/day)	Recovery - WBM GW Inflow (m³/day)
306	2.202517	4.024529	2.26692738	4.08893939	2.5889793	4.4109913	1.0	1.19
291	5.73776464	10.220844	5.92857394	10.4116533	6.88262039	11.3656998	1.4	1.81
265	12.3581209	17.3290434	12.909867	17.8807894	15.6685972	20.6395197	2.0	2.51
241	18.8652065	23.3481249	19.9095867	24.3925051	25.1314882	29.6144066	2.6	3.10
221	24.5101162	29.4272275	26.0815397	30.998651	33.938657	38.8557683	3.2	3.69
200	30.2220178	30.2220178	32.4575958	32.4575958	43.6354858	43.6354858	3.8	3.75
200	32.2242993	32.2242993	34.474978	34.474978	45.7283715	45.7283715	4.0	3.95
200	33.7832387	35.6584275	36.045677	37.9208658	47.3578686	49.2330573	4.1	4.29
193	36.9229422	43.0179963	39.4416032	45.5366574	52.0349087	58.1299628	4.4	5.02
171	42.3390633	47.2209015	45.7128154	50.5946536	62.5815758	67.4634141	4.9	5.42
153	49.4949051	51.4781548	53.6827027	55.6659523	74.6216904	76.60494	5.6	5.83
146	55.5997497	55.5997497	60.1517176	60.1517176	82.9115575	82.9115575	6.2	6.23
146	57.7062582	62.7906933	62.2739293	67.3583644	85.1122849	90.19672	6.4	6.95
130	62.1520587	63.7192693	67.5292186	69.0964291	94.4150179	95.9822284	6.9	7.02
125	64.5406078	64.5406078	70.1918809	70.1918809	98.4482464	98.4482464	7.1	7.09
125	66.2272855	66.2272855	71.8910965	71.8910965	100.210151	100.210151	7.3	7.26
125	67.3974897	67.3974897	73.0699997	73.0699997	101.432549	101.432549	7.4	7.38
125	69.1728077	69.1728077	74.8585155	74.8585155	103.287054	103.287054	7.6	7.55
125	70.1770309	74.6684811	75.8702045	80.3616546	104.336072	108.827522	7.7	8.10
112	75.7807412	79.6293289	82.2125812	86.0611689	114.371781	118.220369	8.2	8.58
101	80.3670773	83.186612	87.4572607	90.2767954	122.908178	125.727712	8.6	8.92
93	84.1268563	86.9746091	91.7188269	94.5665798	129.67868	132.526433	9.0	9.29
85	87.9686693	95.5199618	96.0797452	103.631038	136.635125	144.186417	9.4	10.13
64	95.2073211	98.420469	104.739514	107.952662	152.400481	155.613628	10.1	10.38
55	98.9513429	106.477464	109.132598	116.658719	160.038872	167.564993	10.4	11.17
34	105.6855	108.519836	117.448733	120.28307	176.2649	179.099237	11.1	11.34
26	108.936078	108.936078	121.337331	121.337331	183.343594	183.343594	11.4	11.36
26	111.227661	113.041808	123.645817	125.459963	185.736593	187.55074	11.6	11.77
21	114.963165	121.970821	127.801132	134.808788	191.990966	198.998622	12.0	12.65
2	121.658351	121.658351	136.095846	136.095846	208.283323	208.283323	12.6	12.58
2	125.690781	125.690781	140.157986	140.157986	212.494012	212.494012	13.0	12.98
2	129.429973	129.429973	143.924728	143.924728	216.398505	216.398505	13.4	13.35
2	132.549757	132.549757	147.067499	147.067499	219.65621	219.65621	13.7	13.67
2	135.495255	135.495255	150.034701	150.034701	222.731927	222.731927	14.0	13.96
2	138.050022	138.050022	152.608292	152.608292	225.399641	225.399641	14.2	14.21
2	139.174116	139.174116	153.740668	153.740668	226.573432	226.573432	14.3	14.32
2	140.095155	140.095155	154.668494	154.668494	227.535191	227.535191	14.4	14.42
2	142.215287	142.215287	156.804249	156.804249	229.749058	229.749058	14.6	14.63
2	145.036186	145.036186	159.645934	159.645934	232.694675	232.694675	14.9	14.91
2	148.134211	148.134211	162.766788	162.766788	235.929674	235.929674	15.2	15.22
2	151.54841	151.54841	166.206146	166.206146	239.494828	239.494828	15.6	15.56
2	155.264621	155.264621	169.949742	169.949742	243.375352	243.375352	15.9	15.92
2	157.056967	157.056967	171.755298	171.755298	245.246949	245.246949	16.1	16.10
2	157.332669	157.332669	172.033031	172.033031	245.534841	245.534841	16.1	16.13

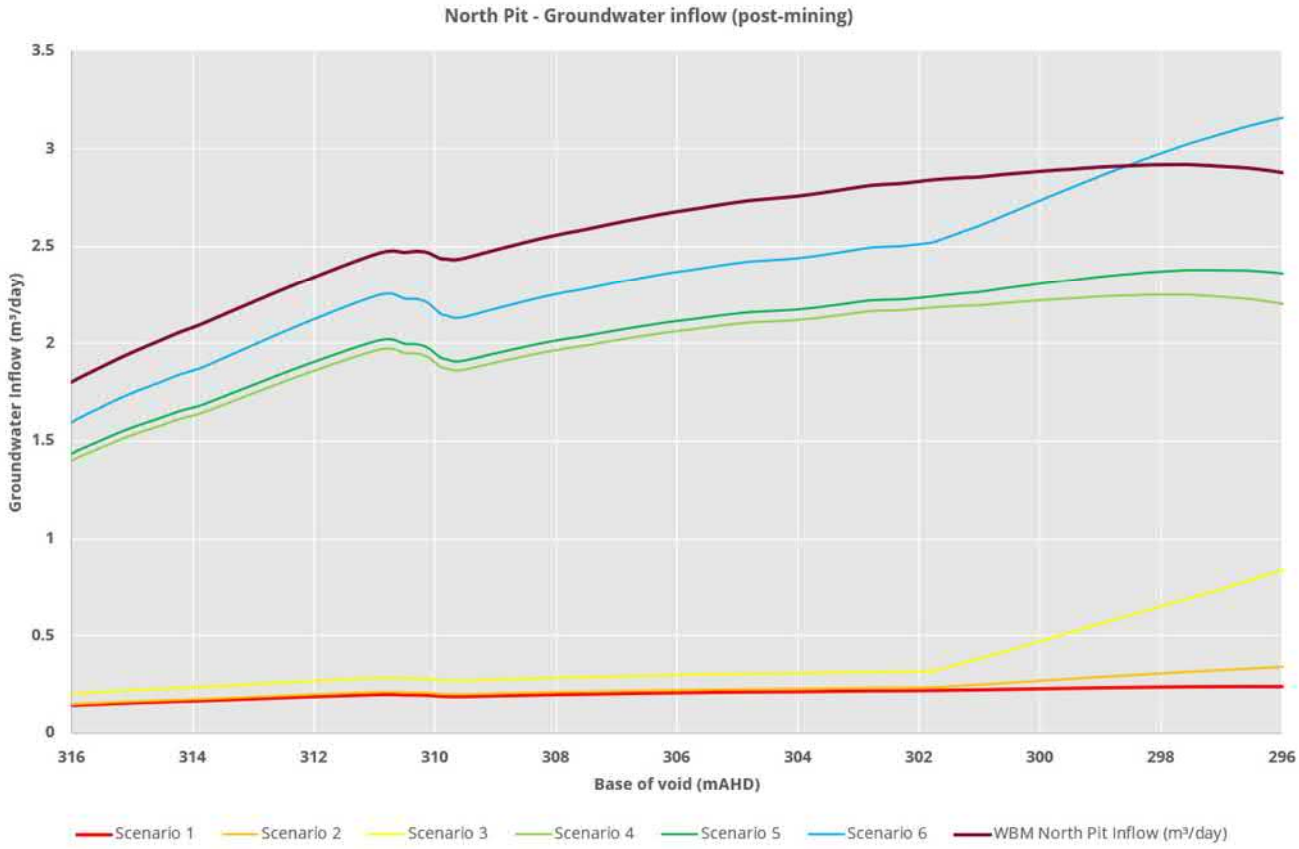
Type	Dewatering	Recovery	Dewatering	Recovery	Dewatering	Recovery		
Scenario	7	7	8	8	9	9		
Open Void Level (mAHD)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	GW Inflow (m³/day)	Mining - WBM GW Inflow (m³/day)	Recovery - WBM GW Inflow (m³/day)
2	157.650856	157.650856	172.353562	172.353562	245.867097	245.867097	16.2	16.16
2	157.823539	157.823539	172.527519	172.527519	246.047416	246.047416	16.2	16.18
2	158.307018	158.307018	173.01456	173.01456	246.552273	246.552273	16.2	16.23
2	158.789349	158.789349	173.500446	173.500446	247.055931	247.055931	16.3	16.28
2	158.979924	158.979924	173.692426	173.692426	247.254933	247.254933	16.3	16.29
2	159.357278	159.357278	174.07256	174.07256	247.648972	247.648972	16.3	16.33
2	159.855834	159.855834	174.57479	174.57479	248.169572	248.169572	16.4	16.38
2	160.127165	160.127165	174.848121	174.848121	248.452901	248.452901	16.4	16.41
2	161.371865	161.371865	176.101994	176.101994	249.752639	249.752639	16.5	16.53
2	162.710596	162.710596	177.450591	177.450591	251.150565	251.150565	16.7	16.67
2	164.322234	164.322234	179.074106	179.074106	252.833467	252.833467	16.8	16.83
2	166.106719	166.106719	180.871743	180.871743	254.69686	254.69686	17.0	17.00
2	167.477729	167.477729	182.252857	182.252857	256.128495	256.128495	17.1	17.14
2	167.855632	167.855632	182.633545	182.633545	256.523108	256.523108	17.2	17.18

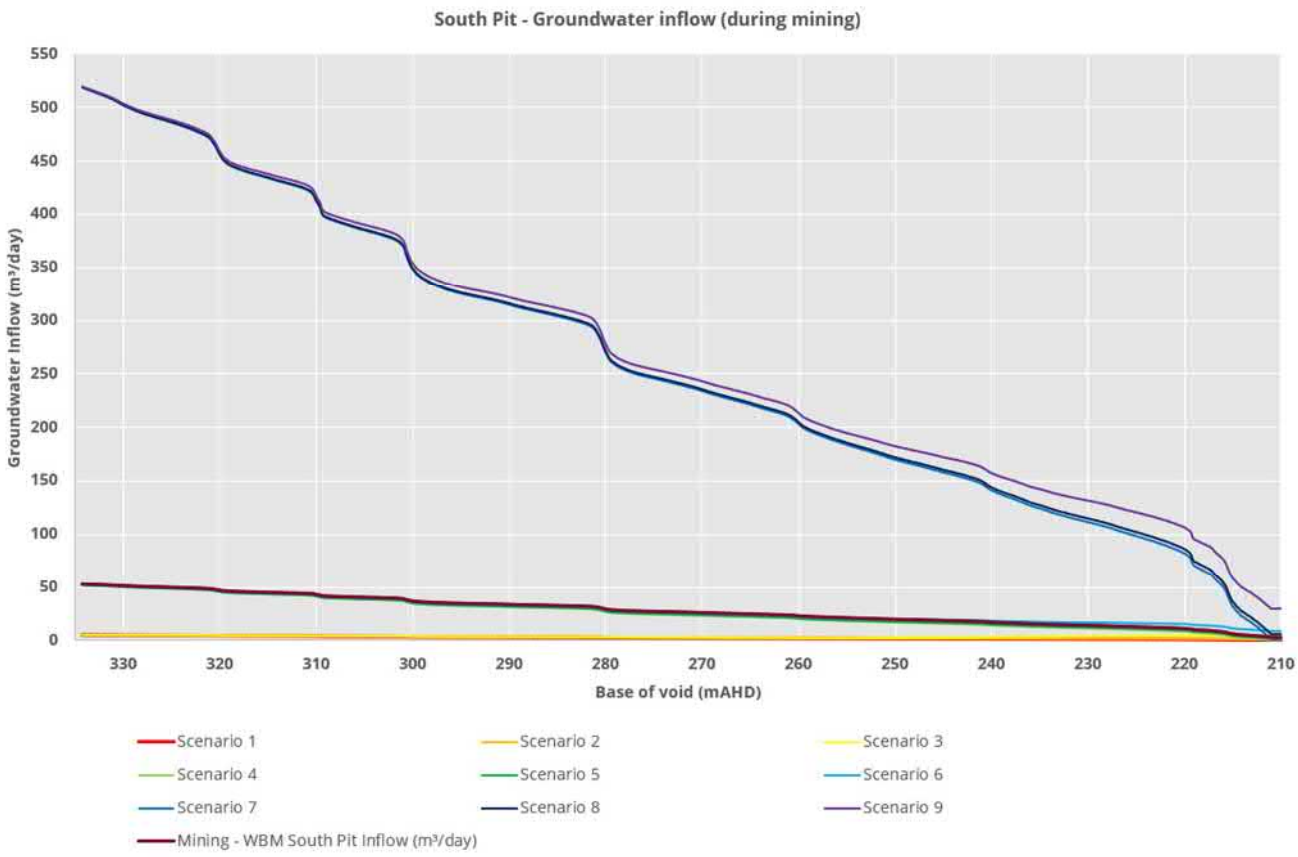
B.3 Graphs of groundwater inflow calculations

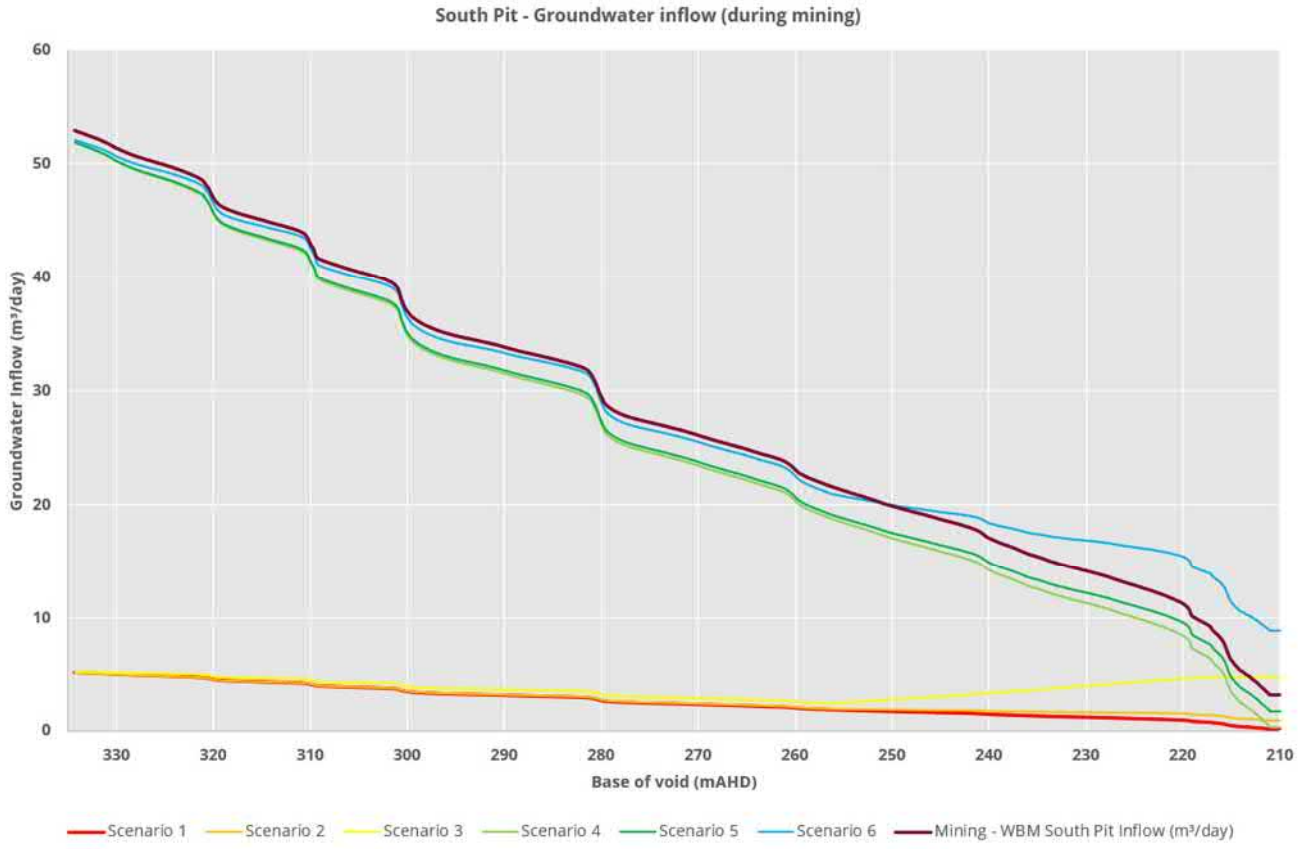


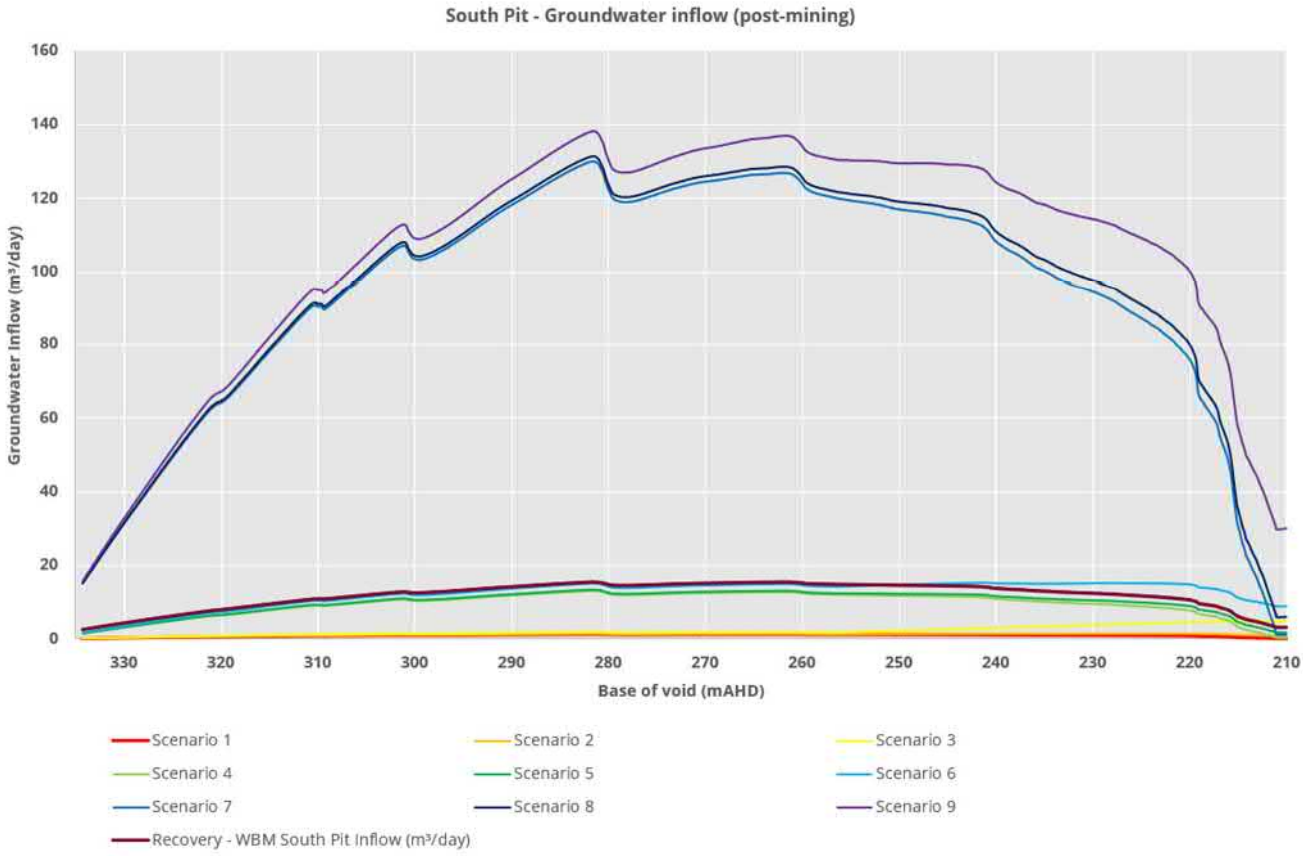


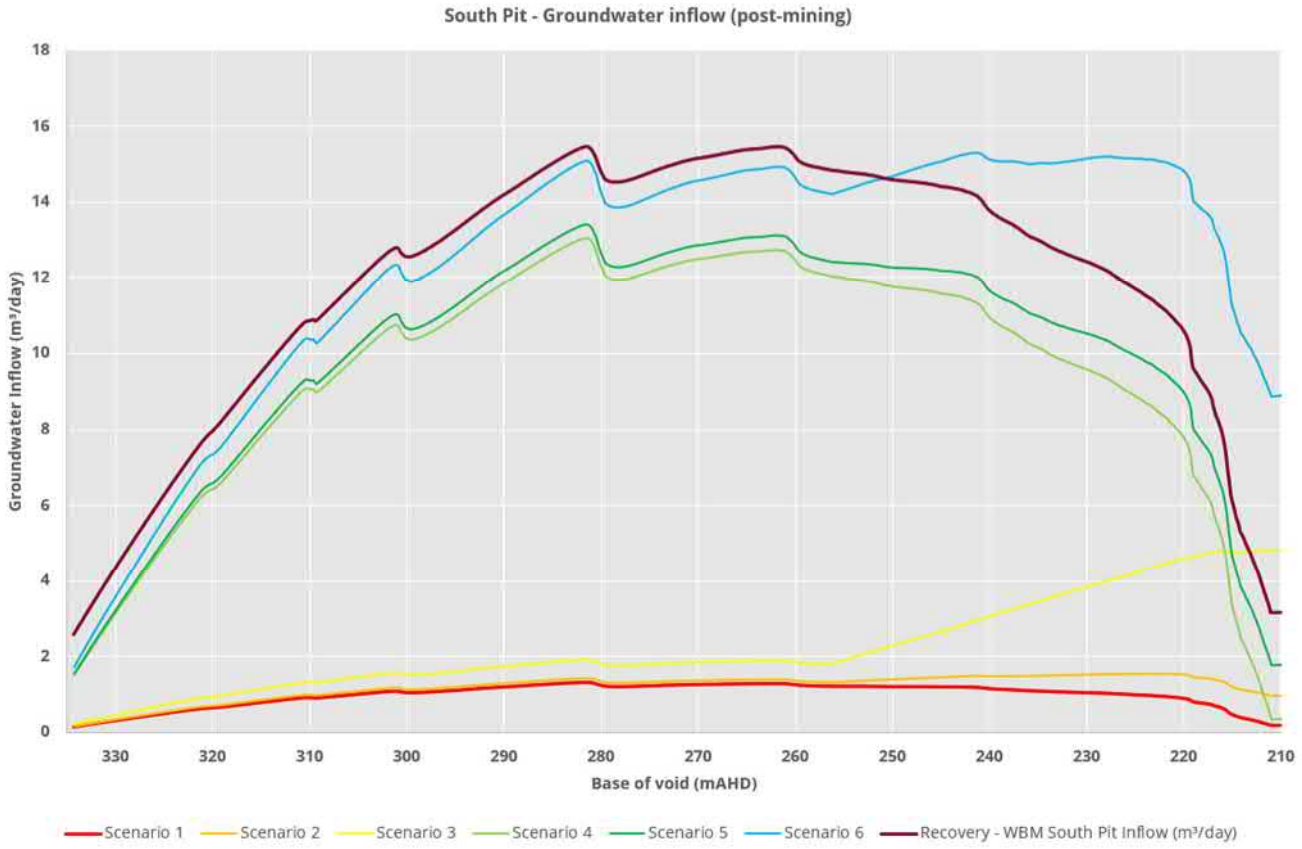

North Pit - Groundwater inflow (post-mining)
Groundwater inflow (m³/day)
30
25
20
15
10
5
0
316
314
312
310
308
306
304
302
300
298
296
Base of void (mAHD)
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
Scenario 7
Scenario 8
Scenario 9
WBM North Pit Inflow (m³/day)

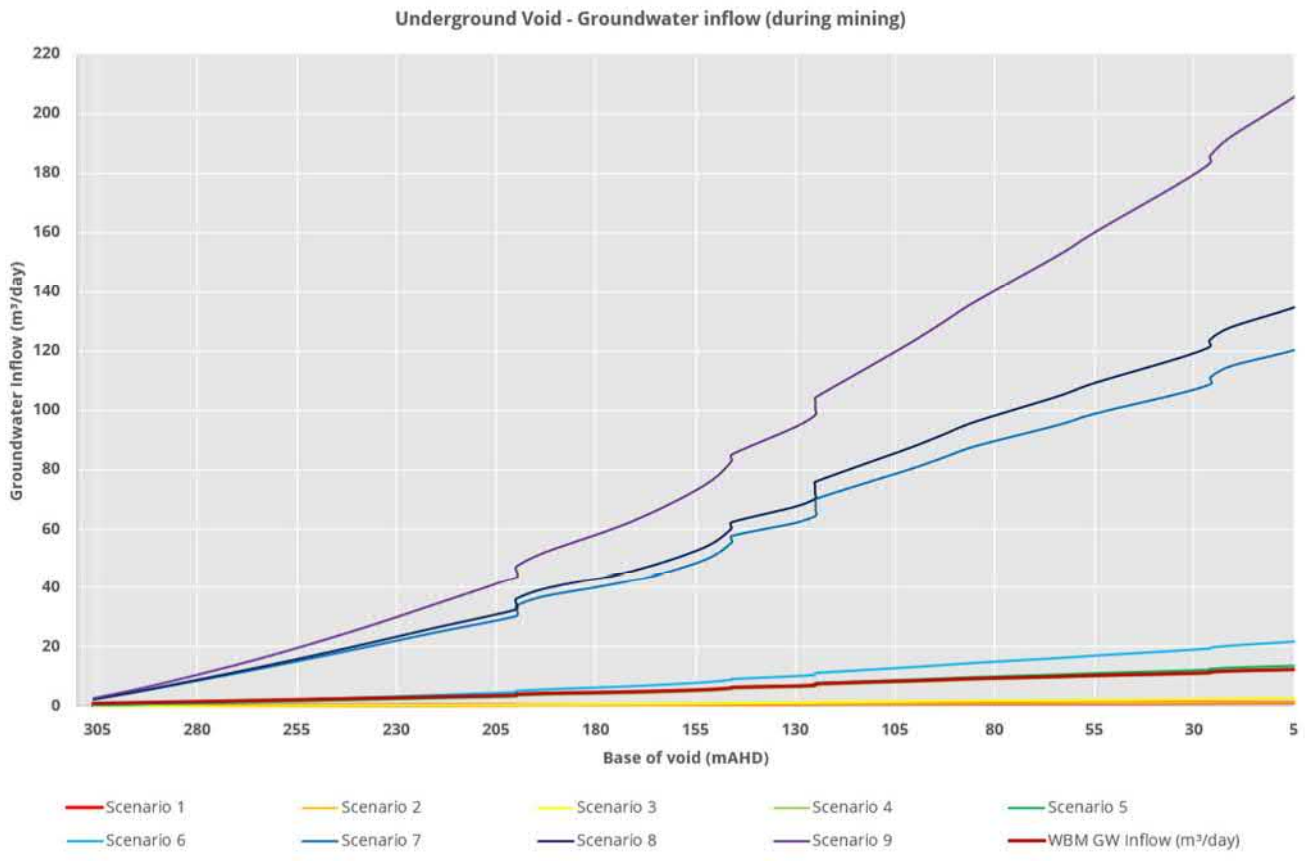

North Pit - Groundwater inflow (post-mining)
Groundwater inflow (m³/day)
3.5
3
2.5
2
1.5
1
0.5
0
316
314
312
310
308
306
304
302
300
298
296
Base of void (mAHD)
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
WBM North Pit Inflow (m³/day)

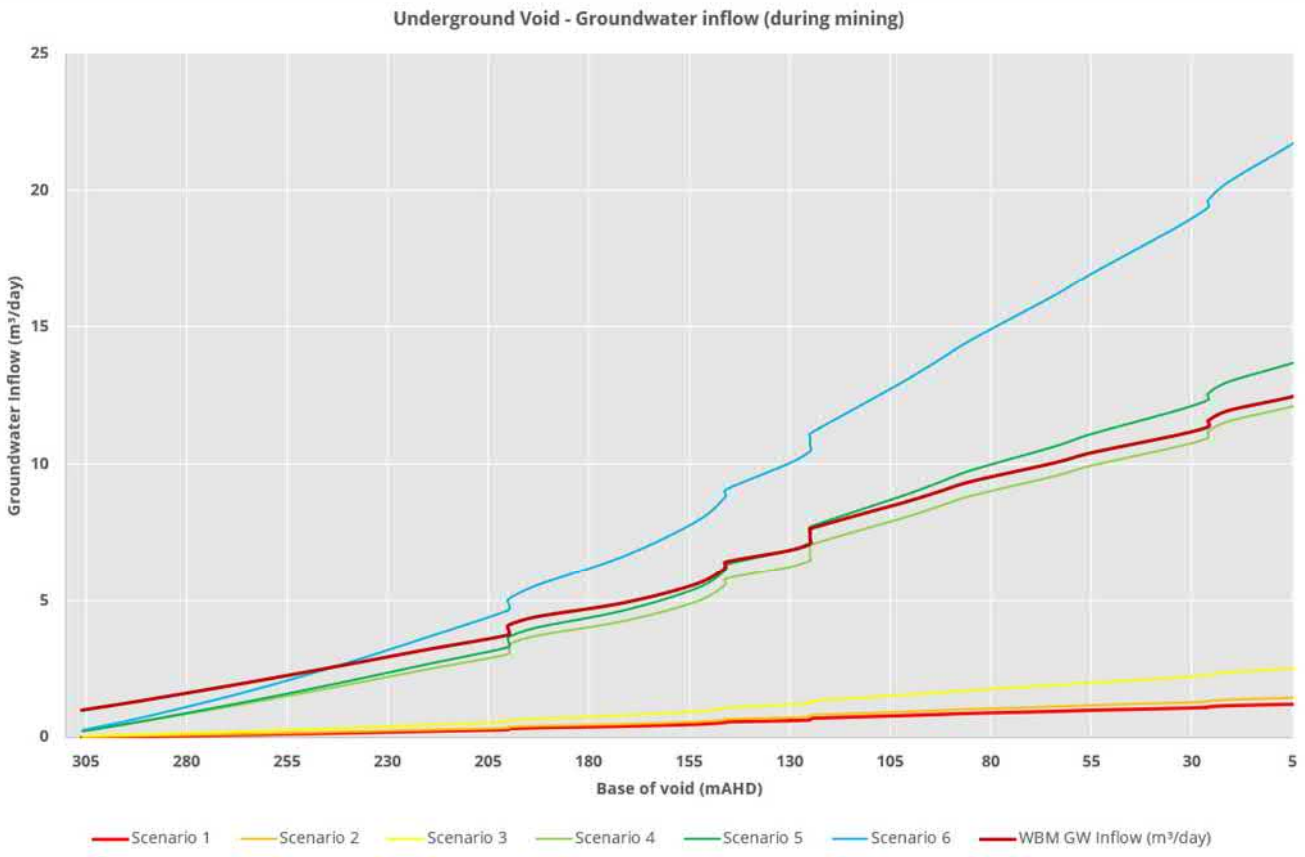

South Pit - Groundwater inflow (during mining)
Groundwater Inflow (m³/day)
550
500
450
400
350
300
250
200
150
100
50
0
330
320
310
300
290
280
270
260
250
240
230
220
210
Base of void (mAHD)
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
Scenario 7
Scenario 8
Scenario 9
Mining - WBM South Pit Inflow (m³/day)

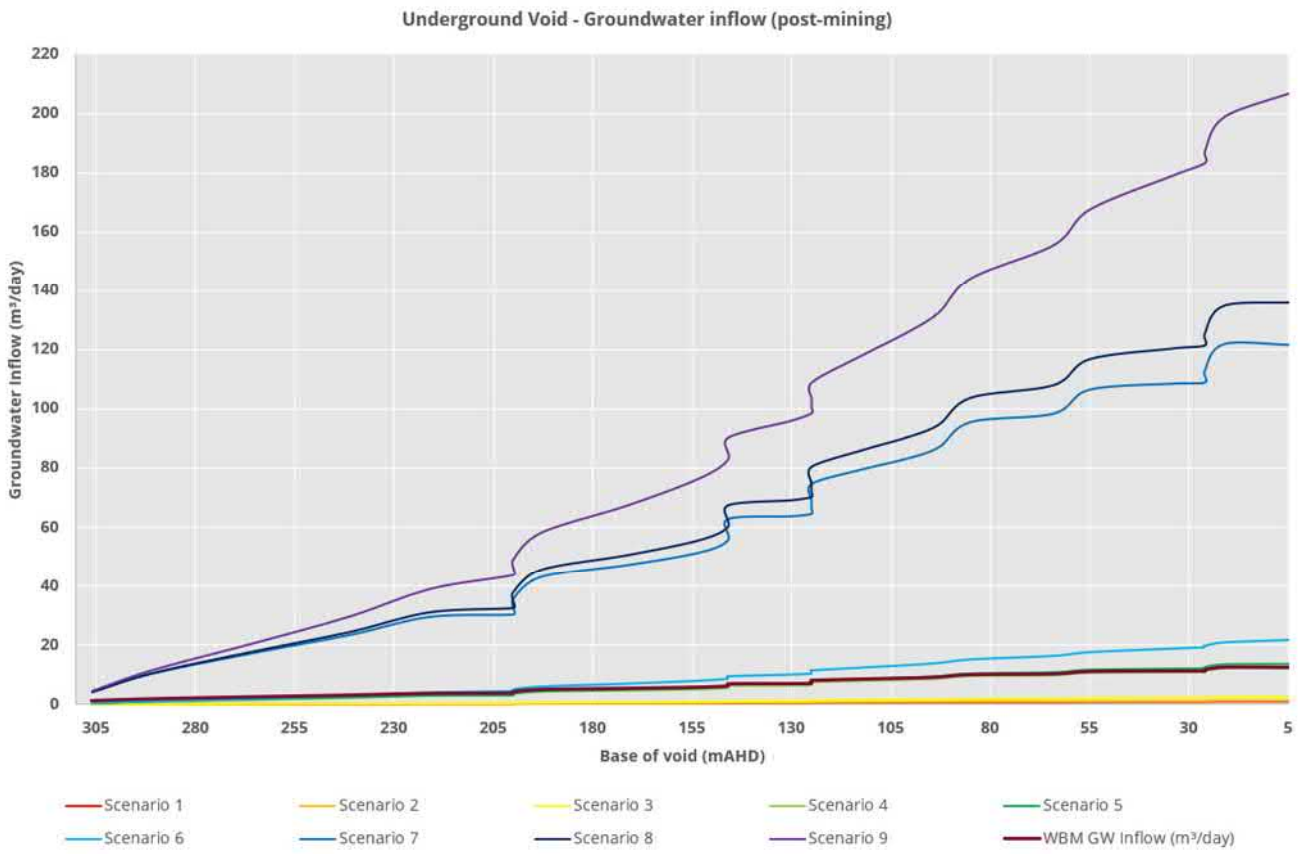

South Pit - Groundwater inflow (during mining)
Groundwater Inflow (m³/day)
60
50
40
30
20
10
0
330
320
310
300
290
280
270
260
250
240
230
220
210
Base of void (mAHD)
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
Mining - WBM South Pit Inflow (m³/day)

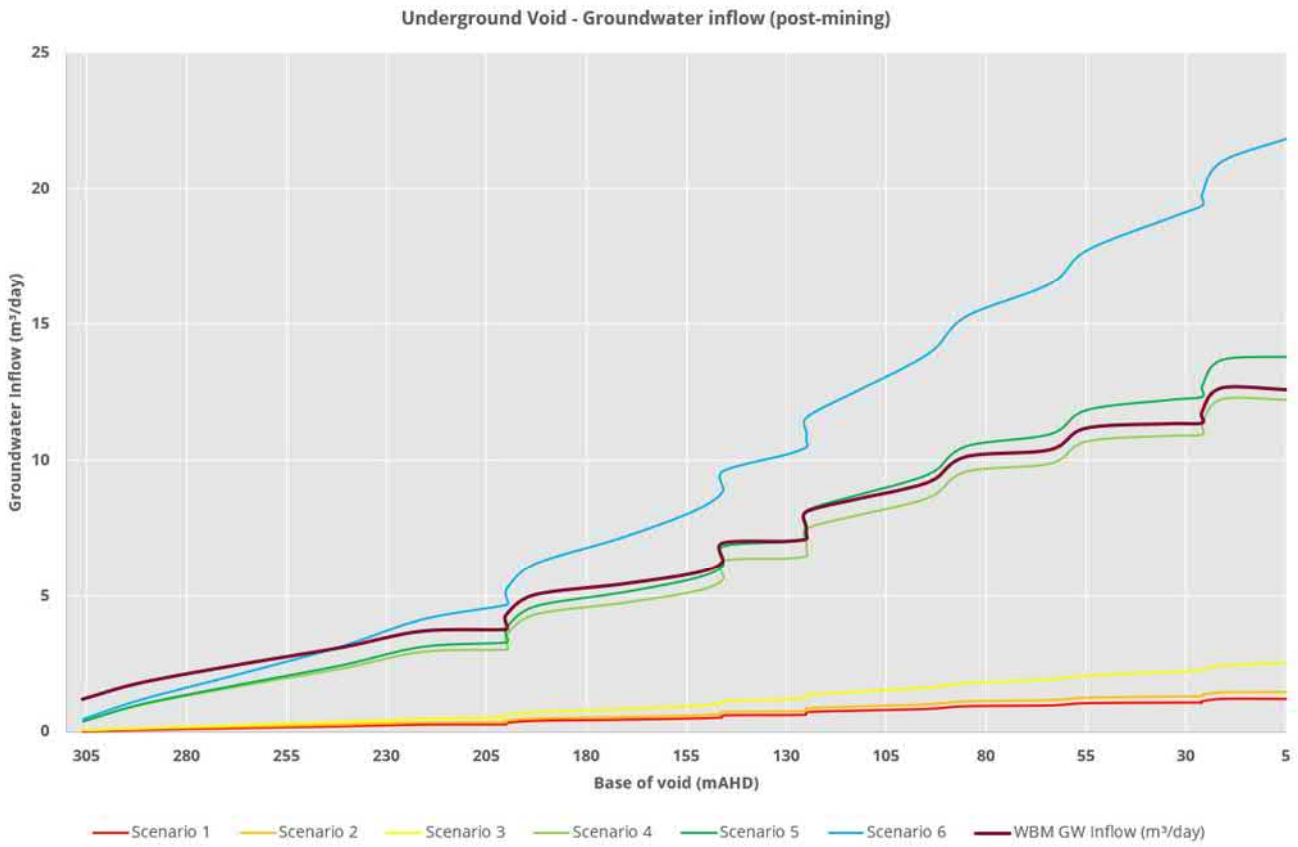

South Pit - Groundwater inflow (post-mining)
Groundwater Inflow (m³/day)
Base of void (mAHD)
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
Scenario 7
Scenario 8
Scenario 9
Recovery - WBM South Pit Inflow (m³/day)


South Pit - Groundwater inflow (post-mining)
Groundwater Inflow (m³/day)
Base of void (mAHD)
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
Recovery - WBM South Pit Inflow (m³/day)


Underground Void - Groundwater inflow (during mining)
Groundwater inflow (m³/day)
220
200
180
160
140
120
100
80
60
40
20
0
305
280
255
230
205
180
155
130
105
80
55
30
5
Base of void (mAHD)
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
Scenario 7
Scenario 8
Scenario 9
WBM GW Inflow (m³/day)


Underground Void - Groundwater inflow (during mining)
Groundwater inflow (m³/day)
25
20
15
10
5
0
305
280
255
230
205
180
155
130
105
80
55
30
5
Base of void (mAHD)
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
WBM GW Inflow (m³/day)


Underground Void - Groundwater inflow (post-mining)
Groundwater Inflow (m³/day)
220
200
180
160
140
120
100
80
60
40
20
0
305
280
255
230
205
180
155
130
105
80
55
30
5
Base of void (mAHD)
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
Scenario 7
Scenario 8
Scenario 9
WBM GW Inflow (m³/day)


Underground Void - Groundwater inflow (post-mining)
Groundwater Inflow (m³/day)
25
20
15
10
5
0
305
280
255
230
205
180
155
130
105
80
55
30
5
Base of void (mAHD)
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
WBM GW Inflow (m³/day)

B.4 Examples of sensitivity analysis calculations

Example of sensitivity analysis calculations

Scenario 9

Open pit Geometry							Radius of Influence					Marinelli and Nicoli (2000)		
UG Void Level (mAHD)	Height (m) (Portal @ 325mAHD)	Volume (m³)	Cumulative Volume of Void (m³)	Cumulative Depth of void (m)	Radius of void (m)	Equivalent Volume Radius (m)	Hydraulic Conductivity Depth Factor	Horizontal Hydraulic Conductivity	Regional GW Level	Drawdown	Radius of Influence	Total GW Inflow	Total GW Inflow	Total GW Inflow
OP_L (h)	Height (m) (Portal @ 325mAHD)	OP_V	OP_V_Cum	OP_D_Cum	Rv	r_0	F_{Kdepth}	K_{h2}	H	s	R	Q_{tot}	Q_{tot}	Q_{tot}
mAHD	m	m³	m³	m	m	sqrt((OP_V_Cum/OP_D_Cum)/pi())	-	m/s	mAHD	m	R=3000 (H-h) √(K_sat)+ r_0	m³/day	m³/day	ML/day
From Void Geometry	From Void Geometry	From Void Geometry	Calculated	Calculated	Calculated	Calculated	Assumed	Assumed	Regional GW Level (assumed level before mining - BAWBR01-BAWB02 June 2018)	Calculated (H - h)	Calculated	Factor allowing for boundary conditions	Calculated	Calculated
	325.00						1	0.000000229	324			100%	-	
306	19.00	421,078	1,406	11	4.85	6.38	1.00	2.29E-07	324.00	18.00	32.22	100%	2.589	0.00259
291	34.00	419,146	5,070	26	6.89	7.88	1.00	2.29E-07	324.00	33.00	55.25	100%	6.883	0.00688
265	60.00	412,171	12,910	52	8.28	8.89	1.00	2.29E-07	324.00	59.00	93.59	100%	15.669	0.01567
241	84.00	403,180	21,168	76	8.96	9.42	1.00	2.29E-07	324.00	83.00	128.57	100%	25.131	0.02513
221	104.00	395,145	28,599	96	9.36	9.74	1.00	2.29E-07	324.00	103.00	157.61	100%	33.939	0.03394
200	125.00	388,532	35,878	117	9.56	9.88	1.00	2.29E-07	324.00	124.00	187.90	100%	43.635	0.04364
200	125.00	382,434	40,876	117	10.20	10.55	1.00	2.29E-07	324.00	124.00	188.56	100%	45.728	0.04573
200	125.00	381,111	44,992	117	10.70	11.06	1.00	2.29E-07	324.00	124.00	189.08	100%	47.358	0.04736
193	132.00	378,686	50,818	124	11.07	11.42	1.00	2.29E-07	324.00	131.00	199.49	100%	52.035	0.05203
171	154.00	376,856	56,816	146	10.84	11.13	1.00	2.29E-07	324.00	153.00	230.78	100%	62.582	0.06258
153	172.00	375,933	69,250	164	11.32	11.59	1.00	2.29E-07	324.00	171.00	257.08	100%	74.622	0.07462
146	179.00	373,603	84,048	171	12.23	12.51	1.00	2.29E-07	324.00	178.00	268.05	100%	82.912	0.08291
146	179.00	371,275	90,663	171	12.70	12.99	1.00	2.29E-07	324.00	178.00	268.53	100%	85.112	0.08511
130	195.00	370,445	96,091	187	12.52	12.79	1.00	2.29E-07	324.00	194.00	291.30	100%	94.415	0.09442
125	200.00	368,918	100,948	192	12.68	12.94	1.00	2.29E-07	324.00	199.00	298.62	100%	98.448	0.09845
125	200.00	367,598	106,404	192	13.01	13.28	1.00	2.29E-07	324.00	199.00	298.97	100%	100.210	0.10021
125	200.00	359,073	110,274	192	13.25	13.52	1.00	2.29E-07	324.00	199.00	299.21	100%	101.433	0.10143
125	200.00	341,715	116,276	192	13.60	13.88	1.00	2.29E-07	324.00	199.00	299.57	100%	103.287	0.10329
125	200.00	326,147	119,742	192	13.80	14.09	1.00	2.29E-07	324.00	199.00	299.78	100%	104.336	0.10434
112	213.00	312,335	130,776	205	13.98	14.25	1.00	2.29E-07	324.00	212.00	318.60	100%	114.372	0.11437
101	224.00	300,019	139,558	216	14.08	14.34	1.00	2.29E-07	324.00	223.00	334.48	100%	122.908	0.12291
93	232.00	290,925	147,450	224	14.22	14.48	1.00	2.29E-07	324.00	231.00	346.10	100%	129.679	0.12968
85	240.00	287,018	155,649	232	14.37	14.61	1.00	2.29E-07	324.00	239.00	357.73	100%	136.635	0.13664
64	261.00	282,285	166,859	253	14.27	14.49	1.00	2.29E-07	324.00	260.00	387.75	100%	152.400	0.15240
55	270.00	271,676	173,940	262	14.32	14.54	1.00	2.29E-07	324.00	269.00	400.72	100%	160.039	0.16004
34	291.00	259,696	183,209	283	14.16	14.36	1.00	2.29E-07	324.00	290.00	430.68	100%	176.265	0.17626
26	299.00	247,302	189,162	291	14.19	14.38	1.00	2.29E-07	324.00	298.00	442.20	100%	183.344	0.18334
26	299.00	232,846	197,427	291	14.50	14.70	1.00	2.29E-07	324.00	298.00	442.51	100%	185.737	0.18574
21	304.00	217,744	207,417	296	14.74	14.93	1.00	2.29E-07	324.00	303.00	449.93	100%	191.991	0.19199
2	323.00	207,417	217,744	315	14.65	14.83	1.00	2.29E-07	324.00	322.00	477.10	100%	208.283	0.20828
2	323.00	197,427	232,846	315	15.15	15.34	1.00	2.29E-07	324.00	322.00	477.61	100%	212.494	0.21249
2	323.00	189,162	247,302	315	15.61	15.81	1.00	2.29E-07	324.00	322.00	478.08	100%	216.399	0.21640
2	323.00	183,209	259,696	315	16.00	16.20	1.00	2.29E-07	324.00	322.00	478.47	100%	219.656	0.21966
2	323.00	173,940	271,676	315	16.36	16.57	1.00	2.29E-07	324.00	322.00	478.84	100%	222.732	0.22273
2	323.00	166,859	282,285	315	16.68	16.89	1.00	2.29E-07	324.00	322.00	479.16	100%	225.400	0.22540
2	323.00	155,649	287,018	315	16.82	17.03	1.00	2.29E-07	324.00	322.00	479.30	100%	226.573	0.22657
2	323.00	147,450	290,925	315	16.93	17.15	1.00	2.29E-07	324.00	322.00	479.42	100%	227.535	0.22754
2	323.00	139,558	300,019	315	17.19	17.41	1.00	2.29E-07	324.00	322.00	479.68	100%	229.749	0.22975
2	323.00	130,776	312,335	315	17.54	17.77	1.00	2.29E-07	324.00	322.00	480.03	100%	232.695	0.23269
2	323.00	119,742	326,147	315	17.93	18.15	1.00	2.29E-07	324.00	322.00	480.42	100%	235.930	0.23593

Example of sensitivity analysis calculations

UG Void Level (mAHD)	Height (m) (Portal @ 325mAHD)	Volume (m³)	Cumulative Volume of Void (m³)	Cumulative Depth of void (m)	Radius of void (m)	Equivalent Volume Radius (m)	Hydraulic Conductivity Depth Factor	Horizontal Hydraulic Conductivity	Regional GW Level	Drawdown	Radius of Influence	Total GW Inflow	Total GW Inflow	Total GW Inflow
OP_L (h)	Height (m) (Portal @ 325mAHD)	OP_V	OP_V_Cum	OP_D_Cum	Rv	r_0	F_{Kdepth}	K_{h2}	H	s	R	Q_{tot}	Q_{tot}	Q_{tot}
mAHD	m	m³	m³	m	m	sqrt((OP_V_Cum/OP_D_Cum)/pi())	-	m/s	mAHD	m	R=3000 (H-h) √(K_sat)+ r_0	m³/day	m³/day	ML/day
From Void Geometry	From Void Geometry	From Void Geometry	Calculated	Calculated	Calculated	Calculated	Assumed	Assumed	Regional GW Level (assumed level before mining - BAWBR01-BAWB02 June 2018)	Calculated (H - h)	Calculated	Factor allowing for boundary conditions	Calculated	Calculated
	325.00						1	0.000000229	324			100%	-	
2	323.00	116,276	341,715	315	18.35	18.58	1.00	2.29E-07	324.00	322.00	480.85	100%	239.495	0.23949
2	323.00	110,274	359,073	315	18.81	19.05	1.00	2.29E-07	324.00	322.00	481.32	100%	243.375	0.24338
2	323.00	106,404	367,598	315	19.03	19.27	1.00	2.29E-07	324.00	322.00	481.54	100%	245.247	0.24525
2	323.00	100,948	368,918	315	19.07	19.31	1.00	2.29E-07	324.00	322.00	481.58	100%	245.535	0.24553
2	323.00	96,091	370,445	315	19.11	19.35	1.00	2.29E-07	324.00	322.00	481.62	100%	245.867	0.24587
2	323.00	90,663	371,275	315	19.13	19.37	1.00	2.29E-07	324.00	322.00	481.64	100%	246.047	0.24605
2	323.00	84,048	373,603	315	19.19	19.43	1.00	2.29E-07	324.00	322.00	481.70	100%	246.552	0.24655
2	323.00	69,250	375,933	315	19.25	19.49	1.00	2.29E-07	324.00	322.00	481.76	100%	247.056	0.24706
2	323.00	56,816	376,856	315	19.27	19.51	1.00	2.29E-07	324.00	322.00	481.78	100%	247.255	0.24725
2	323.00	50,818	378,686	315	19.32	19.56	1.00	2.29E-07	324.00	322.00	481.83	100%	247.649	0.24765
2	323.00	44,992	381,111	315	19.38	19.62	1.00	2.29E-07	324.00	322.00	481.89	100%	248.170	0.24817
2	323.00	40,876	382,434	315	19.41	19.66	1.00	2.29E-07	324.00	322.00	481.93	100%	248.453	0.24845
2	323.00	35,878	388,532	315	19.57	19.81	1.00	2.29E-07	324.00	322.00	482.08	100%	249.753	0.24975
2	323.00	28,599	395,145	315	19.73	19.98	1.00	2.29E-07	324.00	322.00	482.25	100%	251.151	0.25115
2	323.00	21,168	403,180	315	19.93	20.18	1.00	2.29E-07	324.00	322.00	482.45	100%	252.833	0.25283
2	323.00	12,910	412,171	315	20.15	20.41	1.00	2.29E-07	324.00	322.00	482.68	100%	254.697	0.25470
2	323.00	5,070	419,146	315	20.32	20.58	1.00	2.29E-07	324.00	322.00	482.85	100%	256.128	0.25613
2	323.00	1,406	421,078	315	20.37	20.63	1.00	2.29E-07	324.00	322.00	482.90	100%	256.523	0.25652

Example of sensitivity analysis calculations

Scenario 9

		Assumptions					Marinelli and Nicoli (2000)							
UG Void Level (mAHD)	Height (m) (Portal @ 325mAHD)	Average annual rainfall	Average Annual Recharge	Base of Aquifer	Radius of Influence	Regional GW Level	Radius of Influence	Radius of Void	Zone 1 Inflows	Radius of Influence	Radius of Void	Hydraulic Conductivity Factor	Horizontal Hydraulic Conductivity	Vertical Hydraulic Conductivity
OP_L (h)	Height (m) (Portal @ 325mAHD)	P	W	B_{aq}	r_o	GW	r_o	r_p	Q1	r_o	r_p		K_{h2}	K_{v2}
mAHD	m	m/year	m/d	mAHD	m	mAHD	m	m	m³/day	m	m		m/day	m/day
From Void Geometry	From Void Geometry	Assume average in Mt Isa (461 mm/year)	Assume 2% of rainfall	Assume base of open pit	Calculated	Assume level before mining - BAWBR01-BAWB02 June 2018	Calculated	From void geometry	Calculated	Calculated	From void calculations	Linear from top to bottom	Assumed	Assume % of K_h
	325.00	461	10%	2		324		-	-		-	Calculated	Calculated	10%
306	19.00	0.001263014	0.000126301	2	32.22	324	32.22	4.85	0.403	32.22	4.85	1.00	1.98E-02	1.98E-03
291	34.00	0.001263014	0.000126301	2	55.25	324	55.25	6.89	1.193	55.25	6.89	1.00	1.98E-02	1.98E-03
265	60.00	0.001263014	0.000126301	2	93.59	324	93.59	8.28	3.448	93.59	8.28	1.00	1.98E-02	1.98E-03
241	84.00	0.001263014	0.000126301	2	128.57	324	128.57	8.96	6.527	128.57	8.96	1.00	1.98E-02	1.98E-03
221	104.00	0.001263014	0.000126301	2	157.61	324	157.61	9.36	9.821	157.61	9.36	1.00	1.98E-02	1.98E-03
200	125.00	0.001263014	0.000126301	2	187.90	324	187.90	9.56	13.972	187.90	9.56	1.00	1.98E-02	1.98E-03
200	125.00	0.001263014	0.000126301	2	188.56	324	188.56	10.20	14.067	188.56	10.20	1.00	1.98E-02	1.98E-03
200	125.00	0.001263014	0.000126301	2	189.08	324	189.08	10.70	14.140	189.08	10.70	1.00	1.98E-02	1.98E-03
193	132.00	0.001263014	0.000126301	2	199.49	324	199.49	11.07	15.742	199.49	11.07	1.00	1.98E-02	1.98E-03
171	154.00	0.001263014	0.000126301	2	230.78	324	230.78	10.84	21.086	230.78	10.84	1.00	1.98E-02	1.98E-03
153	172.00	0.001263014	0.000126301	2	257.08	324	257.08	11.32	26.174	257.08	11.32	1.00	1.98E-02	1.98E-03
146	179.00	0.001263014	0.000126301	2	268.05	324	268.05	12.23	28.450	268.05	12.23	1.00	1.98E-02	1.98E-03
146	179.00	0.001263014	0.000126301	2	268.53	324	268.53	12.70	28.548	268.53	12.70	1.00	1.98E-02	1.98E-03
130	195.00	0.001263014	0.000126301	2	291.30	324	291.30	12.52	33.607	291.30	12.52	1.00	1.98E-02	1.98E-03
125	200.00	0.001263014	0.000126301	2	298.62	324	298.62	12.68	35.320	298.62	12.68	1.00	1.98E-02	1.98E-03
125	200.00	0.001263014	0.000126301	2	298.97	324	298.97	13.01	35.399	298.97	13.01	1.00	1.98E-02	1.98E-03
125	200.00	0.001263014	0.000126301	2	299.21	324	299.21	13.25	35.453	299.21	13.25	1.00	1.98E-02	1.98E-03
125	200.00	0.001263014	0.000126301	2	299.57	324	299.57	13.60	35.536	299.57	13.60	1.00	1.98E-02	1.98E-03
125	200.00	0.001263014	0.000126301	2	299.78	324	299.78	13.80	35.582	299.78	13.80	1.00	1.98E-02	1.98E-03
112	213.00	0.001263014	0.000126301	2	318.60	324	318.60	13.98	40.199	318.60	13.98	1.00	1.98E-02	1.98E-03
101	224.00	0.001263014	0.000126301	2	334.48	324	334.48	14.08	44.314	334.48	14.08	1.00	1.98E-02	1.98E-03
93	232.00	0.001263014	0.000126301	2	346.10	324	346.10	14.22	47.450	346.10	14.22	1.00	1.98E-02	1.98E-03
85	240.00	0.001263014	0.000126301	2	357.73	324	357.73	14.37	50.694	357.73	14.37	1.00	1.98E-02	1.98E-03
64	261.00	0.001263014	0.000126301	2	387.75	324	387.75	14.27	59.576	387.75	14.27	1.00	1.98E-02	1.98E-03
55	270.00	0.001263014	0.000126301	2	400.72	324	400.72	14.32	63.633	400.72	14.32	1.00	1.98E-02	1.98E-03
34	291.00	0.001263014	0.000126301	2	430.68	324	430.68	14.16	73.520	430.68	14.16	1.00	1.98E-02	1.98E-03
26	299.00	0.001263014	0.000126301	2	442.20	324	442.20	14.19	77.508	442.20	14.19	1.00	1.98E-02	1.98E-03
26	299.00	0.001263014	0.000126301	2	442.51	324	442.51	14.50	77.613	442.51	14.50	1.00	1.98E-02	1.98E-03
21	304.00	0.001263014	0.000126301	2	449.93	324	449.93	14.74	80.237	449.93	14.74	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	477.10	324	477.10	14.65	90.234	477.10	14.65	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	477.61	324	477.61	15.15	90.420	477.61	15.15	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	478.08	324	478.08	15.61	90.592	478.08	15.61	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	478.47	324	478.47	16.00	90.736	478.47	16.00	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	478.84	324	478.84	16.36	90.872	478.84	16.36	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	479.16	324	479.16	16.68	90.989	479.16	16.68	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	479.30	324	479.30	16.82	91.041	479.30	16.82	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	479.42	324	479.42	16.93	91.083	479.42	16.93	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	479.68	324	479.68	17.19	91.181	479.68	17.19	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	480.03	324	480.03	17.54	91.311	480.03	17.54	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	480.42	324	480.42	17.93	91.454	480.42	17.93	1.00	1.98E-02	1.98E-03

Example of sensitivity analysis calculations

UG Void Level (mAHD)	Height (m) (Portal @ 325mAHD)	Average annual rainfall	Average Annual Recharge	Base of Aquifer	Radius of Influence	Regional GW Level	Radius of Influence	Radius of Void	Zone 1 Inflows	Radius of Influence	Radius of Void	Hydraulic Conductivity Factor	Horizontal Hydraulic Conductivity	Vertical Hydraulic Conductivity
OP_L (h)	Height (m) (Portal @ 325mAHD)	P	W	B_{aq}	r_o	GW	r_o	r_p	Q1	r_o	r_p		K_{h2}	K_{v2}
mAHD	m	m/year	m/d	mAHD	m	mAHD	m	m	m³/day	m	m		m/day	m/day
From Void Geometry	From Void Geometry	Assume average in Mt Isa (461 mm/year)	Assume 2% of rainfall	Assume base of open pit	Calculated	Assume level before mining - BAWBR01-BAWB02 June 2018	Calculated	From void geometry	Calculated	Calculated	From void calculations	Linear from top to bottom	Assumed	Assume % of K_h
	325.00	461	10%	2		324		-	-		-	Calculated	Calculated	10%
2	323.00	0.001263014	0.000126301	2	480.85	324	480.85	18.35	91.611	480.85	18.35	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	481.32	324	481.32	18.81	91.782	481.32	18.81	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	481.54	324	481.54	19.03	91.865	481.54	19.03	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	481.58	324	481.58	19.07	91.877	481.58	19.07	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	481.62	324	481.62	19.11	91.892	481.62	19.11	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	481.64	324	481.64	19.13	91.900	481.64	19.13	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	481.70	324	481.70	19.19	91.922	481.70	19.19	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	481.76	324	481.76	19.25	91.944	481.76	19.25	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	481.78	324	481.78	19.27	91.953	481.78	19.27	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	481.83	324	481.83	19.32	91.971	481.83	19.32	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	481.89	324	481.89	19.38	91.993	481.89	19.38	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	481.93	324	481.93	19.41	92.006	481.93	19.41	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	482.08	324	482.08	19.57	92.063	482.08	19.57	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	482.25	324	482.25	19.73	92.125	482.25	19.73	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	482.45	324	482.45	19.93	92.199	482.45	19.93	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	482.68	324	482.68	20.15	92.281	482.68	20.15	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	482.85	324	482.85	20.32	92.345	482.85	20.32	1.00	1.98E-02	1.98E-03
2	323.00	0.001263014	0.000126301	2	482.90	324	482.90	20.37	92.362	482.90	20.37	1.00	1.98E-02	1.98E-03

Example of sensitivity analysis calculations

Scenario 9

UG Void Level (mAHD)	Height (m) (Portal @ 325mAHD)	Degree of anisotropy	Saturated Thickness of Aquifer	Depth of water level in void	Zone 2 Inflows
OP_L (h)	Height (m) (Portal @ 325mAHD)	m_2	h_0	d	Q2
mAHD	m	-	m	m	m^3/day
From Void Geometry	From Void Geometry	srqt(K_h/K_v)	Calculate from regional GWL	Set at 0 during dewatering	
	325.00				
306	19.00	3.16228	18	0	2.186
291	34.00	3.16228	33	0	5.690
265	60.00	3.16228	59	0	12.220
241	84.00	3.16228	83	0	18.604
221	104.00	3.16228	103	0	24.117
200	125.00	3.16228	124	0	29.663
200	125.00	3.16228	124	0	31.662
200	125.00	3.16228	124	0	33.218
193	132.00	3.16228	131	0	36.293
171	154.00	3.16228	153	0	41.496
153	172.00	3.16228	171	0	48.448
146	179.00	3.16228	178	0	54.462
146	179.00	3.16228	178	0	56.564
130	195.00	3.16228	194	0	60.808
125	200.00	3.16228	199	0	63.128
125	200.00	3.16228	199	0	64.811
125	200.00	3.16228	199	0	65.979
125	200.00	3.16228	199	0	67.751
125	200.00	3.16228	199	0	68.754
112	213.00	3.16228	212	0	74.173
101	224.00	3.16228	223	0	78.595
93	232.00	3.16228	231	0	82.229
85	240.00	3.16228	239	0	85.941
64	261.00	3.16228	260	0	92.824
55	270.00	3.16228	269	0	96.406
34	291.00	3.16228	290	0	102.745
26	299.00	3.16228	298	0	105.836
26	299.00	3.16228	298	0	108.123
21	304.00	3.16228	303	0	111.754
2	323.00	3.16228	322	0	118.049
2	323.00	3.16228	322	0	122.074
2	323.00	3.16228	322	0	125.806
2	323.00	3.16228	322	0	128.920
2	323.00	3.16228	322	0	131.860
2	323.00	3.16228	322	0	134.410
2	323.00	3.16228	322	0	135.532
2	323.00	3.16228	322	0	136.452
2	323.00	3.16228	322	0	138.568
2	323.00	3.16228	322	0	141.384
2	323.00	3.16228	322	0	144.476

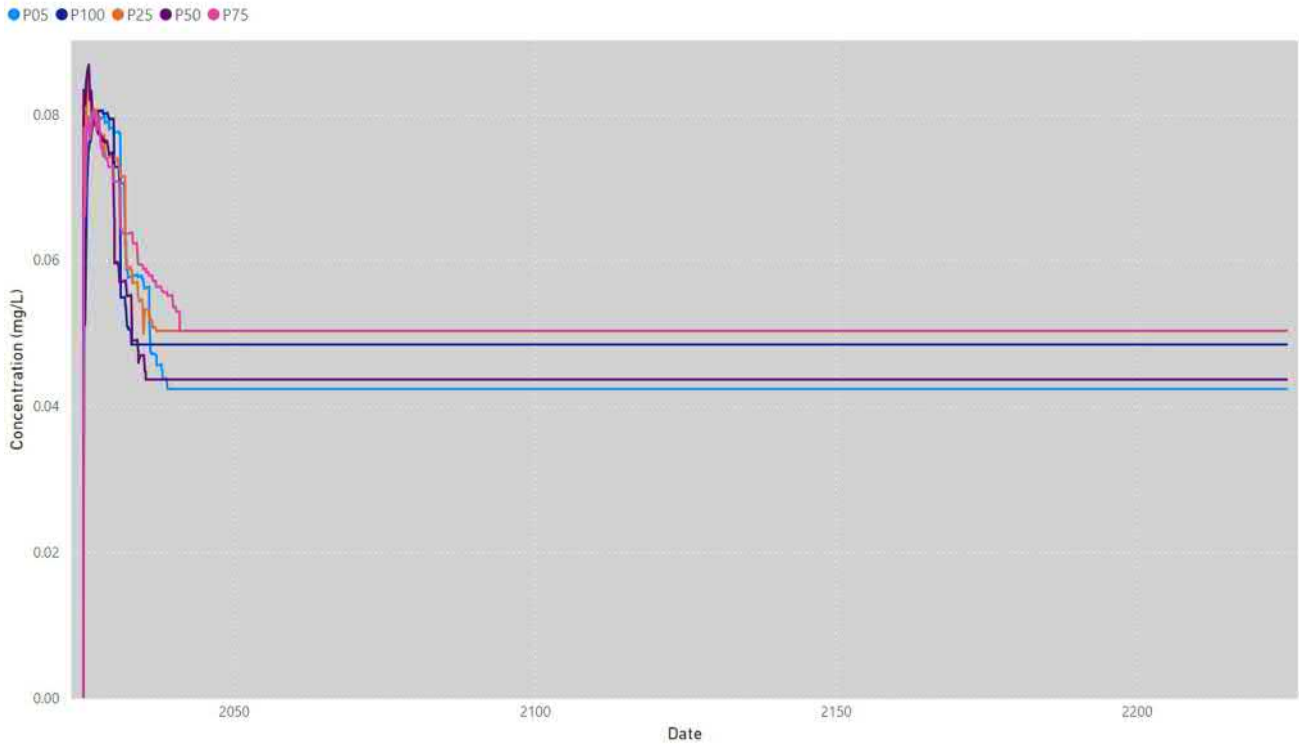
Example of sensitivity analysis calculations

UG Void Level (mAHD)	Height (m) (Portal @ 325mAHD)	Degree of anisotropy	Saturated Thickness of Aquifer	Depth of water level in void	Zone 2 Inflows
OP_L (h)	Height (m) (Portal @ 325mAHD)	m_2	h_0	d	Q2
mAHD	m	-	m	m	m³/day
From Void Geometry	From Void Geometry	srqt(K_h/K_v)	Calculate from regional GWL	Set at 0 during dewatering	
	325.00				
2	323.00	3.16228	322	0	147.884
2	323.00	3.16228	322	0	151.593
2	323.00	3.16228	322	0	153.382
2	323.00	3.16228	322	0	153.658
2	323.00	3.16228	322	0	153.975
2	323.00	3.16228	322	0	154.148
2	323.00	3.16228	322	0	154.630
2	323.00	3.16228	322	0	155.112
2	323.00	3.16228	322	0	155.302
2	323.00	3.16228	322	0	155.678
2	323.00	3.16228	322	0	156.176
2	323.00	3.16228	322	0	156.447
2	323.00	3.16228	322	0	157.689
2	323.00	3.16228	322	0	159.026
2	323.00	3.16228	322	0	160.634
2	323.00	3.16228	322	0	162.415
2	323.00	3.16228	322	0	163.784
2	323.00	3.16228	322	0	164.161

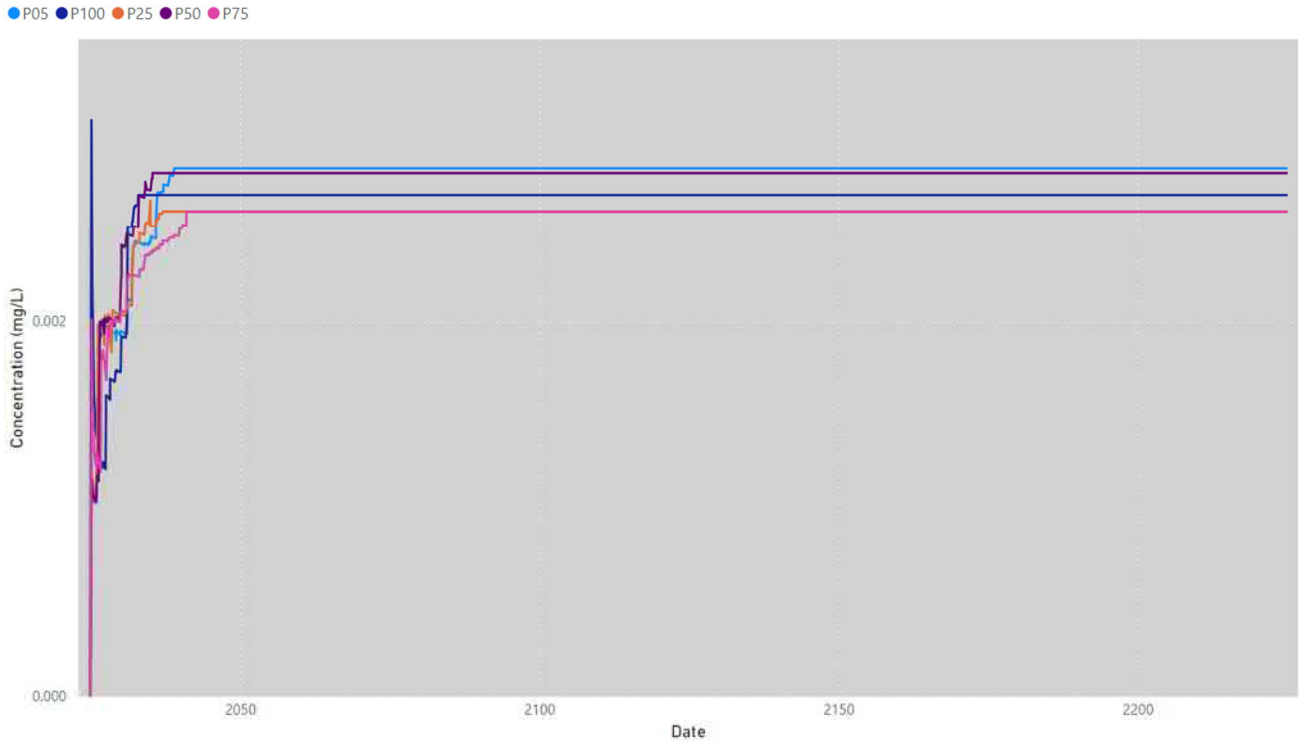
Appendix C Long-term (200 yrs) underground void water quality

C.1 Underground void modelled water quality time series

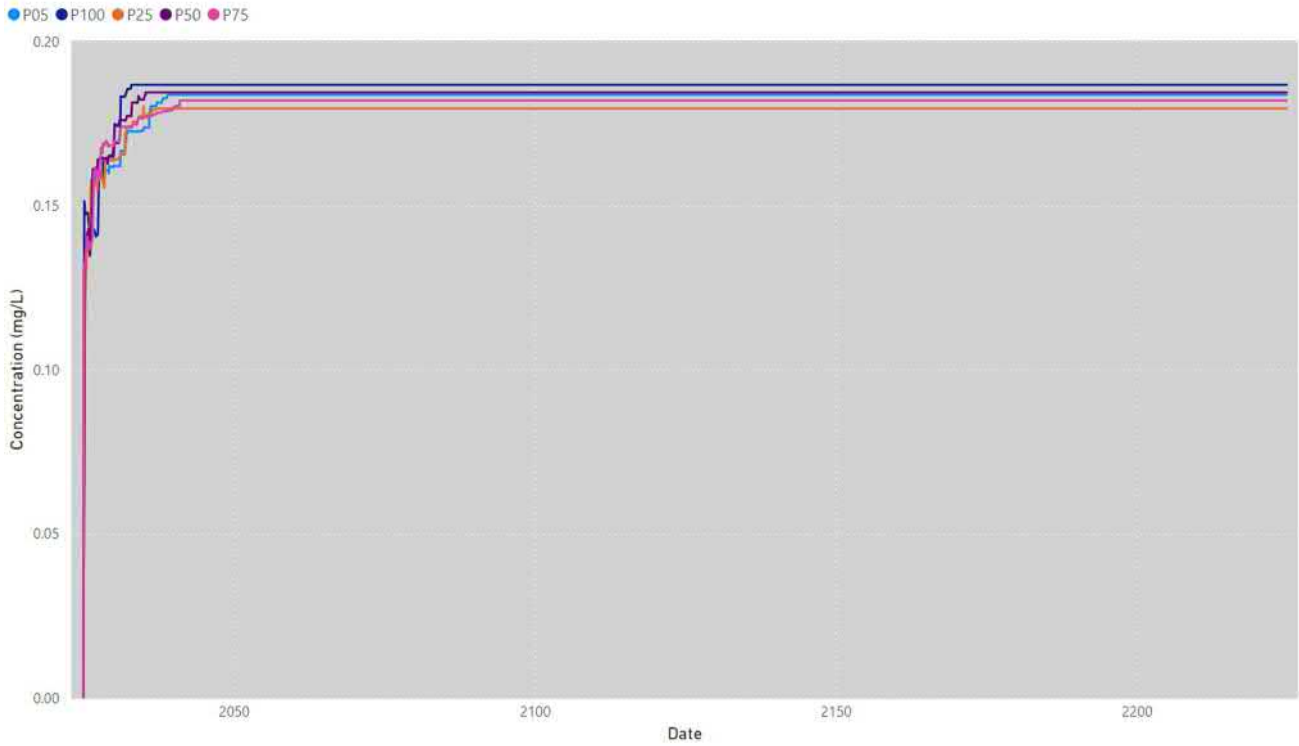
Aluminium



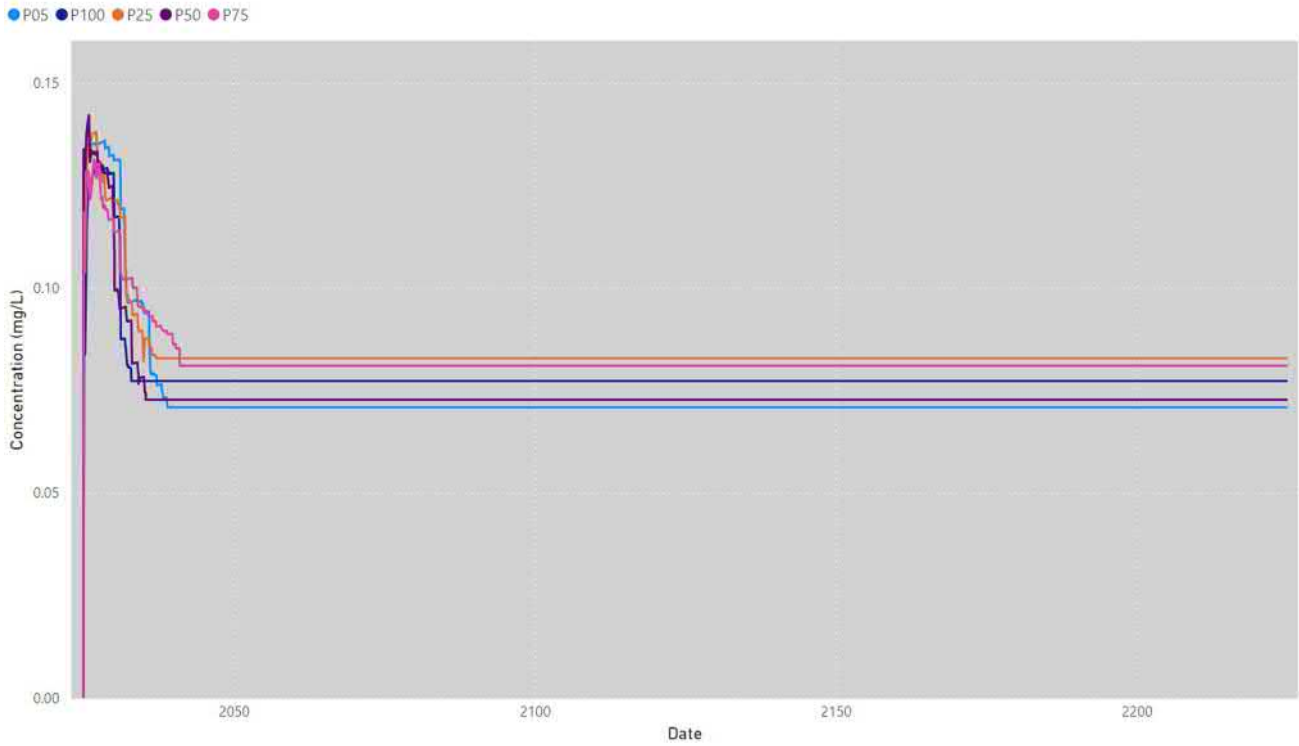
Arsenic



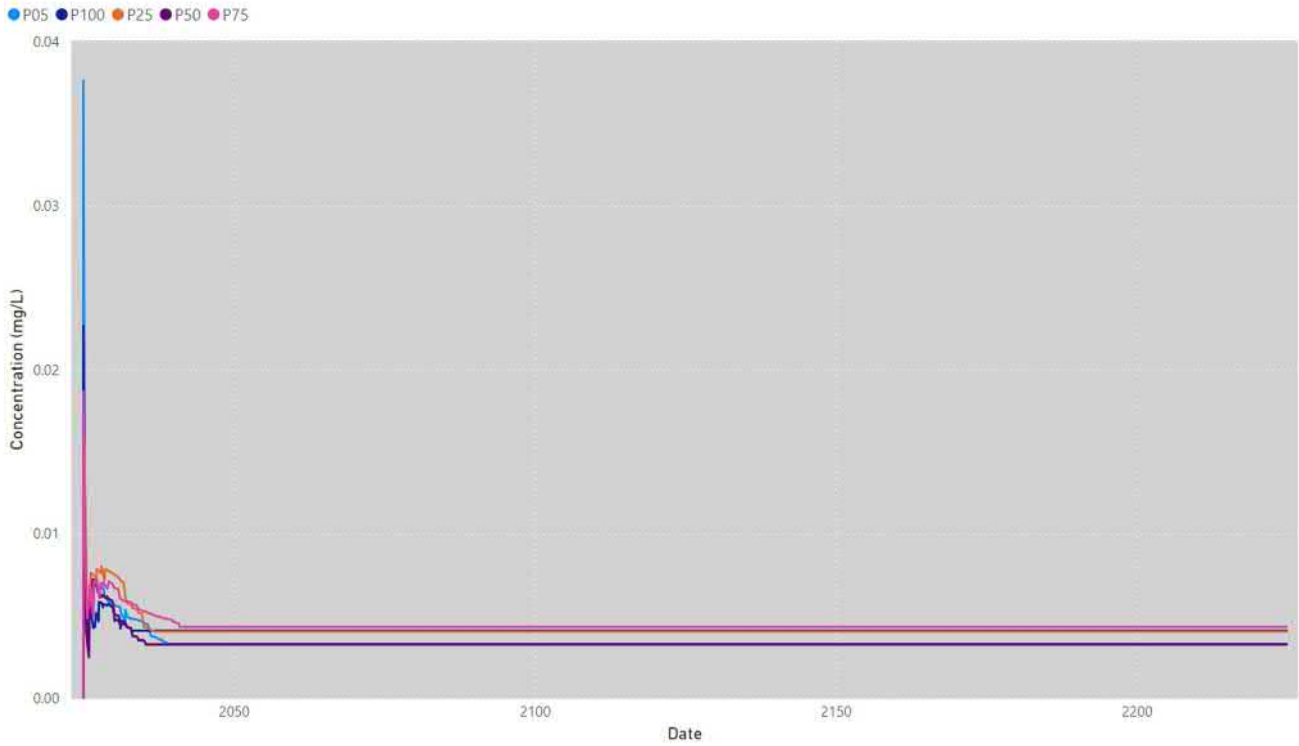
Barium



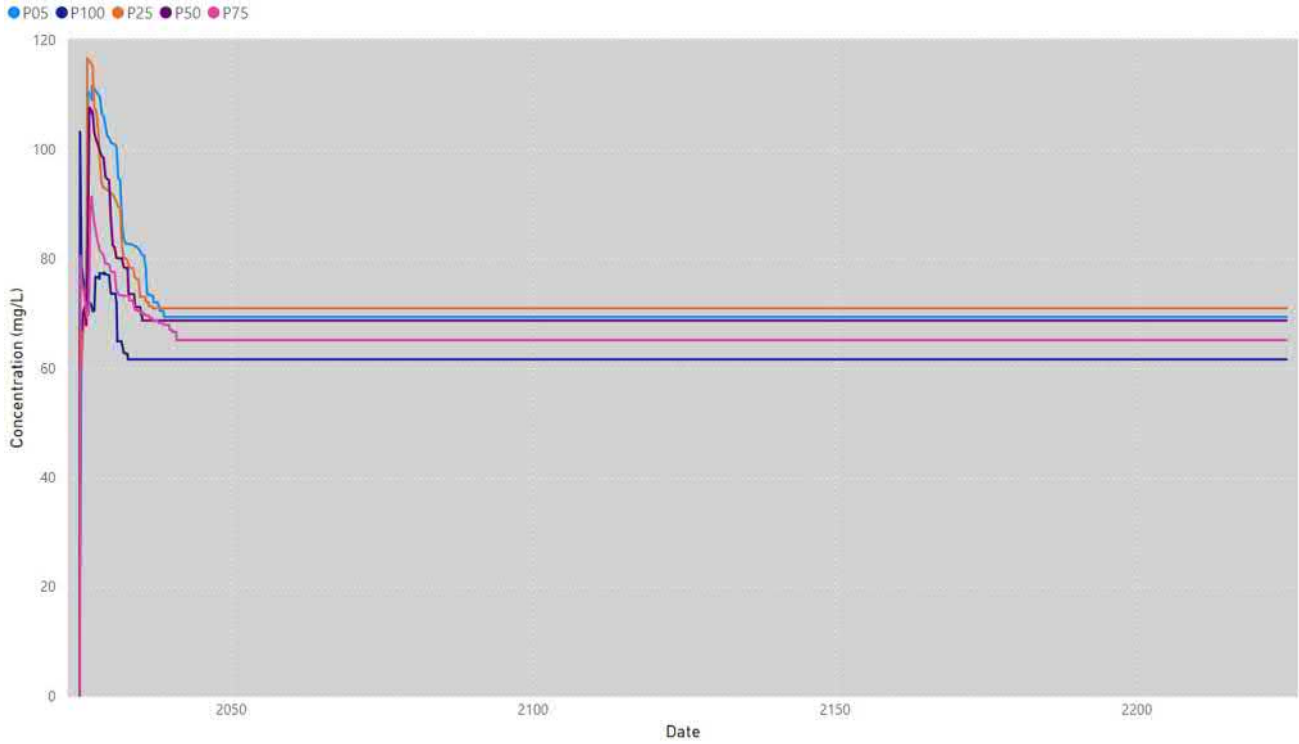
Boron

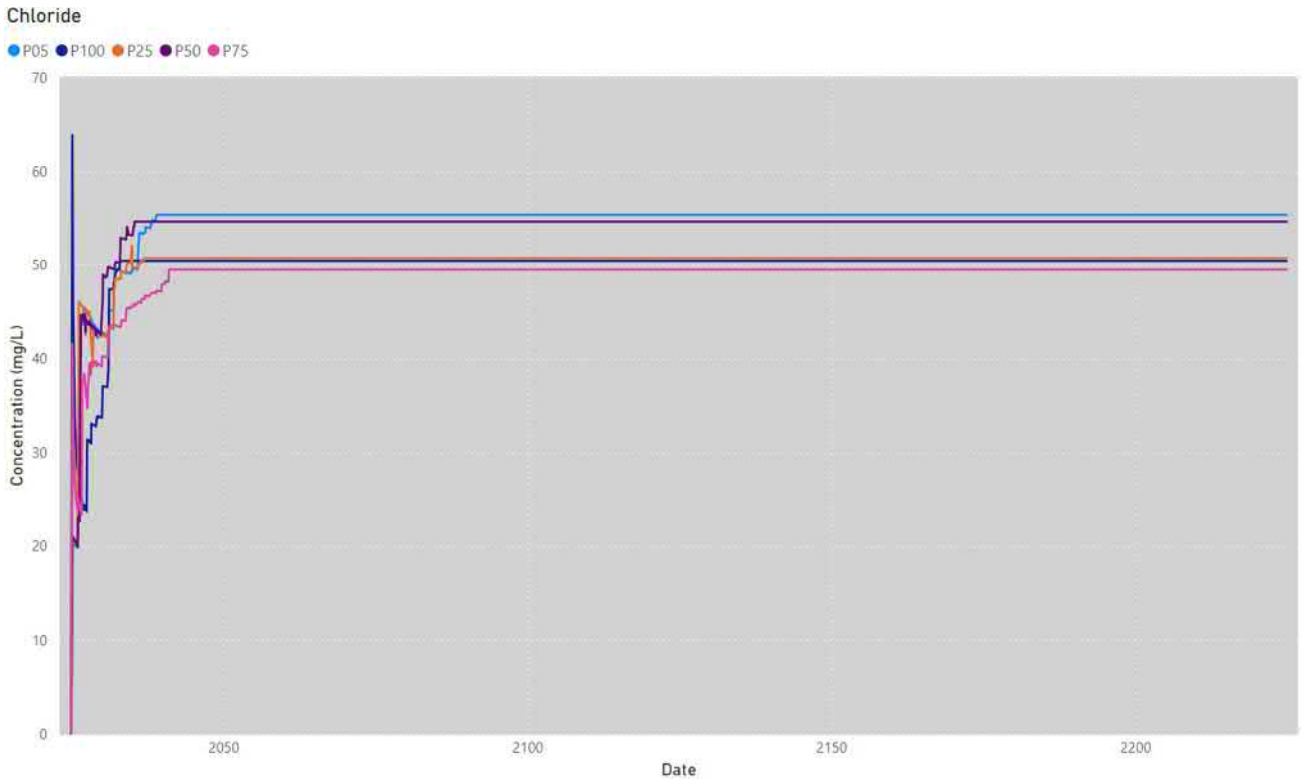


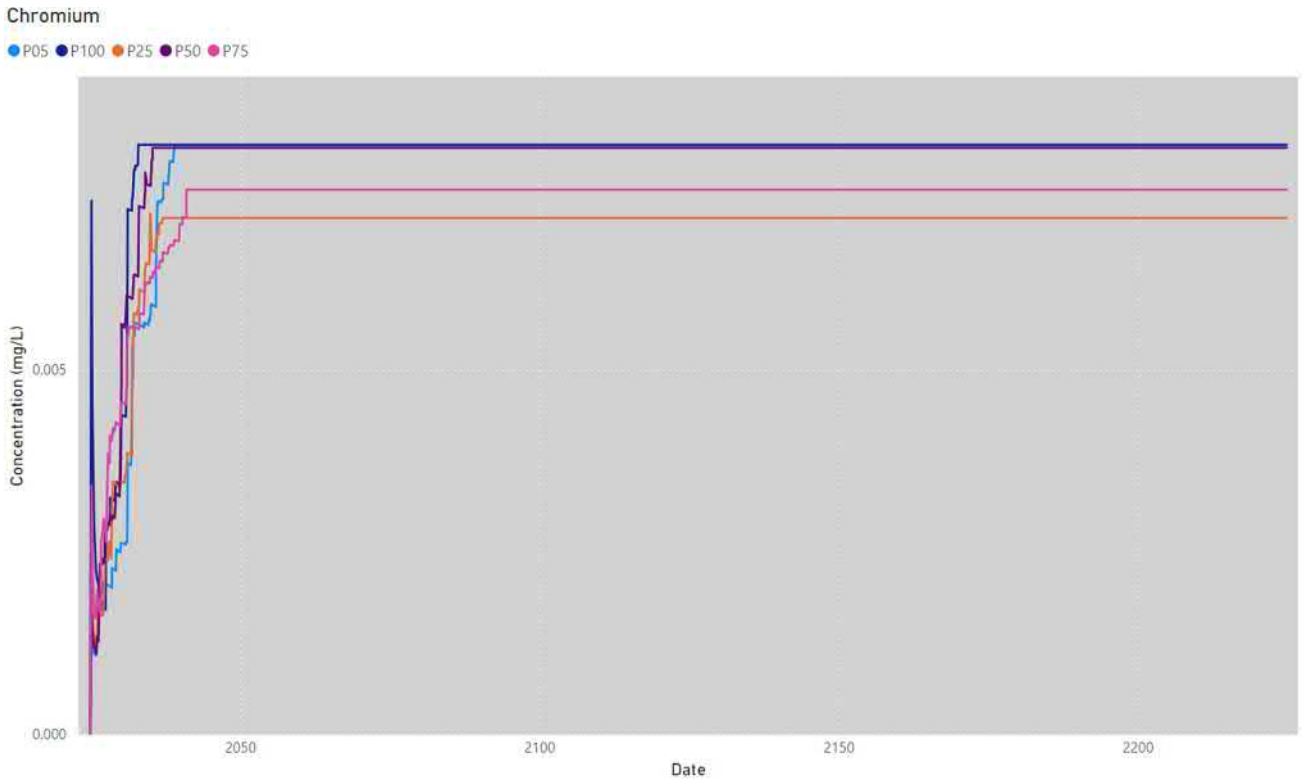
Cadmium



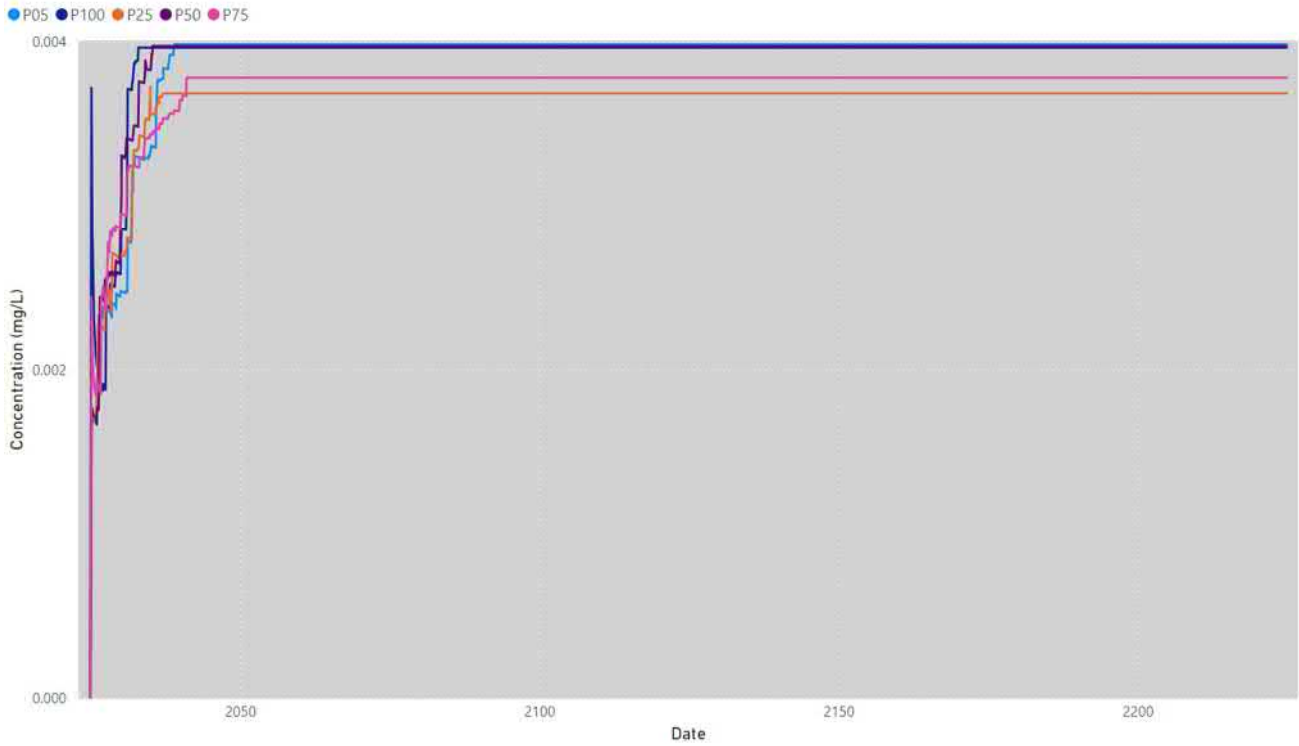
Calcium



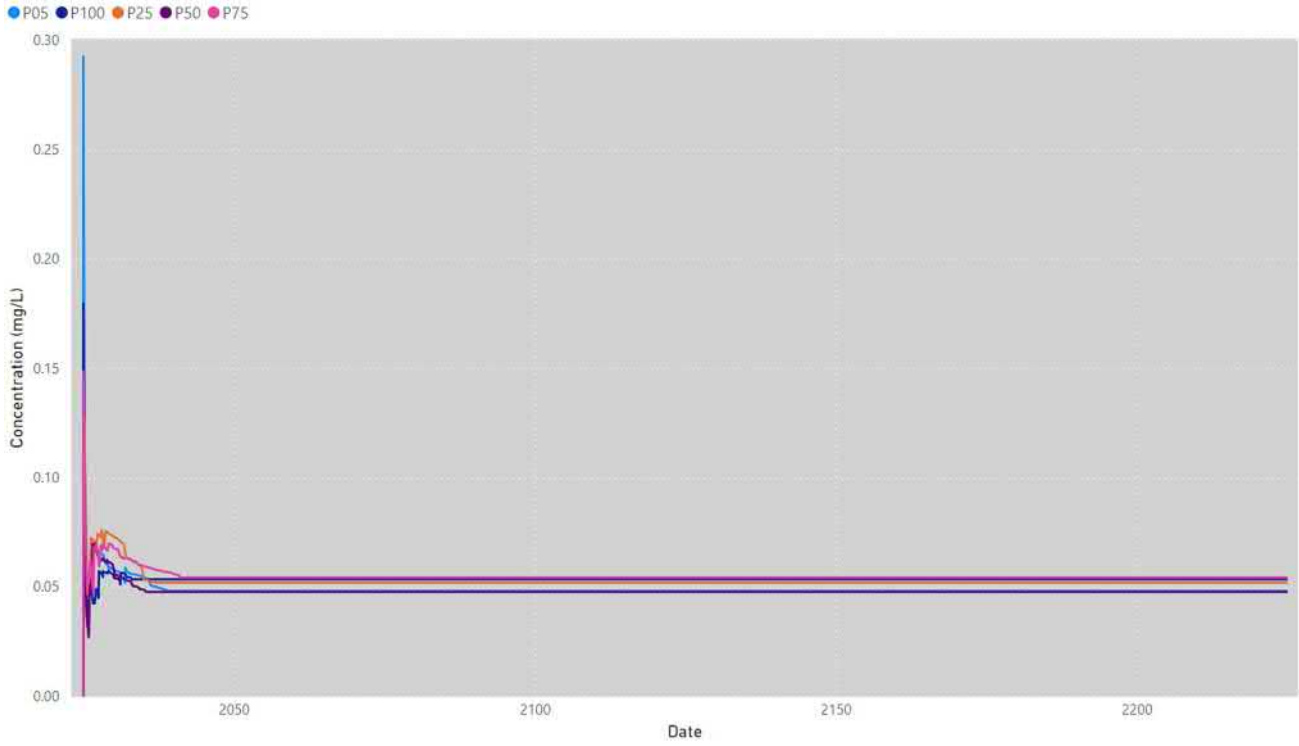

Chloride
P05 P100 P25 P50 P75
70
60
50
40
30
20
10
0
Concentration (mg/L)
2050
2100
2150
2200
Date


Chromium
P05 P100 P25 P50 P75
0.005
0.000
Concentration (mg/L)
2050
2100
2150
2200
Date

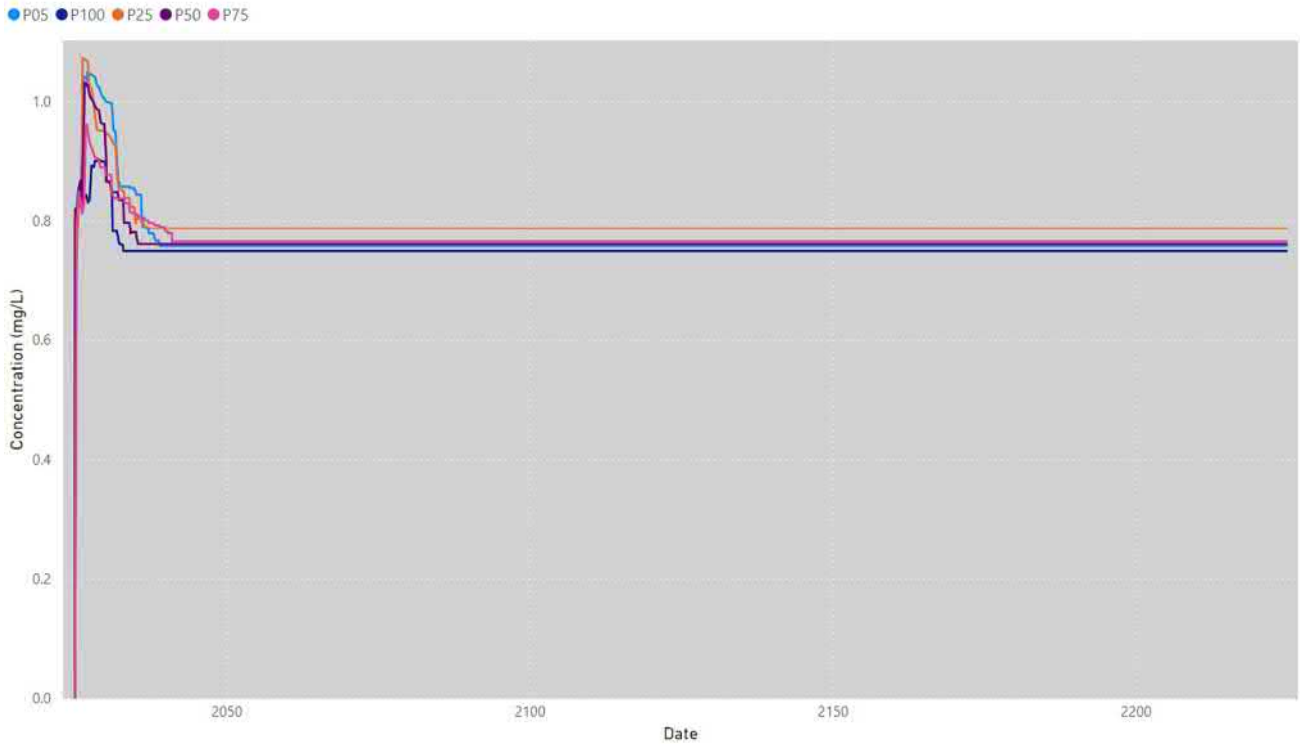
Cobalt



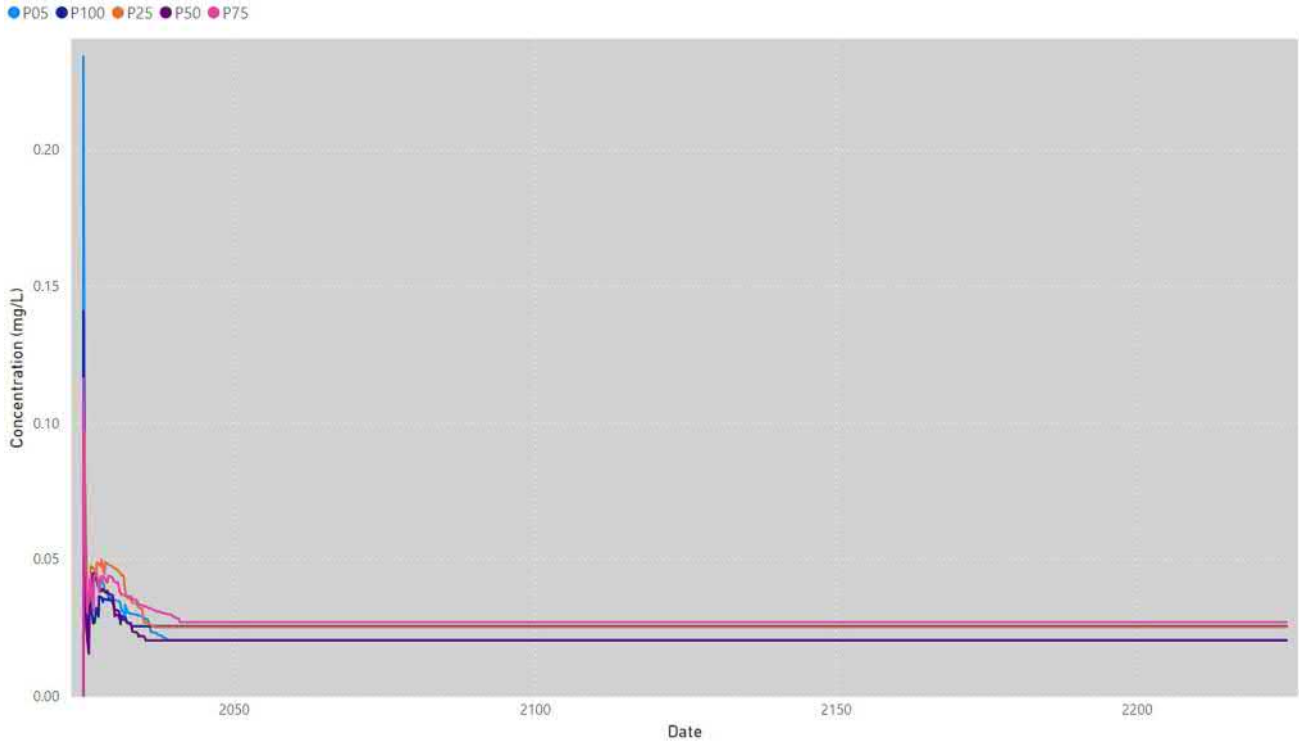
Copper

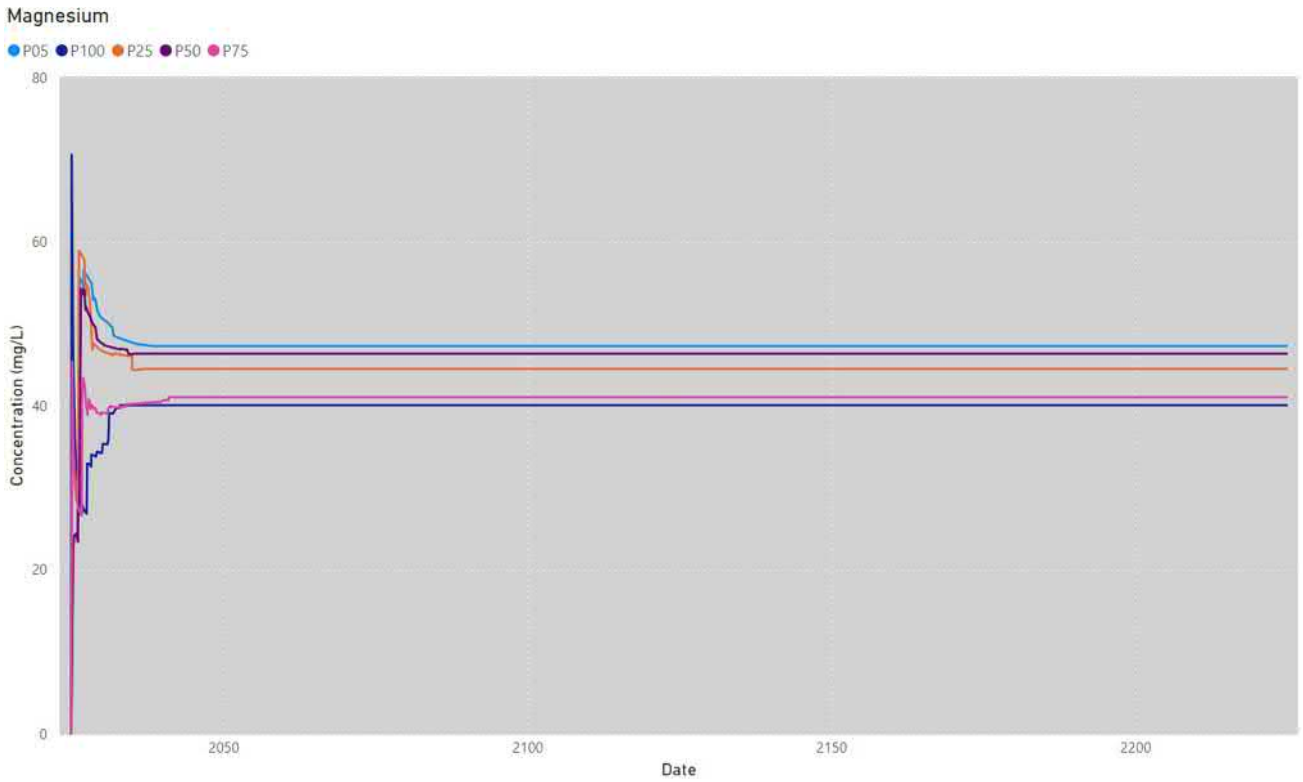


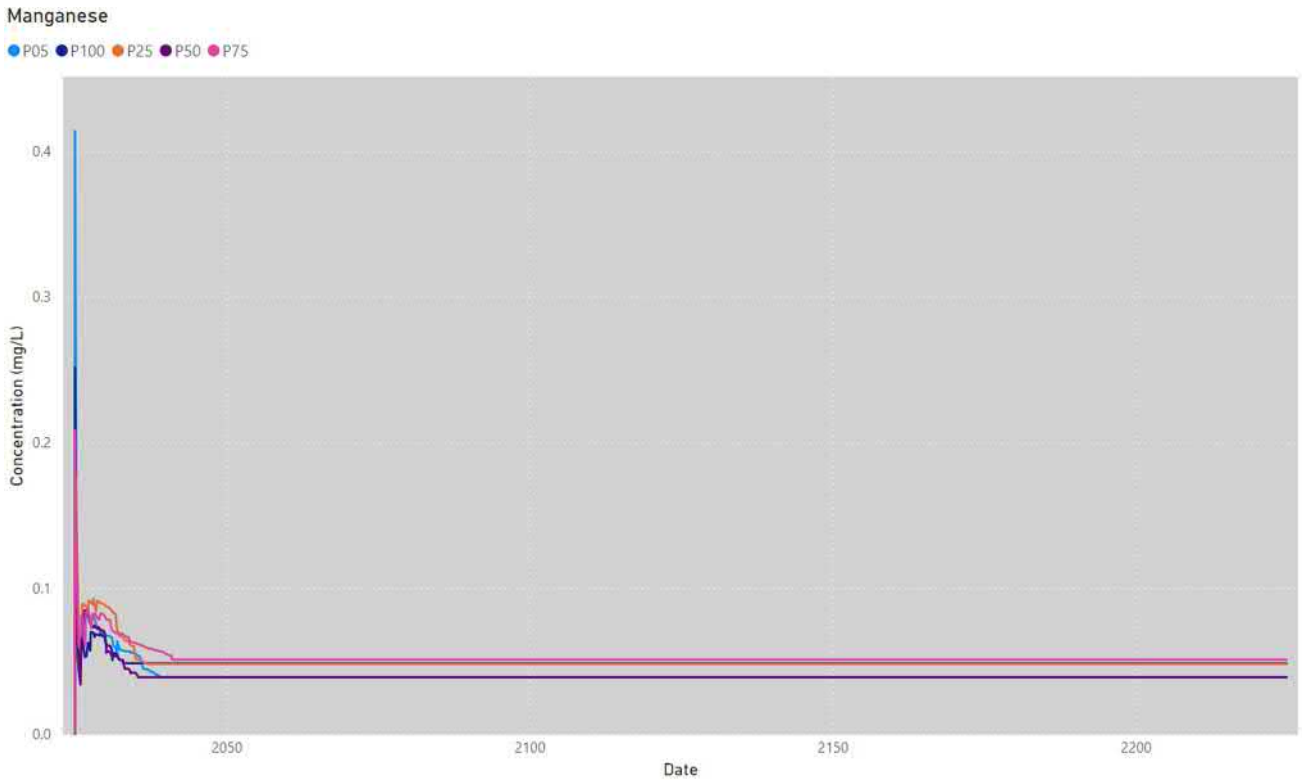
Fluoride



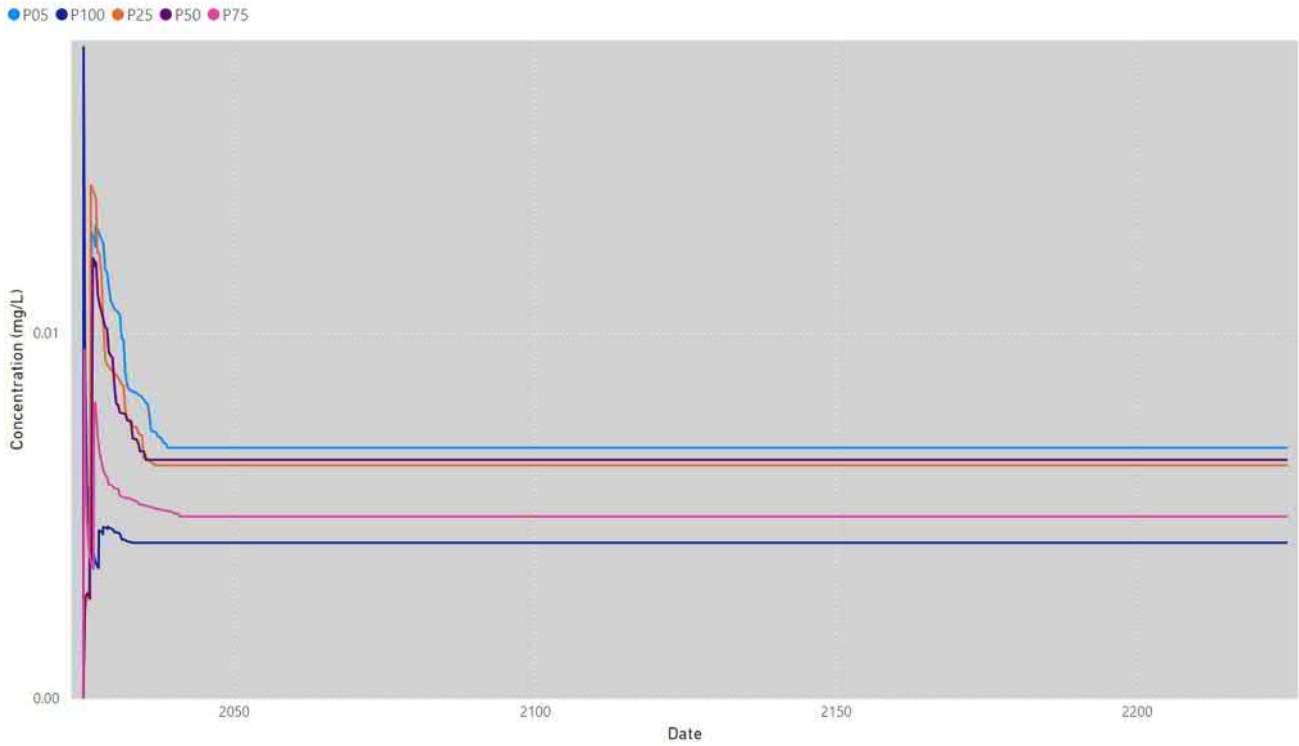
Lead



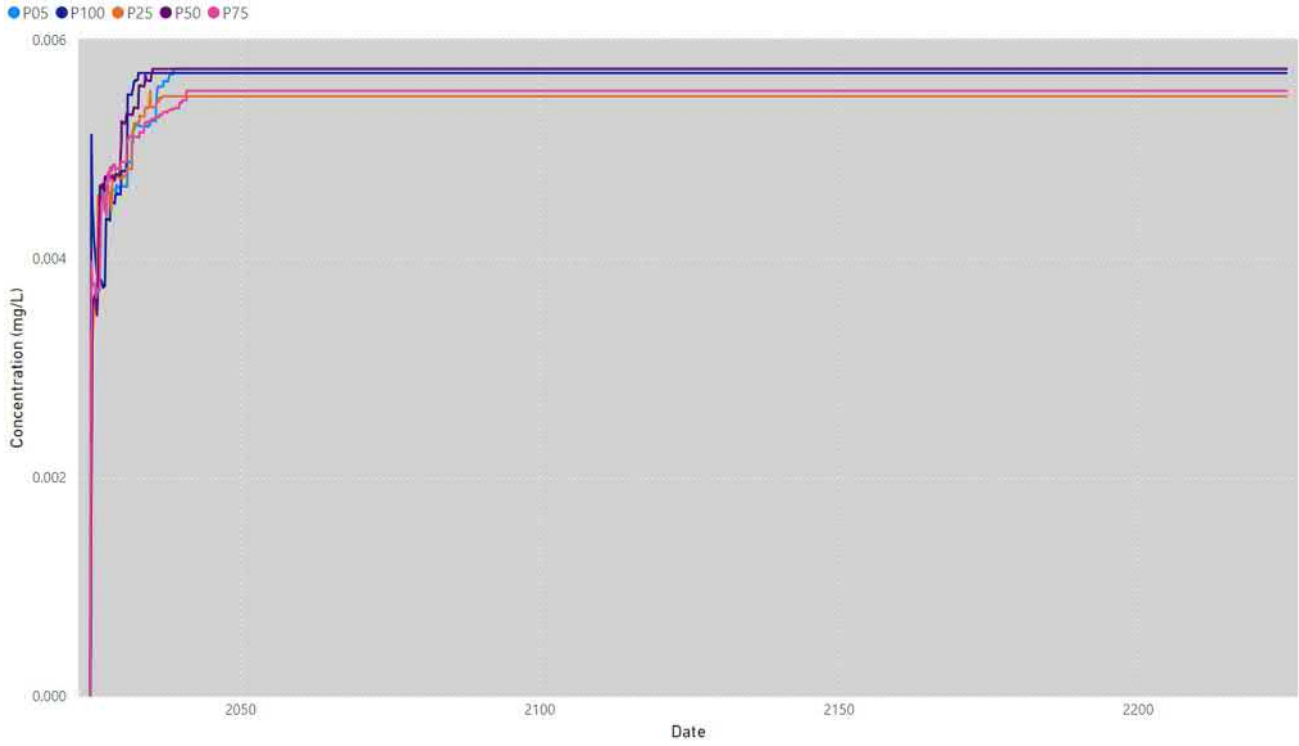

Magnesium
P05 P100 P25 P50 P75
80
60
40
20
0
Concentration (mg/L)
2050
2100
2150
2200
Date

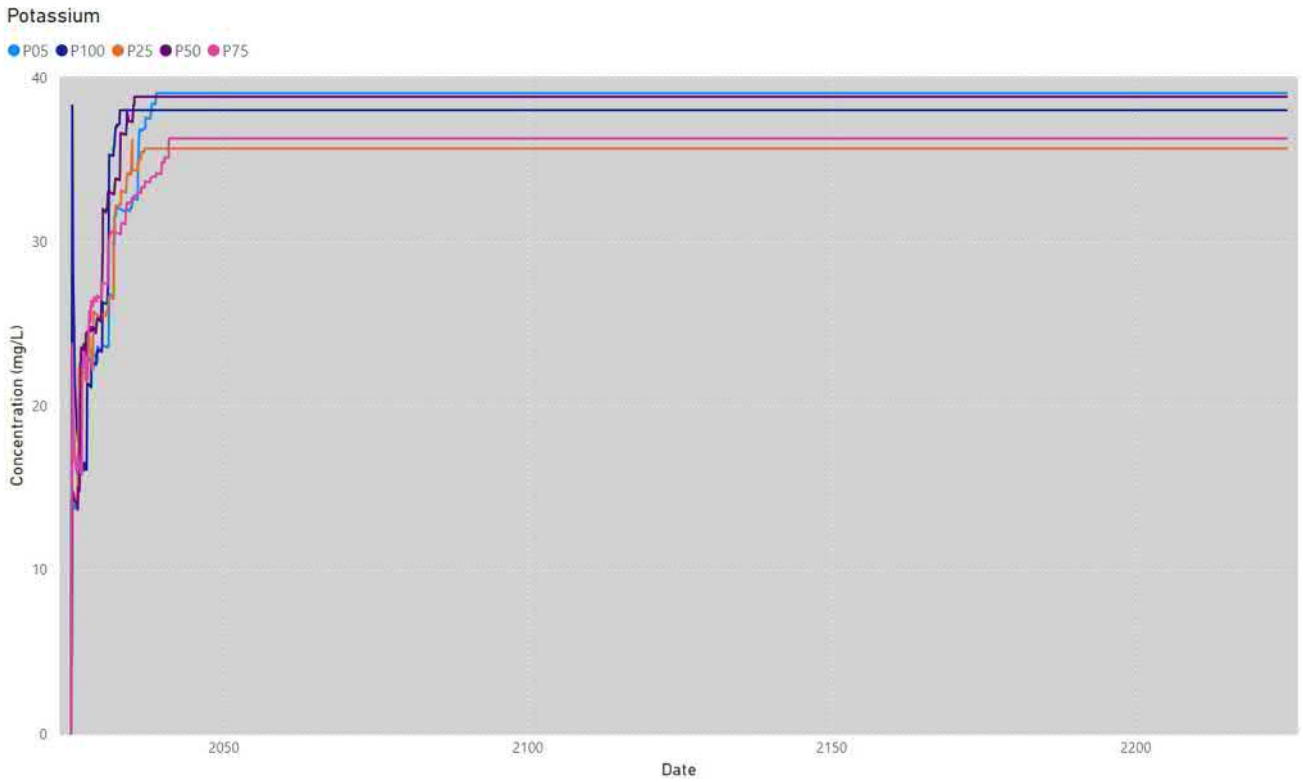

Manganese
P05 P100 P25 P50 P75
0.4
0.3
0.2
0.1
0.0
Concentration (mg/L)
2050
2100
2150
2200
Date

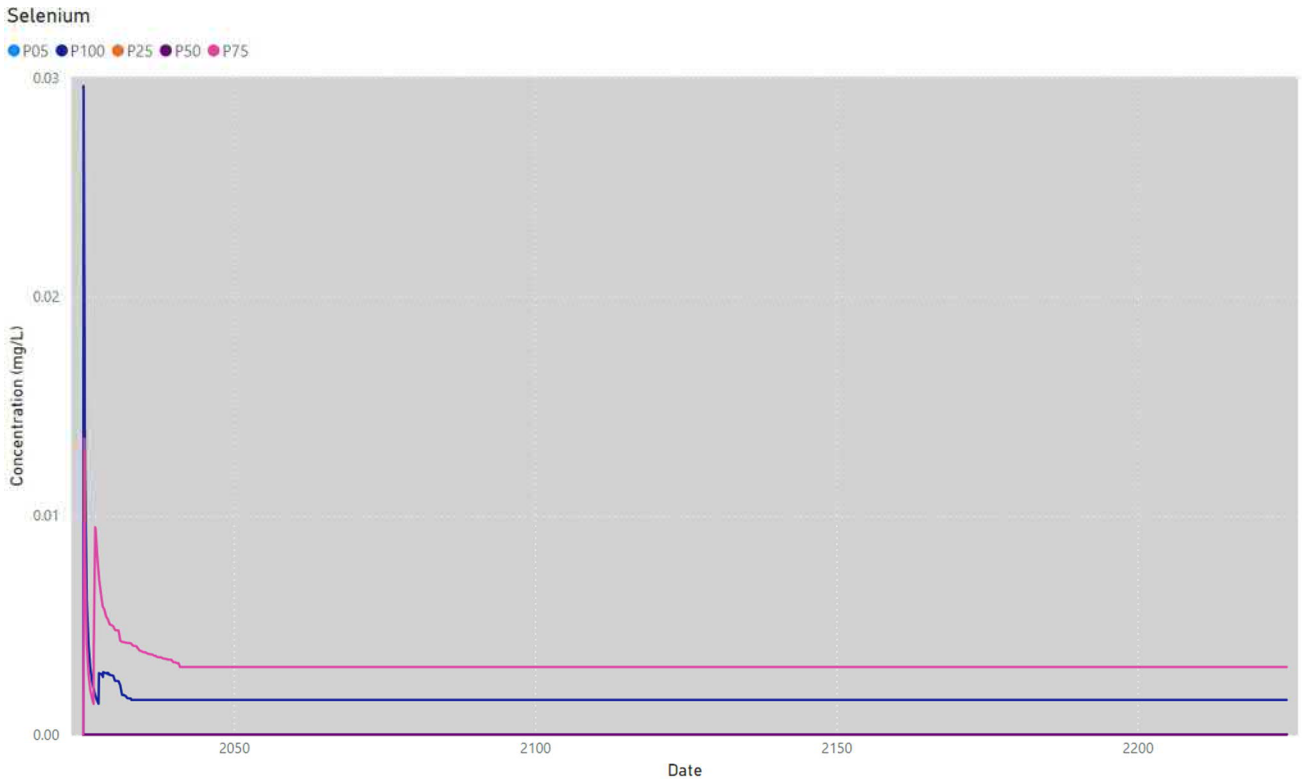
Molybdenum



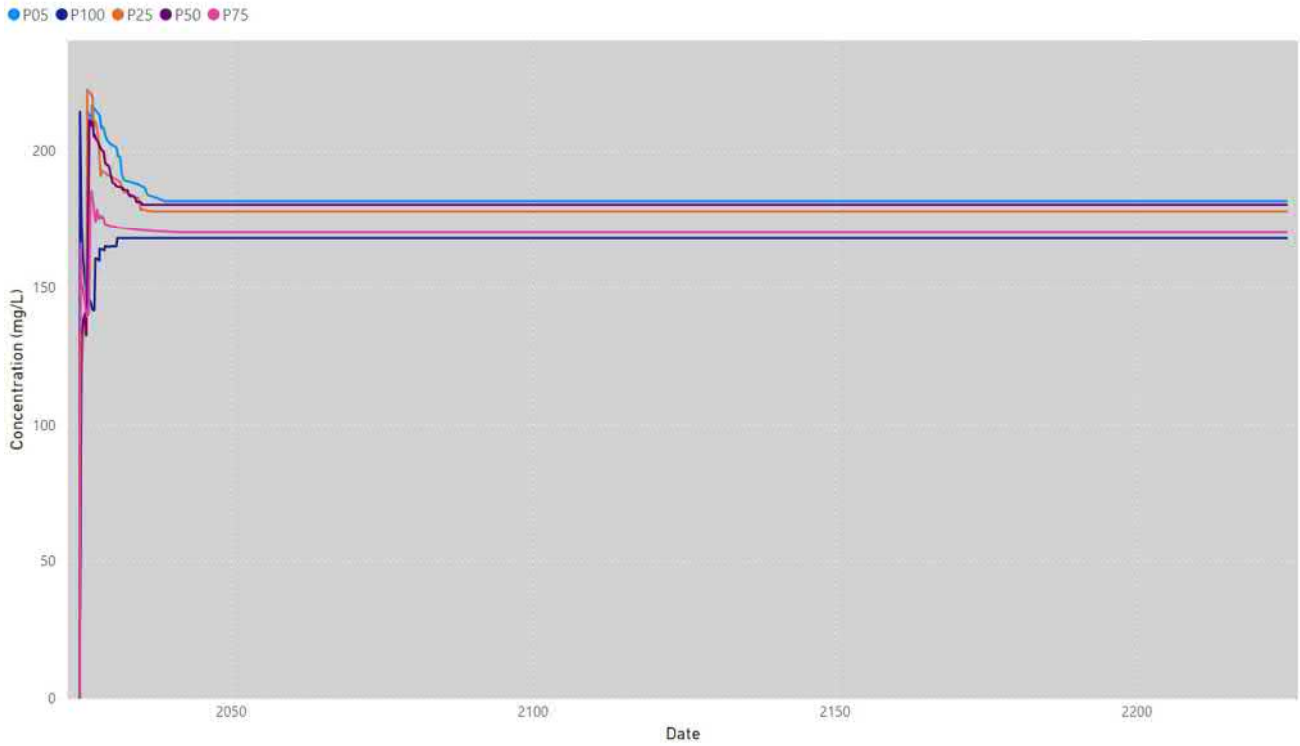
Nickel



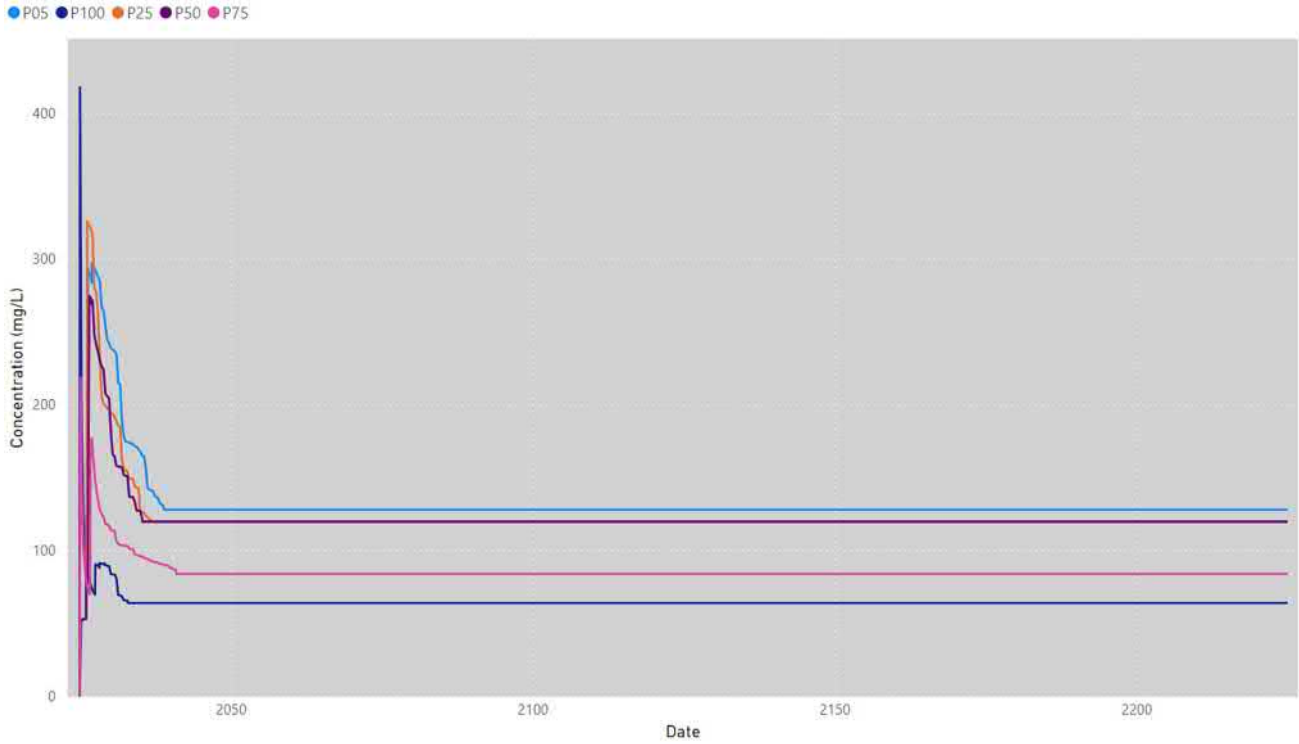

Potassium
P05 P100 P25 P50 P75
40
30
20
10
0
Concentration (mg/L)
2050
2100
2150
2200
Date


Selenium
P05 P100 P25 P50 P75
0.03
0.02
0.01
0.00
Concentration (mg/L)
2050
2100
2150
2200
Date

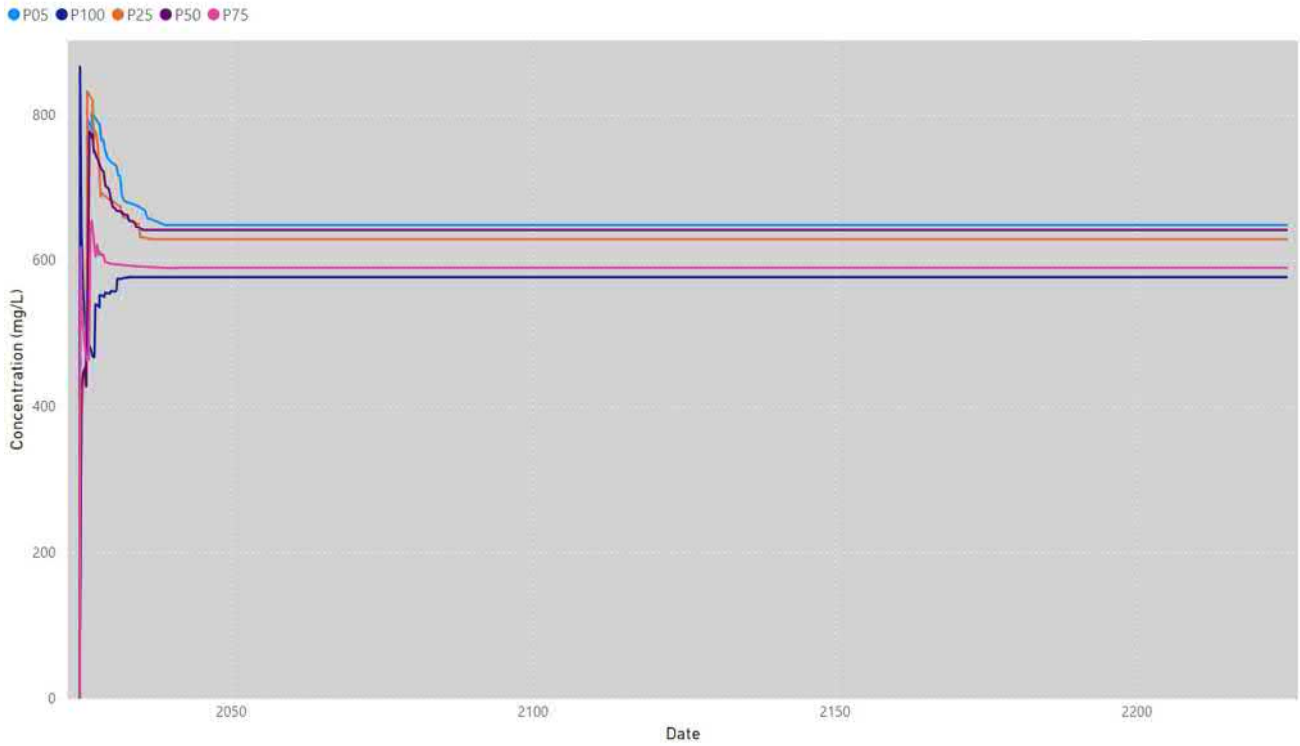
Sodium



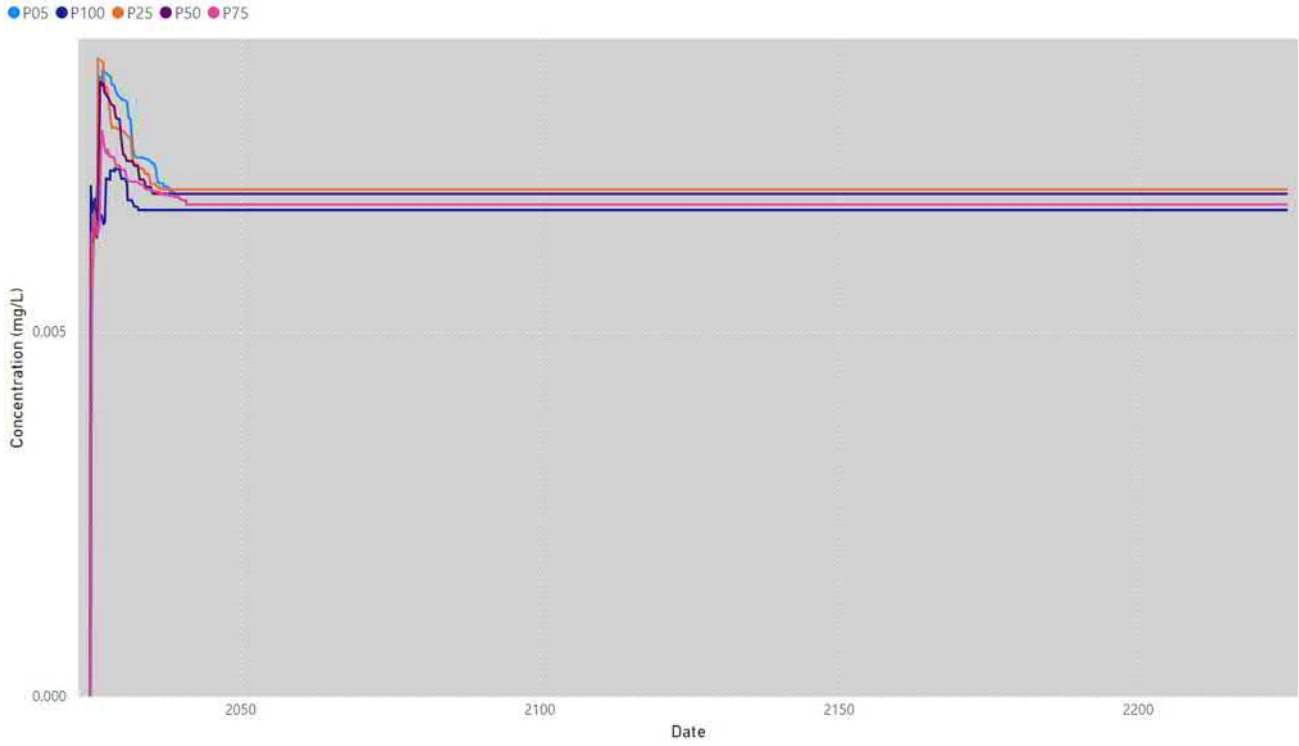
Sulfate



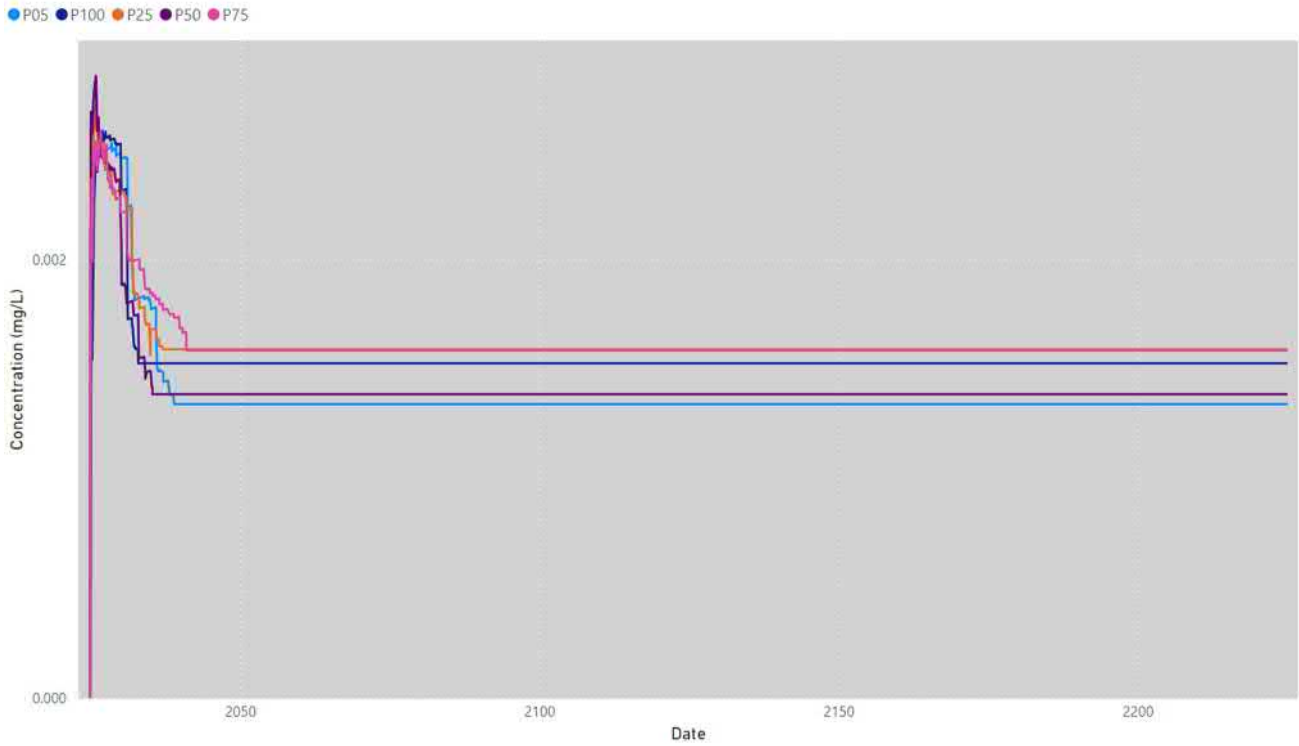
Total Dissolved Solids



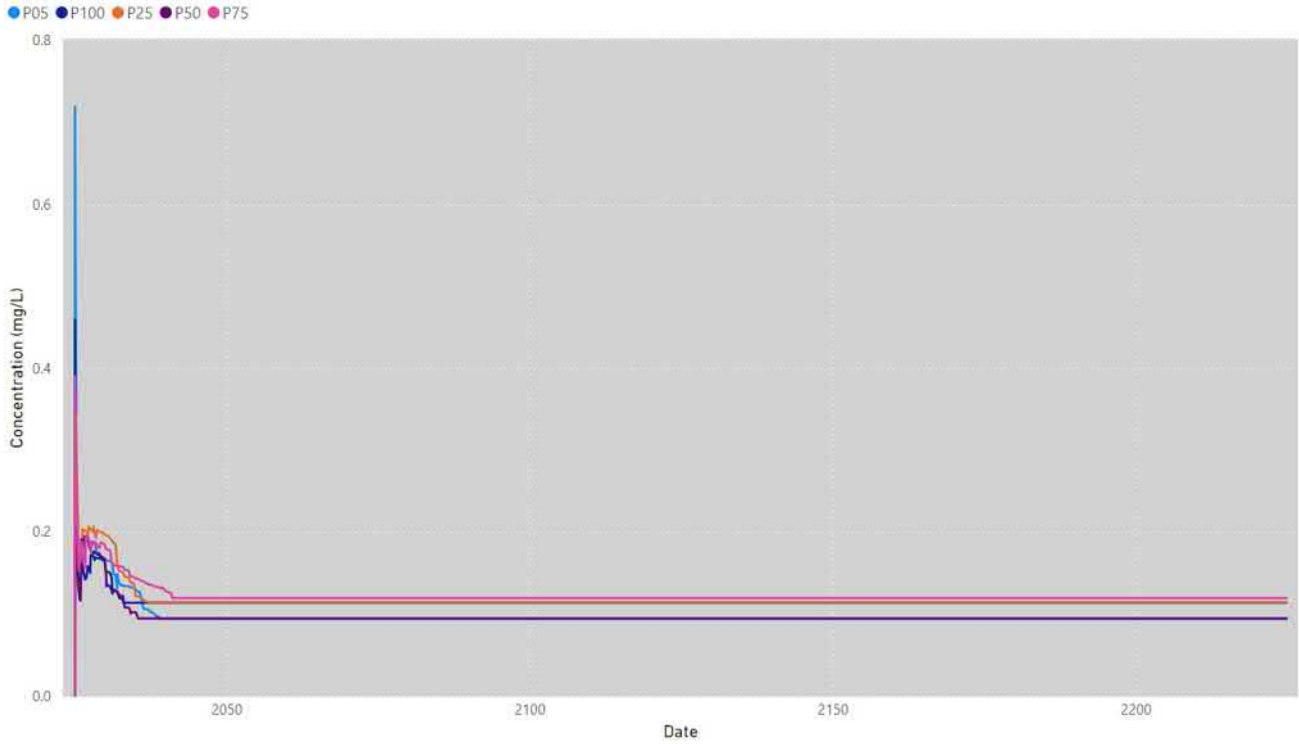
Uranium



Vanadium



Zinc



Appendix D 2023 water quality modelling results for open pits and WRD sediment dam

D.1 Summary of results

D.1.1 WRD Sediment Dam final void water quality

Final void water quality can be summarised as follows:

- The solute concentrations at all times and for both models (i.e. mixing and equilibrium models) remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.
- The main processes that impact solute levels in the sediment dam are dilution due to rainfall runoff into the pit and concentration due to evaporation from the open pit. Due to the presence of the HDPE liner, groundwater inflow or outflow does not occur. The short-term or seasonal variations in solute concentrations can be correlated with the net balance between rainfall and evaporation.
- Under the 75th percentile climatic conditions, the WRD sediment Dam runs dry between early-2040 and end-2045. This affects the water quality in the WRD Sediment Dam.

D.1.2 North Pit water quality

Final void water quality can be summarised as follows:

- The solute concentrations at all times and for both models (i.e. mixing and equilibrium models) remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.
- The main physical processes that impact solute levels in the open pit are dilution due to rainfall runoff, groundwater inflow into the pit, and concentration due to evaporation from the open pit. Groundwater inflow only plays a minor role, with long-term groundwater inflows comprising only ±10% of total inflows into the open pit. Short-term variations in solute concentrations are related to the net flow balance between inflows and evaporation. Whilst groundwater inflow is only a minor component of pit inflows, it does buffer the effect of evaporation on solute concentrations.

D.1.3 South Pit water quality

Final void water quality can be summarised as follows:

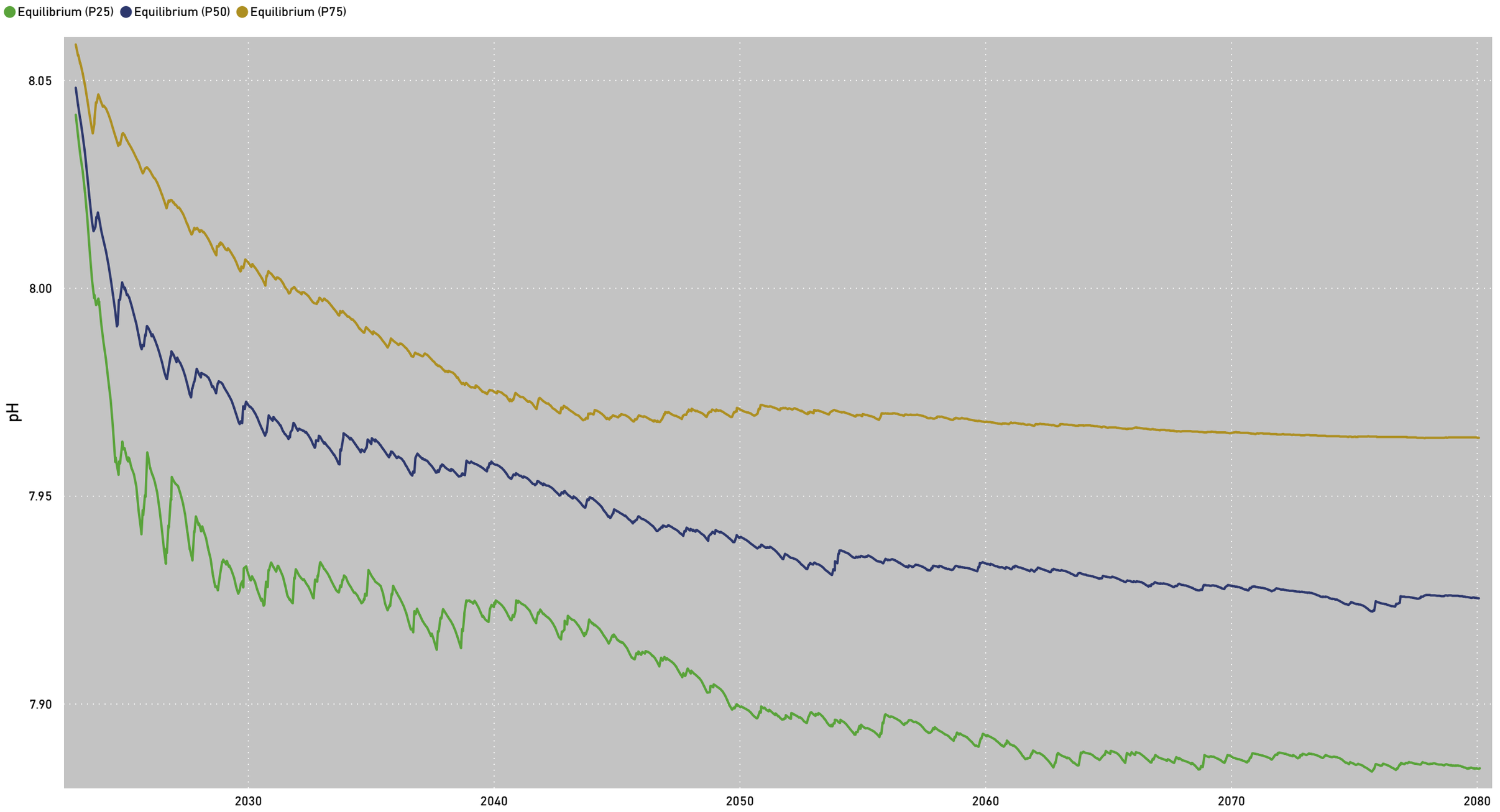
- • The solute concentrations at all times and for both models (i.e. mixing and equilibrium models) and scenarios remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering.
- • The main physical processes that impact solute levels in the open pit are dilution due to rainfall runoff, groundwater inflow into the pit, and concentration due to evaporation from the open pit. Groundwater inflow plays a moderate role, with long-term groundwater inflows (a combination of regional inflow and seepage from the North Pit) comprising ±20% of total inflows into the open pit. Short-term variations in solute concentrations are related to the net flow balance between inflows and evaporation. Groundwater inflow buffers the effect of evaporation on solute concentrations.

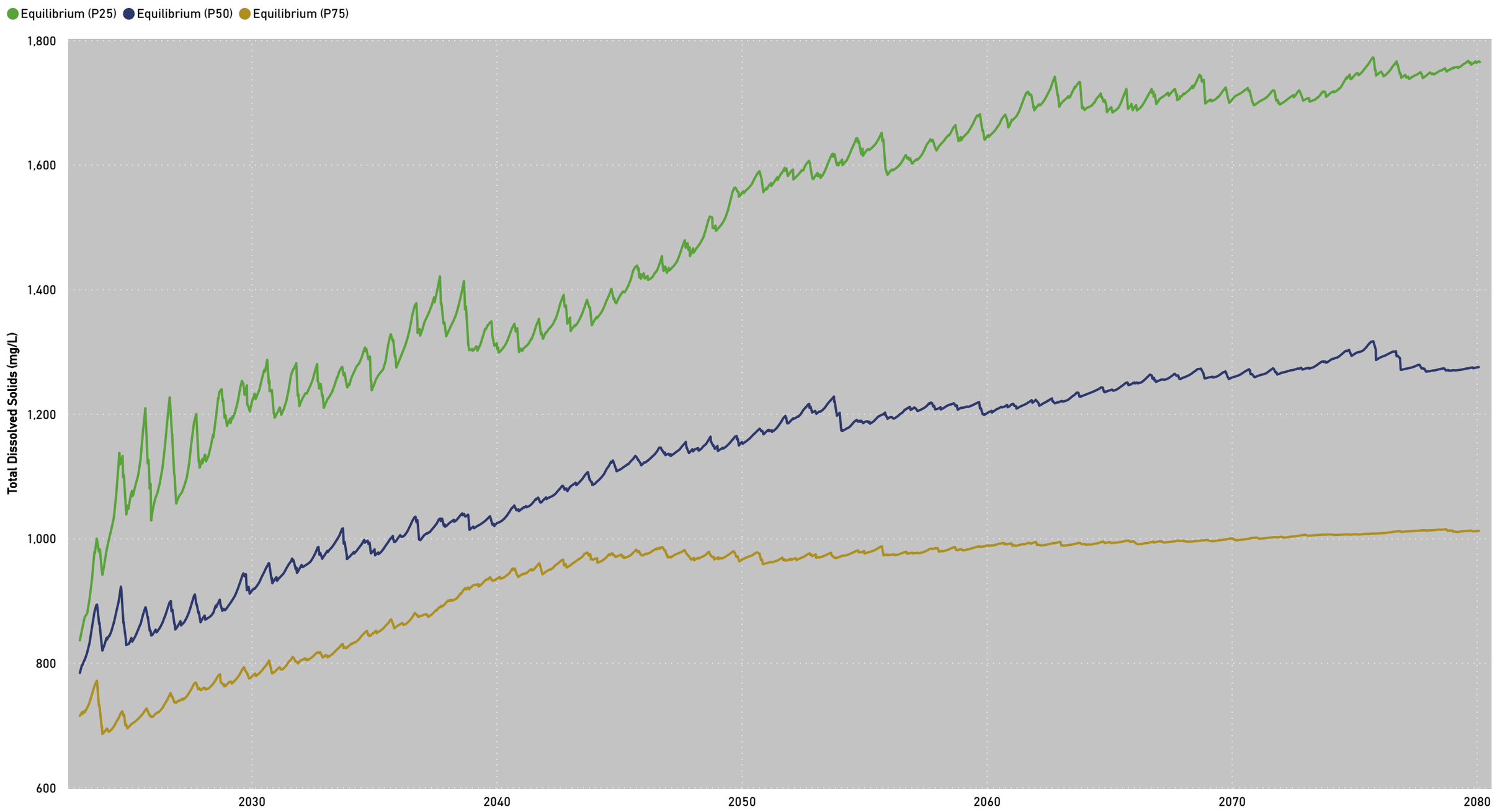
D.1.4 Summary

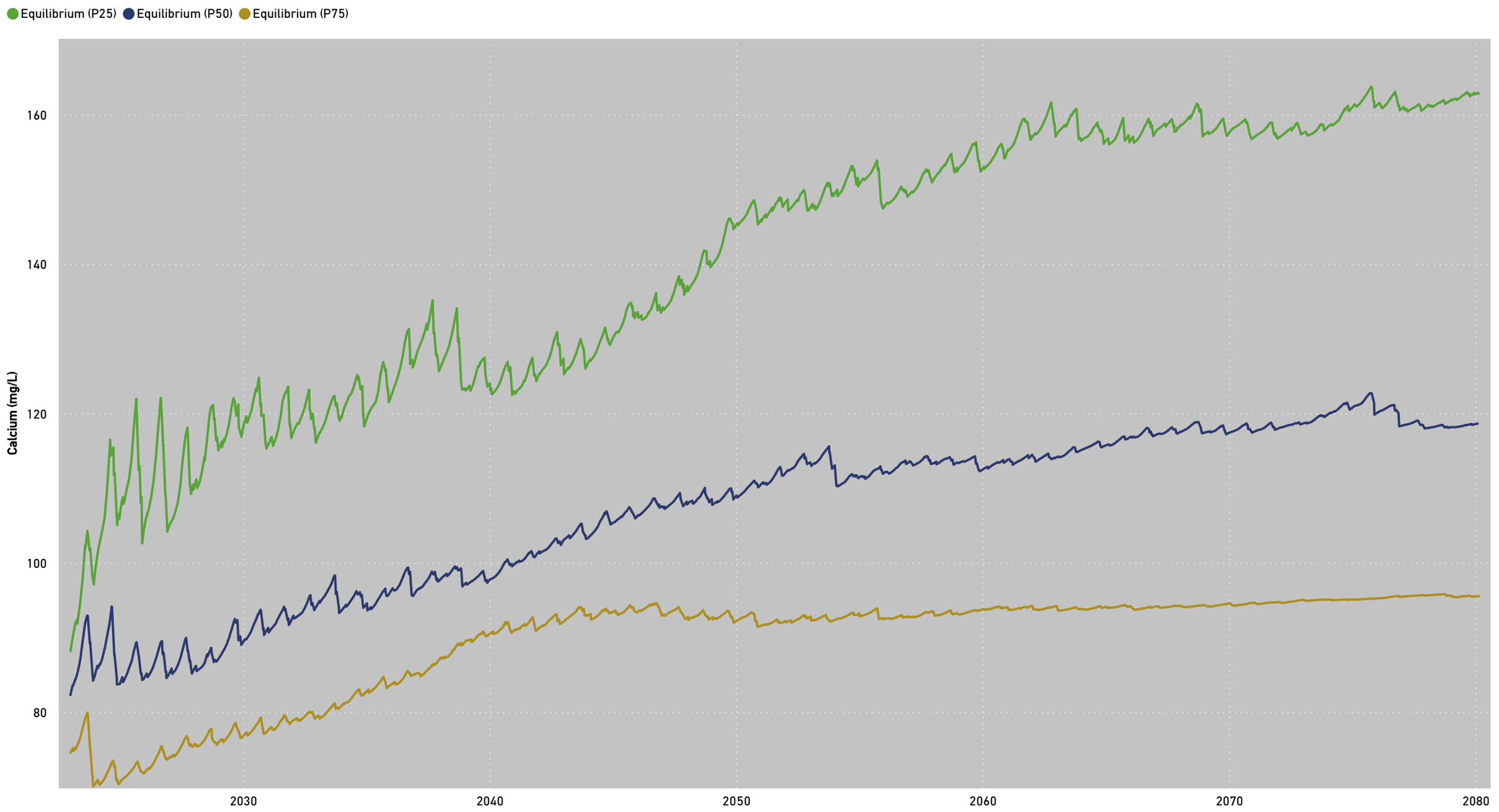
The water quality modelling indicates that the modelled solute concentrations at all times and for both models (i.e. mixing and equilibrium models) remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering. Long-term water quality in the pits and voids is determined by climatic conditions and geochemical reactions and tends to stabilise. The net flow balance between rainfall runoff plus groundwater inflow and evaporation determines short-term variations. Based on the WQM results, the North Pit, South Pit and WRD Sediment Dam are considered suitable as PMLUs for livestock watering.

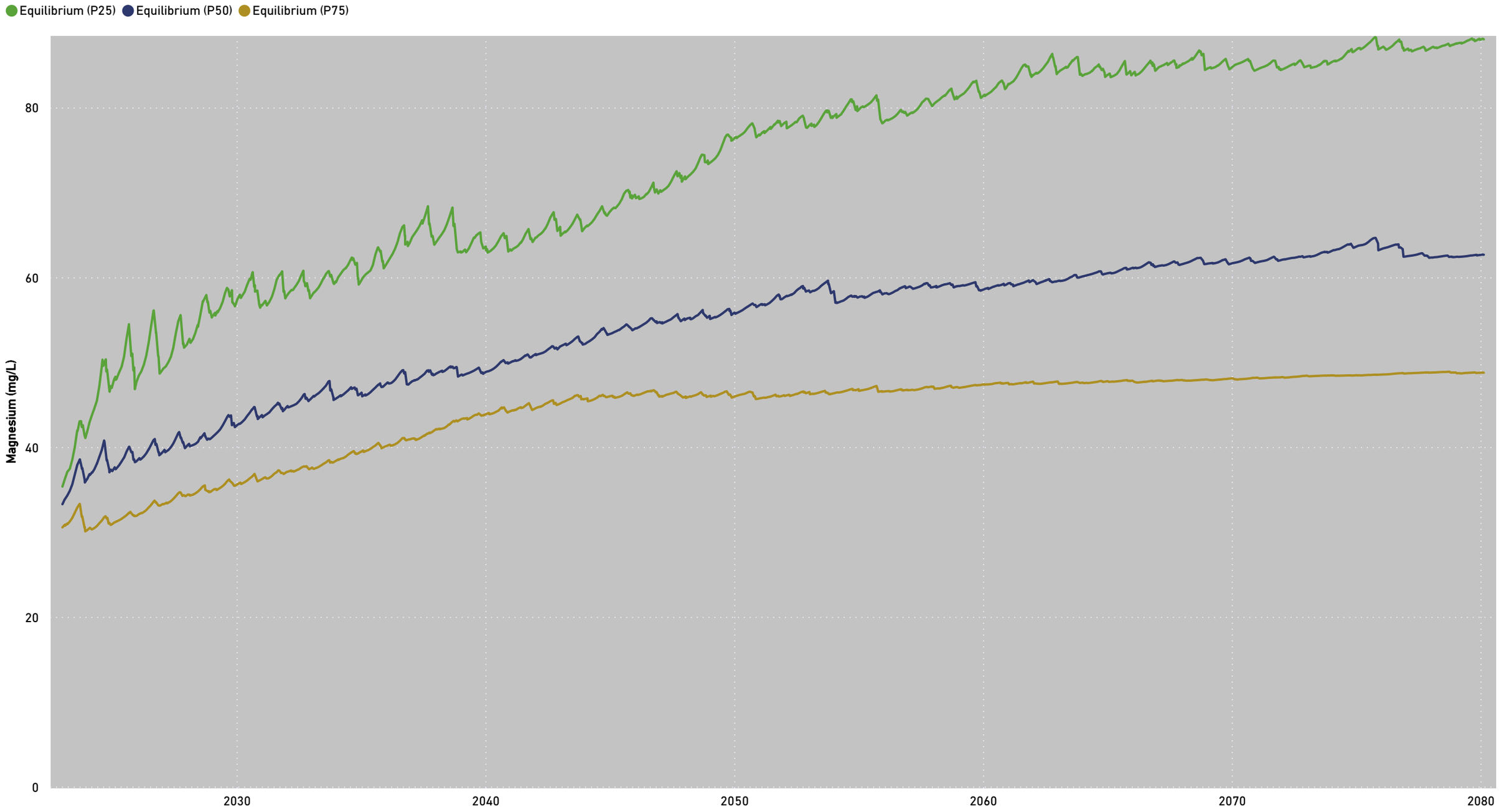
D.2 Water quality time series

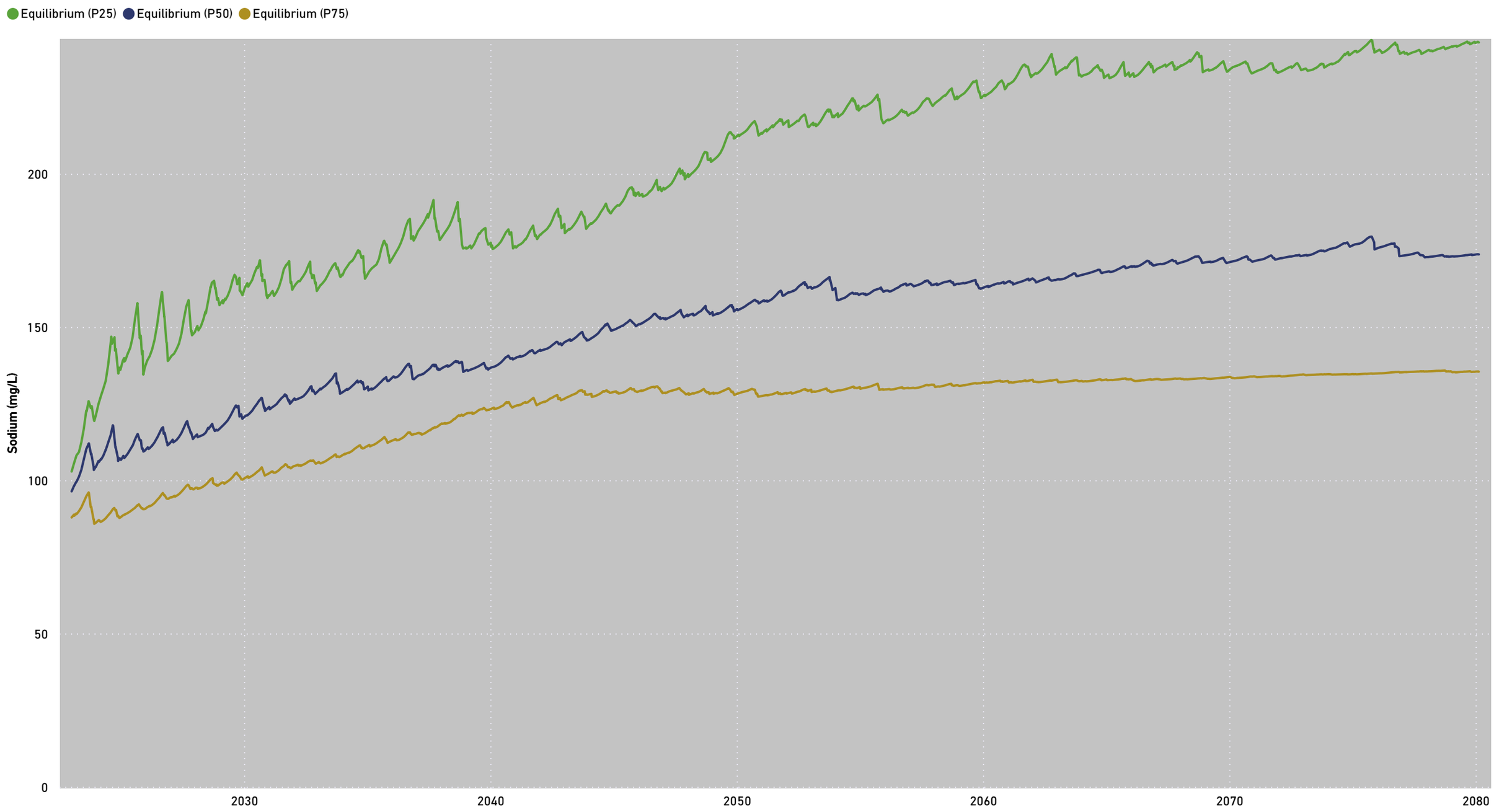
D.2.1 North Pit water quality

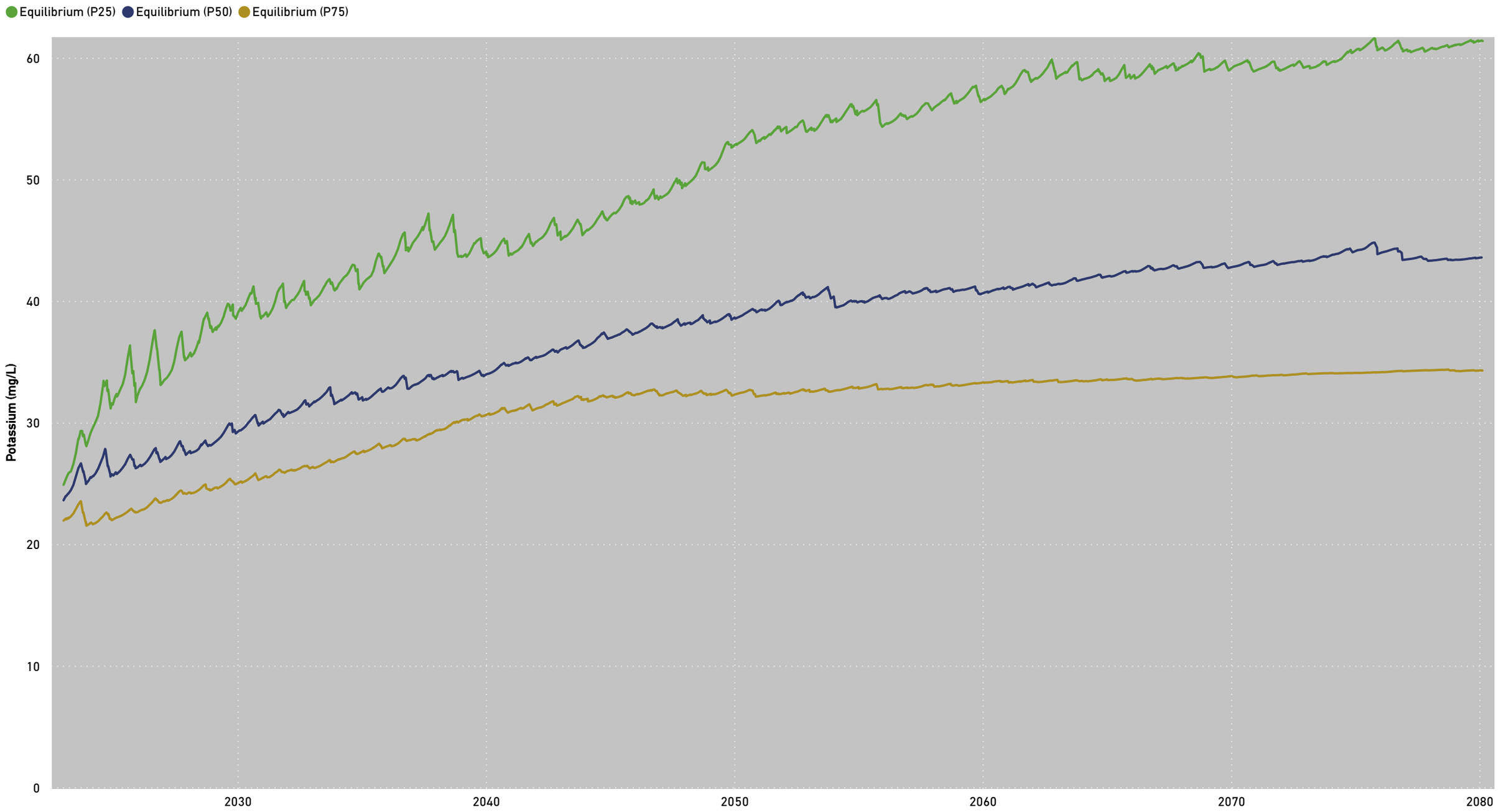

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
pH
8.05
8.00
7.95
7.90
2030
2040
2050
2060
2070
2080

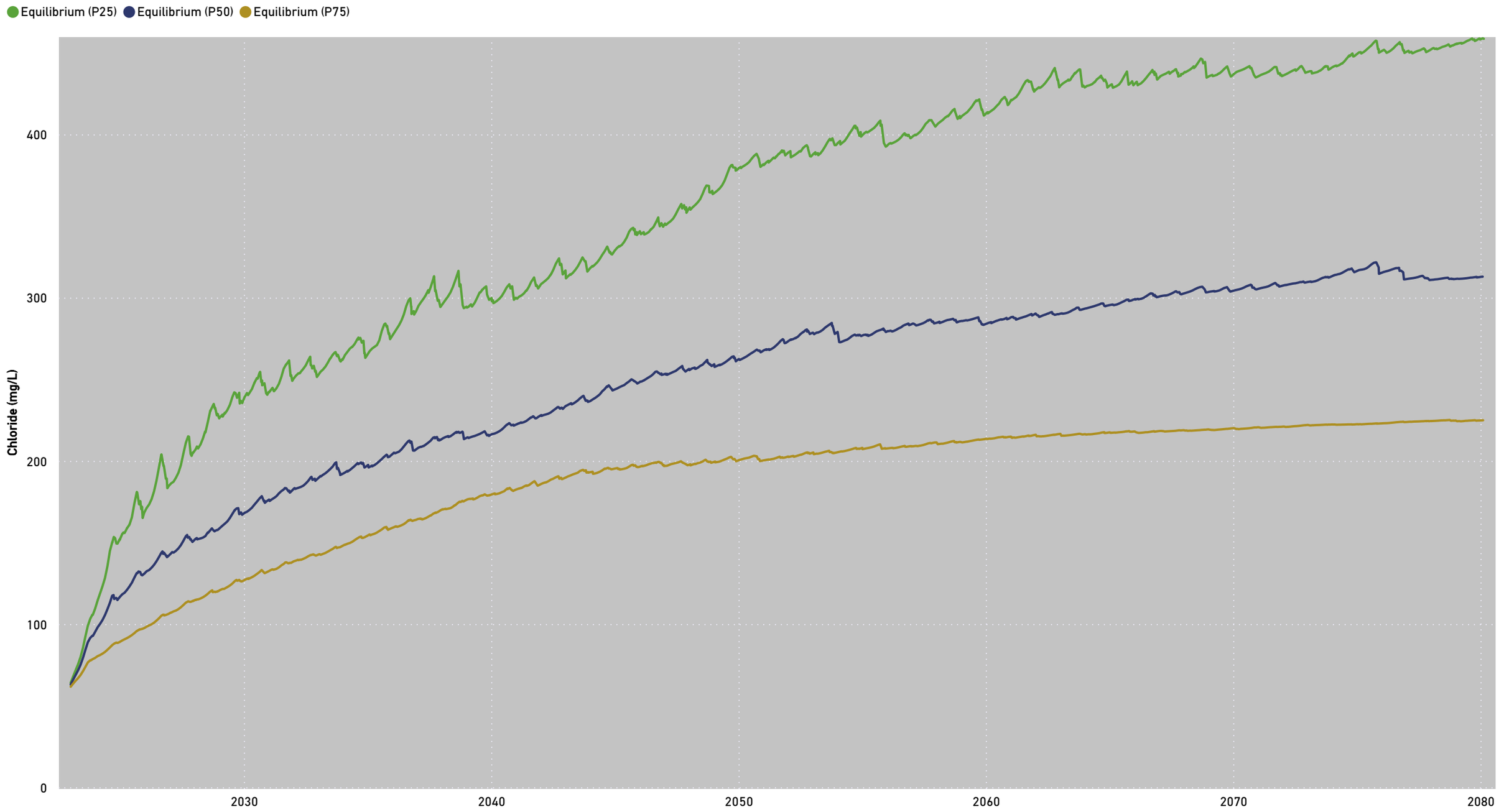

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Total Dissolved Solids (mg/L)
1,800
1,600
1,400
1,200
1,000
800
600
2030
2040
2050
2060
2070
2080

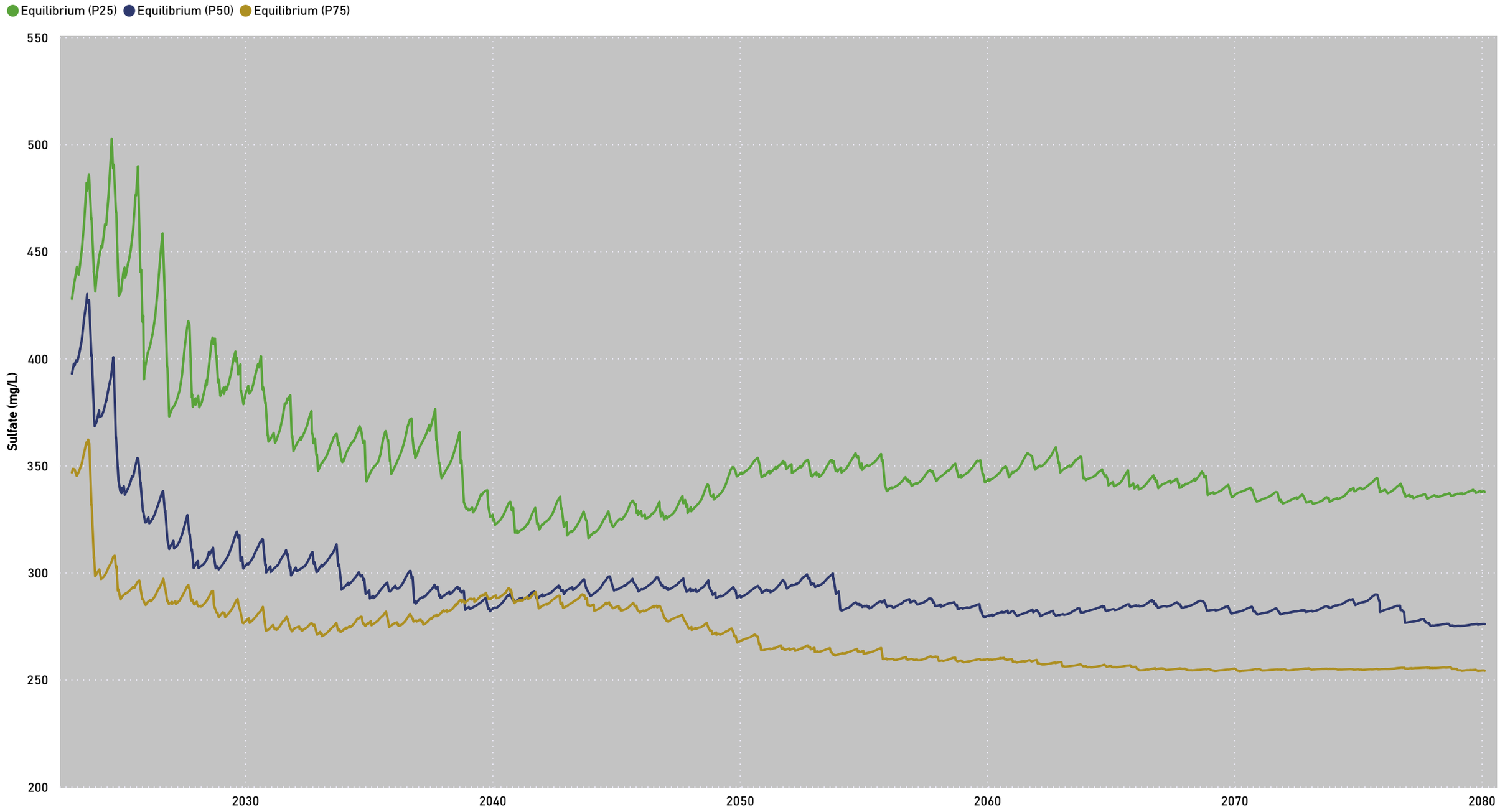

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Calcium (mg/L)
160
140
120
100
80
2030
2040
2050
2060
2070
2080

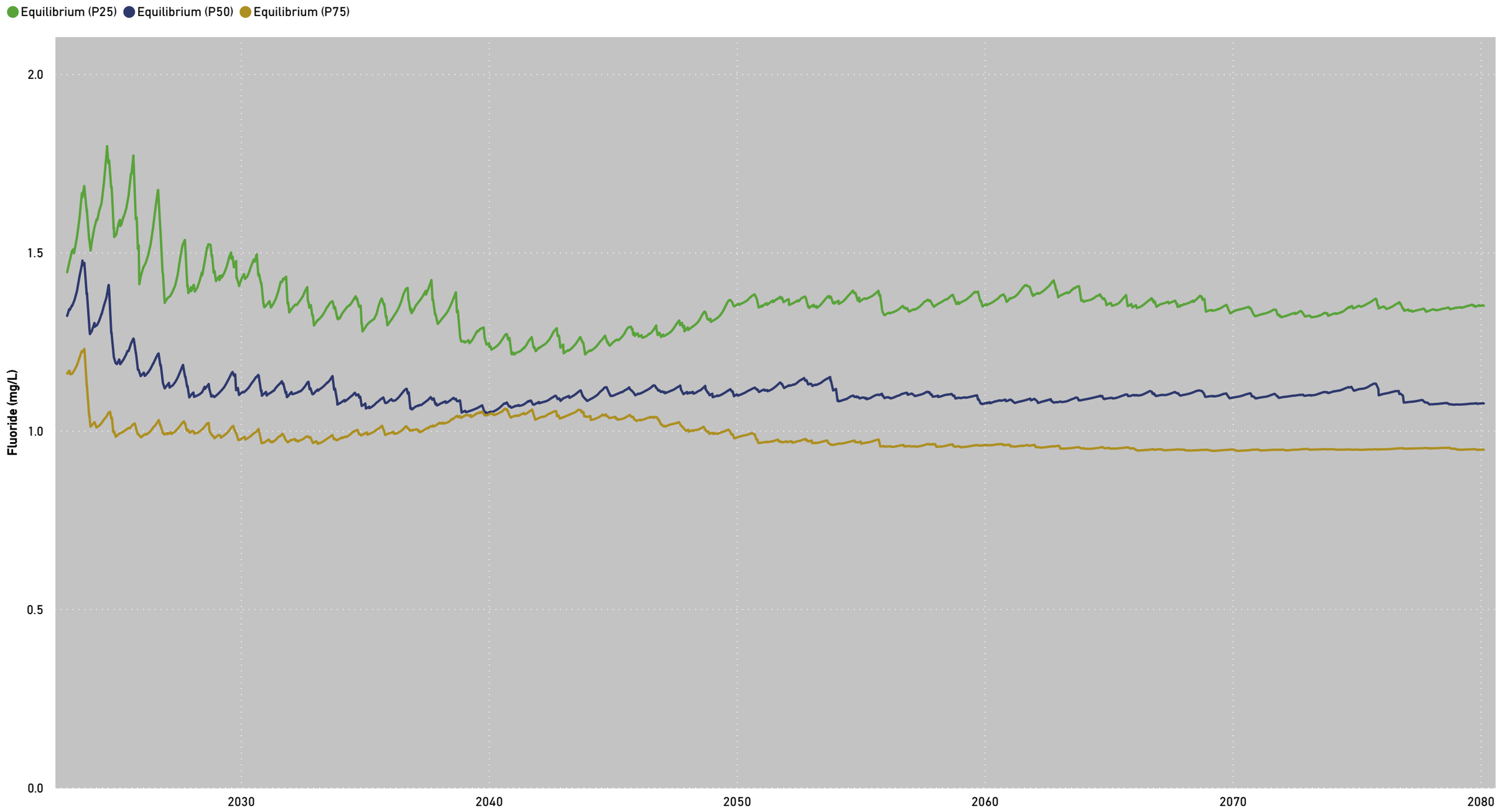

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Magnesium (mg/L)
0
20
40
60
80
2030
2040
2050
2060
2070
2080

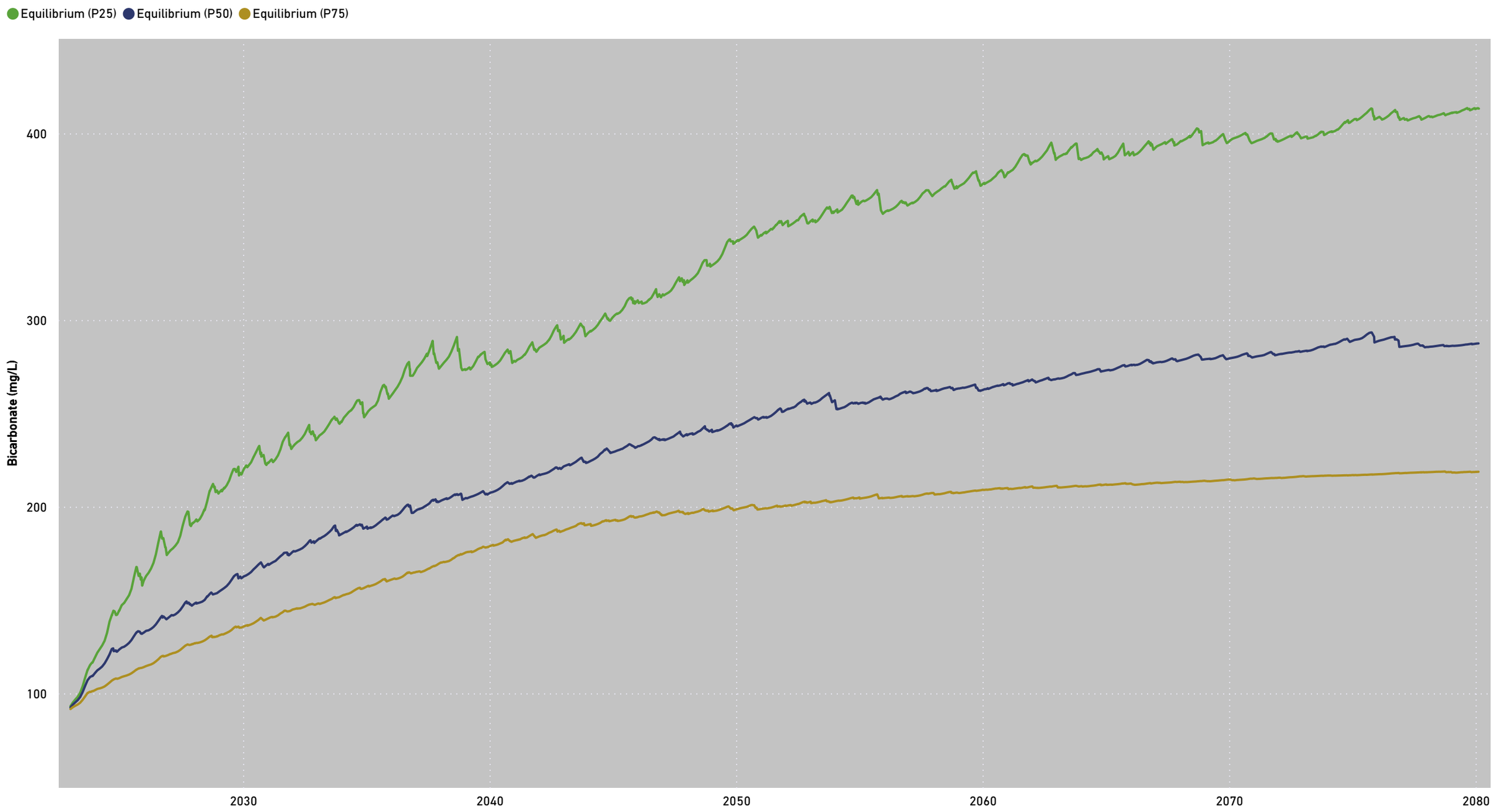

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Sodium (mg/L)
0
50
100
150
200
2030
2040
2050
2060
2070
2080

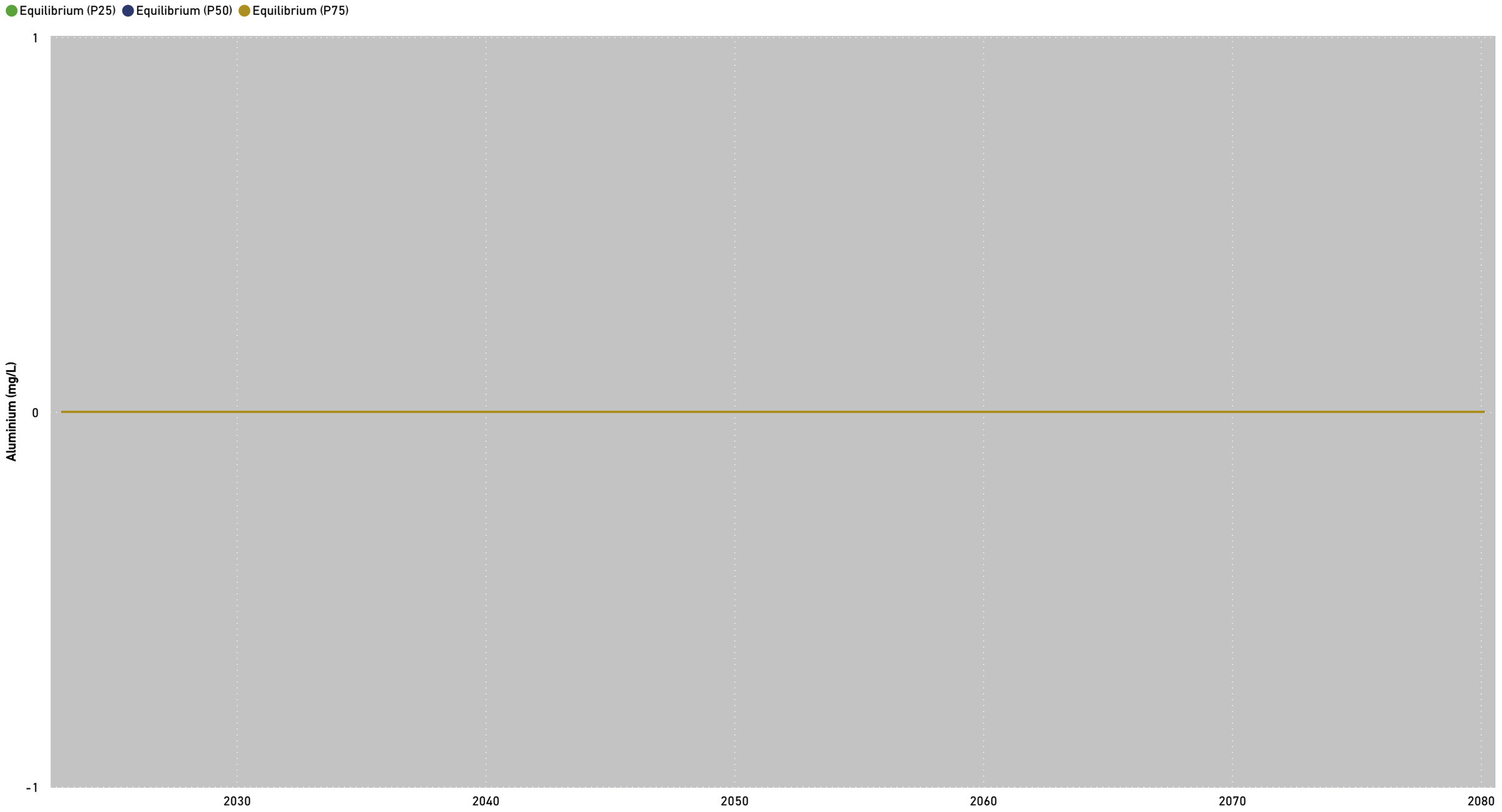

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Potassium (mg/L)
60
50
40
30
20
10
0
2030
2040
2050
2060
2070
2080

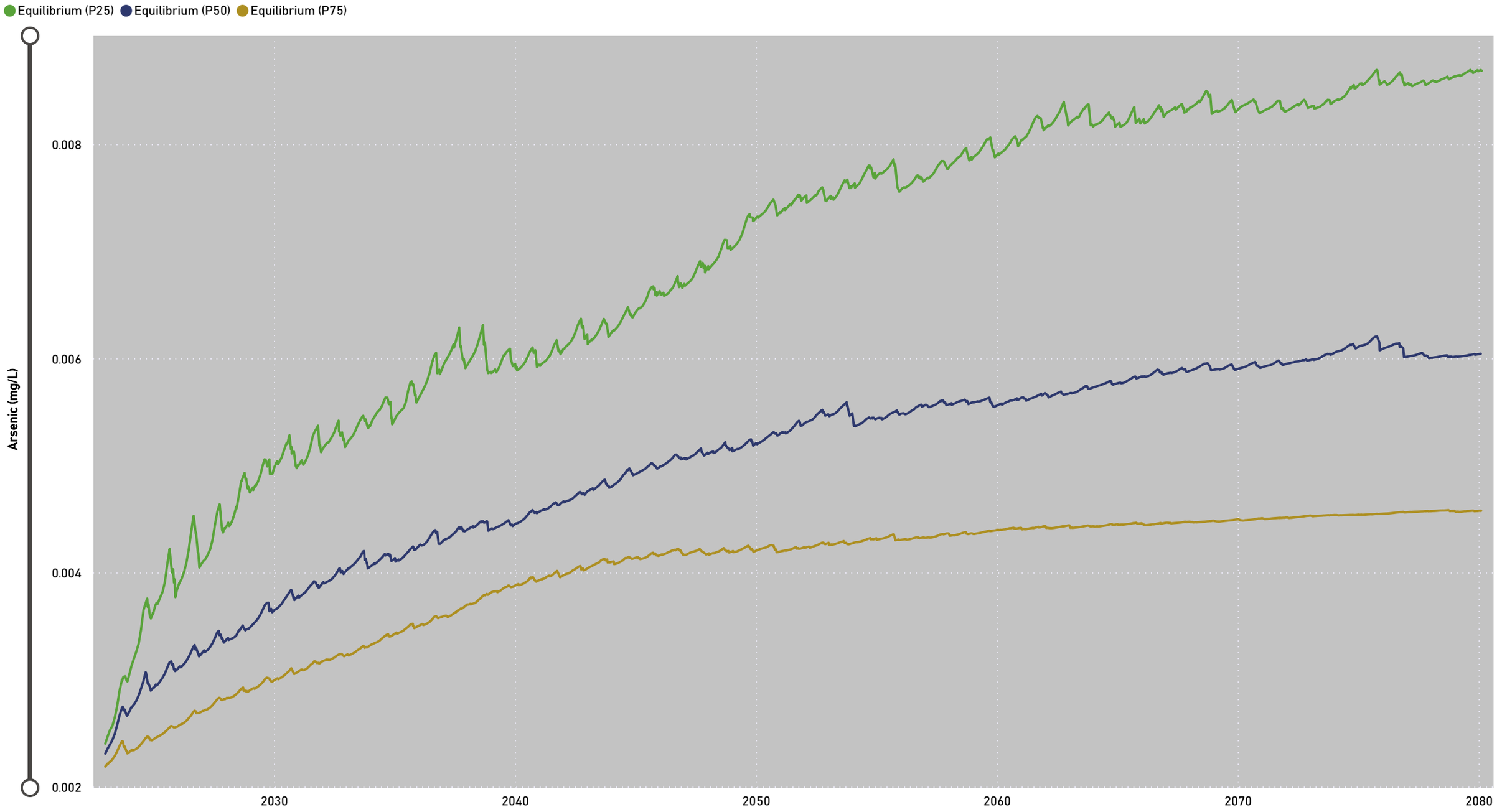

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Chloride (mg/L)
0
100
200
300
400
2030
2040
2050
2060
2070
2080

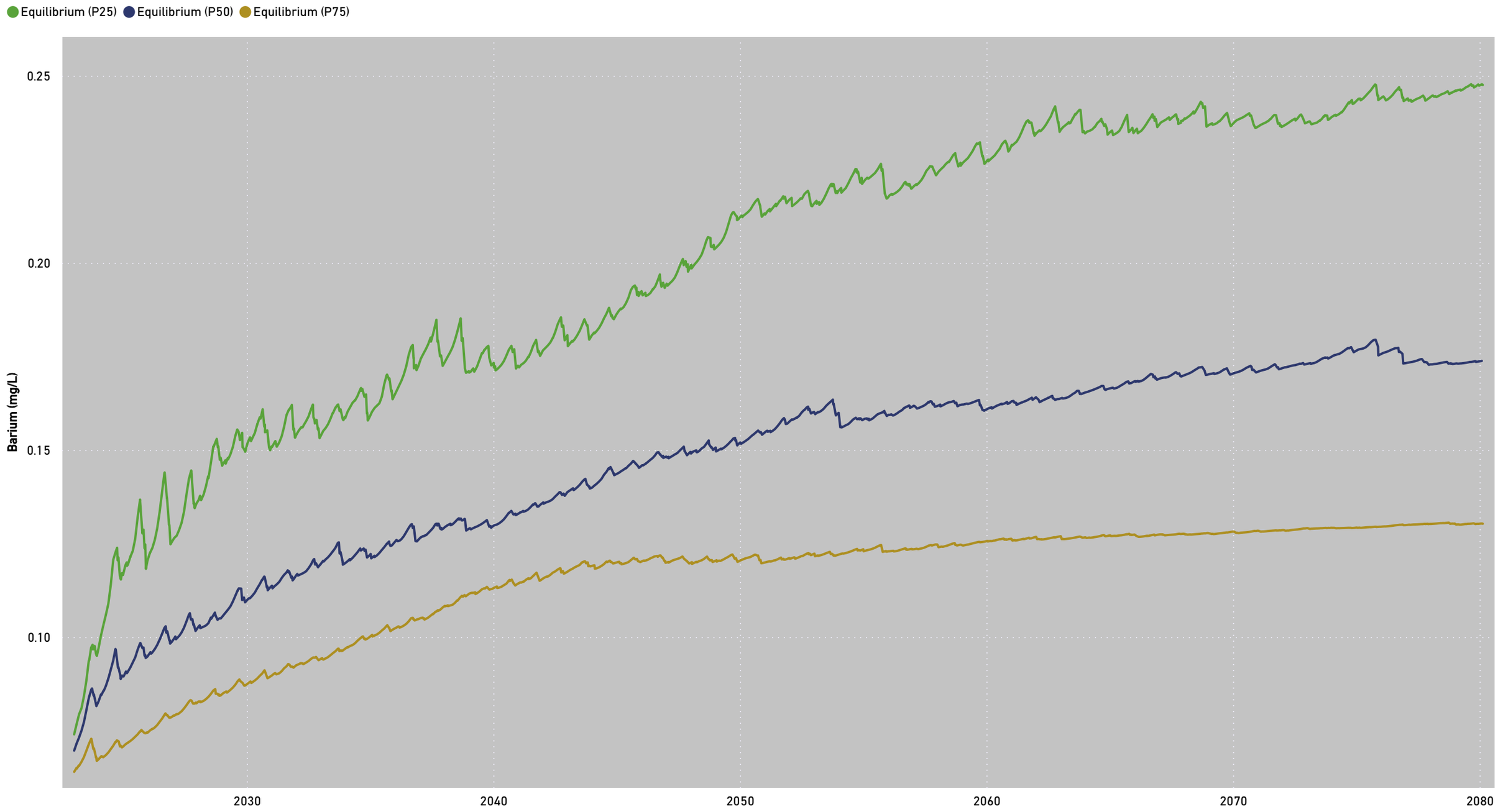

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Sulfate (mg/L)
550
500
450
400
350
300
250
200
2030
2040
2050
2060
2070
2080

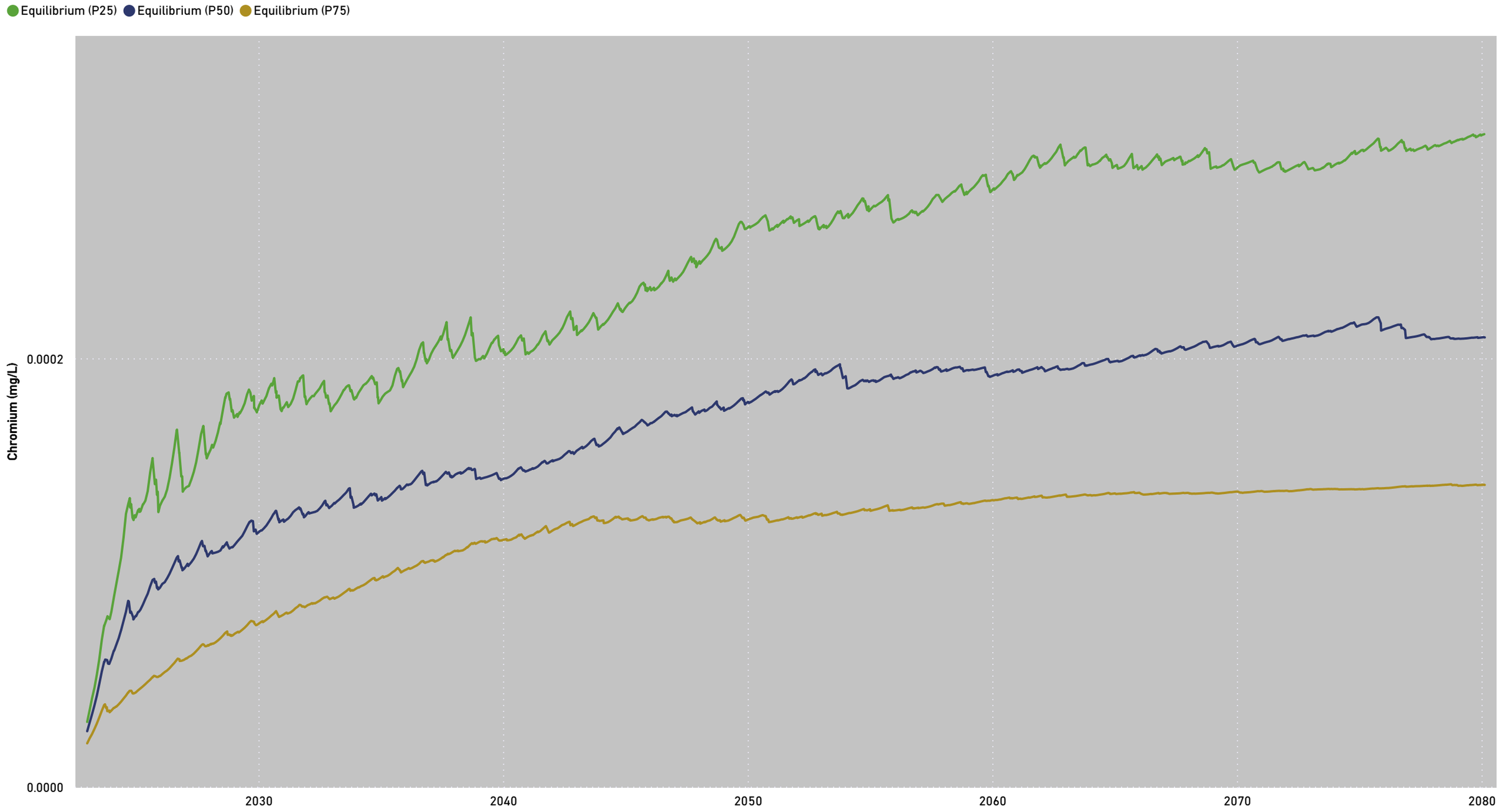

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Fluoride (mg/L)
2.0
1.5
1.0
0.5
0.0
2030
2040
2050
2060
2070
2080

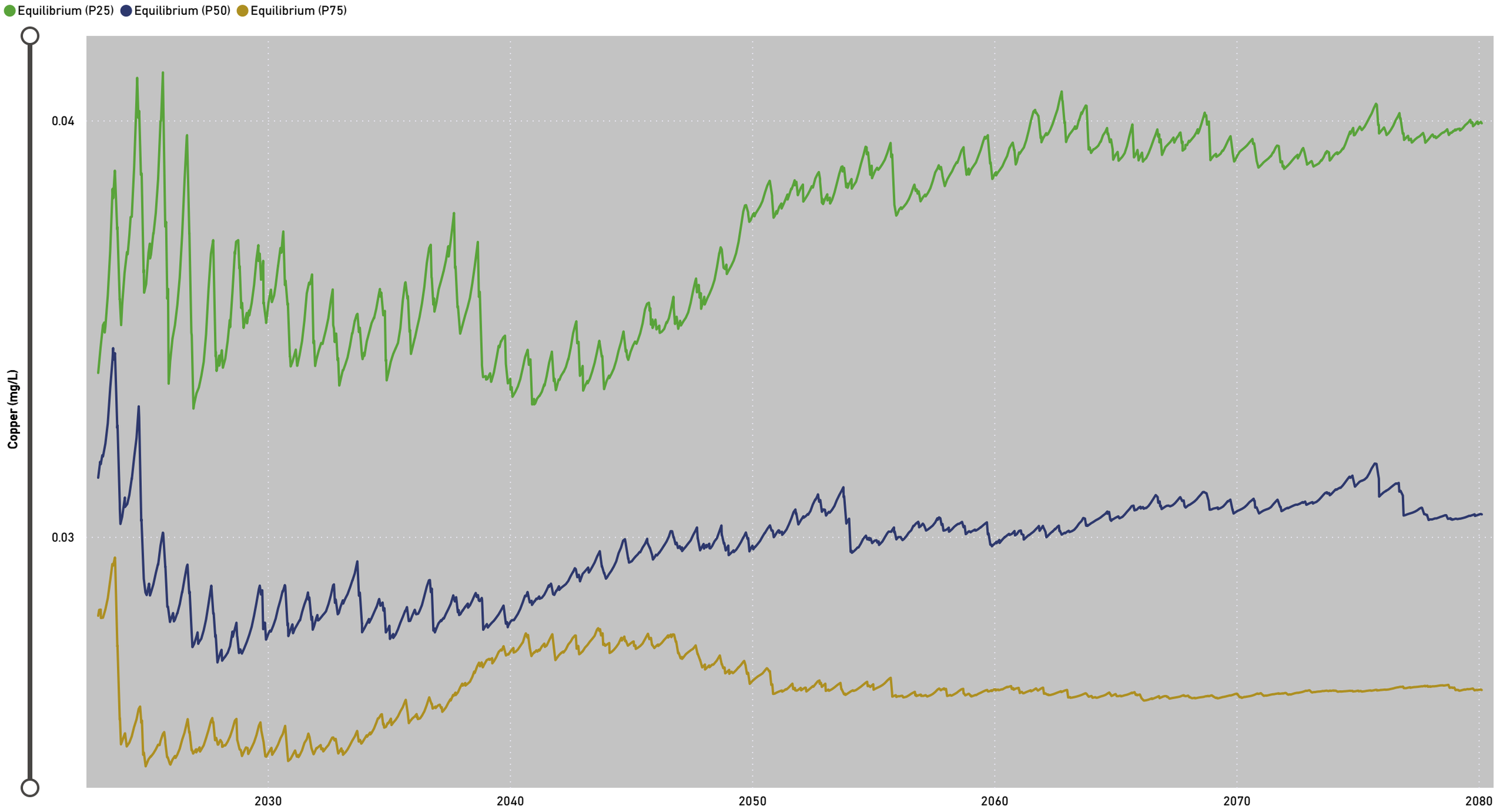

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Bicarbonate (mg/L)
400
300
200
100
2030
2040
2050
2060
2070
2080

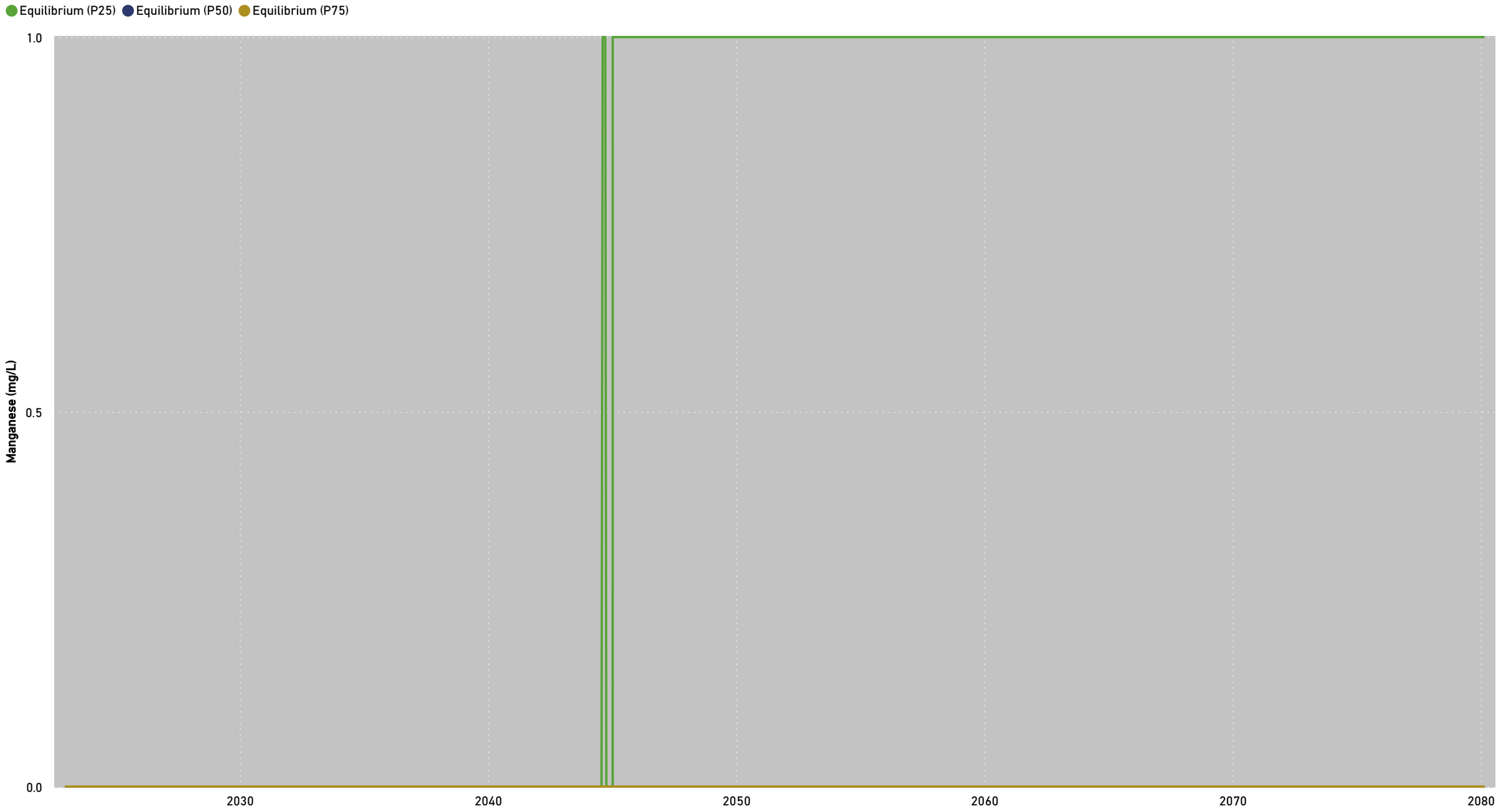

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Aluminium (mg/L)
1
0
-1
2030
2040
2050
2060
2070
2080

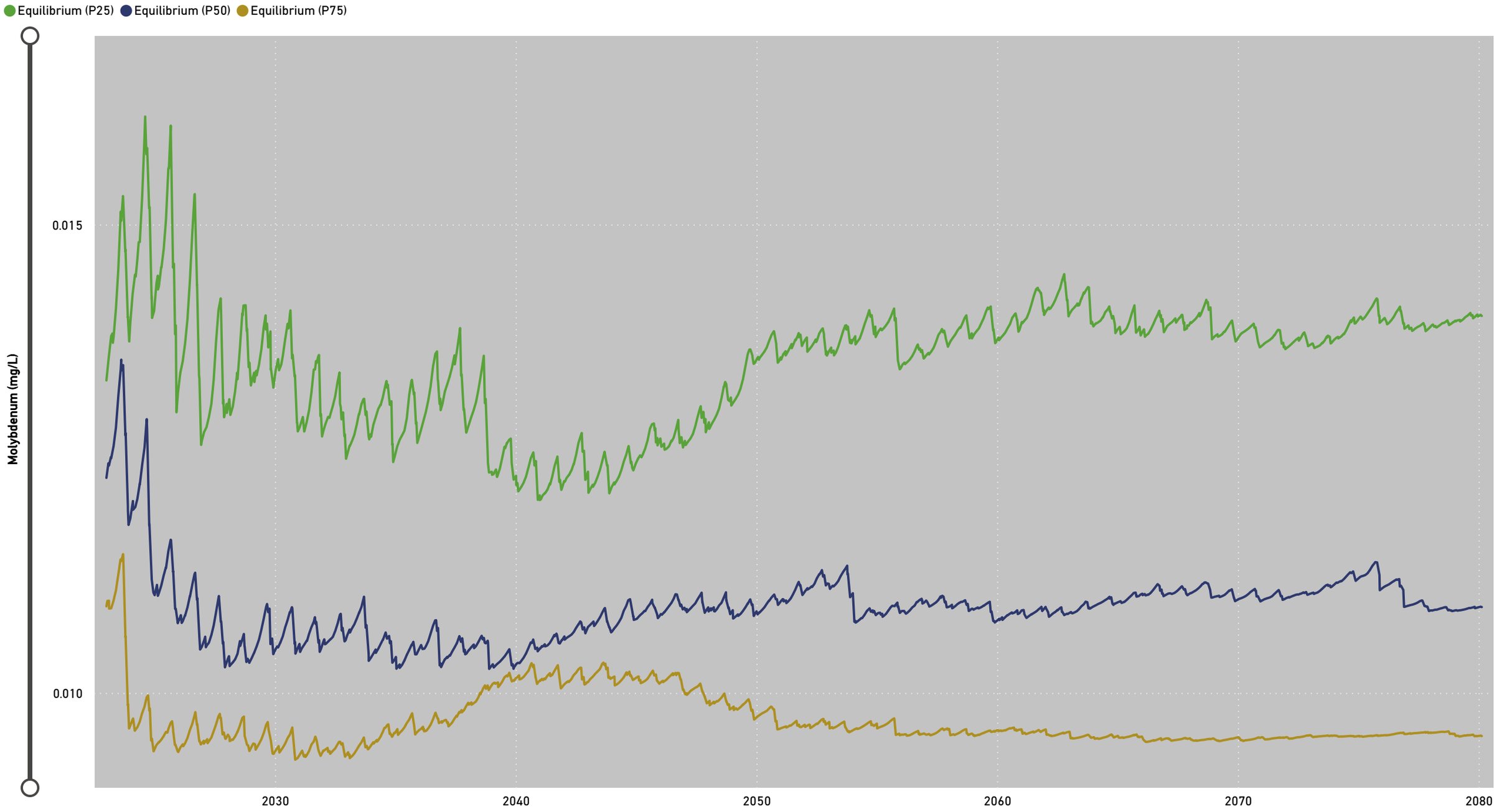

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Arsenic (mg/L)
0.008
0.006
0.004
0.002
2030
2040
2050
2060
2070
2080

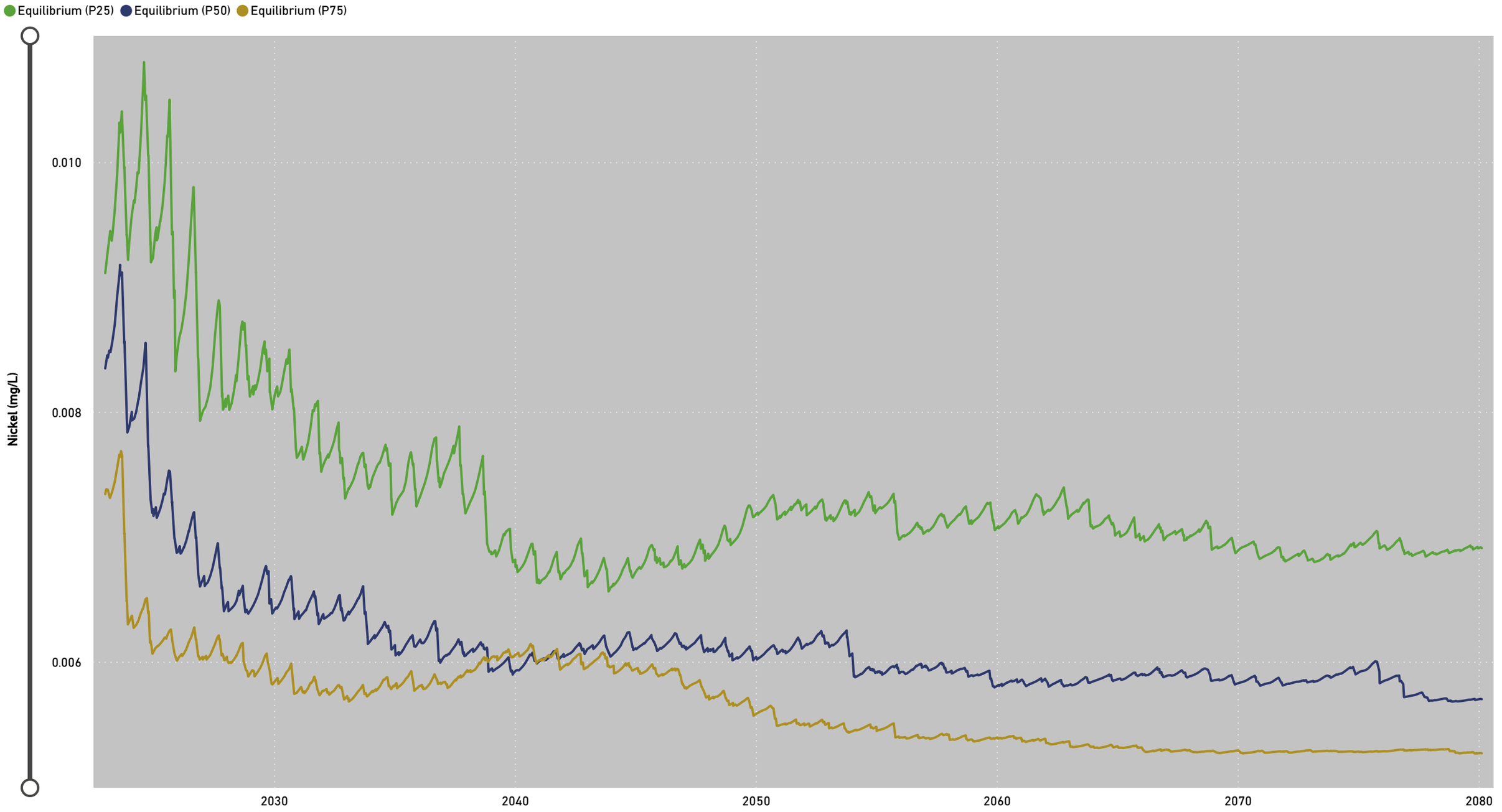

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Barium (mg/L)
0.25
0.20
0.15
0.10
2030
2040
2050
2060
2070
2080

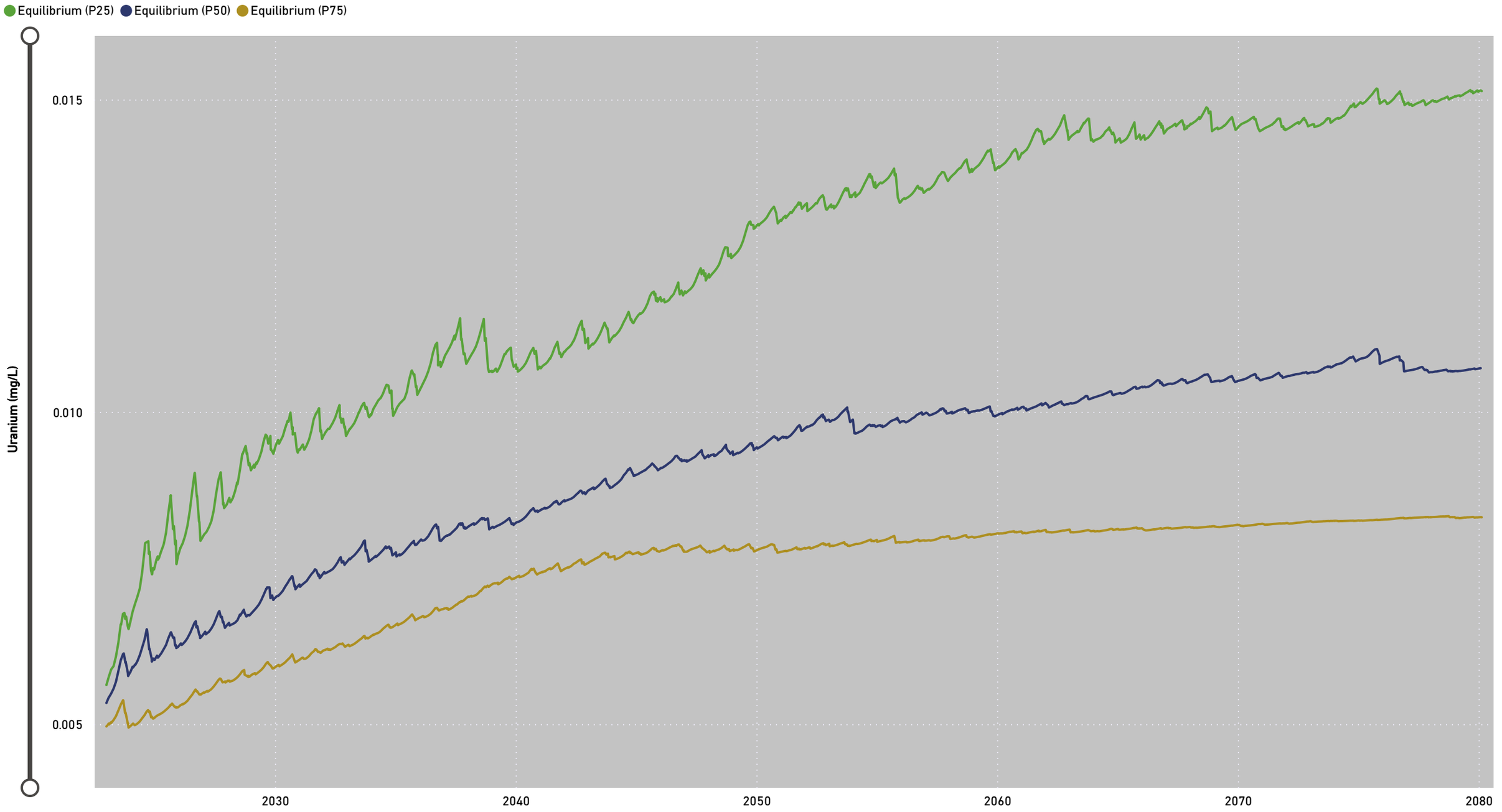

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Chromium (mg/L)
0.0002
0.0000
2030
2040
2050
2060
2070
2080

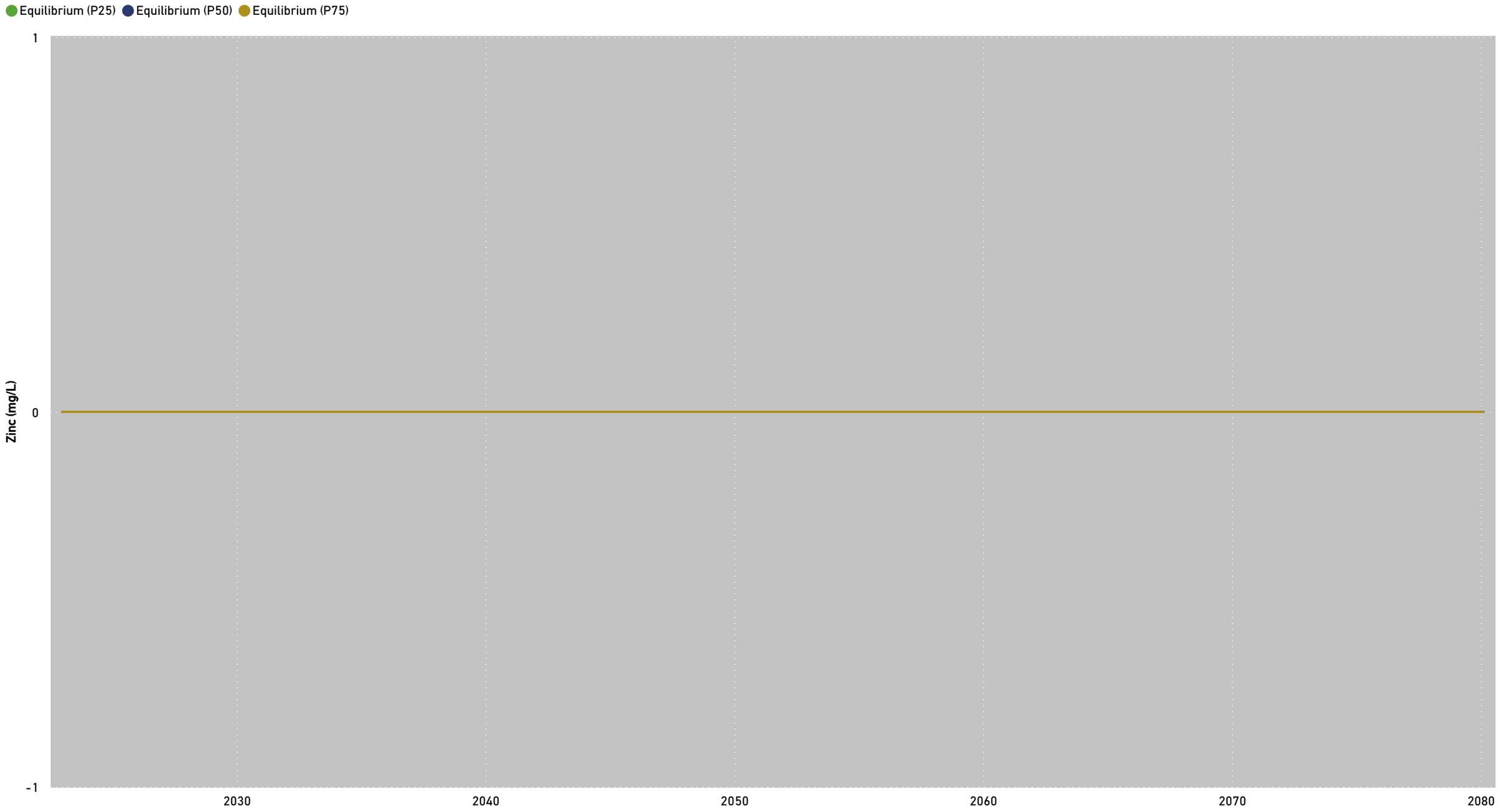

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Copper (mg/L)
0.04
0.03
2030
2040
2050
2060
2070
2080


Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Manganese (mg/L)
1.0
0.5
0.0
2030
2040
2050
2060
2070
2080

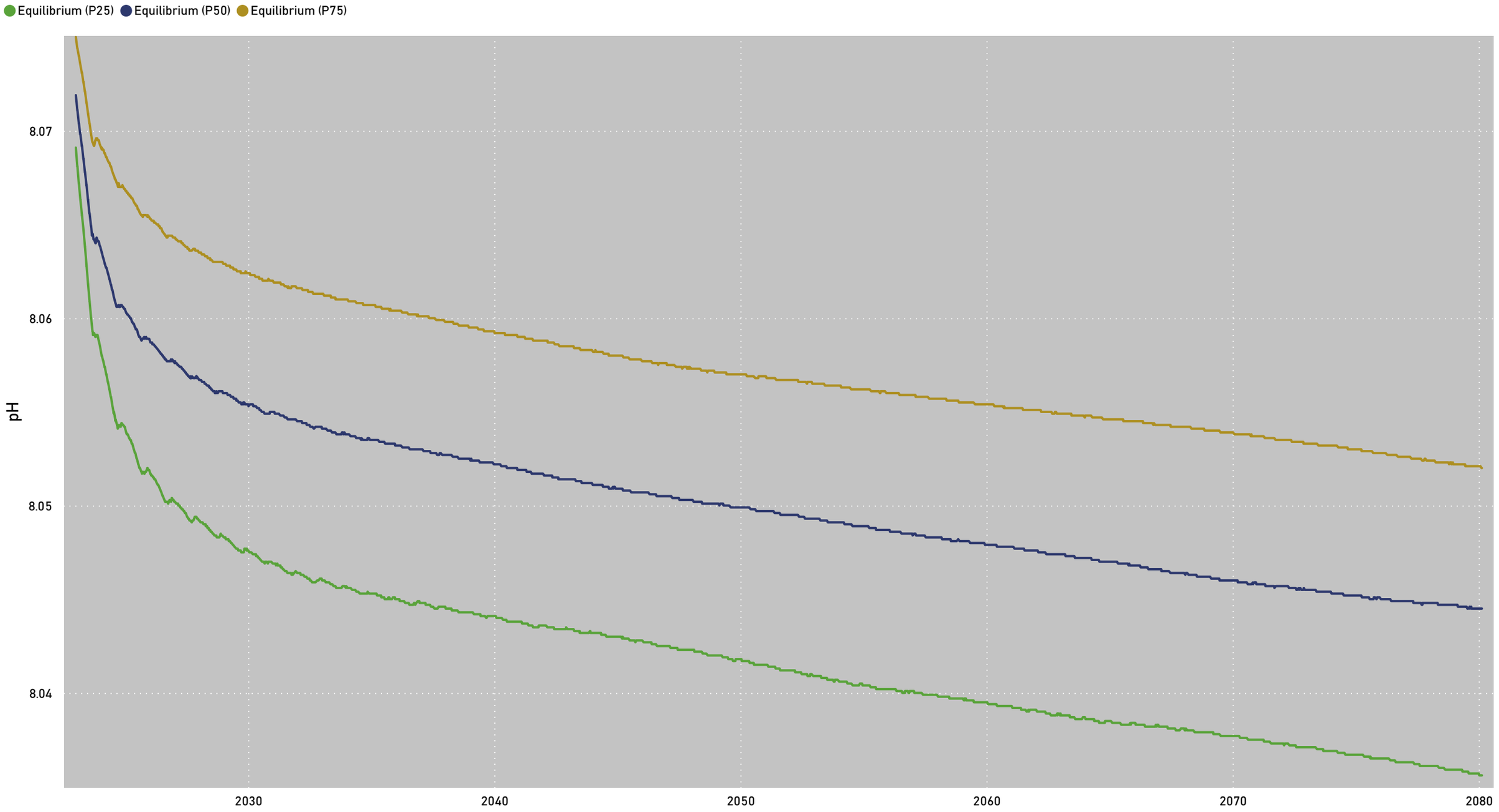

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Molybdenum (mg/L)
0.015
0.010
2030
2040
2050
2060
2070
2080

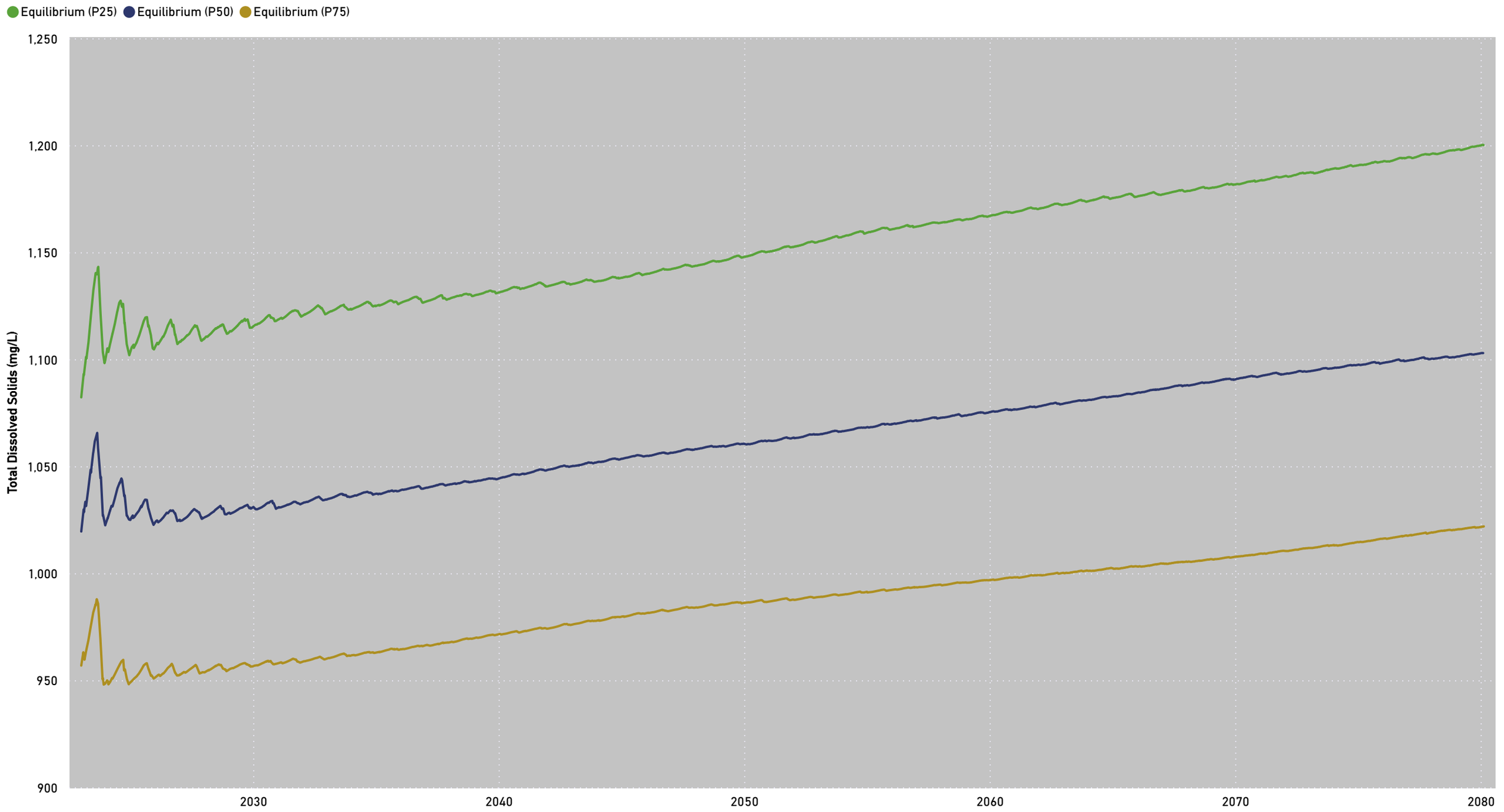

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Nickel (mg/L)
0.010
0.008
0.006
2030
2040
2050
2060
2070
2080

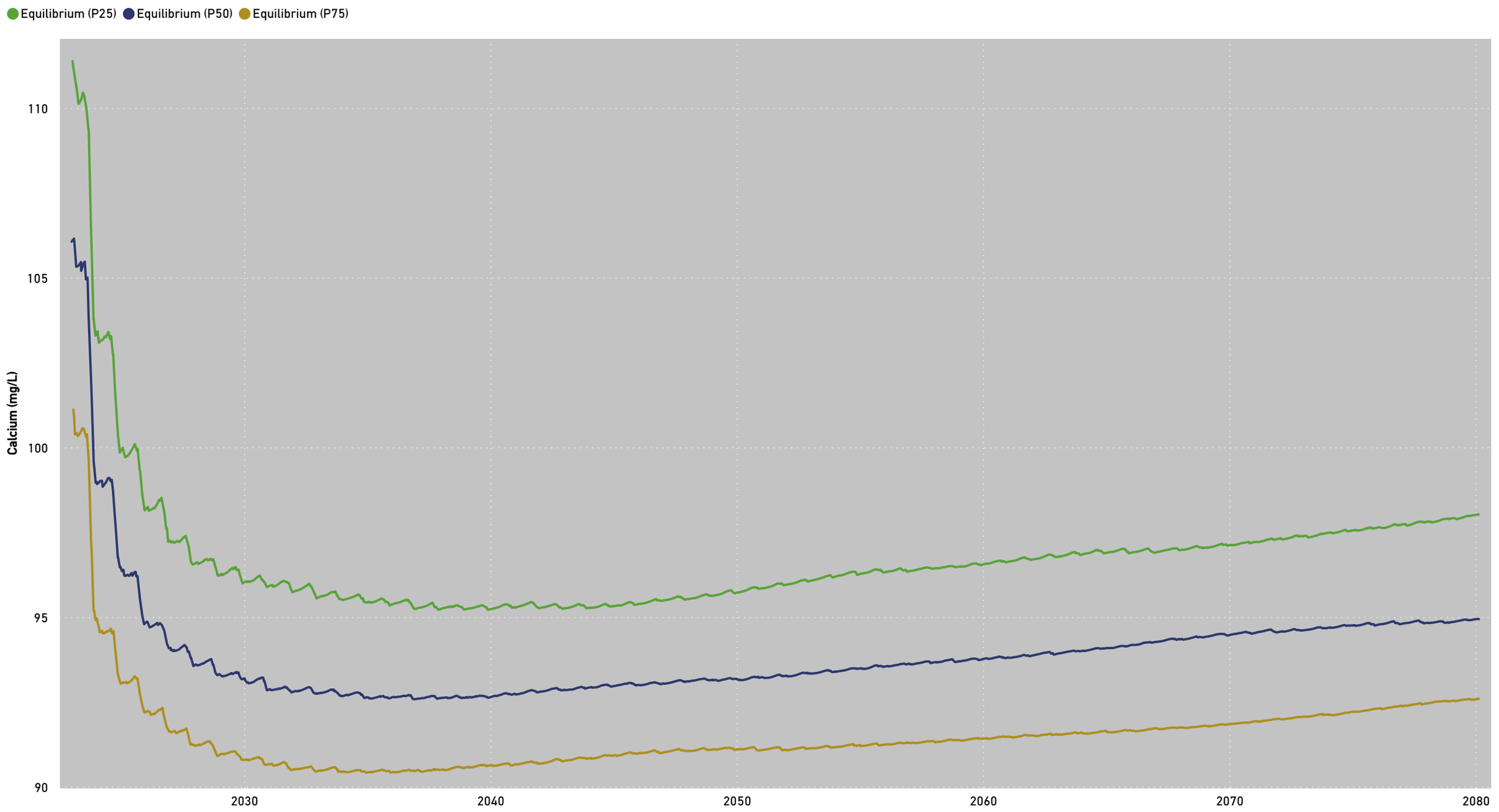

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Uranium (mg/L)
0.015
0.010
0.005
2030
2040
2050
2060
2070
2080

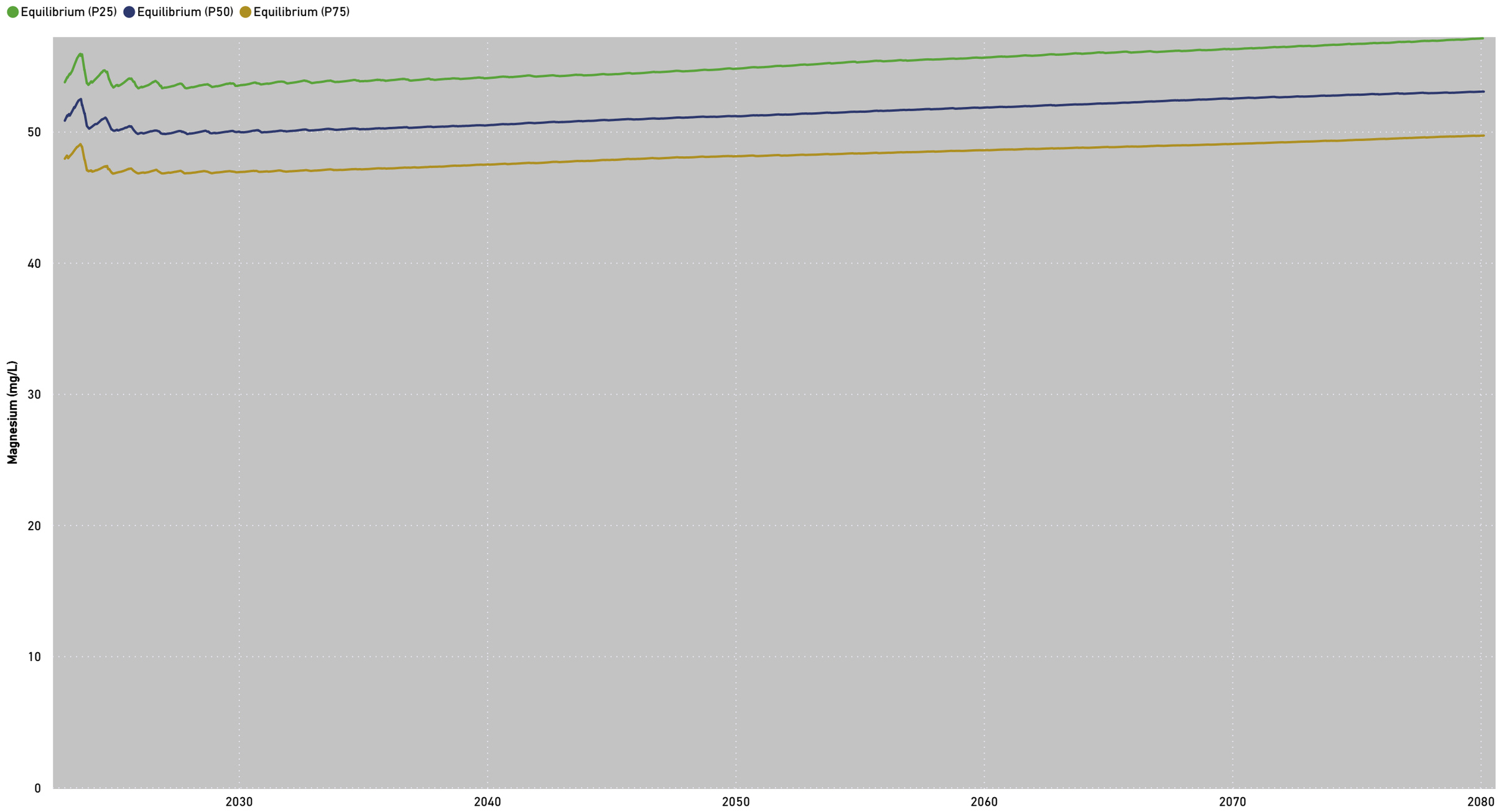

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Zinc (mg/L)
1
0
-1
2030
2040
2050
2060
2070
2080

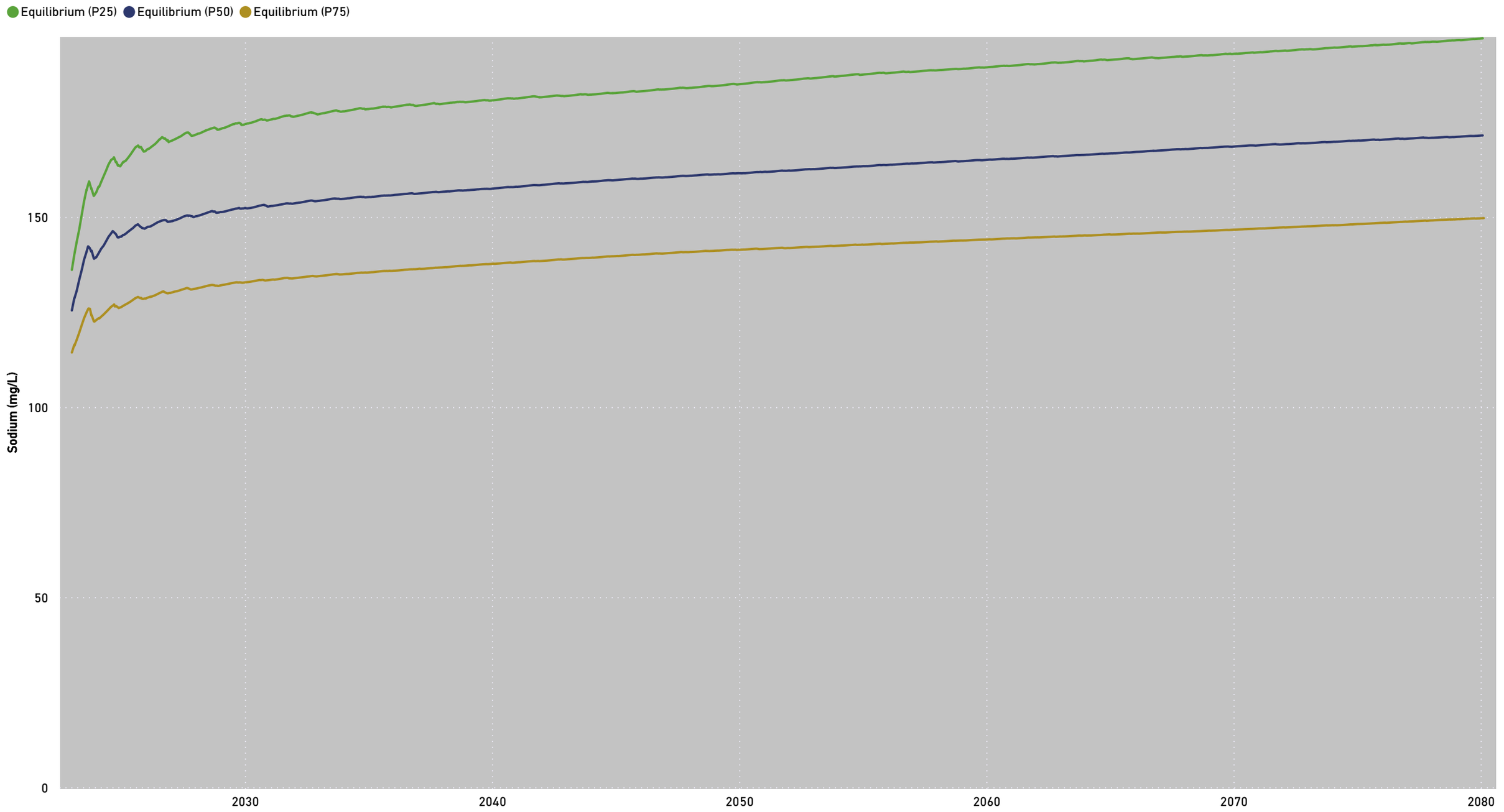
D.2.2 South Pit water quality

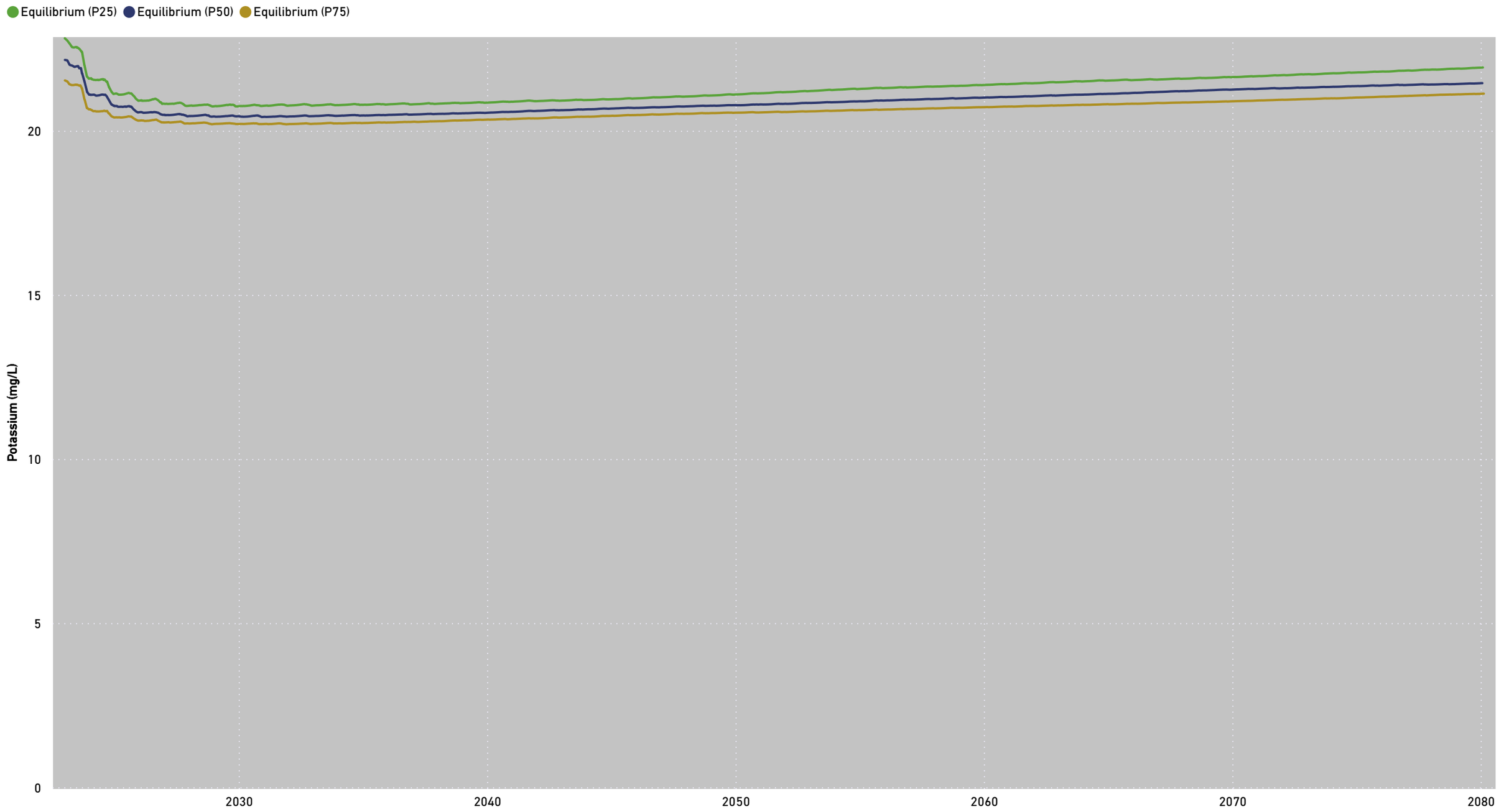

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
pH
8.07
8.06
8.05
8.04
2030
2040
2050
2060
2070
2080

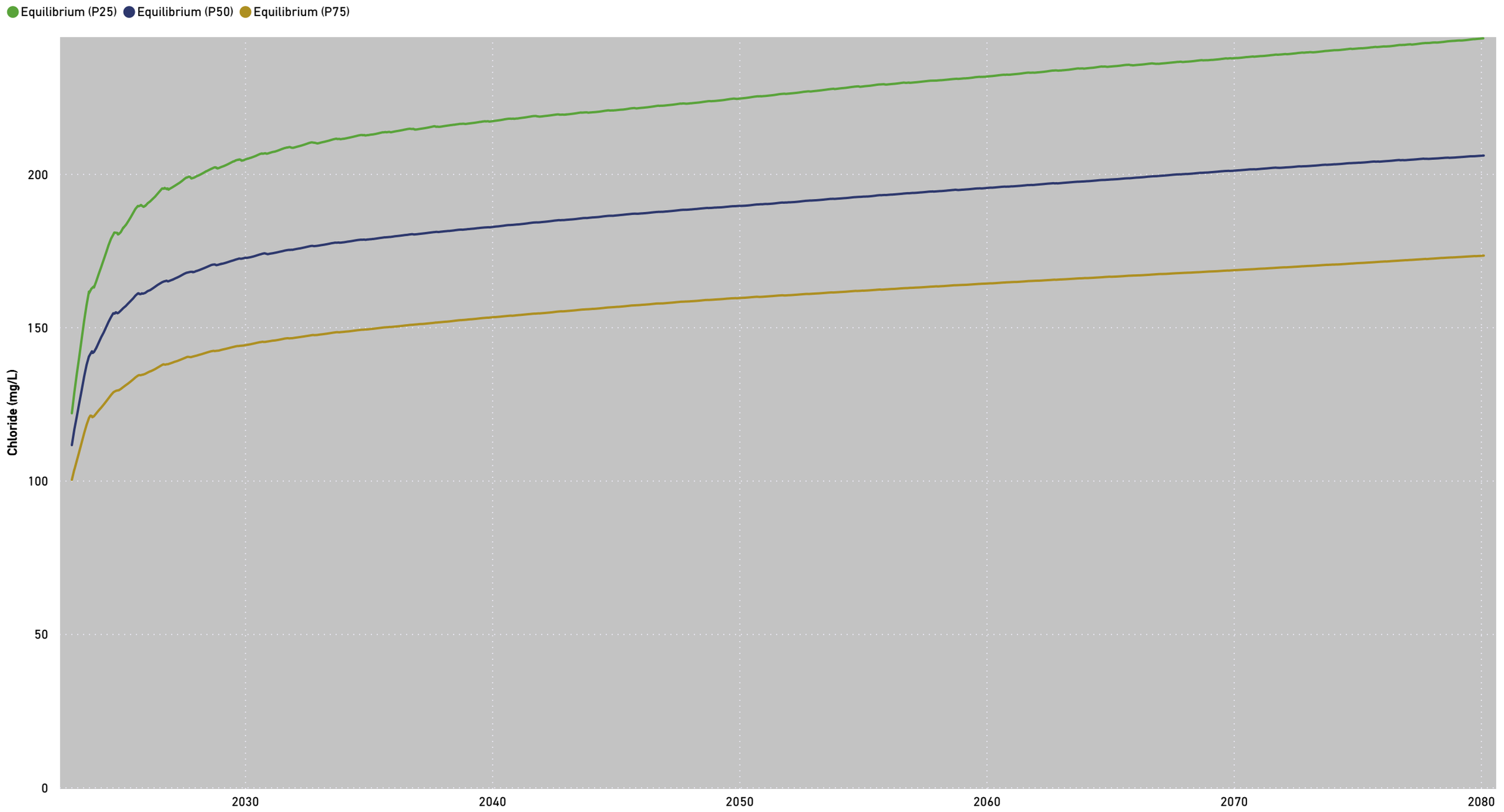

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Total Dissolved Solids (mg/L)
1,250
1,200
1,150
1,100
1,050
1,000
950
900
2030
2040
2050
2060
2070
2080

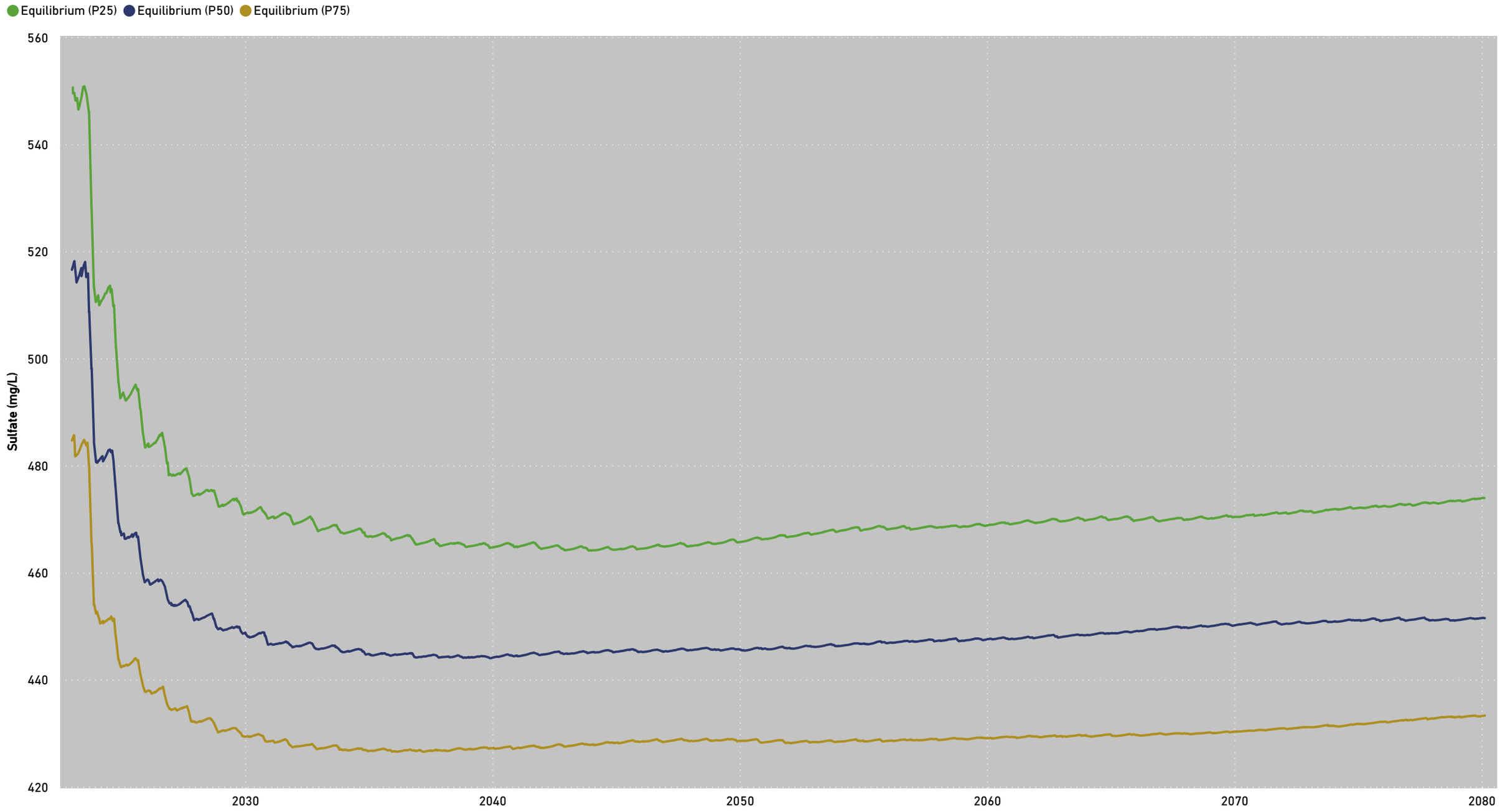

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Calcium (mg/L)
110
105
100
95
90
2030
2040
2050
2060
2070
2080

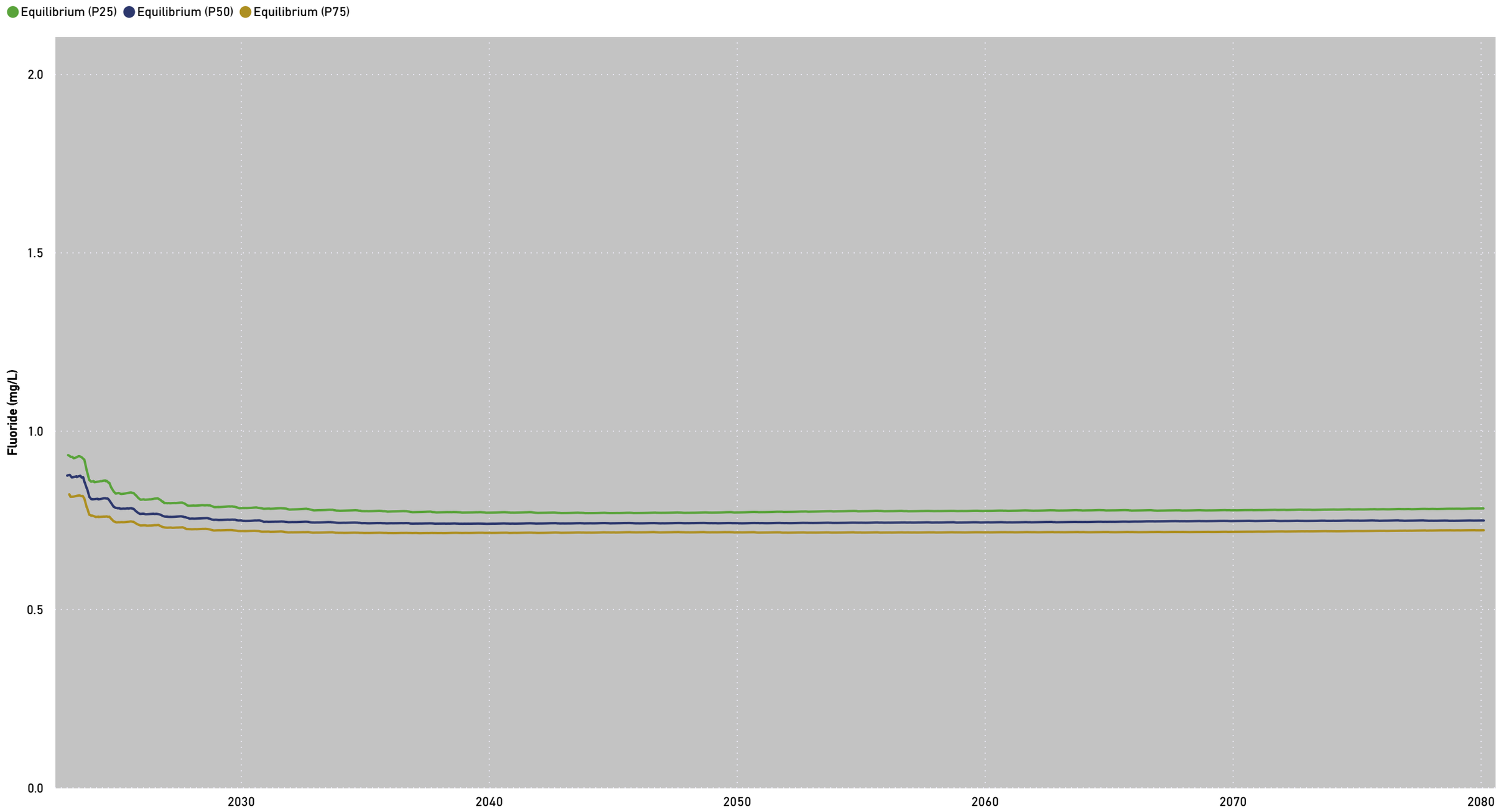

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Magnesium (mg/L)
0
10
20
30
40
50
2030
2040
2050
2060
2070
2080

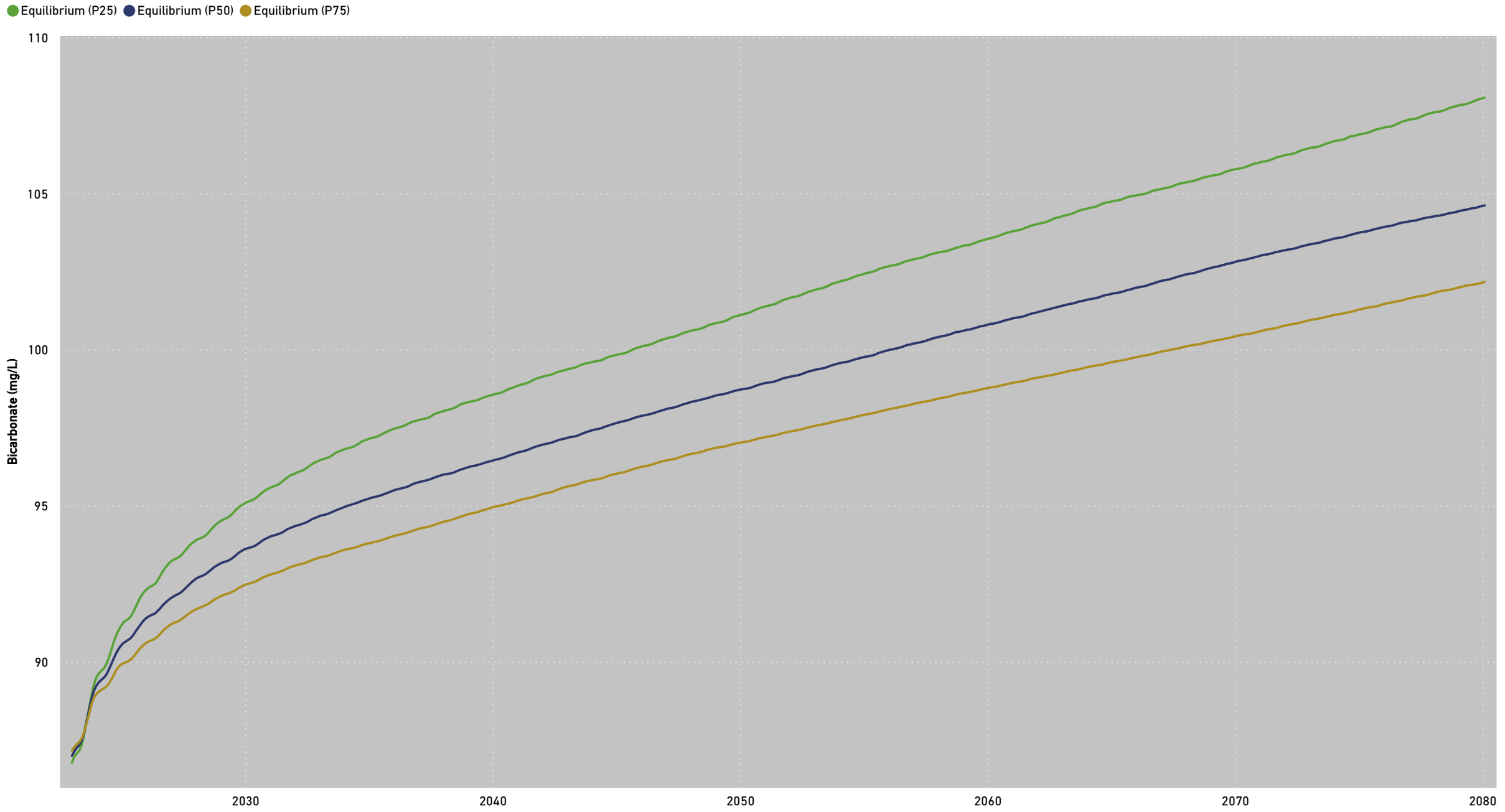

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Sodium (mg/L)
150
100
50
0
2030
2040
2050
2060
2070
2080

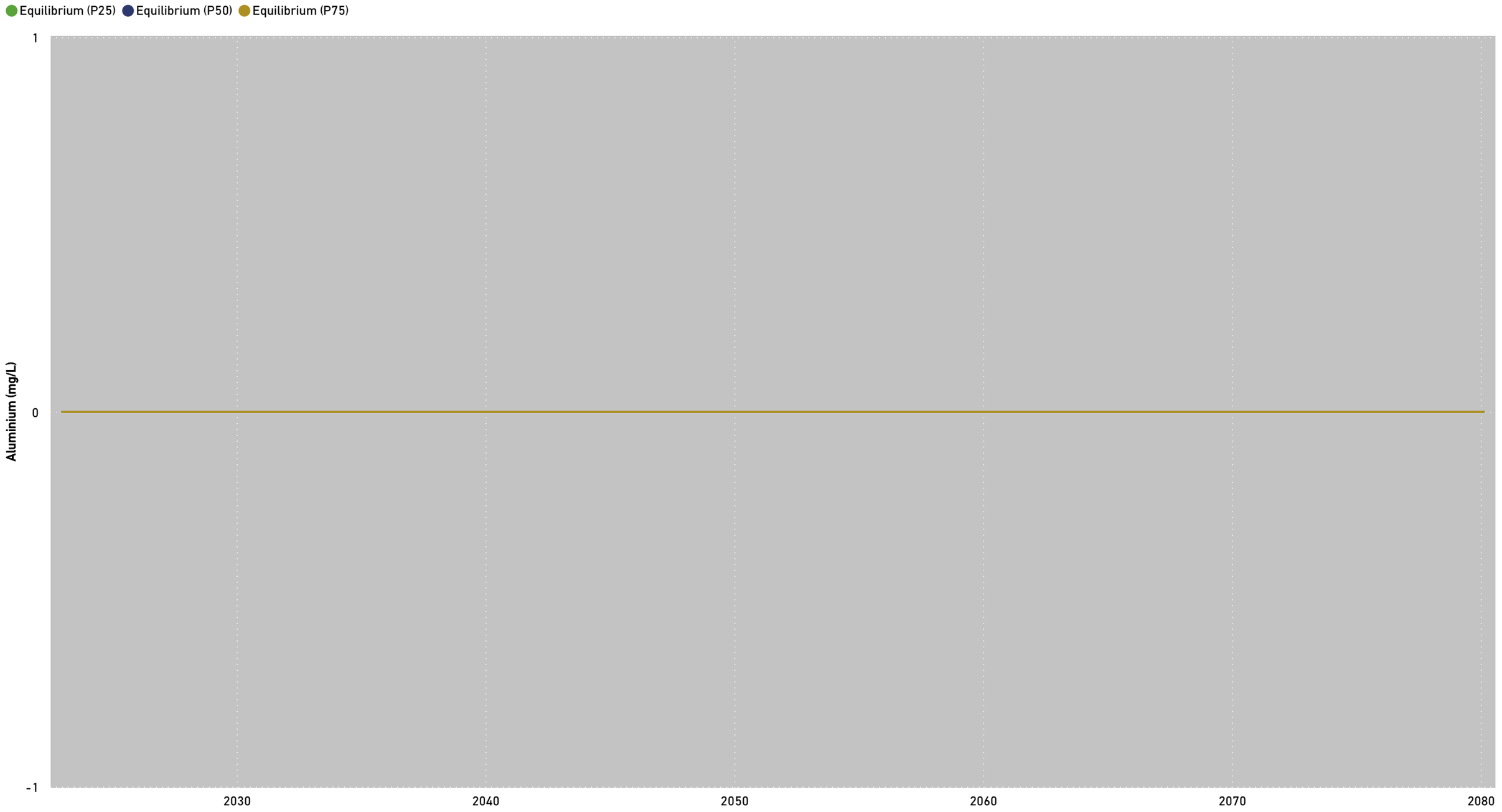

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Potassium (mg/L)
0
5
10
15
20
2030
2040
2050
2060
2070
2080

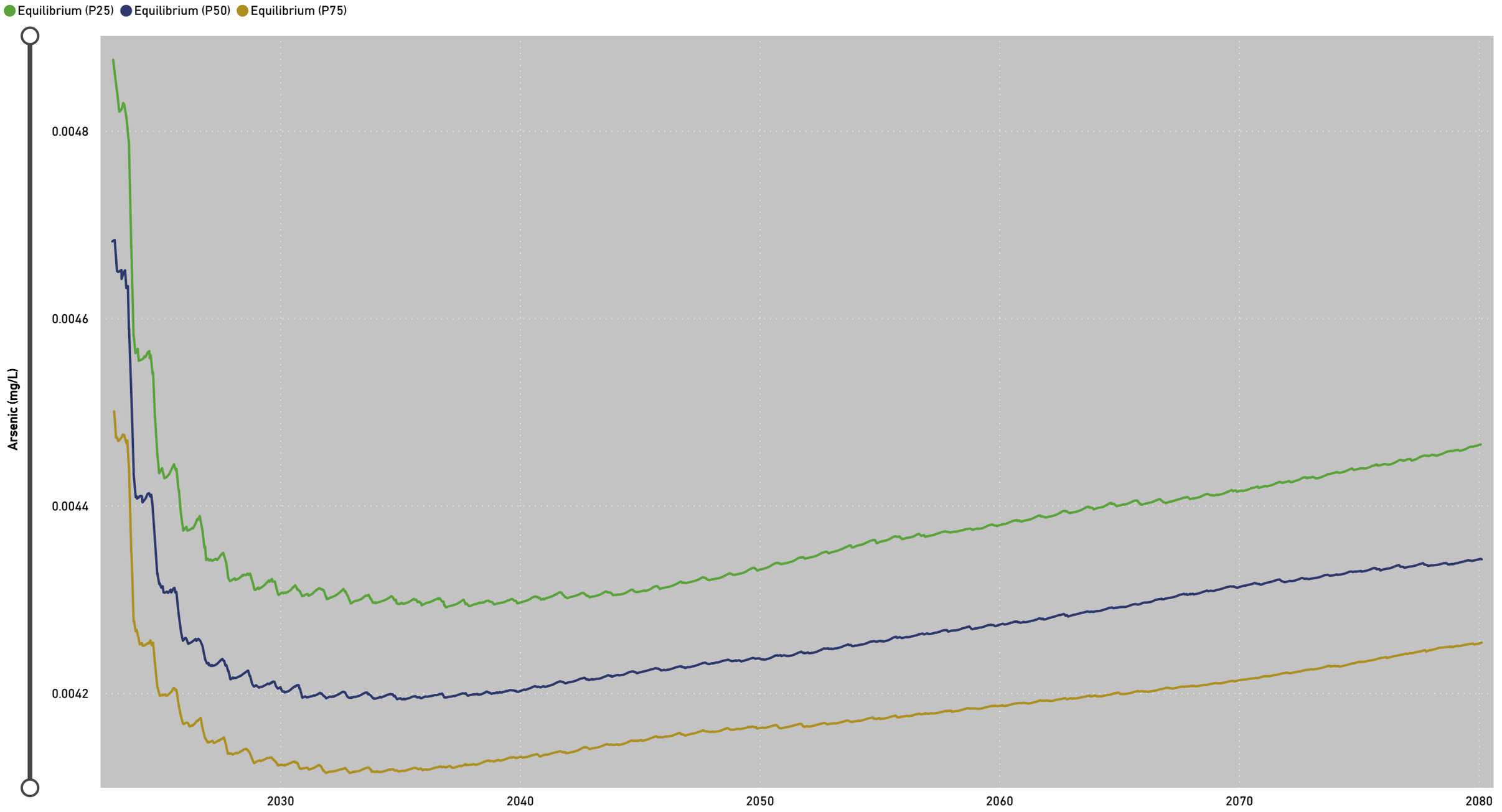

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Chloride (mg/L)
0
50
100
150
200
2030
2040
2050
2060
2070
2080

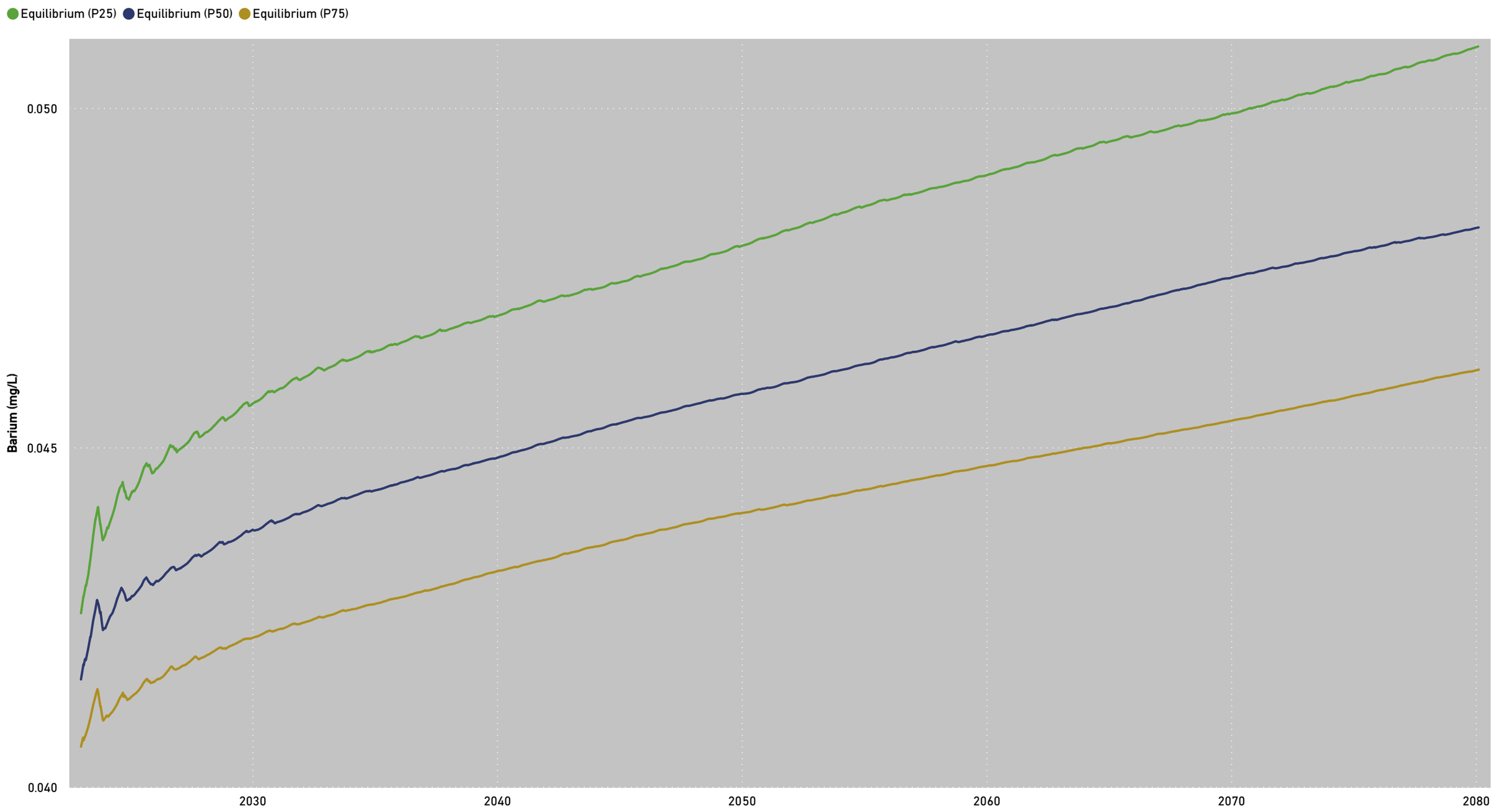

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Sulfate (mg/L)
560
540
520
500
480
460
440
420
2030
2040
2050
2060
2070
2080

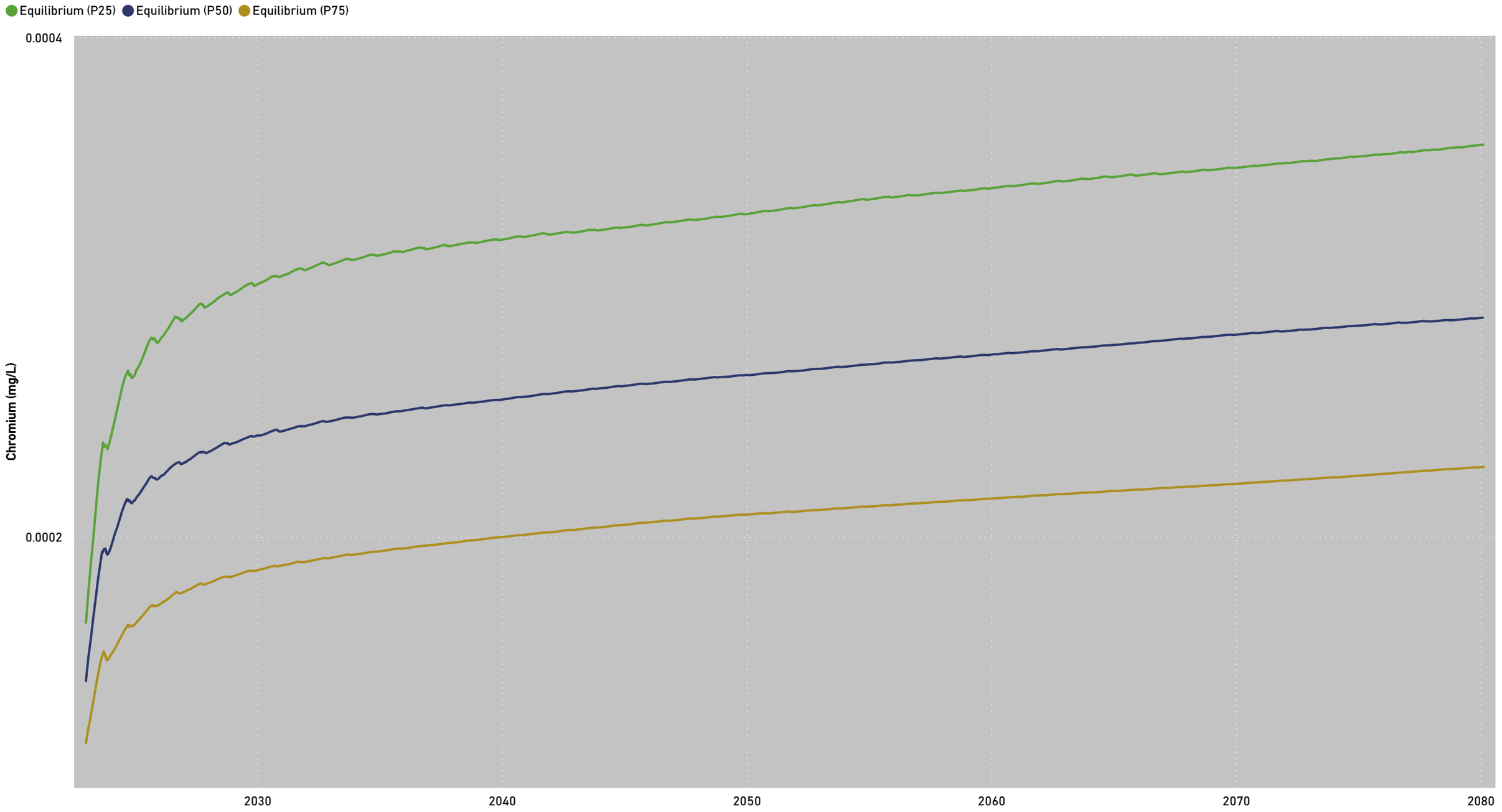

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Fluoride (mg/L)
2.0
1.5
1.0
0.5
0.0
2030
2040
2050
2060
2070
2080

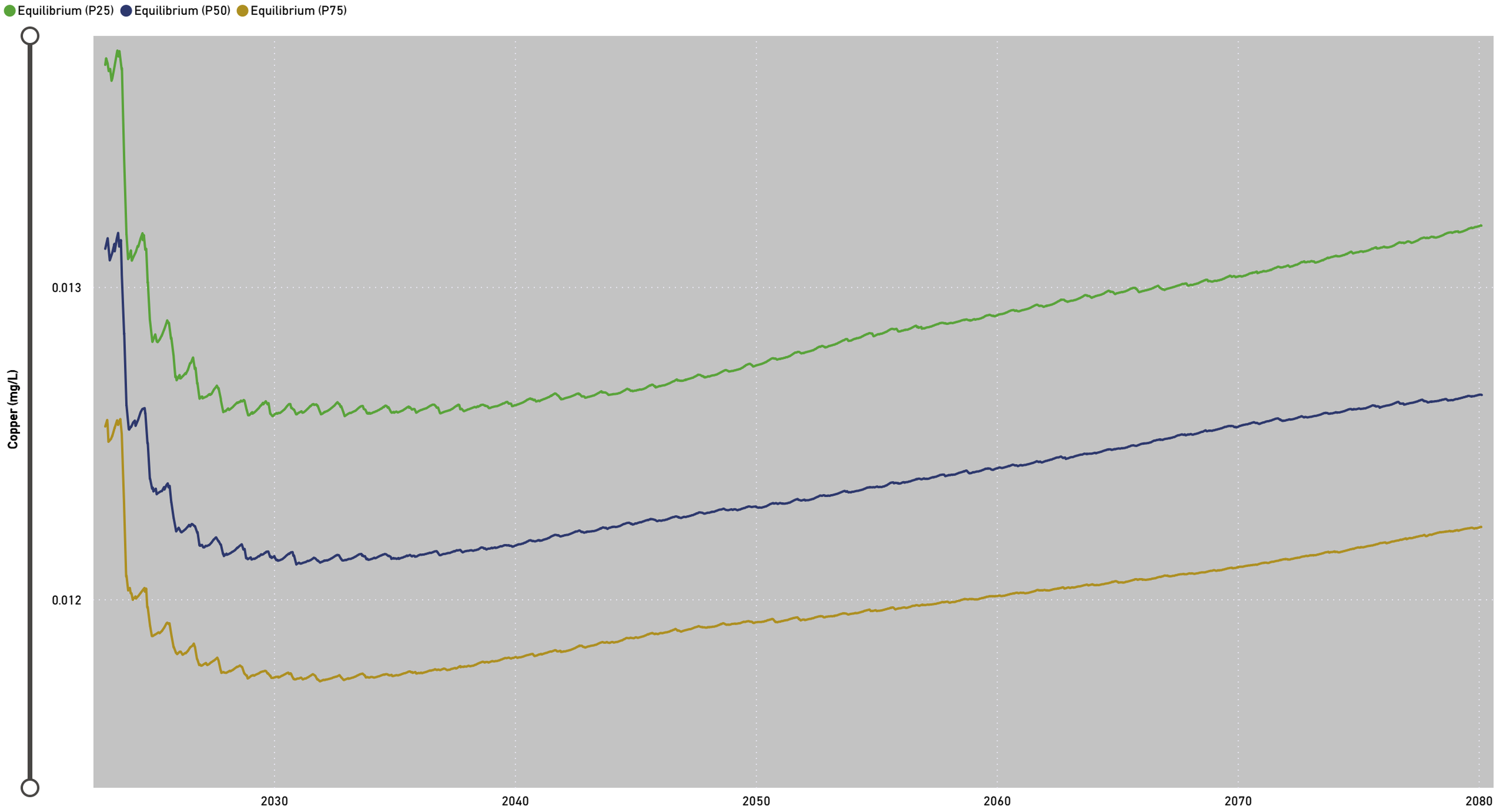

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Bicarbonate (mg/L)
110
105
100
95
90
2030
2040
2050
2060
2070
2080

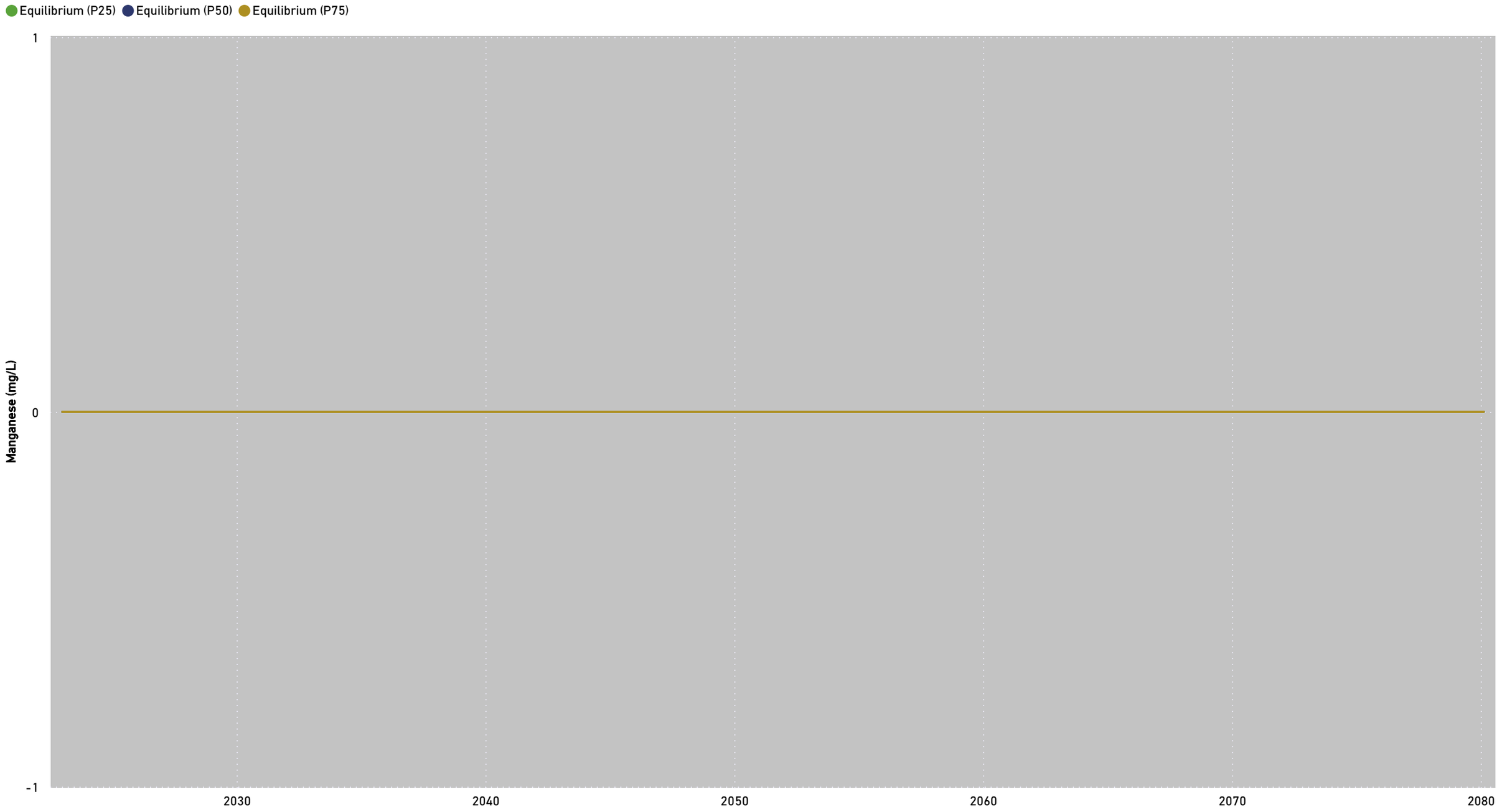

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Aluminium (mg/L)
1
0
-1
2030
2040
2050
2060
2070
2080

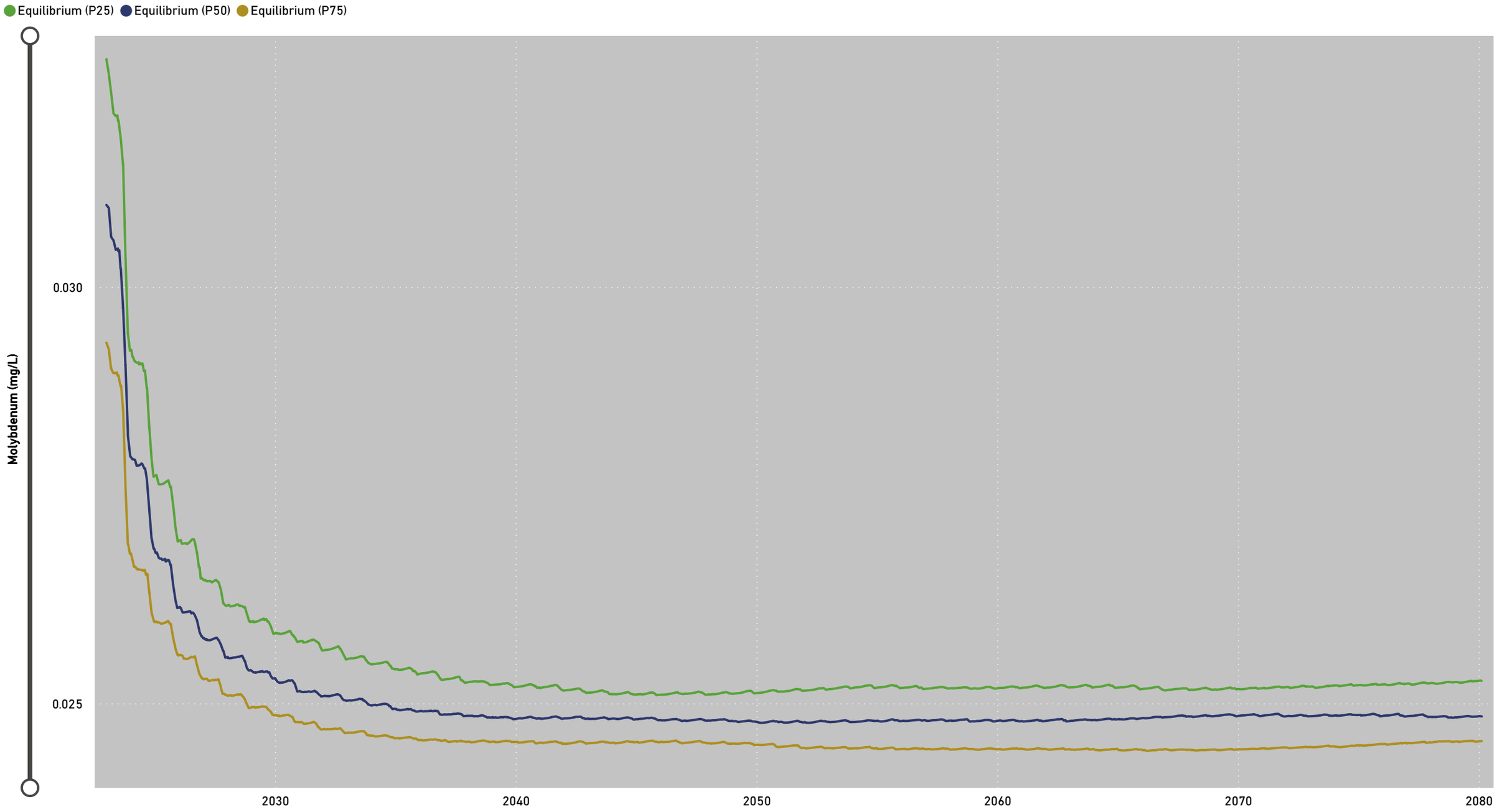

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Arsenic (mg/L)
0.0048
0.0046
0.0044
0.0042
2030
2040
2050
2060
2070
2080

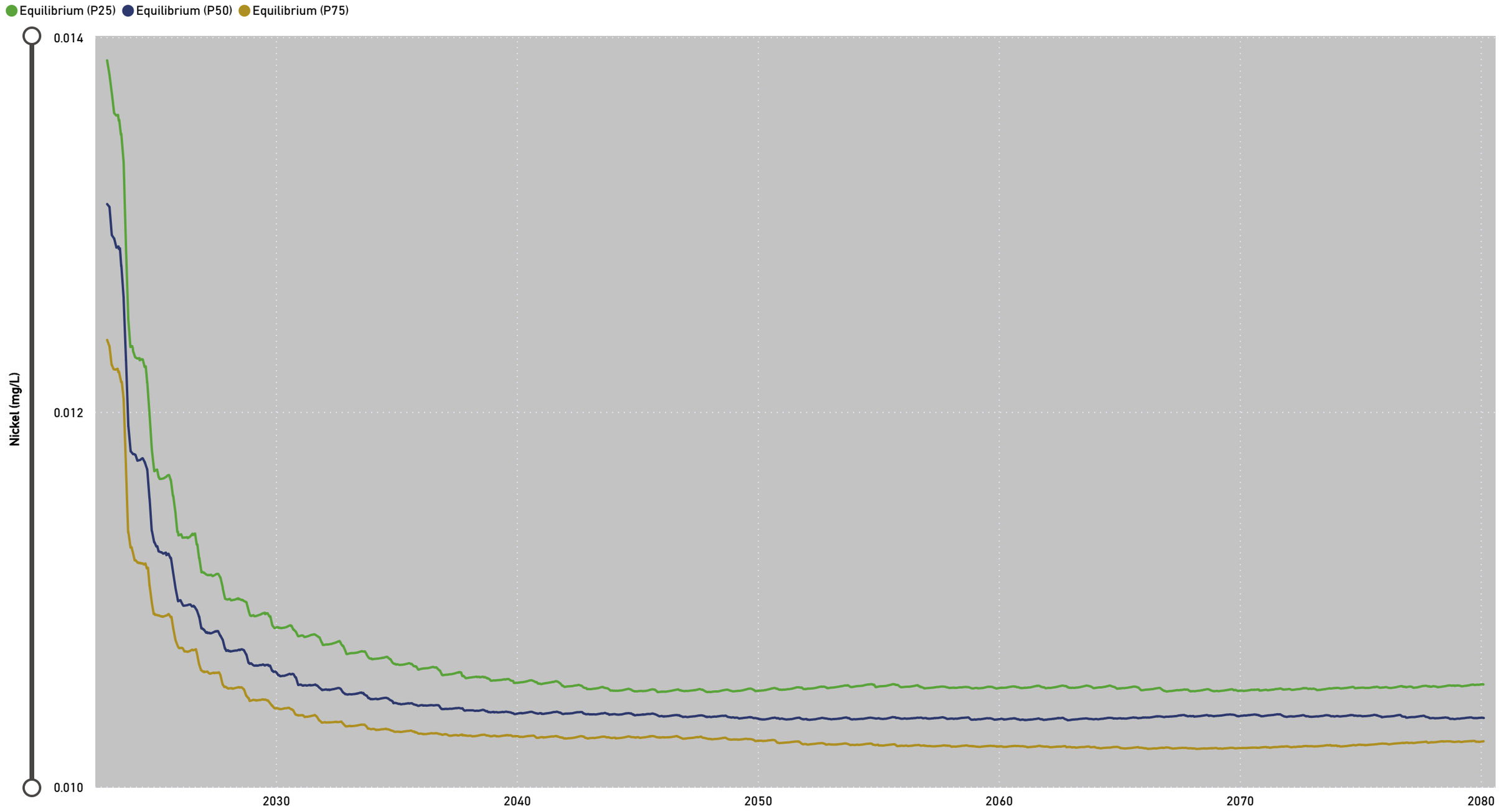

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Barium (mg/L)
0.050
0.045
0.040
2030
2040
2050
2060
2070
2080

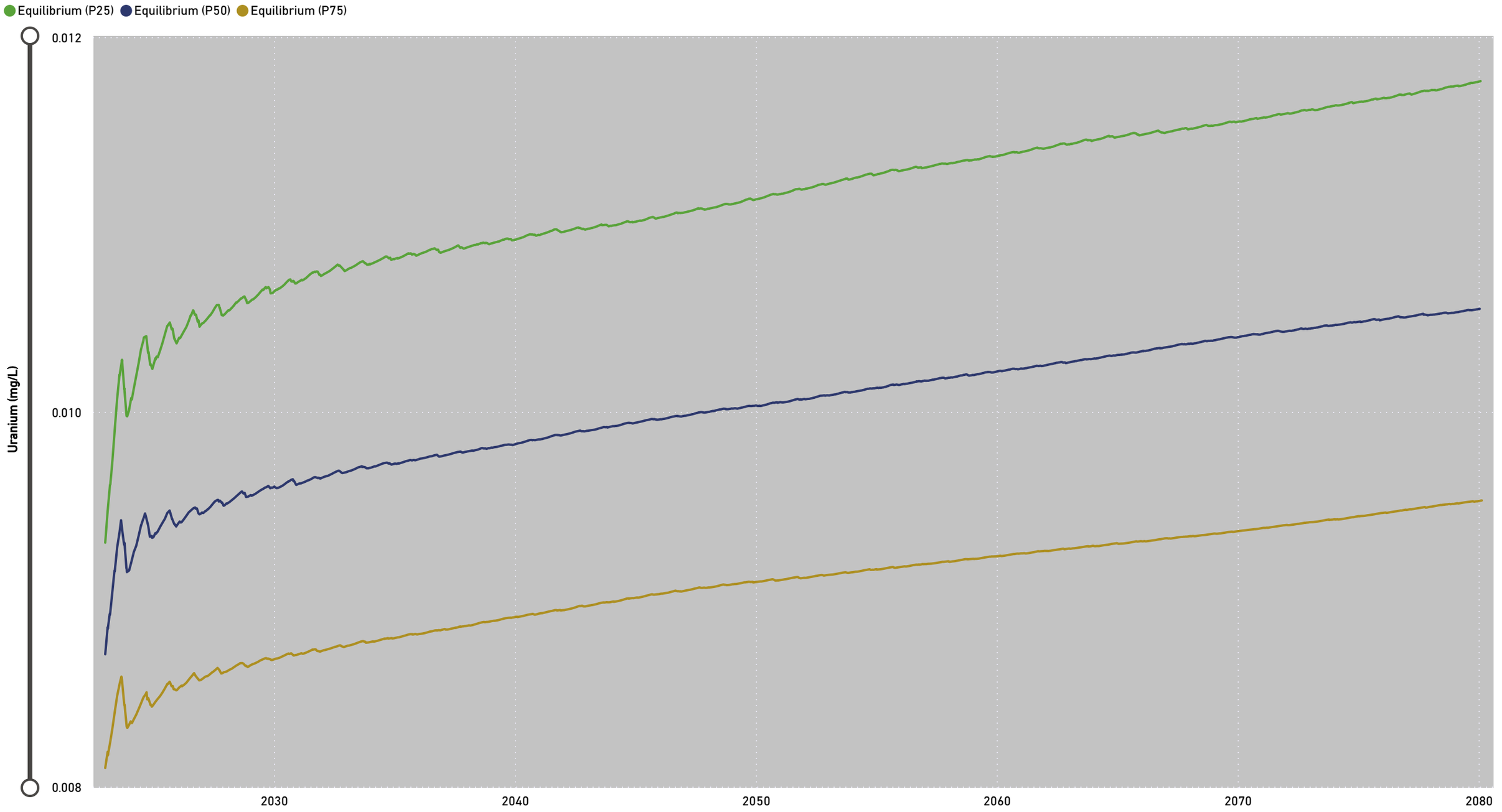

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
0.0004
0.0002
Chromium (mg/L)
2030
2040
2050
2060
2070
2080

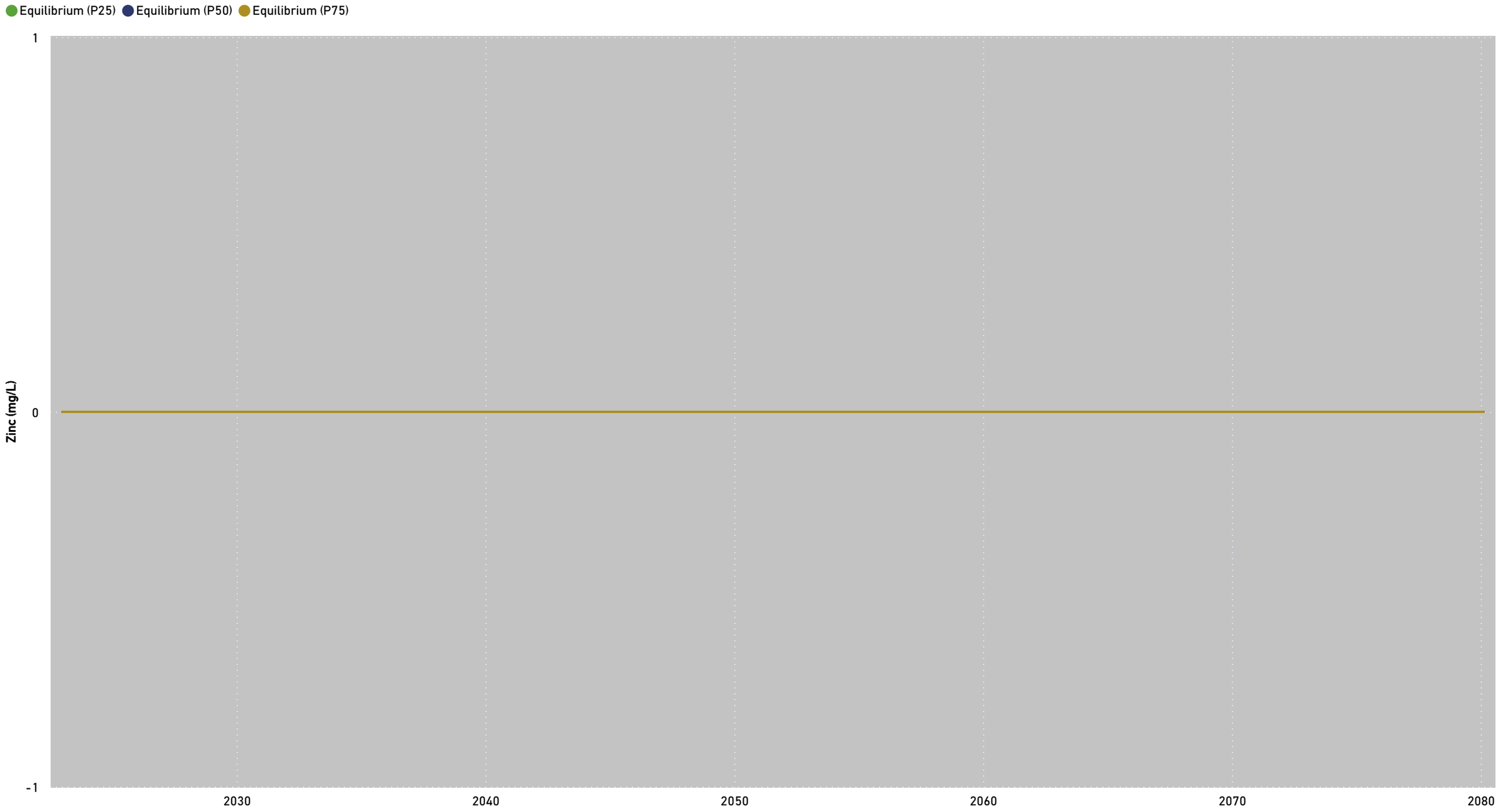

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Copper (mg/L)
0.013
0.012
2030
2040
2050
2060
2070
2080


Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Manganese (mg/L)
1
0
-1
2030
2040
2050
2060
2070
2080

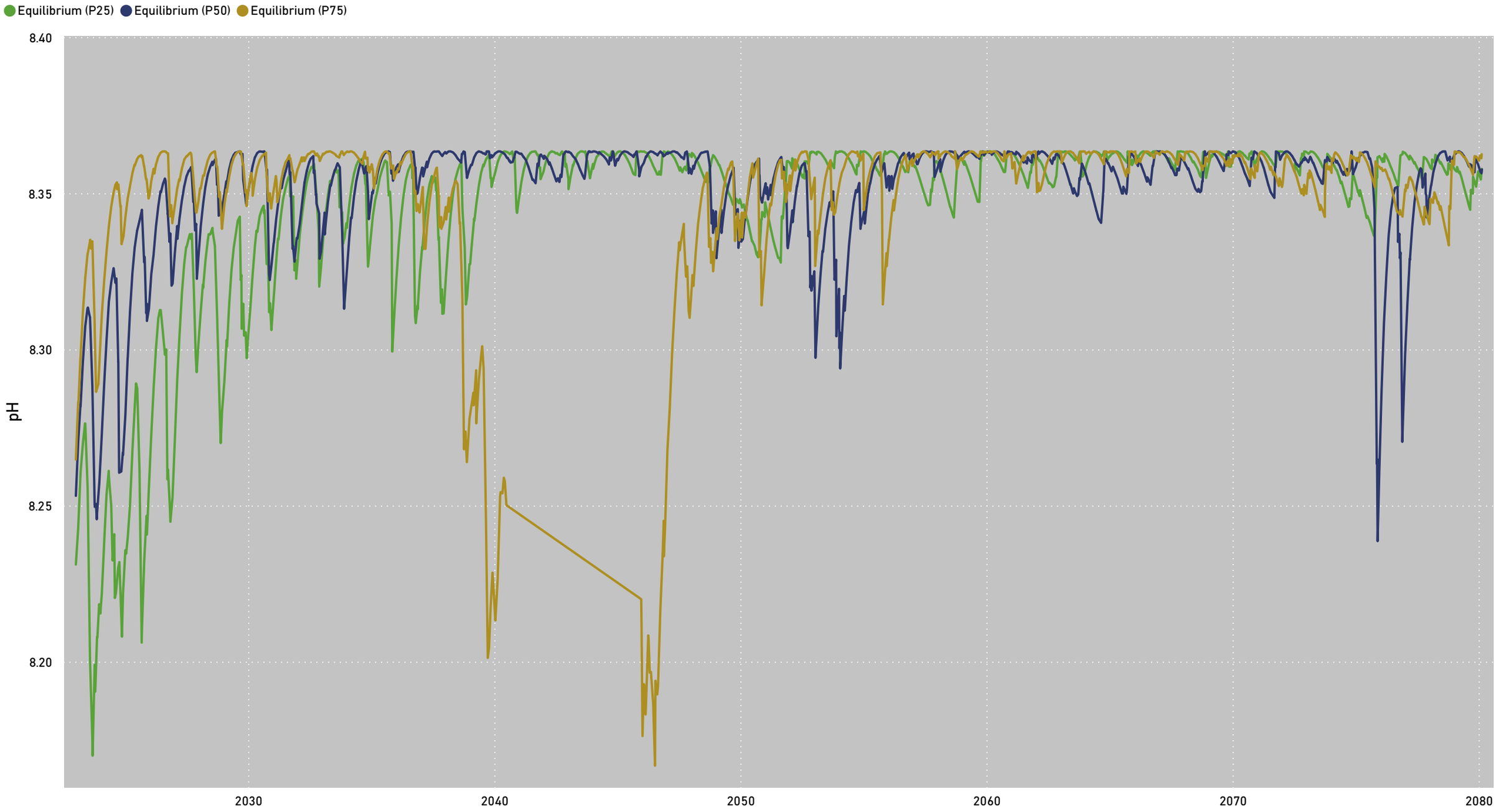

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Molybdenum (mg/L)
0.030
0.025
2030
2040
2050
2060
2070
2080

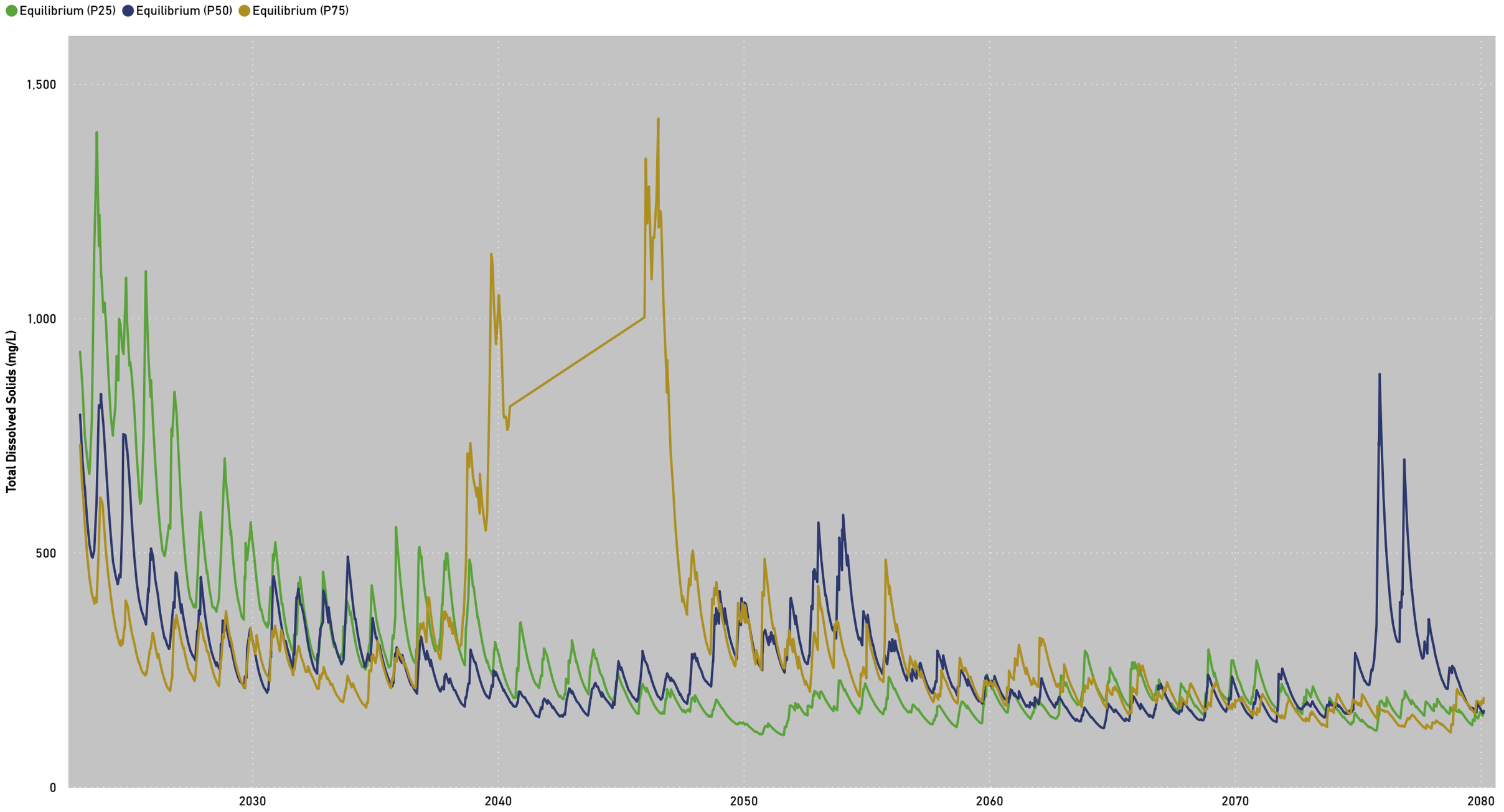

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Nickel (mg/L)
0.014
0.012
0.010
2030
2040
2050
2060
2070
2080

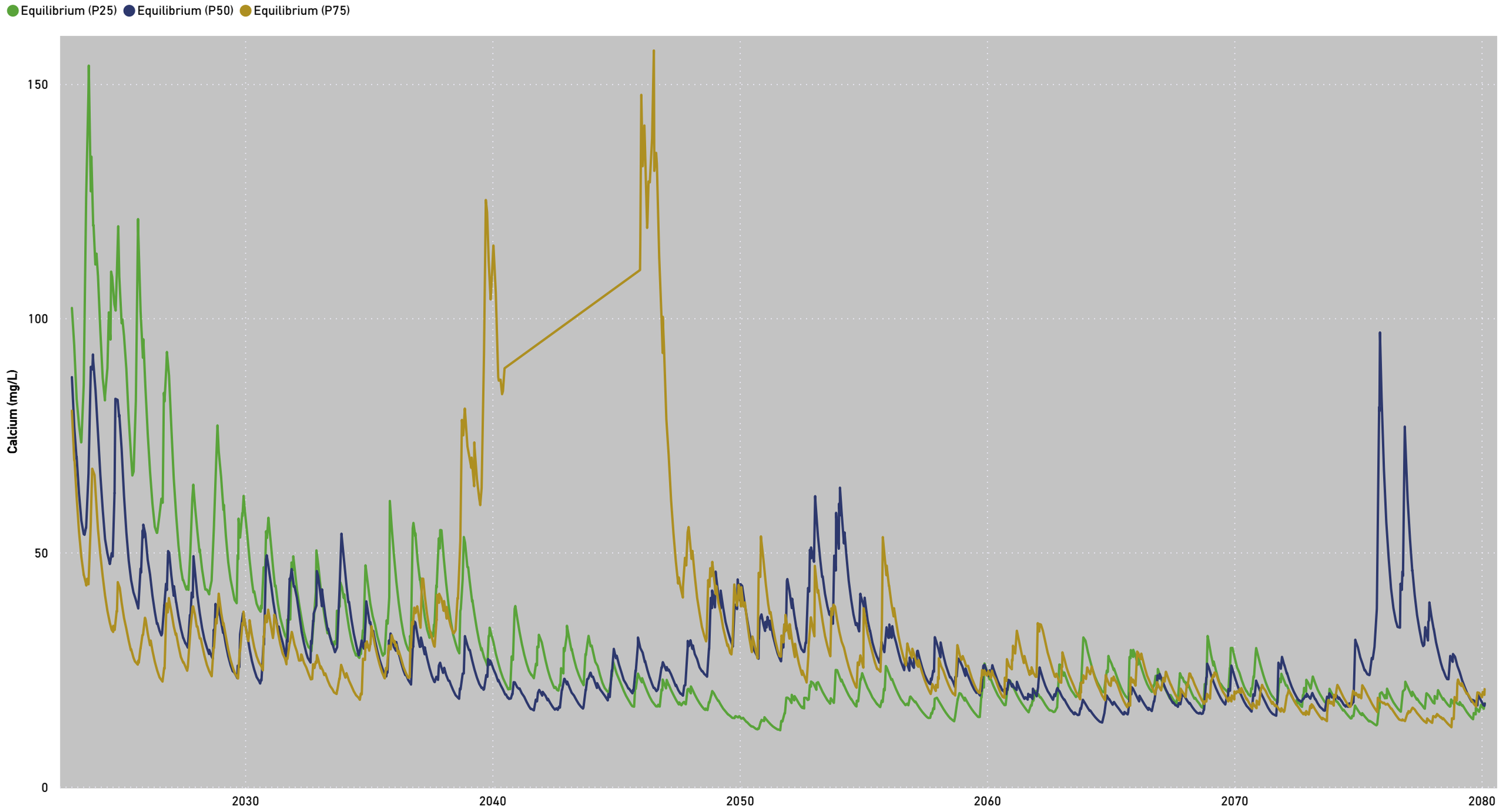

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Uranium (mg/L)
0.012
0.010
0.008
2030
2040
2050
2060
2070
2080

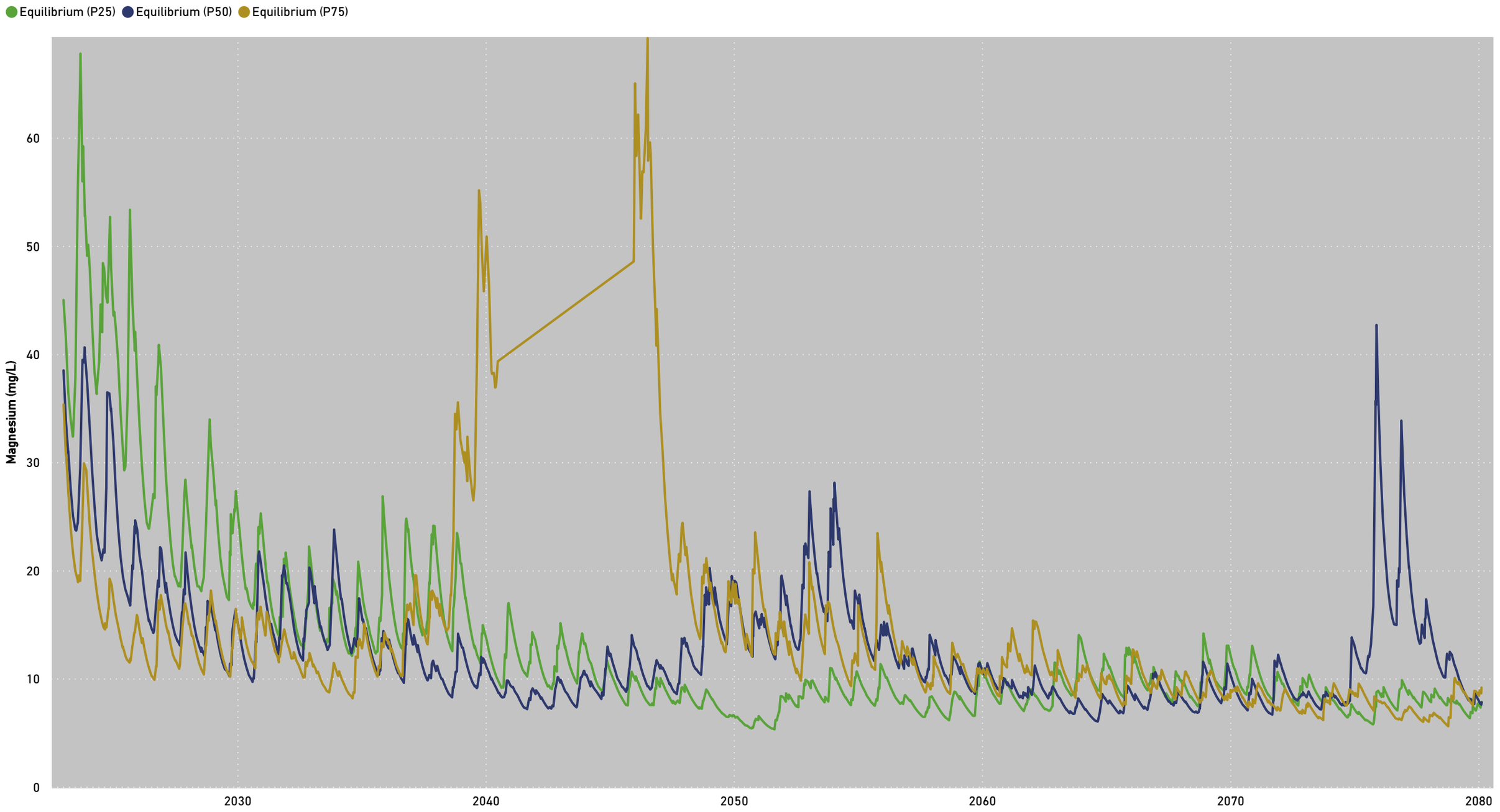

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Zinc (mg/L)
1
0
-1
2030
2040
2050
2060
2070
2080

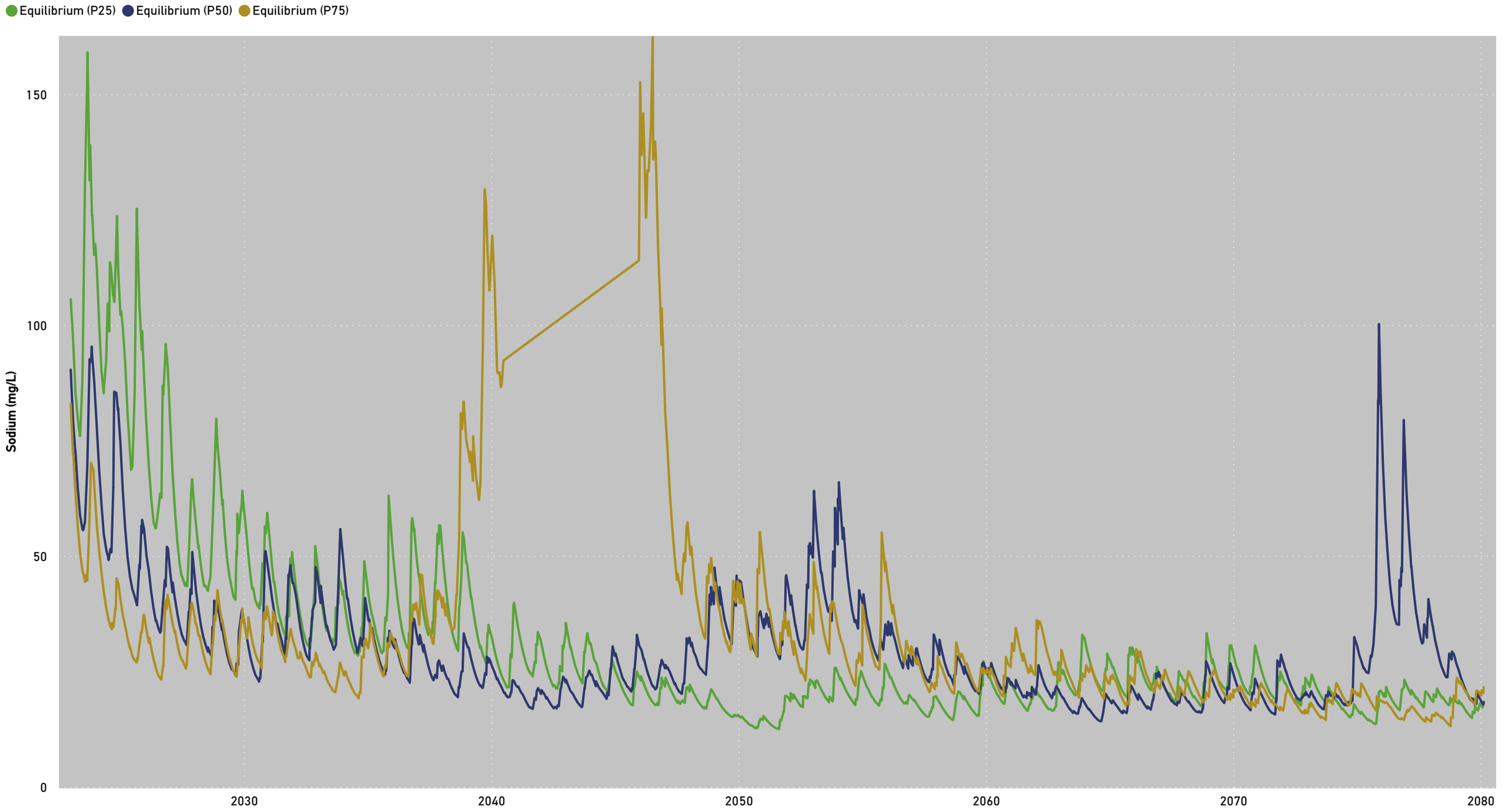
D.2.3 WRD Sediment Dam water quality

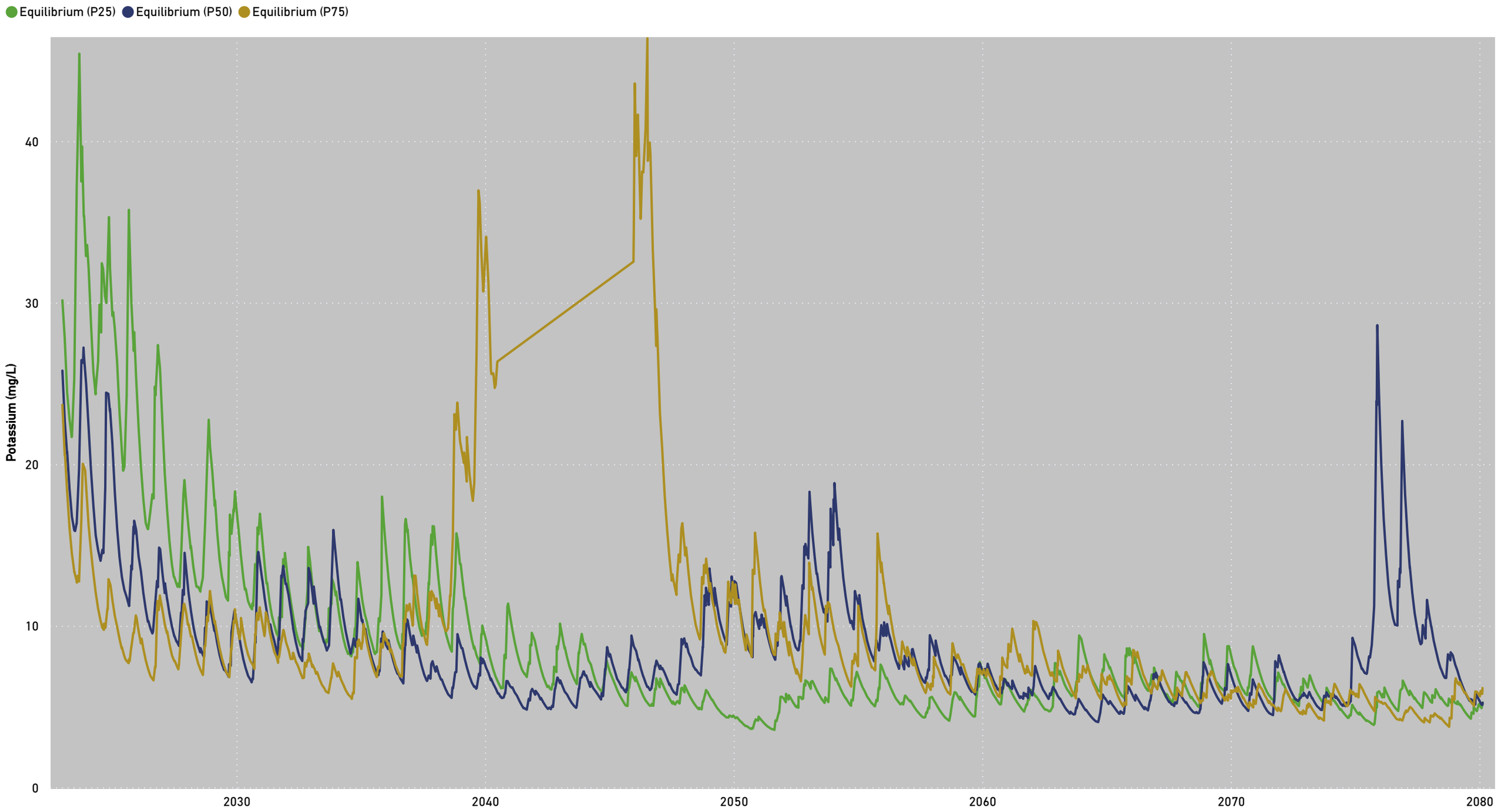

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
pH
8.40
8.35
8.30
8.25
8.20
2030
2040
2050
2060
2070
2080

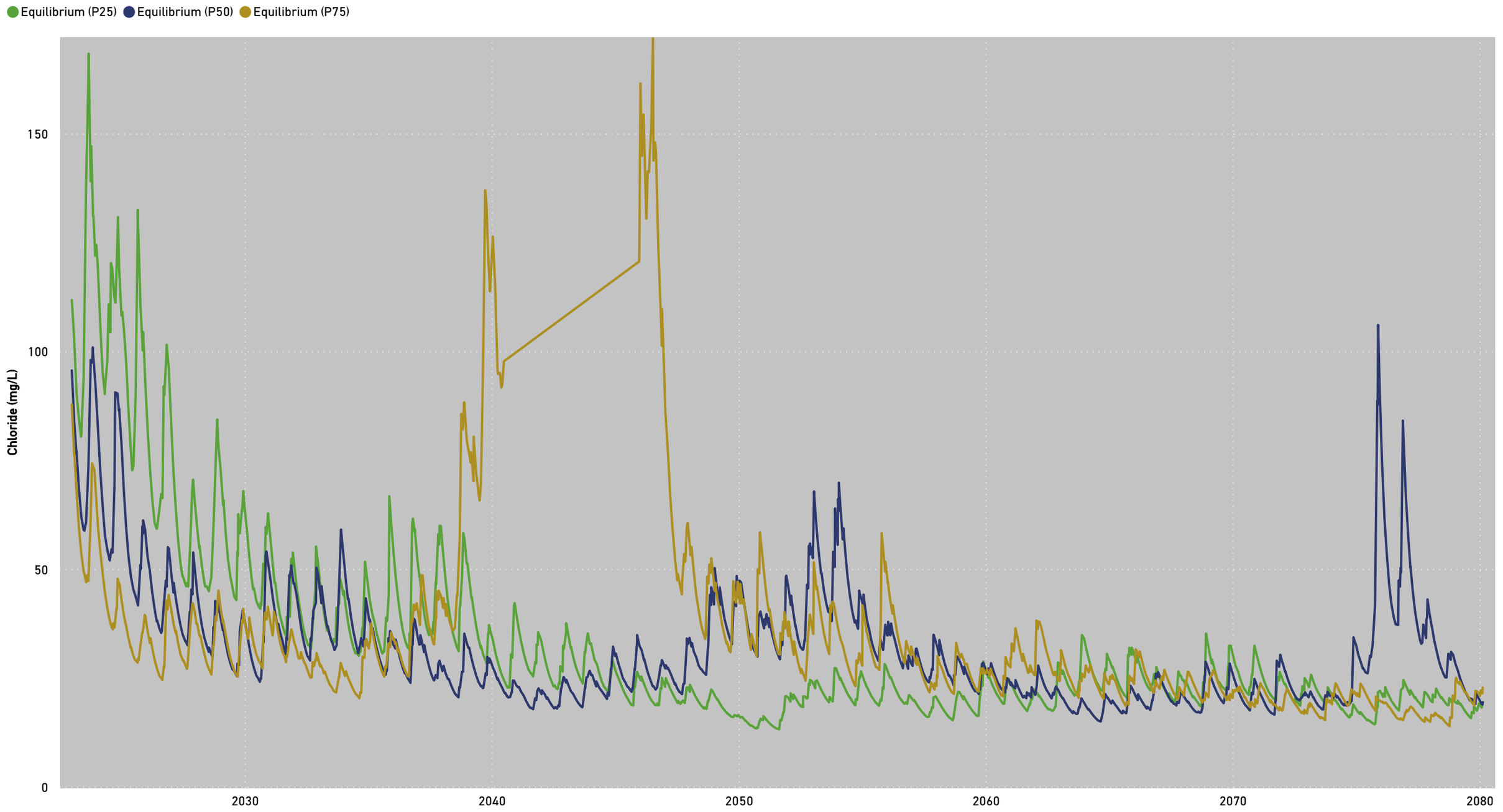

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Total Dissolved Solids (mg/L)
1,500
1,000
500
0
2030
2040
2050
2060
2070
2080

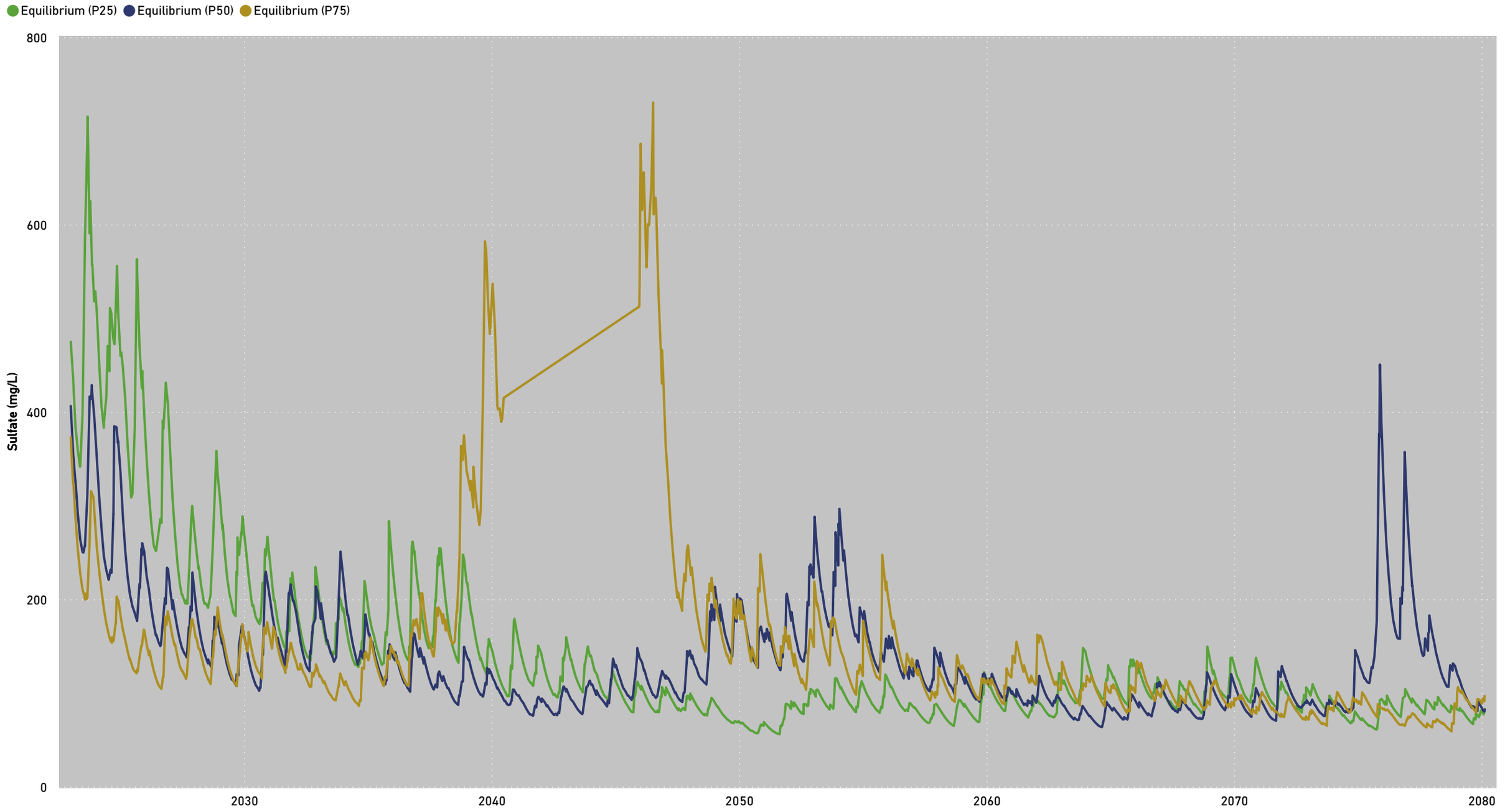

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Calcium (mg/L)
150
100
50
0
2030
2040
2050
2060
2070
2080

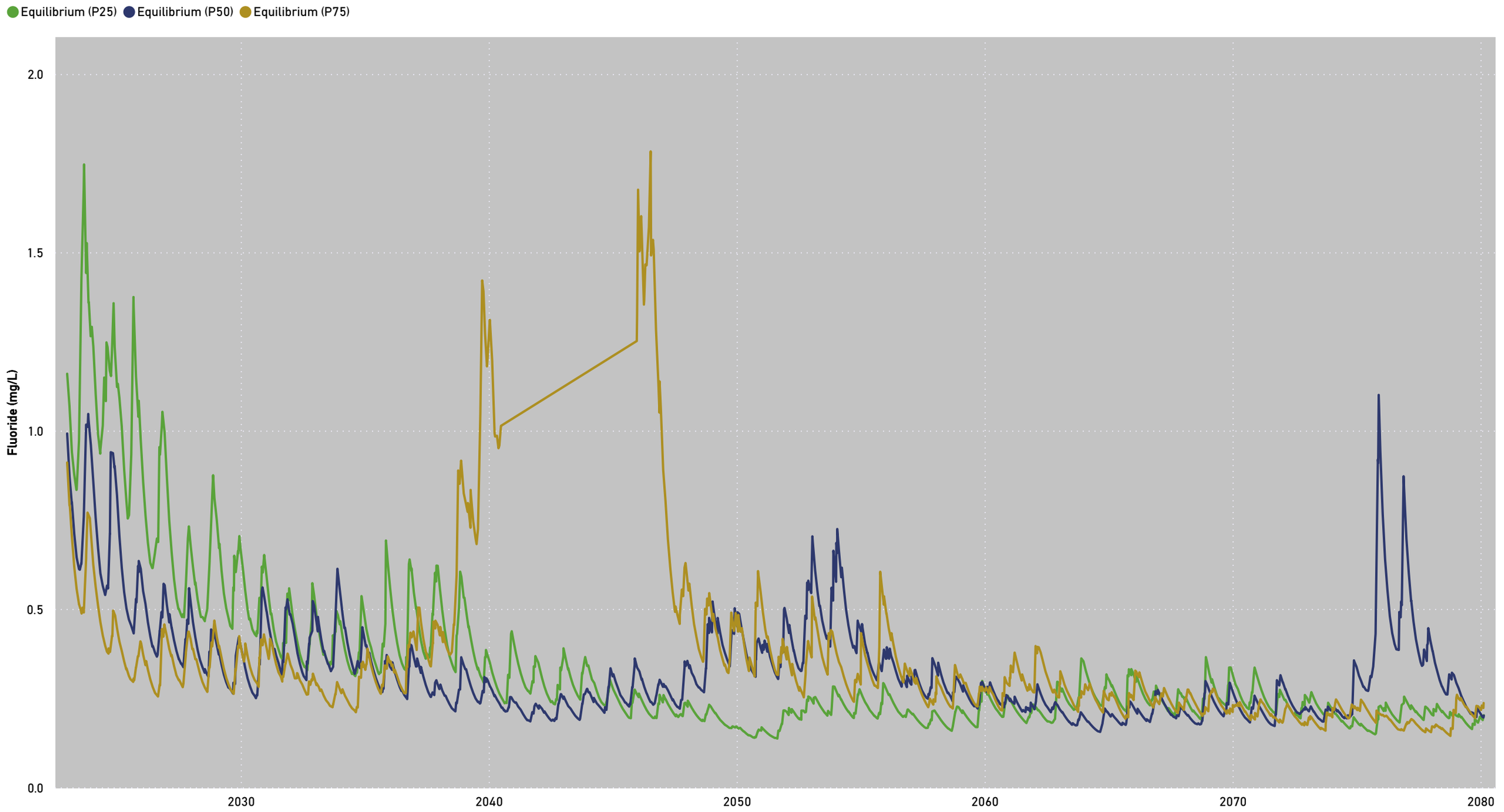

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Magnesium (mg/L)
0
10
20
30
40
50
60
2030
2040
2050
2060
2070
2080

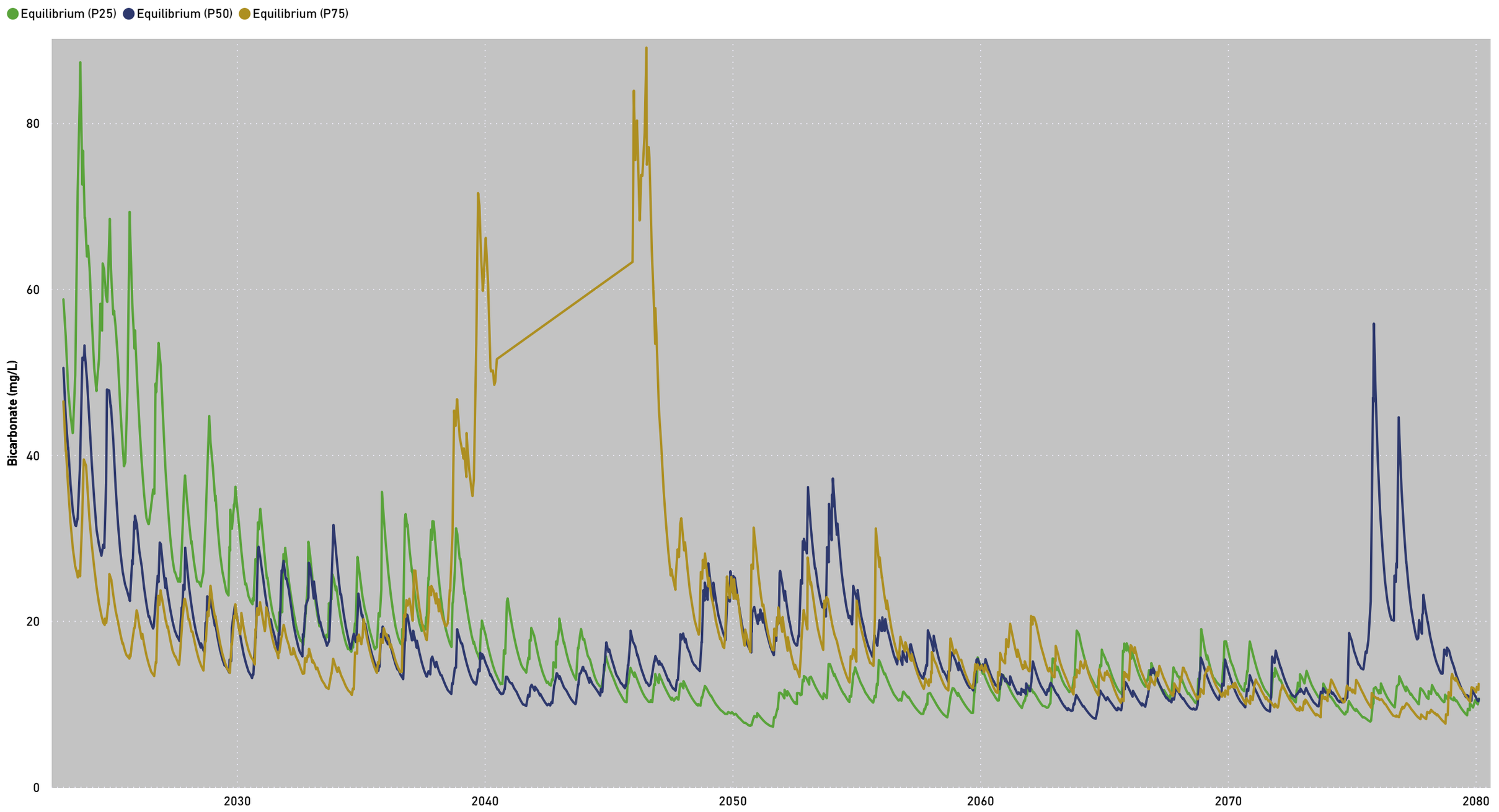

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Sodium (mg/L)
150
100
50
0
2030
2040
2050
2060
2070
2080

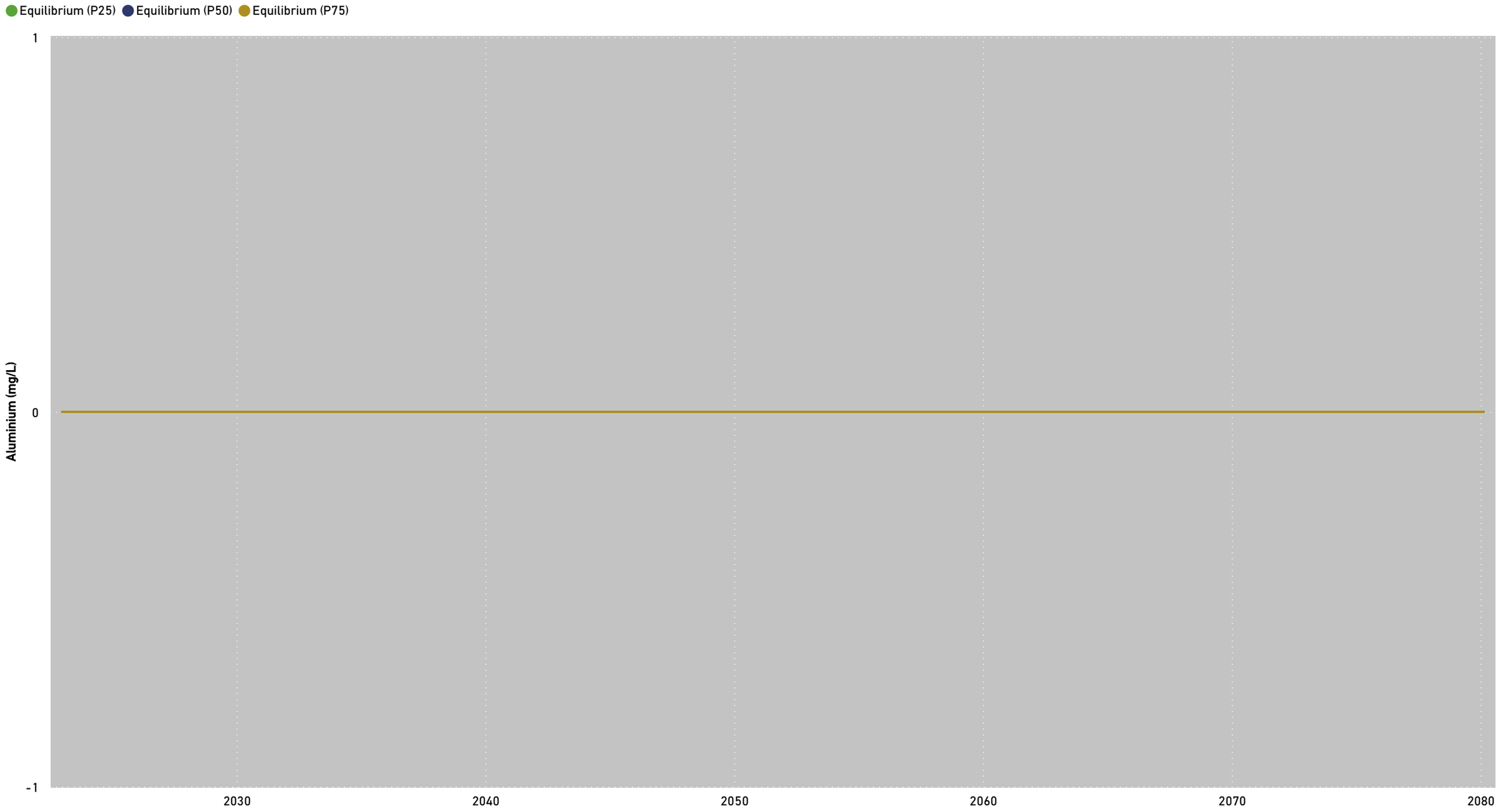

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Potassium (mg/L)
0
10
20
30
40
2030
2040
2050
2060
2070
2080

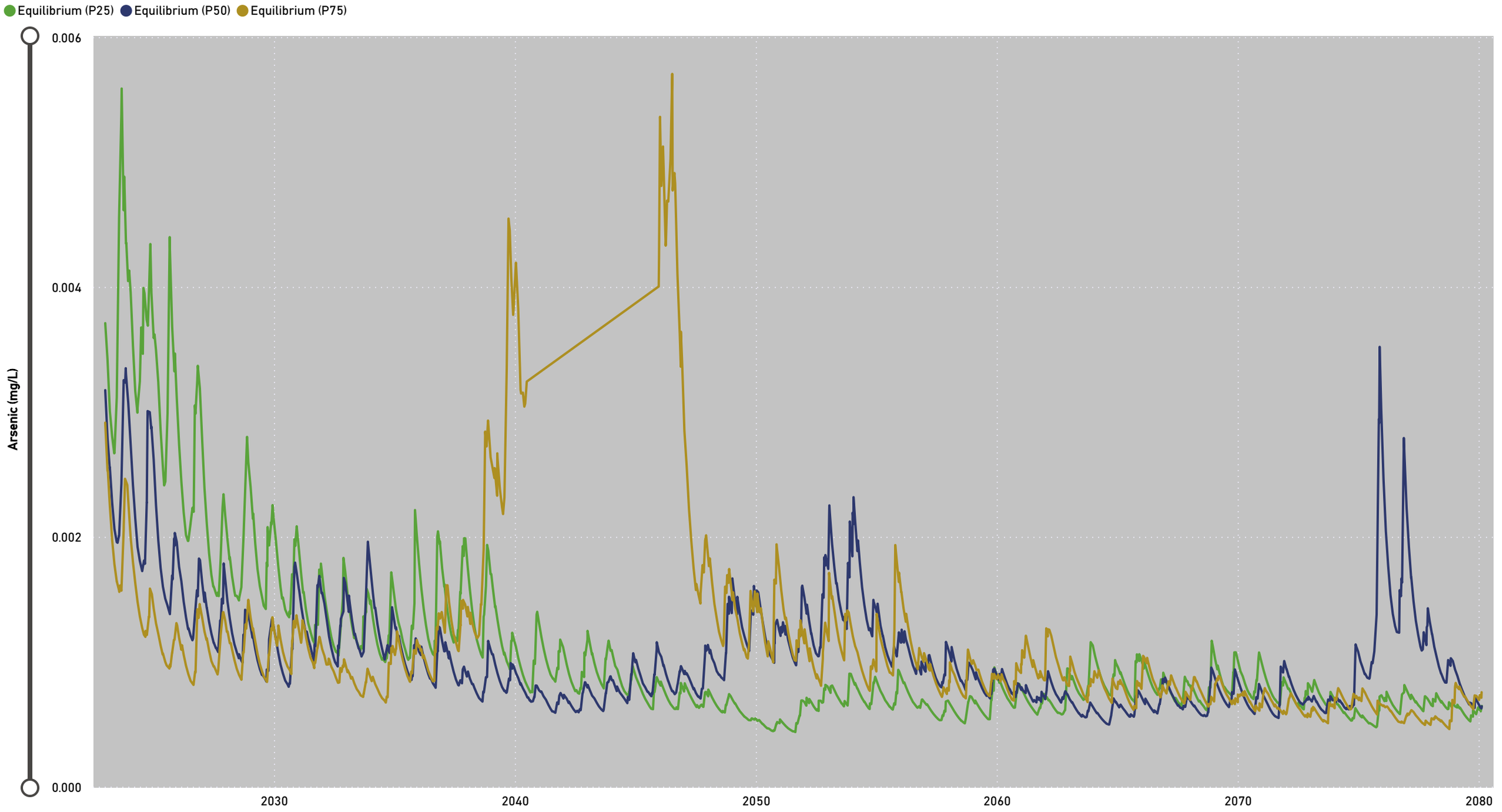

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Chloride (mg/L)
150
100
50
0
2030
2040
2050
2060
2070
2080

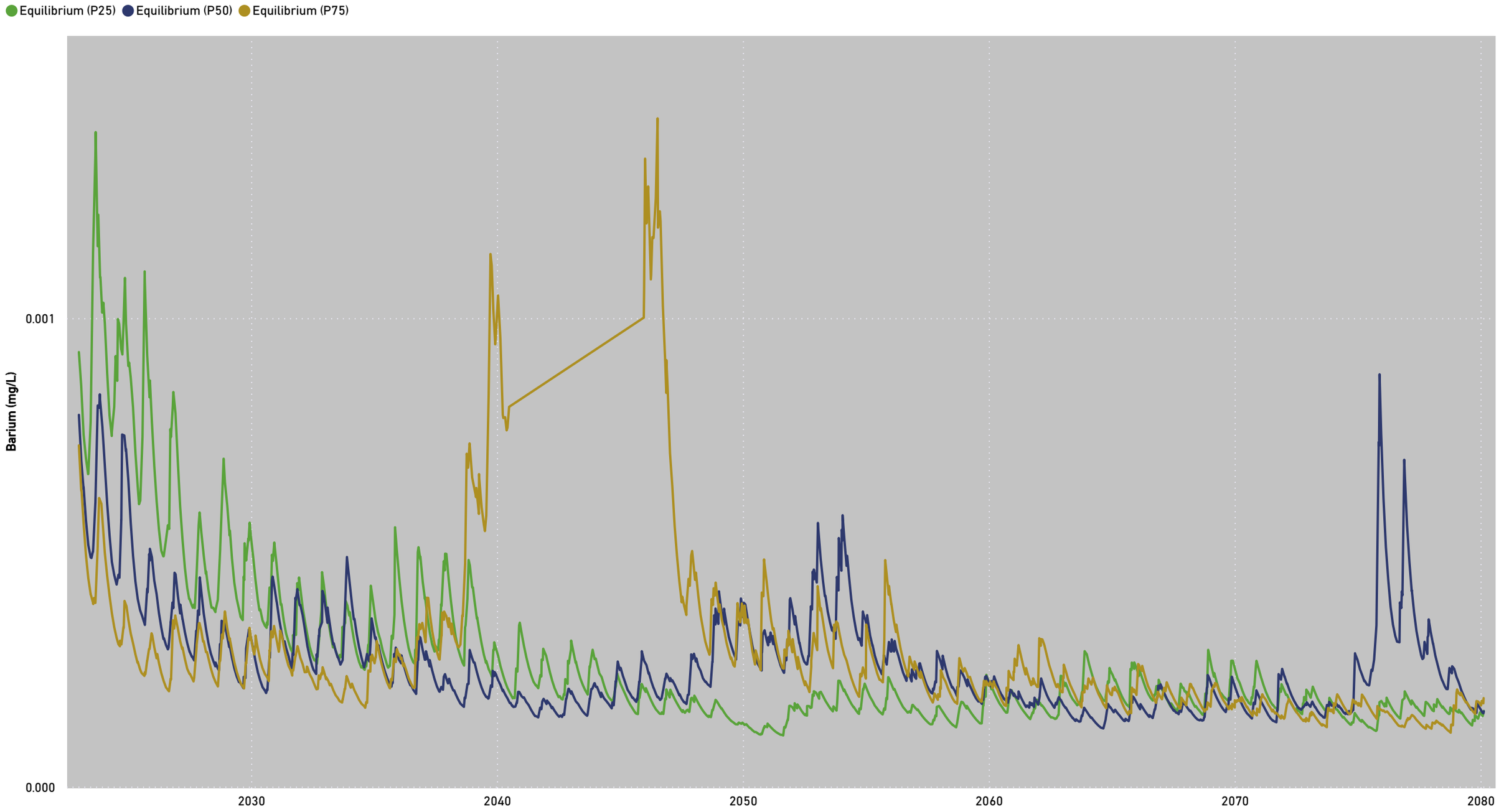

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Sulfate (mg/L)
800
600
400
200
0
2030
2040
2050
2060
2070
2080

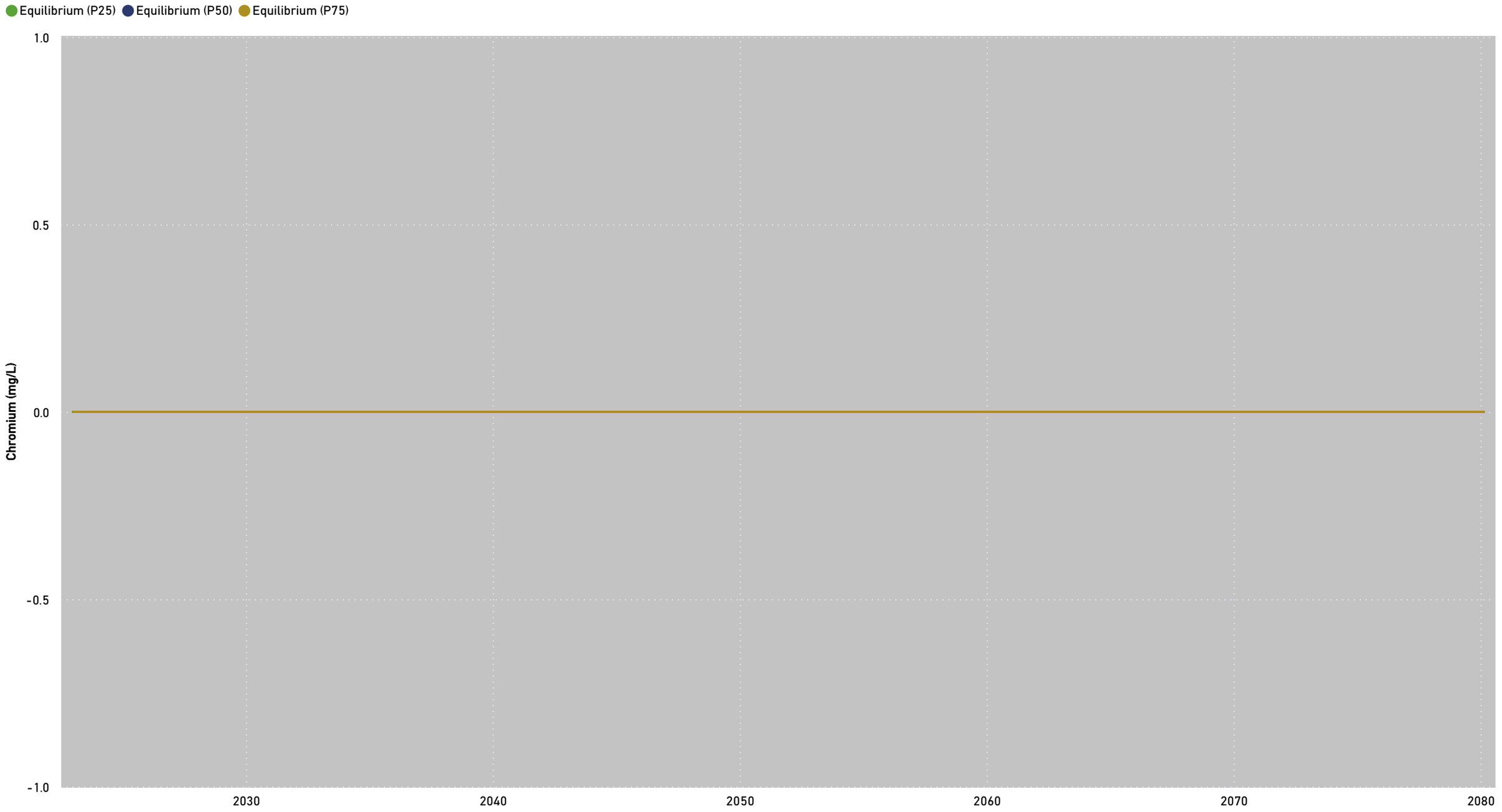

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Fluoride (mg/L)
2.0
1.5
1.0
0.5
0.0
2030
2040
2050
2060
2070
2080

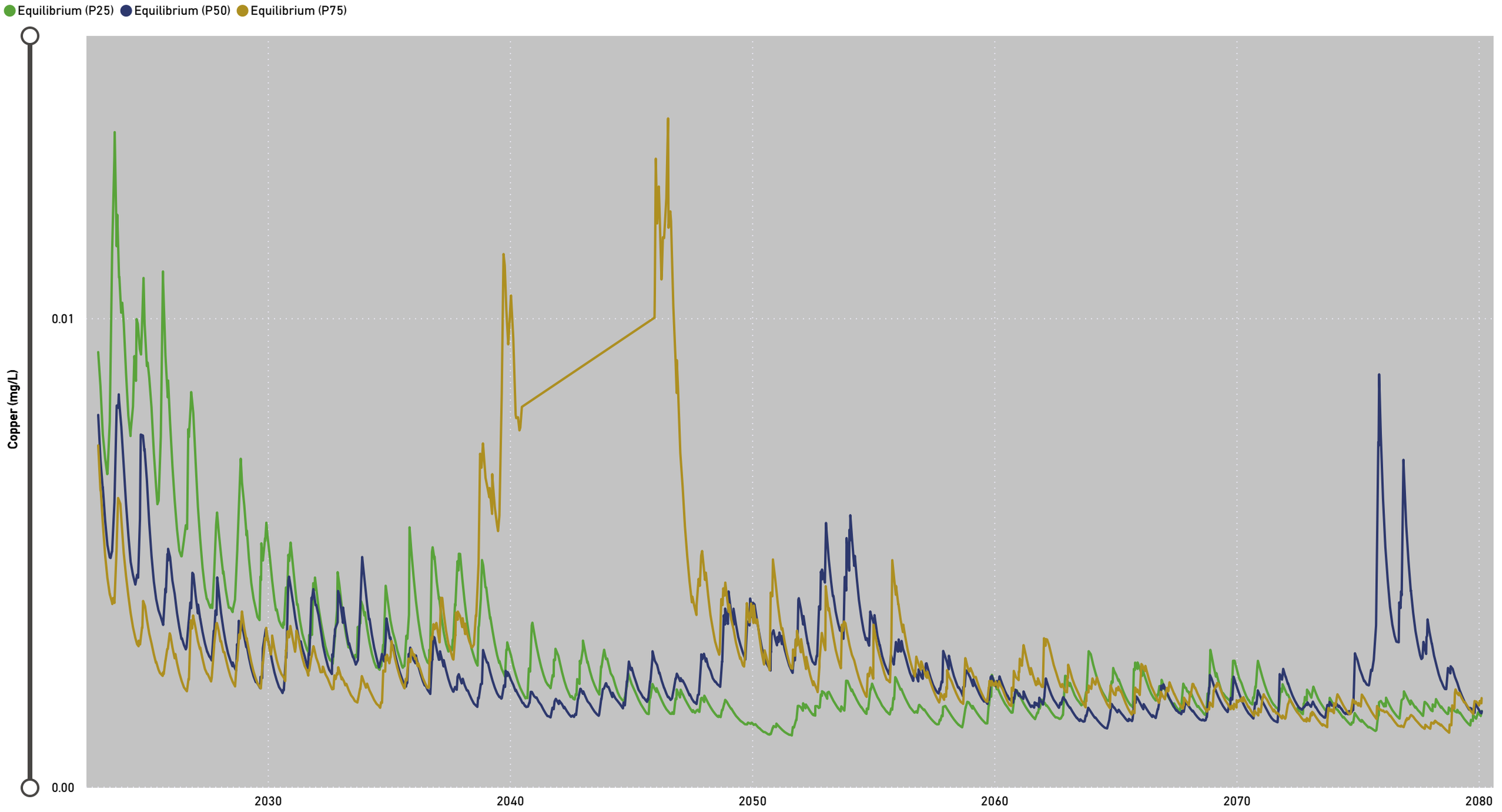

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Bicarbonate (mg/L)
0
20
40
60
80
2030
2040
2050
2060
2070
2080

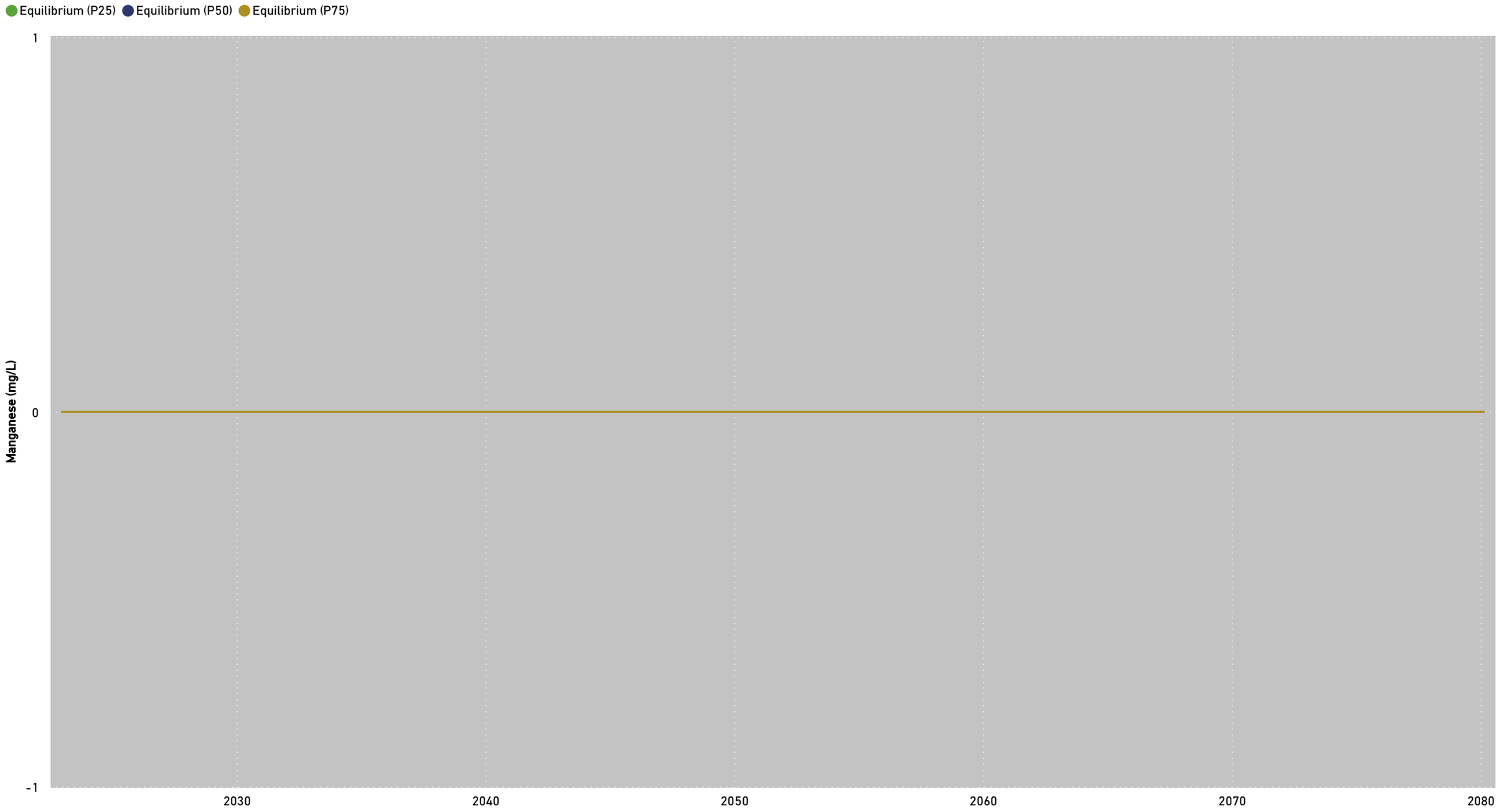

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Aluminium (mg/L)
1
0
-1
2030
2040
2050
2060
2070
2080

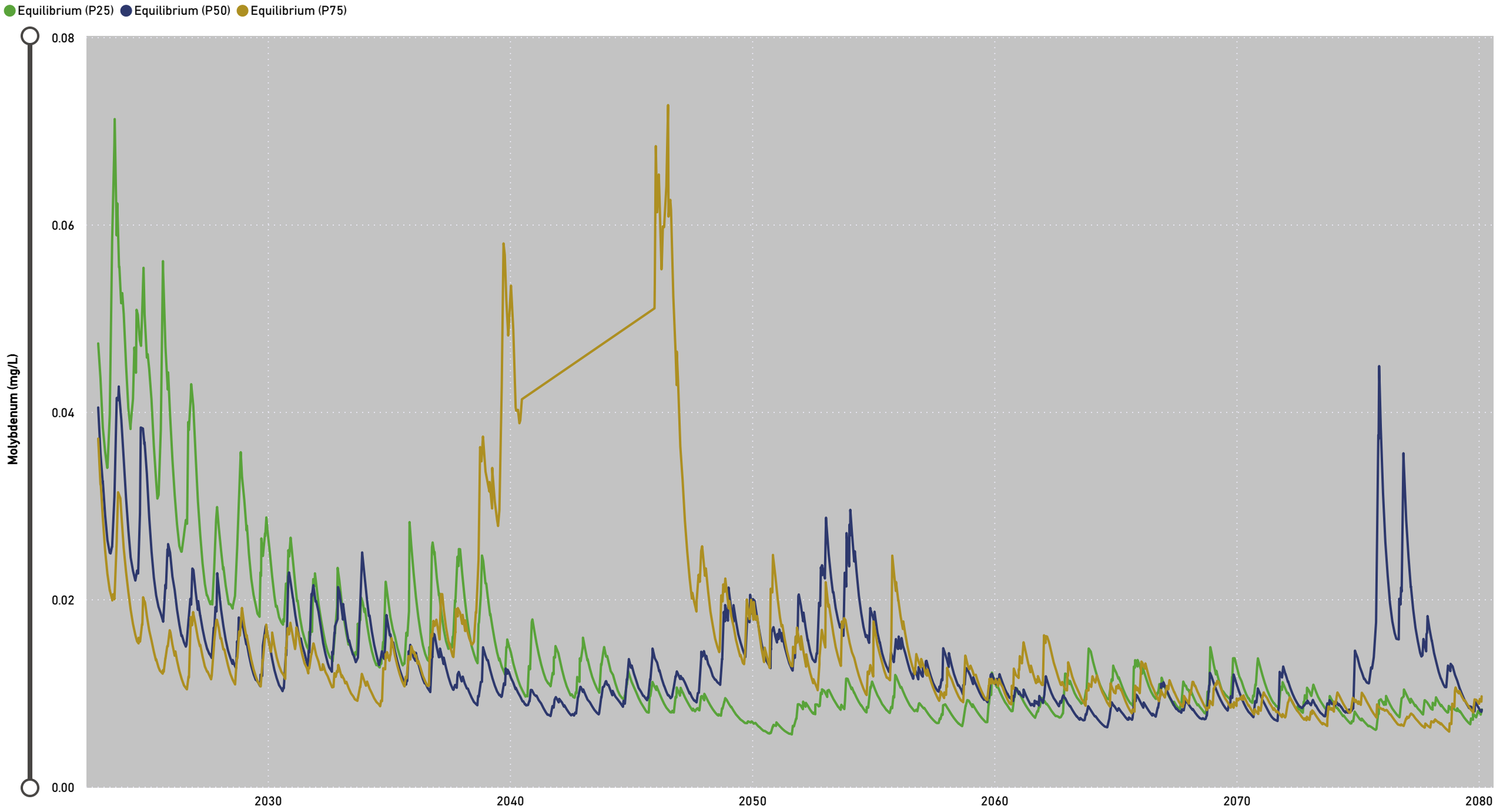

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Arsenic (mg/L)
0.006
0.004
0.002
0.000
2030
2040
2050
2060
2070
2080

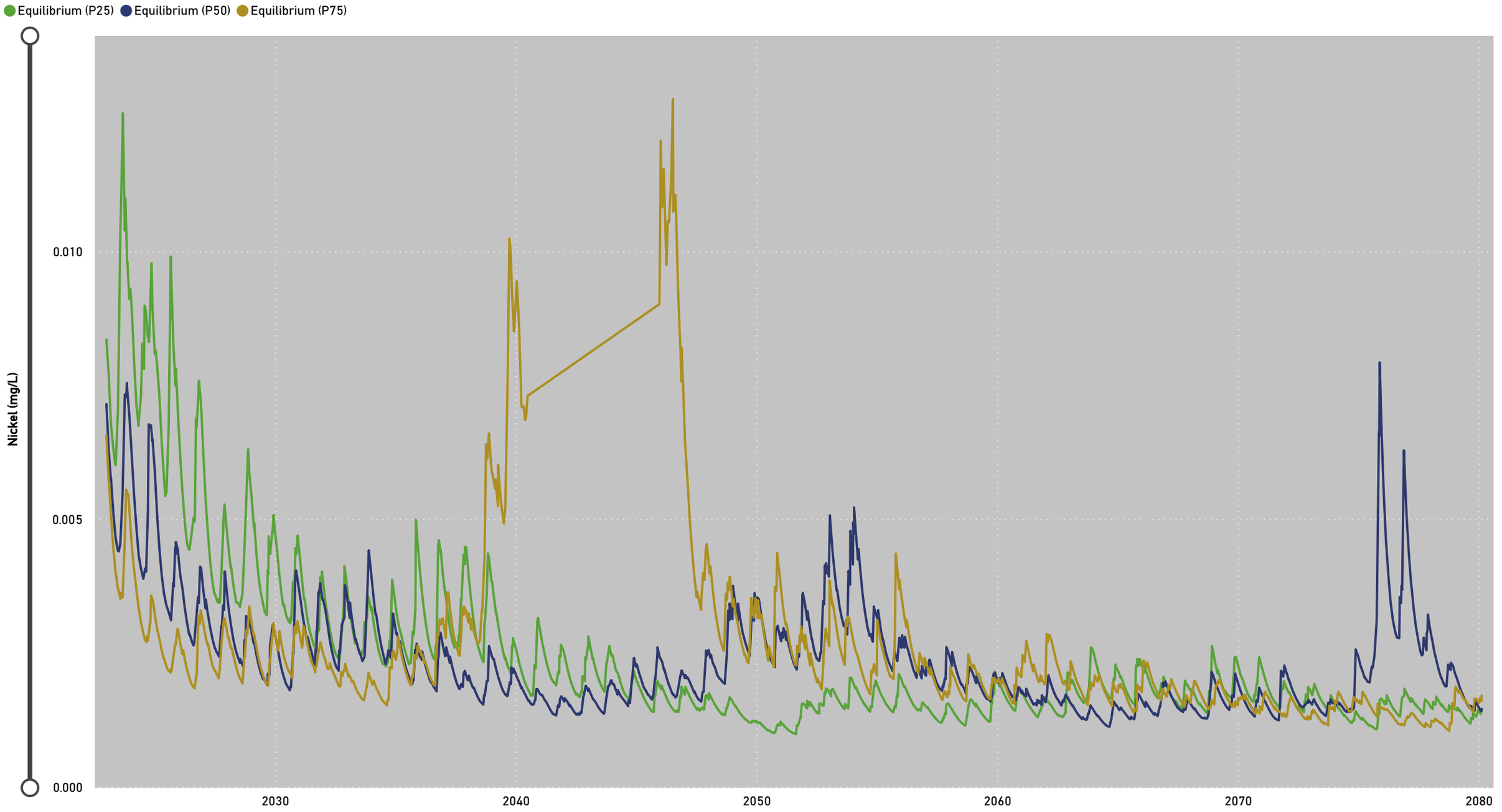

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Barium (mg/L)
0.001
0.000
2030
2040
2050
2060
2070
2080

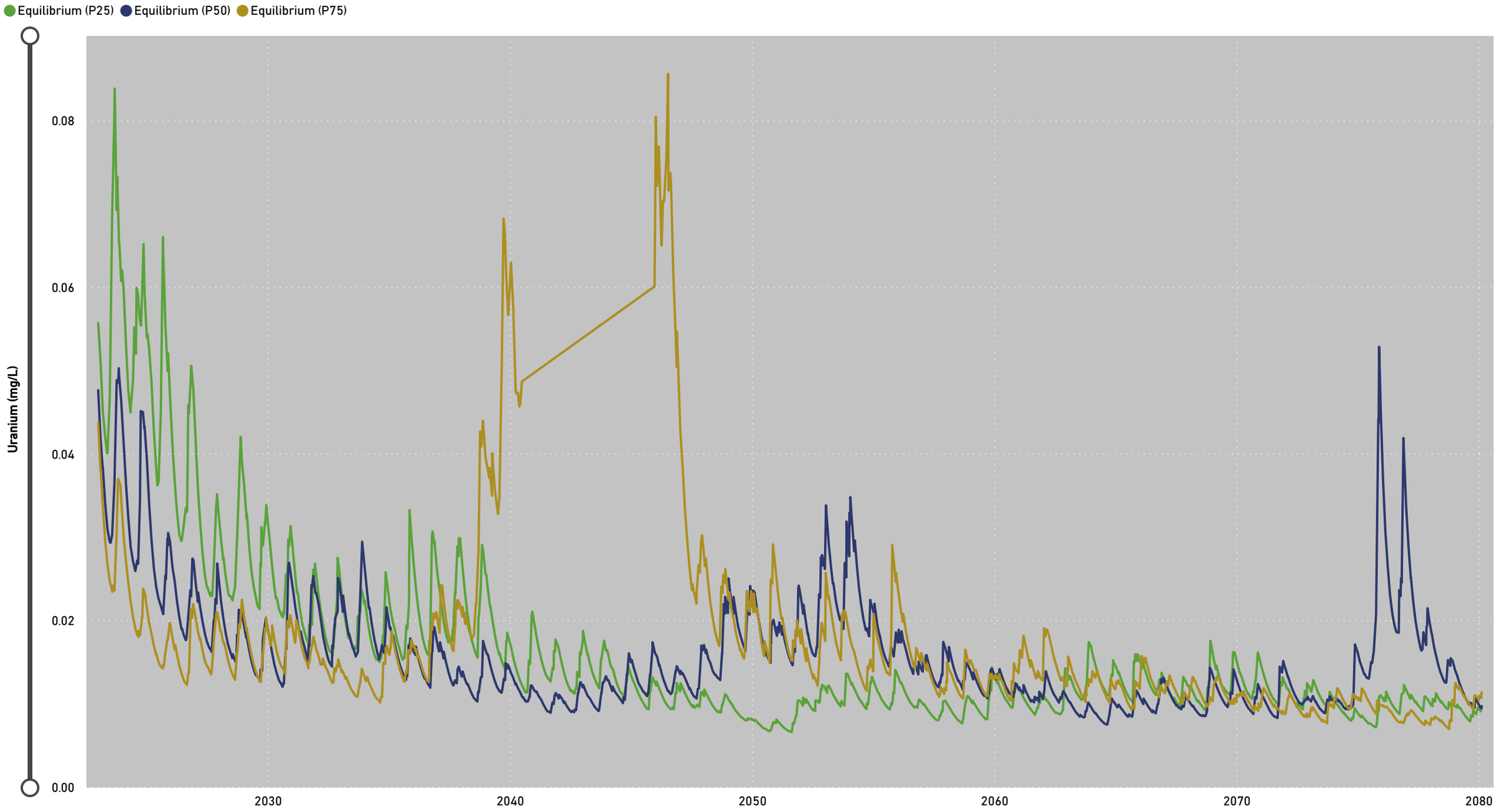

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Chromium (mg/L)
1.0
0.5
0.0
-0.5
-1.0
2030
2040
2050
2060
2070
2080

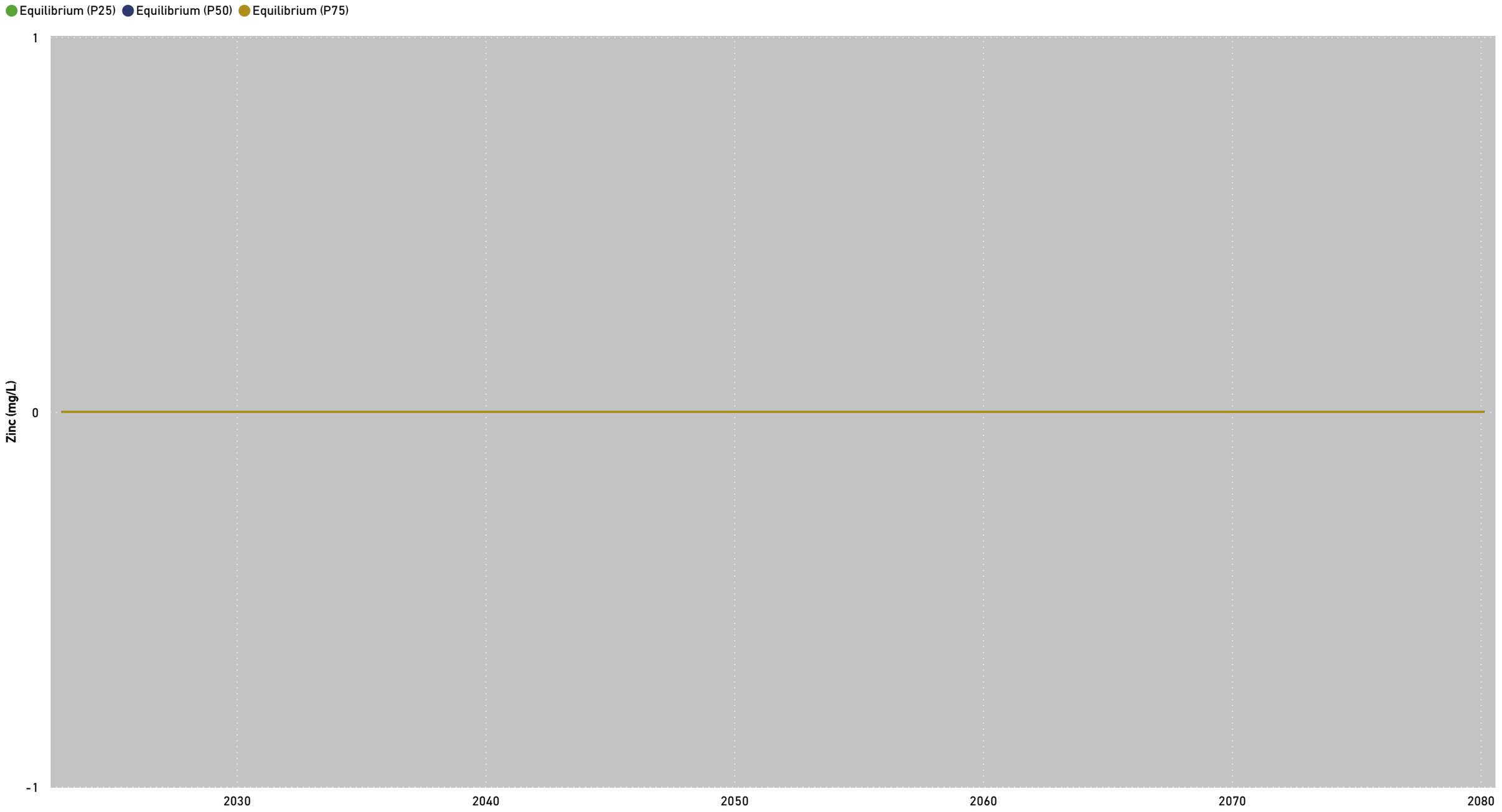

Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Copper (mg/L)
0.01
0.00
2030
2040
2050
2060
2070
2080


Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Manganese (mg/L)
1
0
-1
2030
2040
2050
2060
2070
2080


Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Molybdenum (mg/L)
0.08
0.06
0.04
0.02
0.00
2030
2040
2050
2060
2070
2080


Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Nickel (mg/L)
0.010
0.005
0.000
2030
2040
2050
2060
2070
2080


Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Uranium (mg/L)
0.08
0.06
0.04
0.02
0.00
2030
2040
2050
2060
2070
2080


Equilibrium (P25)
Equilibrium (P50)
Equilibrium (P75)
Zinc (mg/L)
1
0
-1
2030
2040
2050
2060
2070
2080

D.3 Statistical curve fitting results

D.3.1 North Pit statistical curve fitting results

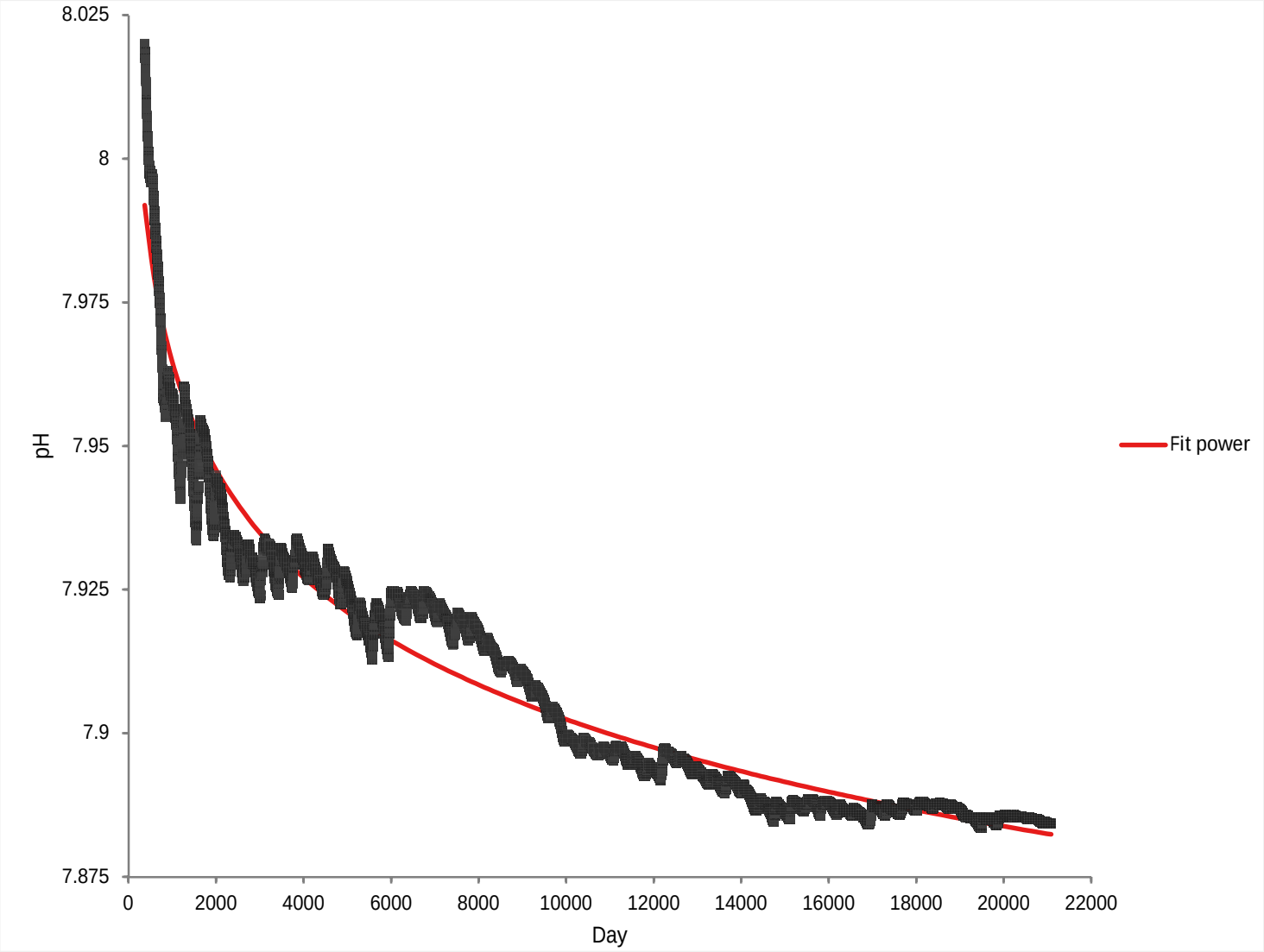
Fit: pH

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:37 by Willy



Fit: pH

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:37 by Willy

Fit

N	41431
Mean of Y	2.06779

Equation: $pH = 8.154 * Day^{-0.003403}$

R^2	0.948
R^2 adjusted	0.948
RMSE	0.000669

Parameter	Estimate	95% CI	SE	t	p-value
Constant	2.099	2.098 to 2.099	3.5511E-05	59095.29	<0.0001
ln Day	-0.003403	-0.003411 to -0.003396	3.9167E-06	-868.95	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.33828	1	0.33828	755080.45	<0.0001
Error	0.01856	41429	0.00000		
Null model	0.35684	41430	0.00001		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: pH

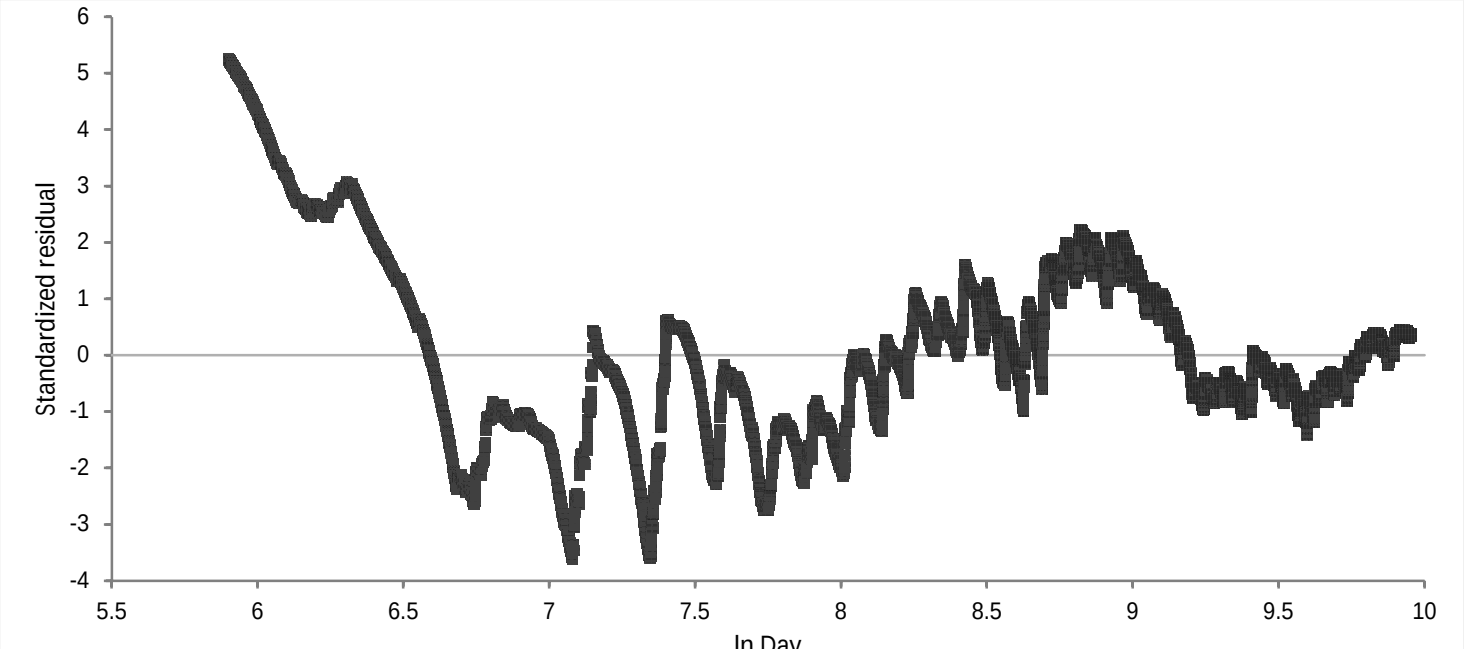
Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:37 by Willy

Residuals



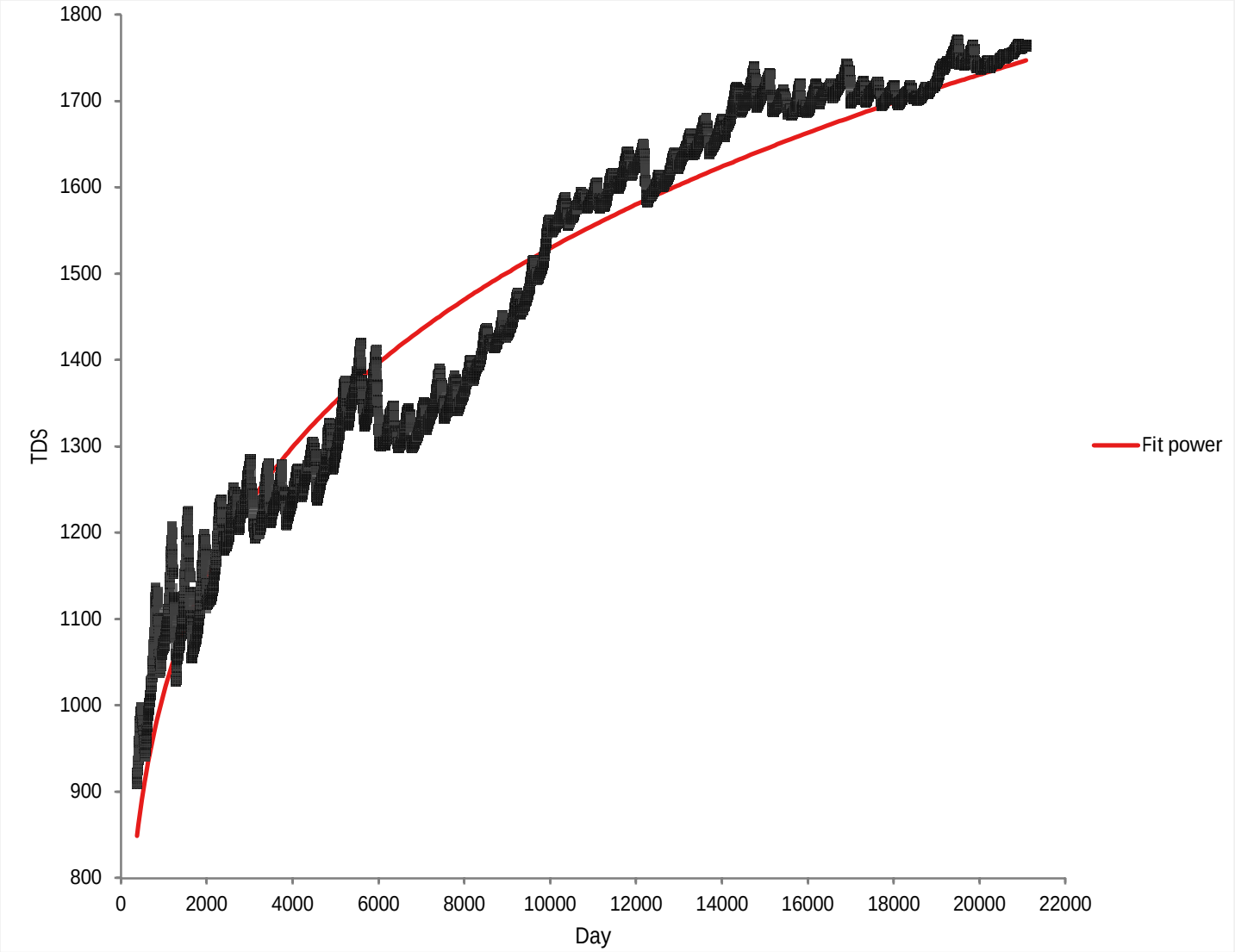
Fit: TDS

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:36 by Willy



Fit: TDS

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:36 by Willy

Fit

N	41431
Mean of Y	7.300

Equation | TDS = 296.9 * Day $^{0.178}$

R^2	0.936
R^2 adjusted	0.936
RMSE	0.0392

Parameter	Estimate	95% CI	SE	t	p-value
Constant	5.694	5.689 to 5.698	2.0800E-03	2737.23	<0.0001
ln Day	0.1780	0.1775 to 0.1784	2.2942E-04	775.87	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	925.300	1	925.300	601971.93	<0.0001
Error	63.681	41429	0.002		
Null model	988.981	41430	0.024		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: TDS

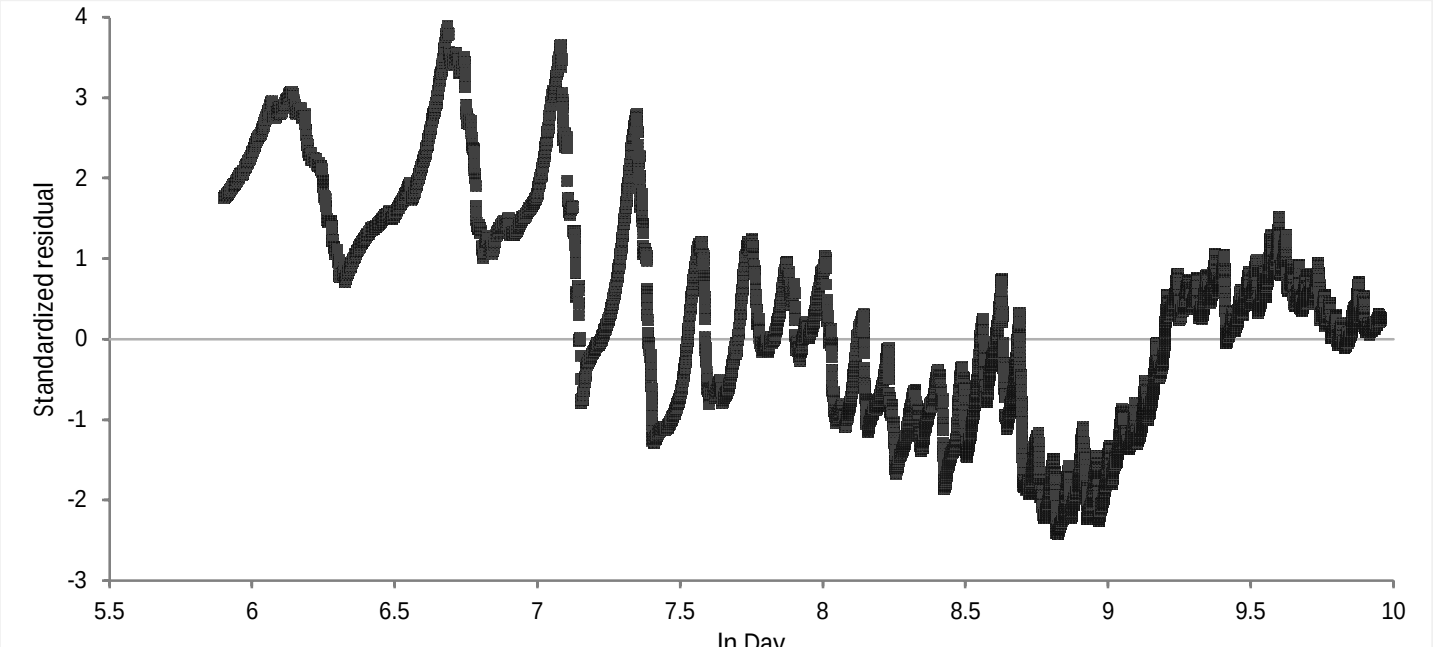
Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:36 by Willy

Residuals

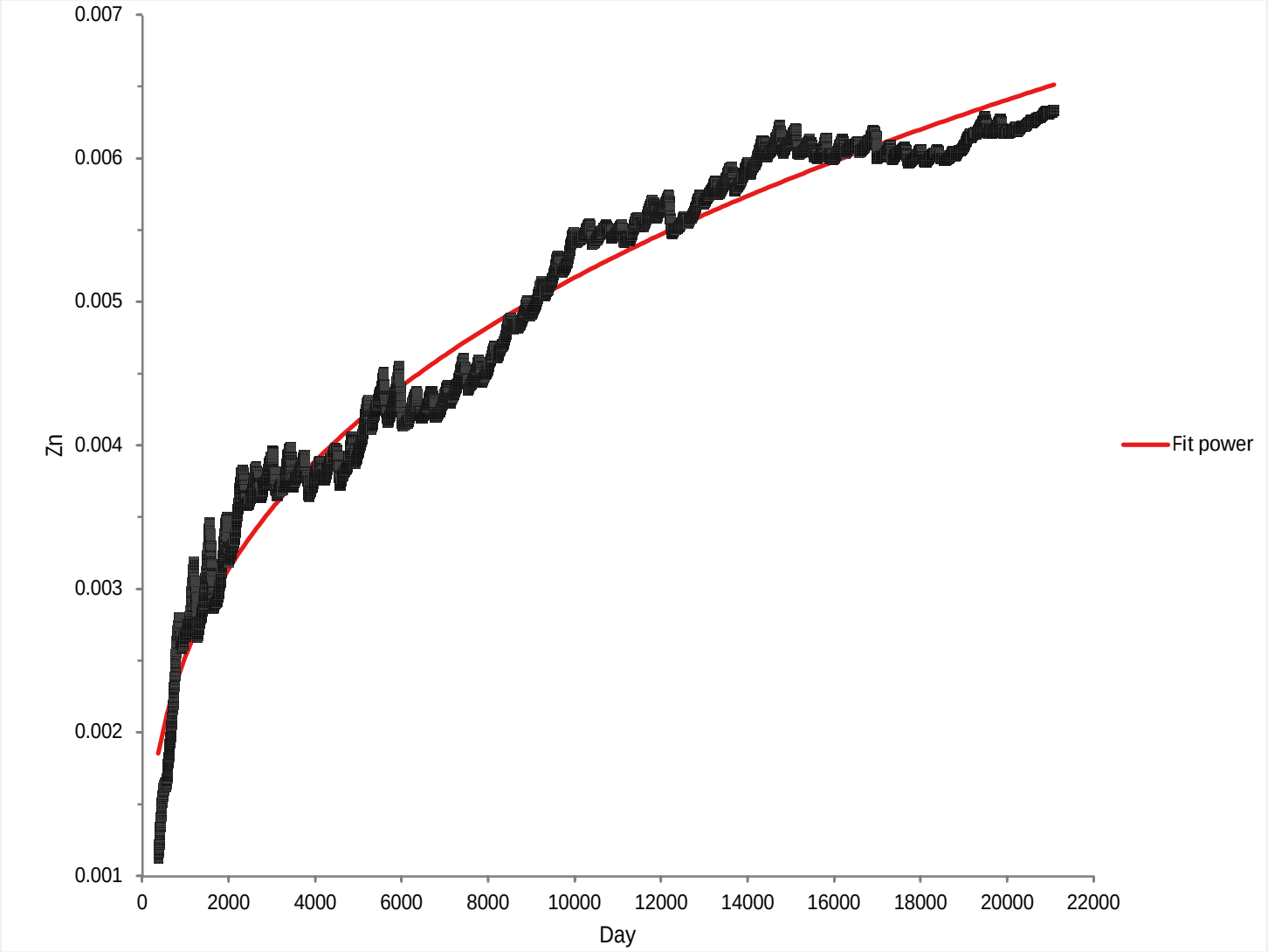


Fit: Zn

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:35 by Willy



Fit: Zn

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:35 by Willy

Fit

N	41431
Mean of Y	-5.32108866

Equation: $Zn = 0.0002988 * Day^{0.3096}$

R^2	0.957
R^2 adjusted	0.957
RMSE	0.055149802

Parameter	Estimate	95% CI	SE	t	p-value
Constant	-8.116	-8.122 to -8.110	2.9259E-03	-2773.76	<0.0001
ln Day	0.3096	0.3089 to 0.3102	3.2272E-04	959.28	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	###########	1	2.798850E+03	920219.94	<0.0001
Error	###########	41429	0.00304150		
Null model	###########	41430	0.07059753		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: Zn

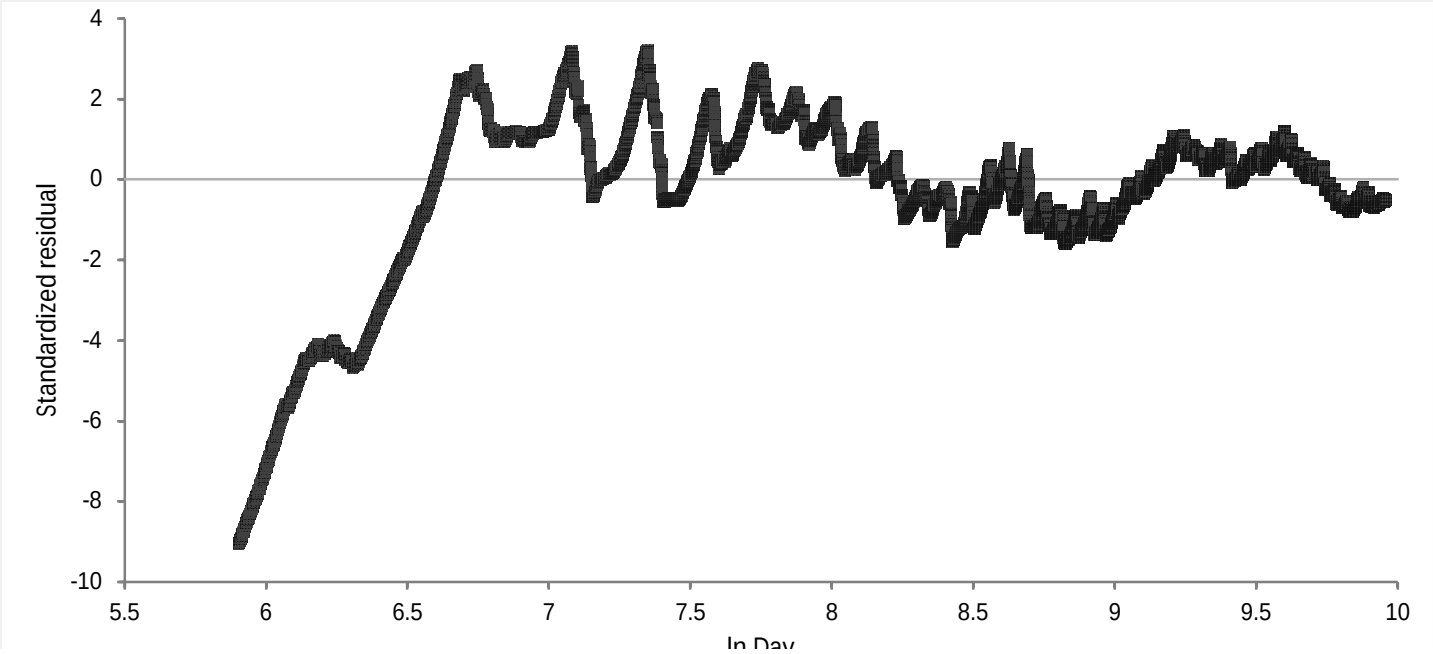
NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:35 by Willy

Analyse-it v5.80.2

Residuals

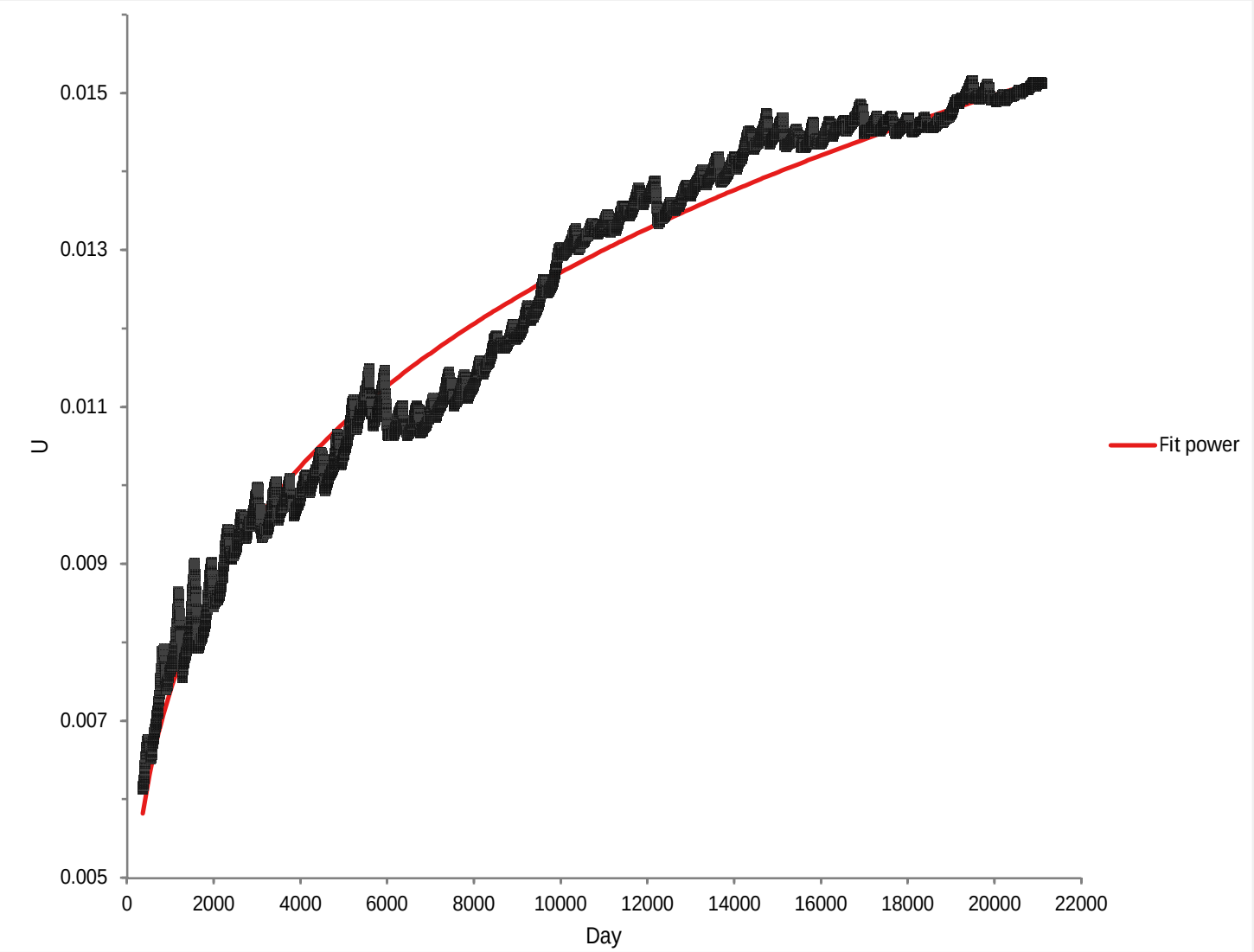


Fit: U

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:33 by Willy



Fit: U

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:33 by Willy

Analyse-it v5.80.2

Fit

N	41431
Mean of Y	-4.40788014

Equation: $U = 0.001447 * Day^{0.236}$

R^2	0.973
R^2 adjusted	0.973
RMSE	0.033310694

Parameter	Estimate	95% CI	SE	t	p-value
Constant	-6.538	-6.541 to -6.535	1.7673E-03	-3699.50	<0.0001
ln Day	0.2360	0.2356 to 0.2363	1.9492E-04	1210.53	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	###########	1	1.625990E+03	1465381.12	<0.0001
Error	45.96971642	41429	0.00110960		
Null model	###########	41430	0.04035627		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: U

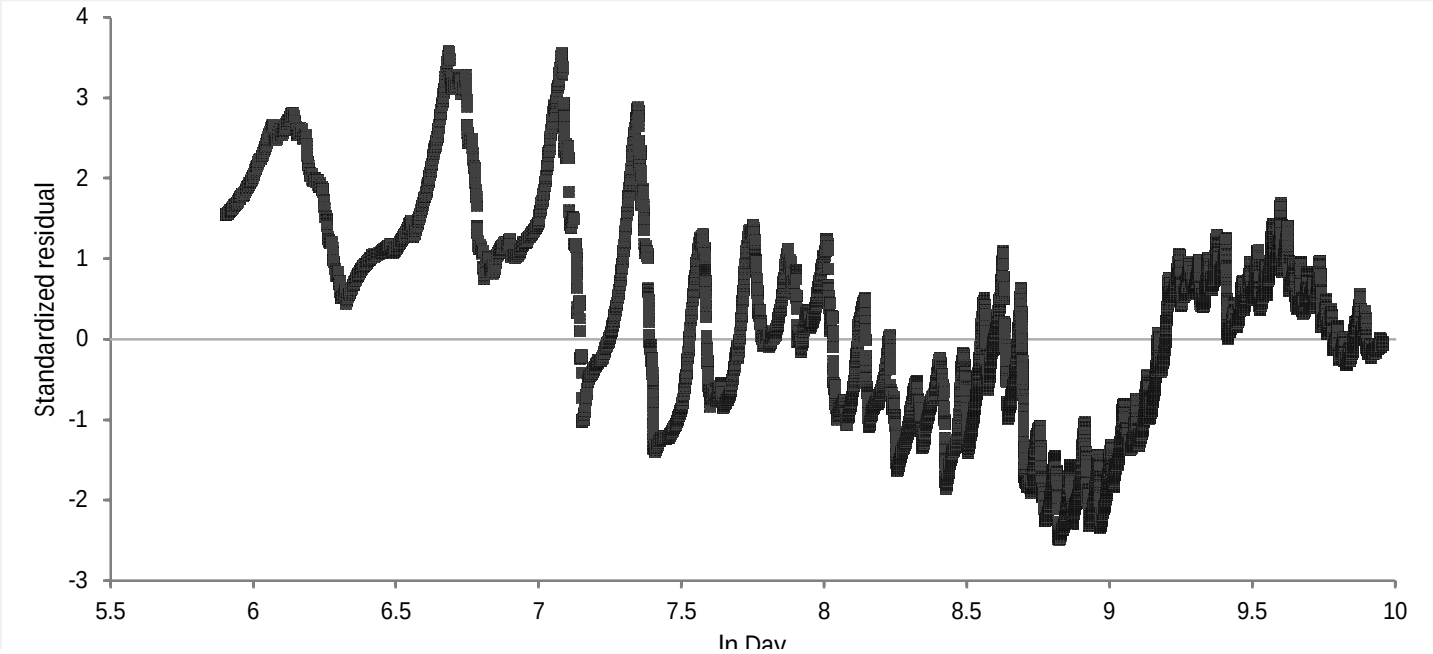
NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:33 by Willy

Analyse-it v5.80.2

Residuals



Fit: Ni

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:32 by Willy

Fit: Ni

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:32 by Willy

Fit

N	41431
Mean of Y	0.00732184

Equation	Ni = 0.01386 - 0.0007248 ln Day

R^2	0.728
R^2 adjusted	0.728
RMSE	0.000371501

Parameter	Estimate	95% CI	SE	t	p-value
Constant	0.01386	0.01383 to 0.01390	1.9710E-05	703.46	<0.0001
ln Day	-7.248E-04	-7.291E-04 to -7.205E-04	2.1739E-06	-333.41	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.01534165	1	0.01534165	111160.90	<0.0001
Error	0.00571774	41429	0.00000014		
Null model	0.02105939	41430	0.00000051		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta \text{Log}(x)$
The model is better than the null model.

Fit: Ni

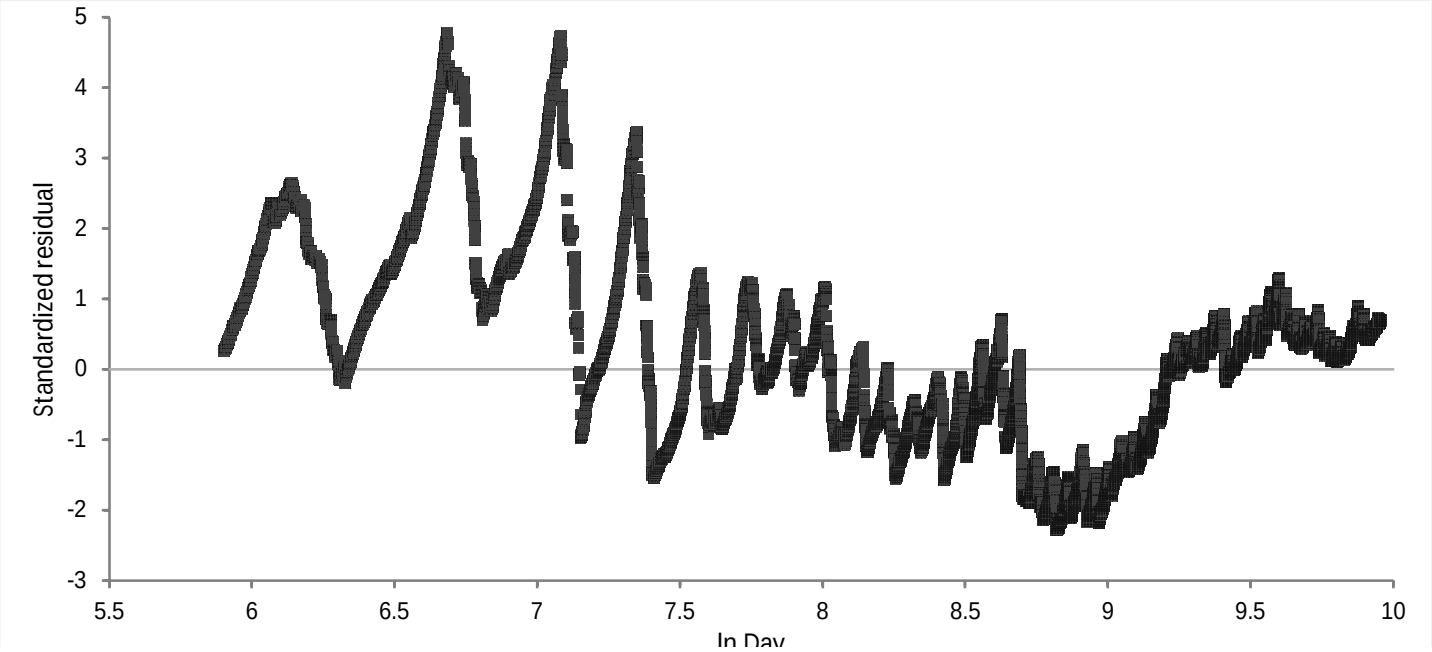
Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:32 by Willy

Residuals

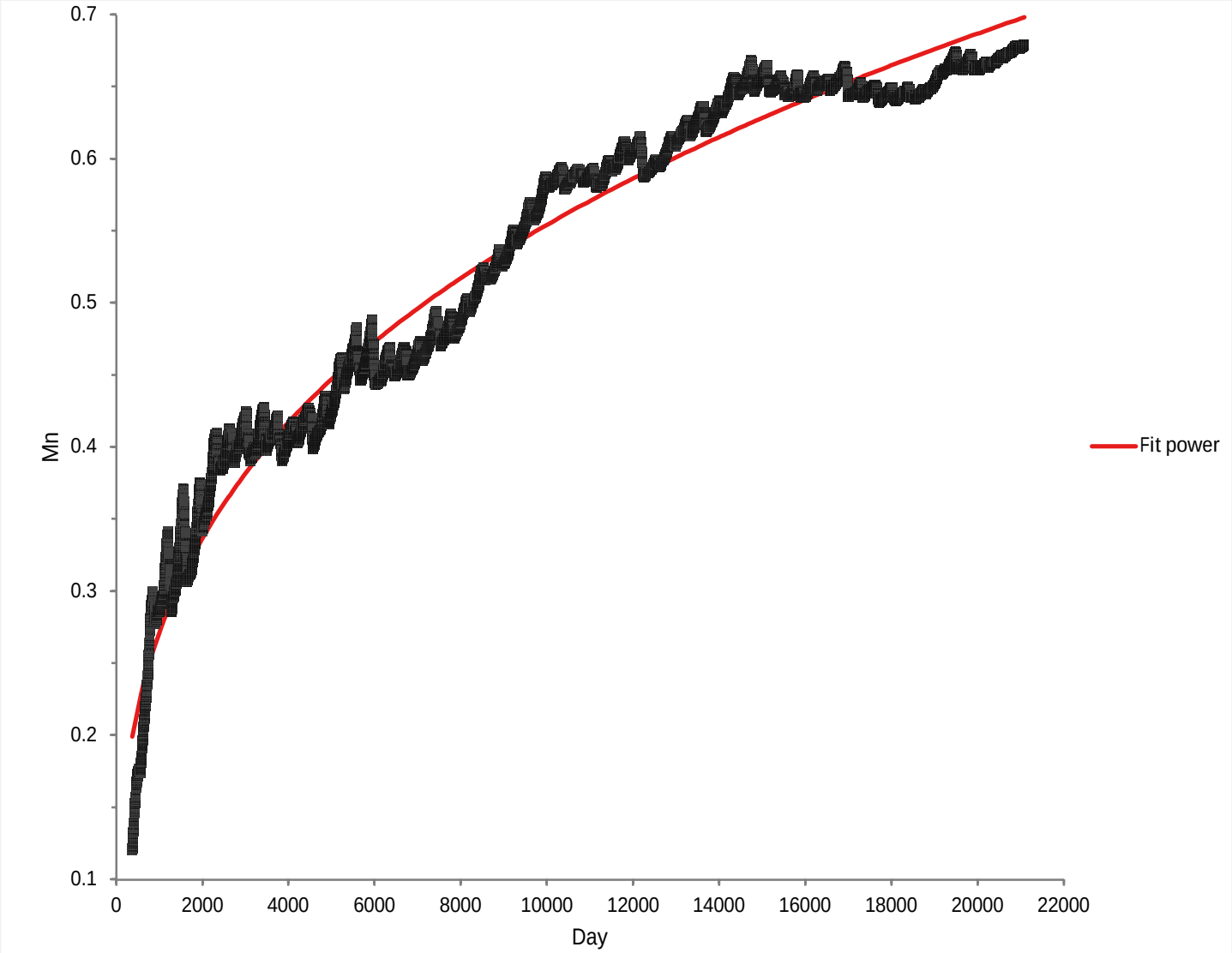


Fit: Mn

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:26 by Willy



Fit: Mn

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:26 by Willy

Fit

N	41431
Mean of Y	-0.646623

Equation: $Mn = 0.03202 * Day^{0.3096}$

R^2	0.957
R^2 adjusted	0.957
RMSE	0.0551499

Parameter	Estimate	95% CI	SE	t	p-value
Constant	-3.441	-3.447 to -3.436	2.9259E-03	-1176.15	<0.0001
ln Day	0.3096	0.3089 to 0.3102	3.2272E-04	959.27	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	2798.813427	1	2798.813427	920204.71	<0.0001
Error	126.006790	41429	0.003042		
Null model	2924.820217	41430	0.070597		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: Mn

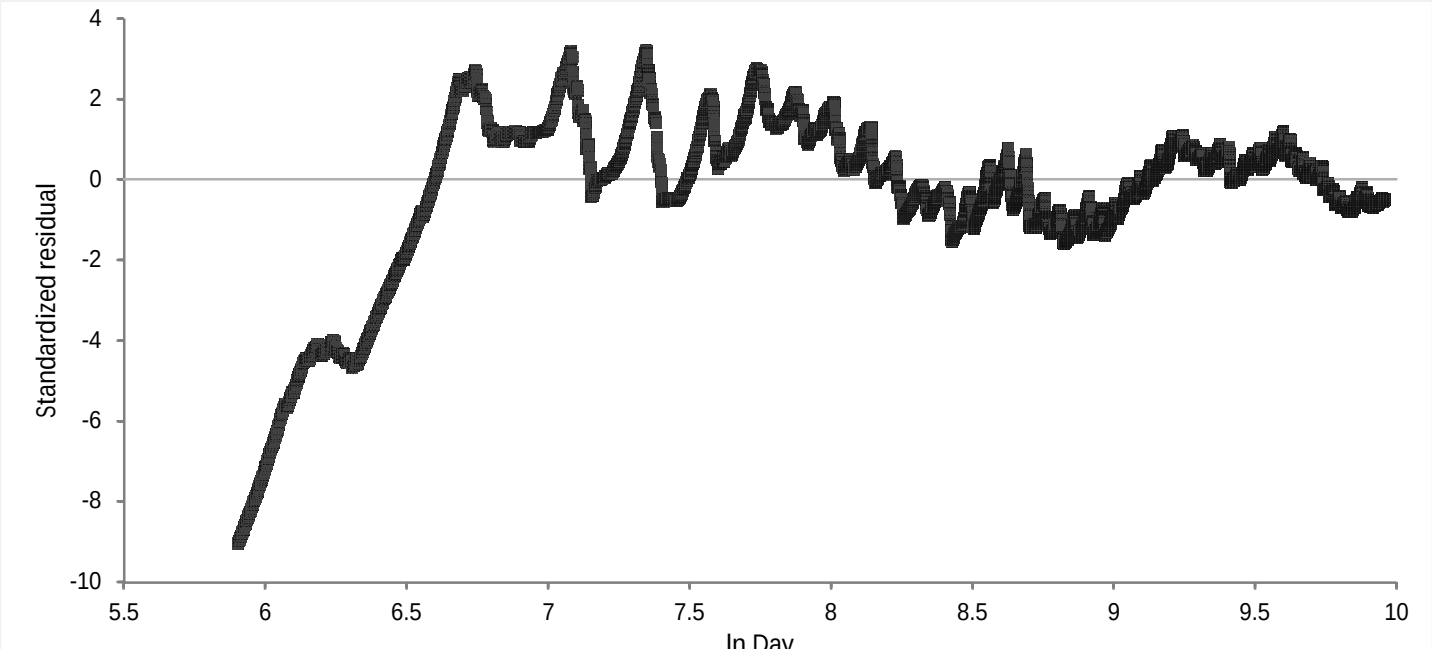
Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 17:26 by Willy

Residuals



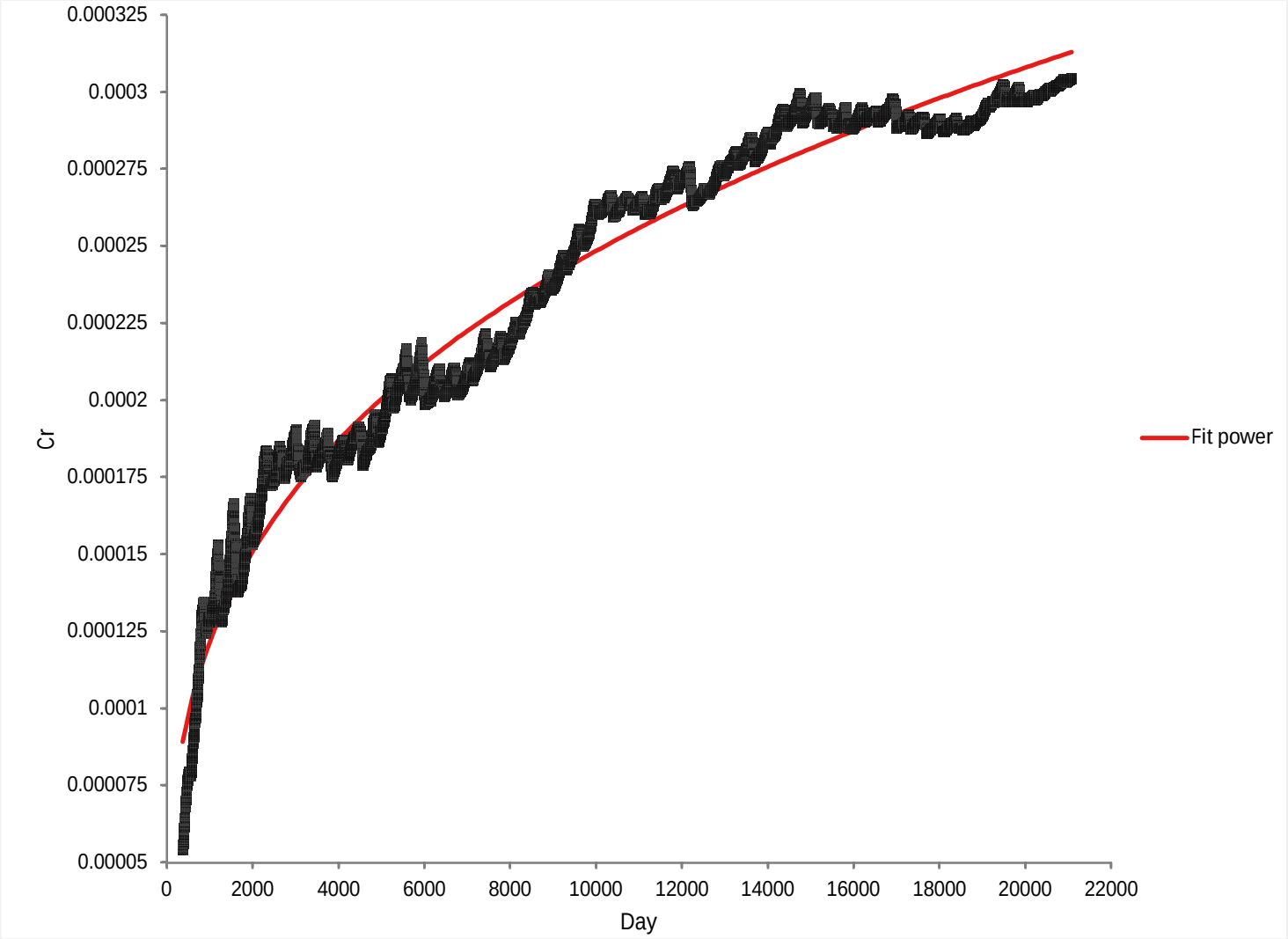
Fit: Cr

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:52 by Willy



Fit: Cr

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:52 by Willy

Fit

N	41431
Mean of Y	-8.356559255

Equation: $Cr = 1.436e\text{-}05 * Day^{0.3096}$

R^2	0.957
R^2 adjusted	0.957
RMSE	0.055149906

Parameter	Estimate	95% CI	SE	t	p-value
Constant	-11.15	-11.16 to -11.15	2.9259E-03	-3811.19	<0.0001
ln Day	0.3096	0.3089 to 0.3102	3.2272E-04	959.28	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	2.798836E+03	1	2.798836E+03	920212.10	<0.0001
Error	1.260068E+02	41429	0.003041512		
Null model	2.924843E+03	41430	0.070597226		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: Cr

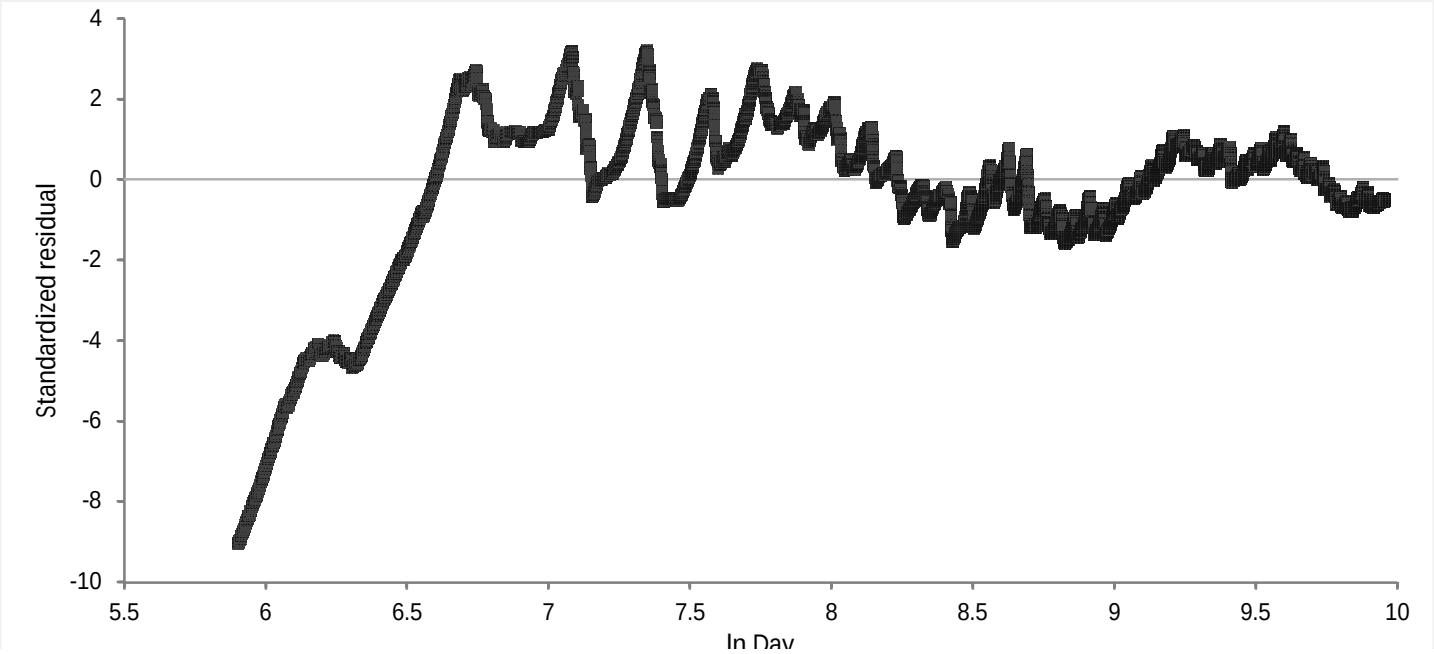
NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:52 by Willy

Analyse-it v5.80.2

Residuals



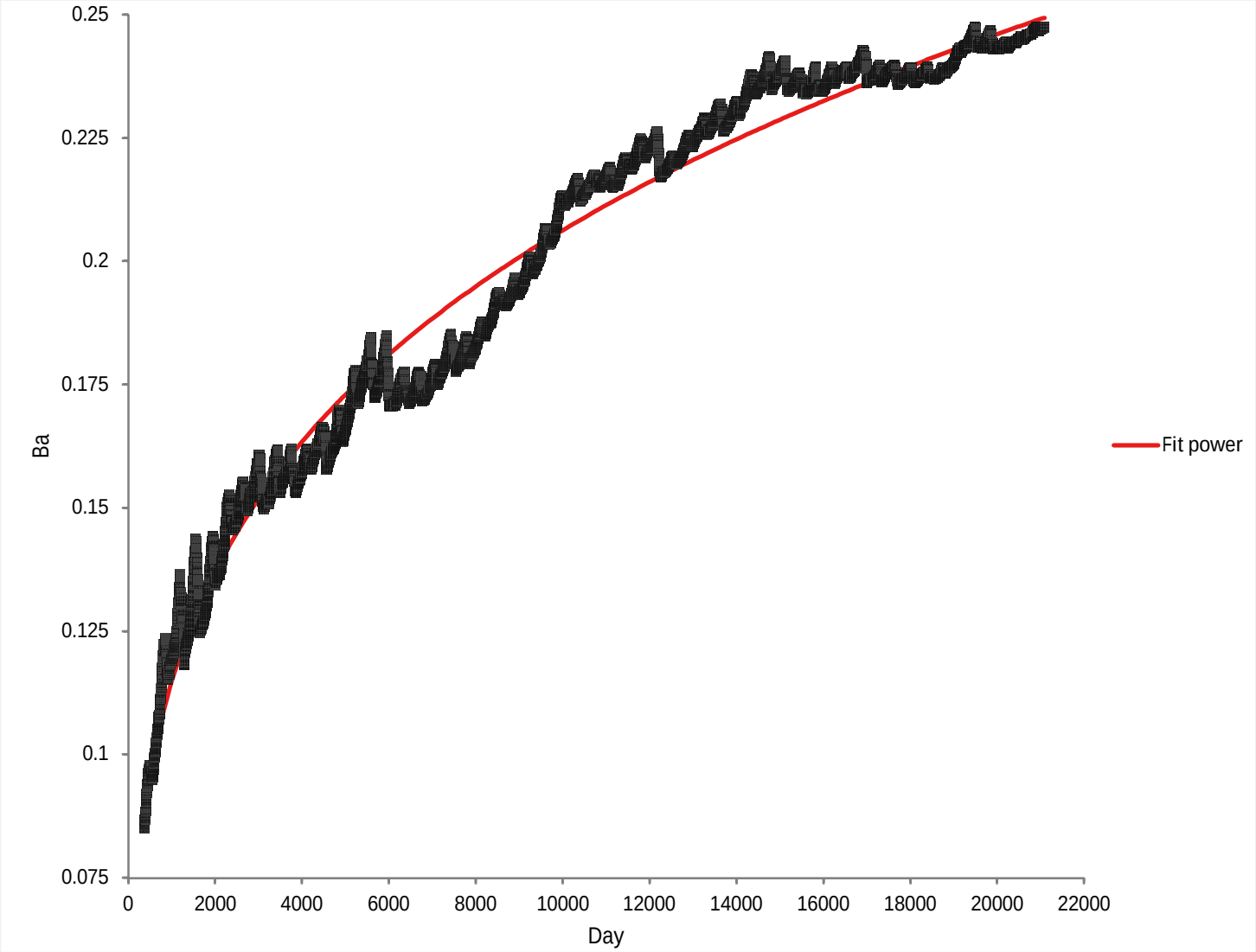
Fit: Ba

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:48 by Willy



Fit: Ba

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:48 by Willy

Fit

N	41431
Mean of Y	-1.6245965

Equation: $Ba = 0.01985 * Day^{0.2542}$

R^2	0.975
R^2 adjusted	0.975
RMSE	0.03382315

Parameter	Estimate	95% CI	SE	t	p-value
Constant	-3.919	-3.923 to -3.916	1.7945E-03	-2184.14	<0.0001
ln Day	0.2542	0.2538 to 0.2546	1.9792E-04	1284.31	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	###########	1	1886.9909461	1649460.01	<0.0001
Error	47.3949943	41429	0.0011440		
Null model	###########	41430	0.0466905		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: Ba

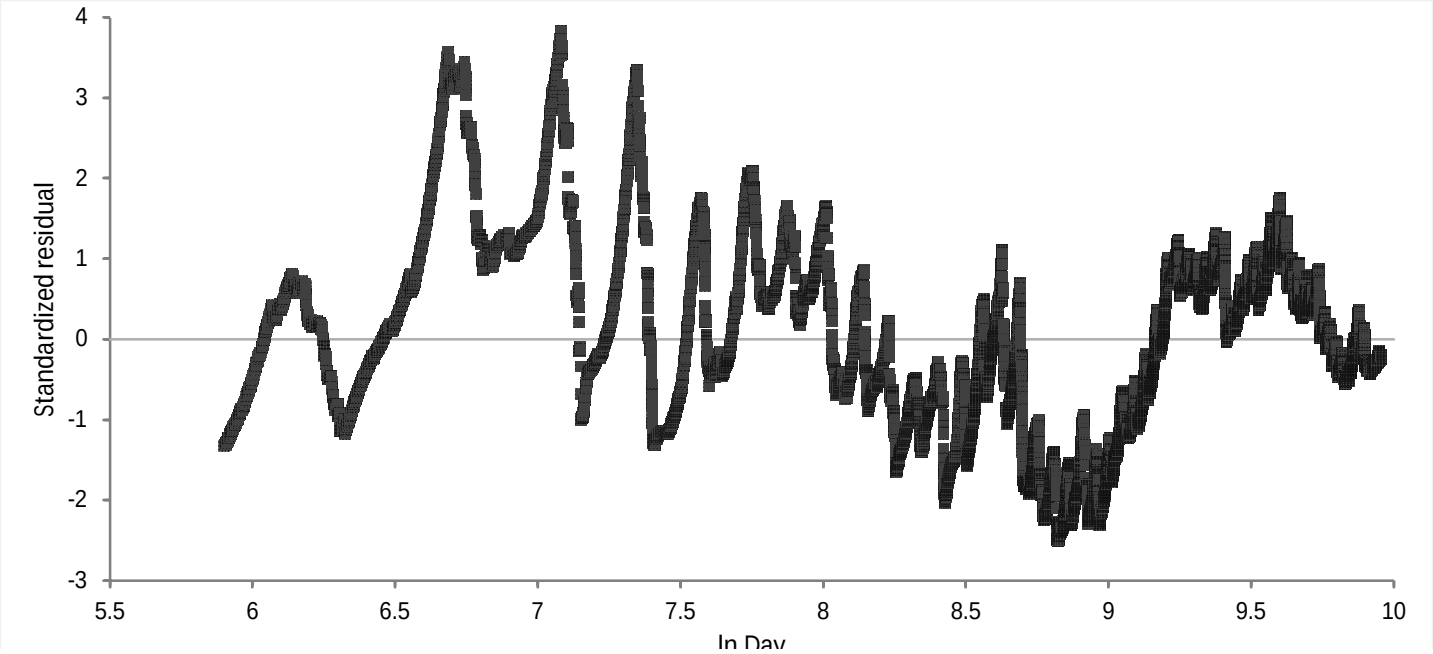
NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:48 by Willy

Analyse-it v5.80.2

Residuals



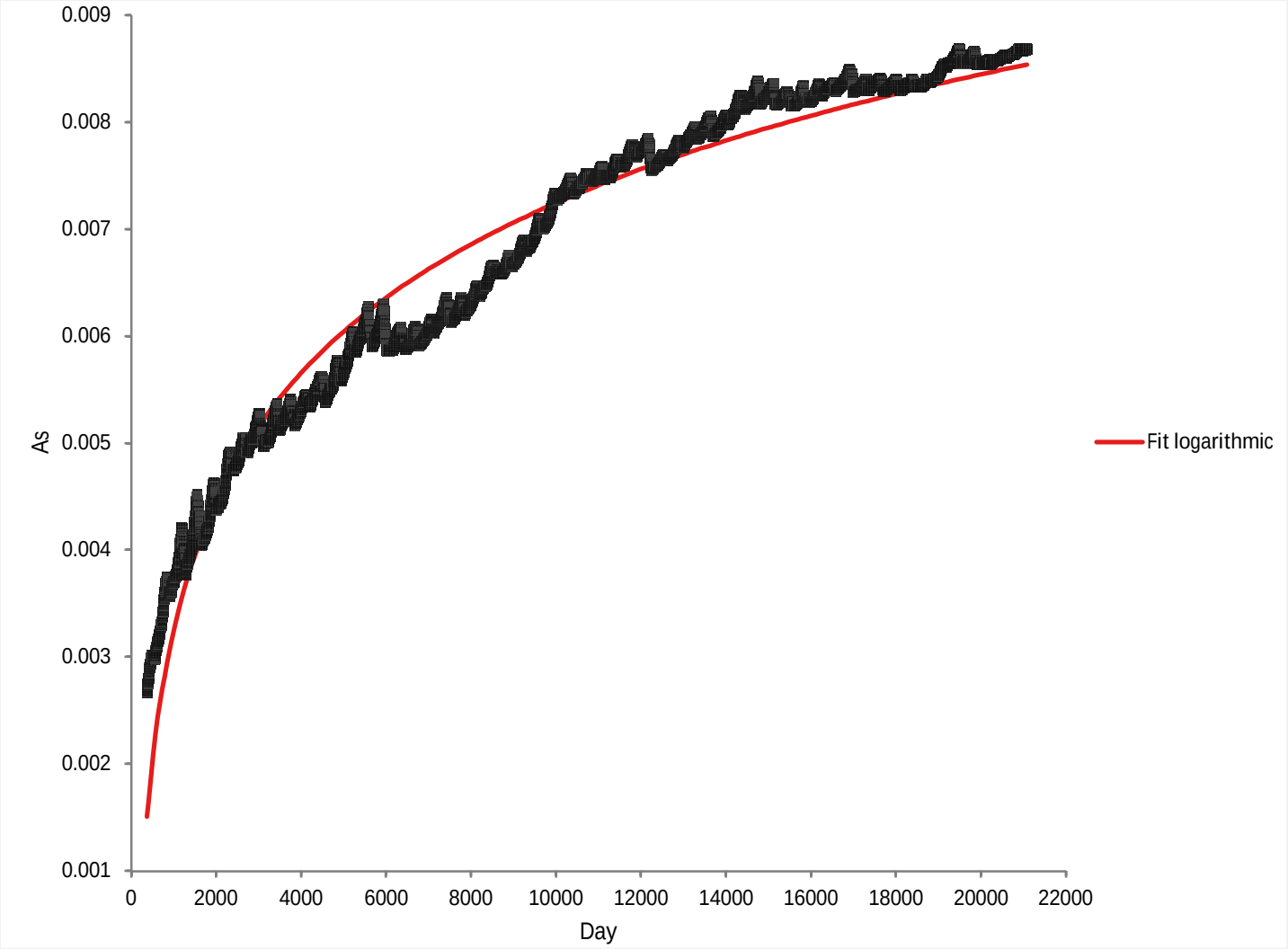
Fit: As

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:47 by Willy



Fit: As

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:47 by Willy

Fit

N	41431
Mean of Y	0.00693101

Equation	As = -0.008723 + 0.001734 ln Day

R^2	0.959
R^2 adjusted	0.959
RMSE	0.000301005

Parameter	Estimate	95% CI	SE	t	p-value
Constant	-0.008723	-0.008754 to -0.008692	1.5970E-05	-546.23	<0.0001
ln Day	0.001734	0.001731 to 0.001737	1.7614E-06	984.47	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.08781196	1	0.08781196	969181.55	<0.0001
Error	0.00375364	41429	0.00000009		
Null model	0.09156560	41430	0.00000221		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta \text{Log}(x)$
The model is better than the null model.

Fit: As

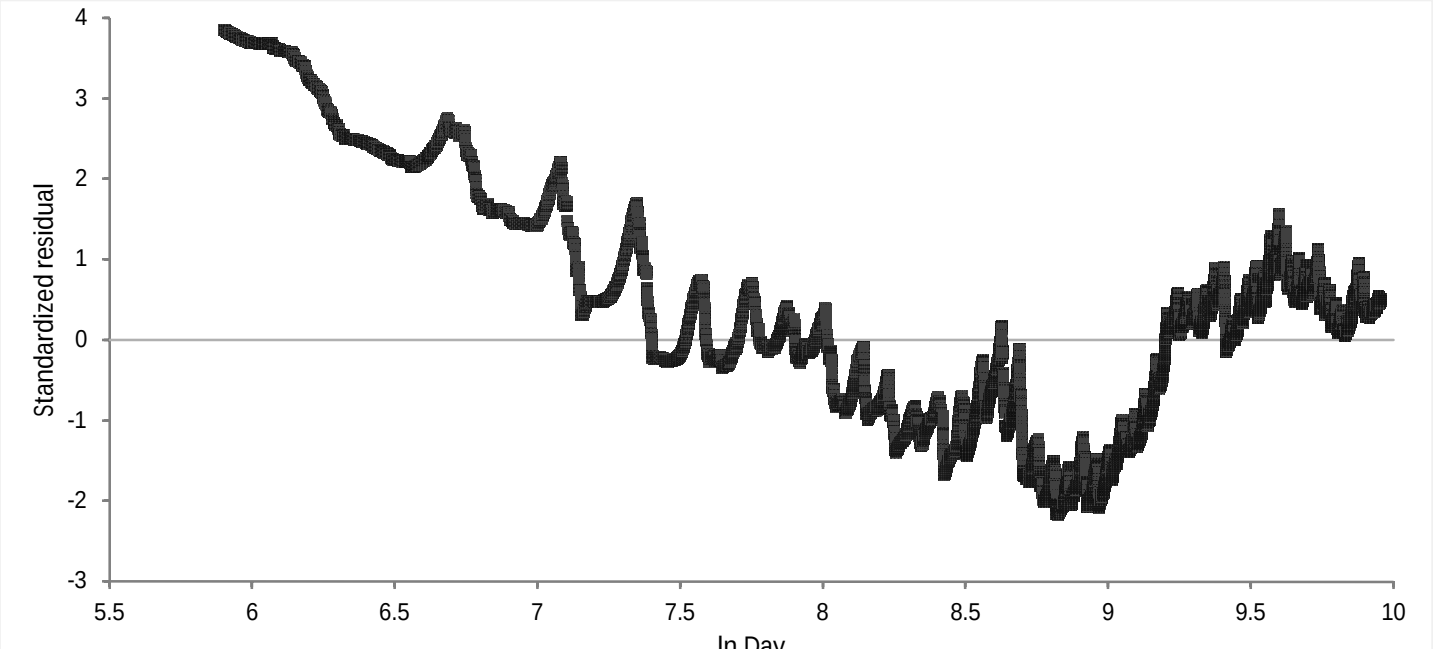
Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:47 by Willy

Residuals



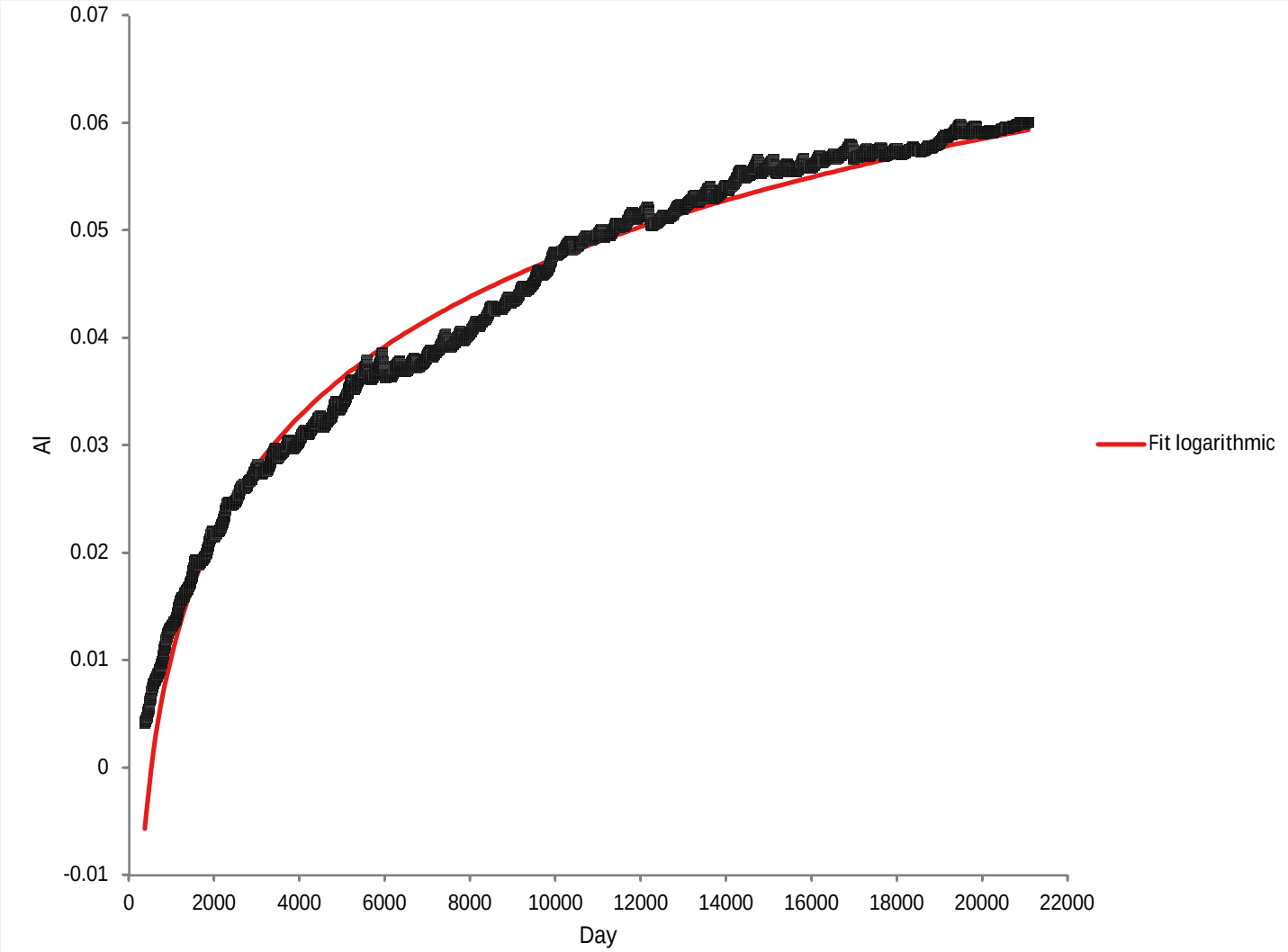
Fit: AI

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:43 by Willy



Fit: AI

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:43 by Willy

Fit

N	41431
Mean of Y	0.04447788

Equation: AI = -0.1003 + 0.01604 ln Day

R^2	0.981
R^2 adjusted	0.981
RMSE	0.001898124

Parameter	Estimate	95% CI	SE	t	p-value
Constant	-0.1003	-0.1005 to -0.1001	1.0070E-04	-996.08	<0.0001
ln Day	0.01604	0.01602 to 0.01606	1.1107E-05	1443.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	7.51201678	1	7.51201678	2085006.64	<0.0001
Error	0.14926348	41429	0.00000360		
Null model	7.66128026	41430	0.00018492		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta \text{Log}(x)$
The model is better than the null model.

Fit: Al

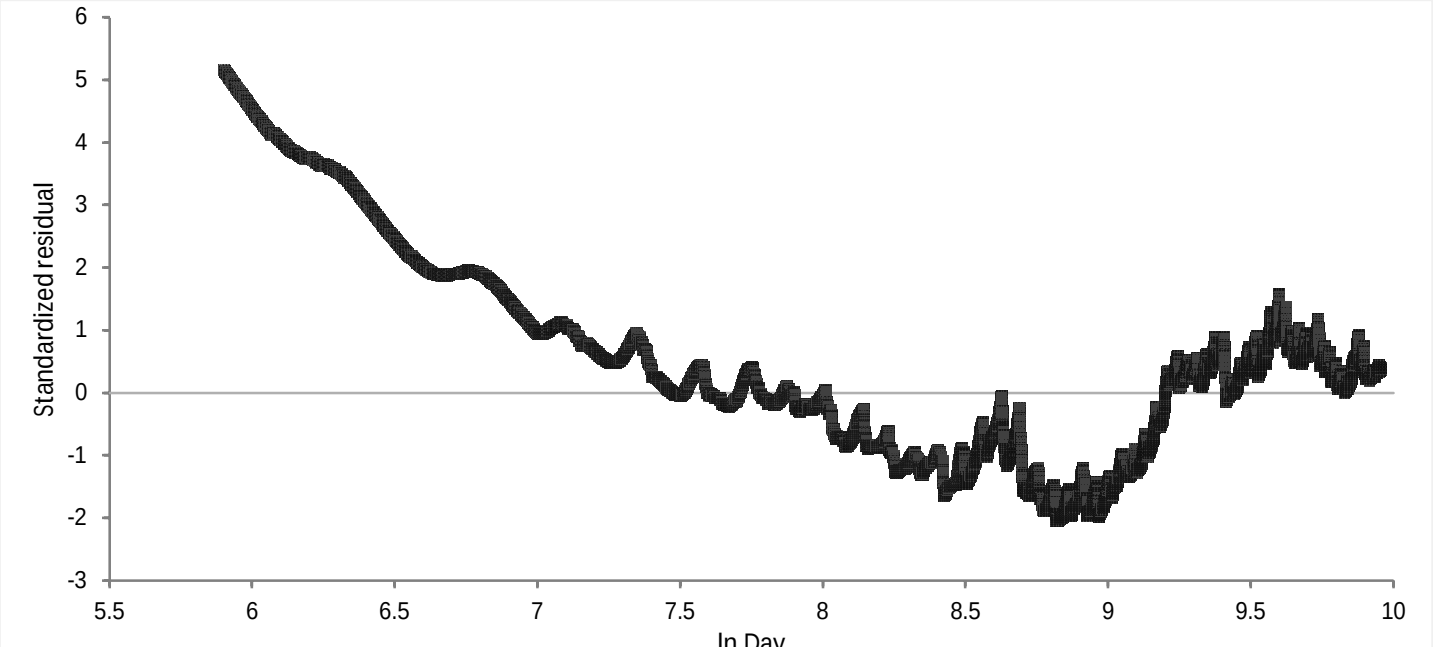
Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:43 by Willy

Residuals



Fit: F

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:41 by Willy

Fit: F

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:41 by Willy

Fit

N	41431
Mean of Y	0.30418

Equation $F = 1.911 * Day^{-0.03802}$

R^2	0.303
R^2 adjusted	0.303
RMSE	0.048396

Parameter	Estimate	95% CI	SE	t	p-value
Constant	0.6474	0.6424 to 0.6524	2.5676E-03	252.14	<0.0001
ln Day	-0.03802	-0.03858 to -0.03747	2.8319E-04	-134.25	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	42.21583	1	42.21583	18024.34	<0.0001
Error	97.03323	41429	0.00234		
Null model	139.24906	41430	0.00336		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

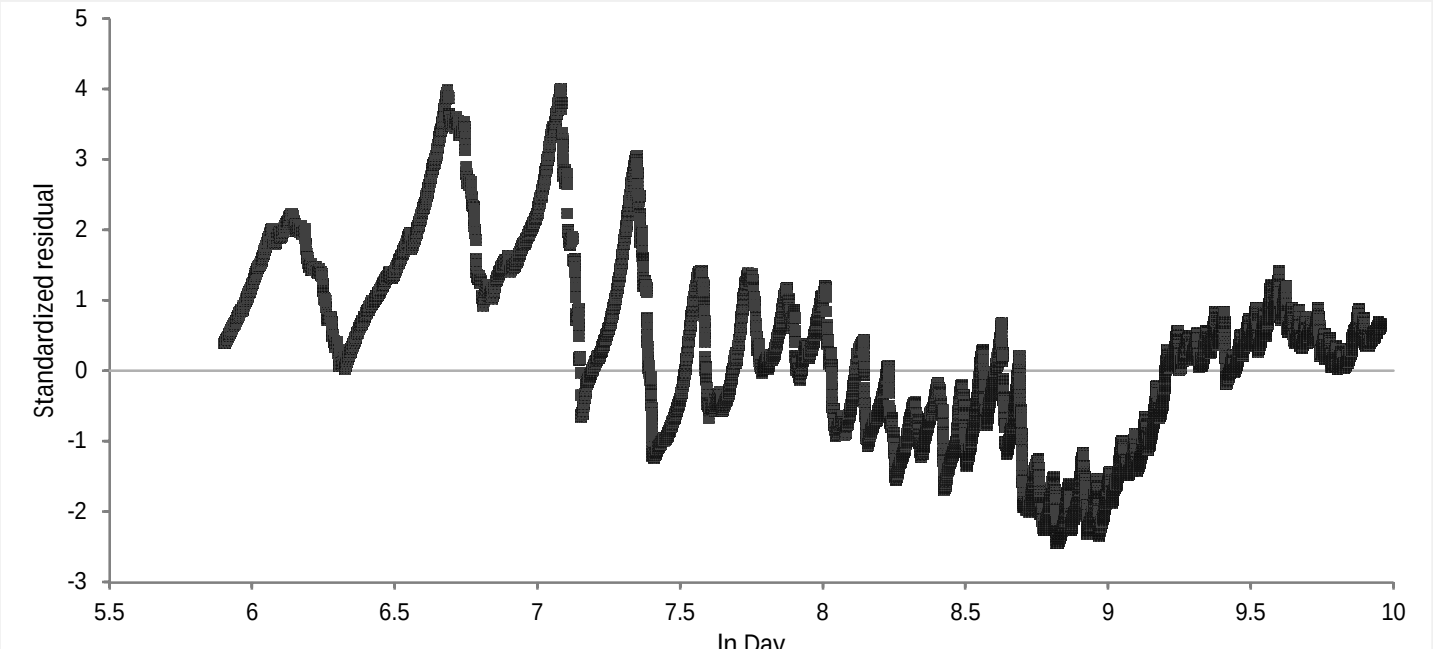
Fit: F

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:41 by Willy

Residuals

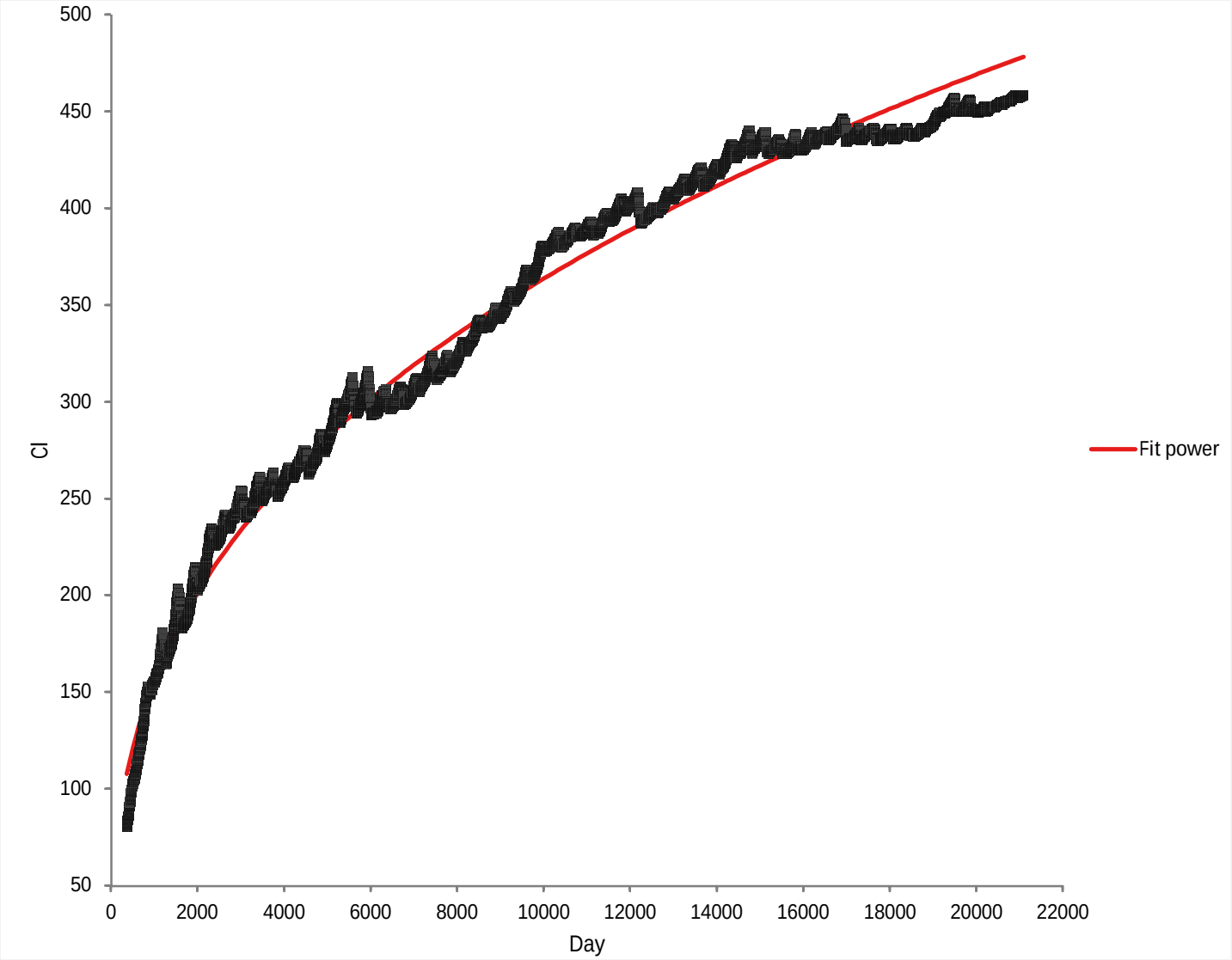


Fit: Cl

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:41 by Willy



Fit: CI

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:41 by Willy

Fit

N	41431
Mean of Y	5.8294

Equation: $CI = 12.36 * Day^{0.3672}$

R^2	0.985
R^2 adjusted	0.985
RMSE	0.03811

Parameter	Estimate	95% CI	SE	t	p-value
Constant	2.515	2.511 to 2.519	2.0217E-03	1243.79	<0.0001
ln Day	0.3672	0.3668 to 0.3676	2.2298E-04	1646.73	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	3937.6417	1	3937.6417	2711705.10	<0.0001
Error	60.1587	41429	0.0015		
Null model	3997.8004	41430	0.0965		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

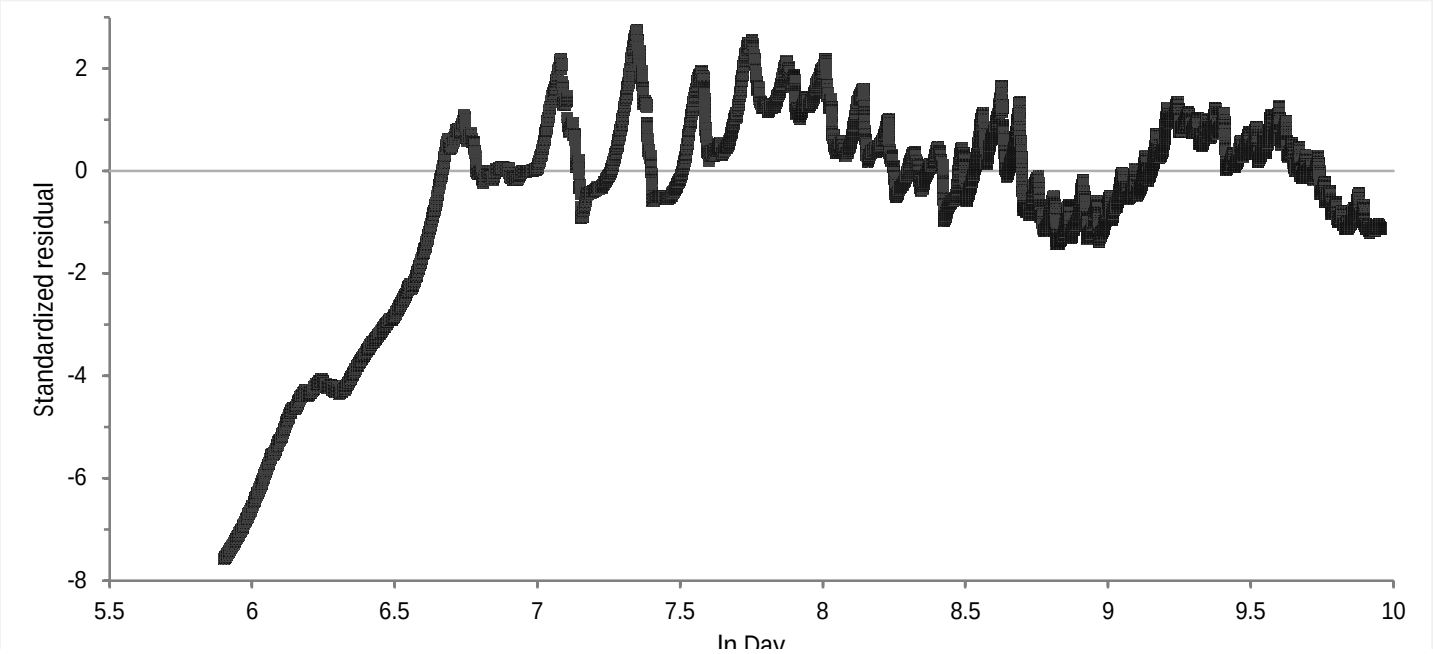
Fit: Cl

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:41 by Willy

Residuals



Fit: SO4

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:39 by Willy

Fit: SO4

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:39 by Willy

Fit

N	41431
Mean of Y	5.861

Equation: $SO4 = 690.6 * Day^{-0.07497}$

R^2	0.650
R^2 adjusted	0.650
RMSE	0.0462

Parameter	Estimate	95% CI	SE	t	p-value
Constant	6.538	6.533 to 6.542	2.4524E-03	2665.71	<0.0001
ln Day	-0.07497	-0.07550 to -0.07444	2.7049E-04	-277.16	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	164.148	1	164.148	76820.18	<0.0001
Error	88.525	41429	0.002		
Null model	252.673	41430	0.006		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: SO4

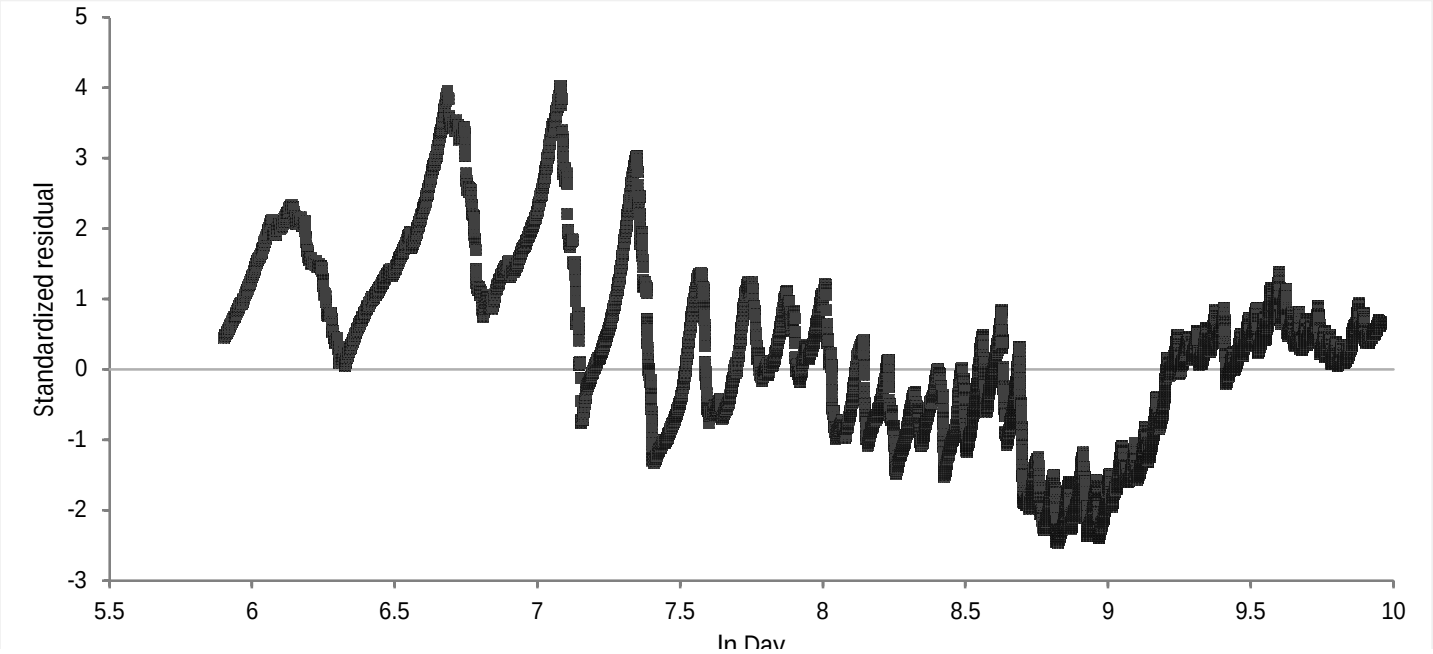
Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:39 by Willy

Residuals

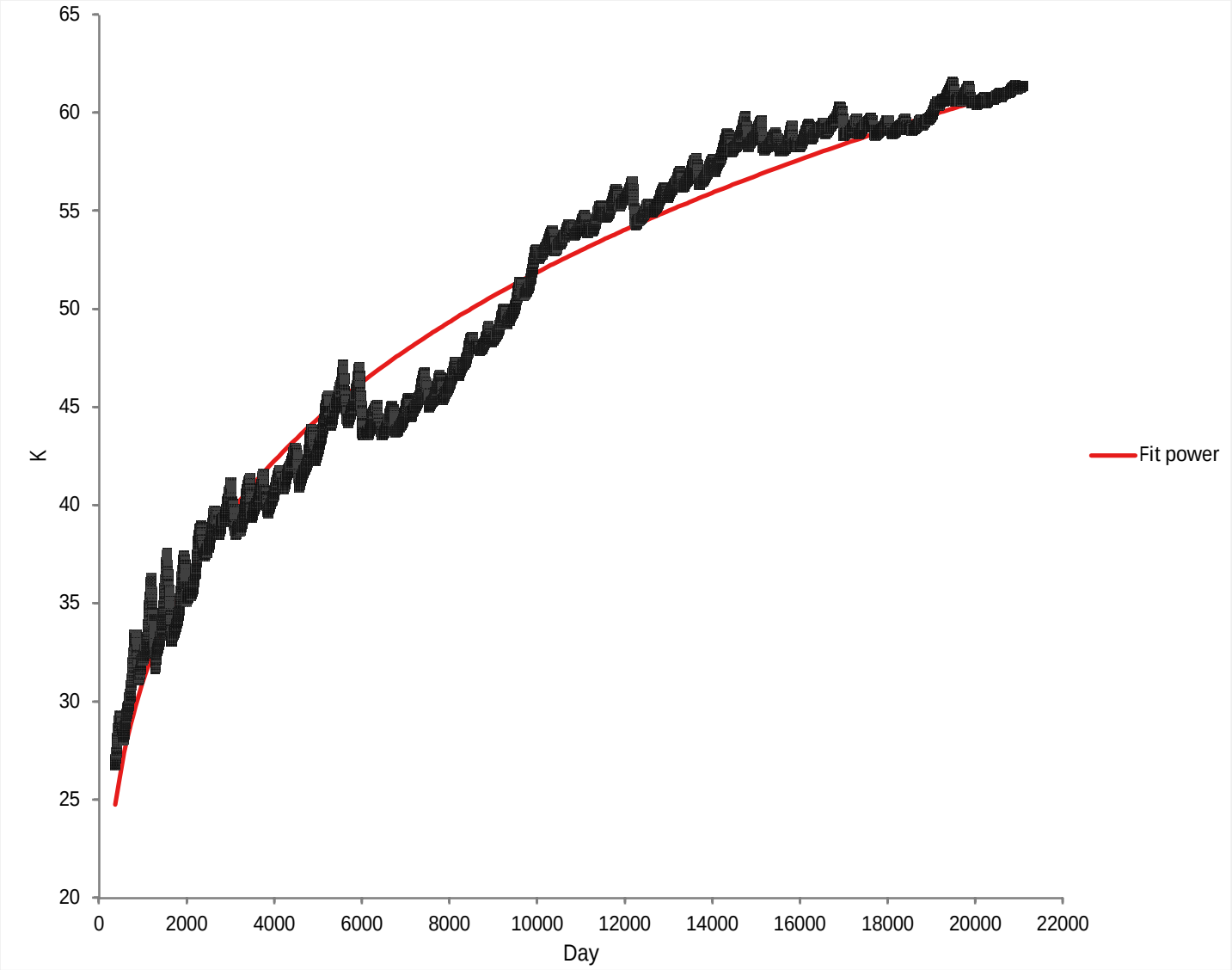


Fit: K

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:37 by Willy



Fit: K

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:37 by Willy

Fit

N	41431
Mean of Y	3.9082

Equation: $K = 6.626 * Day^{0.2234}$

R^2	0.967
R^2 adjusted	0.967
RMSE	0.03451

Parameter	Estimate	95% CI	SE	t	p-value
Constant	1.891	1.887 to 1.895	1.8306E-03	1032.95	<0.0001
ln Day	0.2234	0.2231 to 0.2238	2.0191E-04	1106.67	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	1458.1693	1	1458.1693	1224726.09	<0.0001
Error	49.3257	41429	0.0012		
Null model	1507.4951	41430	0.0364		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: K

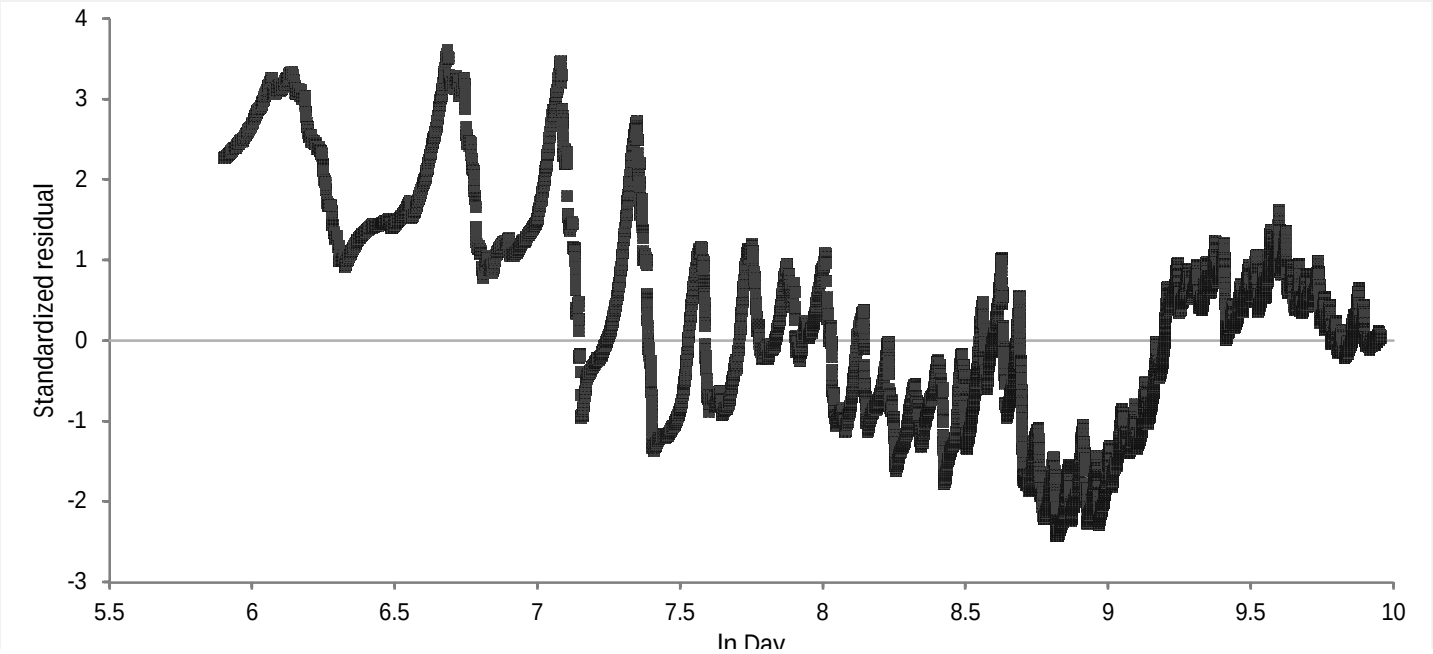
NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:37 by Willy

Analyse-it v5.80.2

Residuals



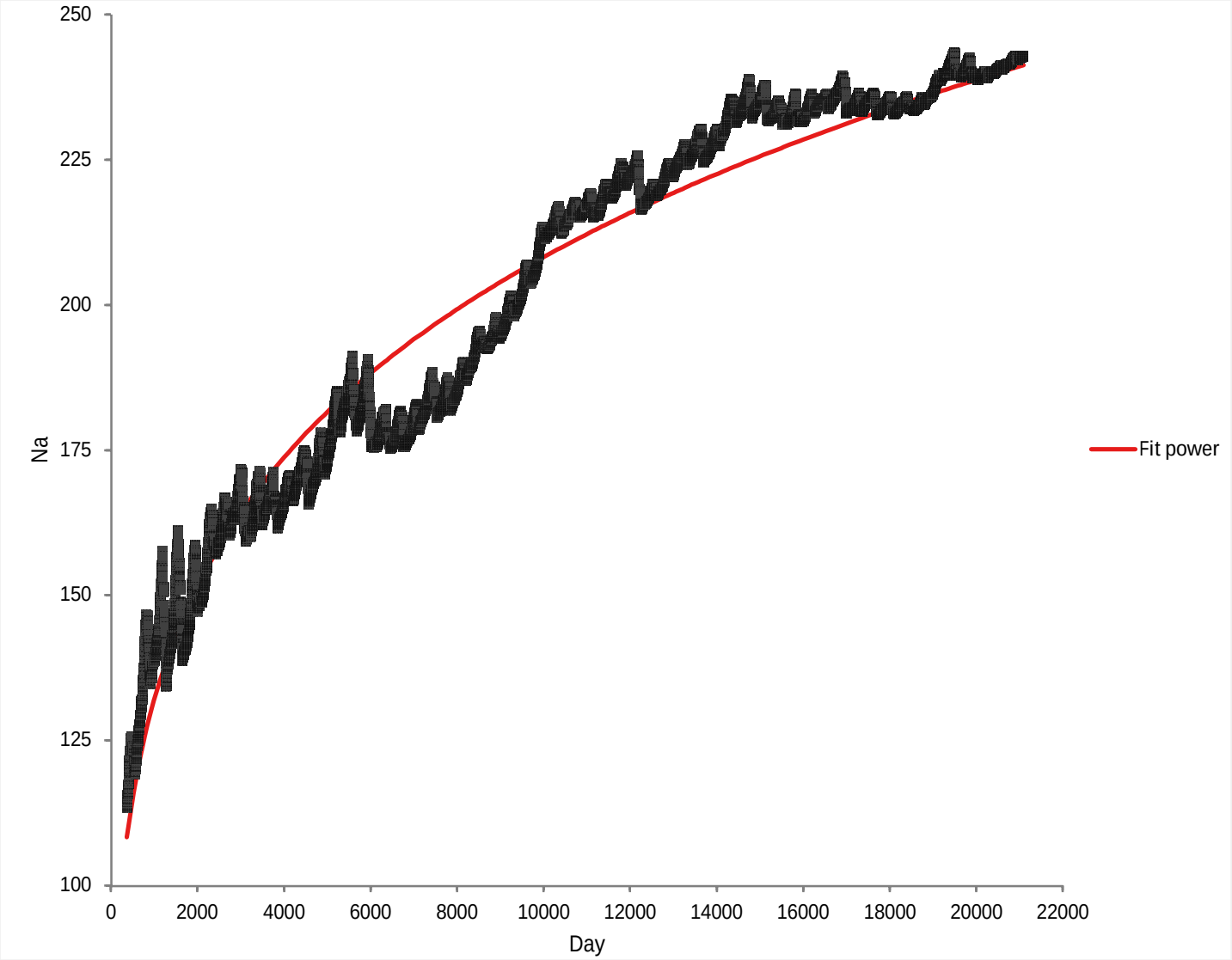
Fit: Na

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:35 by Willy



Fit: Na

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:35 by Willy

Fit

N	41431
Mean of Y	5.303

Equation: $Na = 33.83 * Day^{0.1973}$

R^2	0.949
R^2 adjusted	0.949
RMSE	0.0382

Parameter	Estimate	95% CI	SE	t	p-value
Constant	3.521	3.517 to 3.525	2.0290E-03	1735.54	<0.0001
ln Day	0.1973	0.1969 to 0.1978	2.2379E-04	881.82	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	1137.294	1	1137.294	777608.00	<0.0001
Error	60.592	41429	0.001		
Null model	1197.886	41430	0.029		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: Na

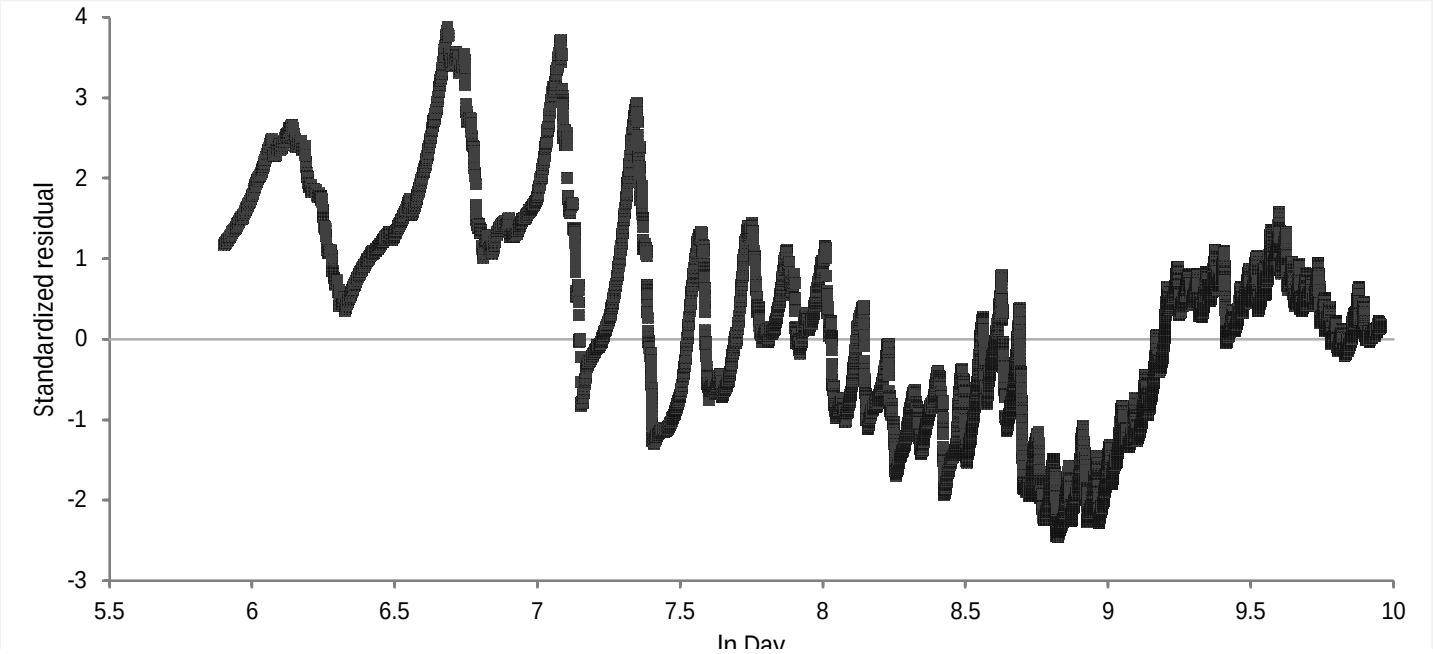
Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:35 by Willy

Residuals



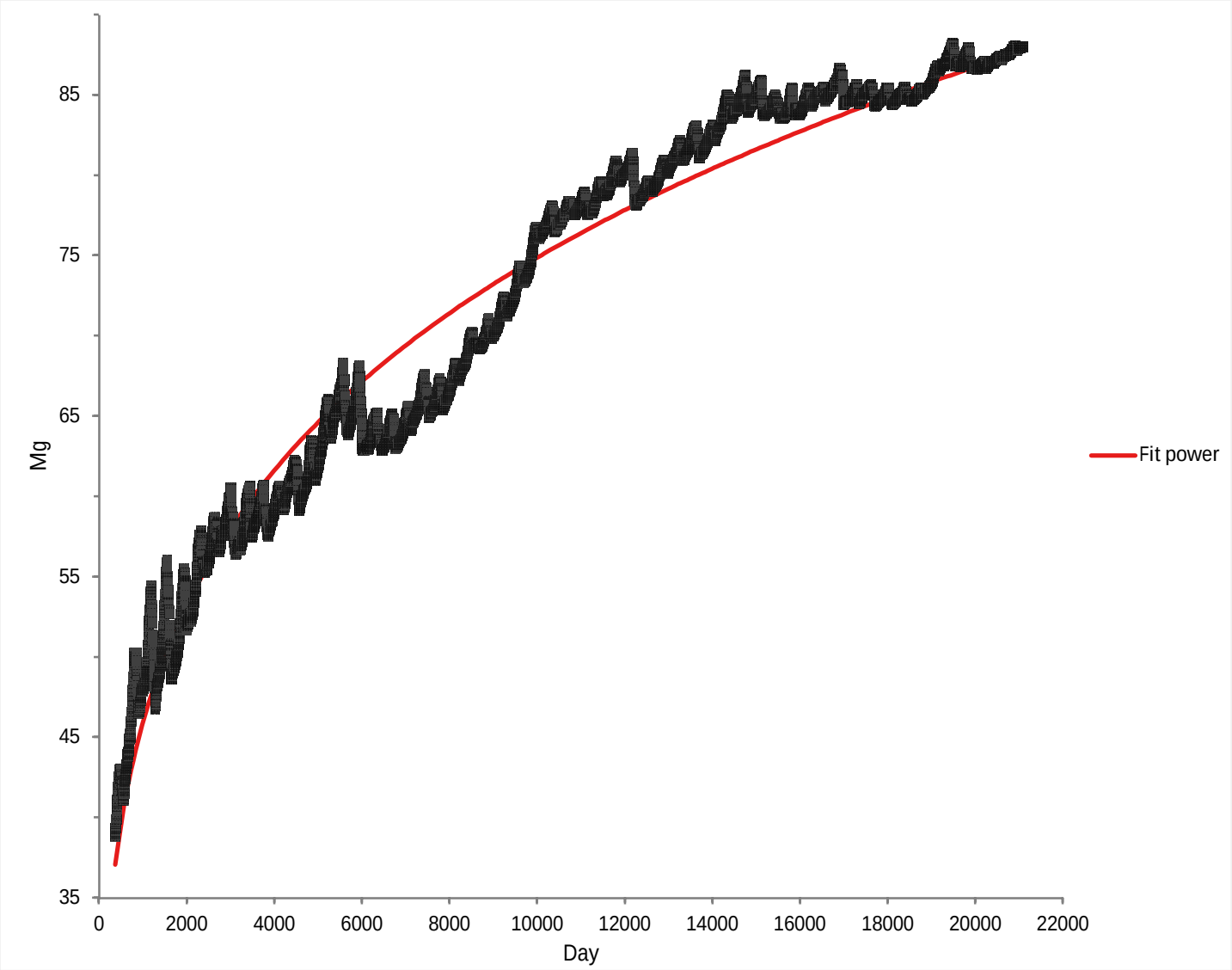
Fit: Mg

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:34 by Willy



Fit: Mg

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:34 by Willy

Fit

N	41431
Mean of Y	4.2771

Equation: $Mg = 10.58 * Day^{0.2124}$

R^2	0.960
R^2 adjusted	0.960
RMSE	0.03640

Parameter	Estimate	95% CI	SE	t	p-value
Constant	2.359	2.356 to 2.363	1.9310E-03	1221.82	<0.0001
ln Day	0.2124	0.2120 to 0.2129	2.1298E-04	997.48	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	1318.0137	1	1318.0137	994971.96	<0.0001
Error	54.8799	41429	0.0013		
Null model	1372.8937	41430	0.0331		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: Mg

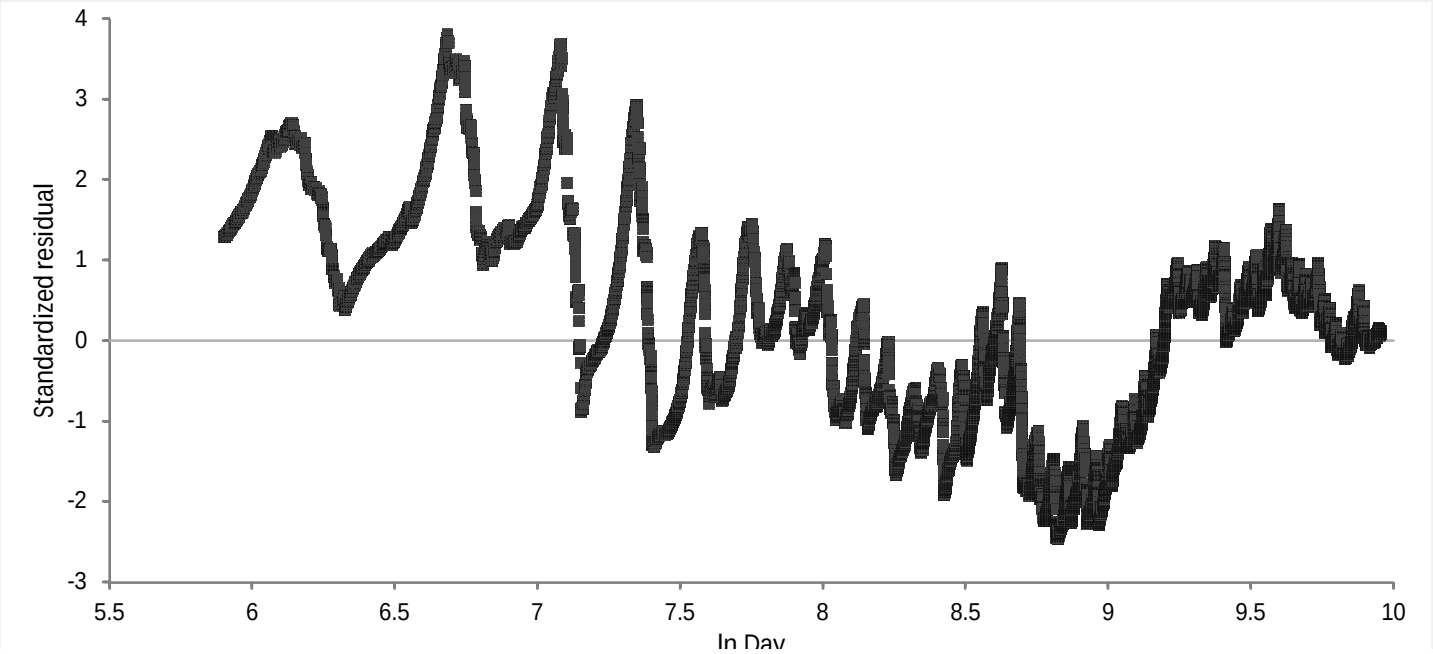
NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:34 by Willy

Analyse-it v5.80.2

Residuals

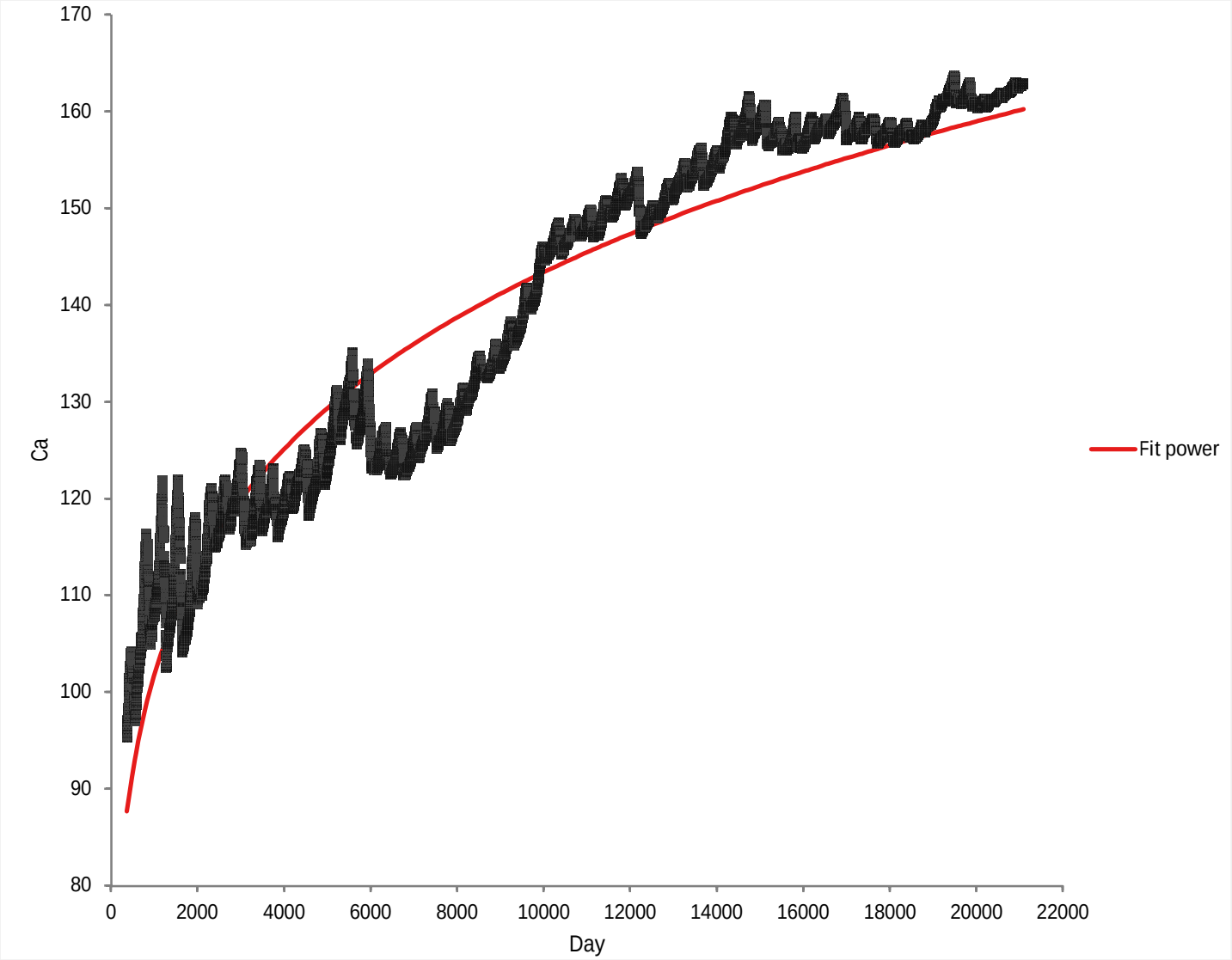


Fit: Ca

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:32 by Willy



Fit: Ca

Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:32 by Willy

Fit

N	41431
Mean of Y	4.9386

Equation: $Ca = 36.47 * Day^{0.1487}$

R^2	0.896
R^2 adjusted	0.896
RMSE	0.04244

Parameter	Estimate	95% CI	SE	t	p-value
Constant	3.597	3.592 to 3.601	2.2517E-03	1597.28	<0.0001
ln Day	0.1487	0.1482 to 0.1491	2.4835E-04	598.56	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	645.3689	1	645.3689	358275.59	<0.0001
Error	74.6269	41429	0.0018		
Null model	719.9957	41430	0.0174		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: Ca

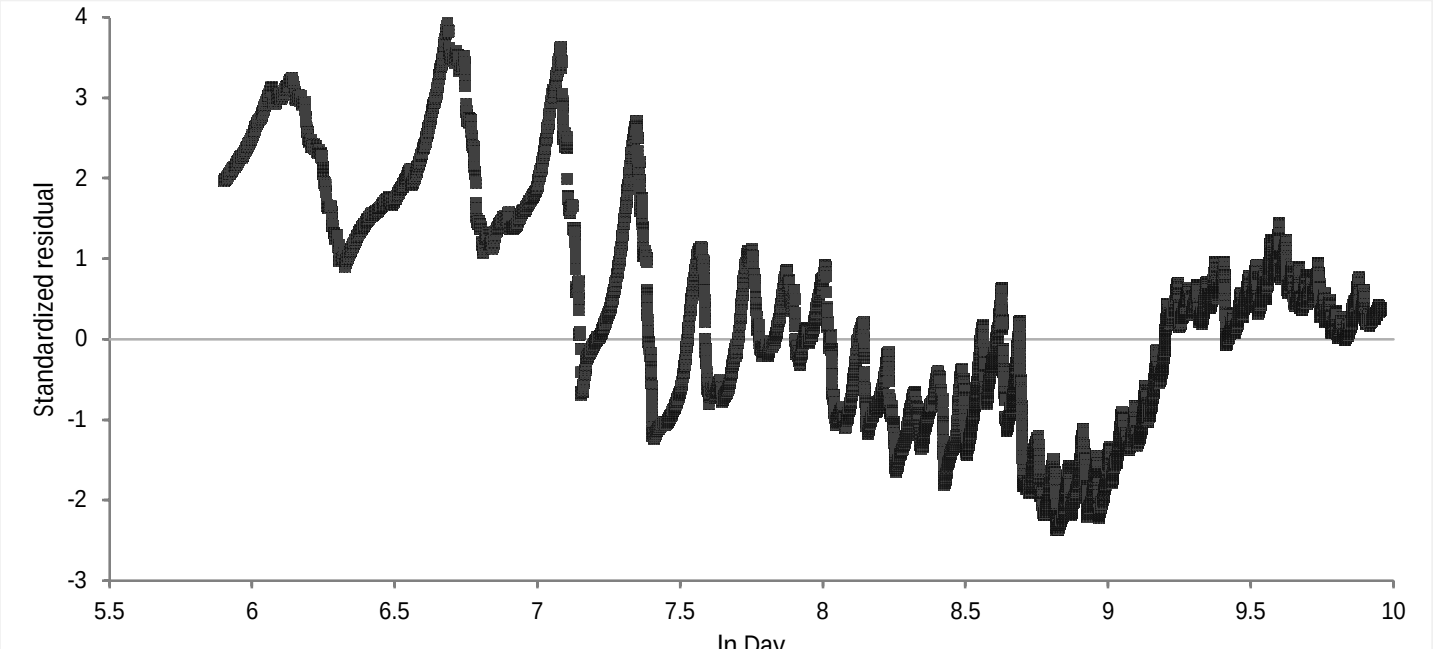
Analyse-it v5.80.2

NP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 16:32 by Willy

Residuals



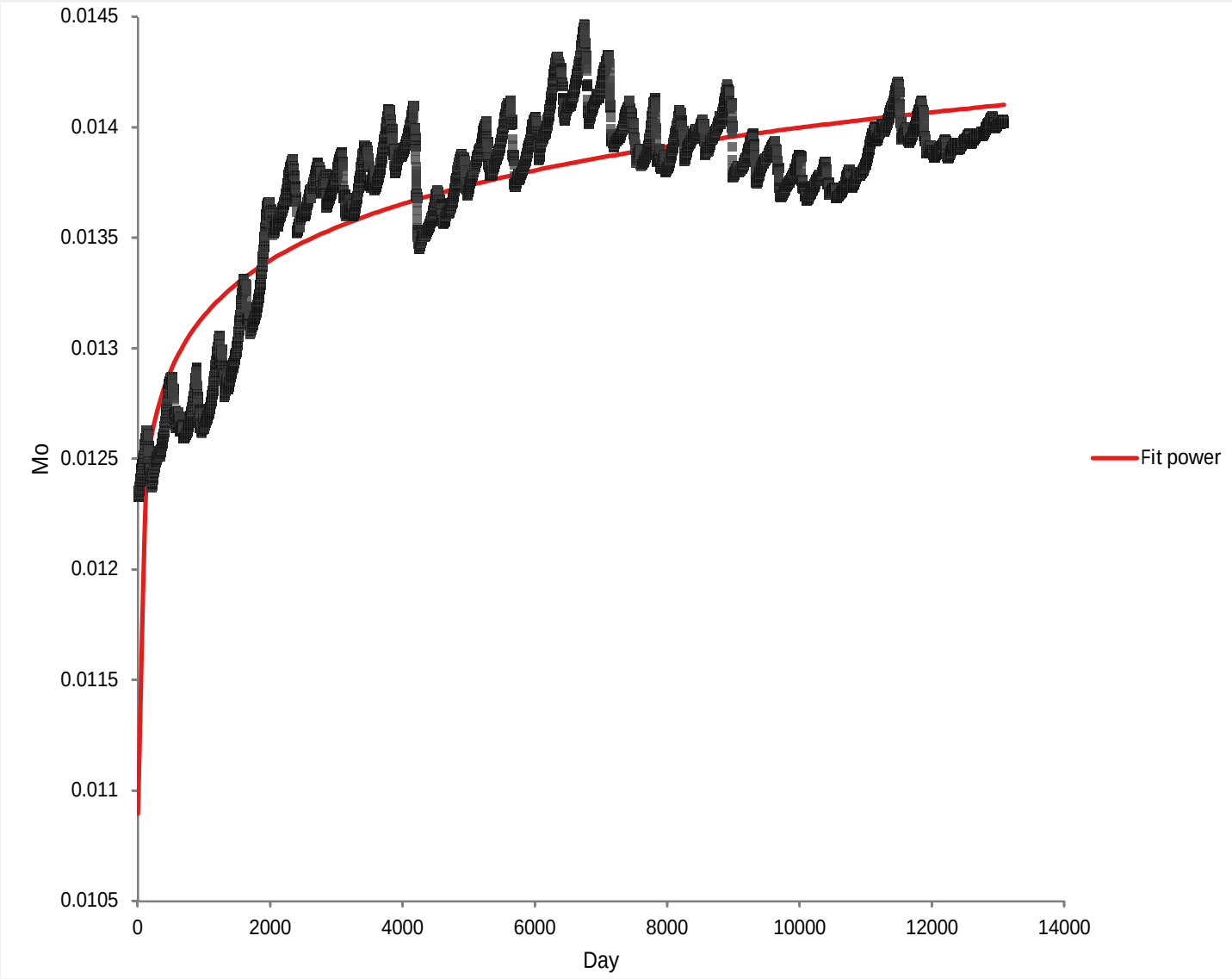
Fit: Mo

Analyse-it v5.80.2

NP Curve Fitting (2) A24:D26185

Filter: No filter

Last updated 29 May 2024 at 17:47 by Willy



Fit: Mo

Analyse-it v5.80.2

NP Curve Fitting (2) A24:D26185

Filter: No filter

Last updated 29 May 2024 at 17:47 by Willy

Fit

N	26161
Mean of Y	-4.2886395

Equation: $Mo = 0.0109 * Day^{0.02722}$

R^2	0.739
R^2 adjusted	0.739
RMSE	0.01612723

Parameter	Estimate	95% CI	SE	t	p-value
Constant	-4.519	-4.521 to -4.518	8.5365E-04	-5294.26	<0.0001
ln Day	0.02722	0.02702 to 0.02742	9.9983E-05	272.24	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	19.2764320	1	19.2764320	74115.17	<0.0001
Error	6.8036303	26159	0.0002601		
Null model	26.0800624	26160	0.0009969		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

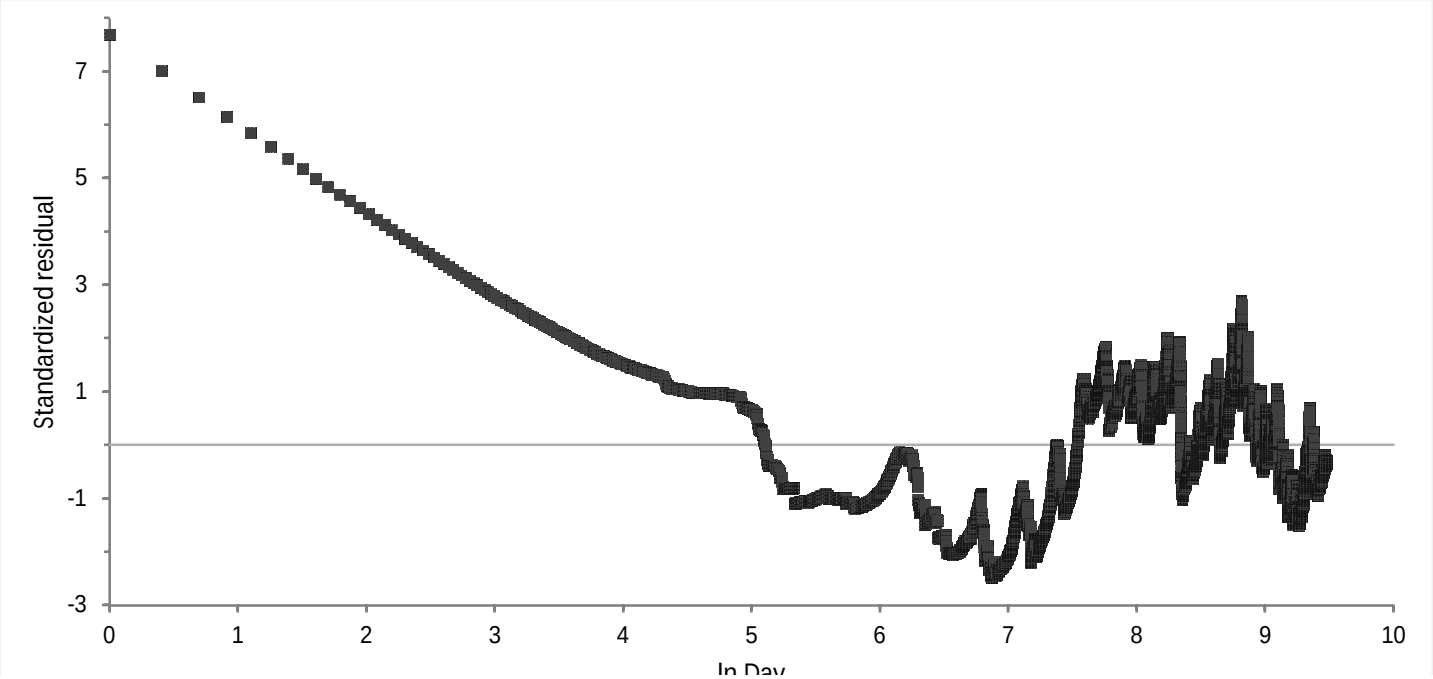
Fit: Mo

NP Curve Fitting (2) A24:D26185

Filter: No filter

Last updated 29 May 2024 at 17:47 by Willy

Residuals



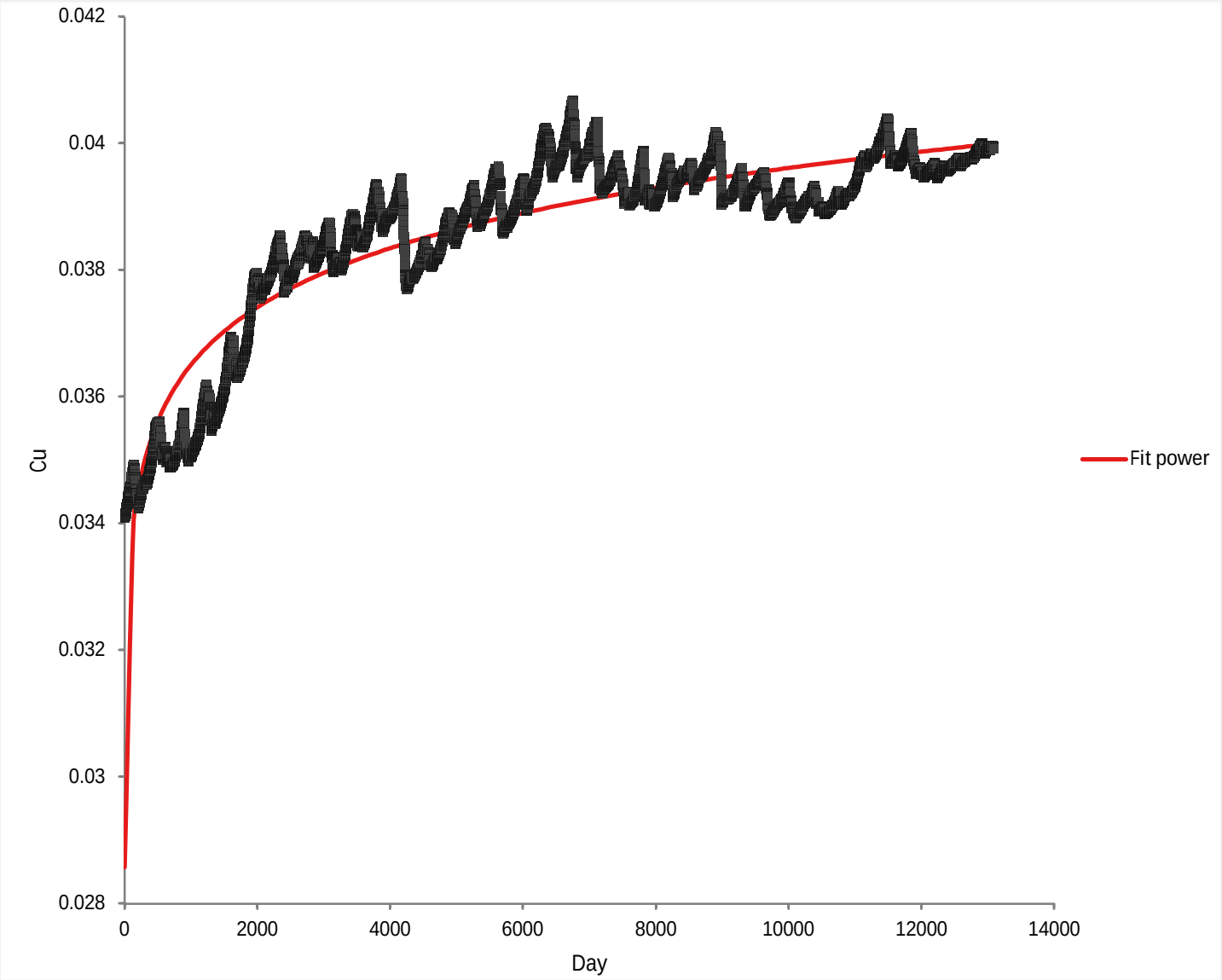
Fit: Cu

Analyse-it v5.80.2

NP Curve Fitting (2) A24:D26185

Filter: No filter

Last updated 29 May 2024 at 17:45 by Willy



Fit: Cu

Analyse-it v5.80.2

NP Curve Fitting (2) A24:D26185

Filter: No filter

Last updated 29 May 2024 at 17:45 by Willy

Fit

N	26161
Mean of Y	-3.2544921

Equation: $Cu = 0.02857 * Day^{0.03547}$

R^2	0.843
R^2 adjusted	0.843
RMSE	0.01525687

Parameter	Estimate	95% CI	SE	t	p-value
Constant	-3.555	-3.557 to -3.554	8.0758E-04	-4402.37	<0.0001
ln Day	0.03547	0.03529 to 0.03566	9.4587E-05	375.01	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	32.7354916	1	32.7354916	140633.22	<0.0001
Error	6.0890859	26159	0.0002328		
Null model	38.8245775	26160	0.0014841		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: Cu

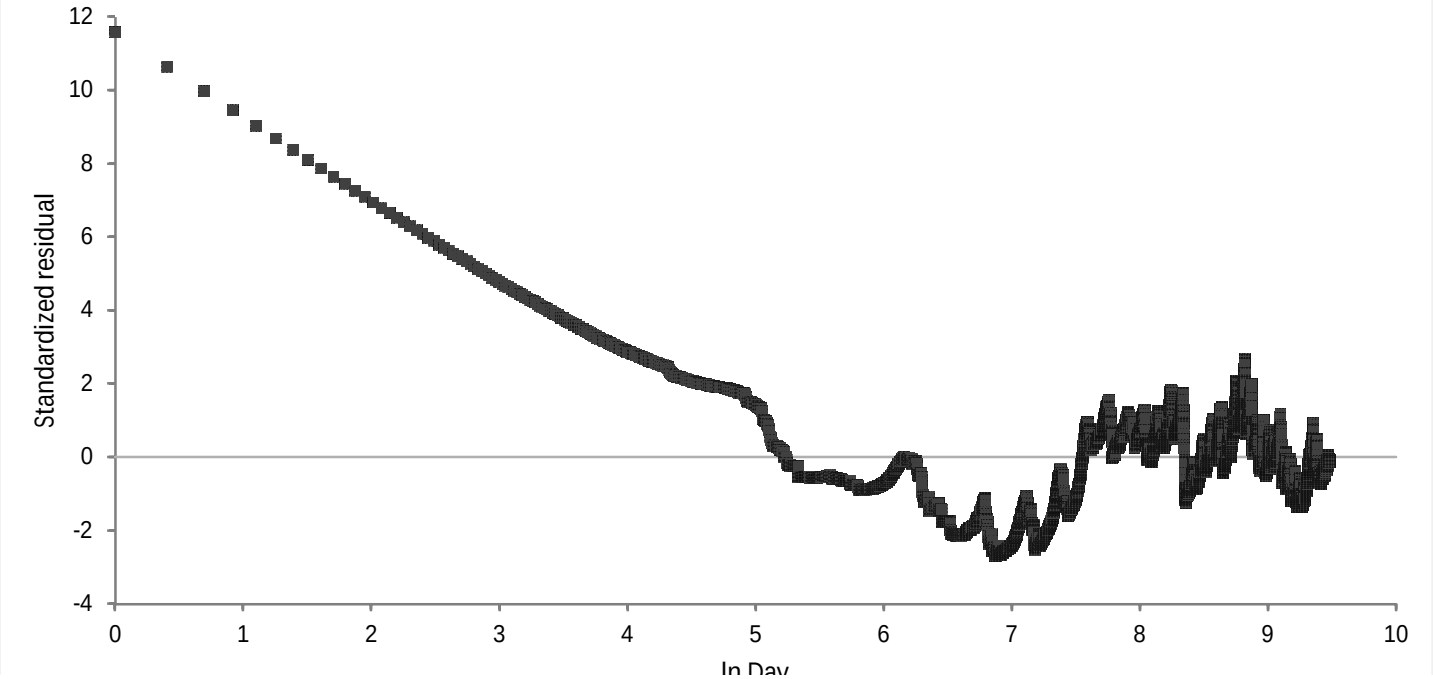
Analyse-it v5.80.2

NP Curve Fitting (2) A24:D26185

Filter: No filter

Last updated 29 May 2024 at 17:45 by Willy

Residuals



D.3.2 South Pit statistical curve fitting results

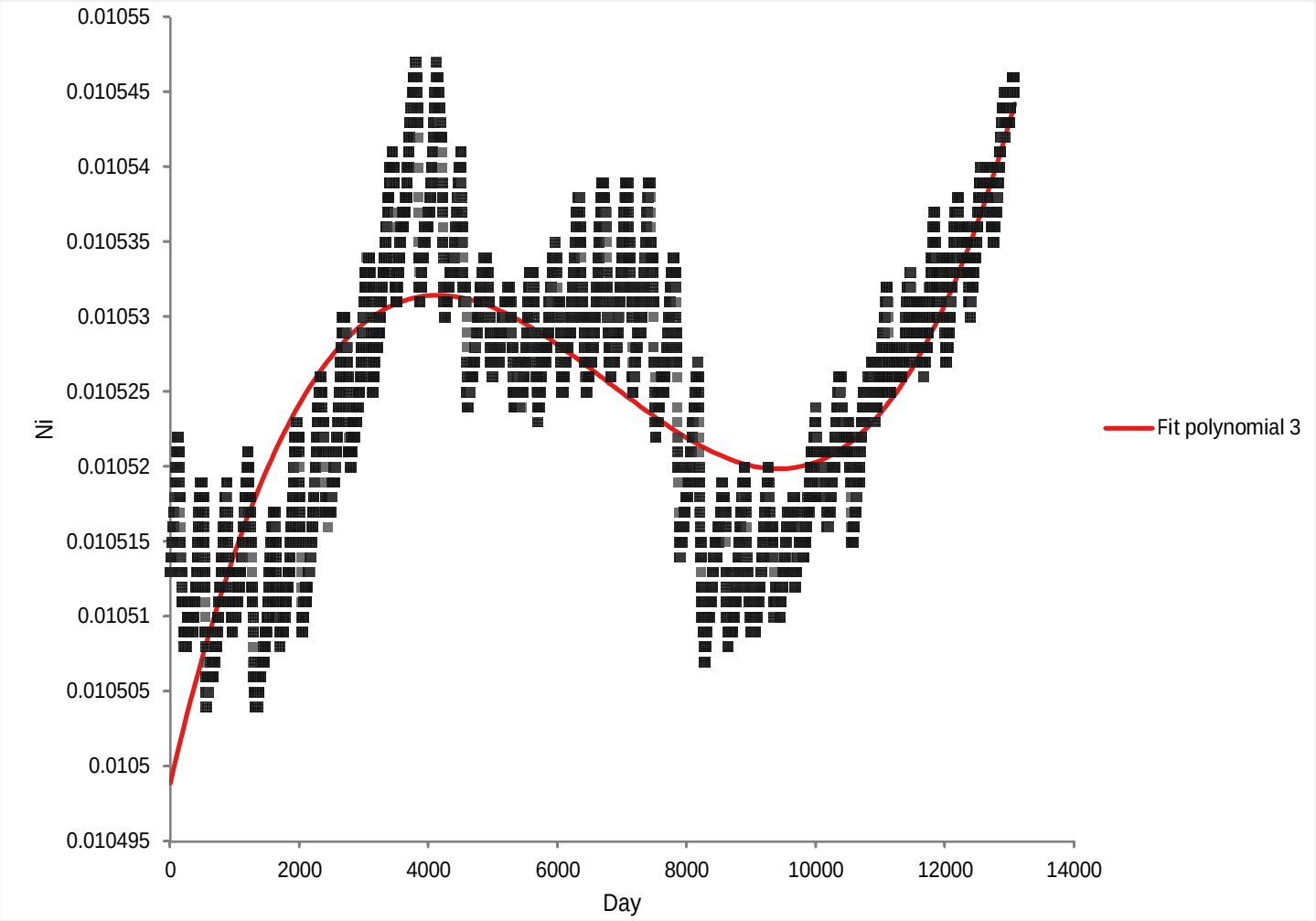
Fit: Ni

Analyse-it v5.80.2

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:59 by Willy



Fit: Ni

Analyse-it v5.80.2

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:59 by Willy

Fit

N	26161
Mean of Y	0.0105248

Equation: $Ni = 0.0105 + 1.842e\text{-}08\ Day - 3.2e\text{-}12\ Day^2 + 1.572e\text{-}16\ Day^3$

R^2	0.577
R^2 adjusted	0.577
RMSE	0.00000635

Parameter	Estimate	95% CI	SE	t	p-value
Constant	0.01050	0.01050 to 0.01050	1.5707E-07	66843.94	<0.0001
Day	1.842E-08	1.822E-08 to 1.862E-08	1.0398E-10	177.15	<0.0001
Day^2	-3.200E-12	-3.236E-12 to -3.164E-12	1.8472E-14	-173.25	<0.0001
Day^3	1.572E-16	1.554E-16 to 1.591E-16	9.2825E-19	169.40	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Fit: Ni

Analyse-it v5.80.2

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:59 by Willy

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.0000014	3	0.0000005	11878.64	<0.0001
Error	0.0000011	26157	0.0000000		
Null model	0.0000025	26160	0.0000000		

H0: $E(Y|X=x) = \mu$

The model is no better than a null model $Y=\mu$.

H1: $E(Y|X=x) = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3$

The model is better than the null model.

Fit: Ni

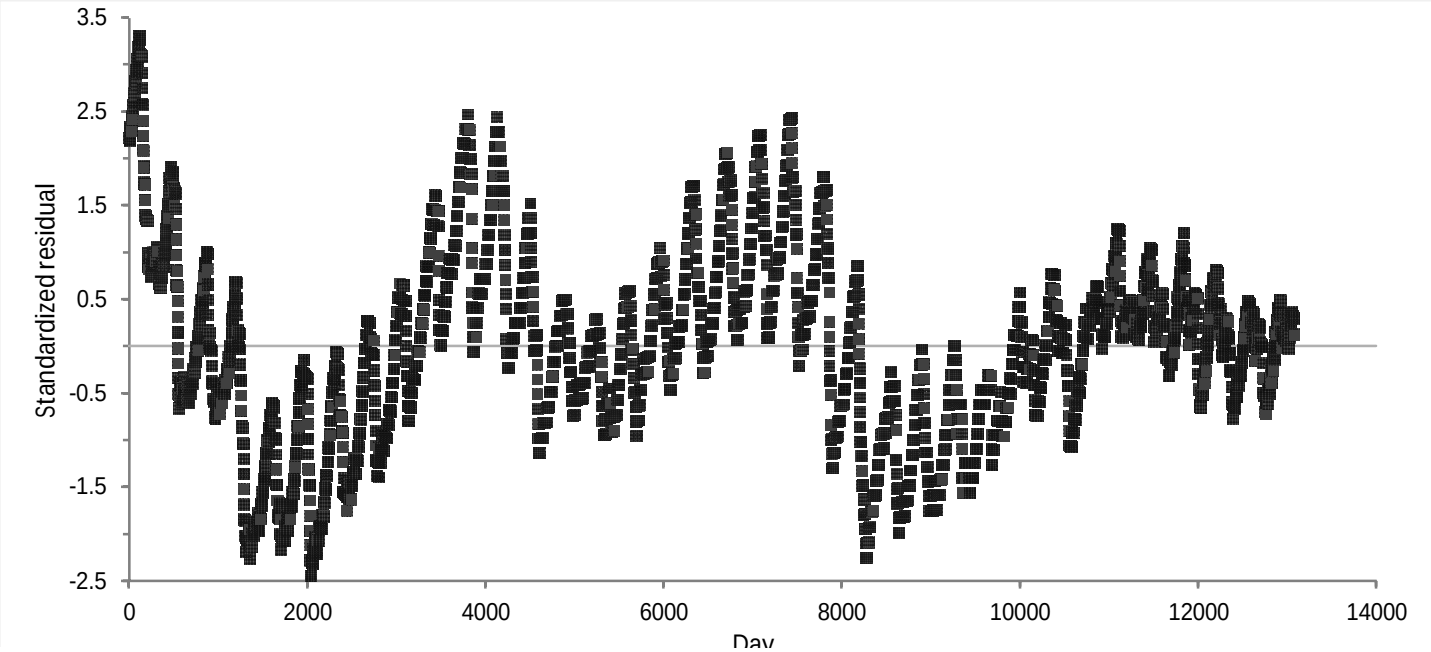
SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:59 by Willy

Analyse-it v5.80.2

Residuals



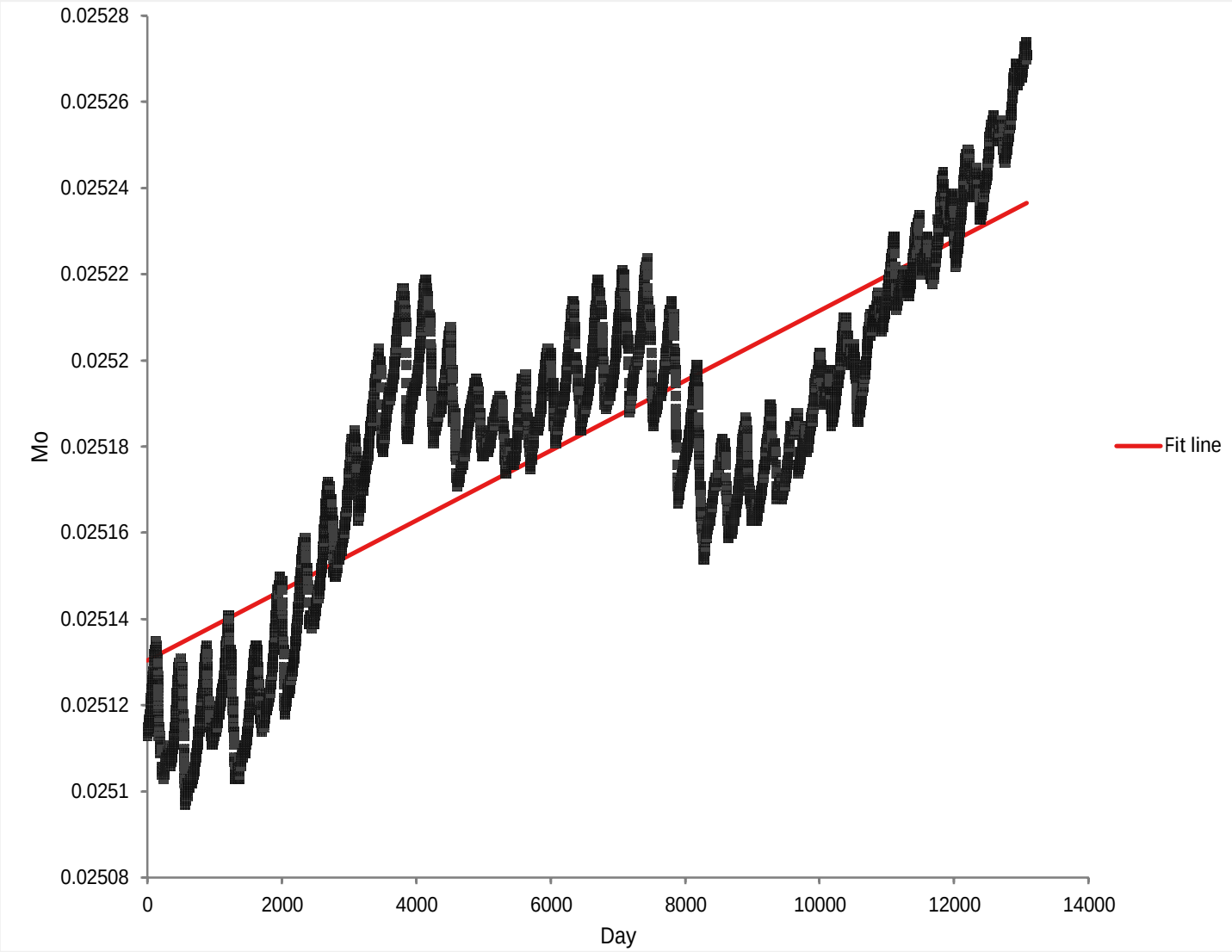
Fit: Mo

Analyse-it v5.80.2

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:58 by Willy



Fit: Mo

Analyse-it v5.80.2

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:58 by Willy

Fit

N	26161
Mean of Y	0.0251834

Equation: Mo = 0.02513 + 8.122e-09 Day

R^2	0.666
R^2 adjusted	0.666
RMSE	0.00002173

Parameter	Estimate	95% CI	SE	t	p-value
Constant	0.02513	0.02513 to 0.02513	2.6872E-07	93517.18	<0.0001
Day	8.122E-09	8.052E-09 to 8.192E-09	3.5582E-11	228.27	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.0000246	1	0.0000246	52105.83	<0.0001
Error	0.0000124	26159	0.0000000		
Null model	0.0000370	26160	0.0000000		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

Fit: Mo

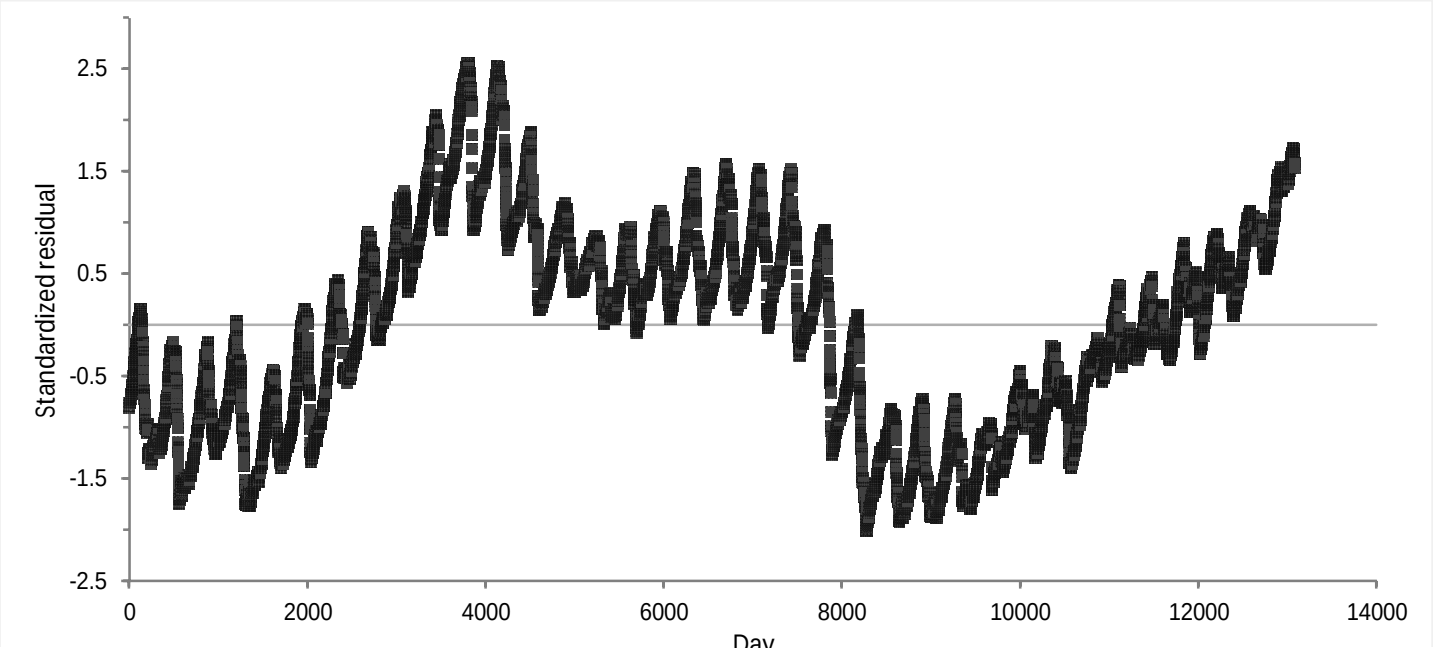
Analyse-it v5.80.2

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:58 by Willy

Residuals



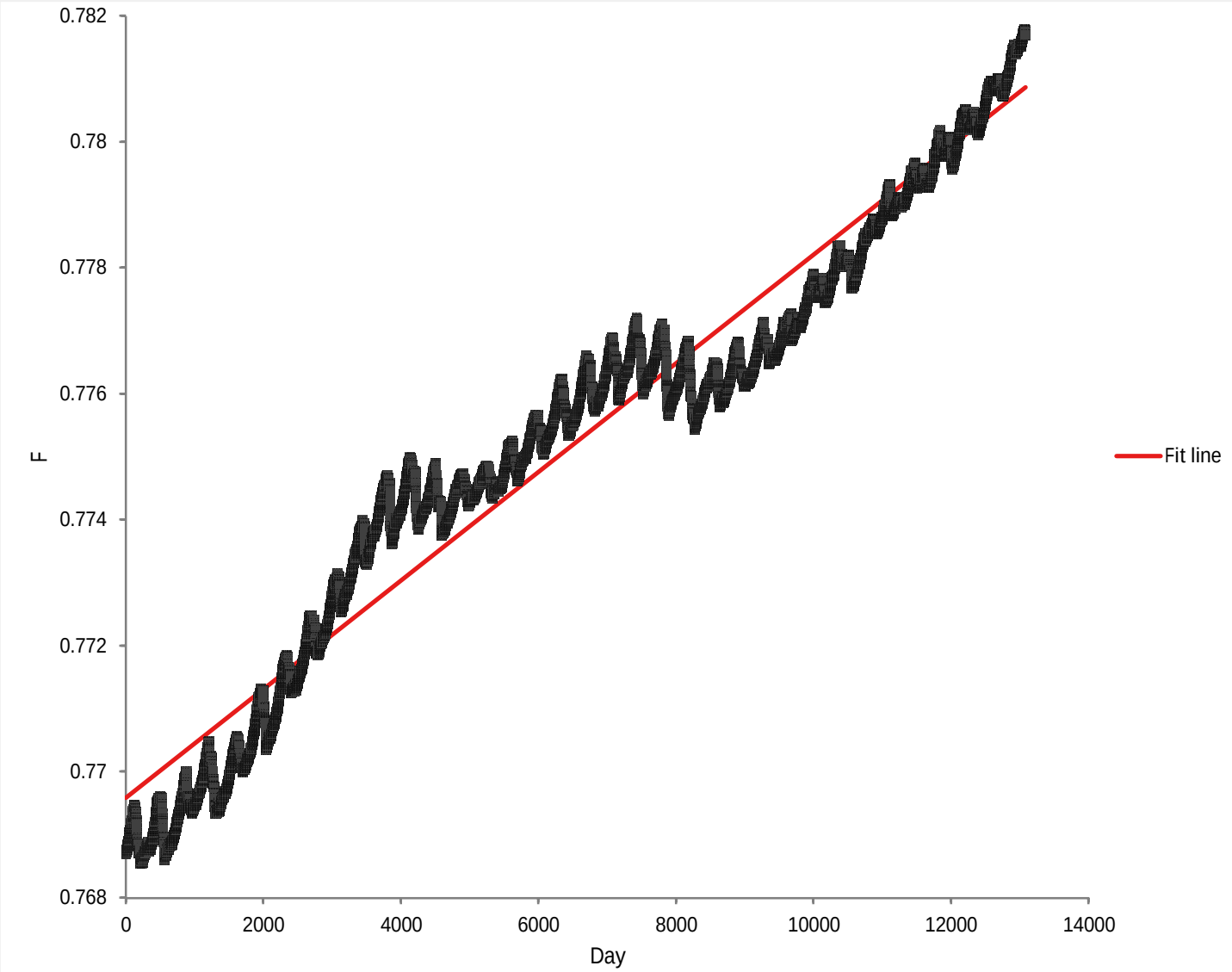
Fit: F

Analyse-it v5.80.2

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:55 by Willy



Fit: F

Analyse-it v5.80.2

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:55 by Willy

Fit

N	26161
Mean of Y	0.775222

Equation	F = 0.7696 + 8.625e-07 Day

R^2	0.951
R^2 adjusted	0.951
RMSE	0.0007411

Parameter	Estimate	95% CI	SE	t	p-value
Constant	0.7696	0.7696 to 0.7696	9.1643E-06	83975.81	<0.0001
Day	8.625E-07	8.602E-07 to 8.649E-07	1.2135E-09	710.82	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.277516	1	0.277516	505265.02	<0.0001
Error	0.014368	26159	0.000001		
Null model	0.291884	26160	0.000011		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

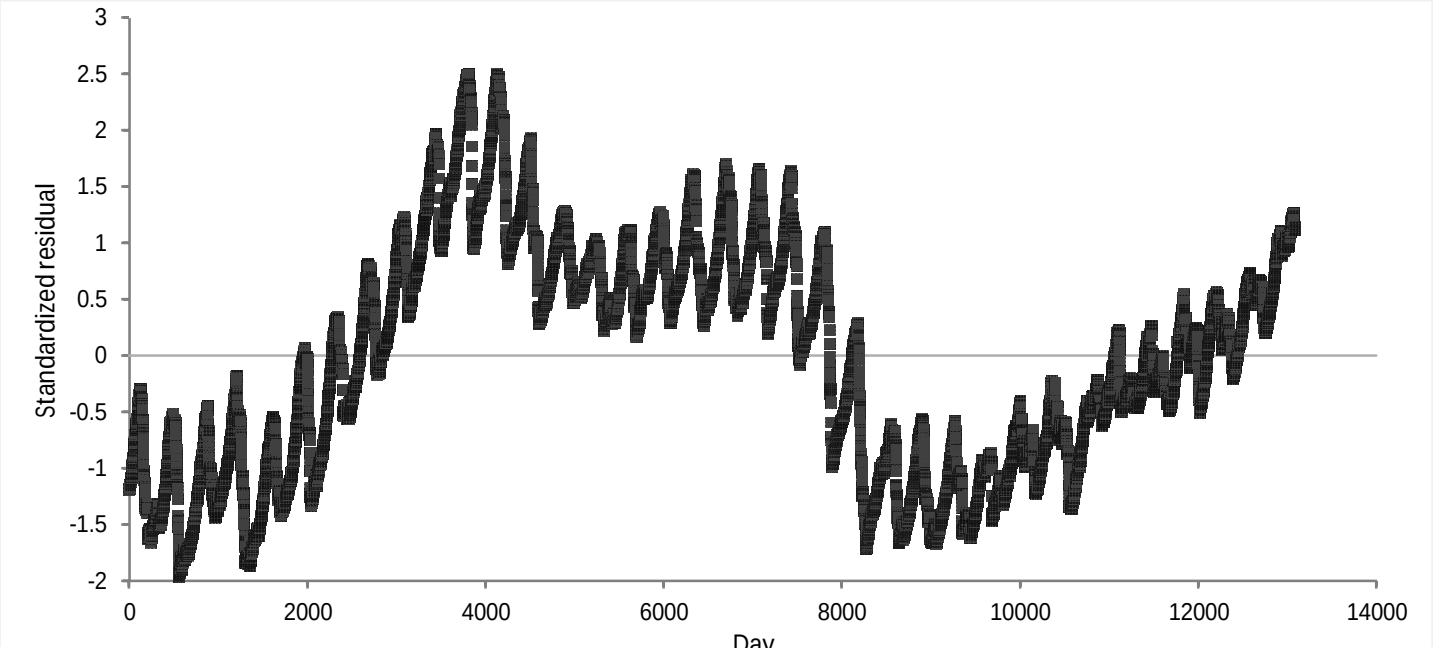
Fit: F

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:55 by Willy

Residuals

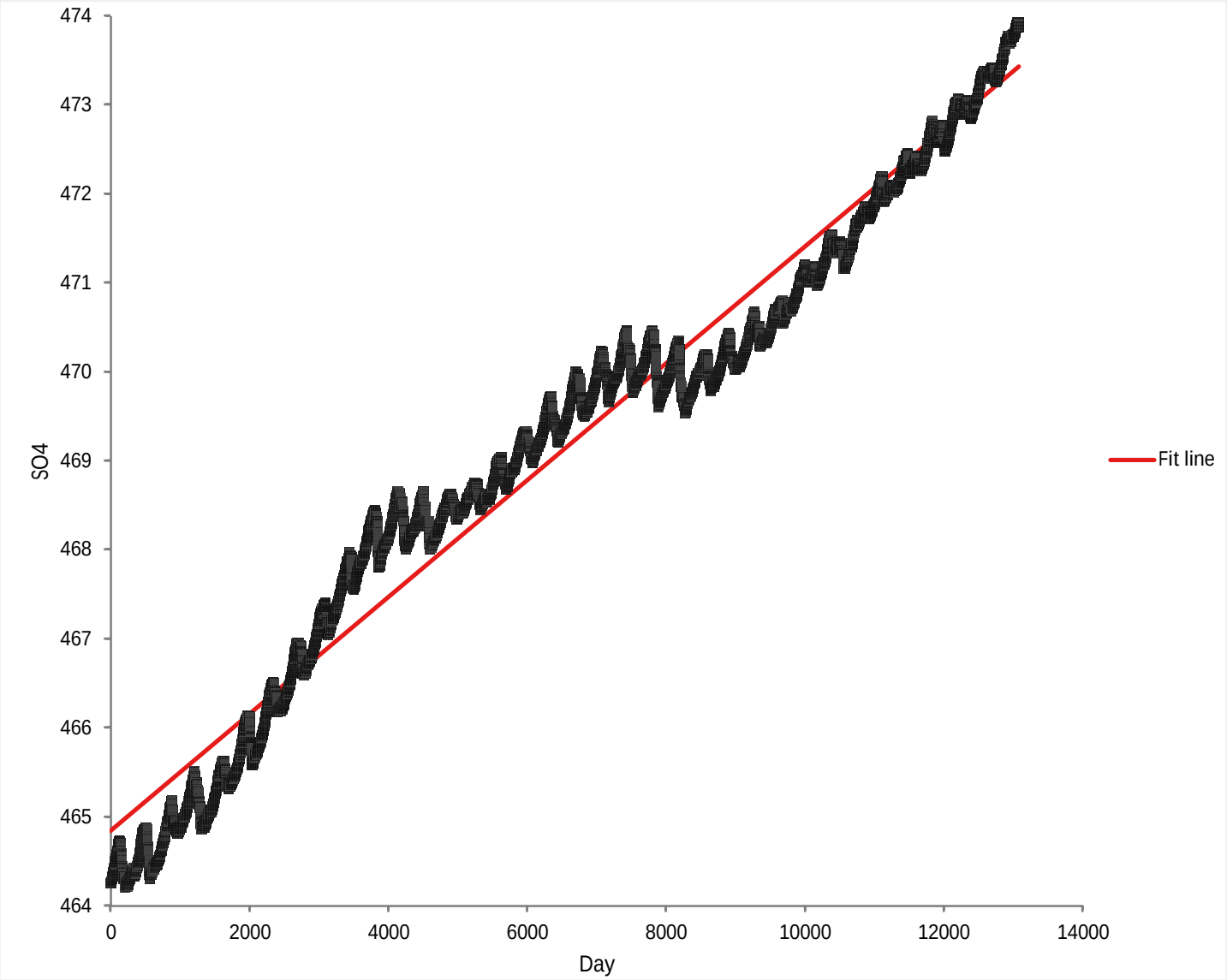


Fit: SO4

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:54 by Willy



Fit: SO4

Analyse-it v5.80.2

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:54 by Willy

Fit

N	26161
Mean of Y	469.131

Equation	SO4 = 464.8 + 0.0006566 Day

R^2	0.968
R^2 adjusted	0.968
RMSE	0.4522

Parameter	Estimate	95% CI	SE	t	p-value
Constant	464.8	464.8 to 464.8	5.5919E-03	83127.09	<0.0001
Day	6.566E-04	6.552E-04 to 6.581E-04	7.4043E-07	886.79	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	160815.720	1	160815.720	786401.13	<0.0001
Error	5349.405	26159	0.204		
Null model	166165.125	26160	6.352		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

Fit: SO4

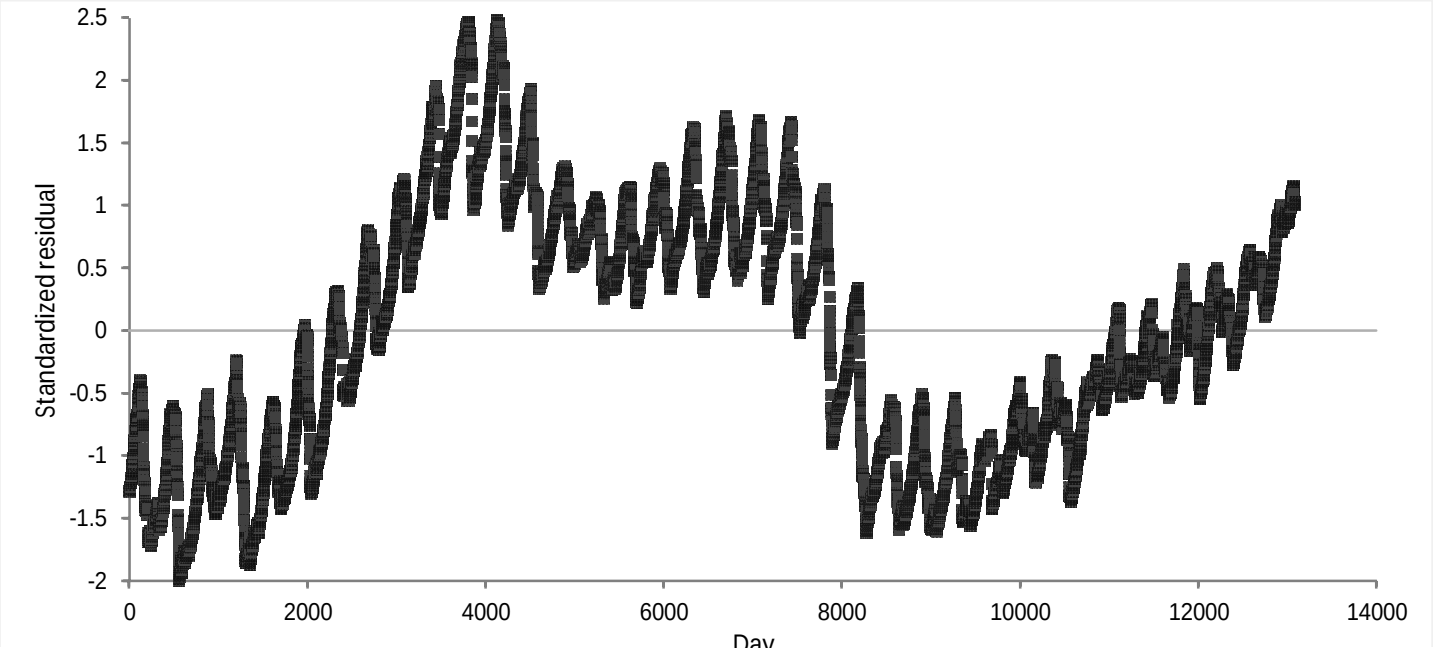
Analyse-it v5.80.2

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:54 by Willy

Residuals

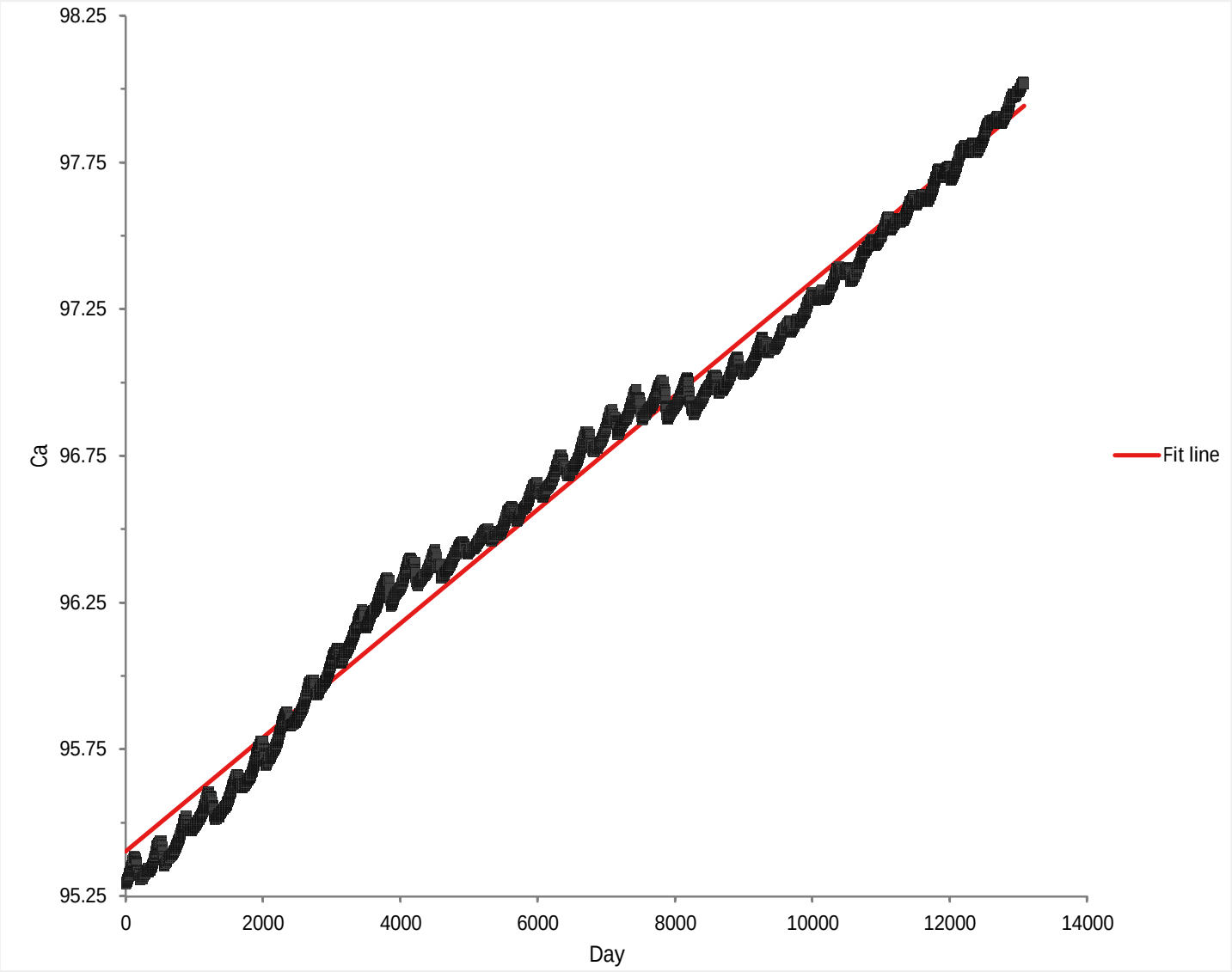


Fit: Ca

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:54 by Willy



Fit: Ca

Analyse-it v5.80.2

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:54 by Willy

Fit

N	26161
Mean of Y	96.6726

Equation: Ca = 95.4 + 0.0001942 Day

R^2	0.988
R^2 adjusted	0.988
RMSE	0.08046

Parameter	Estimate	95% CI	SE	t	p-value
Constant	95.40	95.40 to 95.40	9.9495E-04	95886.46	<0.0001
Day	1.942E-04	1.939E-04 to 1.944E-04	1.3174E-07	1473.75	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	14061.3038	1	14061.3038	2171947.25	<0.0001
Error	169.3548	26159	0.0065		
Null model	14230.6586	26160	0.5440		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

Fit: Ca

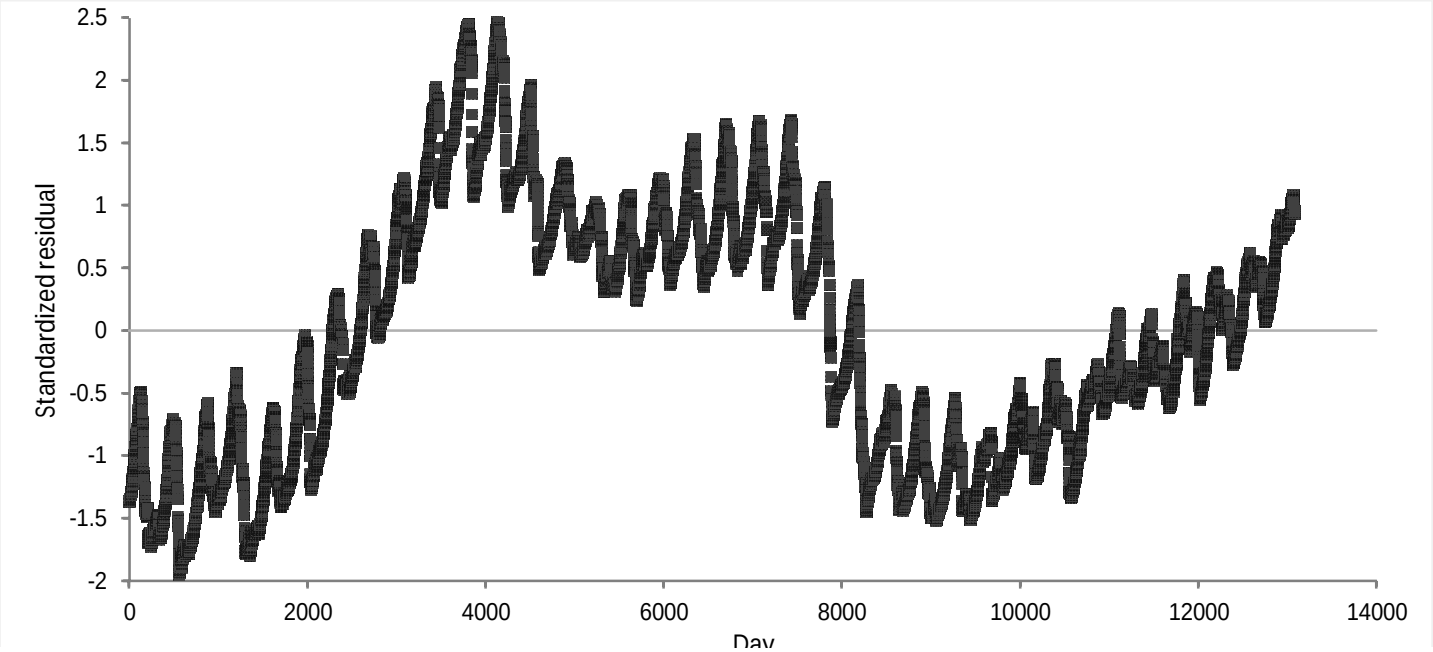
Analyse-it v5.80.2

SP Curve Fitting (3) A27:F26188

Filter: No filter

Last updated 29 May 2024 at 18:54 by Willy

Residuals

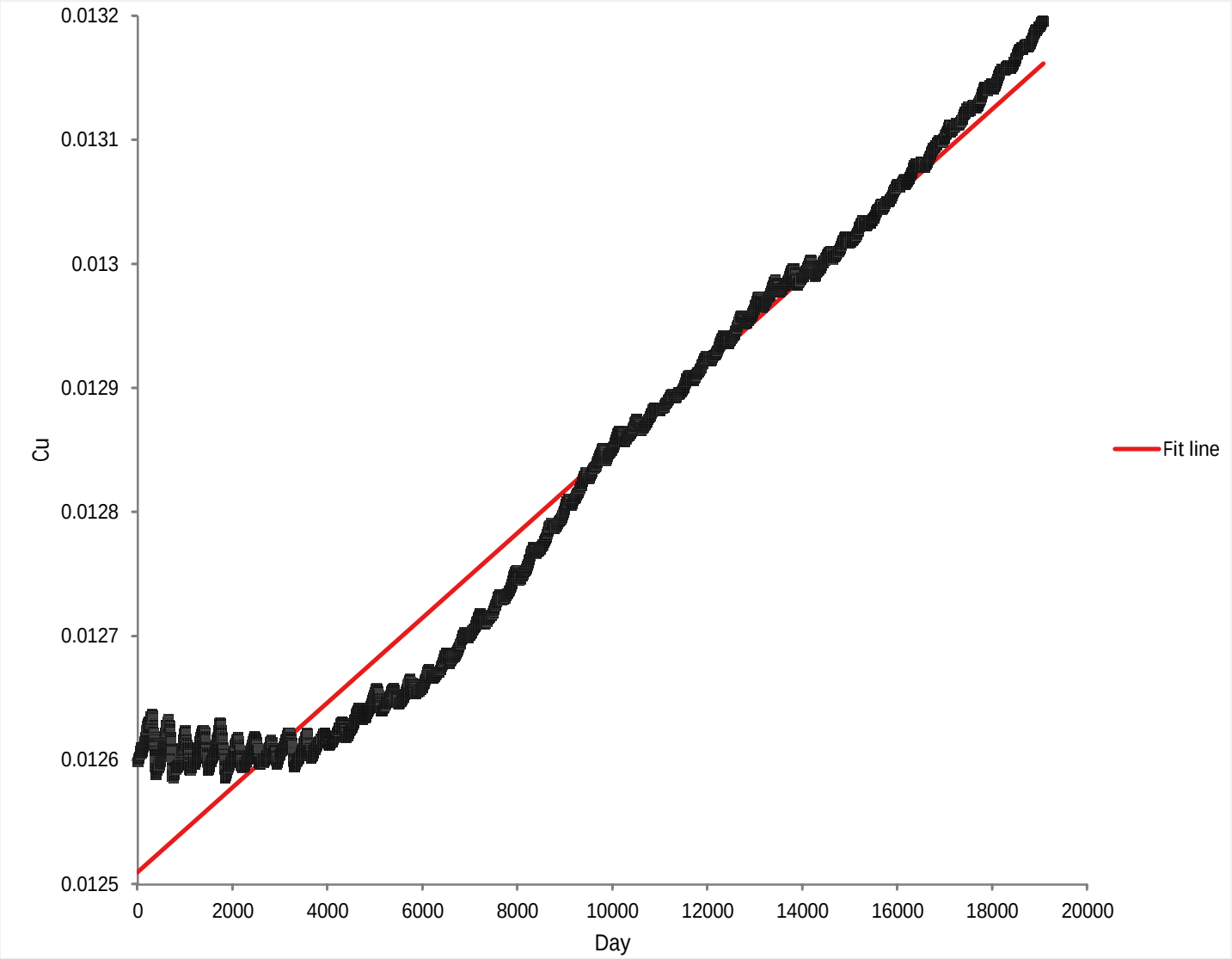


Fit: Cu

SP Curve Fitting (2) A27:I38188

Filter: No filter

Last updated 29 May 2024 at 18:49 by Willy



Fit: Cu

Analyse-it v5.80.2

SP Curve Fitting (2) A27:I38188

Filter: No filter

Last updated 29 May 2024 at 18:49 by Willy

Fit

N	38161
Mean of Y	0.0128353

Equation: Cu = 0.01251 + 3.417e-08 Day

R^2	0.971
R^2 adjusted	0.971
RMSE	0.00003244

Parameter	Estimate	95% CI	SE	t	p-value
Constant	0.01251	0.01251 to 0.01251	3.3218E-07	37658.39	<0.0001
Day	3.417E-08	3.412E-08 to 3.423E-08	3.0153E-11	1133.35	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.0013521	1	0.0013521	1284492.93	<0.0001
Error	0.0000402	38159	0.0000000		
Null model	0.0013923	38160	0.0000000		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

Fit: Cu

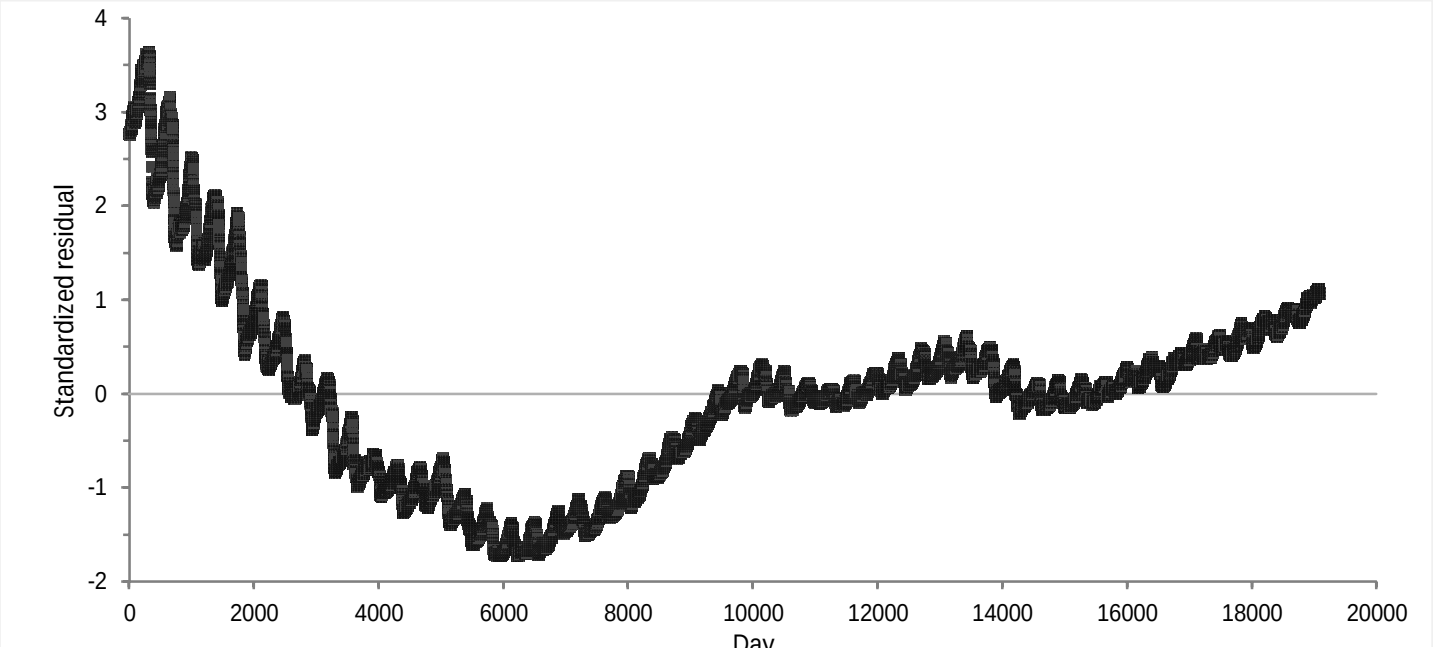
Analyse-it v5.80.2

SP Curve Fitting (2) A27:I38188

Filter: No filter

Last updated 29 May 2024 at 18:49 by Willy

Residuals

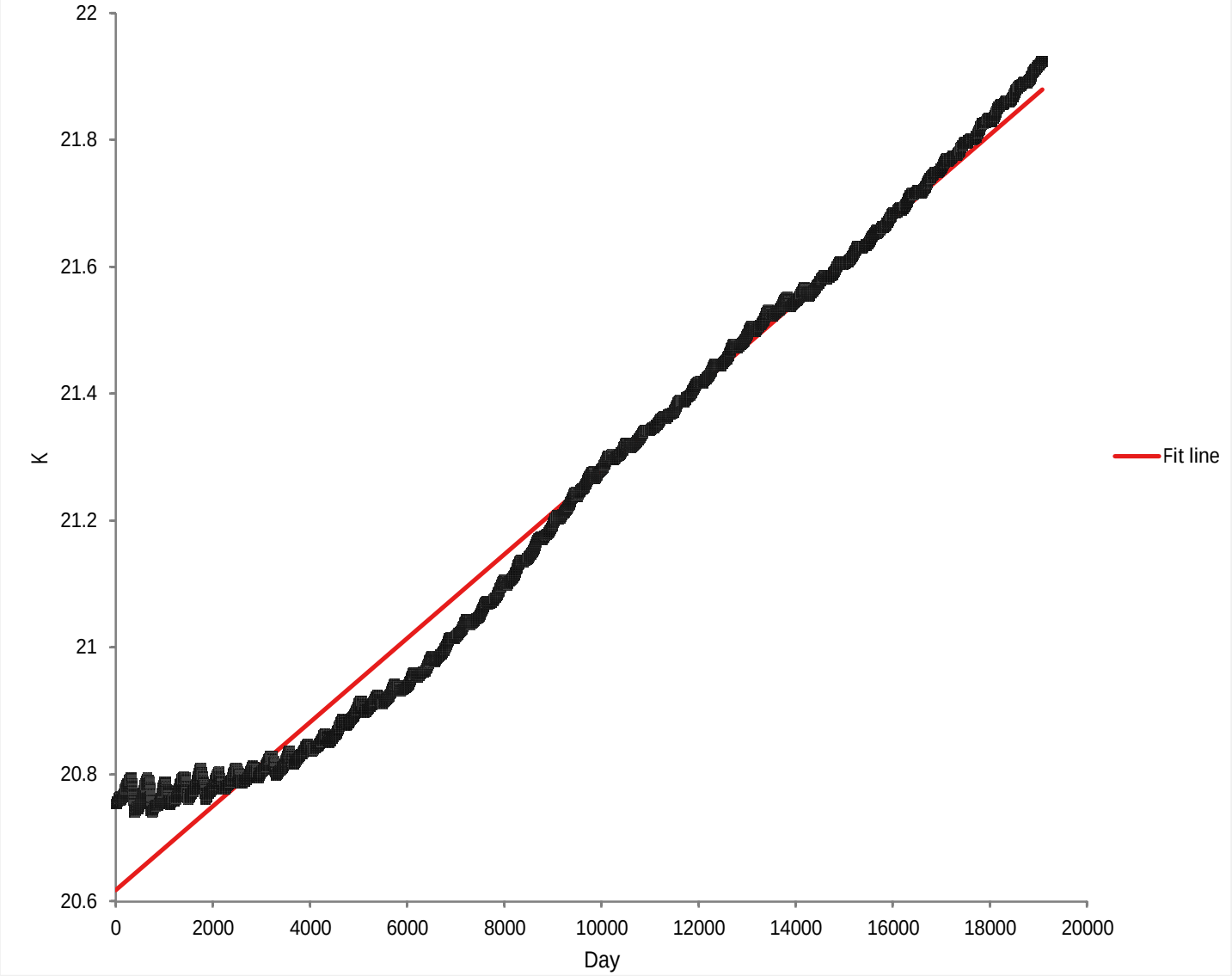


Fit: K

SP Curve Fitting (2) A27:I38188

Filter: No filter

Last updated 29 May 2024 at 18:47 by Willy



Fit: K

Analyse-it v5.80.2

SP Curve Fitting (2) A27:I38188

Filter: No filter

Last updated 29 May 2024 at 18:47 by Willy

Fit

N	38161
Mean of Y	21.2486

Equation	K = 20.62 + 6.616e-05 Day

R^2	0.986
R^2 adjusted	0.986
RMSE	0.04378

Parameter	Estimate	95% CI	SE	t	p-value
Constant	20.62	20.62 to 20.62	4.4821E-04	45999.17	<0.0001
Day	6.616E-05	6.608E-05 to 6.624E-05	4.0686E-08	1626.12	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	5067.7342	1	5067.7342	2644257.00	<0.0001
Error	73.1319	38159	0.0019		
Null model	5140.8662	38160	0.1347		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

Fit: K

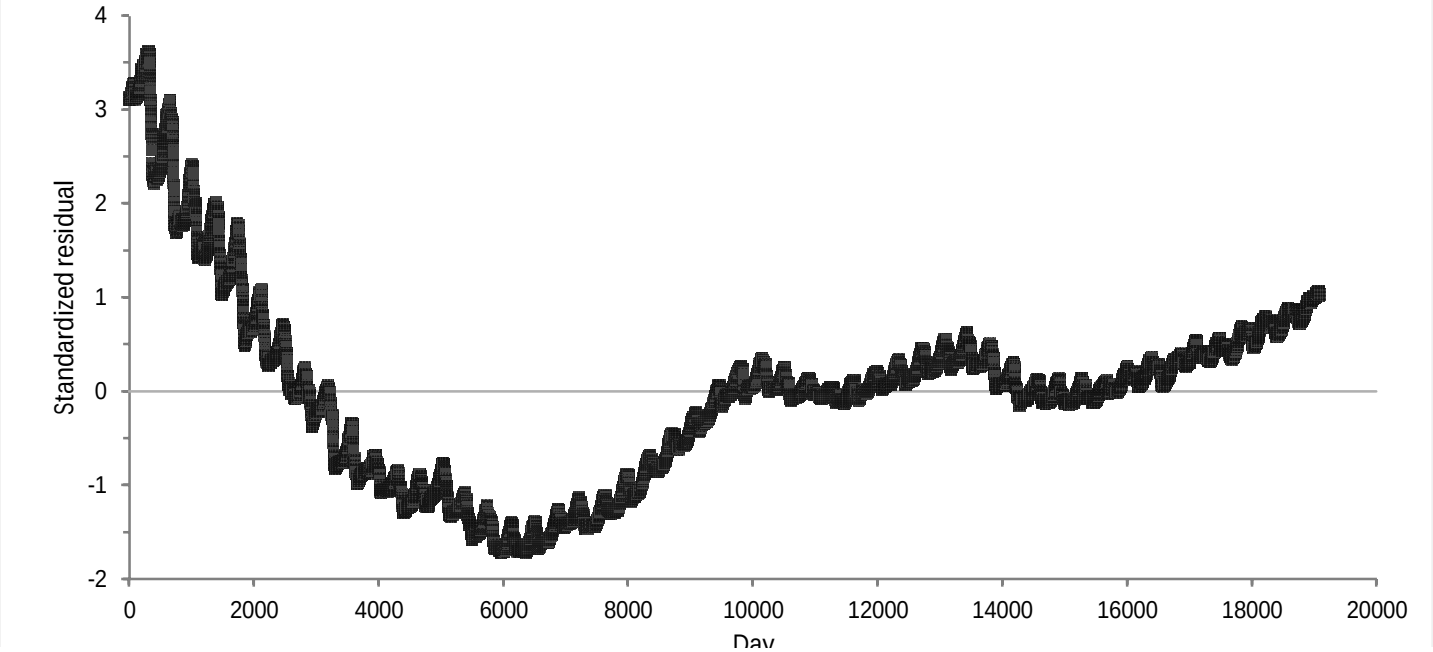
SP Curve Fitting (2) A27:I38188

Filter: No filter

Last updated 29 May 2024 at 18:47 by Willy

Analyse-it v5.80.2

Residuals

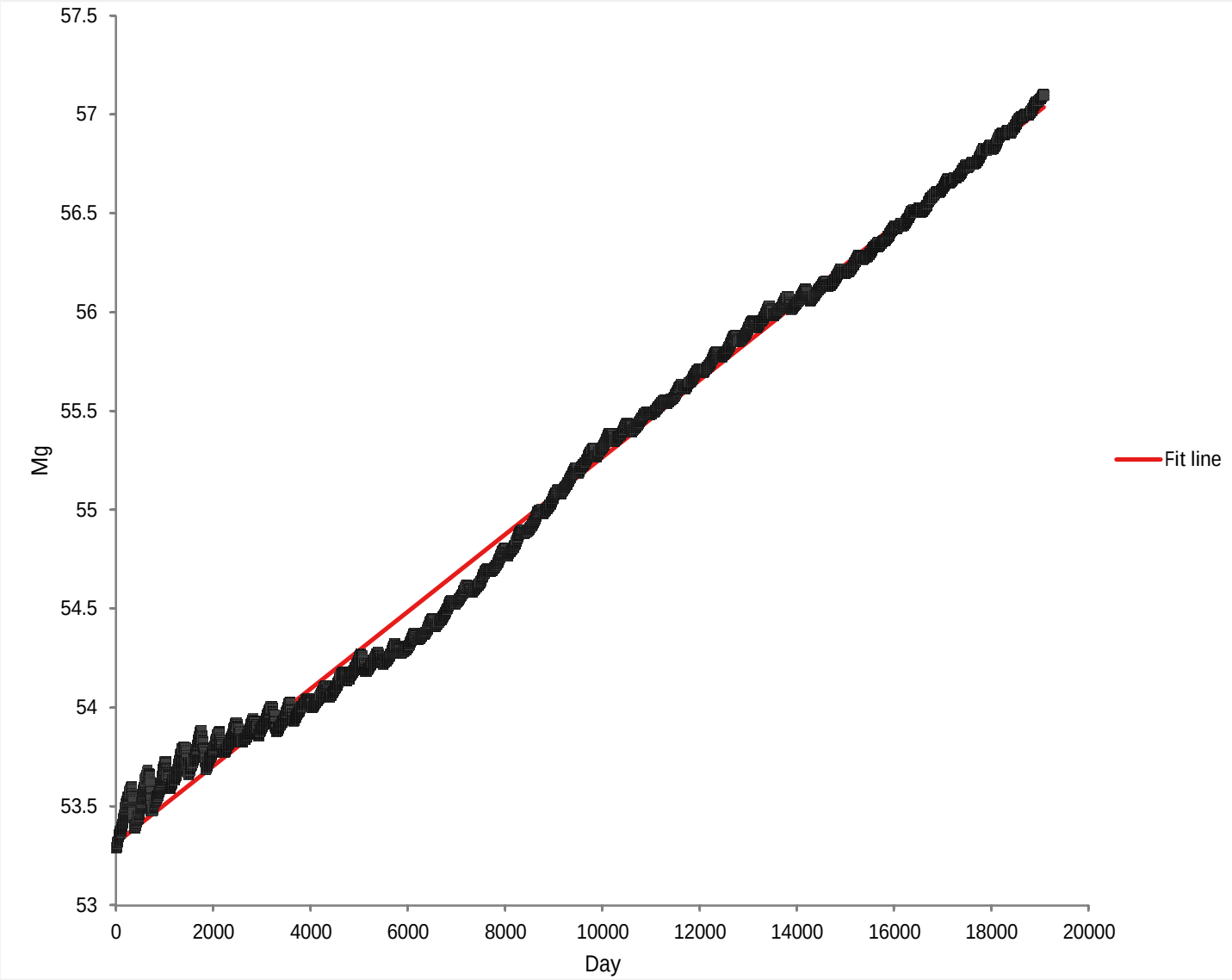


Fit: Mg

SP Curve Fitting (2) A27:I38188

Filter: No filter

Last updated 29 May 2024 at 18:45 by Willy



Fit: Mg

Analyse-it v5.80.2

SP Curve Fitting (2) A27:I38188

Filter: No filter

Last updated 29 May 2024 at 18:45 by Willy

Fit

N	38161
Mean of Y	55.1749

Equation	Mg = 53.31 + 0.0001951 Day

R^2	0.994
R^2 adjusted	0.994
RMSE	0.08226

Parameter	Estimate	95% CI	SE	t	p-value
Constant	53.31	53.31 to 53.32	8.4225E-04	63299.25	<0.0001
Day	1.951E-04	1.949E-04 to 1.952E-04	7.6454E-08	2551.85	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	44068.6653	1	44068.6653	6511914.96	<0.0001
Error	258.2368	38159	0.0068		
Null model	44326.9021	38160	1.1616		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

Fit: Mg

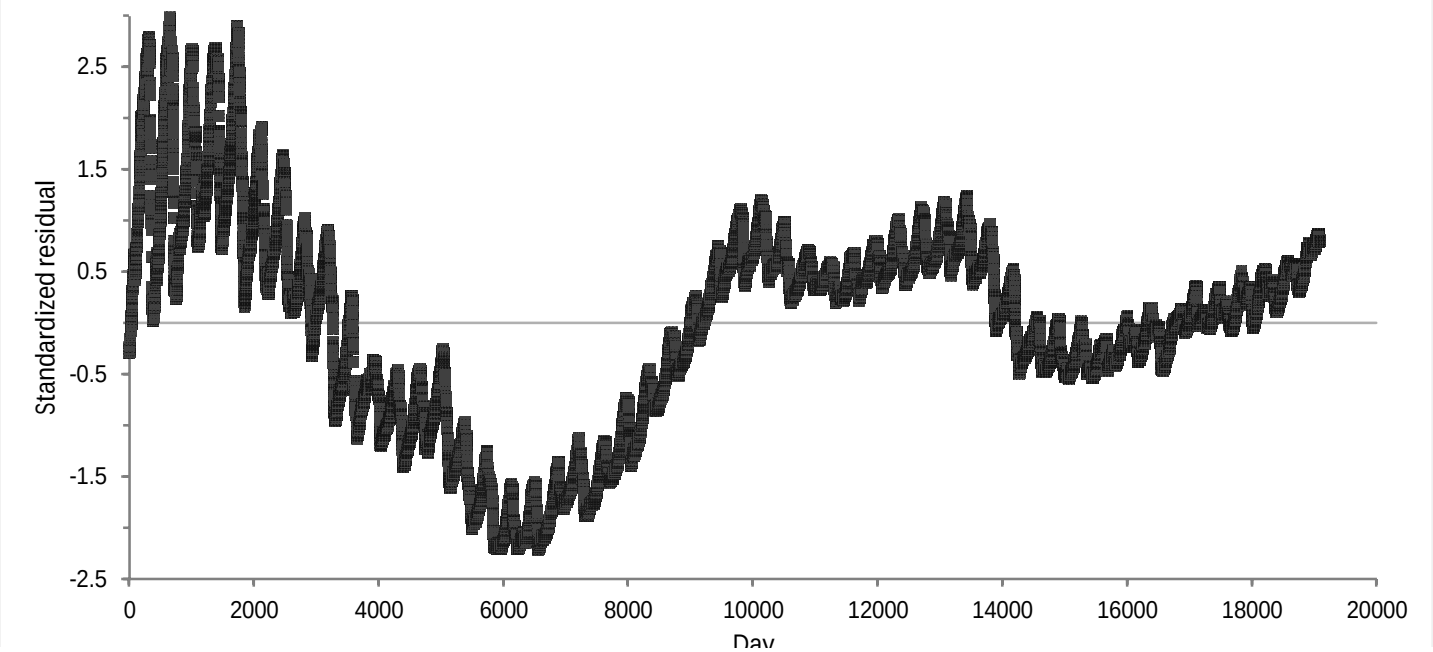
Analyse-it v5.80.2

SP Curve Fitting (2) A27:I38188

Filter: No filter

Last updated 29 May 2024 at 18:45 by Willy

Residuals

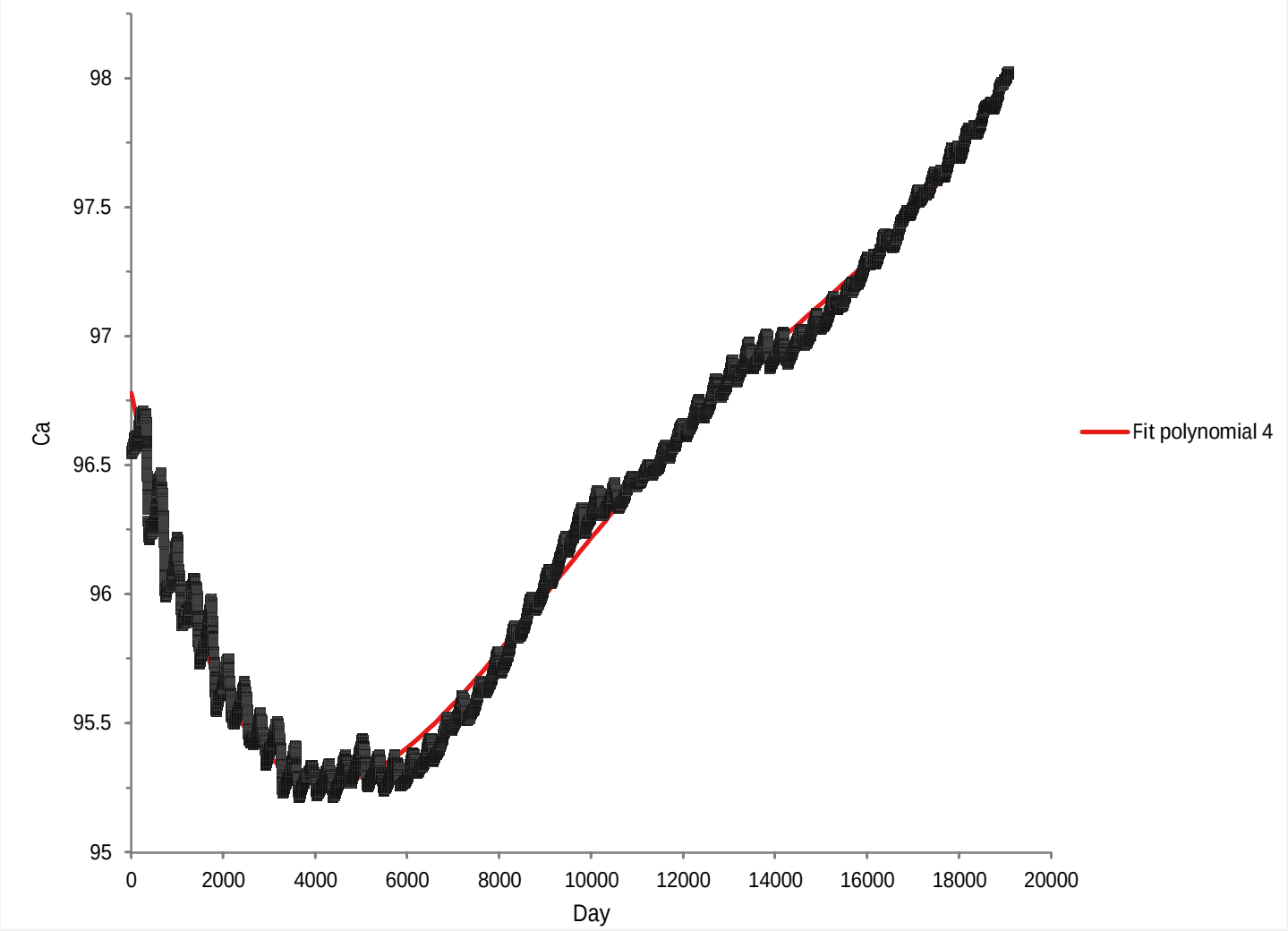


Fit: Ca

SP Curve Fitting (2) A27:I38188

Filter: No filter

Last updated 29 May 2024 at 18:42 by Willy



Fit: Ca

Analyse-it v5.80.2

SP Curve Fitting (2) A27:I38188

Filter: No filter

Last updated 29 May 2024 at 18:42 by Willy

Fit

N	38161
Mean of Y	96.3410

Equation: $Ca = 96.78 - 0.0008399\ Day + 1.481e\text{-}07\ Day^2 - 8.845e\text{-}12\ Day^3 + 1.871e\text{-}16\ Day^4$

R^2	0.993
R^2 adjusted	0.993
RMSE	0.07009

Parameter	Estimate	95% CI	SE	t	p-value
Constant	96.78	96.78 to 96.79	1.7943E-03	53937.99	<0.0001
Day	-8.399E-04	-8.424E-04 to -8.373E-04	1.3030E-06	-644.59	<0.0001
Day^2	1.481E-07	1.475E-07 to 1.486E-07	2.7769E-10	533.29	<0.0001
Day^3	-8.845E-12	-8.887E-12 to -8.802E-12	2.1866E-14	-404.49	<0.0001
Day^4	1.871E-16	1.860E-16 to 1.882E-16	5.6849E-19	329.15	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Fit: Ca

Analyse-it v5.80.2

SP Curve Fitting (2) A27:I38188

Filter: No filter

Last updated 29 May 2024 at 18:42 by Willy

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	25176.4113	4	6294.1028	1281134.01	<0.0001
Error	187.4572	38156	0.0049		
Null model	25363.8685	38160	0.6647		

H0: $E(Y|X=x) = \mu$

The model is no better than a null model $Y=\mu$.

H1: $E(Y|X=x) = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 + \beta_4 x^4$

The model is better than the null model.

Fit: Ca

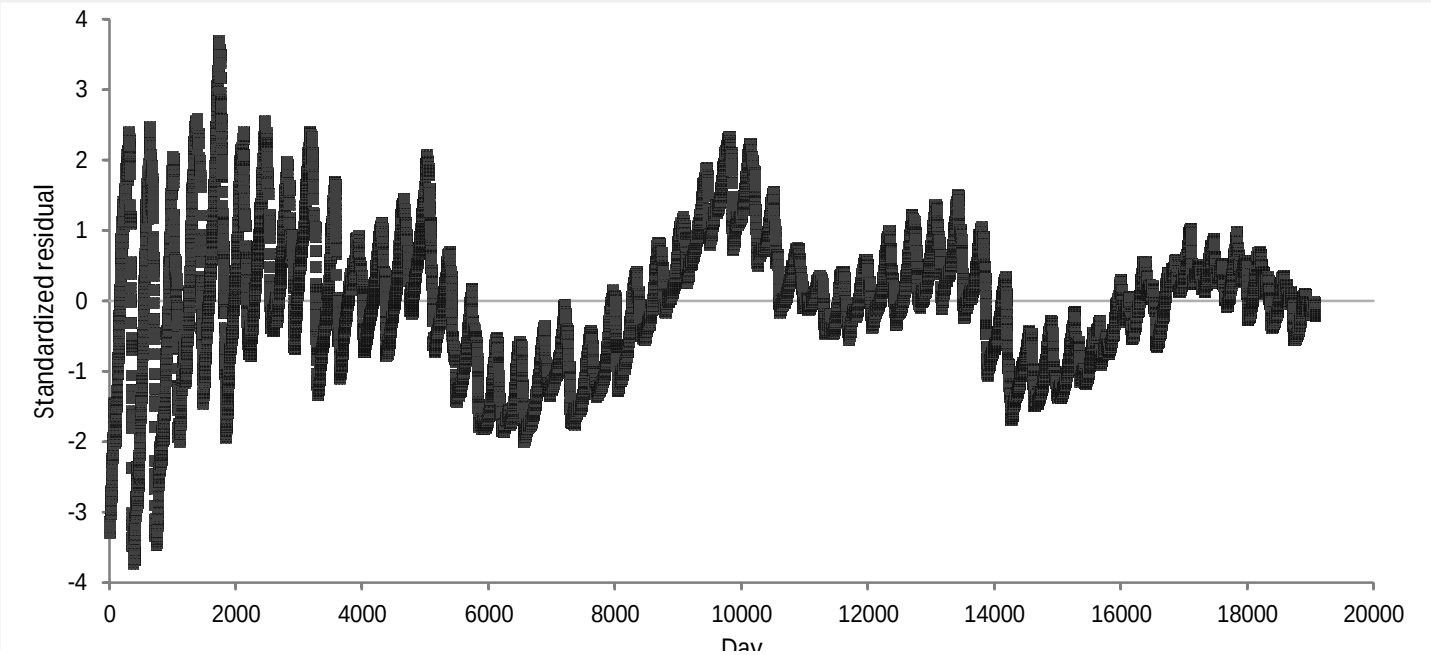
Analyse-it v5.80.2

SP Curve Fitting (2) A27:I38188

Filter: No filter

Last updated 29 May 2024 at 18:42 by Willy

Residuals



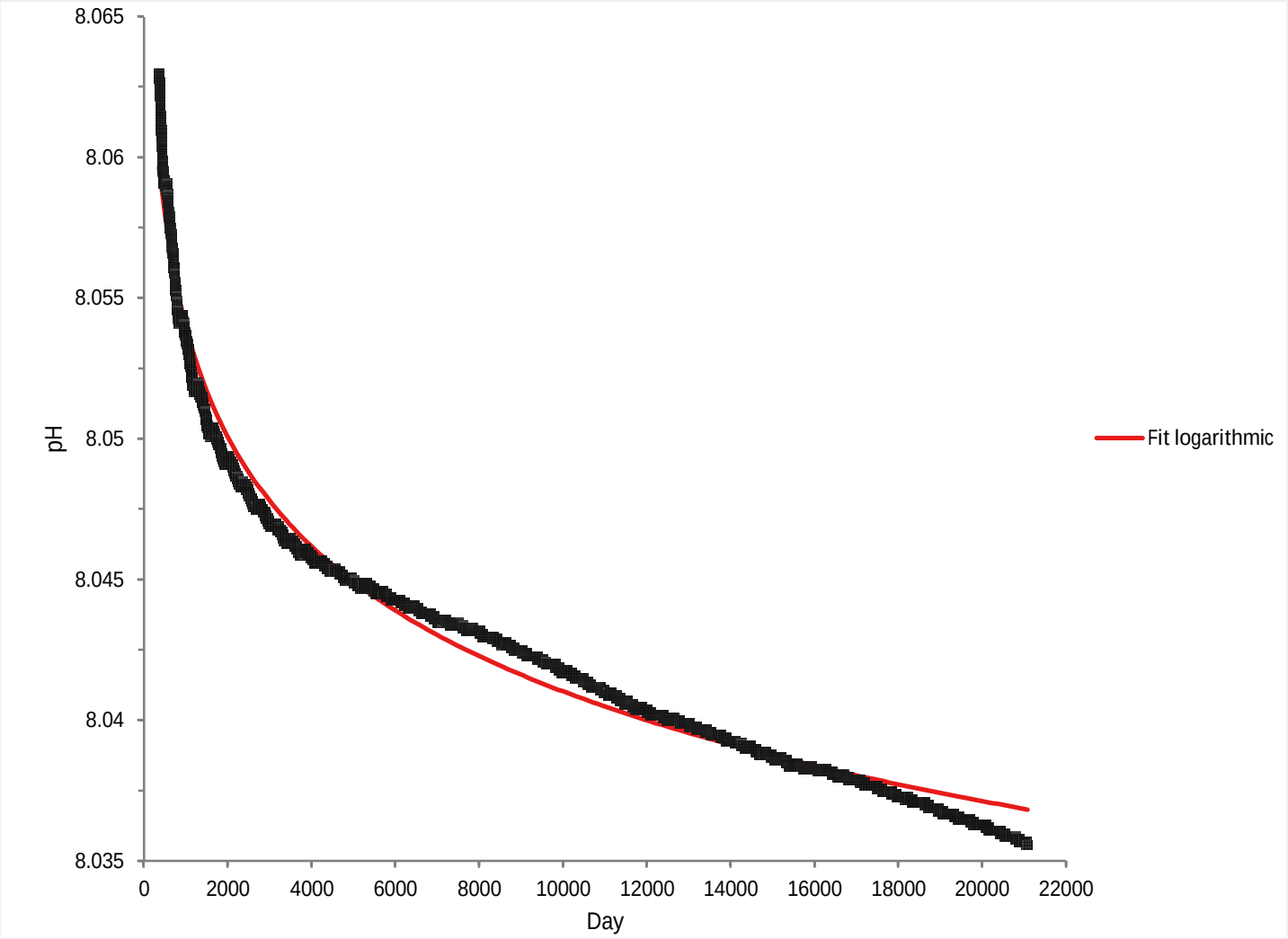
Fit: pH

Analyse-it v5.80.2

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:28 by Willy



Fit: pH

Analyse-it v5.80.2

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:28 by Willy

Fit

N	41431
Mean of Y	8.04206

Equation	pH = 8.093 - 0.005621 ln Day

R^2	0.983
R^2 adjusted	0.983
RMSE	0.000613

Parameter	Estimate	95% CI	SE	t	p-value
Constant	8.093	8.093 to 8.093	3.2539E-05	248710.81	<0.0001
ln Day	-0.005621	-0.005628 to -0.005614	3.5889E-06	-1566.11	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.92260	1	0.92260	2452695.47	<0.0001
Error	0.01558	41429	0.00000		
Null model	0.93818	41430	0.00002		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta \text{Log}(x)$
The model is better than the null model.

Fit: pH

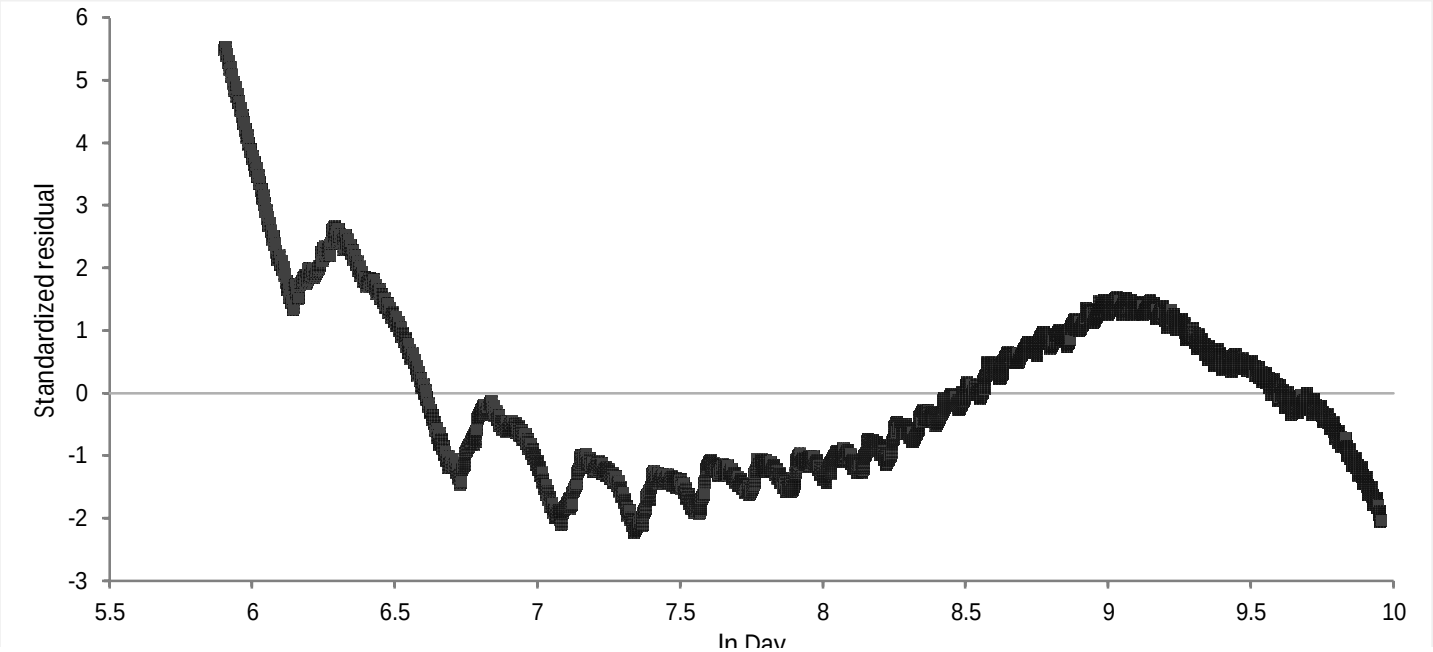
SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:28 by Willy

Analyse-it v5.80.2

Residuals

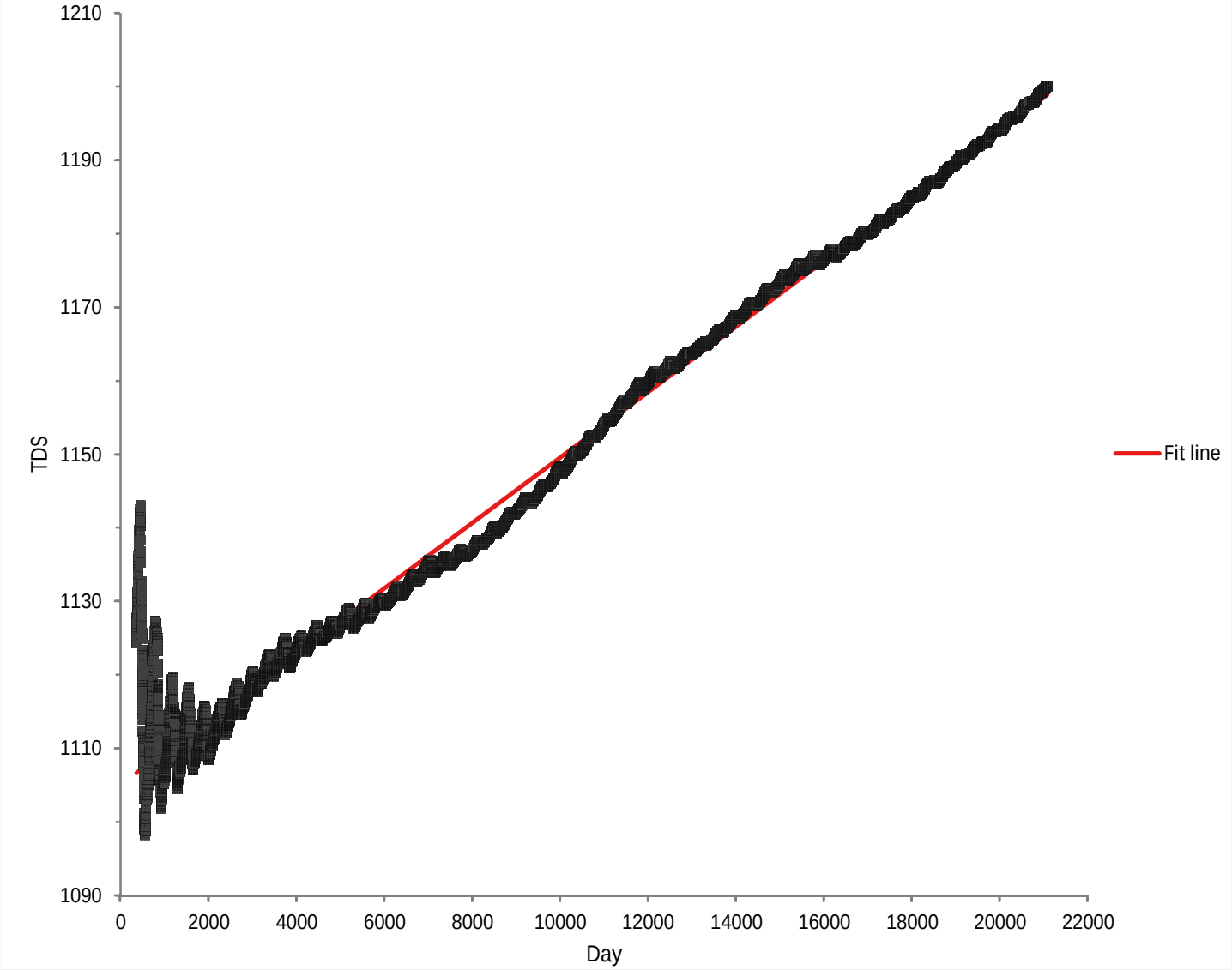


Fit: TDS

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:23 by Willy



Fit: TDS

Analyse-it v5.80.2

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:23 by Willy

Fit

N	41431
Mean of Y	1152.77

Equation	TDS = 1105 + 0.00445 Day

R^2	0.986
R^2 adjusted	0.986
RMSE	3.192

Parameter	Estimate	95% CI	SE	t	p-value
Constant	1105	1105 to 1105	0.032196	34322.27	<0.0001
Day	0.004450	0.004445 to 0.004455	2.6223E-06	1696.86	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	29336184.99	1	29336184.99	2879337.25	<0.0001
Error	422100.19	41429	10.19		
Null model	29758285.18	41430	718.28		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

Fit: TDS

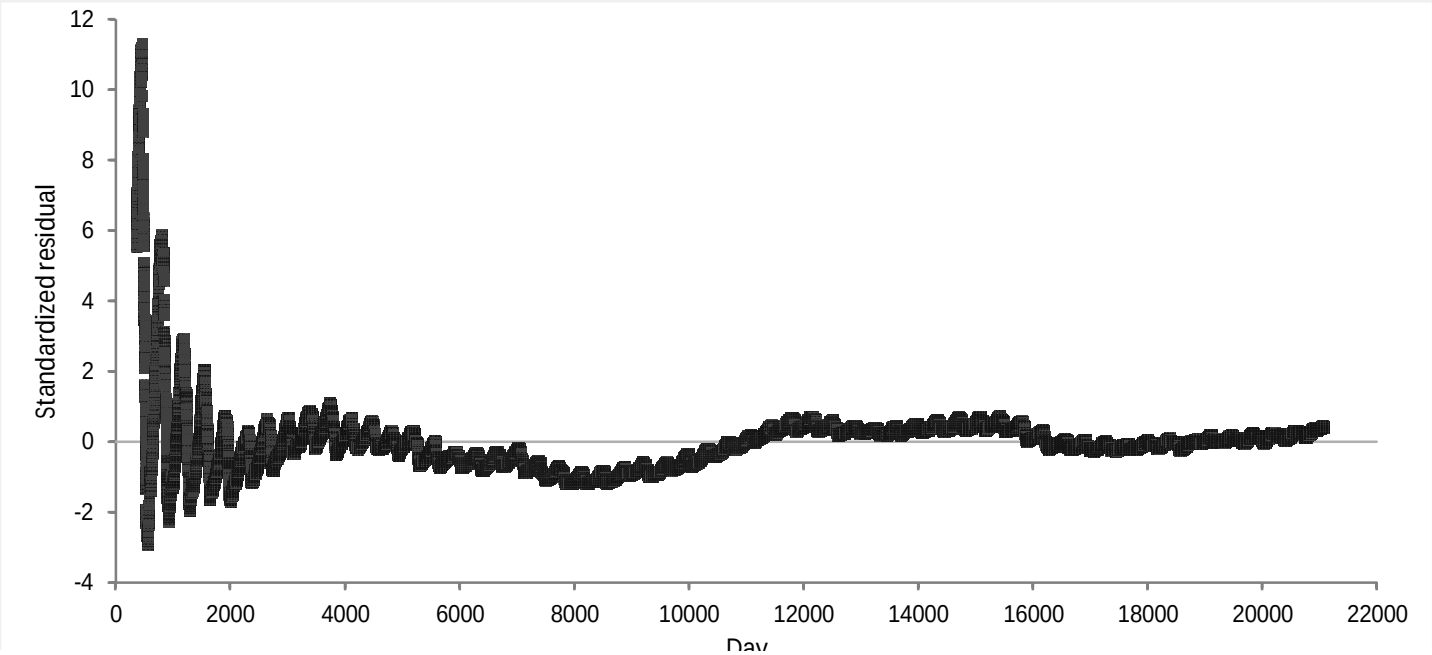
SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:23 by Willy

Analyse-it v5.80.2

Residuals



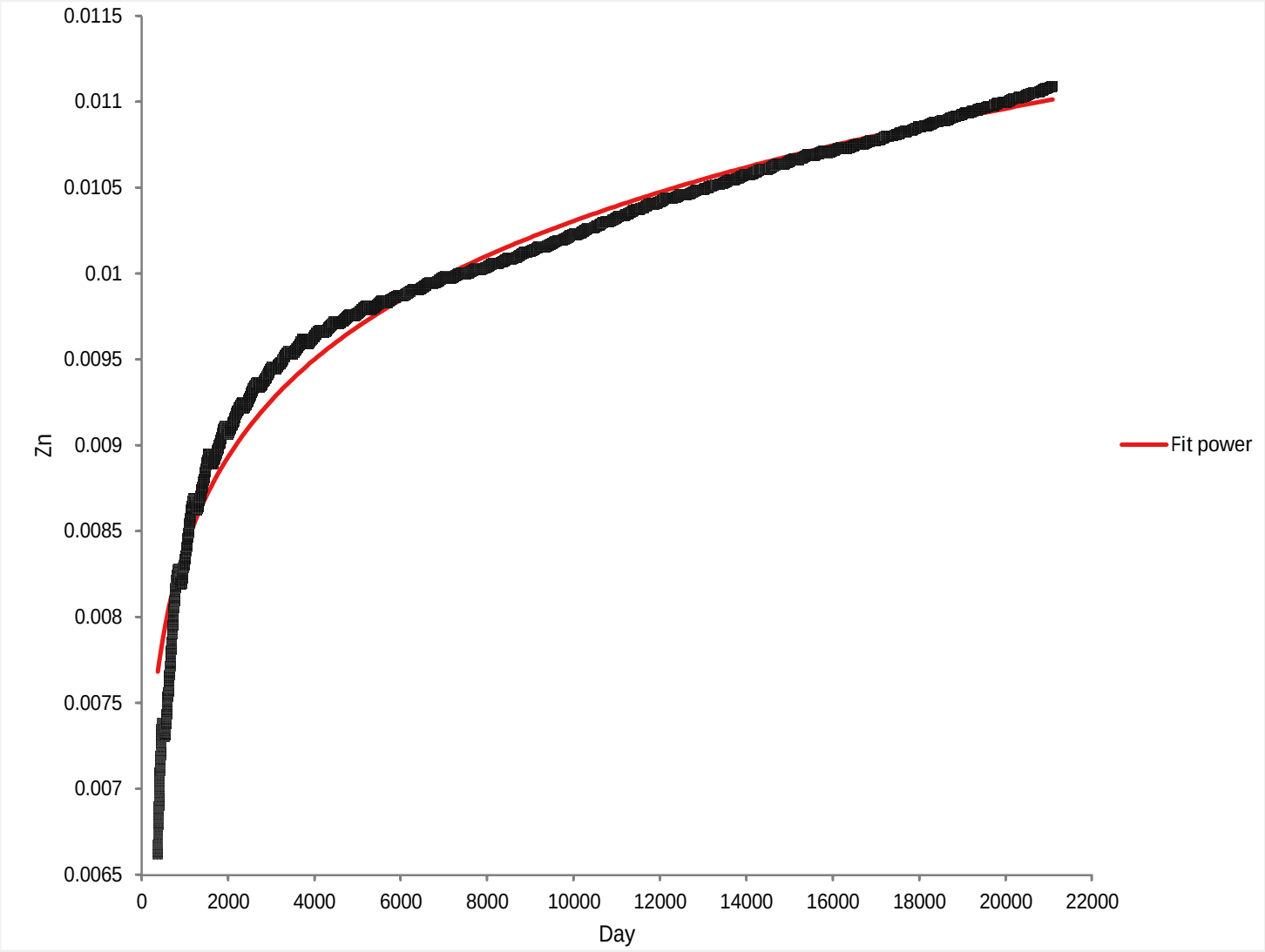
Fit: Zn

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:21 by Willy

Analyse-it v5.80.2



Fit: Zn

Analyse-it v5.80.2

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:21 by Willy

Fit

N	41431
Mean of Y	-4.59112892

Equation $Zn = 0.004548 * Day^{0.08883}$

R^2	0.970
R^2 adjusted	0.970
RMSE	0.013046707

Parameter	Estimate	95% CI	SE	t	p-value
Constant	-5.393	-5.394 to -5.392	6.9218E-04	-7791.38	<0.0001
ln Day	0.08883	0.08868 to 0.08898	7.6344E-05	1163.55	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	###########	1	230.44751674	1353849.02	<0.0001
Error	7.05190165	41429	0.00017022		
Null model	###########	41430	0.00573255		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: Zn

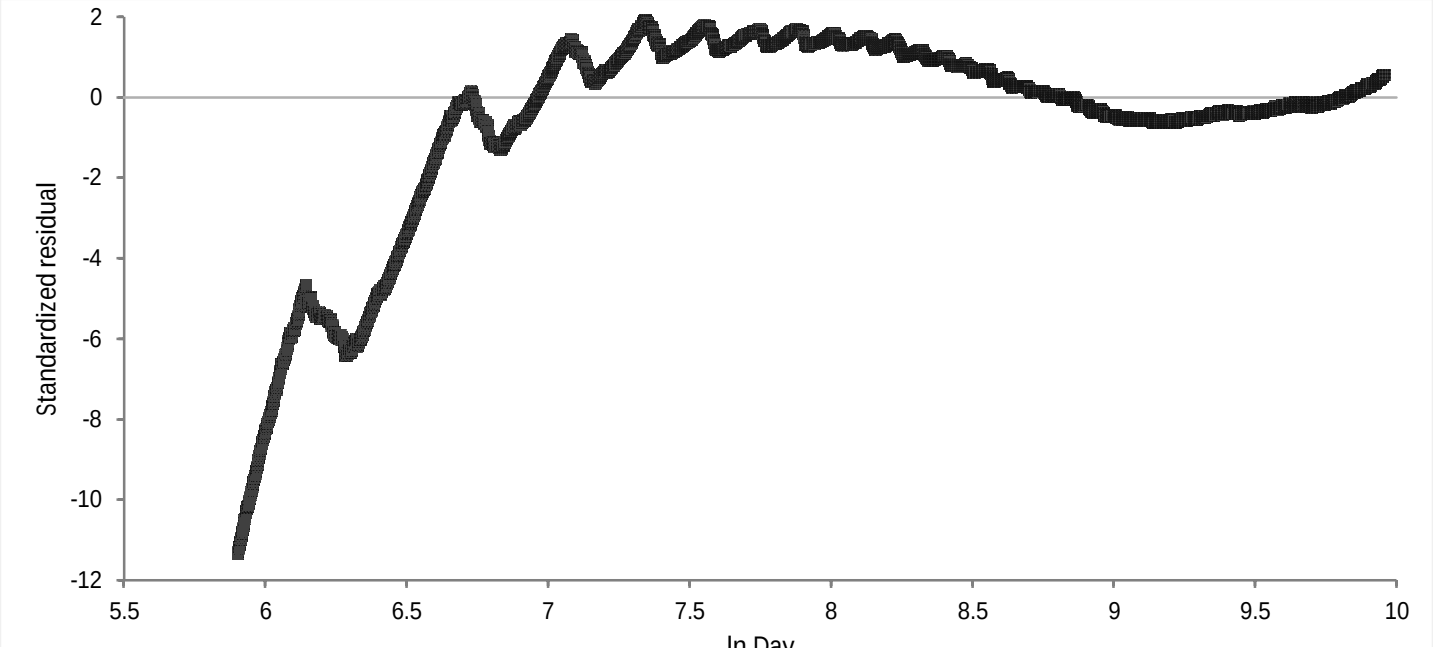
Analyse-it v5.80.2

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:21 by Willy

Residuals



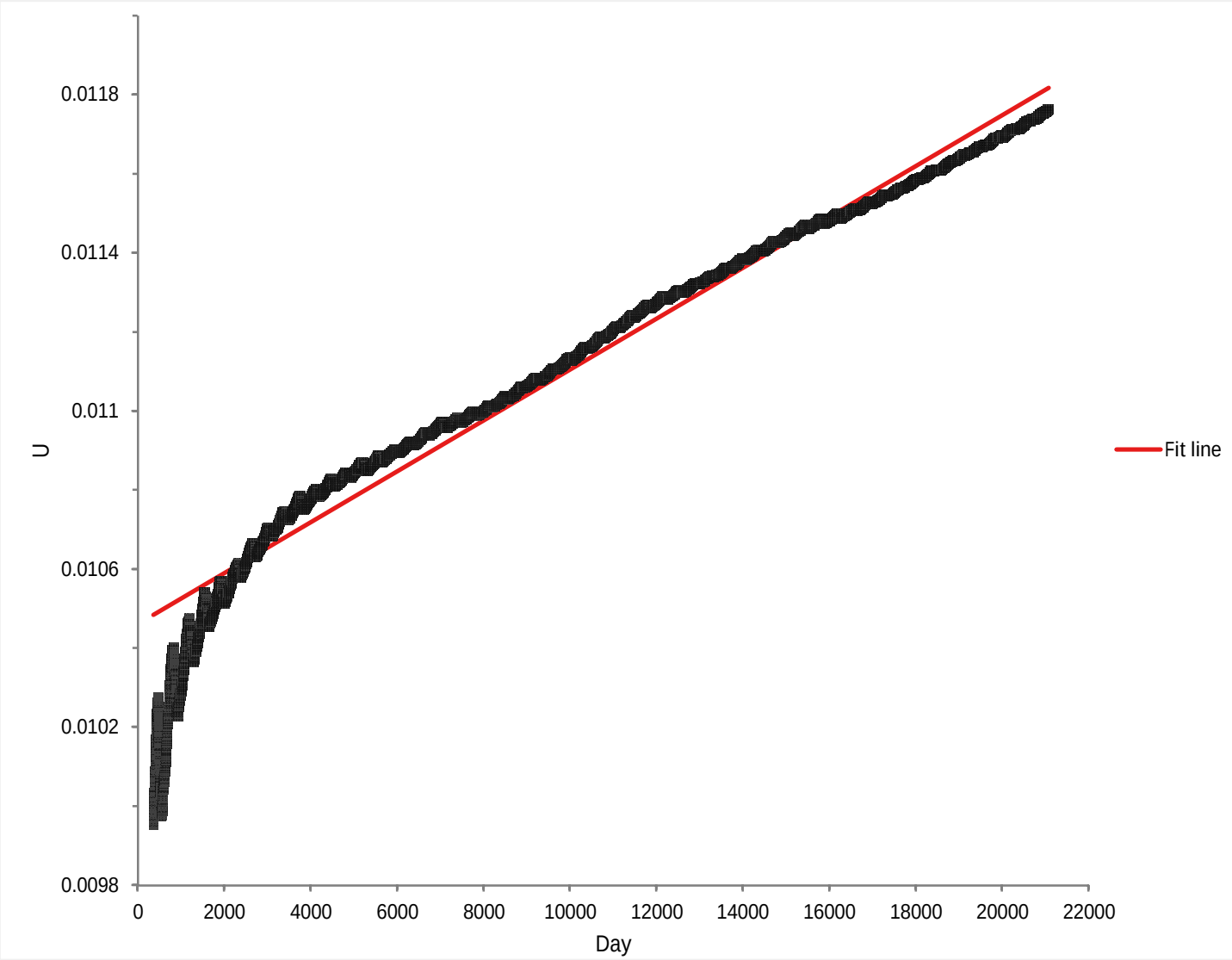
Fit: U

Analyse-it v5.80.2

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:20 by Willy



Fit: U

Analyse-it v5.80.2

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:20 by Willy

Fit

N	41431
Mean of Y	0.01115079

Equation	U = 0.01046 + 6.438e-08 Day

R^2	0.966
R^2 adjusted	0.966
RMSE	0.000072390

Parameter	Estimate	95% CI	SE	t	p-value
Constant	0.01046	0.01046 to 0.01046	7.3018E-07	14325.74	<0.0001
Day	6.438E-08	6.426E-08 to 6.450E-08	5.9472E-11	1082.53	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.00614103	1	0.00614103	1171870.39	<0.0001
Error	0.00021710	41429	0.00000001		
Null model	0.00635813	41430	0.00000015		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

Fit: U

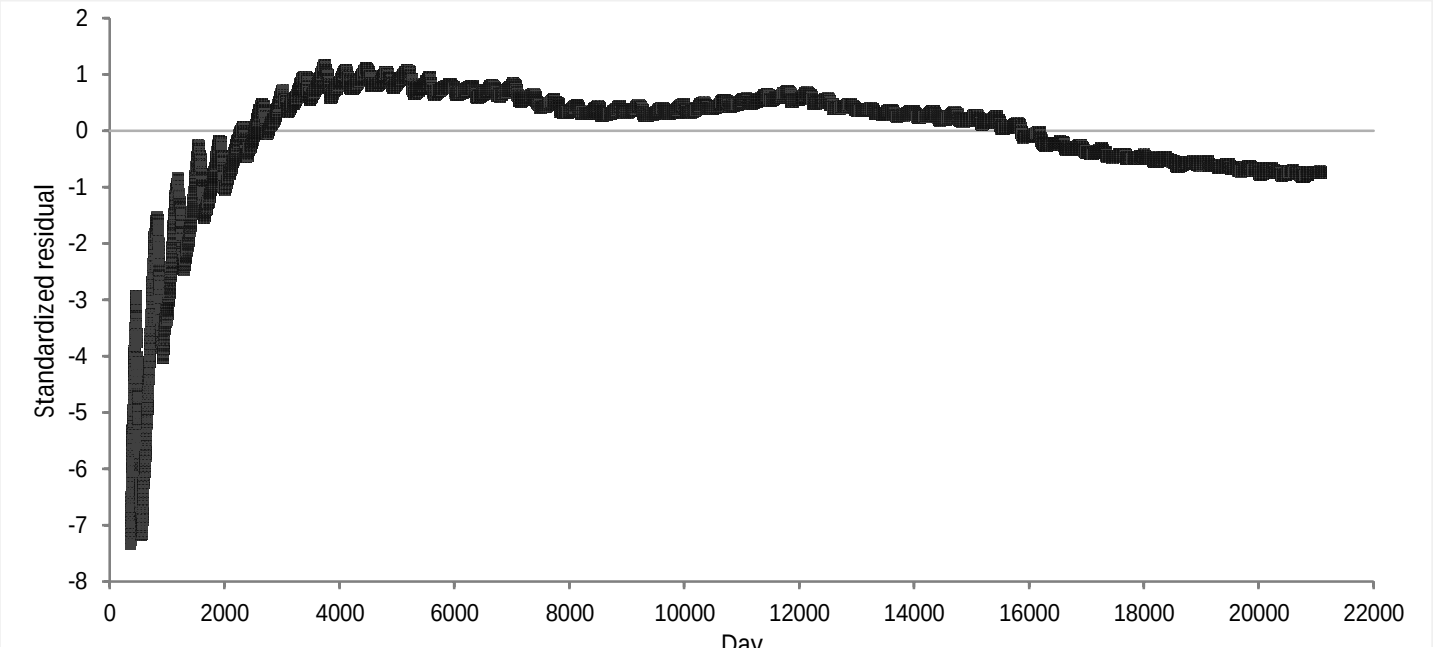
SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:20 by Willy

Analyse-it v5.80.2

Residuals



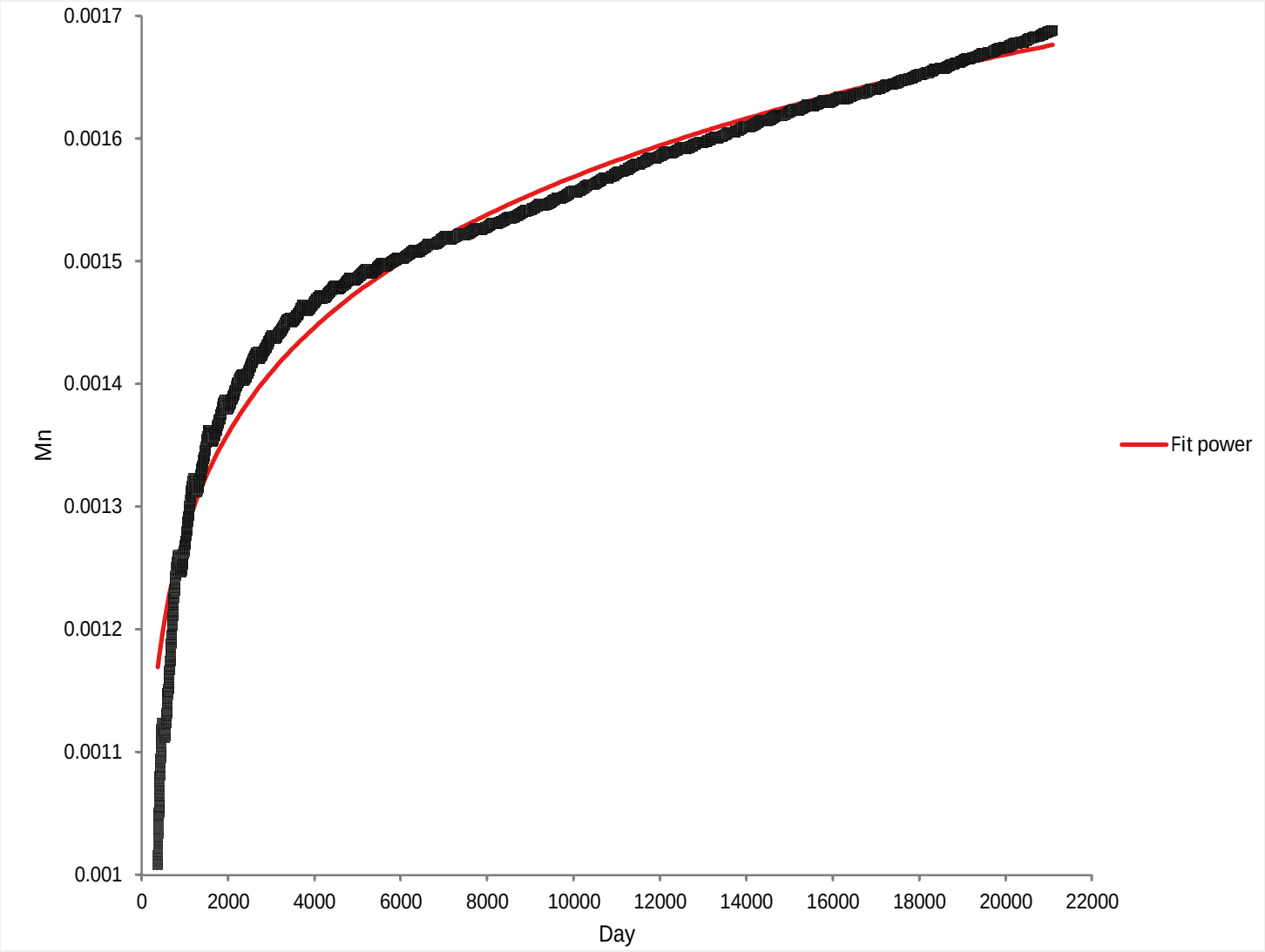
Fit: Mn

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:17 by Willy

Analyse-it v5.80.2



Fit: Mn

Analyse-it v5.80.2

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:17 by Willy

Fit

N	41431
Mean of Y	-6.47355619

Equation: $Mn = 0.0006923 * Day^{0.08883}$

R^2	0.970
R^2 adjusted	0.970
RMSE	0.013047236

Parameter	Estimate	95% CI	SE	t	p-value
Constant	-7.275	-7.277 to -7.274	6.9221E-04	-10510.48	<0.0001
ln Day	0.08883	0.08868 to 0.08898	7.6347E-05	1163.47	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	###########	1	230.43517330	1353666.63	<0.0001
Error	7.05247406	41429	0.00017023		
Null model	###########	41430	0.00573226		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: Mn

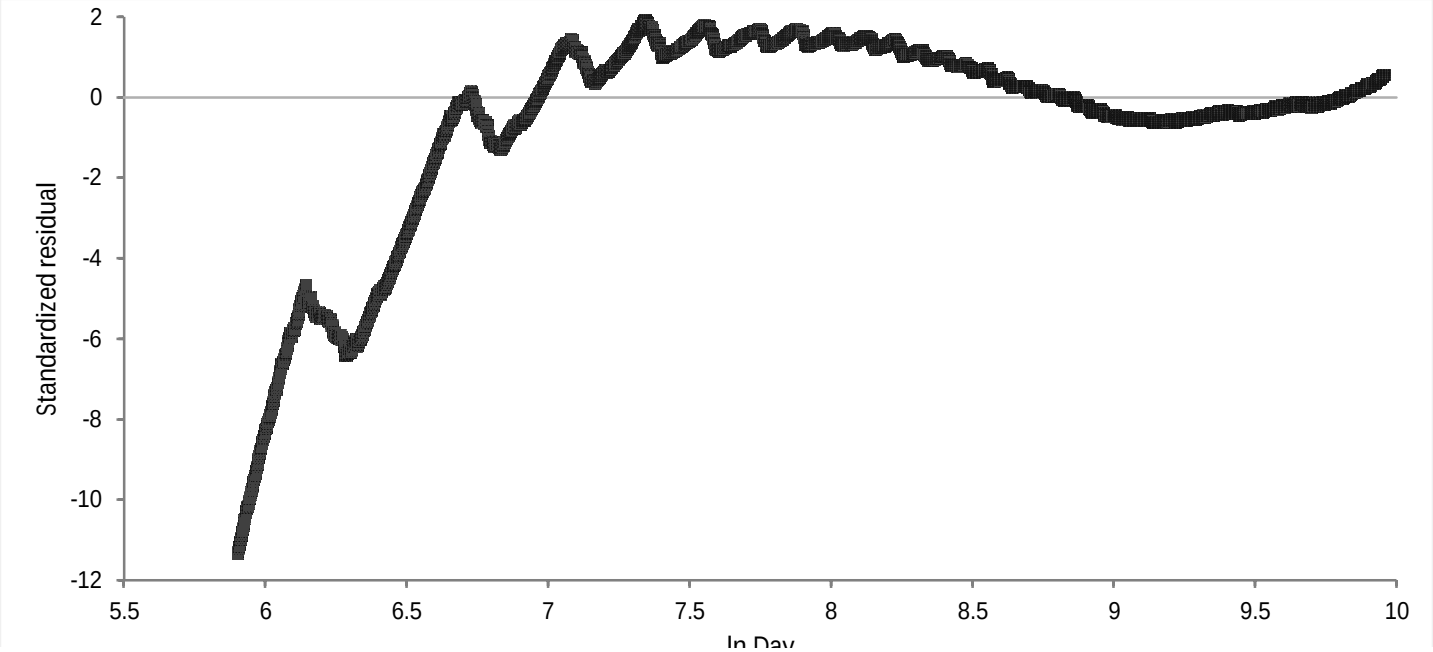
Analyse-it v5.80.2

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:17 by Willy

Residuals

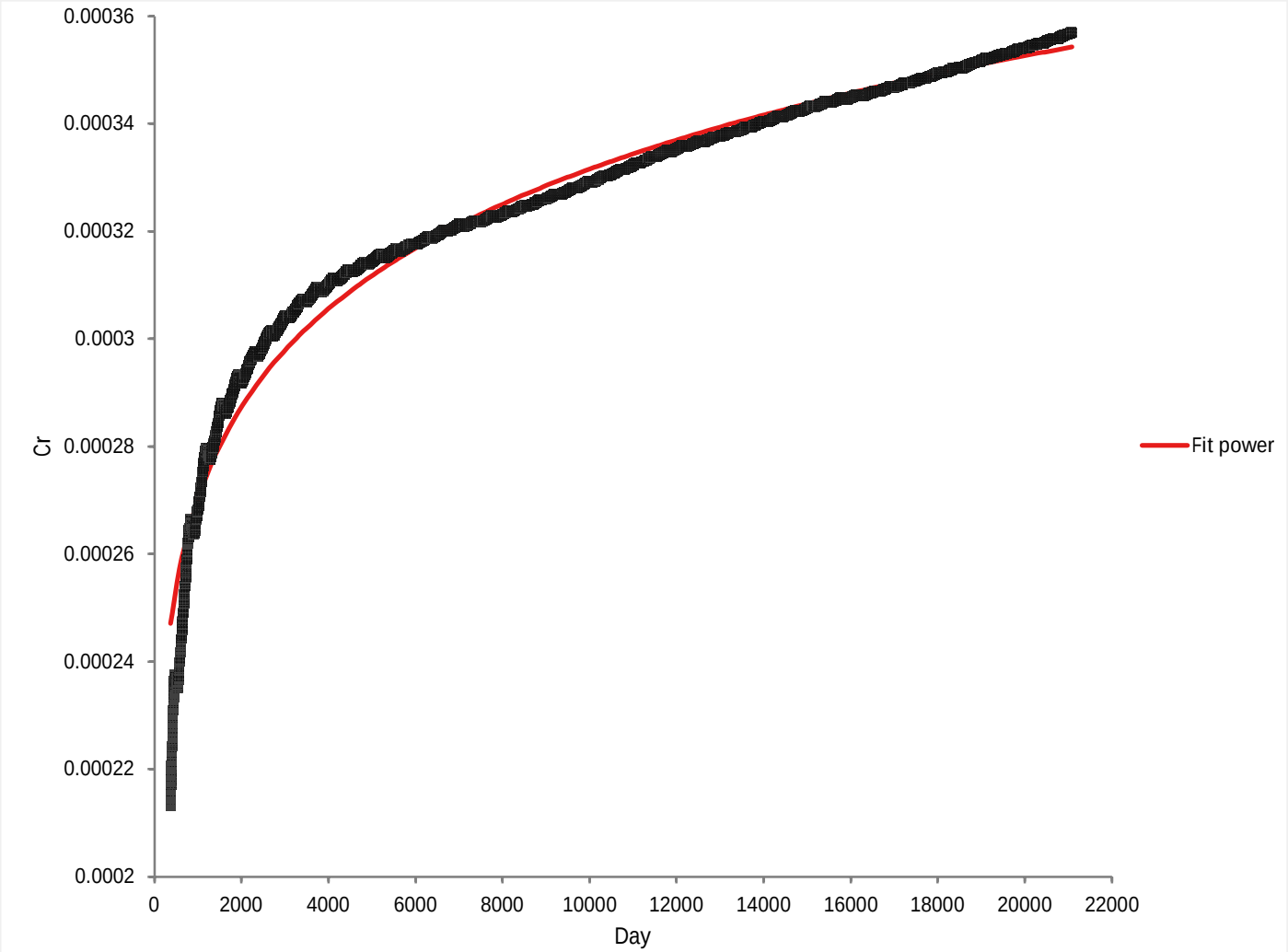


Fit: Cr

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:15 by Willy



Fit: Cr

Analyse-it v5.80.2

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:15 by Willy

Fit

N	41431
Mean of Y	-8.027725696

Equation: $Cr = 0.0001463 * Day^{0.08883}$

R^2	0.970
R^2 adjusted	0.970
RMSE	0.013046652

Parameter	Estimate	95% CI	SE	t	p-value
Constant	-8.830	-8.831 to -8.828	6.9218E-04	-12756.31	<0.0001
ln Day	0.08883	0.08868 to 0.08898	7.6344E-05	1163.56	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	2.304480E+02	1	2.304480E+02	1353863.45	<0.0001
Error	7.051842625	41429	0.000170215		
Null model	2.374999E+02	41430	0.005732558		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: Cr

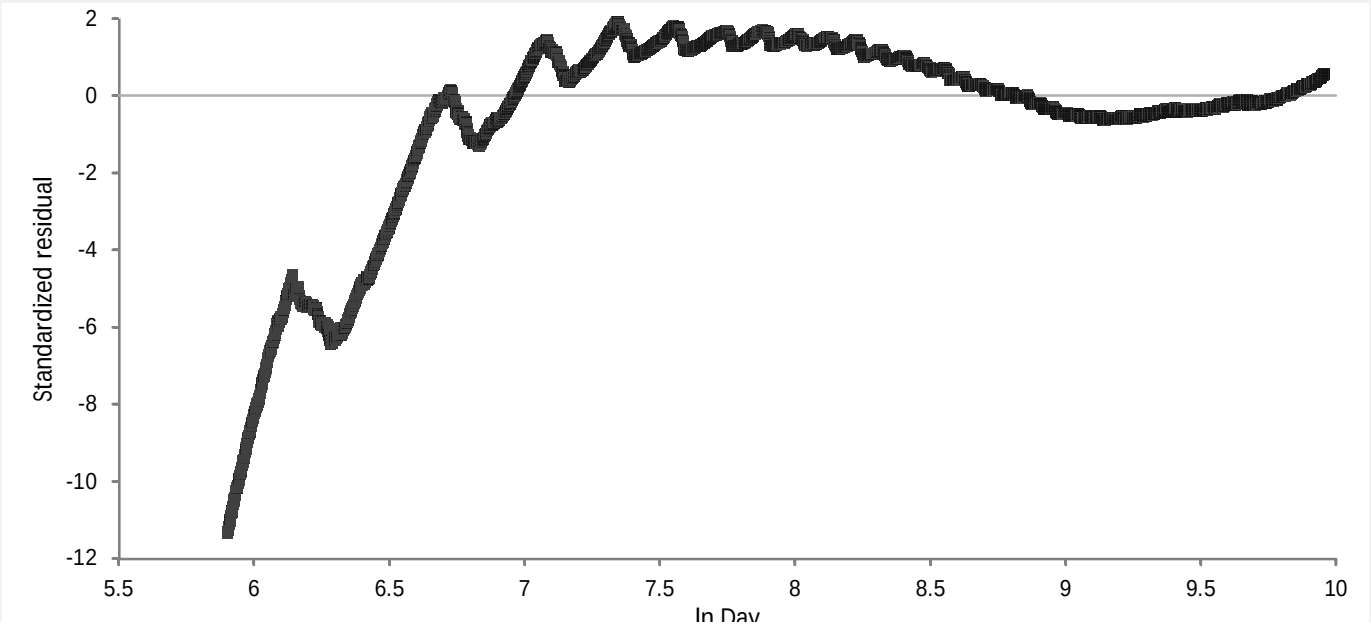
Analyse-it v5.80.2

SP Curve Fitting A27:AF41458

Filter: No filter

Last updated 29 May 2024 at 18:15 by Willy

Residuals



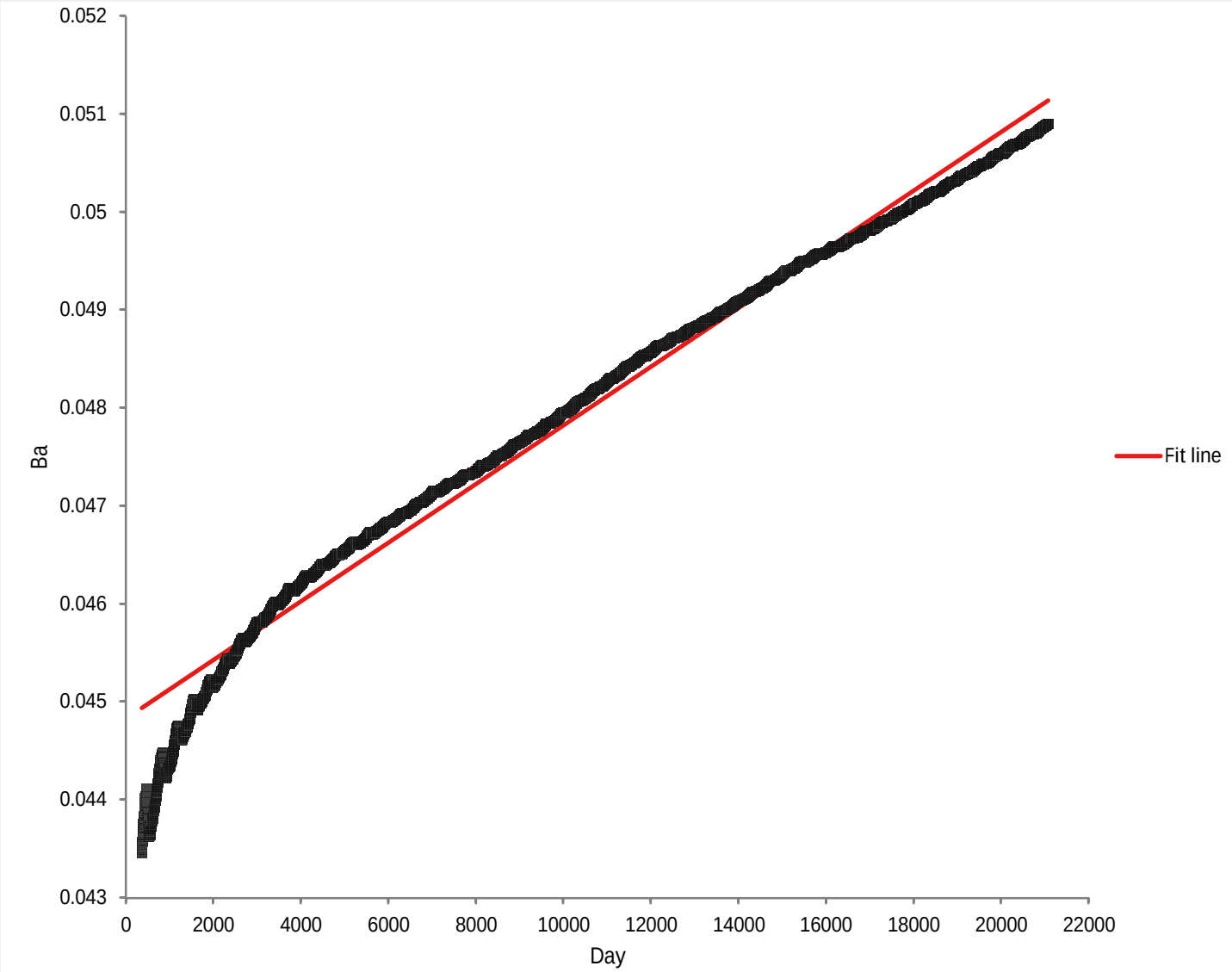
Fit: Ba

Analyse-it v5.80.2

SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:11 by Willy



Fit: Ba

Analyse-it v5.80.2

SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:11 by Willy

Fit

N	41431
Mean of Y	0.0480338

Equation	Ba = 0.04483 + 2.991e-07 Day

R^2	0.981
R^2 adjusted	0.981
RMSE	0.00024769

Parameter	Estimate	95% CI	SE	t	p-value
Constant	0.04483	0.04482 to 0.04483	2.4984E-06	17941.68	<0.0001
Day	2.991E-07	2.987E-07 to 2.995E-07	2.0349E-10	1470.07	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Fit: Ba

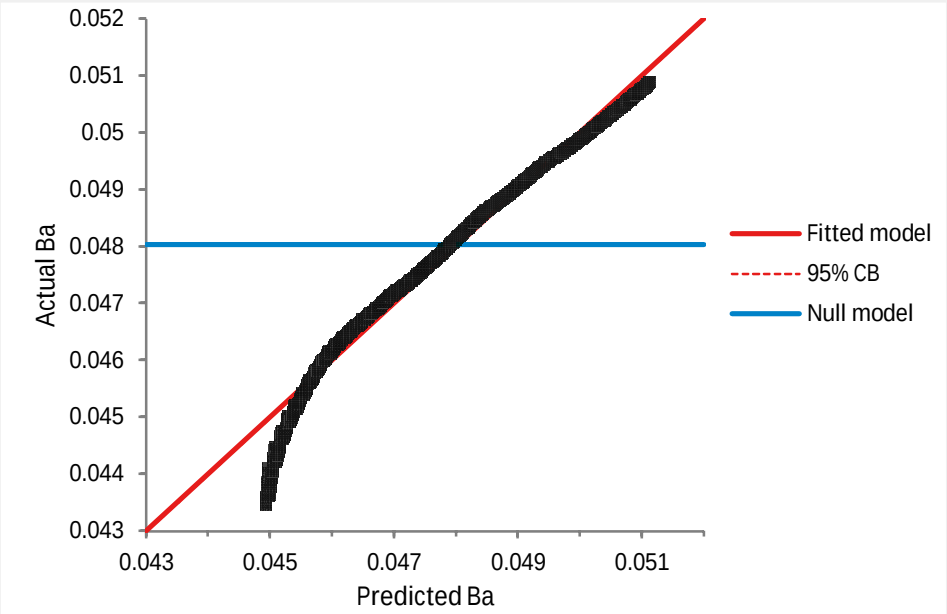
SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:11 by Willy

Analyse-it v5.80.2

Effect of Model



Source	SS	DF	MS	F	p-value
Difference	0.1325896	1	0.1325896	2161120.03	<0.0001
Error	0.0025418	41429	0.0000001		
Null model	0.1351314	41430	0.0000033		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

Fit: Ba

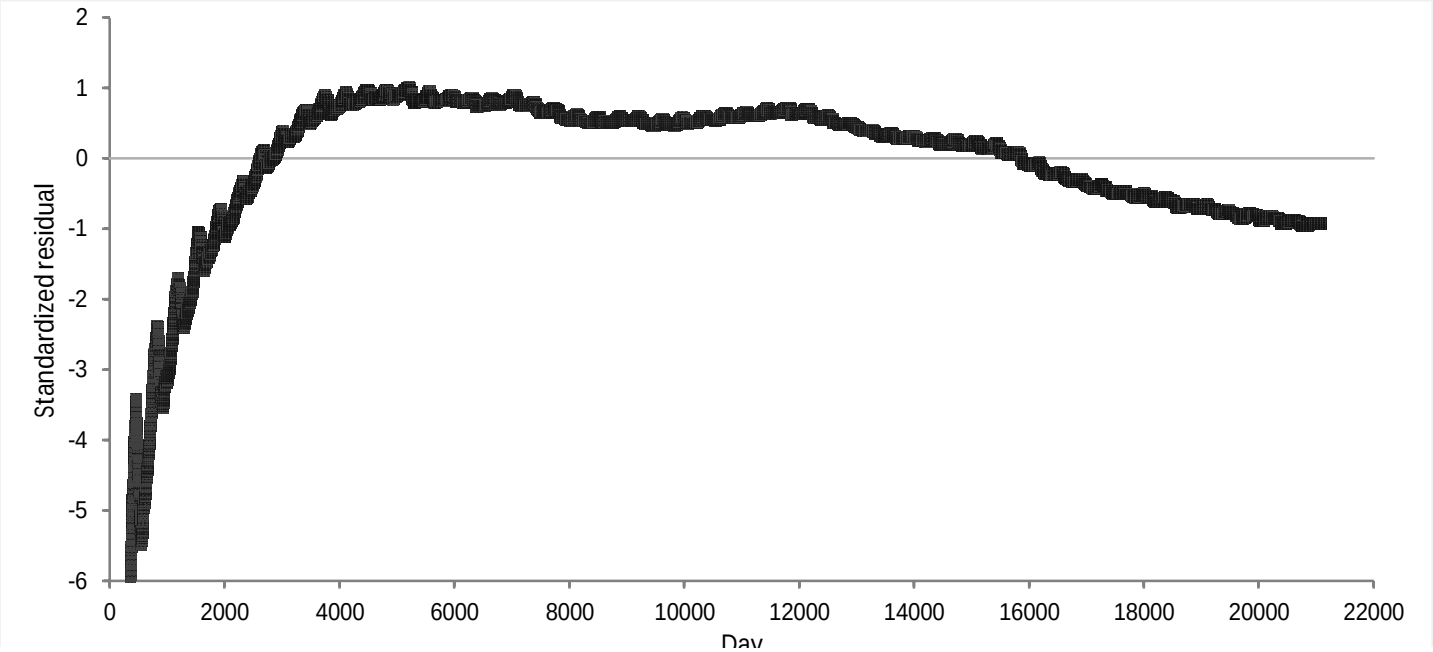
Analyse-it v5.80.2

SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:11 by Willy

Residuals



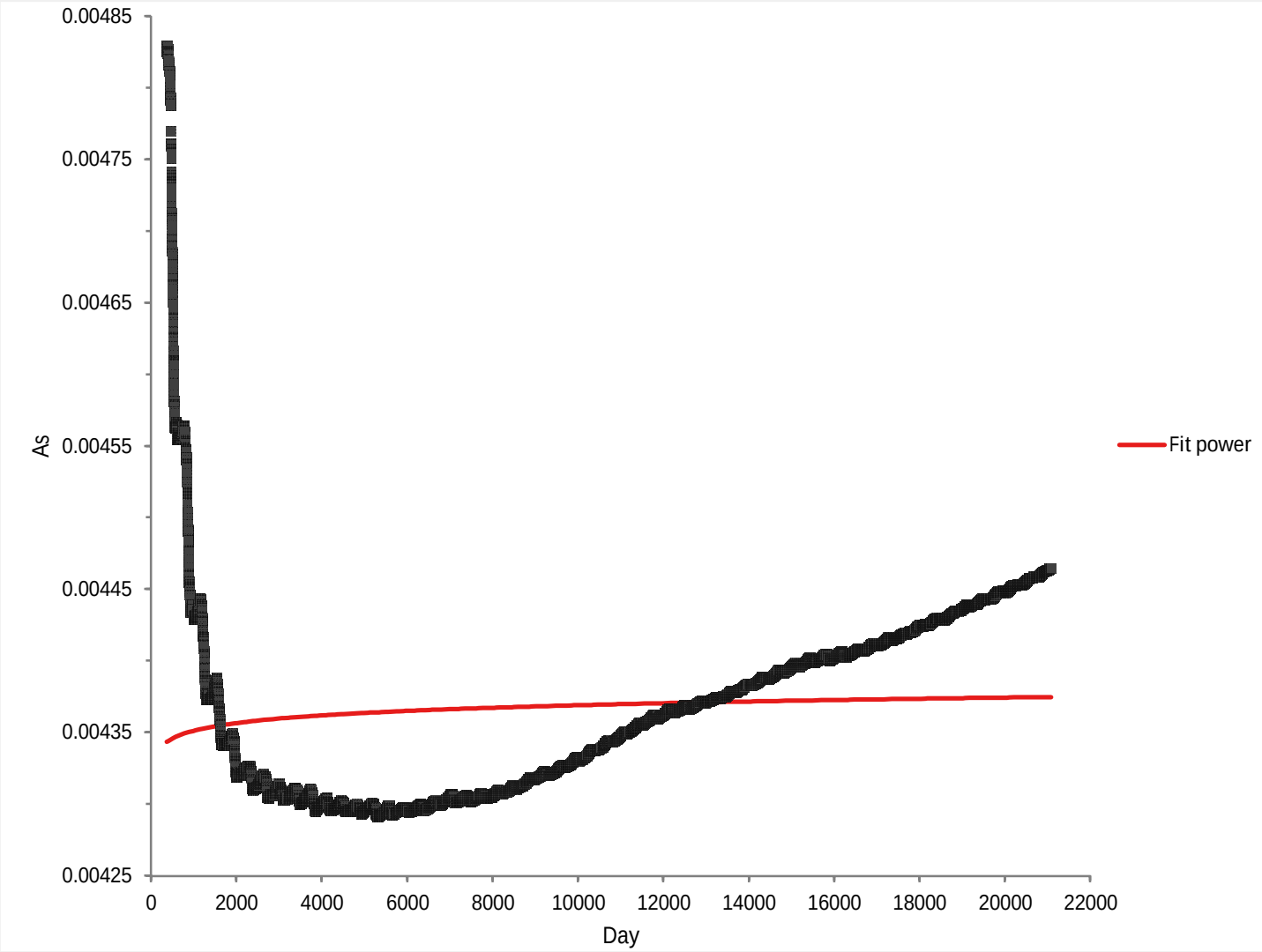
Fit: As

Analyse-it v5.80.2

SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:07 by Willy



Fit: As

Analyse-it v5.80.2

SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:07 by Willy

Fit

N	41431
Mean of Y	-5.43352009

Equation | As = 0.004298 * Day $^{0.001773}$

R^2	0.009
R^2 adjusted	0.009
RMSE	0.015276437

Parameter	Estimate	95% CI	SE	t	p-value
Constant	-5.450	-5.451 to -5.448	8.1048E-04	-6723.84	<0.0001
ln Day	0.001773	0.001598 to 0.001948	8.9392E-05	19.84	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.09182835	1	0.09182835	393.49	<0.0001
Error	9.66826676	41429	0.00023337		
Null model	9.76009511	41430	0.00023558		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: As

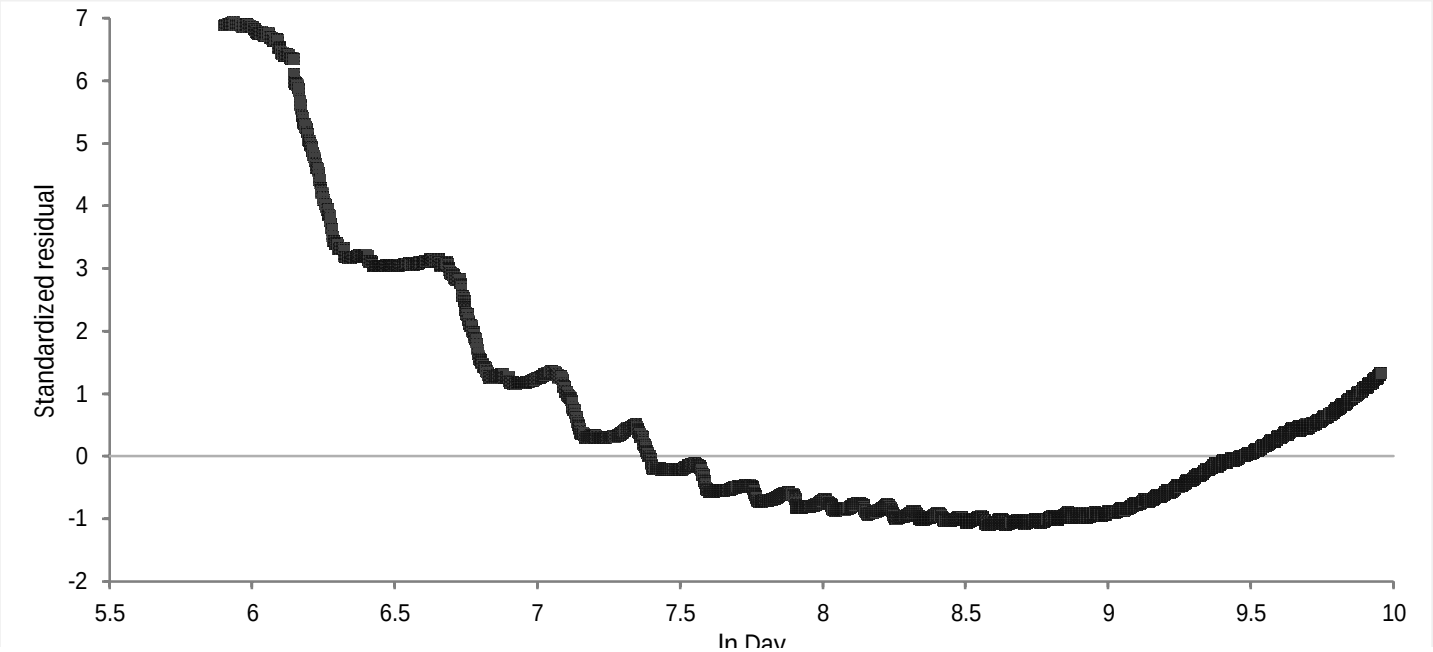
SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:07 by Willy

Analyse-it v5.80.2

Residuals



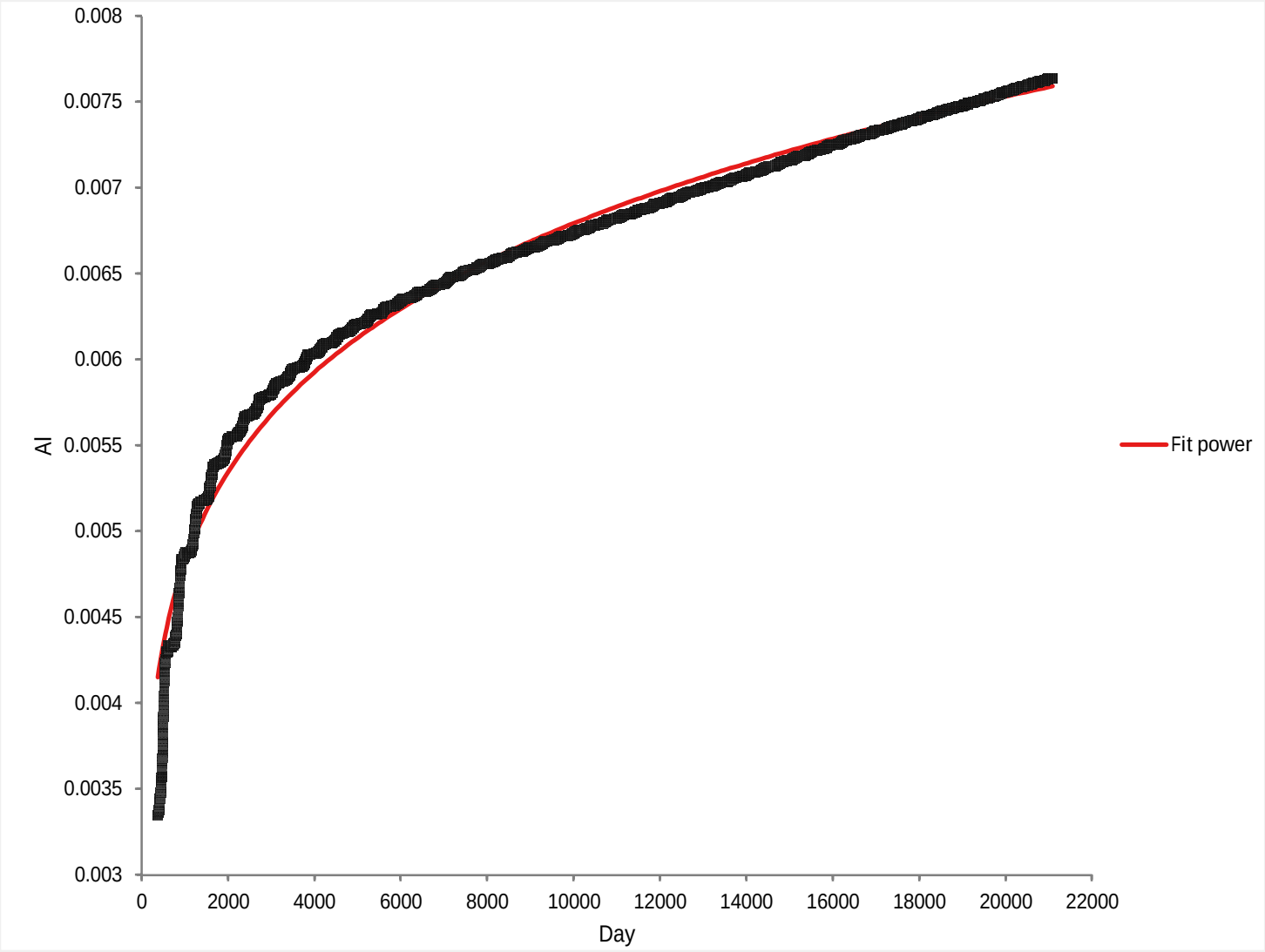
Fit: Al

SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:07 by Willy

Analyse-it v5.80.2



Fit: AI

Analyse-it v5.80.2

SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:07 by Willy

Fit

N	41431
Mean of Y	-5.01893502

Equation: $AI = 0.001724 * Day^{0.1489}$

R^2	0.974
R^2 adjusted	0.974
RMSE	0.020257194

Parameter	Estimate	95% CI	SE	t	p-value
Constant	-6.363	-6.365 to -6.361	1.0747E-03	-5920.42	<0.0001
ln Day	0.1489	0.1486 to 0.1491	1.1854E-04	1255.86	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	###########	1	647.20452652	1577186.23	<0.0001
Error	17.00055186	41429	0.00041035		
Null model	###########	41430	0.01603198		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: Al

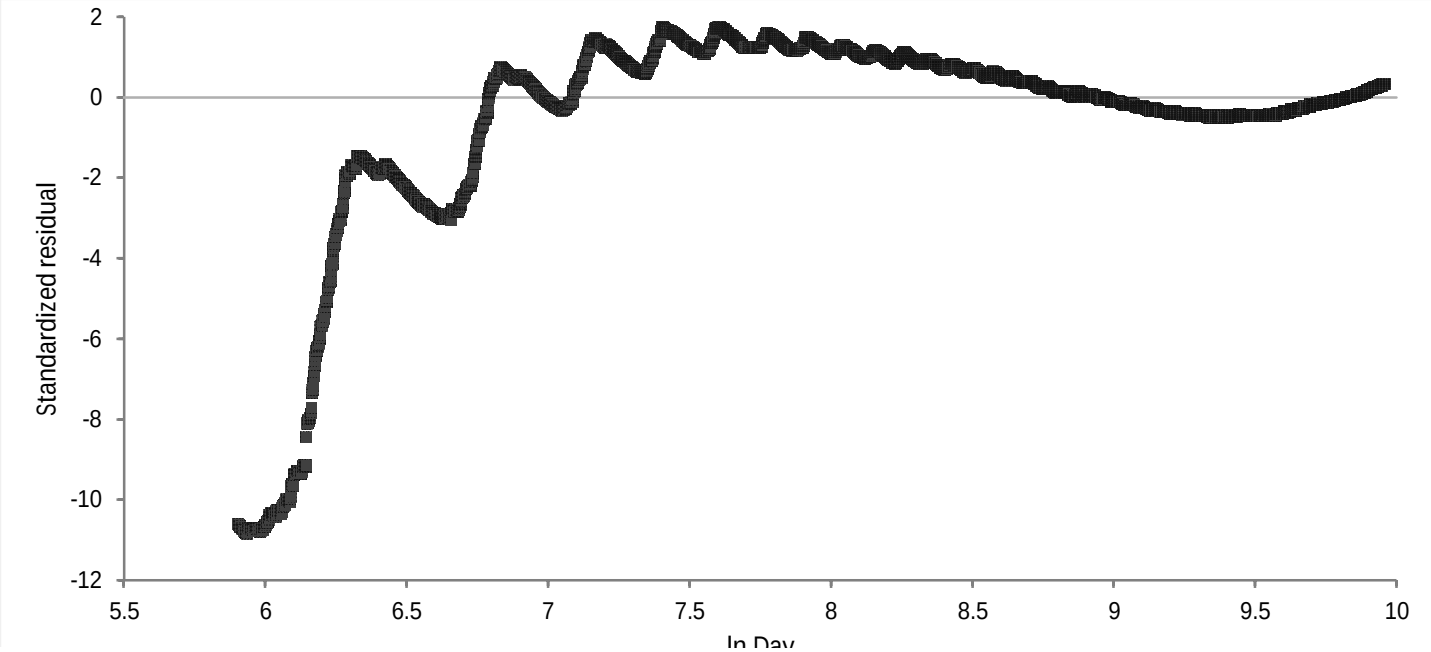
Analyse-it v5.80.2

SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:07 by Willy

Residuals



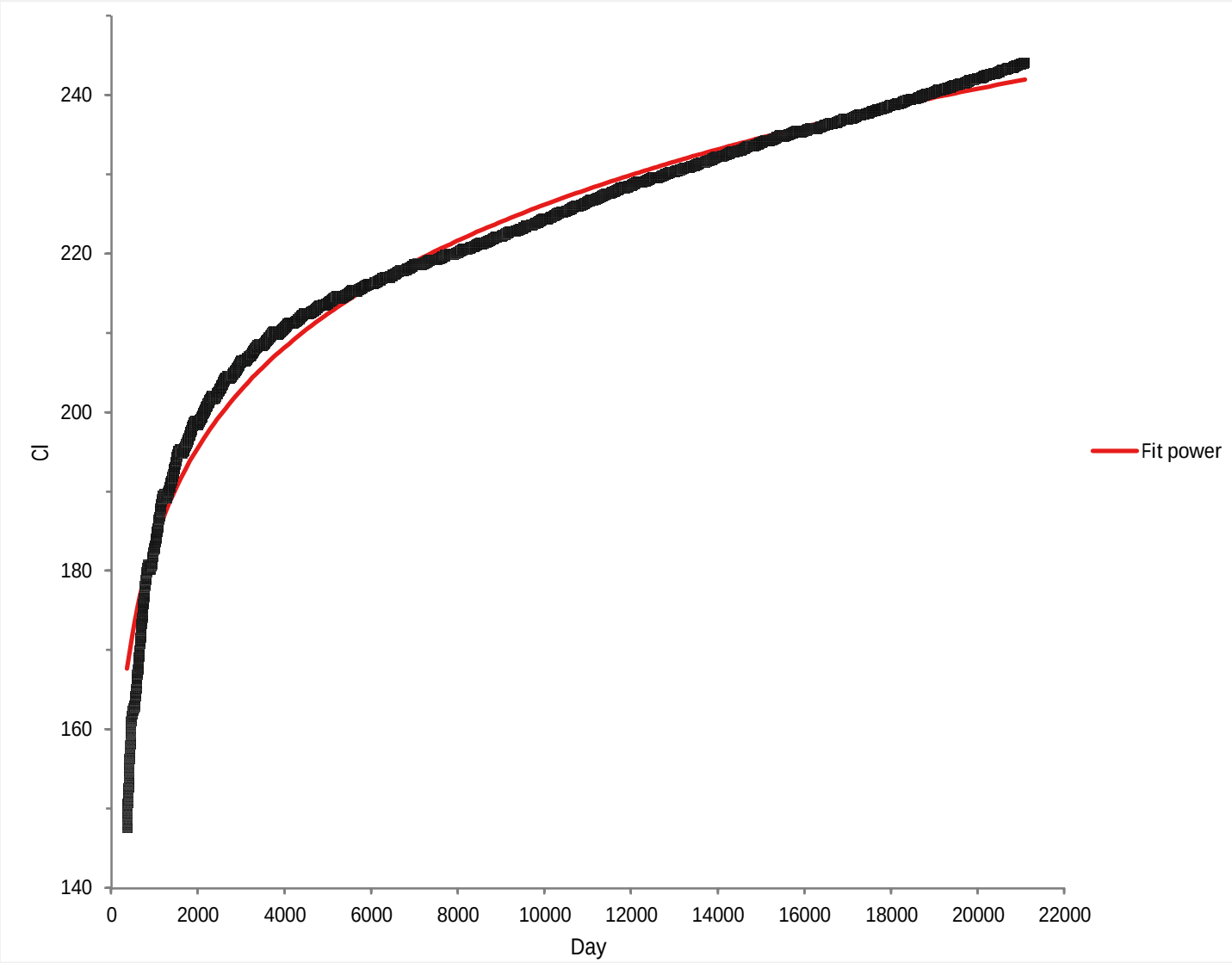
Fit: Cl

Analyse-it v5.80.2

SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:06 by Willy



Fit: Cl

Analyse-it v5.80.2

SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:06 by Willy

Fit

N	41431
Mean of Y	5.405

Equation: $Cl = 98.36 * Day^{0.09042}$

R^2	0.978
R^2 adjusted	0.978
RMSE	0.0115

Parameter	Estimate	95% CI	SE	t	p-value
Constant	4.589	4.587 to 4.590	6.1007E-04	7521.45	<0.0001
ln Day	0.09042	0.09028 to 0.09055	6.7288E-05	1343.72	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	238.750	1	238.750	1805588.24	<0.0001
Error	5.478	41429	0.000		
Null model	244.228	41430	0.006		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: Cl

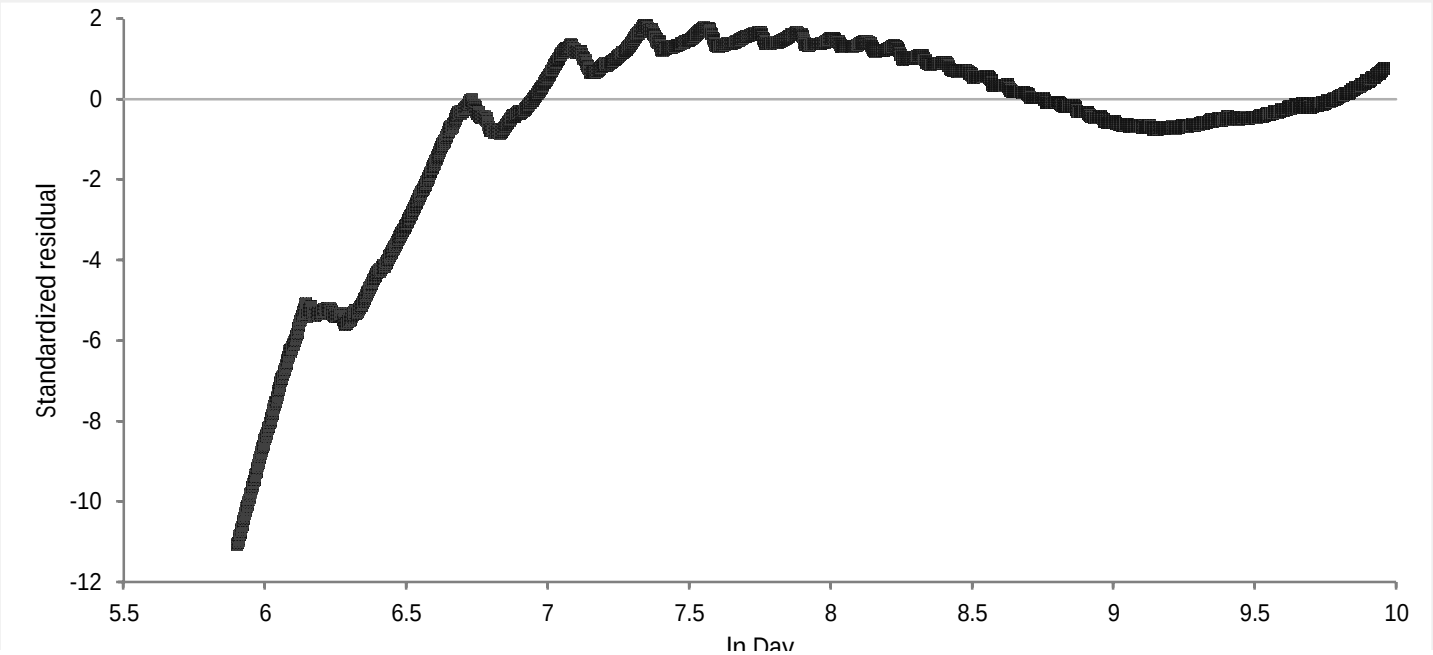
SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:06 by Willy

Analyse-it v5.80.2

Residuals



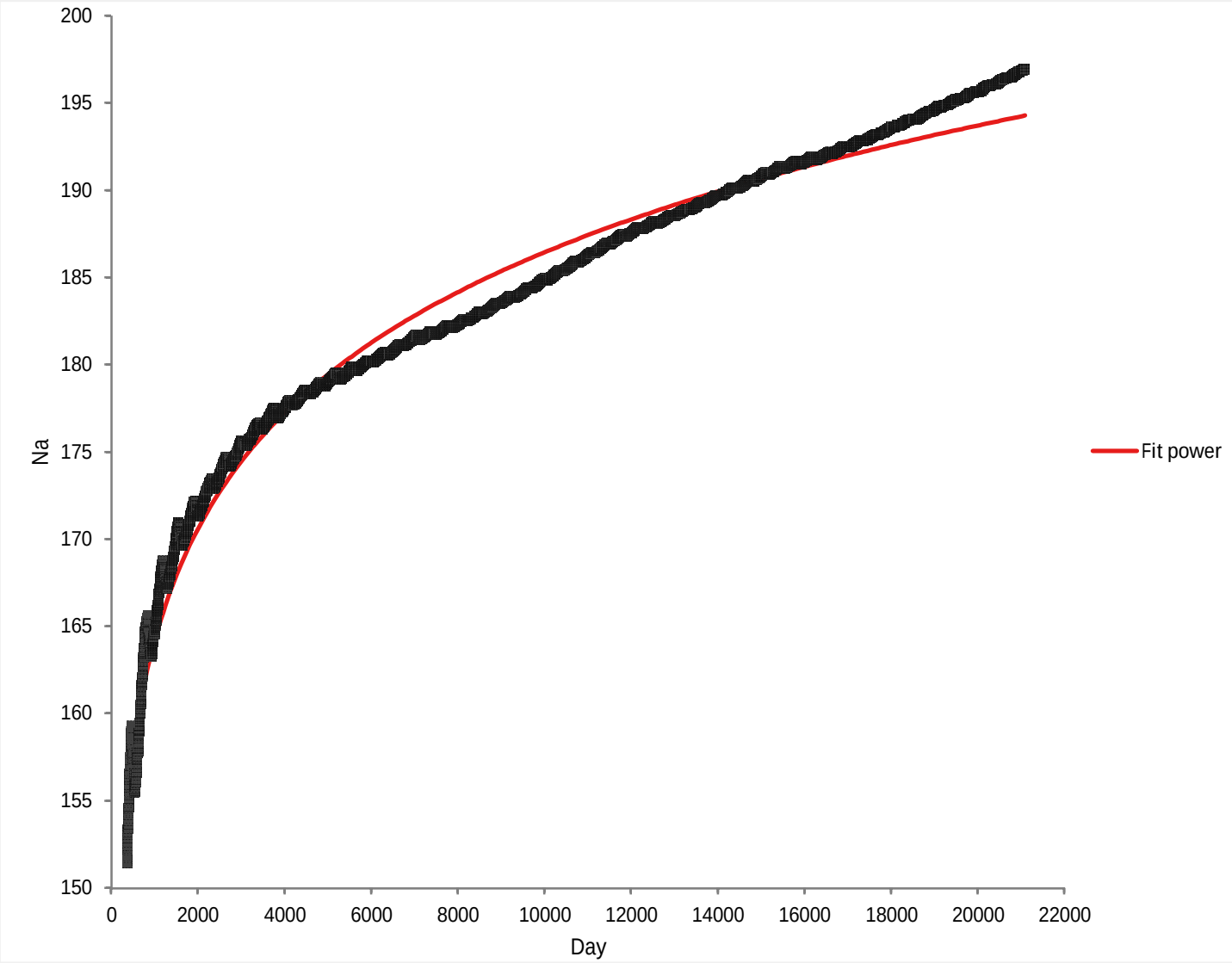
Fit: Na

Analyse-it v5.80.2

SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:02 by Willy



Fit: Na

Analyse-it v5.80.2

SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:02 by Willy

Fit

N	41431
Mean of Y	5.218

Equation: $Na = 112.2 * Day^{0.05518}$

R^2	0.979
R^2 adjusted	0.979
RMSE	0.0068

Parameter	Estimate	95% CI	SE	t	p-value
Constant	4.720	4.719 to 4.721	3.5980E-04	13118.16	<0.0001
ln Day	0.05518	0.05511 to 0.05526	3.9684E-05	1390.58	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	88.935	1	88.935	1933719.45	<0.0001
Error	1.905	41429	0.000		
Null model	90.841	41430	0.002		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha * x^{\beta}$
The model is better than the null model.

Fit: Na

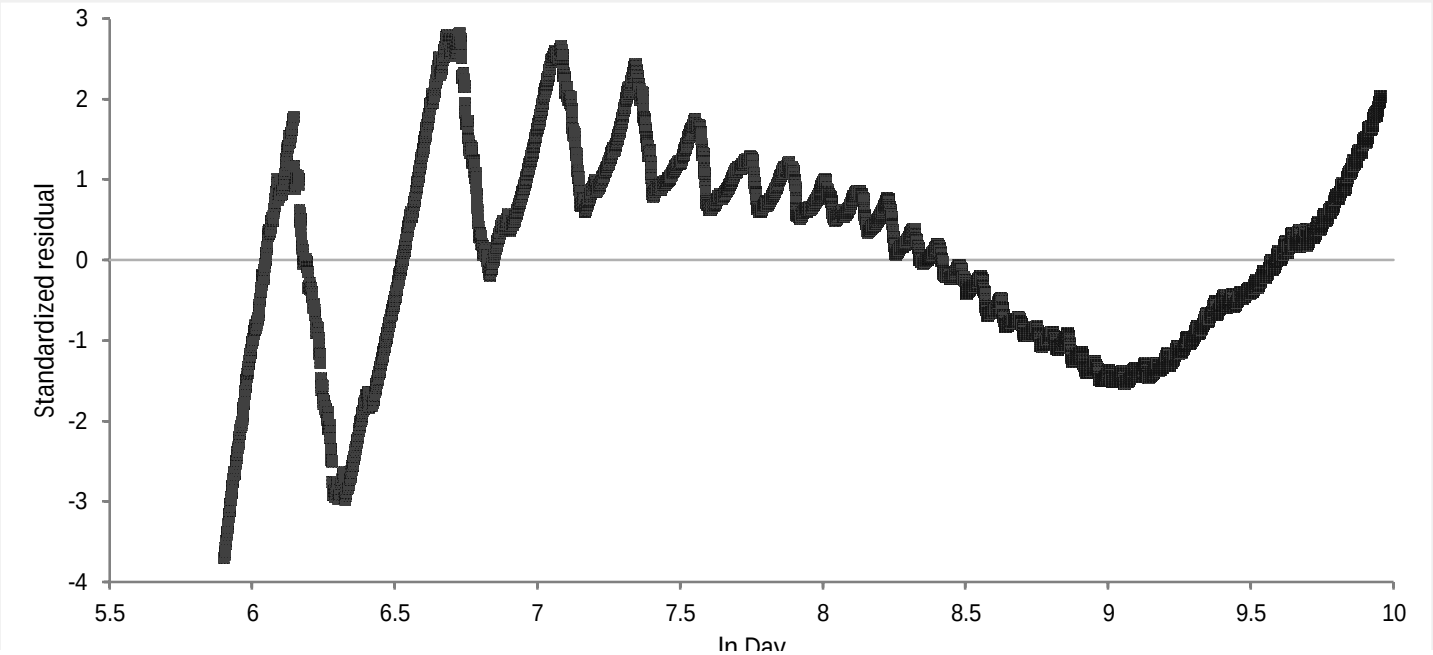
Analyse-it v5.80.2

SP Curve Fitting A24:AF41455

Filter: No filter

Last updated 29 May 2024 at 18:02 by Willy

Residuals



D.3.3 WRD Sediment Dam statistical curve fitting results

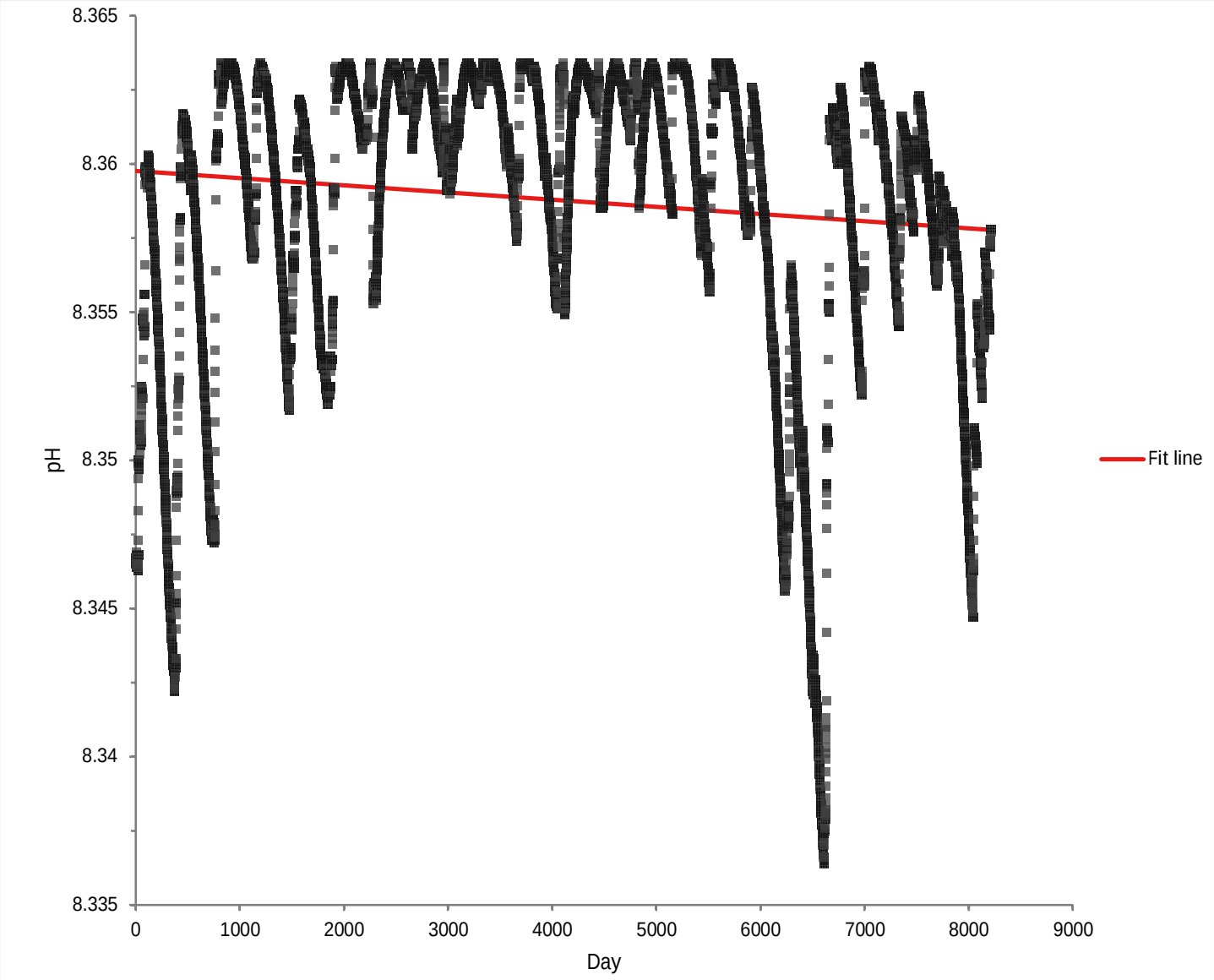
Fit: pH

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:18 by Willy Van Vaerenbergh



Fit: pH

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:18 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	8.35877

Equation	pH = 8.36 - 2.406e-07 Day

R^2	0.012
R^2 adjusted	0.012
RMSE	0.005122

Parameter	Estimate	95% CI	SE	t	p-value
Constant	8.360	8.360 to 8.360	7.9917E-05	104605.72	<0.0001
Day	-2.406E-07	-2.736E-07 to -2.076E-07	1.6849E-08	-14.28	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.00535	1	0.00535	203.92	<0.0001
Error	0.43092	16428	0.00003		
Null model	0.43627	16429	0.00003		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

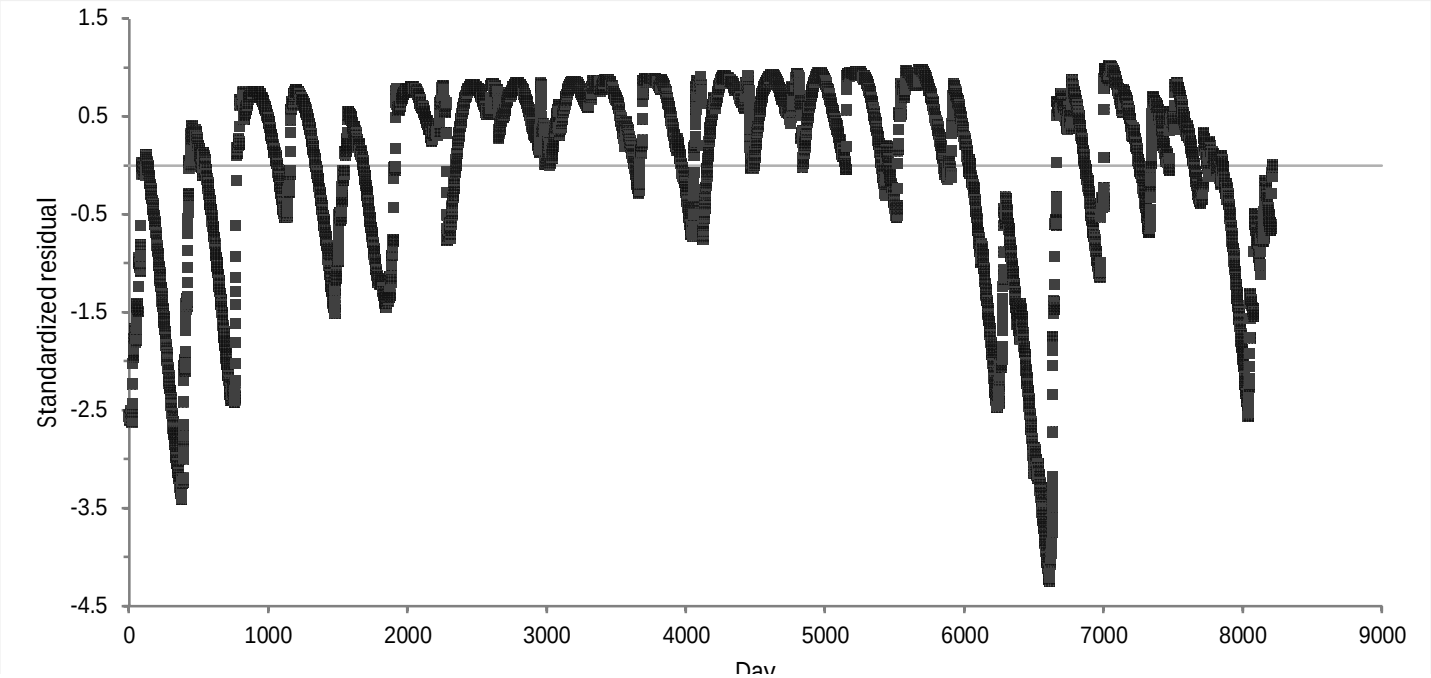
Fit: pH

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:18 by Willy Van Vaerenbergh

Residuals



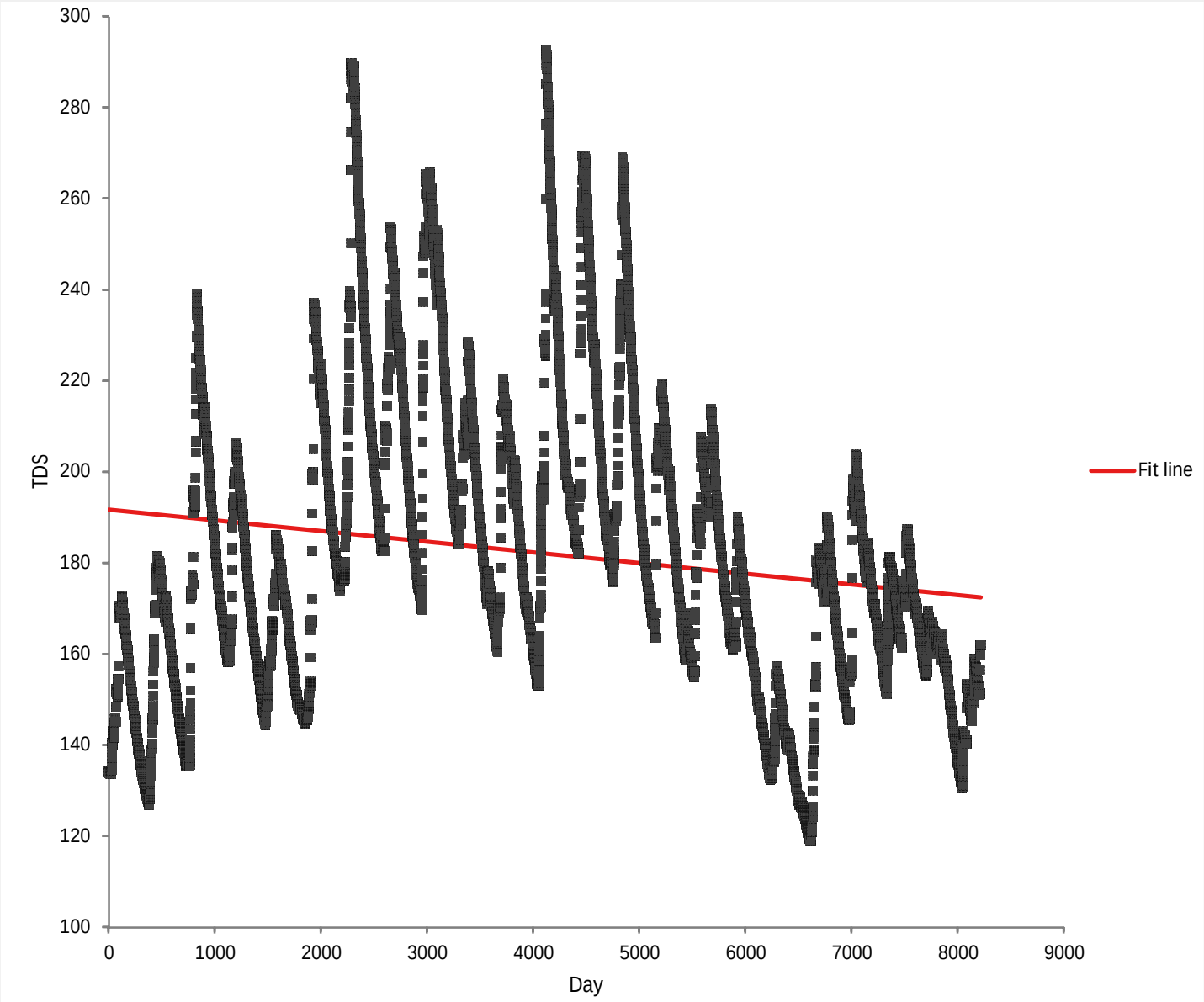
Fit: TDS

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:17 by Willy Van Vaerenbergh



Fit: TDS

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:17 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	182.105

Equation	TDS = 191.7 - 0.002346 Day

R^2	0.029
R^2 adjusted	0.028
RMSE	32.4812

Parameter	Estimate	95% CI	SE	t	p-value
Constant	191.7	190.7 to 192.7	0.50683	378.32	<0.0001
Day	-0.002346	-0.002556 to -0.002137	1.0686E-04	-21.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	508632.536	1	508632.536	482.10	<0.0001
Error	17332000.699	16428	1055.028		
Null model	17840633.235	16429	1085.923		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

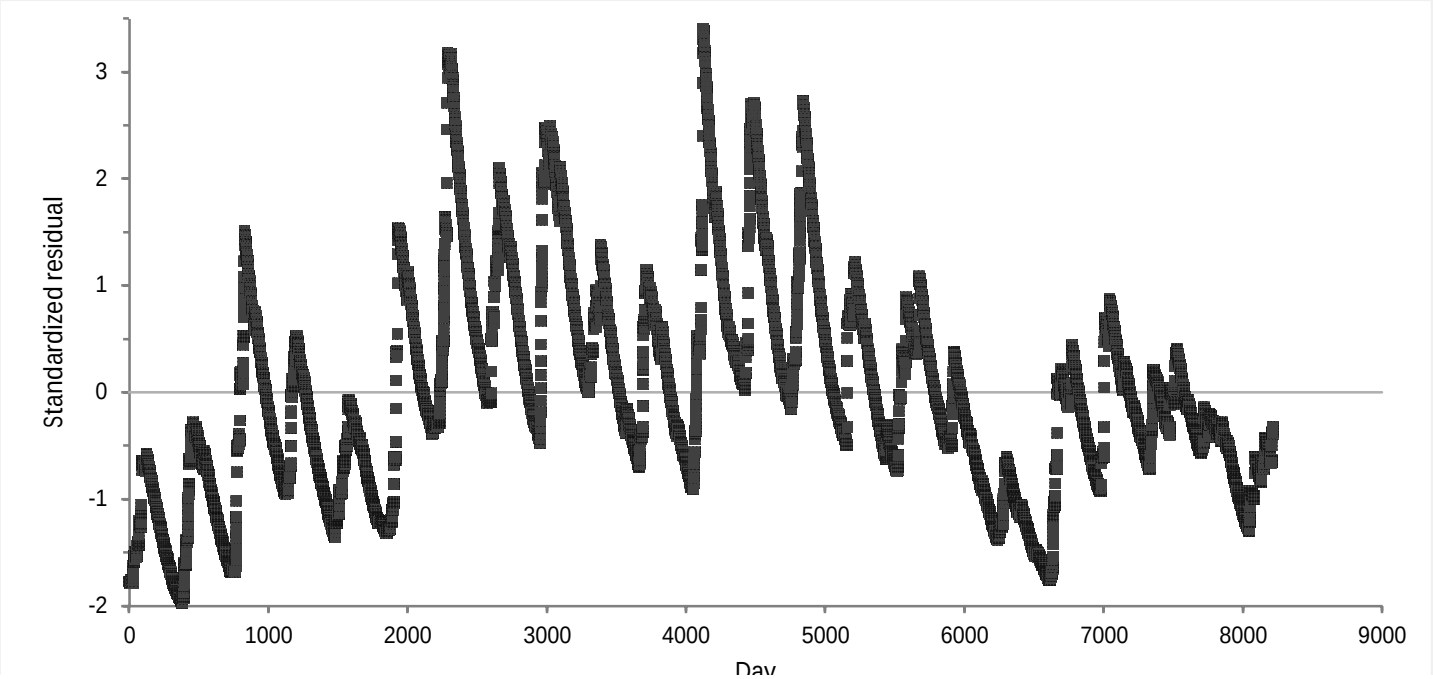
Fit: TDS

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:17 by Willy Van Vaerenbergh

Residuals

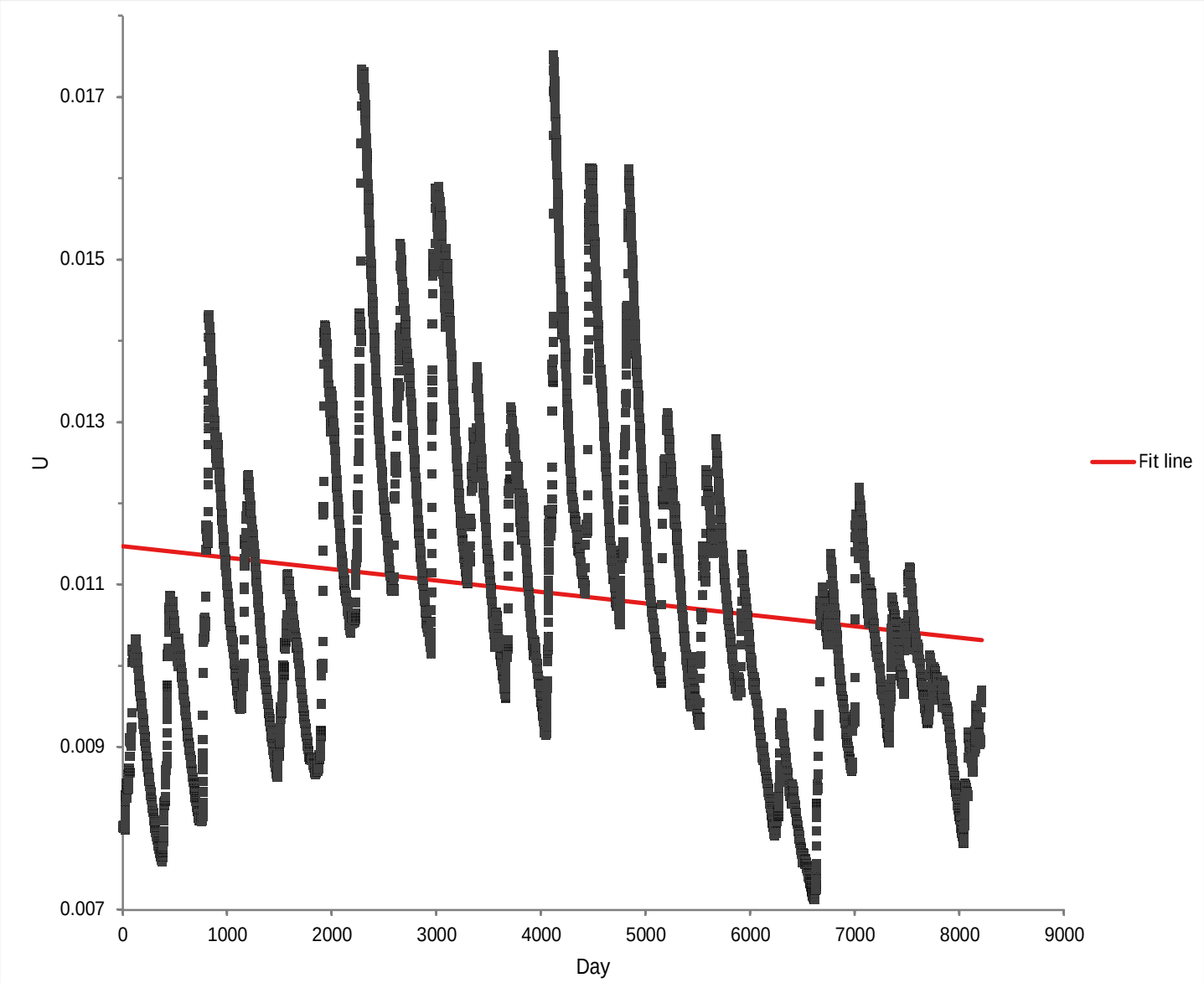


Fit: U

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:16 by Willy Van Vaerenbergh



Fit: U

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:16 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	0.01089318

Equation	U = 0.01147 - 1.405e-07 Day

R^2	0.029
R^2 adjusted	0.028
RMSE	0.001945112

Parameter	Estimate	95% CI	SE	t	p-value
Constant	0.01147	0.01141 to 0.01153	3.0351E-05	377.92	<0.0001
Day	-1.405E-07	-1.530E-07 to -1.280E-07	6.3990E-09	-21.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.00182402	1	0.00182402	482.10	<0.0001
Error	0.06215470	16428	0.00000378		
Null model	0.06397873	16429	0.00000389		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

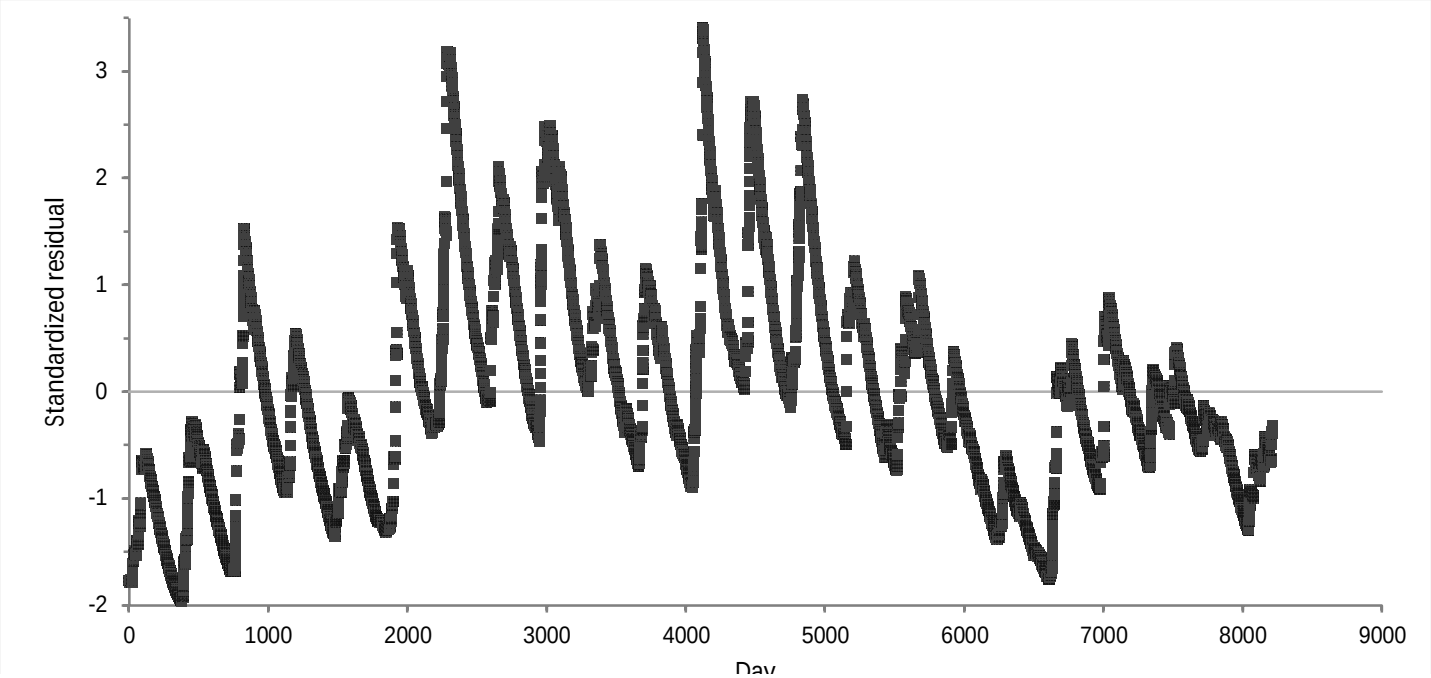
Fit: U

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:16 by Willy Van Vaerenbergh

Residuals

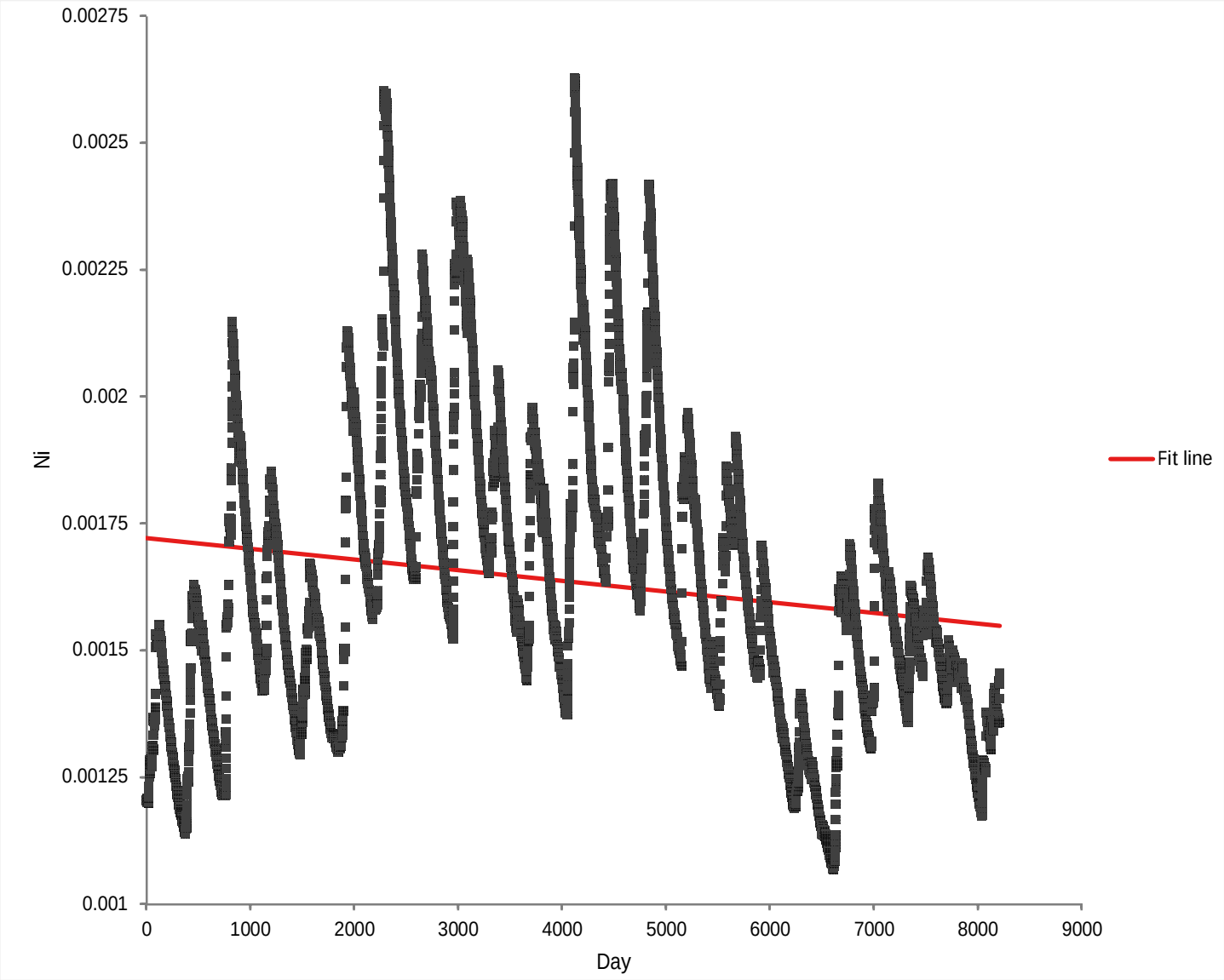


Fit: Ni

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:16 by Willy Van Vaerenbergh



Fit: Ni

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:16 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	0.00163453

Equation	Ni = 0.001721 - 2.108e-08 Day

R^2	0.029
R^2 adjusted	0.028
RMSE	0.000291866

Parameter	Estimate	95% CI	SE	t	p-value
Constant	0.001721	0.001712 to 0.001730	4.5542E-06	377.92	<0.0001
Day	-2.108E-08	-2.296E-08 to -1.920E-08	9.6017E-10	-21.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.00004107	1	0.00004107	482.11	<0.0001
Error	0.00139943	16428	0.00000009		
Null model	0.00144050	16429	0.00000009		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

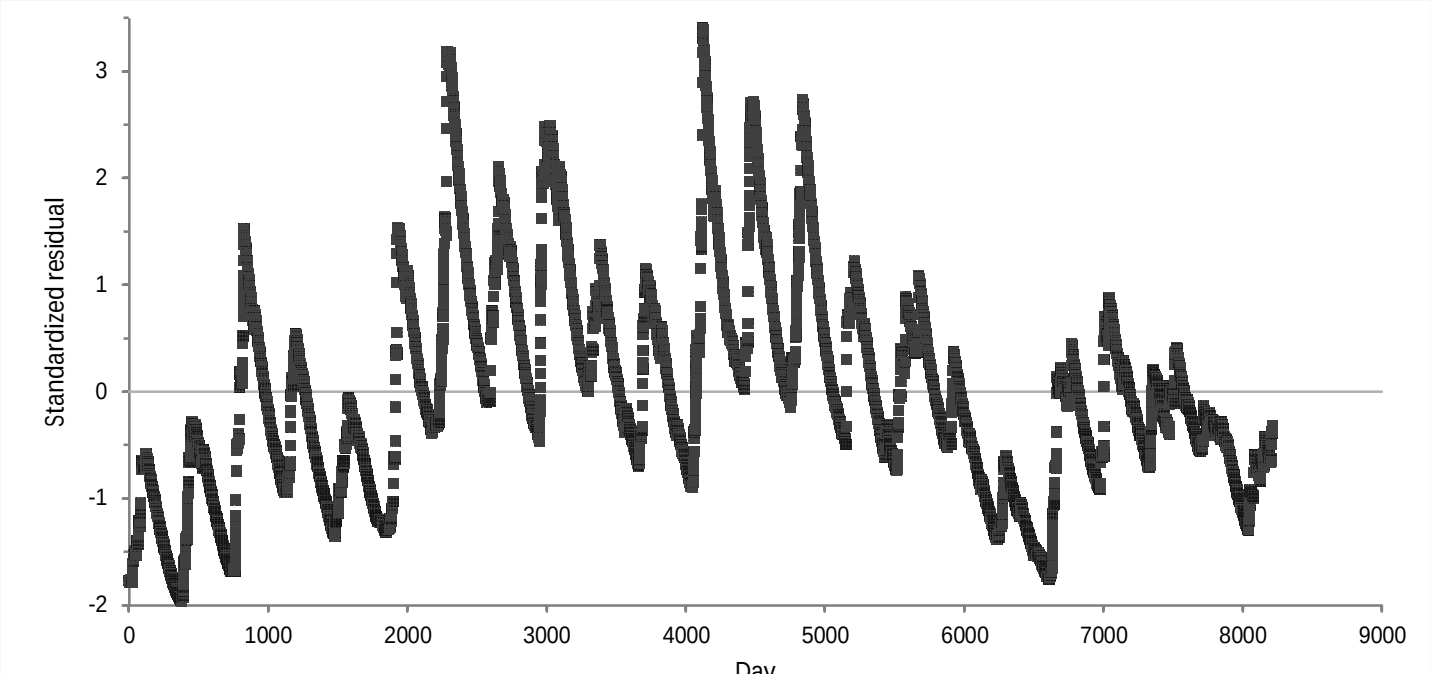
Fit: Ni

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:16 by Willy Van Vaerenbergh

Residuals



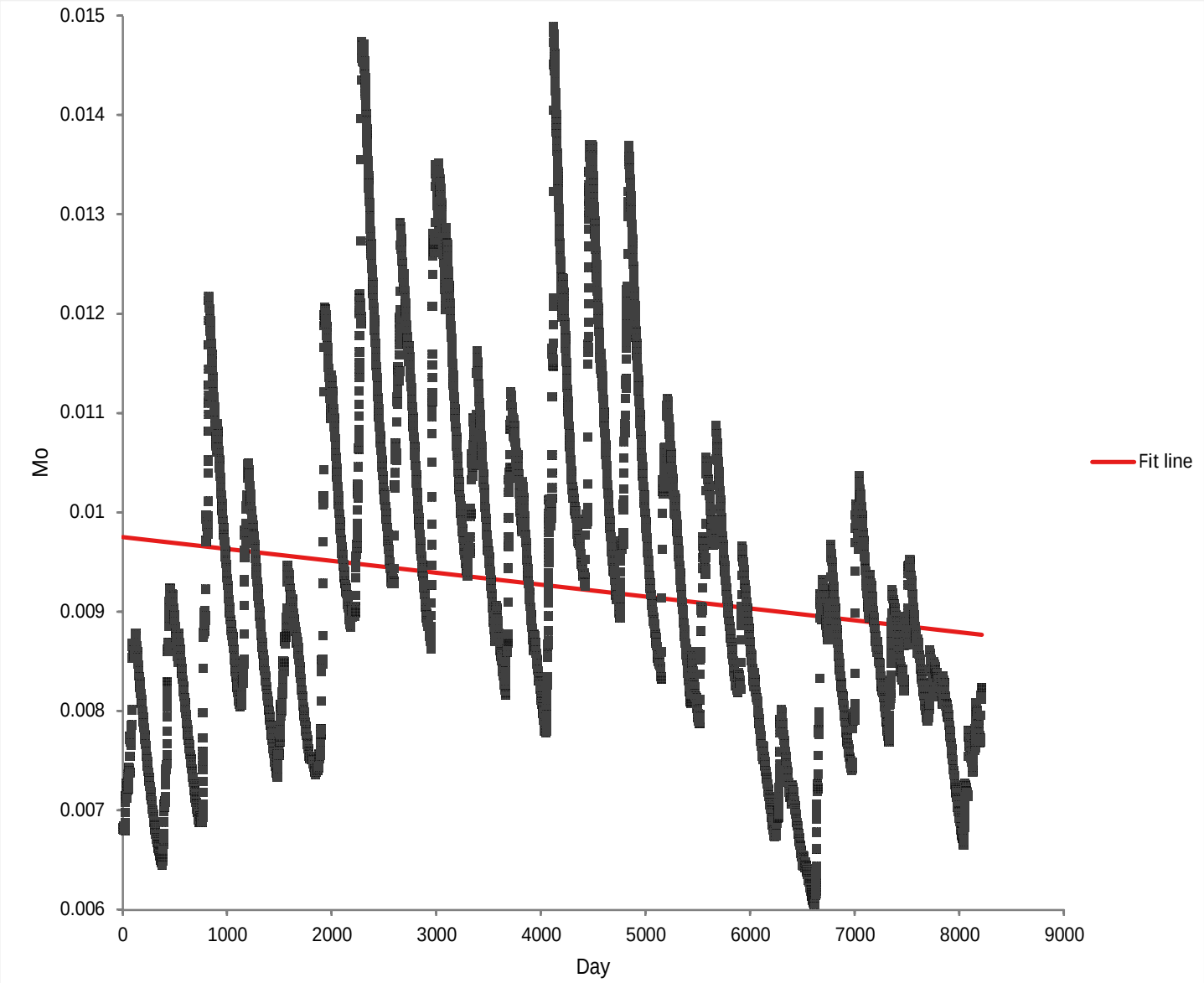
Fit: Mo

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:15 by Willy Van Vaerenbergh



Fit: Mo

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:15 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	0.00925920

Equation	Mo = 0.00975 - 1.194e-07 Day

R^2	0.029
R^2 adjusted	0.028
RMSE	0.001653340

Parameter	Estimate	95% CI	SE	t	p-value
Constant	0.009750	0.009699 to 0.009800	2.5798E-05	377.92	<0.0001
Day	-1.194E-07	-1.301E-07 to -1.088E-07	5.4391E-09	-21.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.00131785	1	0.00131785	482.10	<0.0001
Error	0.04490647	16428	0.00000273		
Null model	0.04622432	16429	0.00000281		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

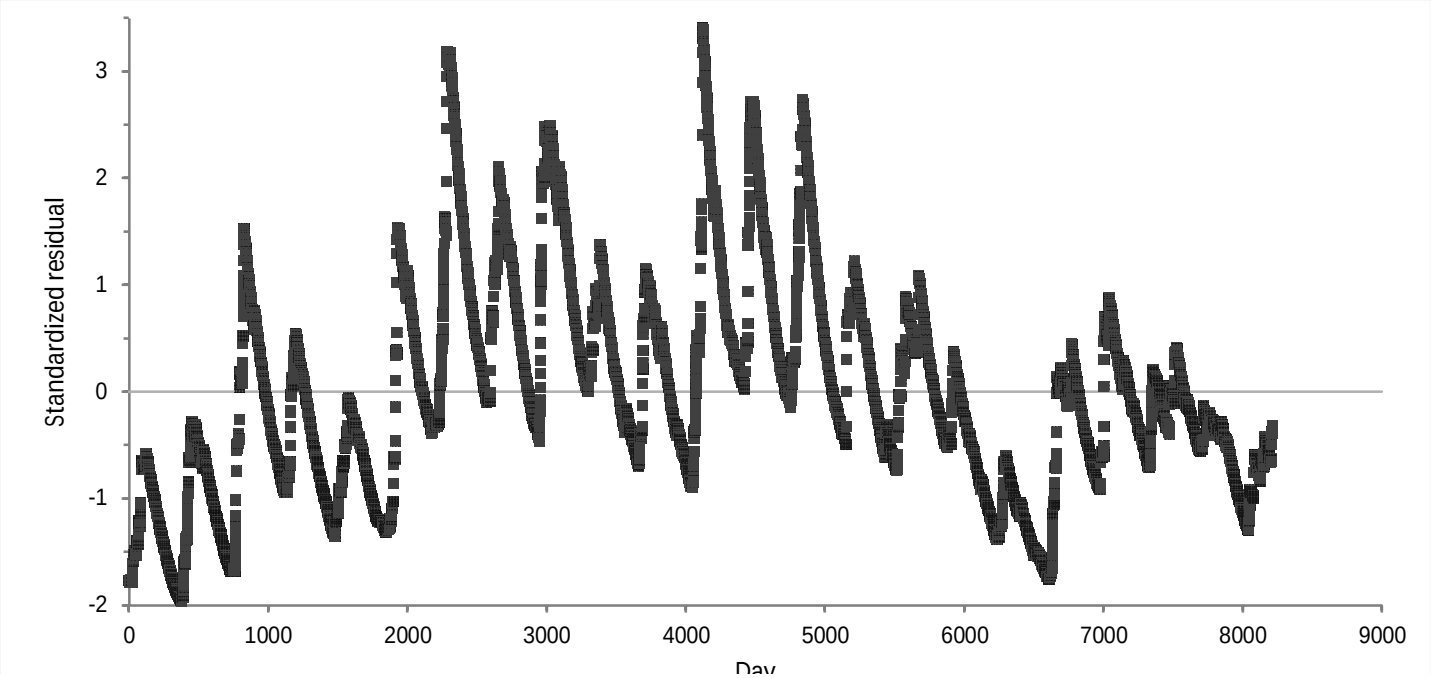
Fit: Mo

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:15 by Willy Van Vaerenbergh

Residuals

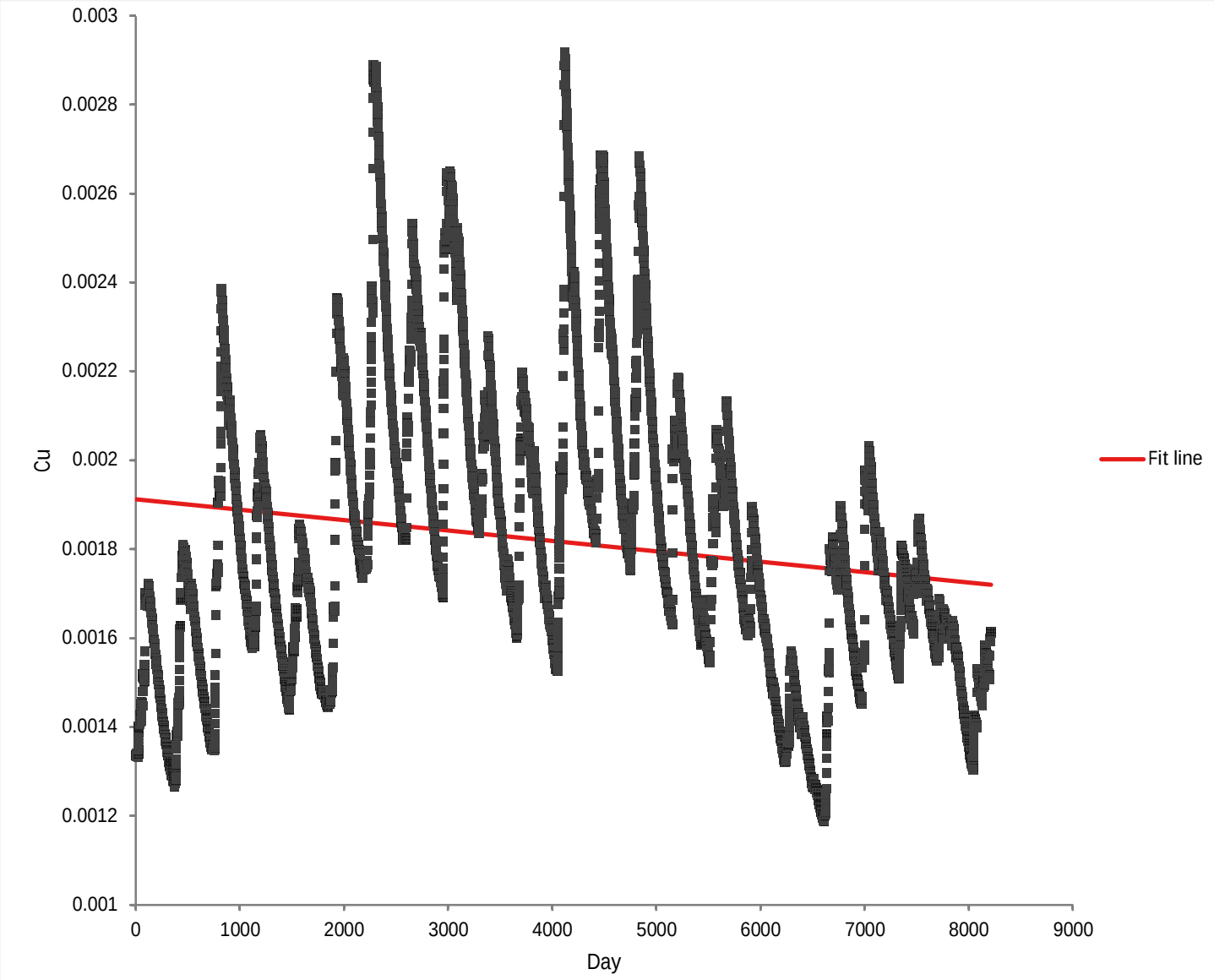


Fit: Cu

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:14 by Willy Van Vaerenbergh



Fit: Cu

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:14 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	0.00181553

Equation	Cu = 0.001912 - 2.342e-08 Day

R^2	0.029
R^2 adjusted	0.028
RMSE	0.000324185

Parameter	Estimate	95% CI	SE	t	p-value
Constant	0.001912	0.001902 to 0.001922	5.0585E-06	377.92	<0.0001
Day	-2.342E-08	-2.551E-08 to -2.133E-08	1.0665E-09	-21.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.00005067	1	0.00005067	482.11	<0.0001
Error	0.00172651	16428	0.00000011		
Null model	0.00177718	16429	0.00000011		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

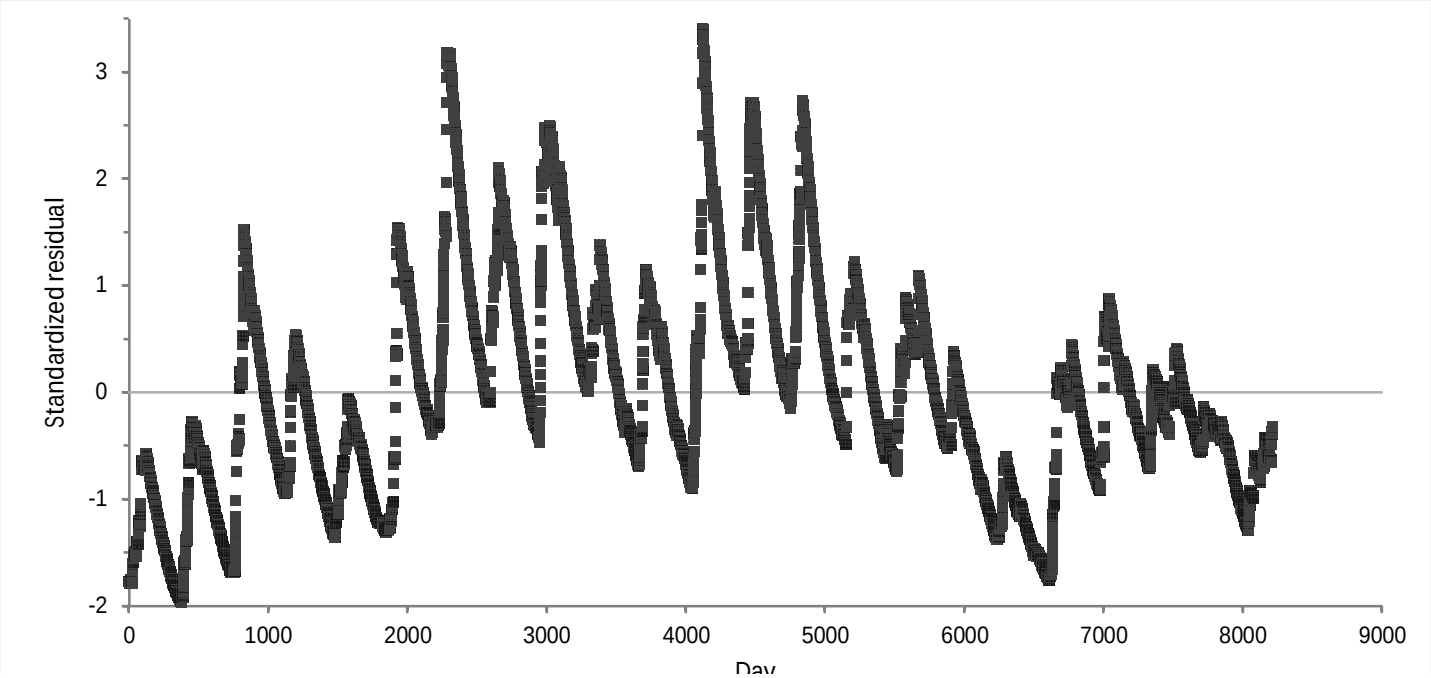
Fit: Cu

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:14 by Willy Van Vaerenbergh

Residuals

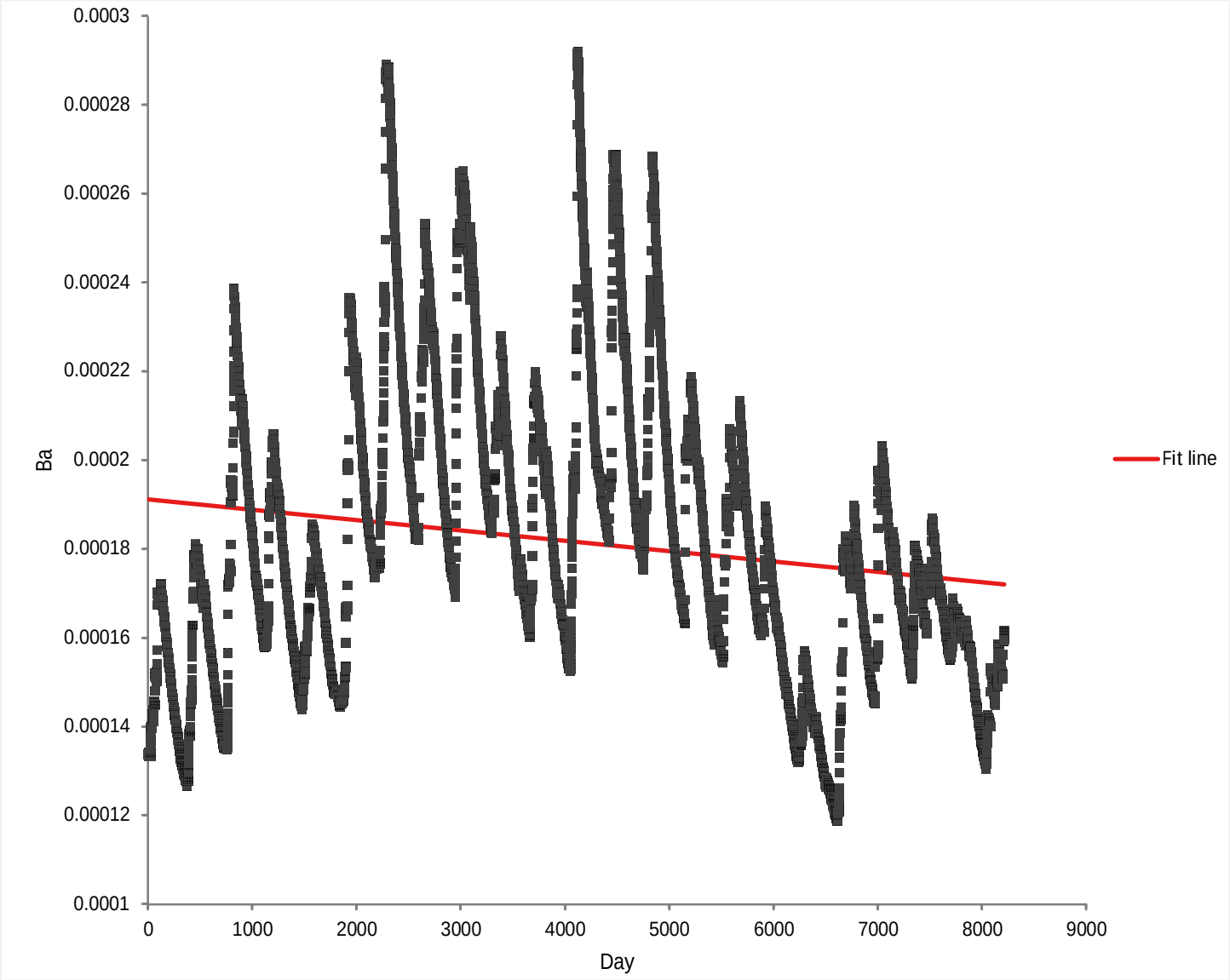


Fit: Ba

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:13 by Willy Van Vaerenbergh



Fit: Ba

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:13 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	0.000181570

Equation	Ba = 0.0001912 - 2.342e-09 Day

R^2	0.029
R^2 adjusted	0.028
RMSE	0.000032422

Parameter	Estimate	95% CI	SE	t	p-value
Constant	1.912E-04	1.902E-04 to 1.922E-04	5.0590E-07	377.92	<0.0001
Day	-2.342E-09	-2.551E-09 to -2.133E-09	1.0666E-10	-21.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.000000507	1	0.000000507	482.10	<0.0001
Error	0.000017268	16428	0.000000001		
Null model	0.000017775	16429	0.000000001		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

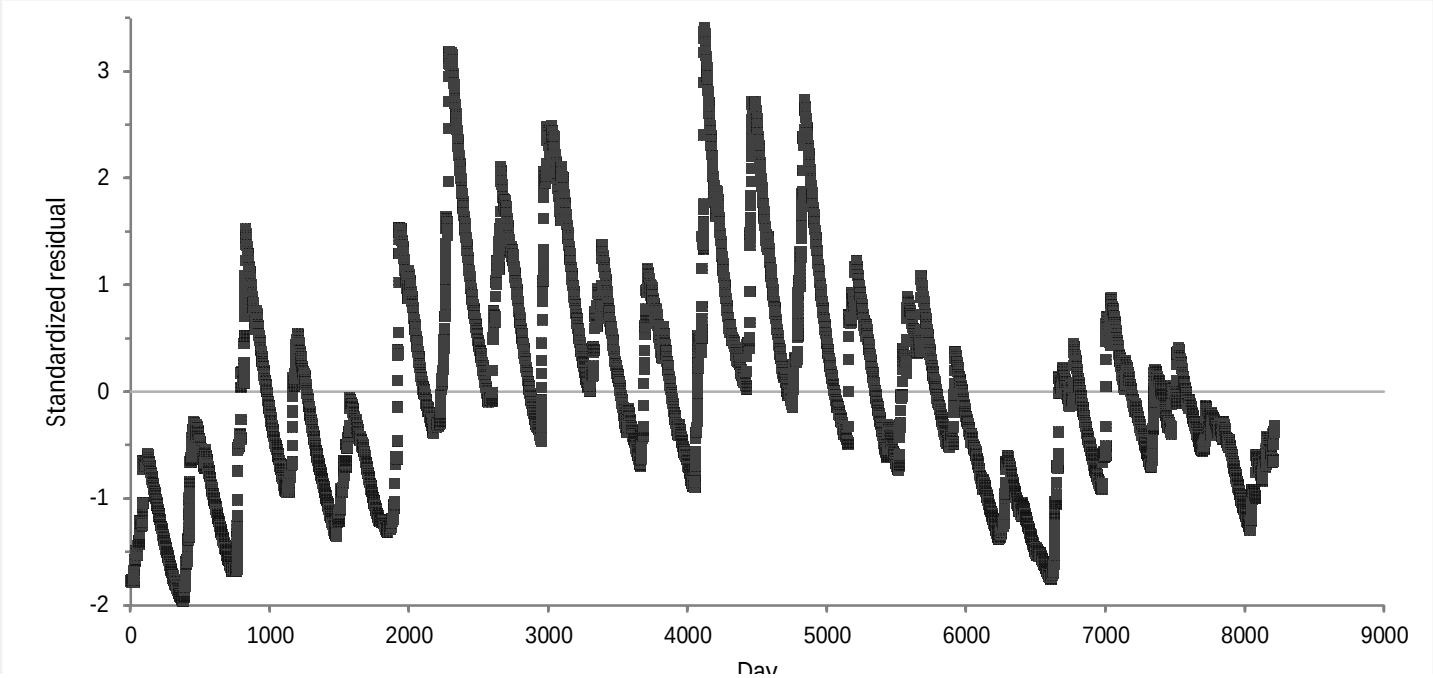
Fit: Ba

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:13 by Willy Van Vaerenbergh

Residuals

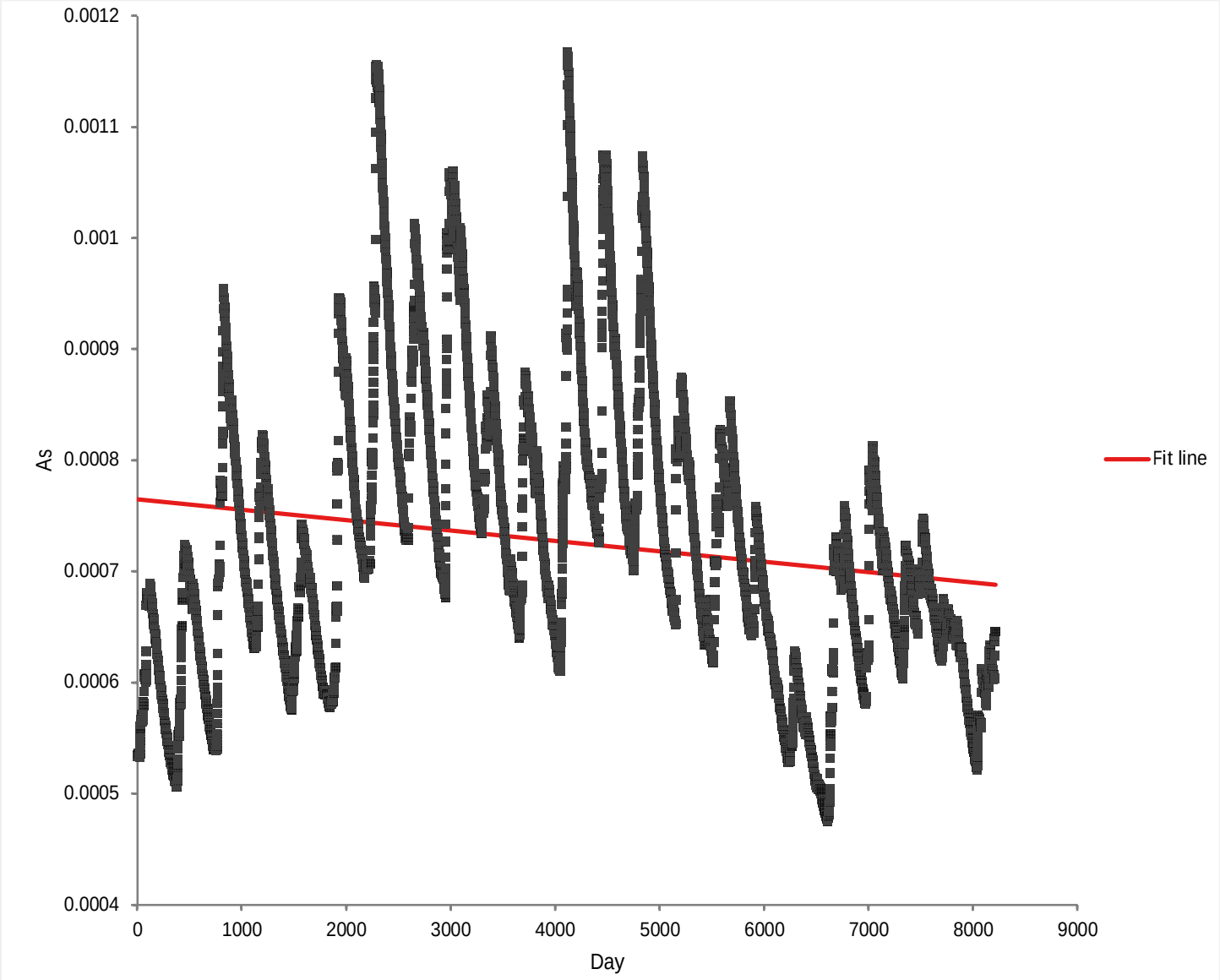


Fit: As

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:13 by Willy Van Vaerenbergh



Fit: As

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:13 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	0.000726212

Equation	As = 0.0007647 - 9.367e-09 Day

R^2	0.029
R^2 adjusted	0.028
RMSE	0.000129674

Parameter	Estimate	95% CI	SE	t	p-value
Constant	7.647E-04	7.607E-04 to 7.687E-04	2.0234E-06	377.92	<0.0001
Day	-9.367E-09	-1.020E-08 to -8.531E-09	4.2660E-10	-21.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.000008107	1	0.000008107	482.11	<0.0001
Error	0.000276242	16428	0.000000017		
Null model	0.000284349	16429	0.000000017		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

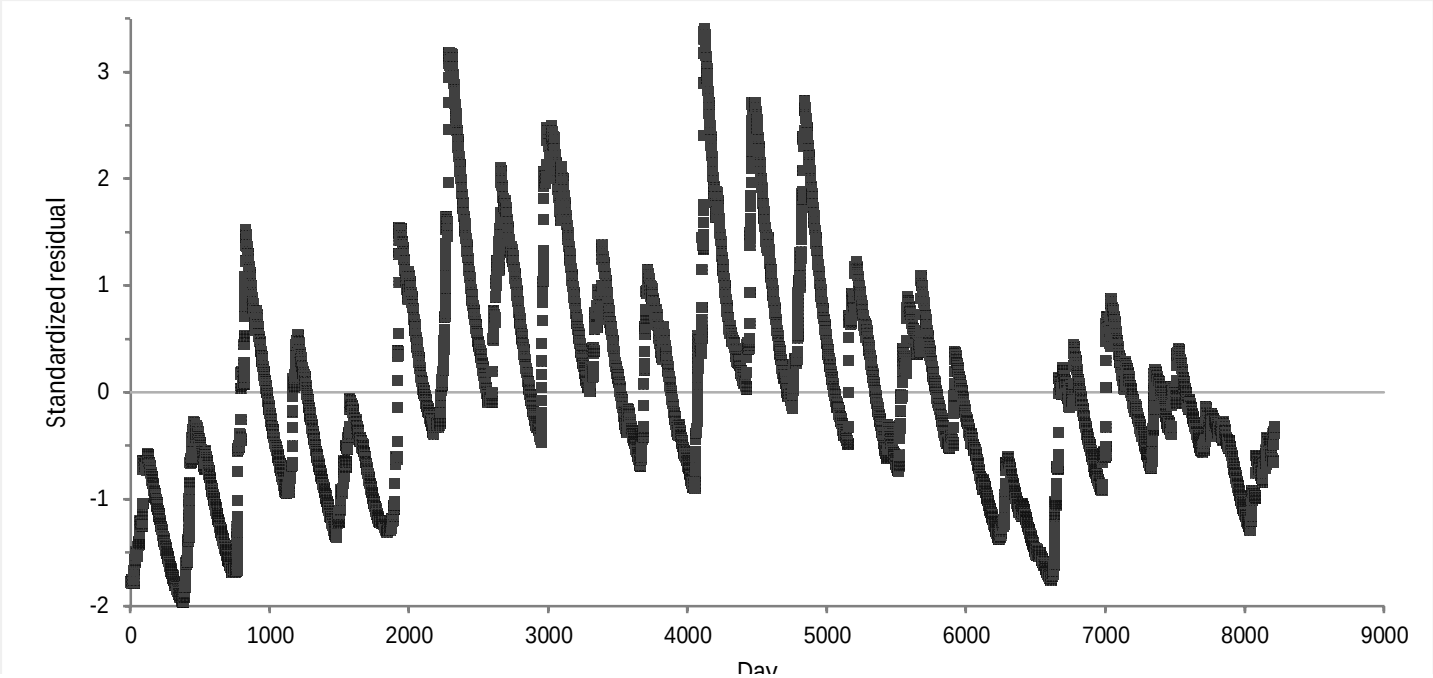
Fit: As

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:13 by Willy Van Vaerenbergh

Residuals



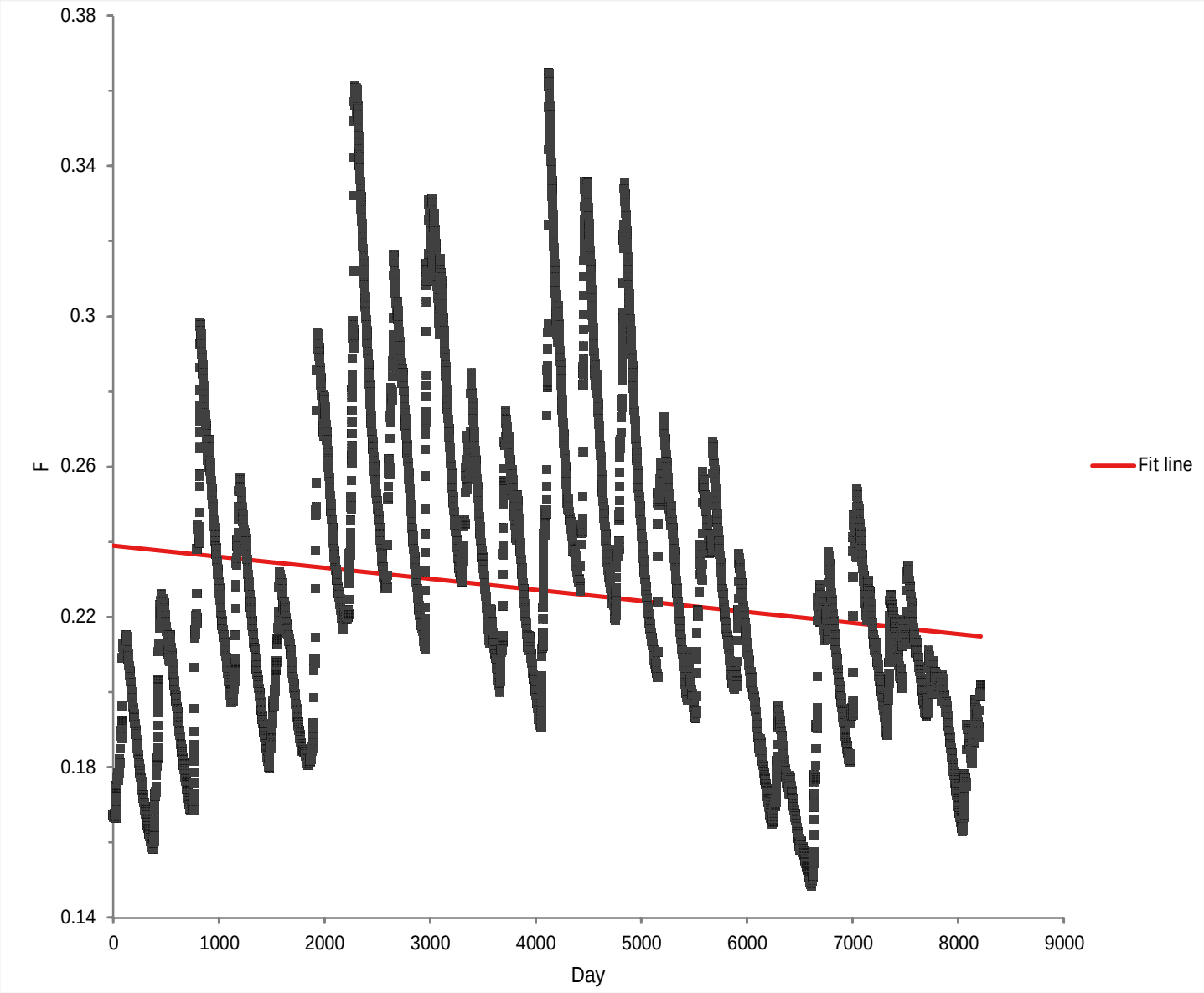
Fit: F

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:12 by Willy Van Vaerenbergh



Fit: F

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:12 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	0.226941

Equation	F = 0.239 - 2.927e-06 Day

R^2	0.029
R^2 adjusted	0.028
RMSE	0.0405231

Parameter	Estimate	95% CI	SE	t	p-value
Constant	0.2390	0.2377 to 0.2402	6.3232E-04	377.92	<0.0001
Day	-2.927E-06	-3.188E-06 to -2.666E-06	1.3331E-07	-21.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	0.791676	1	0.791676	482.11	<0.0001
Error	26.976772	16428	0.001642		
Null model	27.768448	16429	0.001690		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

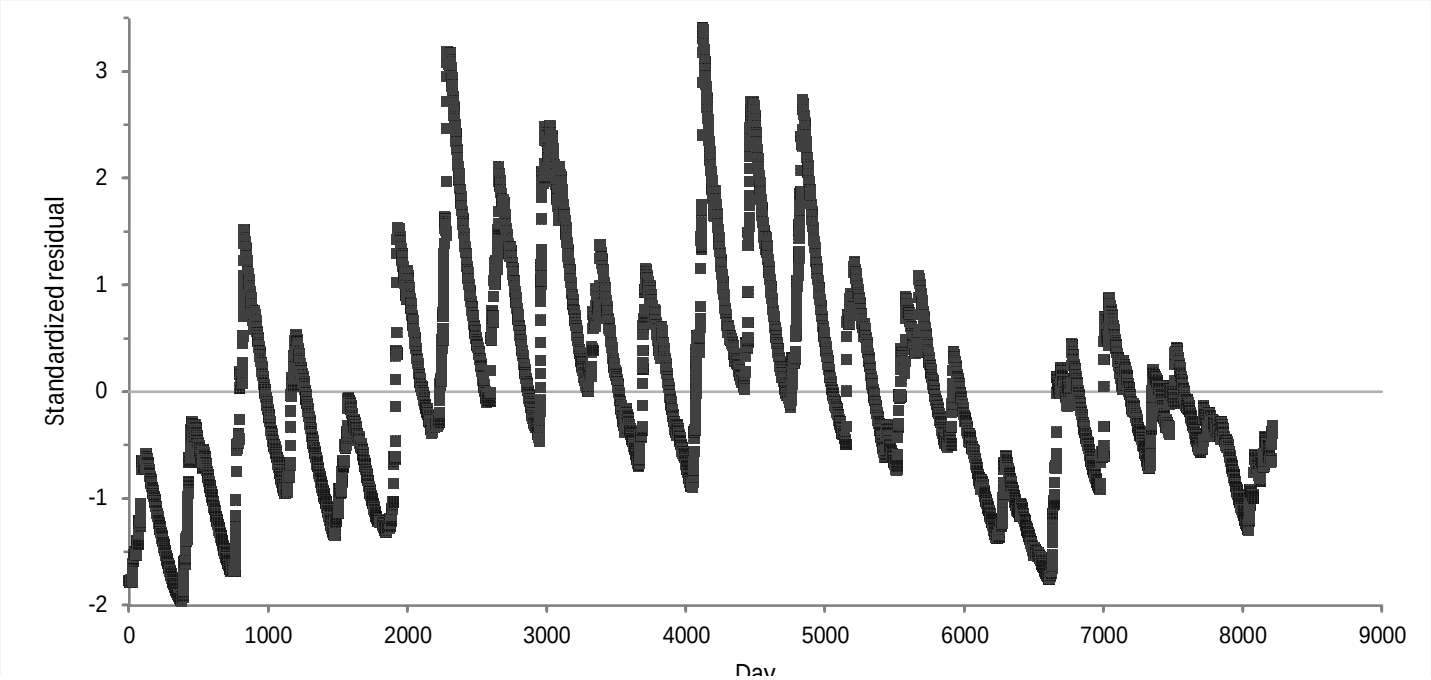
Fit: F

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:12 by Willy Van Vaerenbergh

Residuals



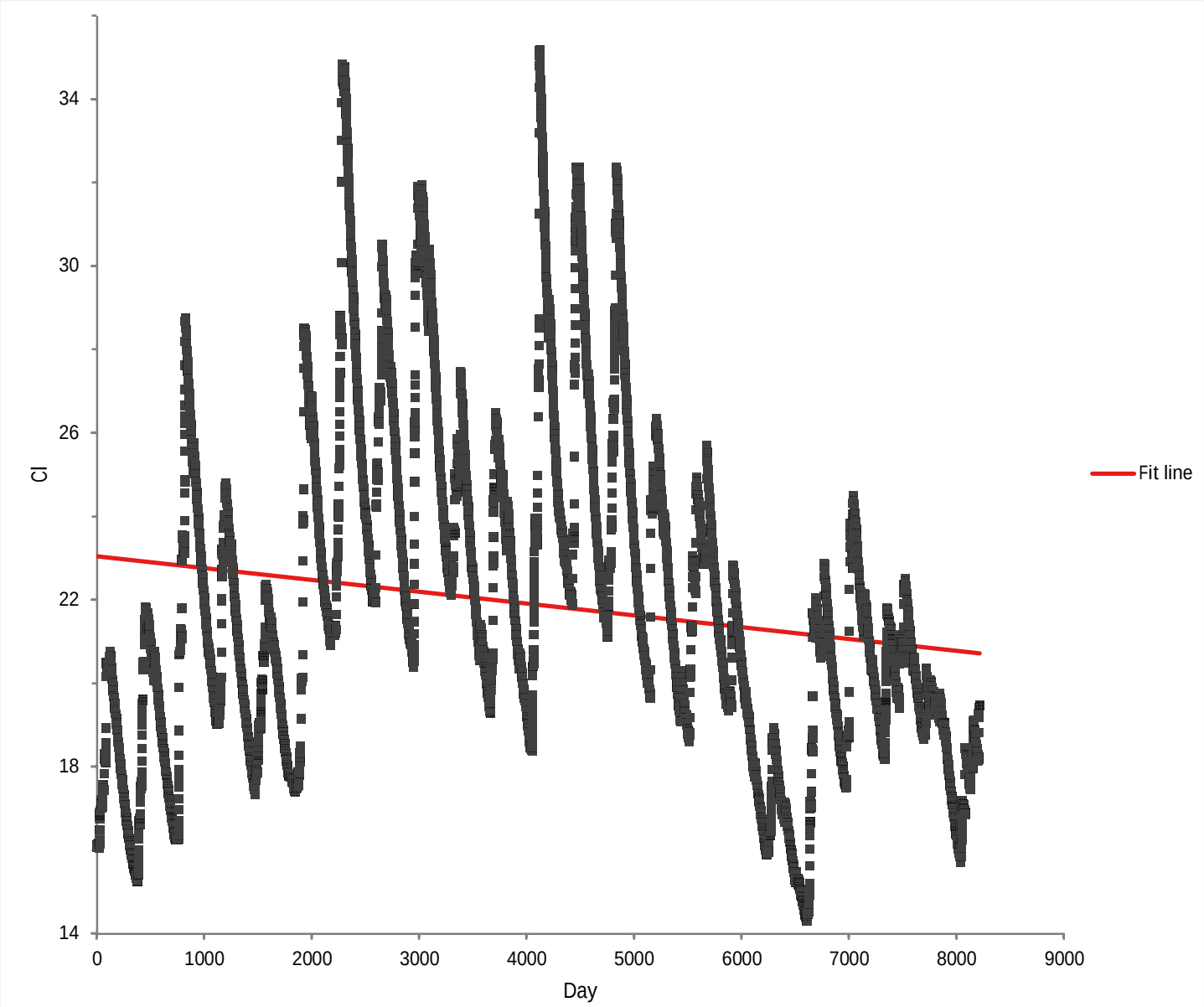
Fit: Cl

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:11 by Willy Van Vaerenbergh



Fit: Cl

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:11 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	21.8800

Equation	Cl = 23.04 - 0.0002822 Day

R^2	0.029
R^2 adjusted	0.028
RMSE	3.90695

Parameter	Estimate	95% CI	SE	t	p-value
Constant	23.04	22.92 to 23.16	0.060963	377.92	<0.0001
Day	-2.822E-04	-3.074E-04 to -2.570E-04	1.2853E-05	-21.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	7359.0545	1	7359.0545	482.11	<0.0001
Error	250760.8923	16428	15.2642		
Null model	258119.9468	16429	15.7112		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

Fit: Cl

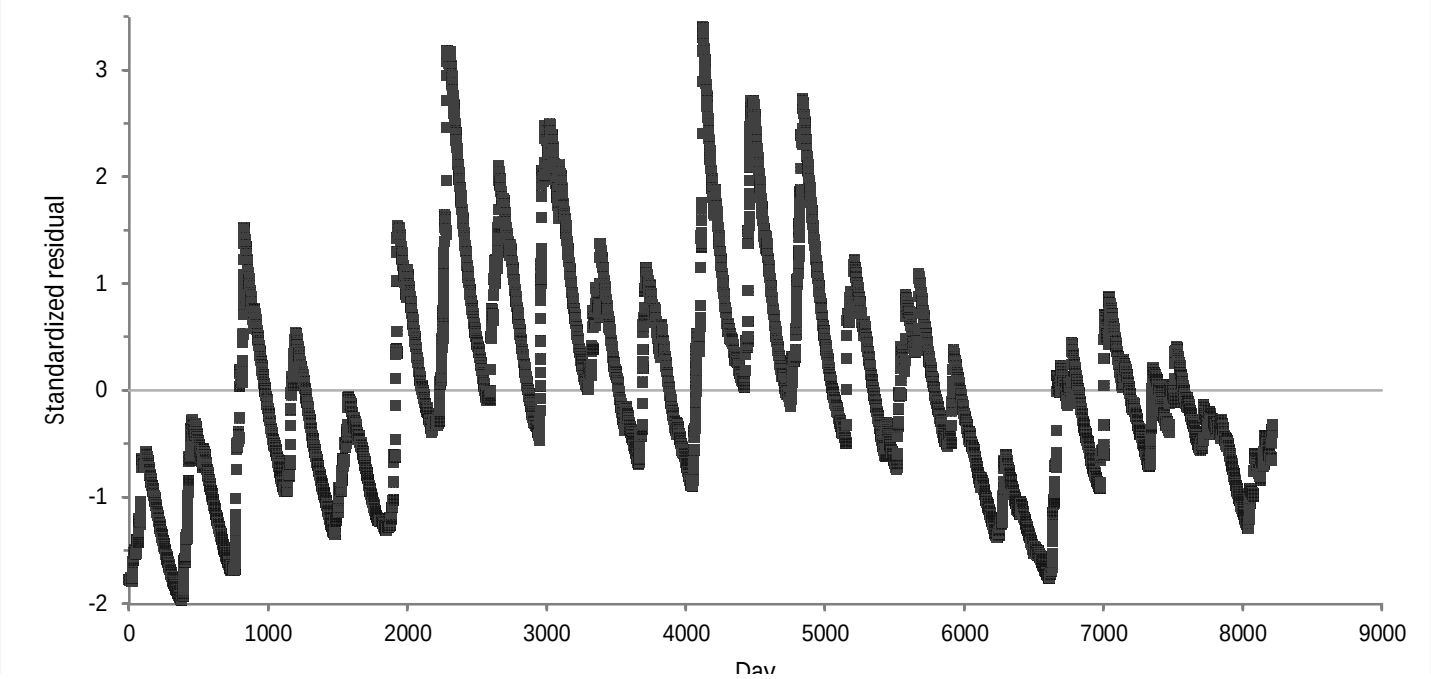
Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:11 by Willy Van Vaerenbergh

Residuals



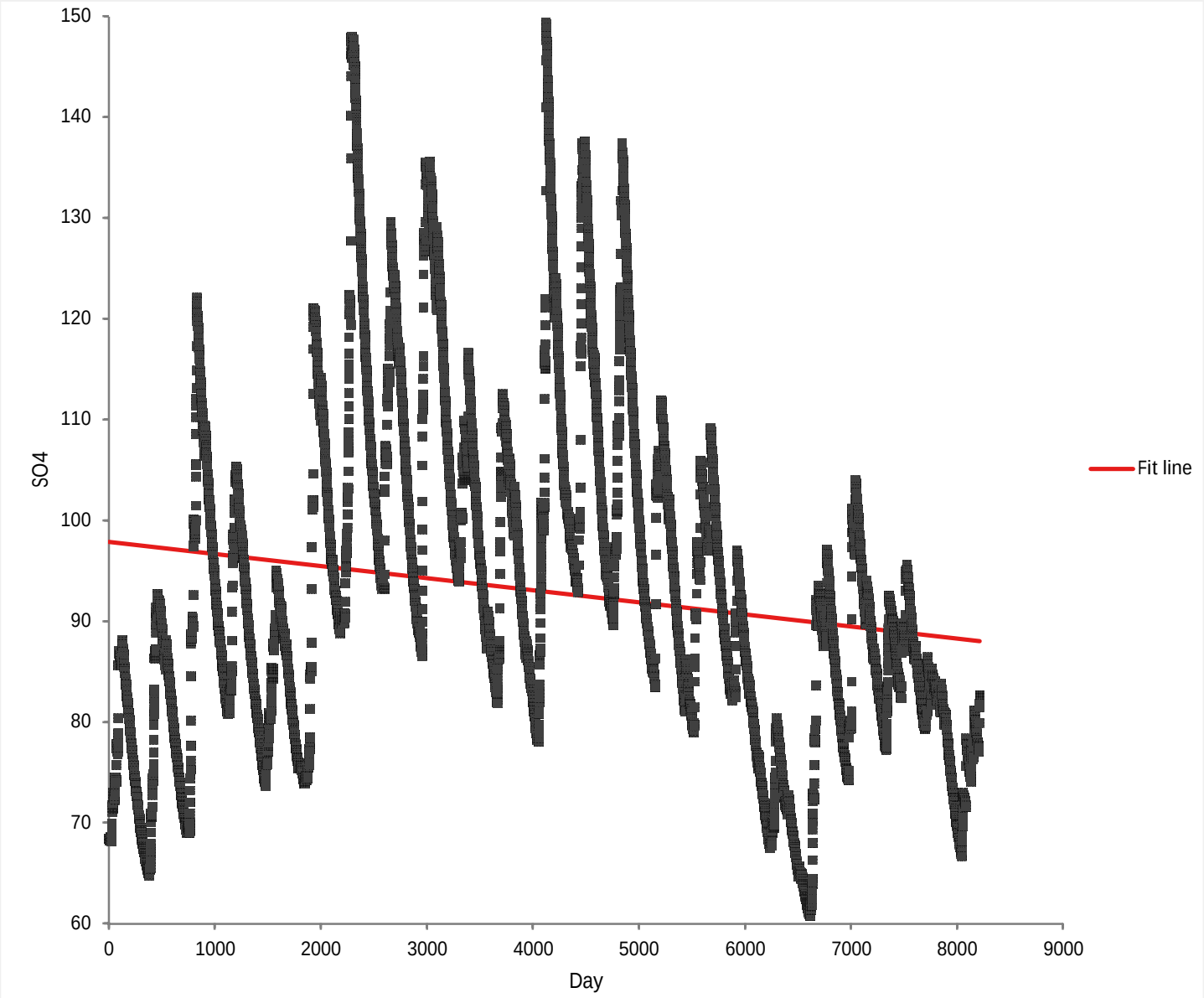
Fit: SO4

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:11 by Willy Van Vaerenbergh



Fit: SO4

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:11 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	92.9377

Equation	SO4 = 97.86 - 0.001199 Day

R^2	0.029
R^2 adjusted	0.028
RMSE	16.59515

Parameter	Estimate	95% CI	SE	t	p-value
Constant	97.86	97.35 to 98.37	0.25895	377.92	<0.0001
Day	-0.001199	-0.001306 to -0.001092	5.4594E-05	-21.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	132771.7613	1	132771.7613	482.11	<0.0001
Error	4524256.1238	16428	275.3991		
Null model	4657027.8851	16429	283.4639		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

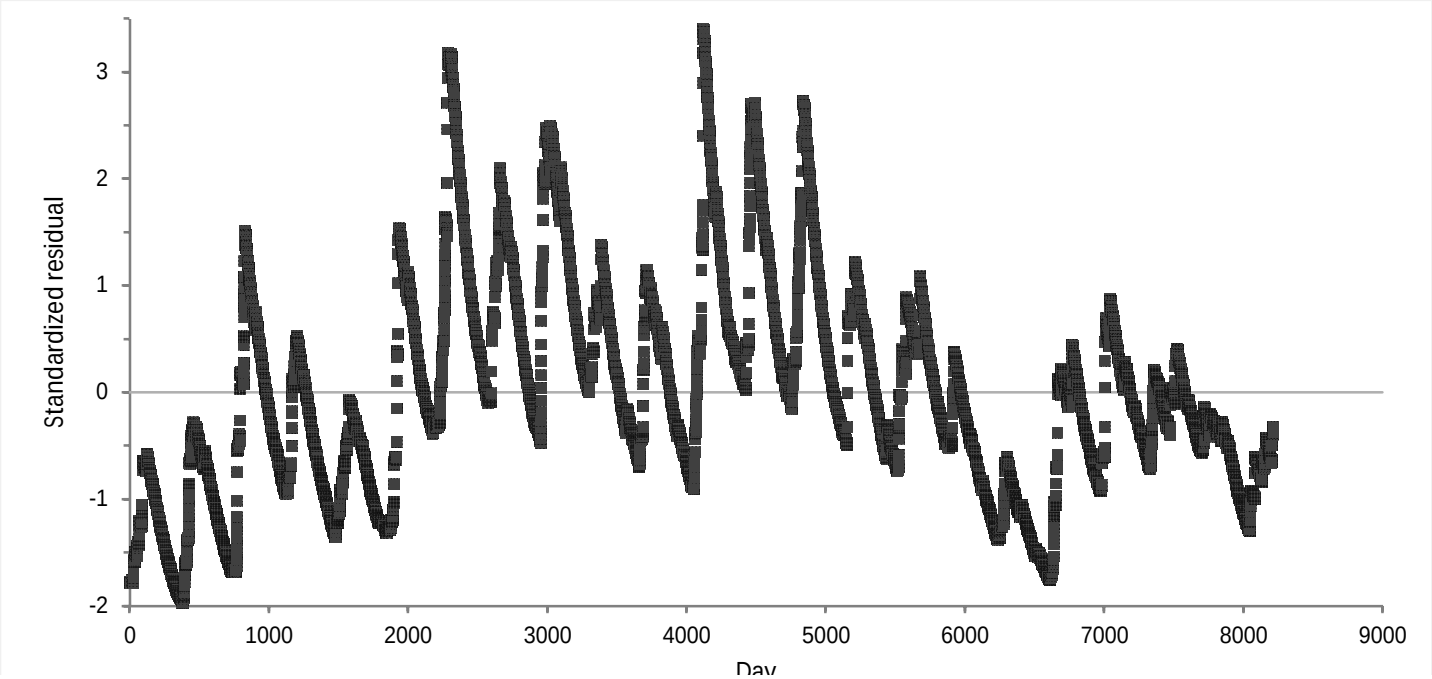
Fit: SO4

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:11 by Willy Van Vaerenbergh

Residuals



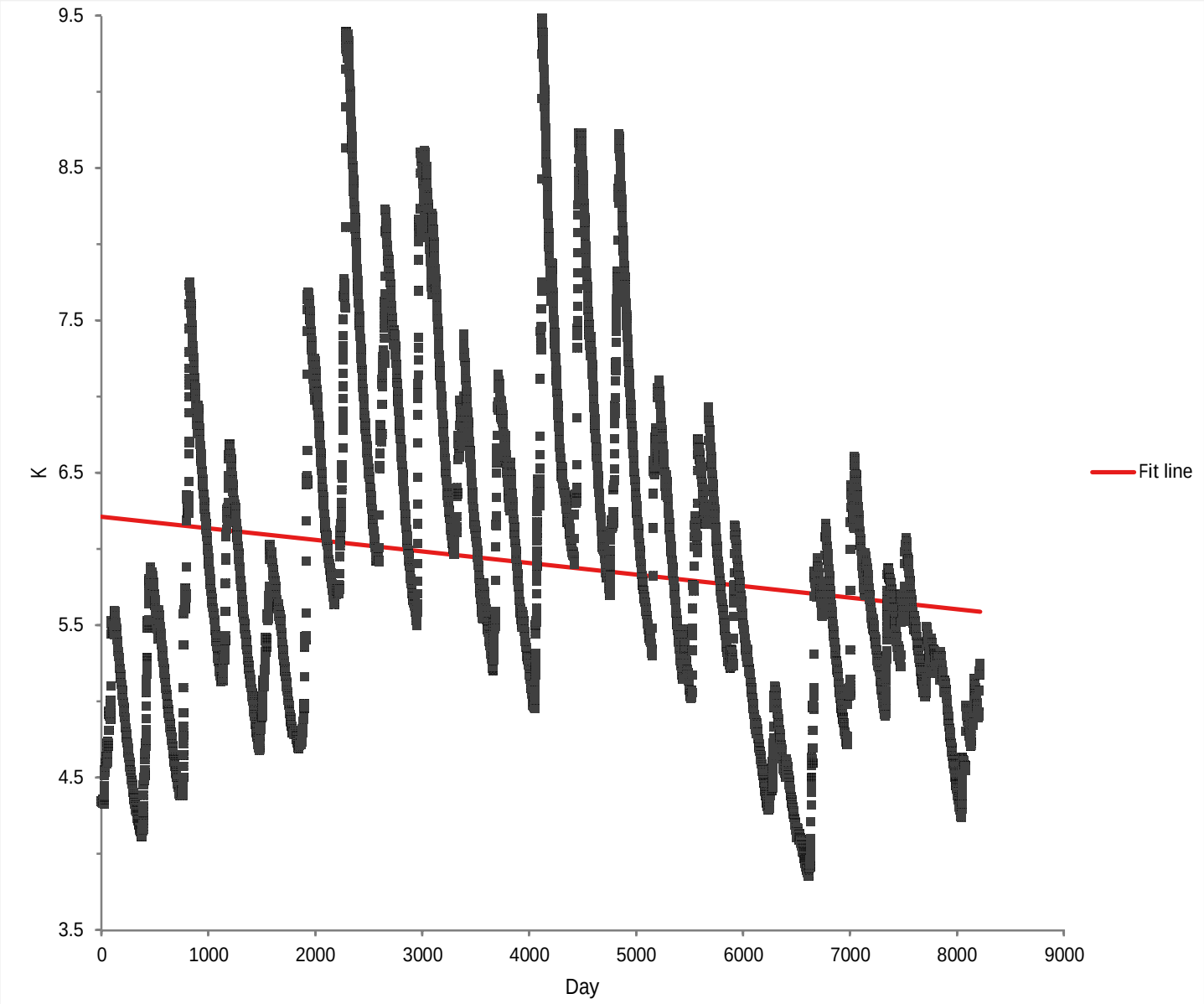
Fit: K

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:10 by Willy Van Vaerenbergh



Fit: K

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:10 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	5.90103

Equation	K = 6.214 - 7.611e-05 Day

R^2	0.029
R^2 adjusted	0.028
RMSE	1.053700

Parameter	Estimate	95% CI	SE	t	p-value
Constant	6.214	6.181 to 6.246	0.016442	377.92	<0.0001
Day	-7.611E-05	-8.291E-05 to -6.932E-05	3.4664E-06	-21.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	535.27367	1	535.27367	482.10	<0.0001
Error	18239.75437	16428	1.11028		
Null model	18775.02804	16429	1.14280		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

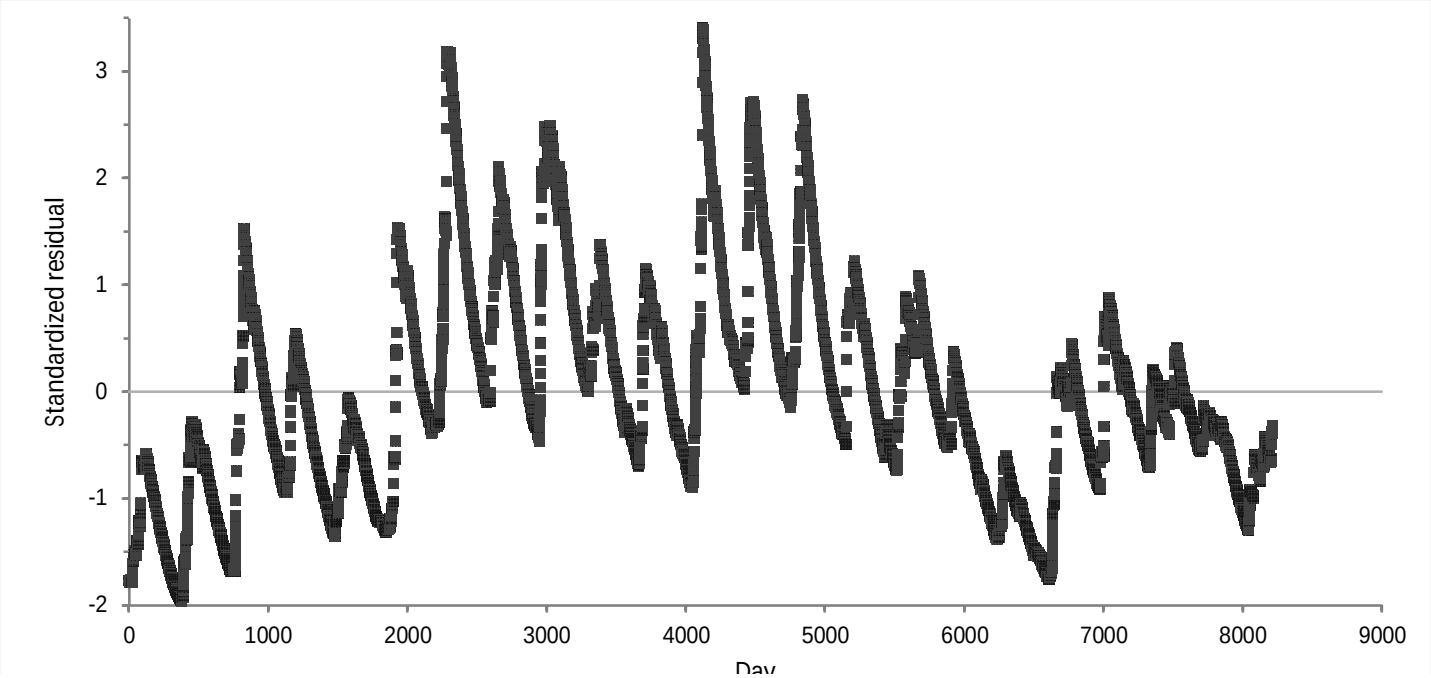
Fit: K

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:10 by Willy Van Vaerenbergh

Residuals

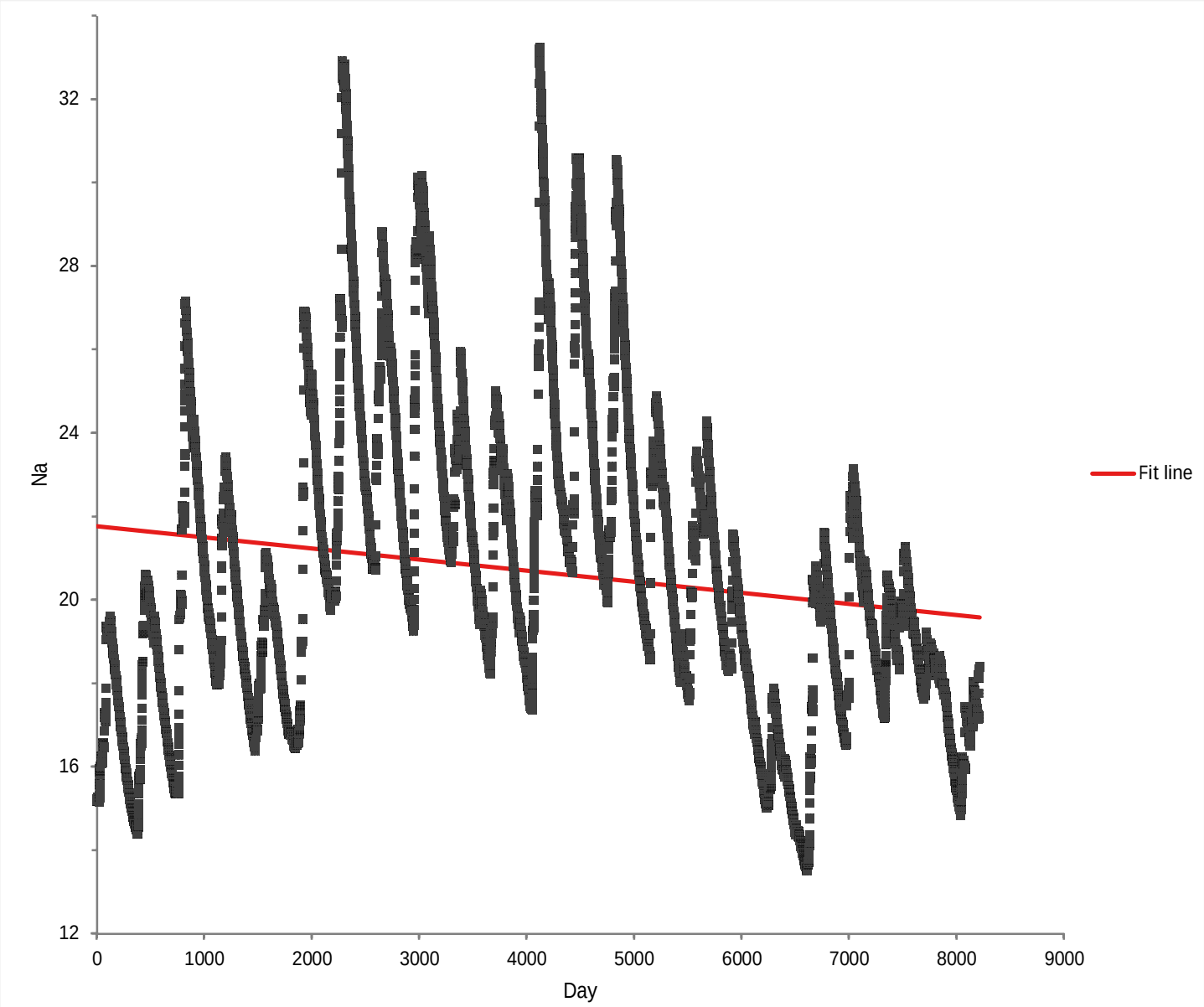


Fit: Na

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:09 by Willy Van Vaerenbergh



Fit: Na

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:09 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	20.6662

Equation	Na = 21.76 - 0.0002666 Day

R^2	0.029
R^2 adjusted	0.028
RMSE	3.69020

Parameter	Estimate	95% CI	SE	t	p-value
Constant	21.76	21.65 to 21.87	0.057581	377.92	<0.0001
Day	-2.666E-04	-2.904E-04 to -2.428E-04	1.2140E-05	-21.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	6565.1491	1	6565.1491	482.11	<0.0001
Error	223709.4365	16428	13.6176		
Null model	230274.5856	16429	14.0163		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

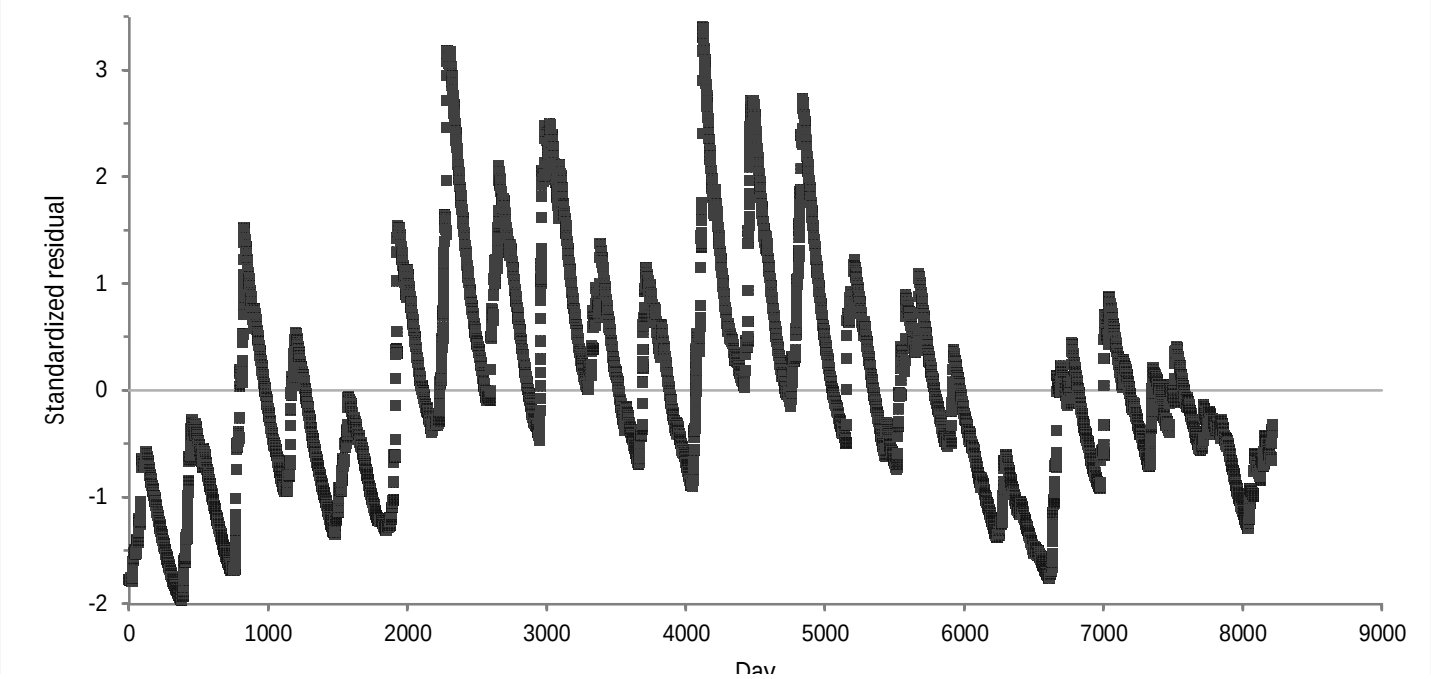
Fit: Na

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:09 by Willy Van Vaerenbergh

Residuals



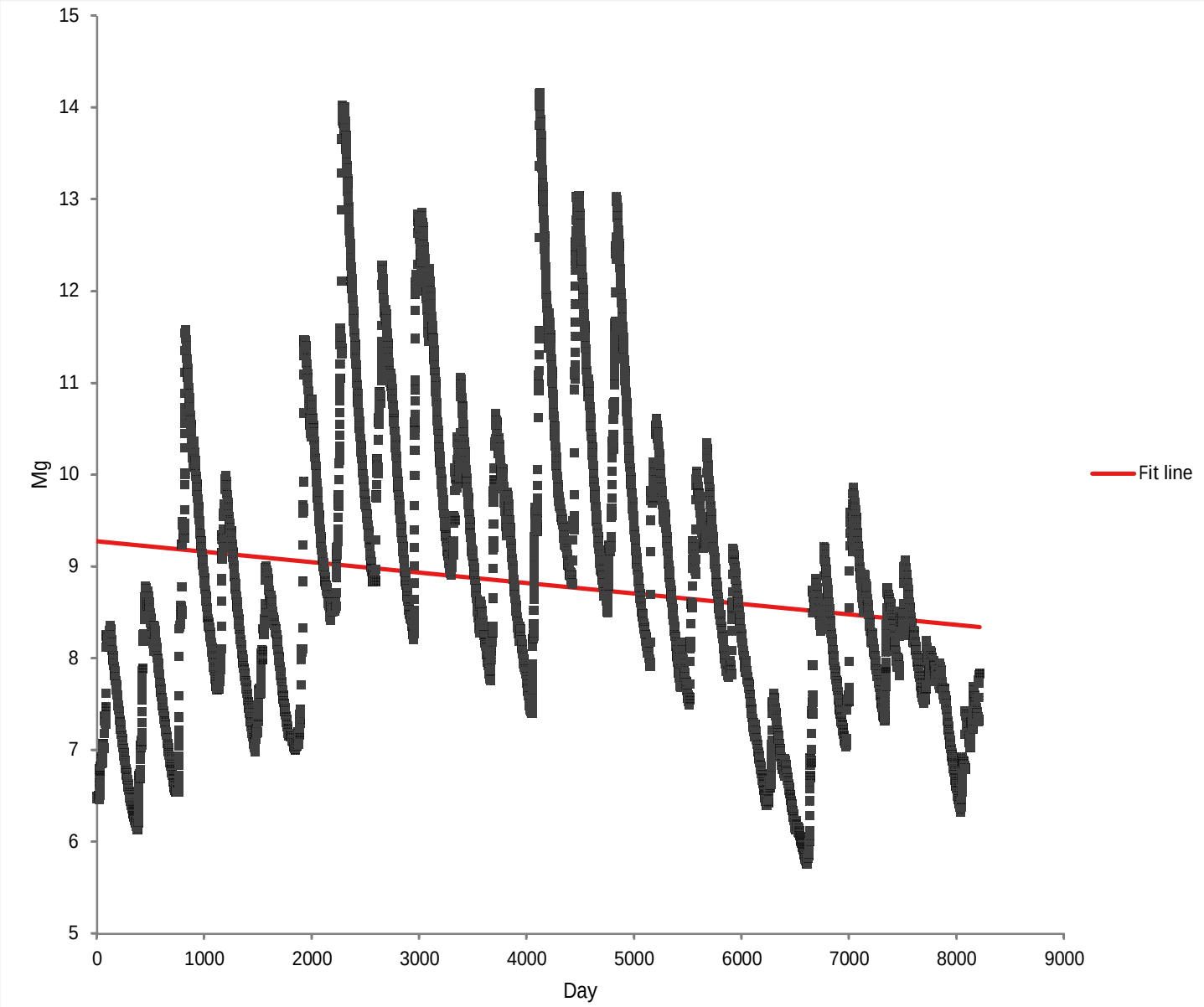
Fit: Mg

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:08 by Willy Van Vaerenbergh



Fit: Mg

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:08 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	8.80785

Equation	Mg = 9.275 - 0.0001136 Day

R^2	0.029
R^2 adjusted	0.028
RMSE	1.572750

Parameter	Estimate	95% CI	SE	t	p-value
Constant	9.275	9.226 to 9.323	0.024541	377.92	<0.0001
Day	-1.136E-04	-1.237E-04 to -1.035E-04	5.1740E-06	-21.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	1192.50640	1	1192.50640	482.10	<0.0001
Error	40635.33752	16428	2.47354		
Null model	41827.84391	16429	2.54598		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

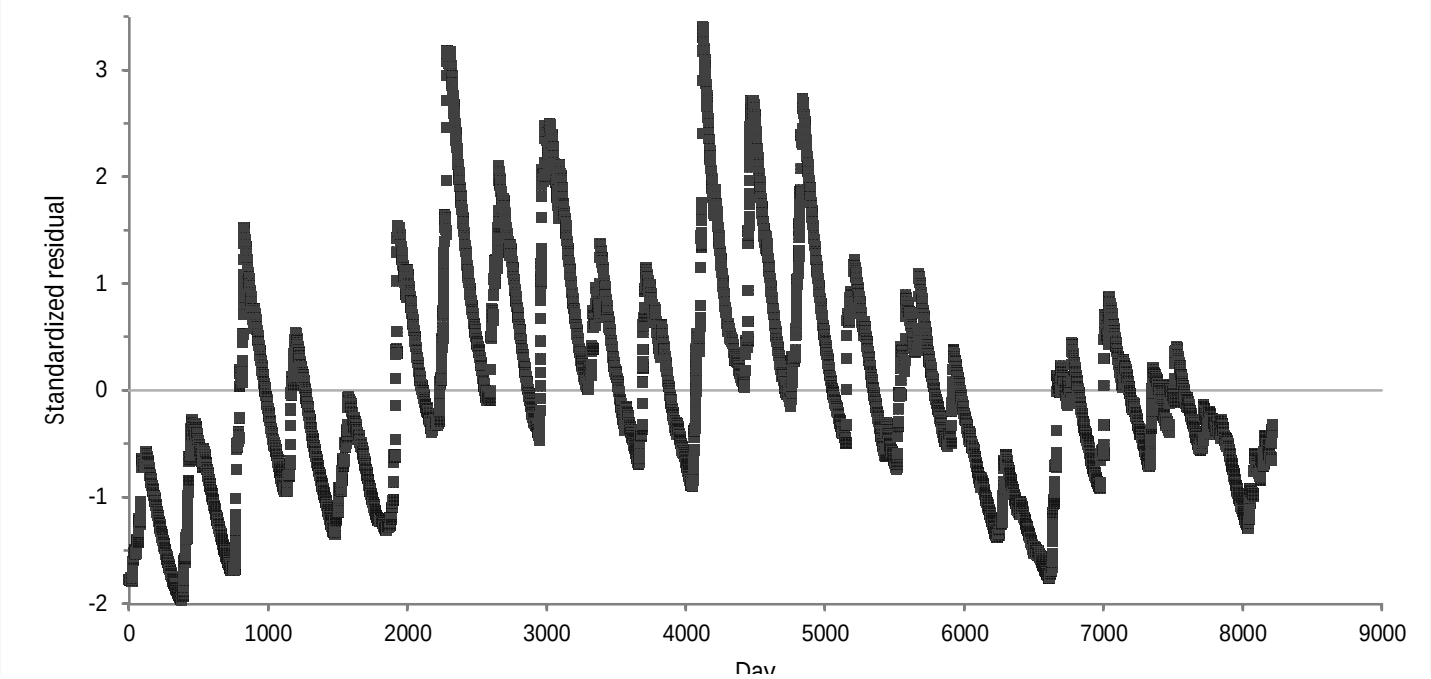
Fit: Mg

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:08 by Willy Van Vaerenbergh

Residuals

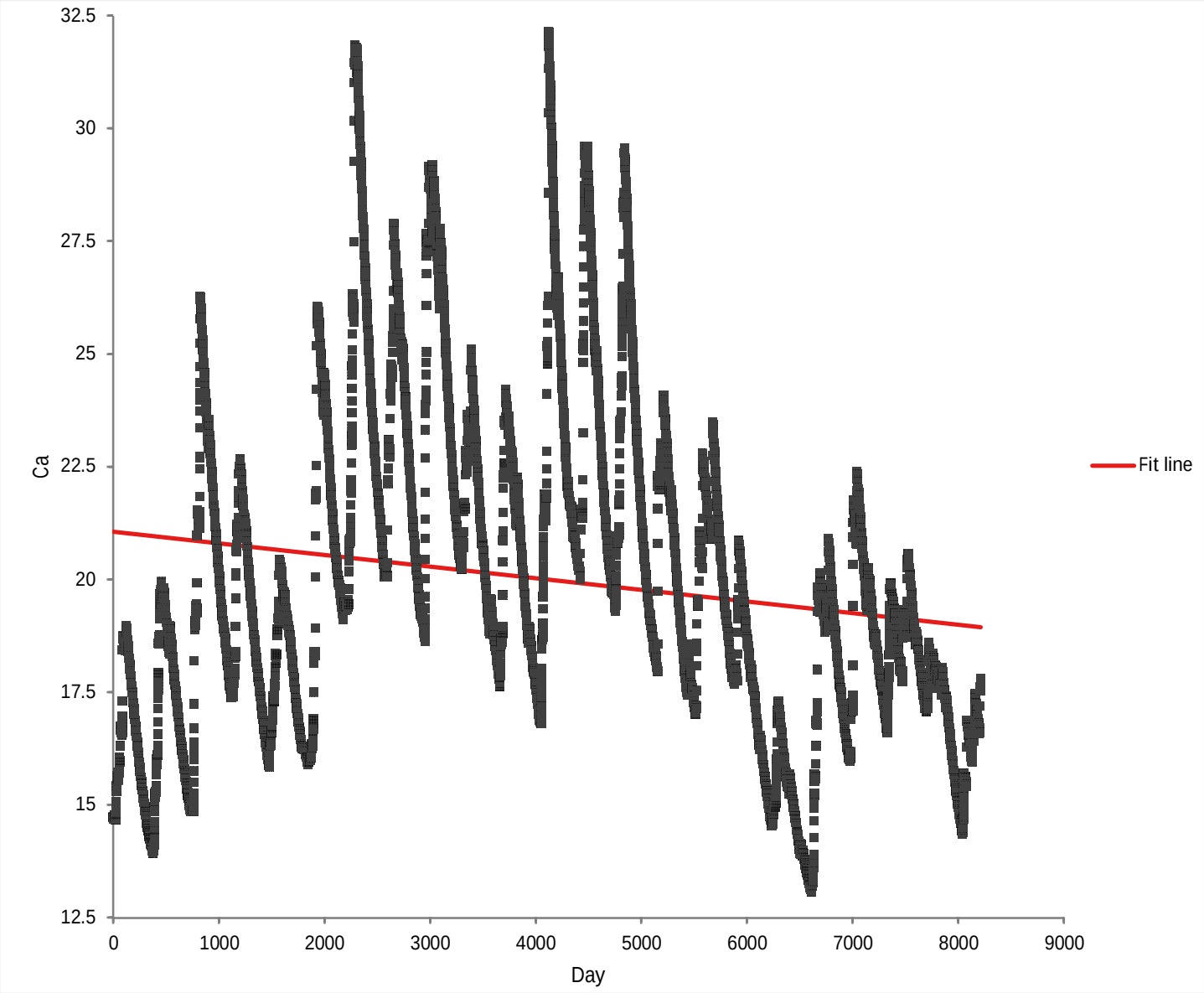


Fit: Ca

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:06 by Willy Van Vaerenbergh



Fit: Ca

Analyse-it v5.80.2

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:06 by Willy Van Vaerenbergh

Fit

N	16430
Mean of Y	20.0009

Equation	Ca = 21.06 - 0.000258 Day

R^2	0.029
R^2 adjusted	0.028
RMSE	3.57140

Parameter	Estimate	95% CI	SE	t	p-value
Constant	21.06	20.95 to 21.17	0.055727	377.92	<0.0001
Day	-2.580E-04	-2.810E-04 to -2.349E-04	1.1749E-05	-21.96	<0.0001

H0: $\beta = 0$
The parameter is equal to 0.
H1: $\beta \neq 0$
The parameter is not equal to 0.

Effect of Model

Source	SS	DF	MS	F	p-value
Difference	6149.1985	1	6149.1985	482.11	<0.0001
Error	209537.1522	16428	12.7549		
Null model	215686.3507	16429	13.1284		

H0: $E(Y|X=x) = \mu$
The model is no better than a null model $Y=\mu$.
H1: $E(Y|X=x) = \alpha + \beta x$
The model is better than the null model.

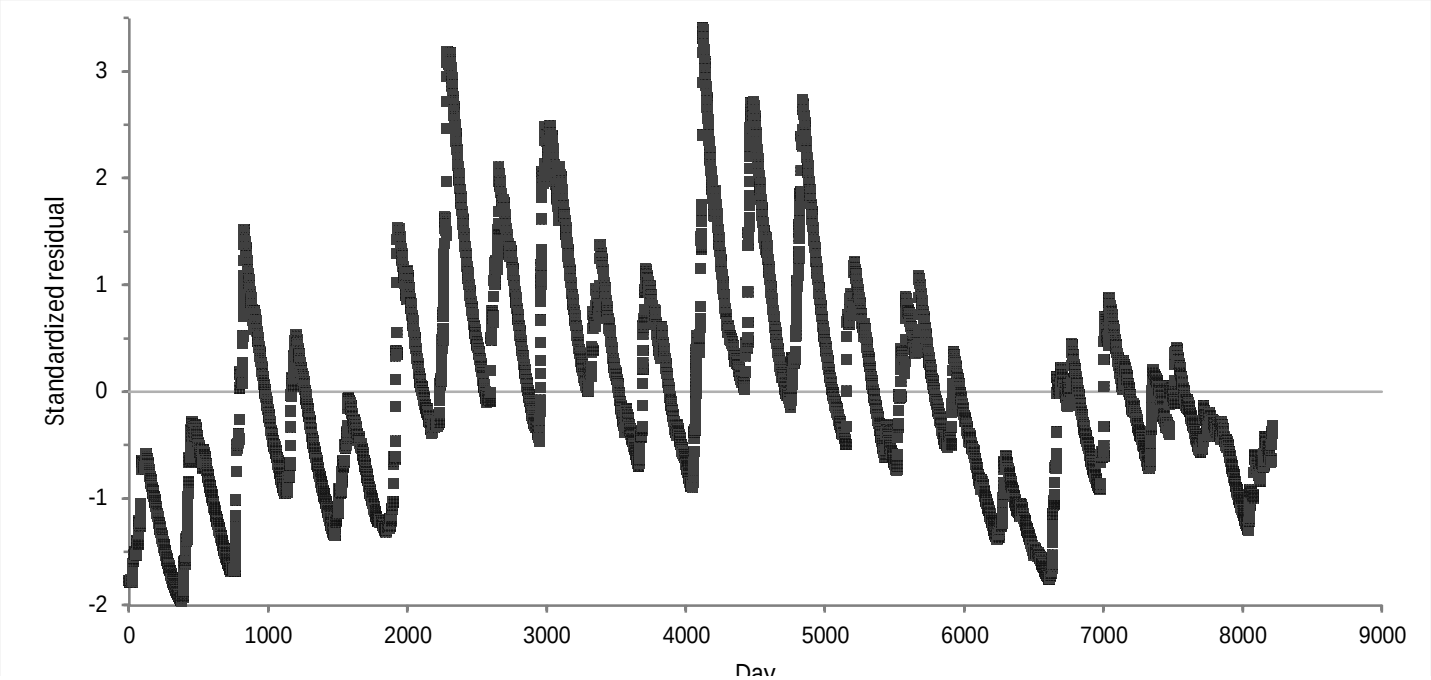
Fit: Ca

Sheet1 (2) A28:AF16458

Filter: No filter

Last updated 29 May 2024 at 21:06 by Willy Van Vaerenbergh

Residuals



Technical Memorandum

WMV Environmental Pty Ltd
PO Box 597
Cannon Hill QLD 4170

From:	Willy Van Vaerenbergh
To:	Gemma Brown, Principal Environment & Mine Closure Planning
Cc:	David Eason, Senior Environment & Community Advisor
Date:	19 August 2024
Project:	J23011 – BCP UG Stage 1 EA Amendment
Re:	Water Balance and Water Quality Modelling Results

1 Introduction

1.1 Proposed underground development project

The Barbara Copper Project (BCP or the Project) is a former open-cut copper and gold mine located within Mining Lease (ML) ML90241. BCP is authorised under Environmental Authority (EA) EPML02840015 for resource activities relevant to mining metals (copper, lead, silver, zinc, gold and iron ore). The Project is an open-cut copper mine that has extracted approximately 772,000 tonnes of ore. The mine operated from June 2019 until March 2021 and was placed in care and maintenance in April 2021.

Round Oak Minerals Pty Limited (Round Oak Minerals), wholly owned by Aeris Resources Limited (Aeris), is the EA holder. Aeris plans to extract a significant copper-gold resource that remains under the South Pit through underground (UG) mining, with the development of the underground mine to be undertaken in two distinct stages, i.e. a, Stage 1 and Stage 2 development.

Stage 1 underground development

Stage 1 of the underground mine development would include surface and underground drilling for mineral resource definition and some stoping, as presented in Figure 1. Relevant information regarding stage 1 is as follows:

- Stage 1 development would be undertaken over a 24-month period between January 2025 and December 2026/January 2027.
- Dewatering of the South Pit is not required.
- The crown pillar will not be removed during the Stage 1 development.
- NAF waste from the development (±250 kilo tonnes) will be hauled to the existing waste rock dump (WRD) for temporary storage, with PAF waste (±40 ktonnes) hauled to the ROM pad for temporary storage
- There will be no movement of in-situ waste rock from the existing WRD as fill for underground stopes during this stage of mining as the waste generated by underground mine development will be sufficient for stope fill, with surplus NAF, also from the underground development, to be rehandled underground in voids at the end of Stage 1.

Aeris is seeking a minor amendment of the current EA for the implementation of the Stage 1 development. Following the completion of the Stage 1 development, Aeris may decide to implement a Stage 2 development, which would likely require a major EA amendment. Alternatively, Aeris may decide not to proceed with the Stage 2 development, with the Project transitioning to rehabilitation and closure.

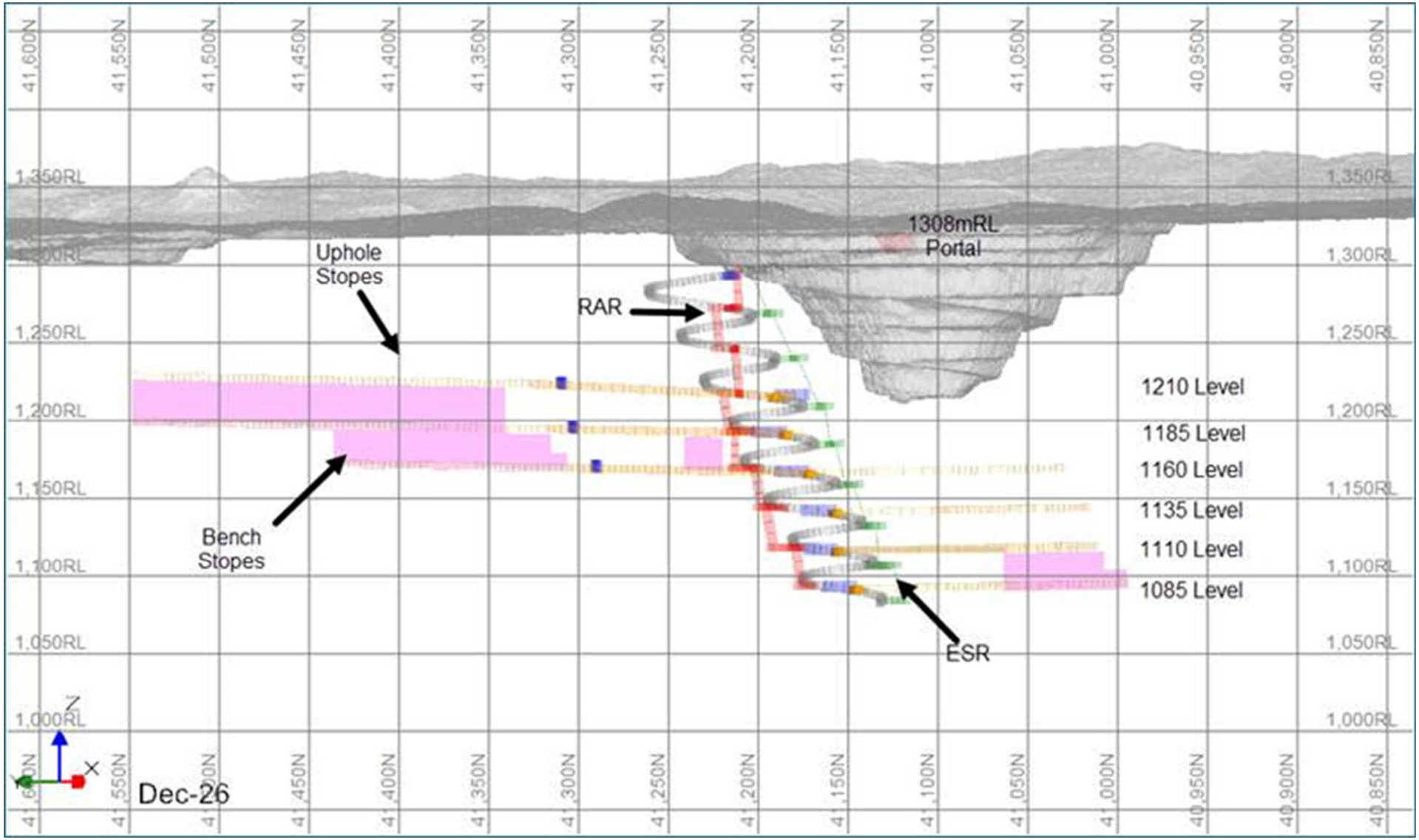


Figure 1 Stage 1 development long section (December 2016/January 2027)

1.2 Stage 1 EA amendment requirements regarding water sampling criteria

Aeris has undertaken a consultation process with the Department of Environment, Science and Innovation (DESI) regarding the submission and approval of a minor EA amendment application for the Stage 1 development. As part of this process, DESI provided feedback that Aeris needs to demonstrate that it can achieve the water sampling criteria as per the current endorsed Progressive Rehabilitation and Closure Plan (PRCP).

The currently approved PRCP Schedule (PRCP-EPML02840015-V1), effective from 23/10/2023, includes the following relevant rehabilitation milestones relating to achieving water sampling criteria:

- RM11 - Achievement of post-mining land use (Water Storage for Stock Water):
  - 3. Long-term water quality in the water storages (RA1) monitored quarterly does not exceed the limits specified in Table 5 for a minimum of 5 consecutive years.

2 Achieving RM11 criteria during/post Stage 1 development

2.1 Impact of Stage 1 underground development on void water balance

The impact of the Stage 1 underground development on the water balance of the existing voids (WRD Sediment Dam, North Pit and South Pit) is considered negligible as:

- The Stage 1 underground development does not require dewatering of the South Pit.
- There is negligible hydraulic connectivity between the underground development and the South Pit, as the portal for the underground development is at 1308mRL (which is above the water level in the pit) and as the crown pillar will remain in place.
- Given the limited scale of the underground development, groundwater inflow and radius of drawdown are considered minimal and are not considered to affect the water levels in the South Pit and North Pit.
- The water demand for the Stage 1 underground development (e.g. for dust suppression is minimal and estimated to be 10ML/month, i.e. ±120ML/year. Based on the South Pit storage curve (Figure 2), this volume can be sourced from the South Pit without significantly affecting the water level in the South Pit.
- There is no requirement to transfer/use water from the North Pit or WRD Sediment Dam for the Stage 1 underground development.

Based on the above, it can be concluded that the Stage 1 underground development will not affect the water balance of the WRD Sediment Dam, the North Pit and the South Pit. In fact, it can be considered that the timeframe for rehabilitation and closure monitoring of the voids has already started, provided that the Stage 2 underground development does not take place.

Therefore, the results of the water balance and water quality studies from the currently approved PRCP, which assumed no underground development, and the associated PRCP Schedule relating to the voids remain valid.

Reference is made to the following technical studies/reports that are included in the Project's PRCP Version 2.0, finalised in response to DESi's RFI:

- Appendix P: "*Barbara Copper Project Progressive Rehabilitation and Closure Planning – Water Management Plan and Water Balance Model*". ATC Williams, March 2023 (Ref 118131.12)

- Appendix T: "*Barbara Copper Project Progressive Rehabilitation and Closure Plan. Water Quality Assessment of North Pit, South Pit and WRD Sediment Dam*". WMV Environmental, March 2023)

2.2 Voids water balance modelling results

Water balance modelling of the voids not affected by underground mining was undertaken by ATC Williams in 2023.

South Pit

Modelled long-term water levels (Figure 3) indicate that the water level in the pit increases rapidly in the first 18 years (to 2040), with the rate of water level rise reducing by 2060 when a state of 'dynamic equilibrium' is achieved. The 'dynamic equilibrium' has minor variations throughout the subsequent years to account for periods of rainfall and evaporation. The mean (average) water level in the South Pit reaches a level of approximately RL 286.5 m to RL 287.5 m.

The water balance modelling indicates that the South Pit will not run dry.

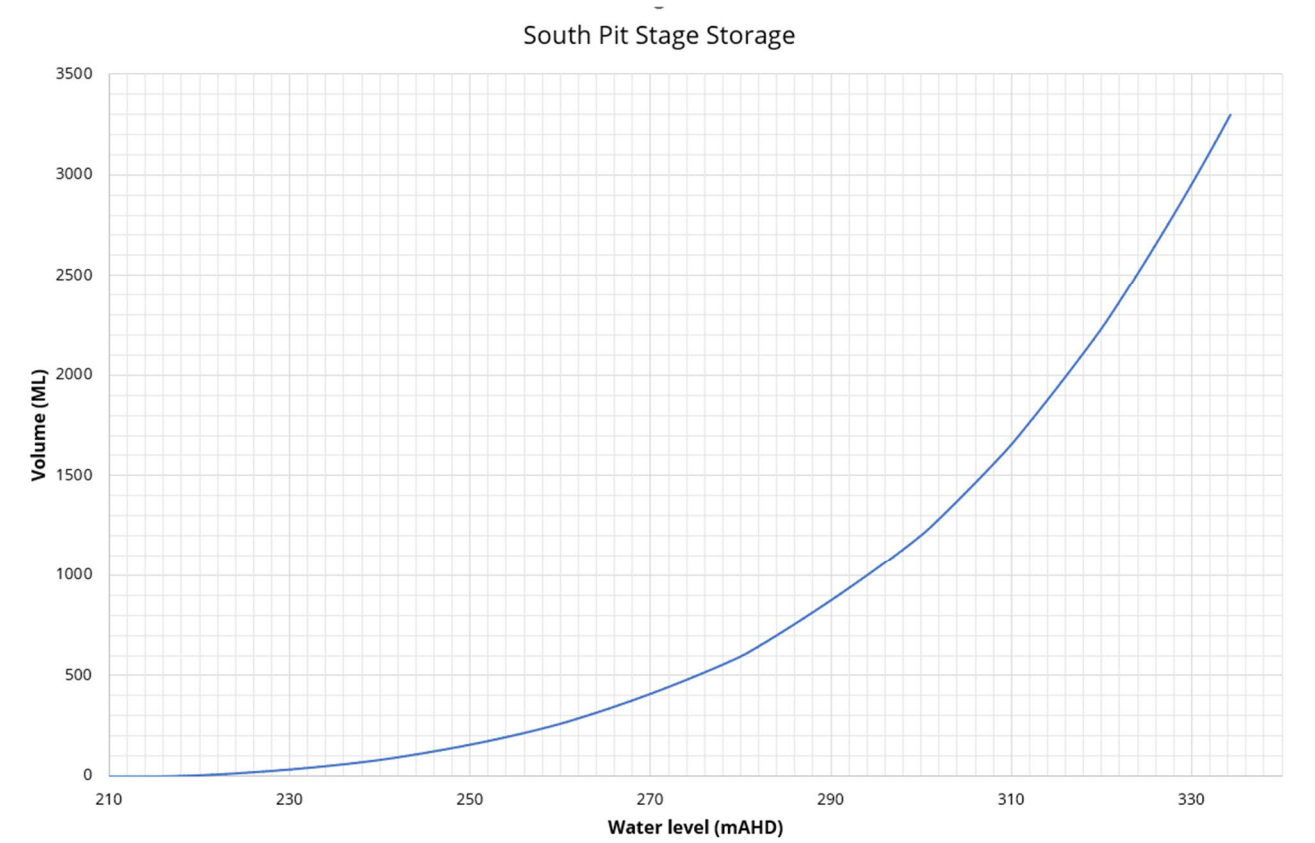


Figure 2 South Pit storage curve

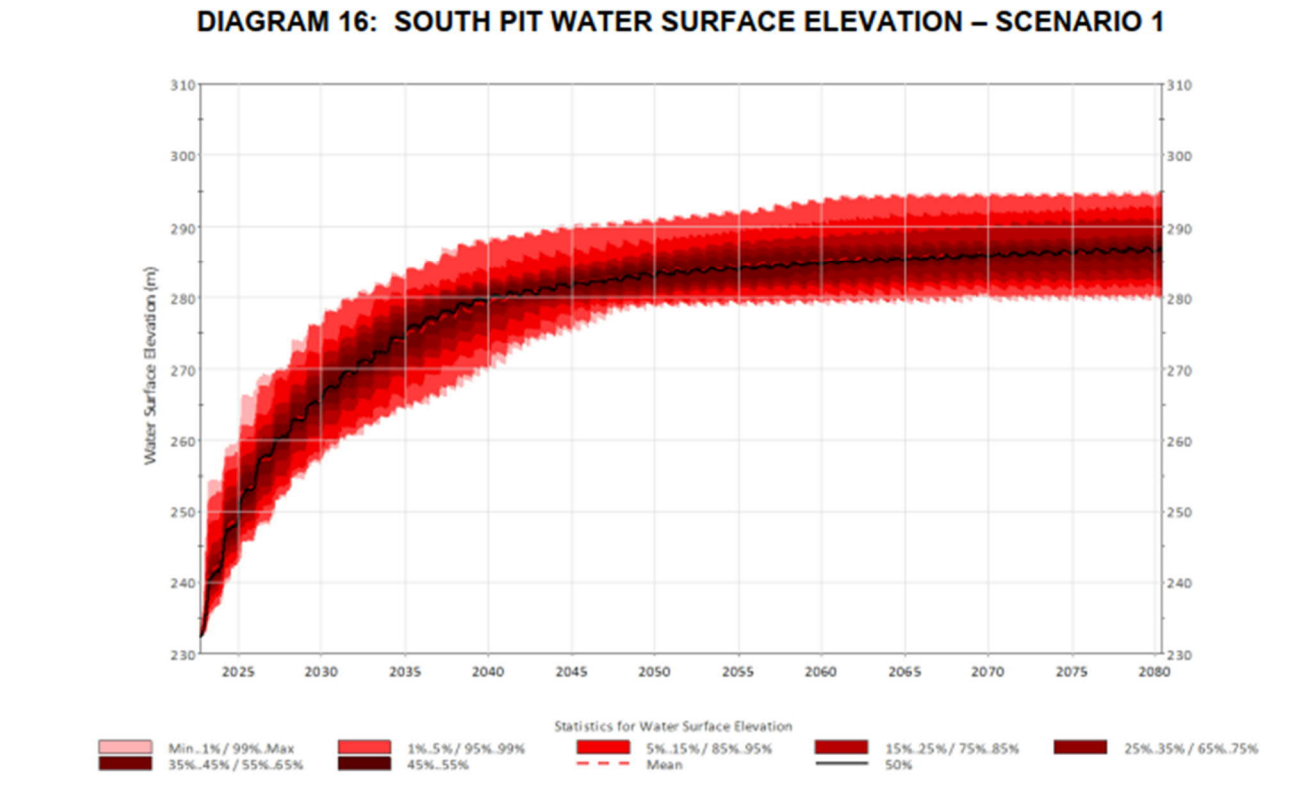


Figure 3 South Pit water levels (2022-2080)

North Pit

Modelled long-term water levels (Figure 4) indicate that the water level in the pit increases rapidly in the first 10-12 years (to 2033/35), with the rate of water level rise then reducing to achieve a state of 'dynamic equilibrium'. The 'dynamic equilibrium' has minor variations throughout the subsequent years to account for periods of rainfall and evaporation. The mean (average) water level in the North Pit reaches a level of approximately RL 308.5 m to RL 309.5 m

The water balance modelling indicates that the North Pit will not run dry.

WRD Sediment Dam

Modelled long-term water levels (Figure 5) indicate that the water level in the sediment dam increases rapidly in the first 5 years (to 2027) with the rate of water level rise then reducing to achieve a state of 'dynamic equilibrium'. The 'dynamic equilibrium' has minor variations throughout the subsequent years to account for periods of rainfall and evaporation. The mean (average) water level in the WRD Sediment Dam reaches a level of approximately RL 333 m to RL 334 m.

The water balance modelling indicates that the WRD Sediment Dam will not run dry.

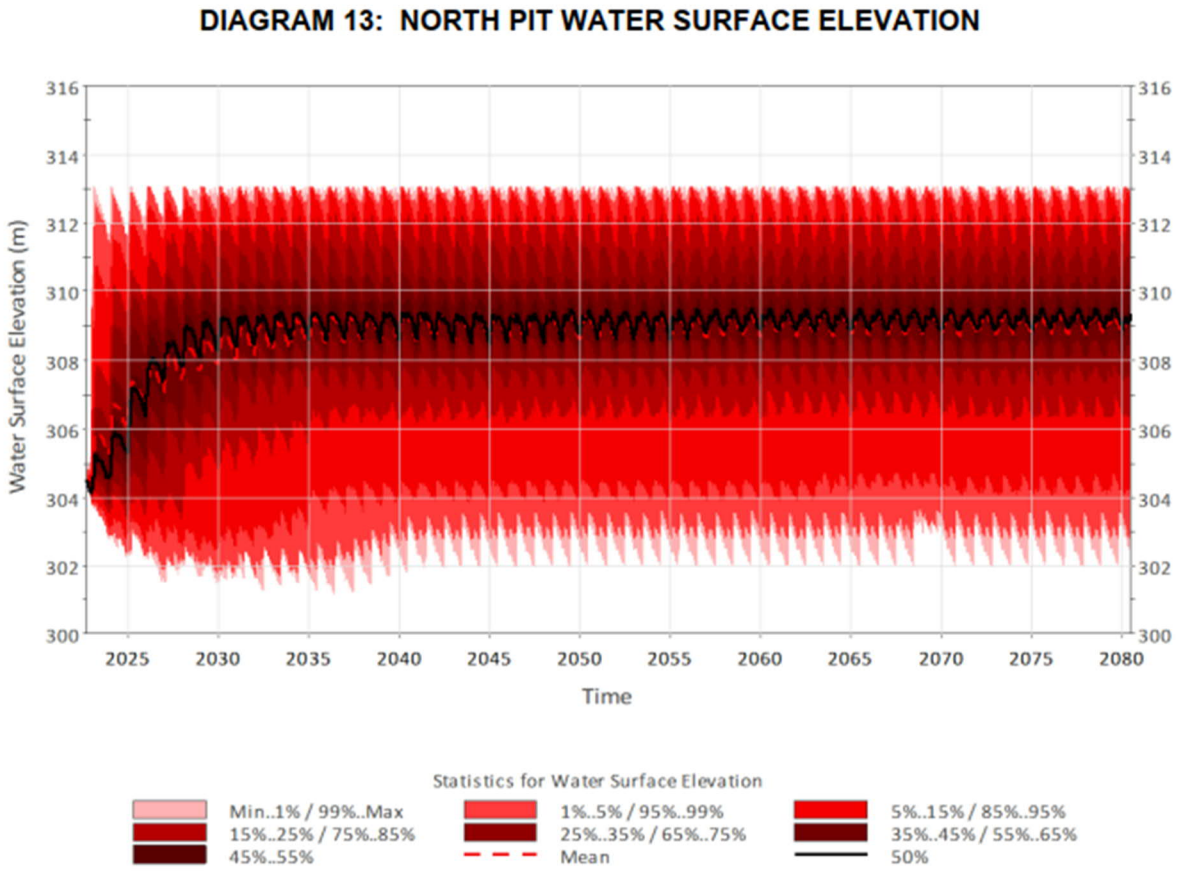


Figure 4 North Pit water levels (2022-2080)

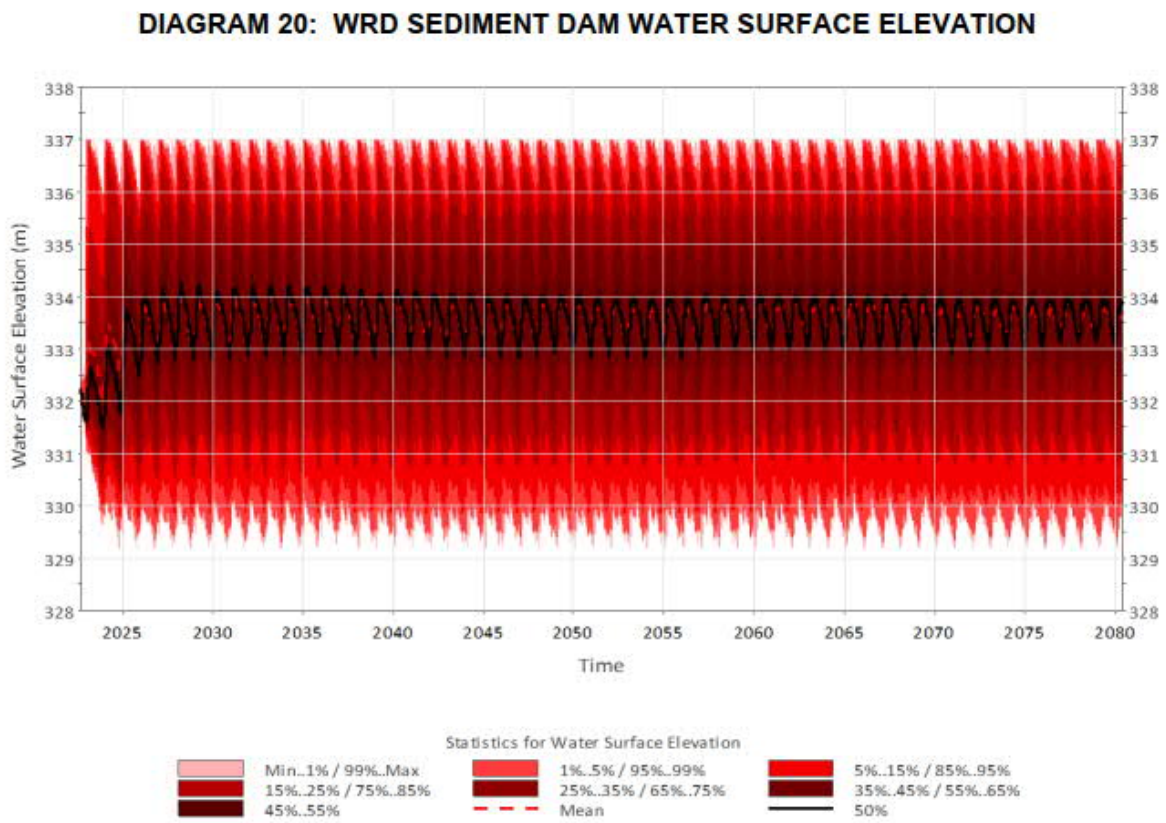


Figure 5 WRD Sediment Dam water levels (2022-2080)

Conclusion with respect to rehabilitation milestone RM11

There are no constraints on water sampling opportunities at the North Pit, South Pit, and WRD Sediment Dam, as these voids will not run dry during and after Stage 1 underground development, and water levels will rise to achieve an equilibrium. Therefore, the requirement for quarterly monitoring over a minimum of 5 consecutive years under rehabilitation milestone RM11 can be achieved.

2.3 Voids water quality modelling results

An assessment of the long-term water quality criteria in the voids was undertaken by WMV Environmental in 2023. The results of the assessment are presented in Appendix A.

The assessment indicates that the modelled solute concentrations at all times and for both models (i.e. mixing and equilibrium models) remain below the applicable ANZECC 2000 Water Quality Guideline values for livestock watering and below the PRCP schedule PRCP EPML02840015 – Table 5: Water quality limits for North and South Pits and WRD Sediment Dam.

Further assessment of final void water quality undertaken by WMV Environmental in 2024, as documented in the technical memo "*J23011 – BCP UG EA Amendment and PRCP. Groundwater impact assessment – sensitivity/uncertainty analysis and long-term water quality.*" (WMV Environmental, May 2024) included the statistical extrapolation of the water quality modelling results from 55 years to 2000 years.

The statistical assessment indicates that the long-term (200-yrs) water quality levels remain below the adopted guidelines.

Conclusion with respect to rehabilitation milestone RM11

The water quality assessments undertaken in 2023 and 2024 demonstrate that long-term water quality in the WRD Sediment Dam, North Pit and South Pit remain below the adopted water quality criteria. Therefore, the requirement for long-term water quality in the water storages (RA1) monitored quarterly not to exceed the limits specified in PRCP Schedule Table 5 for a minimum of 5 consecutive years under rehabilitation milestone RM11 can be achieved.

3 Limitations

This technical memo has been prepared by WMV Environmental Pty Ltd for Round Oak Minerals Ltd/Aeris Resources Limited and may only be used and relied upon by Round Oak Minerals Ltd/Aeris Resources Limited for the purpose agreed between WMV Environmental and Round Oak Minerals Ltd/Aeris Resources Limited as set out in this memo.

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The services undertaken by WMV Environmental Pty Ltd in connection with preparing this memo were limited to those specifically detailed in the memo and are subject to the scope limitations set out in the memo.

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Appendix A Results of water quality modelling

A.1 WRD Sediment Dam

Table 4 Long-term modelled (2080) water quality in WRD Sediment Dam

Parameter/ solute	ANZECC 2000 WQG for Livestock Watering	Mixing Model						Speciation Equilibrium Model					
		P25		P50		P75		P25		P50		P75	
Physico-chemical		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
pH	6.5 - 8.5	8.22	7.91	8.22	7.91	8.22	7.91	8.36	8.36	8.36	8.36	8.36	8.36
TDS (mg/L)	4000	3004	2238	2918	2238	3023	2255	1397	162	1002	161	1426	189
Major Ions (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Calcium	1000	712.6	629.3	712.6	629.3	712.6	629.2	153.9	17.8	110.3	17.7	157.1	20.7
Magnesium	-	67.7	7.8	48.6	7.8	69.2	9.1	67.8	7.8	48.6	7.8	69.2	9.1
Sodium	-	159.0	18.4	123.9	18.3	162.3	21.4	159.0	18.4	123.9	18.3	162.4	21.4
Potassium	-	45.4	5.2	32.5	5.2	46.3	6.1	45.4	5.2	32.5	5.2	46.4	6.1
Sulphate	2000	1852.4	1548.2	1754.7	1548.0	1859.6	1554.7	715.2	82.7	512.4	82.3	730.2	96.2
Chloride	-	280.8	19.5	280.8	19.4	280.8	22.6	280.8	19.5	280.8	19.4	280.8	22.7
Fluoride	2	1.7	0.2	1.3	0.2	1.8	0.2	1.7	0.2	1.3	0.2	1.8	0.2
Bicarbonate	-	184.2	9.7	184.2	9.7	184.2	11.3	184.2	10.6	184.2	10.6	184.2	12.3
Metals (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Aluminium	5	0.0130	0.0000	0.0130	0.0000	0.0130	0.0000	0.0130	0.0000	0.0130	0.0000	0.0130	0.0000
Arsenic	0.5	0.0180	0.0006	0.0180	0.0006	0.0180	0.0008	0.0180	0.0006	0.0180	0.0006	0.0180	0.0008
Barium	-	0.0030	0.0002	0.0030	0.0002	0.0030	0.0002	0.0030	0.0002	0.0030	0.0002	0.0030	0.0002
Chromium	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Copper	0.5	0.0140	0.0016	0.0100	0.0016	0.0143	0.0019	0.0140	0.0016	0.0100	0.0016	0.0143	0.0019
Manganese	-	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Molybdenum	0.15	0.0712	0.0082	0.0510	0.0082	0.0727	0.0096	0.0713	0.0082	0.0510	0.0082	0.0727	0.0096
Nickel	1	0.0126	0.0015	0.0090	0.0014	0.0128	0.0017	0.0126	0.0015	0.0090	0.0014	0.0128	0.0017
Uranium	0.2	0.0838	0.0097	0.0601	0.0096	0.0855	0.0113	0.0838	0.0097	0.0601	0.0096	0.0856	0.0113
Zinc	20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

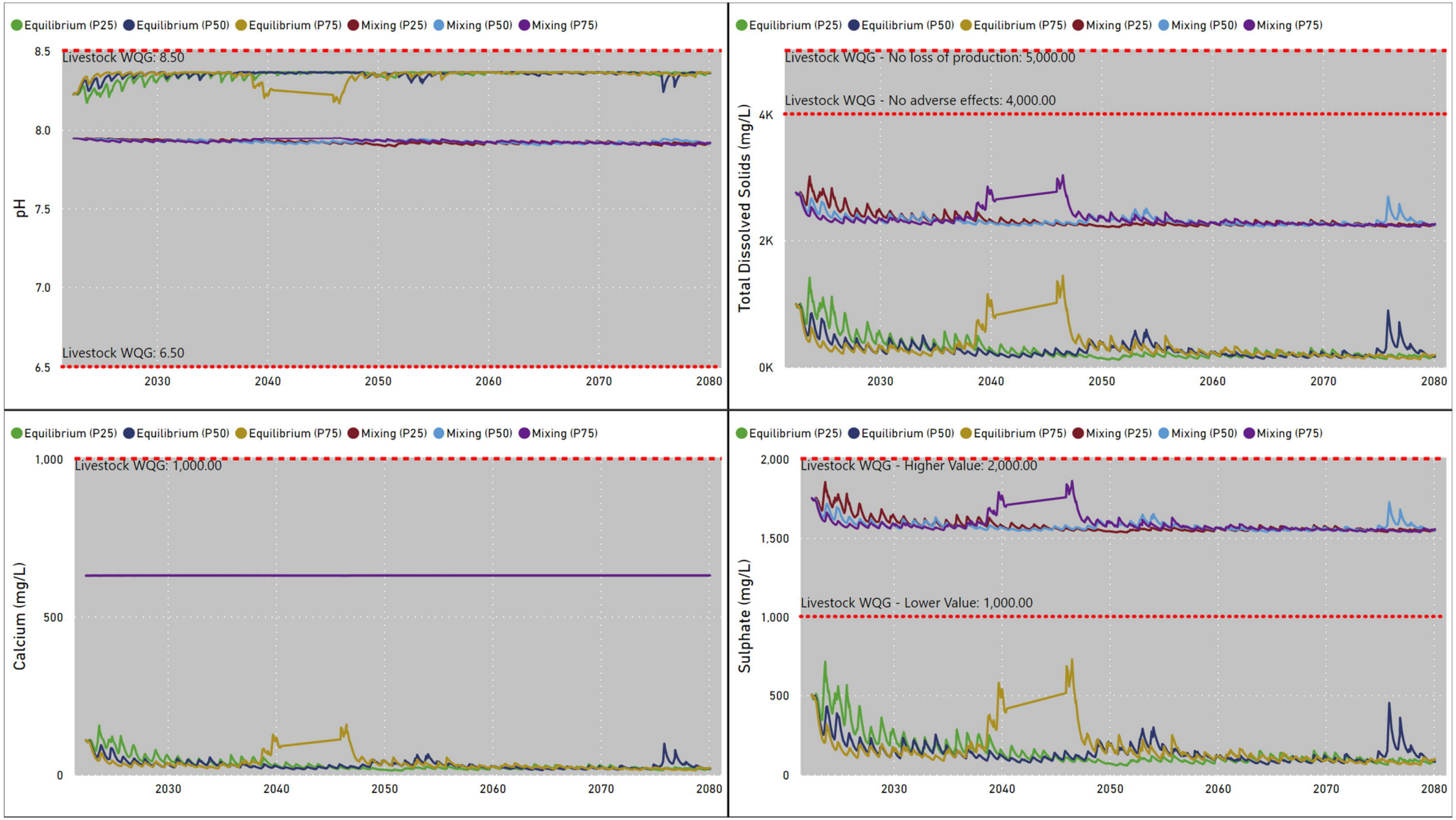

Figure 4 WRD Sediment Dam modelled water quality – pH, TDS, calcium and sulphate

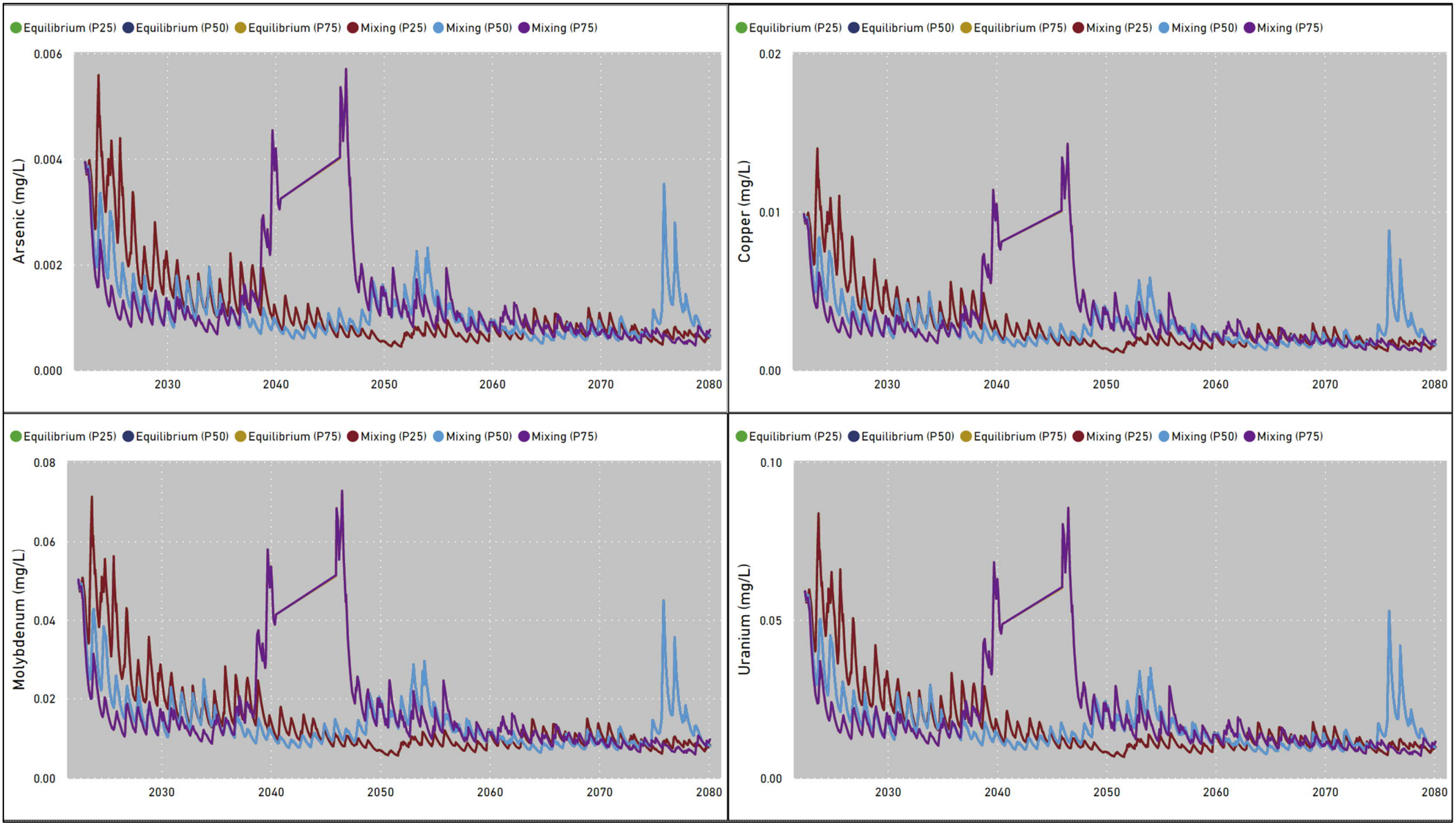

Figure 5 WRD Sediment Dam modelled water quality – arsenic, copper, molybdenum and uranium

A.2 South Pit

Table 6 Long-term modelled (Feb-2080) water quality in South Pit (scenario 1)

Parameter/ solute	ANZECC 2000 WQG for Livestock Watering	Mixing Model						Speciation Equilibrium Model					
		P25		P50		P75		P25		P50		P75	
Physico-chemical		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
pH	6.5 - 8.5	8.20	7.79	8.20	7.79	8.20	7.79	8.20	8.04	8.20	8.04	8.20	8.05
TDS (mg/L)	4000	4154	3074	4154	2976	4154	2893	1981	1200	1981	1103	1981	1022
Major Ions (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Calcium	1000	696.1	651.7	696.1	648.3	696.1	645.4	140.4	98.0	140.4	94.9	140.4	92.6
Magnesium	-	81.5	57.1	81.5	53.0	81.5	49.7	81.5	57.1	81.5	53.0	81.5	49.7
Sodium	-	535.4	196.9	535.4	171.4	535.4	149.6	535.4	197.0	535.4	171.4	535.4	149.7
Potassium	-	27.3	21.9	27.3	21.4	27.3	21.1	27.3	21.9	27.3	21.4	27.3	21.1
Sulphate	2000	1984.2	1800.9	1984.2	1777.7	1984.2	1758.1	705.3	473.9	702.2	451.5	699.9	433.3
Chloride	-	801.4	244.0	801.4	205.8	801.4	173.2	801.4	244.2	801.4	205.9	801.4	173.3
Fluoride	2	1.2	0.8	1.2	0.7	1.2	0.7	1.2	0.8	1.2	0.7	1.2	0.7
Bicarbonate	-	101.5	101.5	98.2	98.2	95.8	95.8	108.1	108.1	104.6	104.6	102.2	102.2
Metals (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Aluminium	5	0.0130	0.0076	0.0130	0.0075	0.0130	0.0074	0.0130	0.0076	0.0130	0.0075	0.0130	0.0074
Arsenic	0.5	0.0060	0.0045	0.0060	0.0043	0.0060	0.0043	0.0060	0.0045	0.0060	0.0043	0.0060	0.0043
Barium	-	0.0509	0.0509	0.0482	0.0482	0.0481	0.0461	0.0509	0.0509	0.0482	0.0482	0.0481	0.0461
Chromium	1	0.0015	0.0004	0.0015	0.0003	0.0015	0.0002	0.0015	0.0004	0.0015	0.0003	0.0015	0.0002
Copper	0.5	0.0164	0.0132	0.0163	0.0126	0.0163	0.0122	0.0164	0.0132	0.0163	0.0127	0.0163	0.0122
Manganese	-	0.0070	0.0017	0.0070	0.0014	0.0070	0.0011	0.0070	0.0017	0.0070	0.0014	0.0070	0.0011
Molybdenum	0.15	0.0445	0.0253	0.0445	0.0248	0.0445	0.0245	0.0445	0.0253	0.0445	0.0248	0.0445	0.0245
Nickel	1	0.0190	0.0105	0.0190	0.0104	0.0190	0.0102	0.0190	0.0105	0.0190	0.0104	0.0190	0.0102
Uranium	0.2	0.0251	0.0118	0.0251	0.0105	0.0251	0.0095	0.0251	0.0118	0.0251	0.0106	0.0251	0.0095
Zinc	20	0.0461	0.0111	0.0461	0.0089	0.0461	0.0071	0.0461	0.0111	0.0461	0.0089	0.0461	0.0071

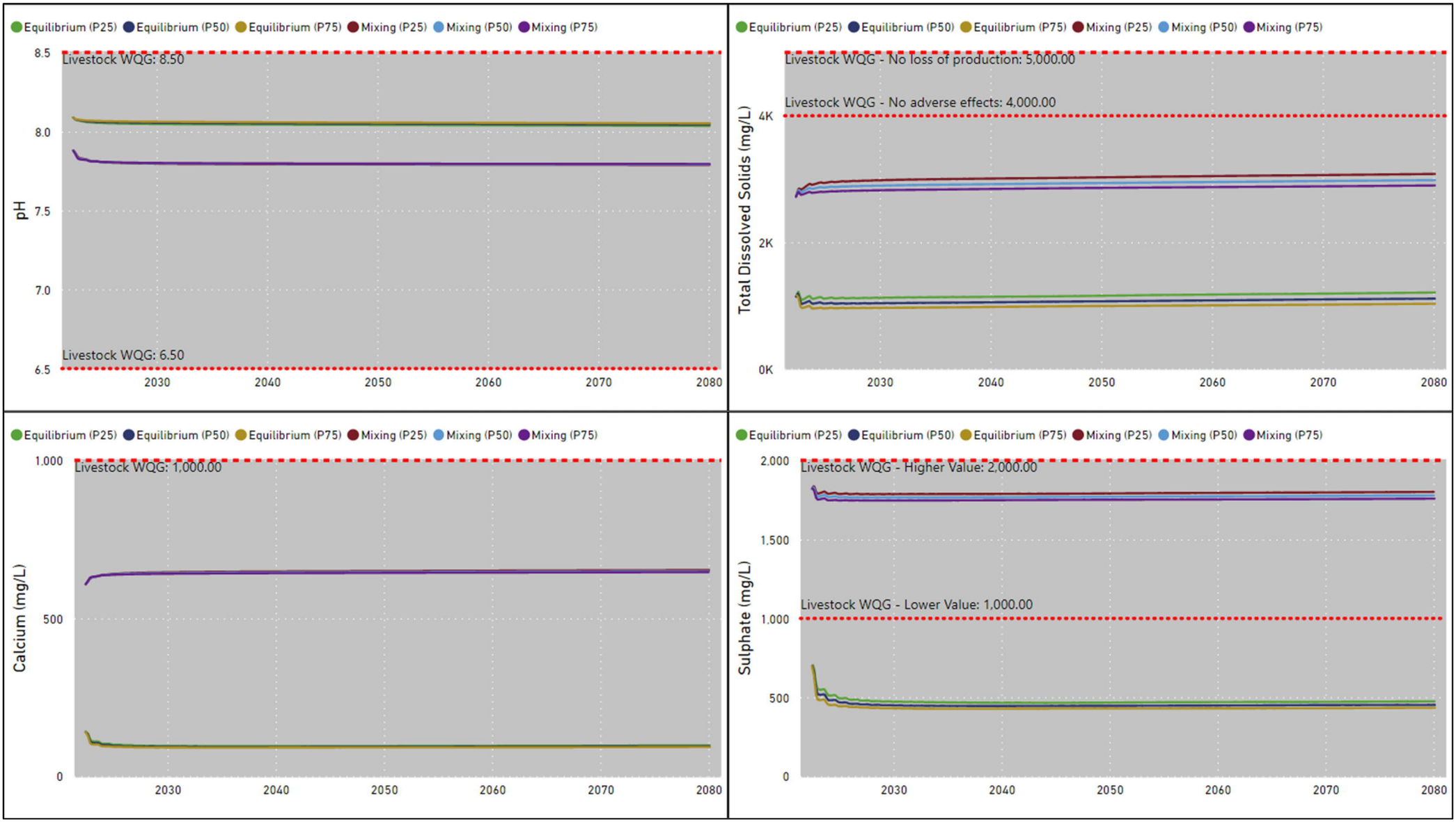

Figure 8 South Pit (scenario 1) modelled water quality – pH, TDS, calcium and sulphate

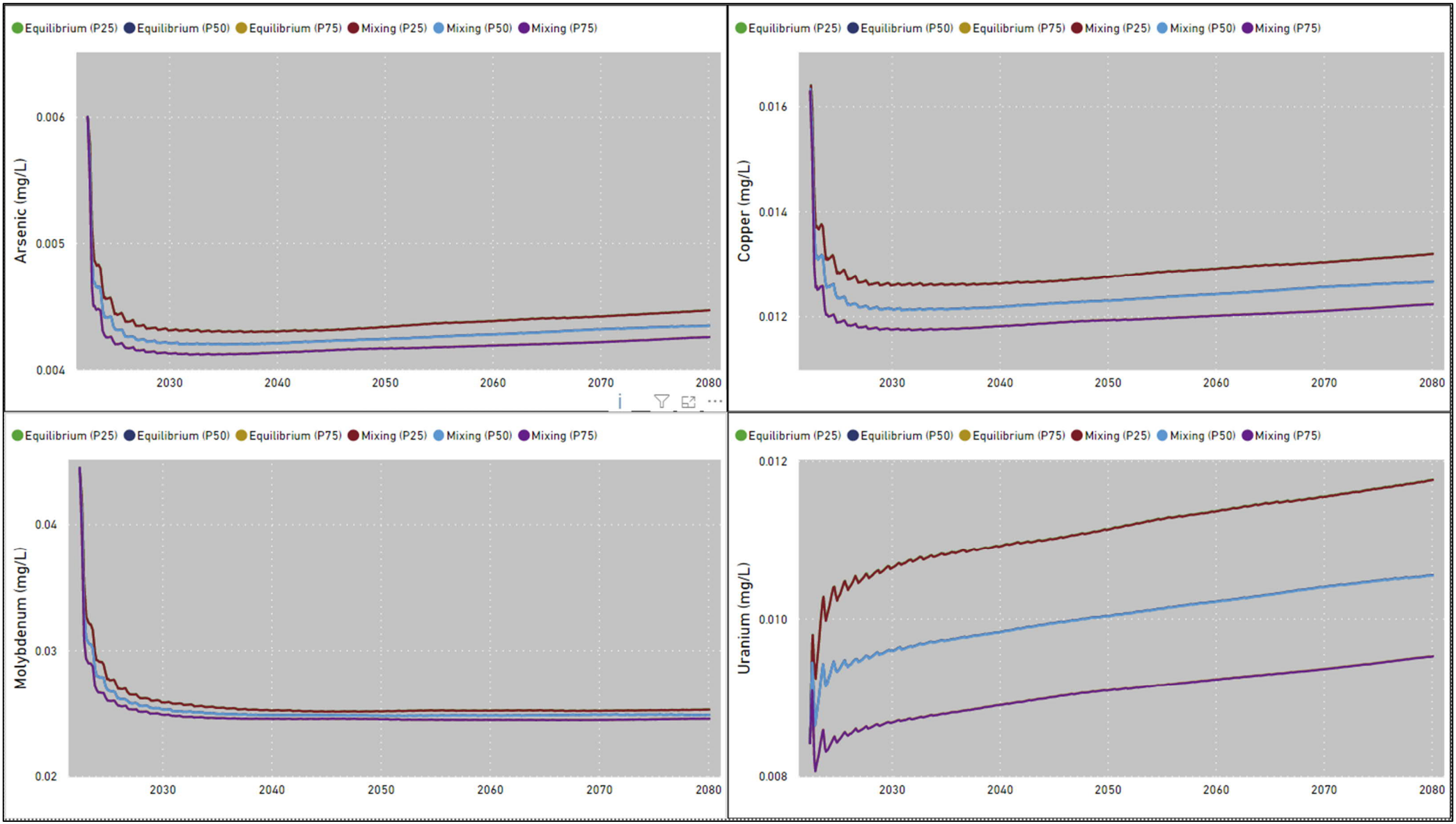

Figure 9 South Pit (scenario 1) modelled water quality – arsenic, copper, molybdenum and uranium

A.3 North Pit

Table 5 Long-term modelled (Feb-2080) water quality in North Pit

Parameter/ solute	ANZECC 2000 WQG for Livestock Watering	Mixing Model						Speciation Equilibrium Model					
		P25		P50		P75		P25		P50		P75	
Physico-chemical		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
pH	6.5 - 8.5	8.20	7.71	8.20	7.72	8.20	7.74	8.20	7.88	8.20	7.93	8.20	7.96
TDS (mg/L)	4000	3766	3764	3320	3288	3020	3018	1772	1765	1316	1275	1014	1012
Major Ions (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Calcium	1000	758.2	758.1	717.8	716.5	700.7	690.6	163.7	162.8	122.7	118.6	95.8	95.5
Magnesium	-	88.2	88.0	64.6	62.6	48.8	48.7	88.3	88.0	64.6	62.6	48.9	48.7
Sodium	-	243.5	242.7	179.4	173.6	135.7	135.4	243.6	242.9	179.5	173.7	135.8	135.4
Potassium	-	61.6	61.3	44.8	43.5	34.3	34.3	61.6	61.4	44.8	43.6	34.4	34.3
Sulphate	2000	1768.7	1764.3	1724.0	1708.9	1720.3	1680.3	502.6	337.6	451.6	275.9	444.0	254.1
Chloride	-	458.6	458.3	357.6	312.6	357.6	224.7	458.9	458.5	357.6	312.7	357.6	224.8
Fluoride	2	1.8	1.3	1.5	1.1	1.5	0.9	1.8	1.4	1.5	1.1	1.5	0.9
Bicarbonate	-	391.1	390.8	275.8	270.0	204.8	204.6	413.6	413.3	293.4	287.4	218.9	218.7
Metals (mg/L)		Max	Final	Max	Final	Max	Final	Max	Final	Max	Final	Max	Final
Aluminium	5	0.0601	0.0601	0.0408	0.0401	0.0286	0.0286	0.0601	0.0601	0.0409	0.0401	0.0286	0.0286
Arsenic	0.5	0.0087	0.0087	0.0062	0.0060	0.0046	0.0046	0.0087	0.0087	0.0062	0.0060	0.0046	0.0046
Barium	-	0.2476	0.2474	0.1902	0.1736	0.1902	0.1302	0.2477	0.2475	0.1902	0.1737	0.1902	0.1303
Chromium	1	0.0007	0.0003	0.0007	0.0002	0.0007	0.0001	0.0007	0.0003	0.0007	0.0002	0.0007	0.0001
Copper	0.5	0.0411	0.0399	0.0353	0.0305	0.0347	0.0263	0.0412	0.0399	0.0353	0.0305	0.0347	0.0263
Manganese	-	1.5012	0.6787	1.5012	0.4676	1.5012	0.3141	1.5012	0.6790	1.5012	0.4678	1.5012	0.3142
Molybdenum	0.15	0.0161	0.0140	0.0139	0.0109	0.0137	0.0095	0.0162	0.0140	0.0139	0.0109	0.0137	0.0095
Nickel	1	0.0108	0.0069	0.0096	0.0057	0.0094	0.0053	0.0108	0.0069	0.0096	0.0057	0.0095	0.0053
Uranium	0.2	0.0152	0.0151	0.0110	0.0107	0.0083	0.0083	0.0152	0.0151	0.0110	0.0107	0.0083	0.0083
Zinc	20	0.0140	0.0063	0.0140	0.0044	0.0140	0.0029	0.0140	0.0063	0.0140	0.0044	0.0140	0.0029

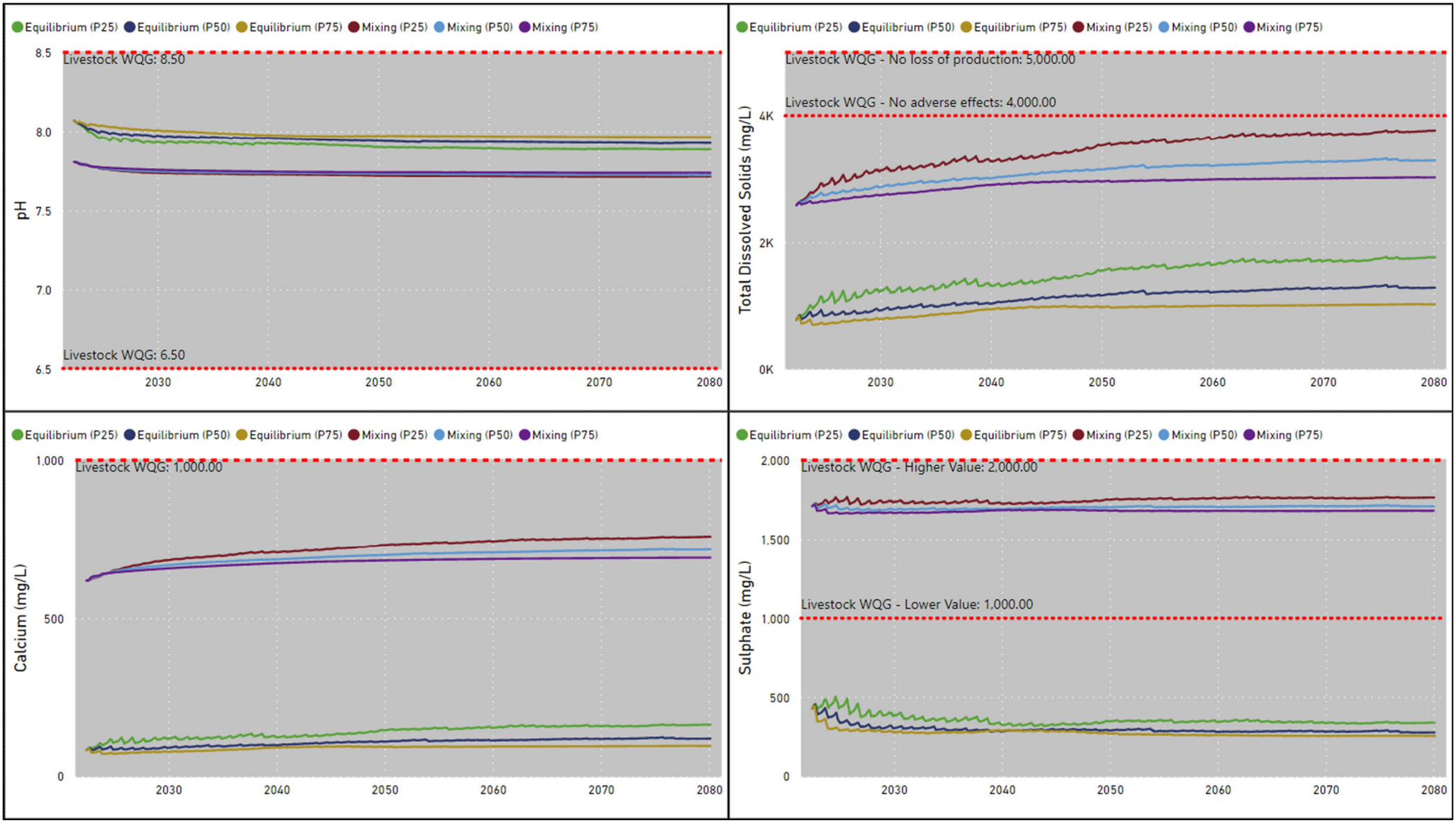

Figure 6 North Pit modelled water quality – pH, TDS, calcium and sulphate

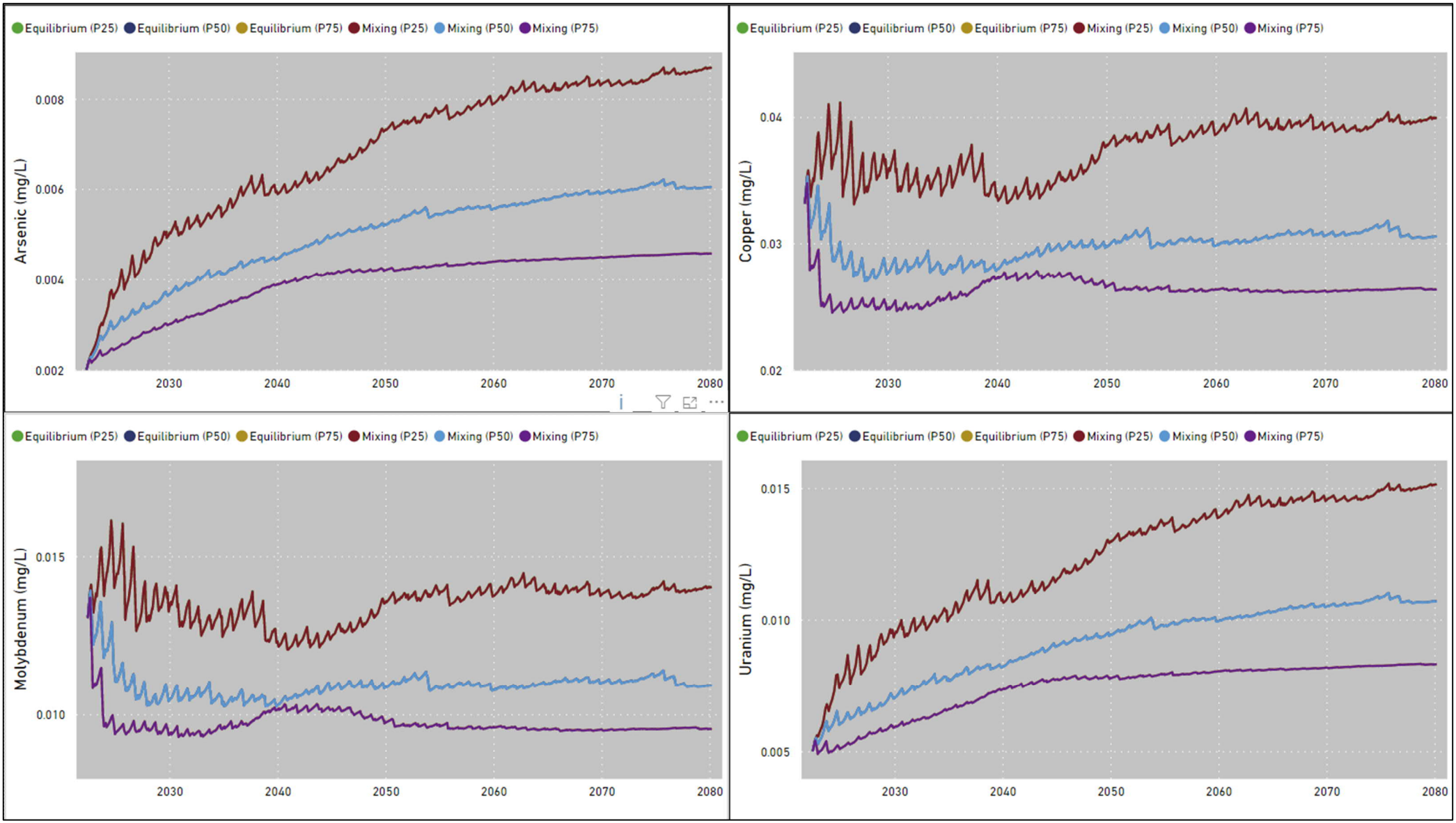

Figure 7 North Pit modelled water quality – arsenic, copper, molybdenum and uranium

Cover Design

Supplementary Report

Barbara Copper Project

Prepared for Exco Resources Limited | March 2023

Aeris RESOURCES

SGMenvironmental

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Cover Design

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Table of contents

1.0 Introduction 1
1.1 Scope 1
2.0 Review 3
2.1 The WRD 3
2.2 Cover theory 3
2.3 Preferred cover 4
2.4 Laboratory analysis to support cover design 5
2.4.1 Particle size distribution 5
2.4.2 Fertility 6
2.4.3 Plant available water 9
2.4.4 Erosion stability 10
3.0 The trials 13
3.1 Method 13
3.1.1 Sensor calibrations 13
3.1.2 Installation of instruments 13
3.2 Preferred cover results 14
3.2.1 Sensor calibration 14
3.2.2 Water balance 15
4.0 SVFlux modelling 17
4.1 Method 17
4.1.1 Model geometry 17
4.1.2 Mesh geometry 17
4.1.3 Initial conditions 18
4.1.4 Analysis method 20
4.2 Results and discussion 21
4.2.1 Water balance 21
4.2.2 Future performance 23
4.2.3 Industry benchmarking 24
5.0 Conclusions 27
References 33
Appendix A Method for calibrating matric suction sensors 35

Photograph

Photo 1 Sensor pair 13

Figure

Figure 1 Cove elements compared to undisturbed soil profiles 4
Figure 2 Preferred cover 5

Figure 3 Particle size distribution 6
Figure 4 Cover material laboratory SWCCs (a) coarse and fine NAF waste rock (b) clay / soil 9
Figure 5 Fine NAF waste rock matric suction calibration function 14
Figure 6 NAF waste rock matric suction calibration function 15
Figure 7 Preferred cover (observed) water balance 15
Figure 8 Model dimensions 17
Figure 9 Preferred cover SWCCs (a) fine NAF waste rock (b) coarse NAF waste rock (c) RPL 19
Figure 10 Unsaturated hydraulic conductivity functions 20
Figure 11 Preferred cover (observed versus modelled) water balance (a) artificial rainfall (b) evaporation (c) stored infiltration (d) seepage 22
Figure 12 Soil / clay matric suction calibration function 36

Table

Table 1 Scope 1
Table 2 Cover material physical characterisation 6
Table 3 Fertility of NAF waste rock and clay / soil 8
Table 4 SWCC fitting parameters for pressure plate 10
Table 5 Water storage potential 10
Table 6 Erosion potential of NAF waste rock and clay / soil 11
Table 7 Sensor burial depth in the preferred cover 14
Table 8 Saturated hydraulic conductivity 20
Table 9 Rainfall model scenarios 21
Table 10 Preferred cover SVFlux water balance results 24

Important note about your report

This Report is provided for the exclusive use of the Client pursuant to the Scope of Works dated 18 October 2022, which requires us to provide Services relating to responding to a request for information (RFI) issued by the Department of Environment and Science (DES) (the scope of work).

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1.0 Introduction

SGM environmental Pty Limited (SGME) was engaged by Exco Resources Limited to develop an engineered cover system (the cover) and erosion potential advice for the Barbara Copper Mine (the Project) waste rock dump (WRD). The design process is described in:

- *Cover Design Barbara Copper Mine* (the cover design report) (SGME 2022a); and
- *Calibrated Erosion Modelling | Waste Rock Dump* (the erosion assessment) (SGME 2021).

The cover design report and erosion assessment were prepared having regard for the requirements of the *Guideline: Progressive Rehabilitation and Closure Plan* (PRC plans) (the PRC plan guideline) and was submitted to the Department of Environment and Science (DES) as a PRC plan appendix.

After the submission of the PRC plan, DES issued a request for information (RFI) under section 140 of the *Environmental Protection Act 1994* (EP Act).

1.1 Scope

This report responds to the DES RFI statements that relate to the cover design report and the erosion assessment (Table 1).

Table 1 Scope

Number	DES RFI statement	Section where it is addressed
4	… Figure 6-24 provides a preferred cover design and shows a 1 metre (m) thick layer of rock which section 6.5.2 describes as coarse waste rock. It is unclear how coarse waste rock will provide an infiltration storage layer.	2.1-2.3 2.4.2 2.4.3
5	Provide further information to demonstrate the preferred cover design will achieve long term structural stability, considering the matters raised. This is likely to require additional overland flow and rainfall studies at higher gradients which better replicate the final landform to either demonstrate no rill development or to provide derived values for updated erosion modelling. Consideration should be given to whether Water Erosion Prediction Project (WEPP) is the most appropriate model to demonstrate erosional stability of this high-risk landform given that other models (such as SIBERIA or CAESARLisflood) will model landform evolution, consider features or points on the landform which may become unstable and determine landform sustainability over long time periods. Include additional information to demonstrate the suitability of the cover design to support vegetative growth, which in-turn informs the erosional stability of the landform and integrity of the reduced permeability layer (RPL).	2.4.4

Number	DES RFI statement	Section where it is addressed
7	Provide details on the calibration and installation of the moisture tension and water content sensors.	3.1 Appendix A 3.1.2
	Provide the fitting parameters for the measured, in situ data and for the predicted soil water characteristic curves (SWCCs). Confirm these parameters against published data and values generated by soil water retention software such as RETC.	2.4.3 — laboratory 4.1.3.2a — in situ
8	Provide the initial upper and lower boundary conditions used to run HYDRUS.	4.1.3
9	Provide a better estimate of bare soil evaporation and its (seasonal) fluctuation over the simulation period.	4.1.3
10	Provide reasoning and validation why the saturated hydraulic conductivity of the growth medium soil was set as 5.1×10^{-9} metres per second (m/s) and re-model the water balance using HYDRUS using appropriate values.	Table 8 4.2.1 5.0
11	Provide comment and model simulation outcomes on the potential decline in surface infiltration with aggregate dispersion.	Table 6 2.4.1
12	Present the cover column water balance in graphical format for each parameter (rainfall, evaporation, storage, drainage) as a function of time.	3.2.2
13	Present the water balance predicted by HYDRUS in graphical format for each parameter (rainfall, evaporation, storage, drainage) as a function of time.	4.2.1
14	Provide a graphical comparison of measured and modelled water balance outcomes.	4.2.1
15	Provide a statistical comparison of model efficiency against the measured data.	4.2.1
16	Provide a detailed discussion / interpretation of the water balance for the three cover scenarios, with supporting documentation from the published literature	4.2.1 4.2.4 — only for the preferred cover, since the outcome is not being questioned
17	If any assumptions or input data are found to not reflect the cover system design study, modelling is to be repeated and if possible use 2-D HYDRUS when applying outcomes to recommendations for waste dump design and performance criteria, particularly in terms of seepage rates.	5.0 — not needed

2.0 Review

2.1 The WRD

The majority (89%) of waste rock is non-acid forming (NAF) with a small percentage being potentially acid forming (PAF) or uncertain. All PAF waste rock is stored on a NAF base that was constructed to a minimum thickness of 5 m. The final landform includes PAF waste rock containment in a central portion of the NAF base to keep the PAF cell at least 5 m from the surface of the WRD. A cover is required to limit infiltration into the PAF cell, which could potentially mobilise geochemical load.

2.2 Cover theory

Design of the cover for the WRD has been based on climatic conditions, available materials, and design objectives. The design objectives align with the PRC plan guideline, which require:

- land to be returned to a condition similar to pre-existing conditions or to an agreed post-mining land use (PMLU);
- land to be returned to a stable condition that is not compromised by surface instability and erosion, and is safe;
- that the final landform is geochemically stable to the extent that it does not impact surface water and / or groundwater quality;
- the PMLU has regard for the land use in the surrounding region; and
- land can sustain the PMLU.

Fundamentally, the design objectives will not be met if the cover does not provide plant available water to sustain vegetation, and limit percolation of water into the PAF cell. Limiting percolation reduces the potential for geochemical load. Geochemical load may carry products from sulfide oxidation as well as products associated with secondary acidic salts and neutralisation to the receiving environment (generally formed when contaminant load is less than the contaminant generation rate due to oxidation processes).

To meet the design objectives the cover must therefore balance water storage and release (and geochemical load control) with erosion stability so that cover performance does not degrade with time. How this might be achieved is demonstrated by comparing potential cover elements to an undisturbed soil analogue (Figure 1).

Figure 1 shows undisturbed Dermosol and Kandosol profiles, both of which are common in the region around the Project. In the centre of the figure is potential elements for a concept cover:

- vegetation;
- soil;
- infiltration storage layer (ISL);
- capillary break (CB); and
- RPL.

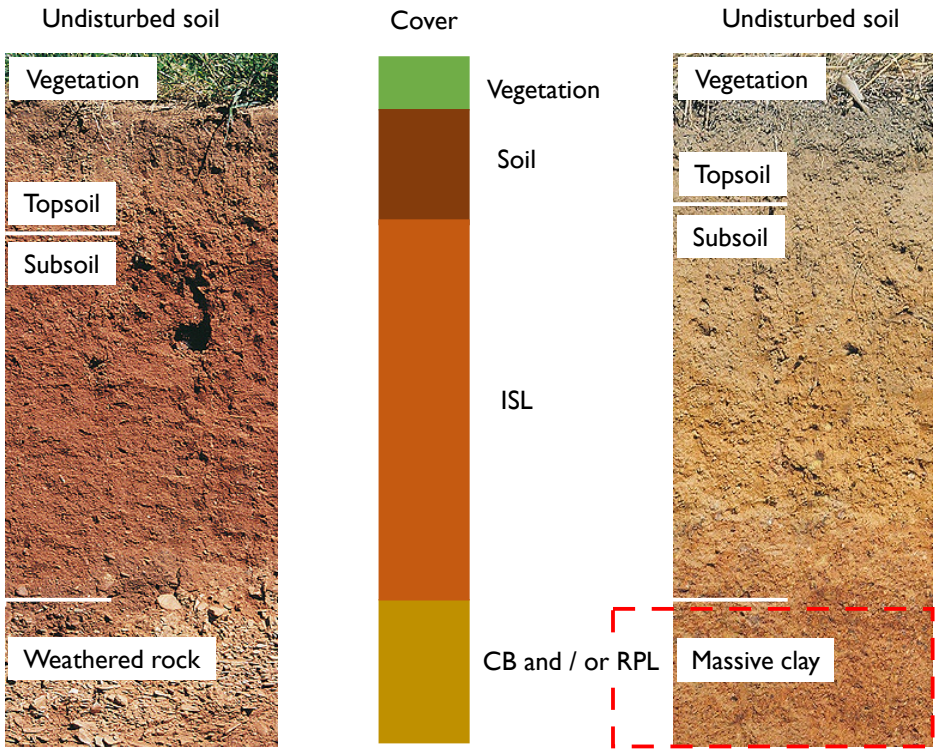

Figure 1 Cover elements compared to undisturbed soil profiles

Figure 1 illustrates that each cover element is comparable to soil horizons that might be found in an undisturbed soil profile:

- Vegetation — may be included in the cover, but it may also have no vegetation if the analogue is a rock out crop, or another sparsely vegetated landform feature.
- Soil — stripped topsoil stockpiled during mining inevitably will include some subsoil; therefore, the mixed soil product used in the cover is required to function the same as an undisturbed soil profile ie as a vegetation establishing medium. If vegetation cannot be established then substituting soil with NAF waste rock may be appropriate to limit erosion potential.
- ISL — ideally during mining, subsoil that is not hostile to vegetation, would be stockpiled separately and replaced as the ISL in the cover. However, the material balance at closure may be deficit and an alternative such as NAF waste rock may be used instead. NAF waste rock may not have the same water storage as subsoil and this must be accounted for in the design.
- CB and / or RPL — these layers are analogous to a weathered rock or massive clay horizon respectively. They are often used in cover design to promote extra water storage in the cover element (usually an ISL) above them so it can be removed by evaporation and / or transpiration. Therefore, one or both of these layers might be needed where the ISL is made of NAF waste rock.

2.3 Preferred cover

The preferred cover, decided from SGME (2022a) was trial 3 (Figure 2):

- a 0.5 m RPL of fine compacted NAF waste rock;
- a 1 m ISL of coarse NAF waste rock above the RPL; and
- a 0.3 m layer of fine NAF waste rock.

The preferred cover was chosen because:

- the inclusion of a crushed NAF waste rock product at the top of the cover acts as either a growth medium, or as erosion resistant ground cover;
- the coarse nature of NAF waste rock slows runoff water velocity and reduces the potential for erosion; and
- the RPL limits seepage potential by promoting extra water storage in the ISL.

The cover is a hybrid of a store and release cover and an erosion protection cover.

Cross section	Thickness	Material properties	Material density
Growth medium	0.3 m	Crushed waste rock	1.6 t/m^3
ISL	1.0 m	Coarse waste rock	1.8 t/m^3
RPL	0.5 m	Fine compacted waste rock (<10 mm)	2.1 t/m^3

Figure 2 Preferred cover

SGME (2022) recommended that the preferred cover be tested in a field scale trial before being built on the WRD.

2.4 Laboratory analysis to support cover design

2.4.1 Particle size distribution

Physical characterisation of NAF waste rock and clay / soil was done to confirm that NAF waste rock would make a suitable ISL.

The particle size distribution of coarse NAF waste rock, fine NAF waste rock and clay / soil is in Figure 3.

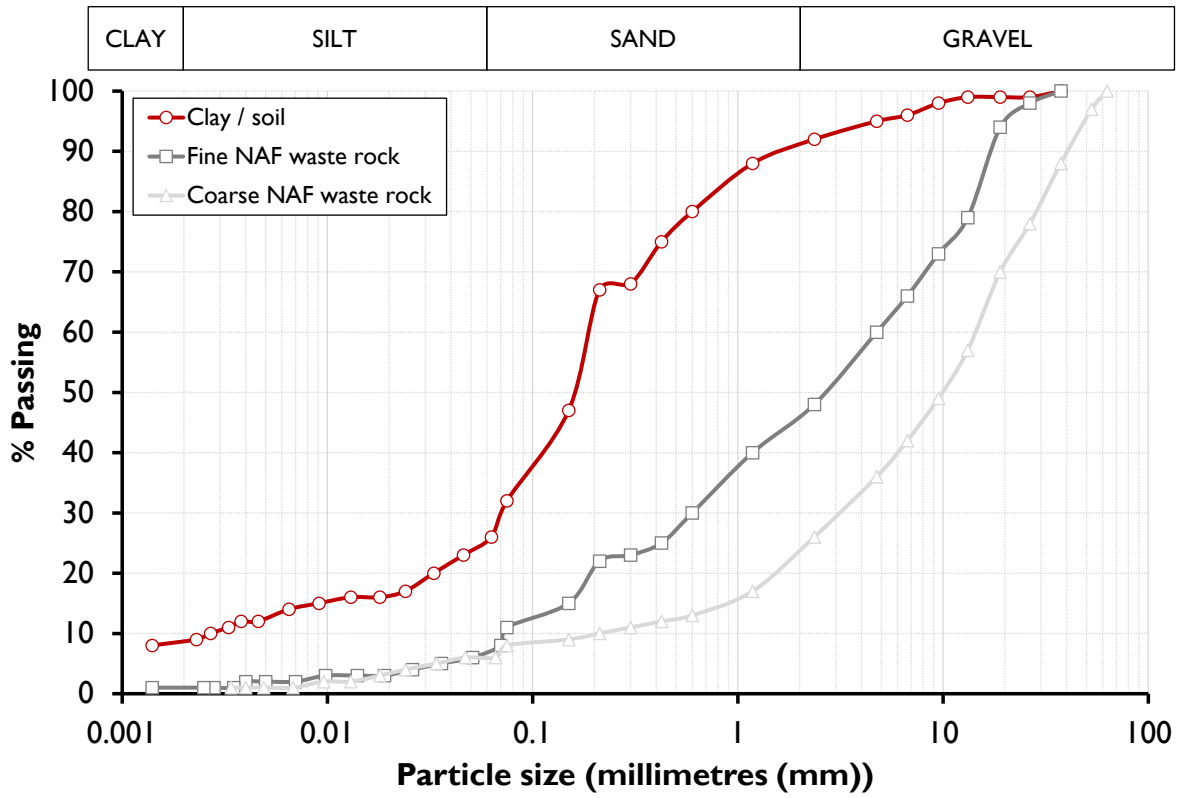

Figure 3 Particle size distribution

Each cover material was characterised using the effective size, D_{10}, which is the particle size in millimetres (mm) through which 10% passes; the uniformity coefficient, (C_u); and the coefficient of curvature (C_c) (Table 2).

Table 2 Cover material physical characterisation

Material	D_{10} (mm)	D_{30} (mm)	D_{60} (mm)	C_u	C_c
Coarse NAF waste rock	0.3	3	15	50	2
Fine NAF waste rock	0.07	0.6	4.75	67.9	1.1
Clay / soil	0.0027	0.07	0.185	68.5	1.5

It should be noted that the name coarse NAF waste rock is used to differentiate the ISL from the growth media (fine NAF waste rock). The coarse NAF waste rock of the ISL is run-of-mine and the fine NAF waste rock of the growth media has been scalped to increase the proportion of innate fines.

All three cover materials are well graded and have a low capacity for segregation of fine and coarse particles. This will reduce the potential formation of preferential flow paths.

2.4.2 Fertility

Fertility analysis for NAF waste rock and clay / soil has been summarised in Table 3 from SGME (2022). The analysis shows that by comparison:

- NAF waste rock has a lower electrical conductivity (EC) and chloride range indicating that whilst the clay / soil may be saline, the NAF waste rock is not;
- NAF waste rock is deficient in phosphorous (P) — this is common in Australian soils; and

- NAF waste rock has fertility (expressed as cation exchange capacity (CEC); that is dominated by calcium (Ca).

It was concluded from the fertility analysis that NAF waste rock can be used as a substitute for clay / soil as a growth medium in the cover because it is less likely to introduce salinity.

Table 3 Fertility of NAF waste rock and clay / soil

Analyte	Units	NAF waste rock	Clay / soil	Comment
pH (1:5)	pH units	9-9.5	7.1-9.1	NAF waste rock is more alkaline
EC (1:5)	MicroSemen per centimetre (µS/cm)	140-150	110-8,700	NAF waste rock has a lower EC
Water-soluble chloride	milligrams per kilogram (mg/kg)	10-16	22-14,000	NAF waste rock has a lower chloride concentration
P (Colwell)	mg/kg	**<limit of reporting**	7-25	**NAF waste rock is deficient**
Nitrite and nitrate	mg/kg	8-13	3-210	NAF waste rock and clay / soil are comparable
Total organic carbon	%	0.3-0.4	0.3-0.54	NAF waste rock and clay / soil are comparable
Organic matter	%	0.52-0.69	0.52-0.94	NAF waste rock and clay / soil are comparable
CEC	milli-equivalent per 100 gram (meq/100 g)	15-17	15-47	NAF waste rock and clay / soil are comparable
Exchangeable potassium (K)	%	1.7	0.7-0.9	NAF waste rock and clay / soil are comparable
Exchangeable Ca	%	94.7-94.9	22.8-24.1	NAF waste rock CEC has a higher concentration of exchangeable Ca
Exchangeable Mg	%	2.2-2.6	1.7-11.4	NAF waste rock and clay / soil are comparable
Diethylenetriaminepentaacetic acid (DTPA) extractable metals				
Copper (Cu)	mg/kg	5-13	1.6-3.7	NAF waste rock and clay / soil are comparable
Zinc (Zn)	mg/kg	0.26-0.47	0.35-0.85	
Manganese (Mn)	mg/kg	4.4-5.2	6.1-53	
Iron (Fe)	mg/kg	26-35	13-15	

2.4.3 Plant available water

Coarse and fine NAF waste rock and clay / soil samples had their soil water characteristic curves (SWCCs) tested on a pressure plate (Figure 4). Empirical SWCCs were fitted to the measured data using the Van Genuchten and Mualem function (Van Genuchten 1980) (Figure 4 and Table 4) and are reported against a typical SWCC using the Fredlund & Xing (1994) empirical fits (Mercer et al 2019). The difference in the SWCCs from the pressure plate to typical SWCCs reported in Mercer et al (2019) is because:

- NAF waste rock samples contain up to 10% fines (silt and clay fraction) (Figure 3) whereas a typical well-graded (GW)-gravel is screened to exclude the silt and clay fraction; and
- the clay / soil particle size distribution shows gap grading in the smaller gravel to sand fraction (Figure 3) which has slightly reduced the water storage potential compared to typical silt and clay with low plasticity (CL-ML) soil.

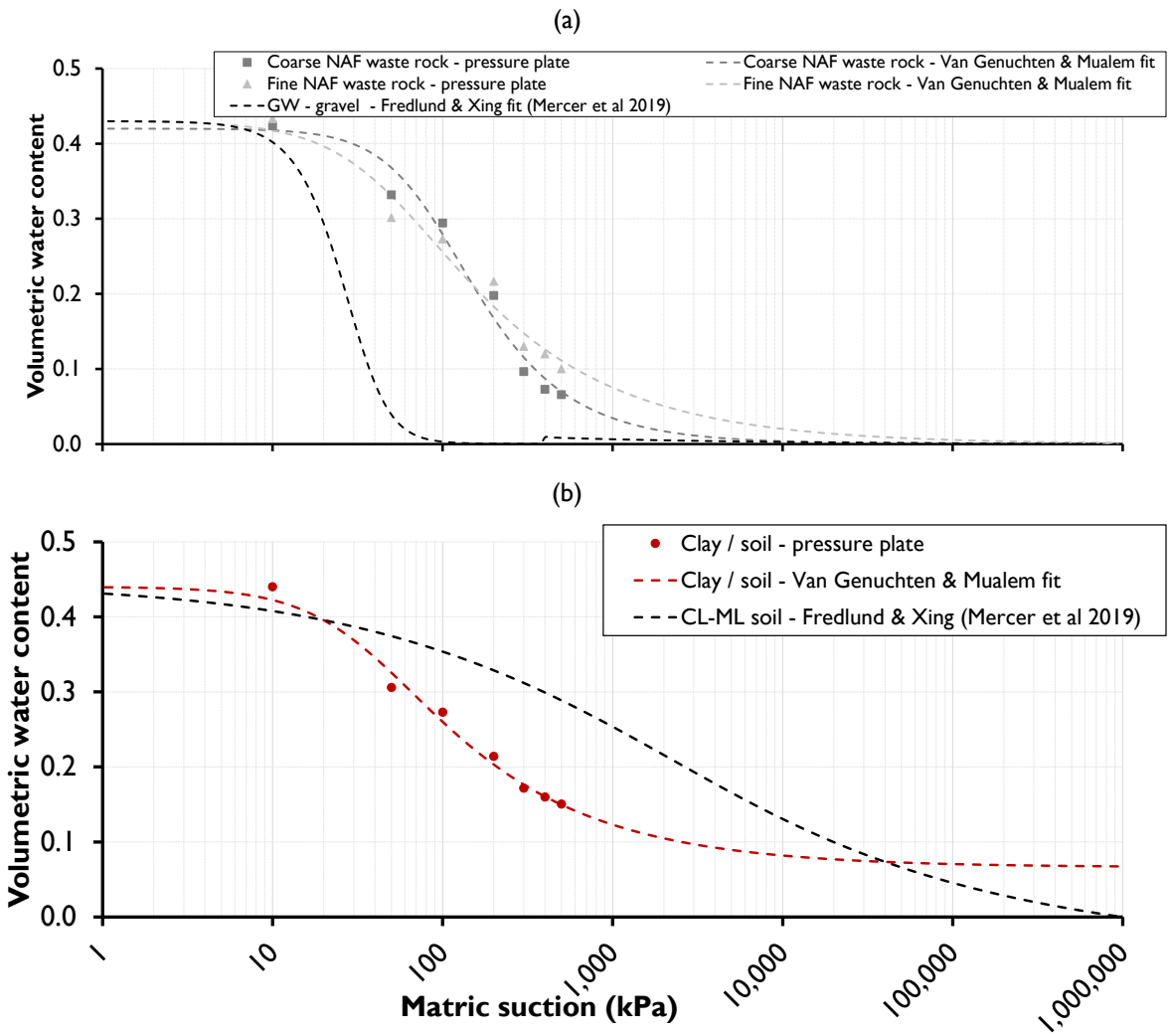

Figure 4 Cover material laboratory SWCCs (a) coarse and fine NAF waste rock (b) clay / soil

It should be noted that laboratory defined SWCCs are often different to in situ measured SWCCs, this is discussed in Section 4.1.3.

Table 4 SWCC fitting parameters for pressure plate

Material	a[1]	n[2]	m[3]
Clay / soil	0.0289	1.5599	0.4967
Fine NAF waste rock	0.0207	1.5743	0.5948
Coarse NAF waste rock	0.0120	2.0026	0.8669

1. Fitting parameter related to air entry value (kPa)
2. Fitting parameter related to maximum slope of the curve
3. Fitting parameter related to curvature of the slope

The SWCCs (Figure 4) have been used to decide the suitability of coarse and fine NAF waste rock for the cover by comparison to clay / soil (Table 5).

Table 5 Water storage potential

Material	Saturated VWC	Residual VWC	Water storage (mm/m)
Clay / soil	0.44	0.09	350
Coarse NAF waste rock	0.42	0.00	420
Fine NAF waste rock	0.43	0.00	430

1. VWC = volumetric water content

Table 5 and Figure 4 show that:

- clay / soil has the lowest water storage potential; however, its higher residual VWC would allow it to support vegetation longer under water stress conditions;
- coarse and fine NAF waste rock have a higher water storage potential; but will desaturate / desiccate to very low residual VWC, suggesting that they have a lower capacity to support vegetation under water stress;
- the gradient of the SWCC between saturation and residual VWC suggest that coarse and fine NAF waste rock would desaturate / desiccate more rapidly than clay / soil.

Notwithstanding the noted limitations of coarse and fine waste rock, cover design was progressed on the basis that an RPL could be used to overcome the limitations (Section 2.2) because an RPL will promote extra storage in the ISL (coarse or fine NAF waste rock). This would be advantageous because coarse and fine NAF waste rock has more potential water storage capacity then clay / soil. The extra water storage could be accessed by vegetation during times of water stress. The concept of 'perched' plant available water in the ISL has been demonstrated at Century Mine (Rohde et al 2016).

2.4.4 Erosion stability

The following general remarks are made with respect to the DES comment:

The stability of the batters on the WRD have not been adequately demonstrated, given:

- the low slope gradients investigated during the rainfall and overland flow studies,

- the potential for tunnel erosion to commence,

- concerns regarding the ability of the capping and ISL layers to support vegetative growth,

- the potential impacts from plant roots encroaching on the RPL,

…

- how cover system limits seepage

The WEPP model was run for actual slope configurations of the landform this is described in SGME (2021).

There is no potential for tunnel erosion, waste rock does not slake or disperse, this is described herein.

The preferred cover is a hybrid of a store and release cover and erosion protection cover. Modelling (Section 4.0) does not include vegetation and shows that the cover will mee the design objectives without it.

The only long-term trial for the region is Century. That cover is similar to what is being proposed here, so far as both covers include an RPL and ISL made of waste rock (Rohde et at 2016). The Century cover has semi matures growing in the ISL and there is no evidence to suggest that the performance of the cover is being compromised by tree roots. A Further example of the interaction of tree roots with the RPL has been presented for Endeavour Mine (NSW) (Rohde et al 2017). At that Mine tree roots have spread laterally after they have reached the low permeability layer.

Seepage through the preferred cover is less than 6% (Table 10) of cumulative rainfall and performs better than most other published Australian examples (Section 4.2.3).

2.4.4.1 Chemical

The potential for aggregate stability of NAF waste rock and clay / soil was assessed in the laboratory by testing (Table 6):

- exchangeable sodium percentage (ESP);
- the ratio of calcium to magnesium (Ca:Mg); and
- electro-chemical stability index (ESI).

Table 6 Erosion potential of NAF waste rock and clay / soil

Analyte	Units	NAF waste rock[1]	Clay / soil[1]	Comment
ESP	%	1-1.1	1.2-74.8	Clay soil is likely dispersive, NAF waste rock is not
Ca:Mg	-	36.6-42.2	2.1-13.3	Clay / soil is dominated by Mg indicating a greater potential for slaking. NAF waste rock is dominated by Ca and likely non-dispersive
ESI[1]	-	0.127-0.140	0.087-0.137	The ESI indicates that salinity is high enough to provide some stability through the coagulation of dispersed clay particles.

1. ESI = EC (1:5) (dS/m) / ESP (%)

NAF waste rock chemistry indicates that it is stable and not prone to either slaking or dispersion. By comparison the clay / soil will likely slake and disperse; however, the potential may be reduced due to its high salinity. Therefore, NAF waste rock can be used as a substitute for soil because it is not prone to erosion.

2.4.4.2 WEPP

Erosion potential was further tested on NAF waste rock in a rainfall simulator and overland flow flume (SGME 2021).

The erosion assessment showed that the WRD will experience negligible erosion rates (<0.6 tonnes per hectare per year (t/ha/y)) and is stable because it is unlikely to develop significant rills. Similarly, the maximum erosion rates modelled (<0.37 t/ha/y) indicate that the final landform will be stable in the event of extreme rainfall. It should be noted that the predicted (and negligible) erosion rates are considerably less than average and maximum erosion rates of <5 t/ha/y and <10 t/ha/y taken from Landloch (2013) and Lu et al (2001).

The very low erosion rates predicted by WEPP can be attributed to the high effective hydraulic conductivity of the cover. While the high hydraulic conductivity will limit potential for sheet and rill erosion, sediment may be transported through minor forms of tunnel erosion; noting that, the NAF waste rock chemistry (Section 2.4.4.1) indicates aggregate stability.

The following statement gives a response to:

> *… Consideration should be given to whether Water Erosion Prediction Project (WEPP) is the most appropriate model to demonstrate erosional stability of this high-risk landform given that other models (such as SIBERIA or CAESARLisflood) will model landform evolution, consider features or points on the landform which may become unstable and determine landform sustainability over long time periods.*

The PRC plan guideline states the following as mandatory (a must statement):

- erosion assessments to determine landform heights, gradients, profiles, and material placement; and
- slope profile design considering the interactions between soil erodibility, rainfall erosivity, landform height, gradient and vegetation cover to identify acceptable erosion rates over a long-term average.

The PRC plan guideline also says:

> *The landform design objective must be targeted at achieving long-term stability. To demonstrate this, the applicant must provide an analysis of future stability based on the factors described above (eg landform evolution modelling).*

It is important to note that landform evolution modelling (LEM) is described as an example in the quote and is not a mandatory action.

The SGME erosion assessment provides an analysis of future stability for the WRD and shows that it poses a very-low erosion risk. For this reason, and the reasons given above, LEM assessment is not needed.

3.0 The trials

3.1 Method

3.1.1 Sensor calibrations

3.1.1.1 VWC

VWC sensors were not calibrated because EC was expected to remain below 10,000 µS/cm (Campbell 2000).

3.1.1.2 Matric suction

Matric suction sensors are recommended for use for ranges between 10-1,000 kilopascals (kPa). These sensors are regularly calibrated for suctions greater than 1,000 kPa (Flint et al 2002). The calibration functions extend up to 1,000,000 kPa (Appendix A).

3.1.2 Installation of instruments

The trials include buried pairs of sensors in the different layers of the preferred cover. The sensor pairs are a matric suction sensor and a VWC sensor (Photo 1). The depth of each sensor pair is in Table 7. Each layer of the preferred cover was compacted to the density in Figure 2.

Photo 1 Sensor pair

Table 7 Sensor burial depth in the preferred cover

Sensor number	Sensor depth (m bgl)
11 / B	0.1
12 / C	0.2
13 / D	1.1
14 / E	1.3
15 / F	1.6

1. Khaki = fine NAF waste rock, Light grey = coarse NAF waste rock (ISL), dark grey = compacted fine NAF waste rock (RPL)

3.2 Preferred cover results

3.2.1 Sensor calibration

Calibration functions for the preferred cover are in Figure 5-Figure 6. The sensor calibration for clay / soil is in Appendix A.

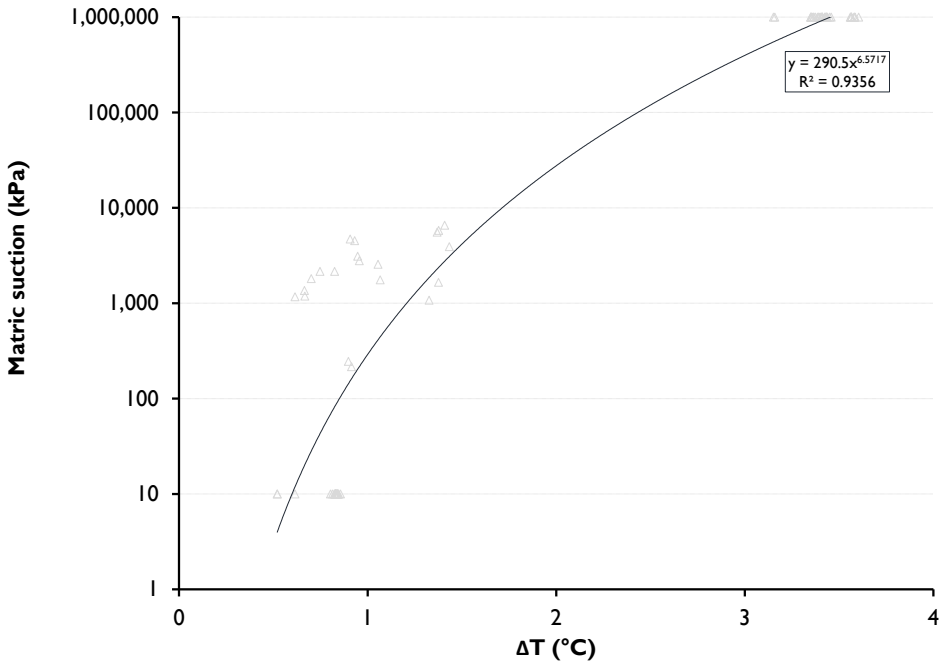

Figure 5 Fine NAF waste rock matric suction calibration function

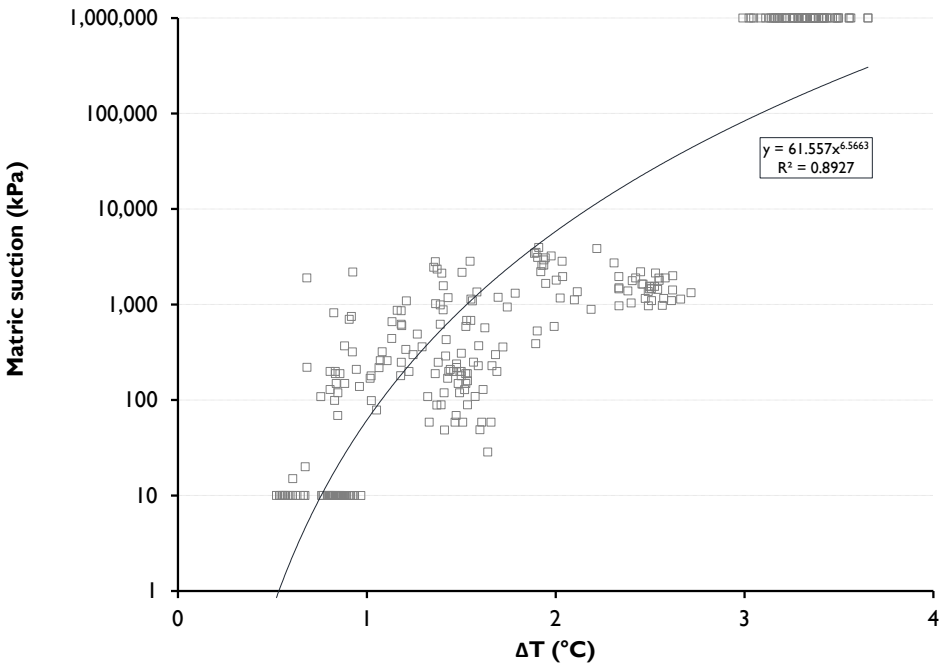

Figure 6 NAF waste rock matric suction calibration function

3.2.2 Water balance

540 millimetres (mm) of artificial rainfall was applied to the preferred cover:

- eight 30 mm artificial rainfall events; and
- six 50 mm artificial rainfall events.

The resulting water balance is in Figure 7:

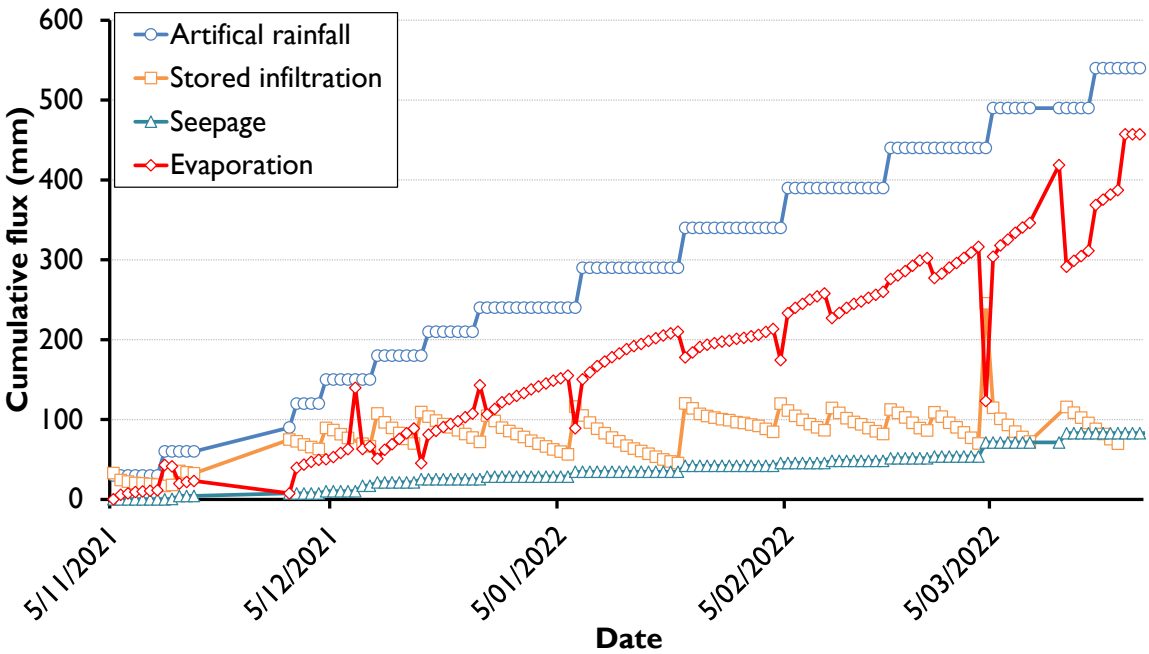

Figure 7 Preferred cover (observed) water balance

It should be noted that the water balance result in Figure 7 is for the column trial. It is not an indication of how the preferred cover can be expected to perform under normal rainfall conditions. That is, Figure 7 is representative of the outcome of applying 540 mm of rainfall over about five months and has been used to calibrated the SVFlux model (the model) (Section 4.0)

Evaporation is calculated by subtracting water storage and seepage from artificial rainfall.

4.0 SVFlux modelling

A semi-calibrated model for the preferred cover has been built in the model, which is a finite element analysis model that can simulate the process of water flow including infiltration, evaporation and seepage.

The modelling in this section of the report is used to validate the preferred cover model that was previously built in HYDRUS (SGME 2022).

Modelling presented herein supersedes previous modelling done in HYDRUS, since the freeware version of HYDRUS cannot perform the water balance modelling that has been requested by DES.

4.1 Method

4.1.1 Model geometry

The model has been built to replicate the column trial (Figure 8):

- a 0.5 m RPL of fine compacted NAF waste rock;
- a 1 m ISL of coarse NAF waste rock above the RPL; and
- a 0.3 m layer of fine NAF waste rock.

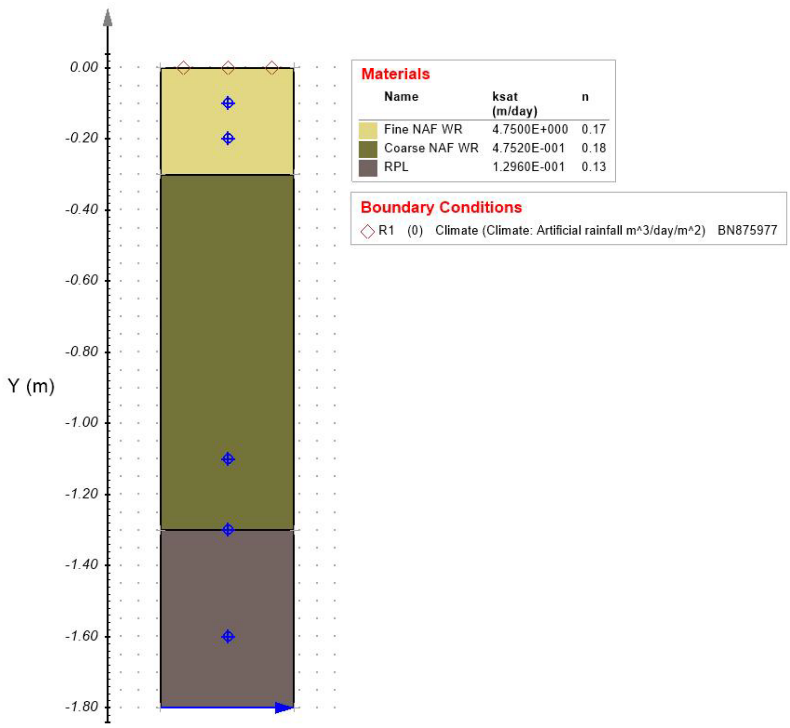

Figure 8 Model dimensions

4.1.2 Mesh geometry

A mesh is a geometry object containing a collection of adjacent non-overlapping triangles. SVFlux supports a constrained surface mesh (also known as a triangulated irregular network or TIN). This type of mesh is defined such that triangles do not 'fold' on themselves, and every X-Y coordinate is unique. Therefore, a valid surface mesh cannot contain overlapping or vertically-oriented triangles.

The automatic mesh generate algorithm was used; the global element size was 0.2 m.

4.1.3 Initial conditions

The model has been set-up to allow ponding of water on the cover ie no runoff and has not included transpiration ie no vegetation.

The same initial conditions were used in HYDRUS, but are not repeated here since:

- they are not different; and
- this model supersedes the HYDRUS model.

4.1.3.1 Potential and actual evaporation

Potential evaporation has been estimated in the model using the Penman (1948) method with the following inputs (medians from Longpaddock (SILO) data):

- air temperature constant — 24.1 degrees (°) (median from 128 year SILO data);
- relative humidity constant — 39.75% (median from 128 year SILO data);
- net radiation constant — 6.4 megajoules per metre square per day (MJ/m2/day) (median from 128 year SILO data); and
- wind speed constant — 5 metres per day (m/day) (median from 128 year SILO data).

Actual evapotranspiration is calculated in the model using the modified Wlison-Penmen equation (Wilson et al 1994).

4.1.3.2 Physical characteristics

a SWCCs

A SWCC is the relationship between VWC and matric suction.

The in situ SWCCs for each material were fitted to the results of the trials using the Van Genuchten and Mualem function (Van Genuchten 1980) (Figure 9).

In Figure 9 the in situ SWCCs are compared to a typical SWCC (Section 2.4.3) (Mercer et al 2019). It is not uncommon for in situ SWCCs to be different to typical and / or laboratory defined SWCCs (Williams & Rohde 2009). Laboratory drying SWCCs, generally obtained using reconstituted samples from a saturated state, will destroy the effects of any structure and cementation that exist in situ, and are generally not representative of in situ conditions. Material uniformity and construction control can also have a very large influence on field SWCC data.

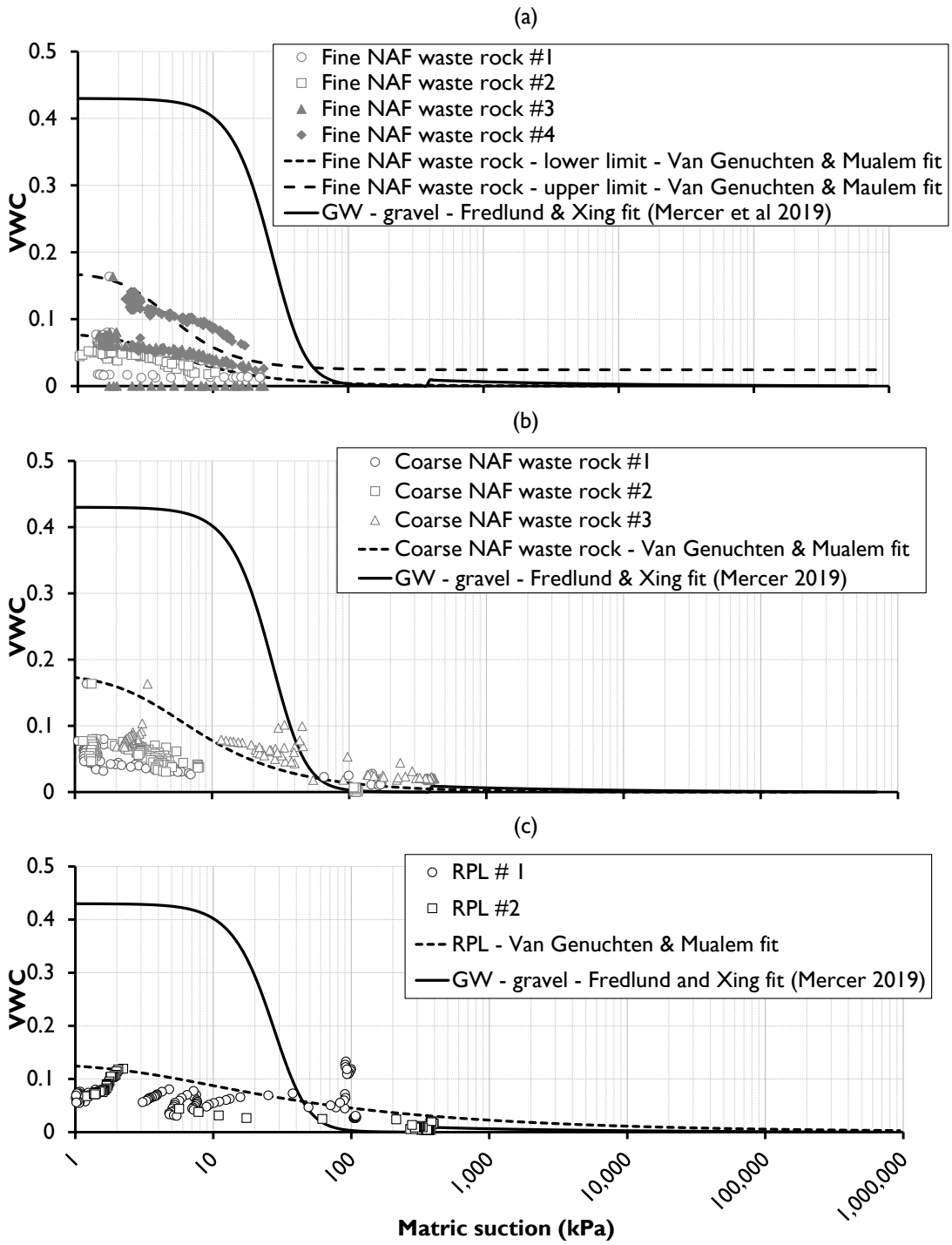

Figure 9 Preferred cover SWCCs (a) fine NAF waste rock (b) coarse NAF waste rock (c) RPL

b Unsaturated hydraulic conductivity function

The ability of a material to transport or conduct water under both saturated and unsaturated conditions is reflected by the unsaturated hydraulic conductivity function.

SVFlux has built in capability to estimate the unsaturated hydraulic conductivity function (Figure 10) using the SWCC and saturated hydraulic conductivity (Table 8).

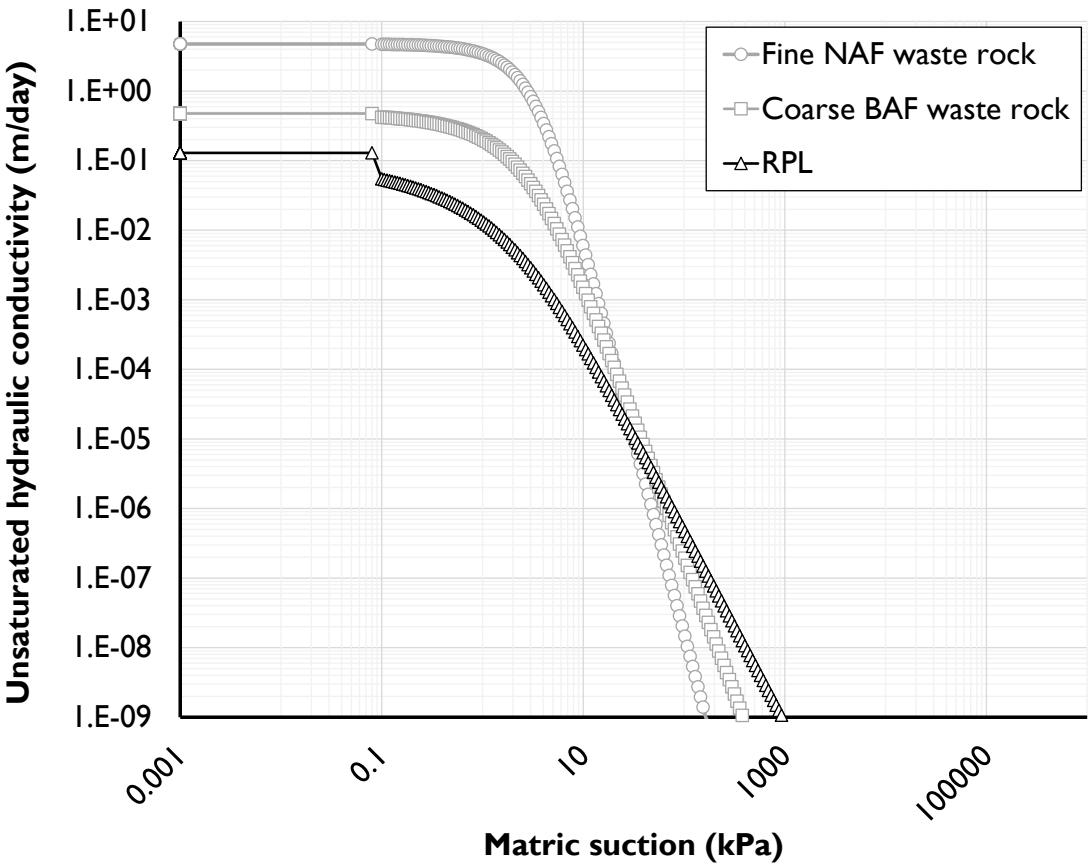

Figure 10 Unsaturated hydraulic conductivity functions

Table 8 Saturated hydraulic conductivity

Material	Saturated hydraulic conductivity	Saturated hydraulic conductivity
Fine NAF waste rock	4.75 m/day[1]	5.5-10-5 m/s[1]
Coarse NAF waste rock	0.4752 m/day	5.5x10-6 m/s[2]
RPL	0.1296 m/day	1.5x10-6 m/s[2]

1. Assumed to be highly permeability following Greeves et al (1995)
2. Trilab falling head results at 95% of maximum dry density (SGME 2022)

It is noted that the saturated permeability of soil in the HYDRUS model was set at 5.1 x 10^{-9} metres per second (m/s). The cover option that included a soil growth medium has not been remodelled in this report. The analysis is only for the preferred cover.

4.1.4 Analysis method

A series of transient analyses have been done:

- the artificial rainfall schedule;
- the average year;
- the wettest year; and
- the driest year.

The rainfall scenarios are in Table 9.

Table 9 Rainfall model scenarios

Scenarios	Year	Rainfall (mm)
Wet	2009	1,198.0
Average	1957	463.4
Dry	1926	117.2

4.2 Results and discussion

4.2.1 Water balance

The water balance for the artificial rainfall transient analysis is in Figure 11 and is compared to the water balance from the column trial (Figure 7). Differences between the model and the column trial are discussed in the following paragraphs.

The model has calculated a higher actual evaporation rate then was observed in the column trials. This result was not unexpected since the column trials were kept under cover to protect them from incidental rainfall (Figure 11):

- actual evaporation from the column trials was 71%; and
- actual evaporation from the model was 91%

The Bureau of Meteorology (BoM) estimates that the annual pan evaporation rate for Cloncurry is between 2,800-3,200 mm, which is up to six times greater than mean annual rainfall (500 mm) (BoM 2023). Noting that, actual evaporation will be limited in the field by matric suction, and therefore would be expected to be below pan evaporation. Given that NAF waste rock has a very low residual water content (Figure 4 and Figure 9) it is not unreasonable that most stored water in the preferred cover would be lost as evaporation. Further, residual water content would be reached well below 3,000 kPa (Figure 4 and Figure 9), beyond which evaporation would be effectively shut down (Wilson et al 1997).

The modelled actual evaporation rate has resulted in decreased storage of infiltration (Figure 11). Both the column trial and the model predict that seepage will start when the degree of saturation in the cover is about 50%. That is, if the 1,800 mm cover has an average porosity of 12% (Figure 4 and Figure 9) then the maximum amount of stored water at saturation is approximately 200 mm. Maximum seepage through the cover is about 18.5% of cumulative rainfall (100 mm) for the column trial and the model. Noting that, the start of seepage in the model is delayed because of the higher actual evaporation rate, which keeps the cover unsaturated for longer.

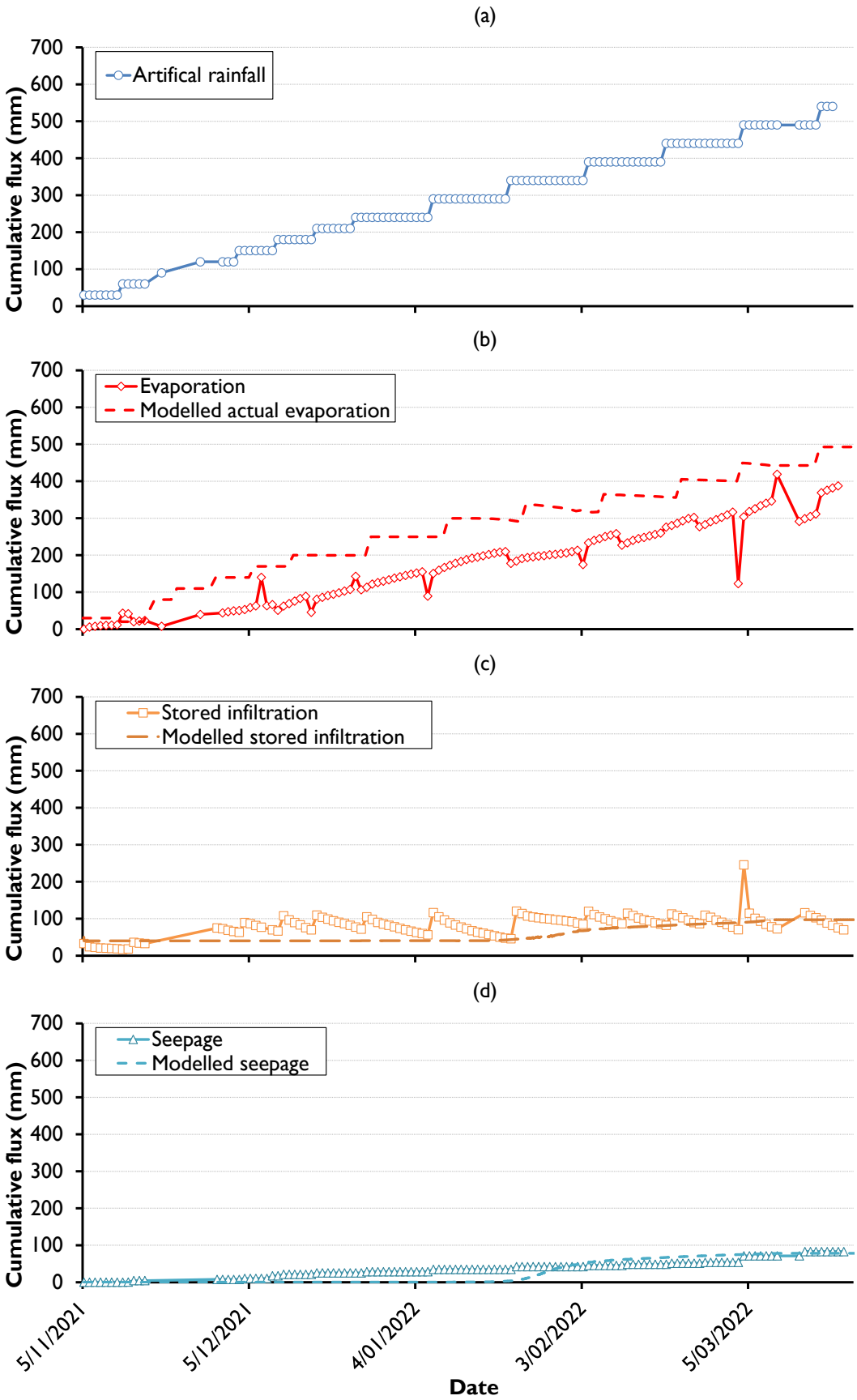

Figure 11 Preferred cover (observed versus modelled) water balance (a) artificial rainfall (b) evaporation (c) stored infiltration (d) seepage

The following statement gives a response to:

Provide a statistical comparison of model efficiency against the measured data.

The PRC plan guidelines state that a cover is required for the surface treatment of a contaminating mine landform or other waste material. Management to make sure contaminants are not released to the receiving environment is critical to rehabilitation success. Therefore, the cover must be appropriate for the type of waste and reflect a risk-based approach having consideration for:

- results from geochemical characterisation;
- type and physical characteristics of the material being covered;
- site conditions;
- availability of suitable cover materials (both quality and quantity);
- criteria for discharge (ie to protect environmental values); and
- suitable vegetation.

SGME (2022) presented (in Appendix A) a review of waste rock geochemistry done by Environmental Geochemistry International Pty Ltd (EGi) (EGi 2014), who found that waste rock:

- is predominately NAF (89%) and has low sulfur content;
- is largely non-saline;
- is significantly enriched with cobalt, copper and selenium;
- has minor enrichment of some samples with bismuth; and
- in the event of acidic conditions, would likely have increased concentrations of dissolved metals including copper, iron, aluminium, cobalt, manganese, nickel and zinc.

The geochemistry review demonstrated that a cover would be needed for the PAF cell.

SGME (2022) (in Appendix B) assessed site conditions via a risk assessment that concluded that the cover would need to:

- limit rainfall infiltration into the WRD to prevent seepage and mobilisation of oxidation products from PAF waste rock that may form acid mine drainage impacting on surface water and / or groundwater; and
- provide long term geotechnical and erosional stability.

Six cover options (SGME 2022 — Appendix B), devised from experience at the Wallace South Project (Rohde et al 2016), and regionally were assessed and ranked with the best three options progressing to the column trials. Noting that cover options that:

- incorporated NAF waste rock were viewed as better options because of their durability against erosion; and
- are erosion resistant and not dependent on vegetation for stability, but will require an RPL or CB to limit seepage.

The process to design the cover has complied with the PRC plan guidelines, statistical comparison of the model is not a requirement.

4.2.2 Future performance

Future performance of the preferred cover for wet, dry and average year rainfall is in Table 10 and includes runoff since the surface of the WRD would be graded to promote runoff. Vegetation transpiration has been excluded from the model.

Table 10 Preferred cover SVFlux water balance results

	Dry year	Average year	Wet year
Rainfall (mm)	117.2	463.4	1,198.0
Stored infiltration (%)	15	11	9
Seepage (%)	0	2	6
Actual evaporation (%)	85	87	75
Runoff (%)	0	2	10

The following statement gives a response to:

> *Provide comment and model simulation outcomes on the potential decline in surface infiltration with aggregate dispersion.*

NAF waste rock chemistry indicates that it is stable and not prone to either slaking or dispersion (Table 6). Further the NAF waste rock is well graded which will limit the potential for particle redistribution after placement (Section 2.4.1). Therefore, while there may be some mechanical redistribution of fines within the cover (ie 'washing in'), it is not expected to occur to an extent that it would alter the cover performance.

4.2.3 Industry benchmarking

Australian literature that relates to cover geometry is typically for mono (ISL only) or duplex (an ISL underlain by an RPL) layer covers:

Mt Whaleback Mine and Peak Gold Mine exemplify mono layer covers since the cover is an ISL only (Ayres et al. 2003; O'Kane et al. 2000; O'Kane & Walters 2003; Jamson & Rohde 2019) (Figure 12).

Kidston Mine, Cadia Mine, Century Mine, Endeavour Mine and Mary Kathleen Mine exemplify duplex covers as the covers use a RPL overlain by an ISL (Williams et al. 1997; Durham 2002; Wilson 2000; Rohde & Williams 2009; Rohde et al. 2016; Rohde et al. 2017; Jamson & Rohde 2019; Lottermoser et al. 2003) (Figure 12).

The ratio of evaporation to rainfall (evaporation:rainfall) exceeds two at all of the mines, meaning that a store and release cover is appropriate (Table 11 and Figure 12).

Table 11 Summary of climate for Australian mines with cover trials

Location	Rainfall (mm)	Evaporation (mm)	Evaporation:rainfall
Kidston Mine	700	2,800	4
Mt Whaleback Mine	320	3,000	~ 9
Cadia Mine	900	2,000	~ 2
Century Mine	544	2,700	~ 5
Endeavor Mine	400	1,200	3
Mary Kathleen Mine	420	2,800	~ 6.5

Figure 12 Locations of mines with cover trials

Cover performance is difficult to determine from literature with the reviewer often required to make some assumptions to estimate the performance of the cover (where performance relies on the estimation of seepage percentage from the base of the cover). Some examples of seepage that has been reported in literature include:

- 2.0 m and 4.0 m mono layer cover options from Mt Whaleback Mine;
- 1.5-2.0 m duplex layer cover at Kidston Gold Mine;
- 2.0 m duplex layer cover at Cadia Mine;
- 2.0 m duplex layer cover at Century Mine;
- 0.4-0.8 m duplex layer coves at Endeavor Mine; and
- 1.5 m duplex layer cover at Mary Kathleen Mine.

From Figure 13 it is notable that cover performance monitoring has only been reported for short periods. The performance of the covers, from the estimation of seepage percentage, ranges from near zero for Kidston Mine (duplex layer cover) to nearly 30% for Mt Whaleback Mine (mono layer cover) and Mary Kathleen Mine (duplex layer cover). Century Mine which has the most comparable climate to the Mine (Figure 13), has limited seepage of between 1.5-3.6%.

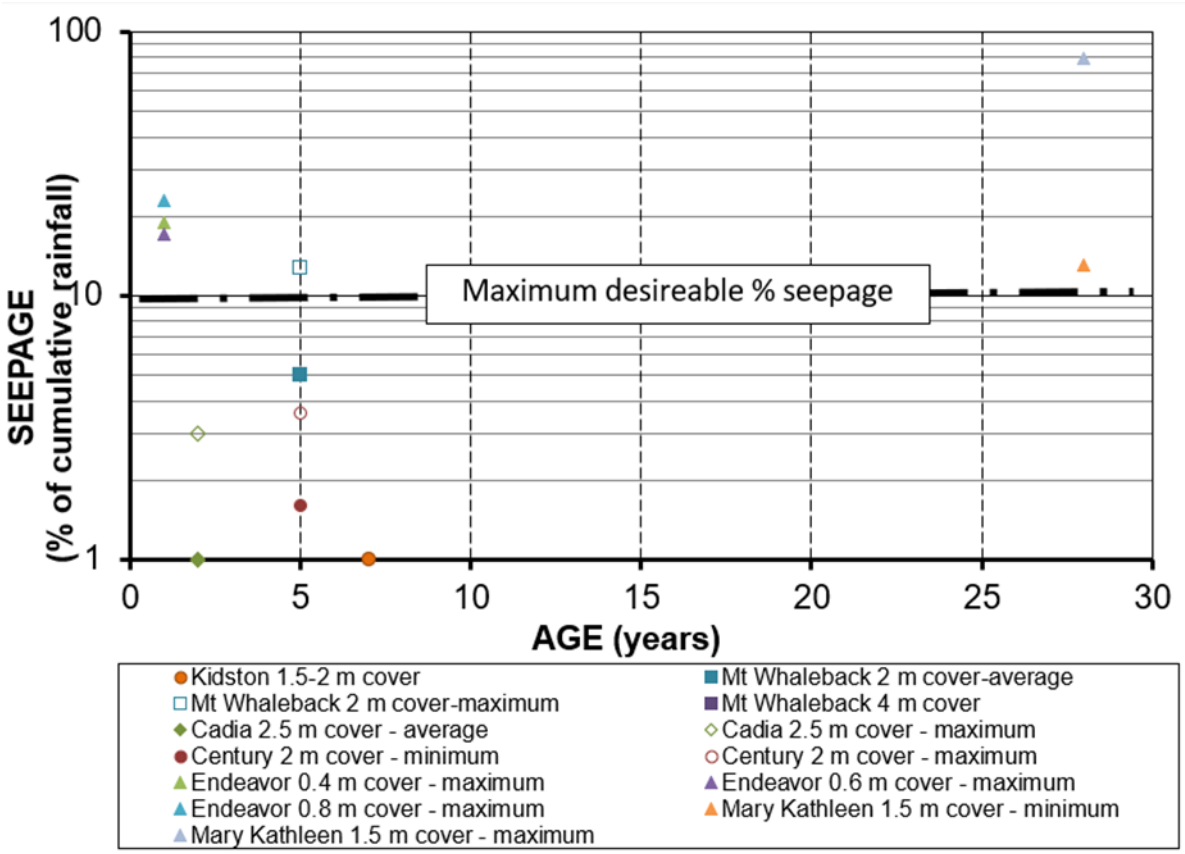

Figure 13 Performance of Australian cover trials

The maximum desirable percentage seepage rate in Figure 13 (10%) is ~ equivalent to 8.6 x 10^{-4} m/s, being the approximate natural rate of groundwater recharge in semi-arid Australian climates (Cook et al. 2004).

The model shows that preferred cover performs comparably to those in literature and below the maximum desirable seepage rate.

5.0 Conclusions

Concluding remarks are summarised in Table 12. It is recommended that a full-scale field trial of the preferred cover be undertaken to verify that the preferred cover will function as estimated from the model. It is envisaged that the trials would need to run for at least five years before reliable results can be produced to calibrate the model (Rohde et at 2016).

Table 12 Conclusions

Number	DES RFI statement	Conclusions
4	… Figure 6-24 provides a preferred cover design and shows a 1metre (m) thick layer of rock which section 6.5.2 describes as coarse waste rock. It is unclear how coarse waste rock will provide an infiltration storage layer.	The name coarse NAF waste rock is used to differentiate the ISL from the growth media (fine NAF waste rock). The coarse NAF waste rock of the ISL is run-of-mine and the fine NAF waste rock of the growth media has been scalped to increase the proportion of innate fines. Both NAF waste rock products are well graded, with little potential for particle redistribution. The NAF waste rock is not prone to slaking or dispersion and has low salinity. NAF waste rock fertility is comparable to soil (Table 3), but is deficient to P.

Number	DES RFI statement	Conclusions
5	Provide further information to demonstrate the preferred cover design will achieve long term structural stability, considering the matters raised. This is likely to require additional overland flow and rainfall studies at higher gradients which better replicate the final landform to either demonstrate no rill development or to provide derived values for updated erosion modelling. Consideration should be given to whether Water Erosion Prediction Project (WEPP) is the most appropriate model to demonstrate erosional stability of this high-risk landform given that other models (such as SIBERIA or CAESARLisflood) will model landform evolution, consider features or points on the landform which may become unstable and determine landform sustainability over long time periods. Include additional information to demonstrate the suitability of the cover design to support vegetative growth, which in-turn informs the erosional stability of the landform and integrity of the reduced permeability layer (RPL).	The PRC plan guideline states the following as mandatory (a must statement): • erosion assessments to determine landform heights, gradients, profiles, and material placement; and • slope profile design considering the interactions between soil erodibility, rainfall erosivity, landform height, gradient and vegetation cover to identify acceptable erosion rates over a long-term average. The PRC plan guideline also says: *The landform design objective must be targeted at achieving long-term stability. To demonstrate this, the applicant must provide an analysis of future stability based on the factors described above (eg landform evolution modelling).* It is important to note that LEM is described as an example in the quote and is not a mandatory action. The SGME erosion assessment provides an analysis of future stability for the WRD and shows that it poses a very-low erosion risk. For this reason, and the reasons given above, LEM assessment is not needed.
7	Provide details on the calibration and installation of the moisture tension and water content sensors.	VWC sensors were not calibrated because the EC was expected to be below 10,000 µS/cm (Campbell 2000). Calibration functions are in Figure 5 and Figure 6 for NAF waste rock. Installation of sensors is described in Section 3.1.2.
	Provide the fitting parameters for the measured, in situ data and for the predicted soil water characteristic curves (SWCCs). Confirm these parameters against published data and values generated by soil water retention software such as RETC.	Laboratory and in situ SWCCs are described in Section 2.4.3 and Section 4.1.3.2a respectively. SWCCs are compared to typical SWCC from Mercer et al (2019). It is not uncommon for in situ SWCCs to be different to typical and / or laboratory defined SWCCs (Williams & Rohde 2009). Laboratory drying SWCCs, generally obtained using reconstituted samples from a saturated state, will destroy the effects of any structure and cementation that exist in situ, and are generally not representative of in situ conditions. Material uniformity and construction control can also have a very large influence on field SWCC data.

Number	DES RFI statement	Conclusions
8	Provide the initial upper and lower boundary conditions used to run HYDRUS.	Section 4.1.3
9	Provide a better estimate of bare soil evaporation and its (seasonal) fluctuation over the simulation period.	Potential evaporation has been estimated in the model using the Penman (1948) method with the following inputs (medians from SILO data): • air temperature constant — 24.1 °(median from 128 year SILO data); • relative humidity constant — 39.75% (median from 128 year SILO data); • net radiation constant — 6.4 MJ/m2/day (median from 128 year SILO data); and • wind speed constant — 5 m/day (median from 128 year SILO data). Actual evapotranspiration is calculated in the model using the modified Wlison-Penmen equation (Wilson et al 1994).
10	Provide reasoning and validation why the saturated hydraulic conductivity of the growth medium soil was set as 5.1×10^{-9} metres per second (m/s) and re-model the water balance using HYDRUS using appropriate values.	The preferred cover does not include soil because there is limited supply of soil available for rehabilitation work. Model validation presented in this report is limited to the preferred cover. Validation of the model is in Section 4.2.1.
11	Provide comment and model simulation outcomes on the potential decline in surface infiltration with aggregate dispersion.	NAF waste rock chemistry indicates that it is stable and not prone to either slaking or dispersion (Table 6). Further the NAF waste rock is well graded which will limit the potential for particle redistribution after placement (Section 2.4.1). Therefore, while there may be some mechanical redistribution of fines within the cover (ie 'washing in'), it is not expected to occur to an extent that it would alter the cover performance.
12	Present the cover column water balance in graphical format for each parameter (rainfall, evaporation, storage, drainage) as a function of time.	The column trial water balance is in Section 3.2.2.

Number	DES RFI statement	Conclusions
13	Present the water balance predicted by HYDRUS in graphical format for each parameter (rainfall, evaporation, storage, drainage) as a function of time.	The SVFlux water balance is in Section 4.2.1.
14	Provide a graphical comparison of measured and modelled water balance outcomes.	Graphical comparison is in Section 4.2.1. Differences between the model and the column trial are discussed in the following paragraphs. The model has calculated a higher actual evaporation rate then was observed in the column trials. This result was not unexpected since the column trials were kept under cover to protect them from incidental rainfall (Figure 11): – actual evaporation from the column trials was 71%; and – actual evaporation from the model was 91% The Bureau of Meteorology (BoM) estimates that the annual pan evaporation rate for Cloncurry is between 2,800-3,200 mm, which is up to six times greater than mean annual rainfall (500 mm) (BoM 2023). Noting that, actual evaporation will be limited in the field by matric suction, and therefore would be expected to be below pan evaporation. Given that NAF waste rock has a very low residual water content (Figure 4 and Figure 9) it is not unreasonable that most stored water in the preferred cover would be lost as evaporation. Further, residual water content would be reached well below 3,000 kPa (Figure 4 and Figure 9), beyond which evaporation would be effectively shut down (Wilson et al 1997). The modelled actual evaporation rate has resulted in decreased storage of infiltration (Figure 11). Both the column trial and the model predict that seepage will start when the degree of saturation in the cover is about 50%. That is, if the 1,800 mm cover has an average porosity of 12% (Figure 4 and Figure 9) then the maximum amount of stored water at saturation is approximately 200 mm. Maximum seepage through the cover is about 18.5% of cumulative rainfall (100 mm) for the column trial and the model. Noting that, the start of seepage in the model is delayed because of the higher actual evaporation rate, which keeps the cover unsaturated for longer.

15	Provide a statistical comparison of model efficiency against the measured data.	The PRC plan guidelines state that a cover is required for the surface treatment of a contaminating mine landform or other waste material. Management to make sure contaminants are not released to the receiving environment is critical to rehabilitation success. Therefore, the cover must be appropriate for the type of waste and reflect a risk-based approach having consideration for: • results from geochemical characterisation; • type and physical characteristics of the material being covered; • site conditions; • availability of suitable cover materials (both quality and quantity); • criteria for discharge (ie to protect environmental values); and • suitable vegetation. SGME (2022) presented (in Appendix A) a review of waste rock geochemistry done by Egi (2014), who found that waste rock: • is predominately NAF (89%) and has low sulfur content; • largely non-saline; • is significantly enriched with cobalt, copper and selenium; • has minor enrichment of some samples with bismuth; and • in the event of acidic conditions, would likely have increased concentrations of dissolved metals including copper, iron, aluminium, cobalt, manganese, nickel and zinc. The geochemistry review demonstrated that a cover would be needed for the PAF cell. SGME (2022) (in Appendix B) assessed site conditions via a risk assessment that concluded that the cover would need to: • limit rainfall infiltration into the WRD to prevent seepage and mobilisation of oxidation products from PAF waste rock that may form acid mine drainage impacting on surface water and / or groundwater; and • provide long term geotechnical and erosional stability.

Number	DES RFI statement	Conclusions
		Six cover options (SGME 2022 — Appendix B), devised from experience at the Wallace South Project and regionally (Rohde 2016), were assessed and ranked with the best three options progressing to the column trials. Noting that cover options that: • incorporated NAF waste rock were viewed as better options because of their durability against erosion; and • are erosion resistant and not dependent on vegetation for stability, but will require an RPL or CB to limit seepage. The process to design the cover has complied with the PRC plan guidelines, statistical comparison of the model is not a requirement.
16	Provide a detailed discussion / interpretation of the water balance for the three cover scenarios, with supporting documentation from the published literature	Future performance of the preferred cover is in Table 10. How the cover performs against other industry examples is discussed in Section 4.2.3. The model shows that preferred cover performs comparably to those in literature and below the maximum desirable seepage rate. The maximum desirable percentage seepage rate in Figure 13 (10%) is ~ equivalent to 8.6×10^{-4} m/s, being the approximate natural rate of groundwater recharge in semi-arid Australian climates (Cook et al. 2004).
17	If any assumptions or input data are found to not reflect the cover system design study, modelling is to be repeated and if possible use 2-D HYDRUS when applying outcomes to recommendations for waste dump design and performance criteria, particularly in terms of seepage rates.	The verified model in SVFlux supports the HYDRUS results; noting that, performance under wet year conditions in the SVFlux model has resulted in better performance because of the inclusion of an actual evaporation rate in the model.

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Appendix A

Method for calibrating matric suction sensors

The matric suction sensors were individually calibrated by comparing the measured the change in temperature (ΔT) of the matric suction sensors to the matric suction of each material. The matric suction was determined by measuring total suction with a dew-point water potential meter and calculating osmotic suction from electrical conductivity (EC). Matric suction was then calculated by subtracting osmotic suction from total suction. The following method was used to calibrate the matric suction sensors:

1. Place oven dried matric suction sensors into oven dried cover material and allow them to come to equilibrium for 24 hours. The measured change in temperature (ΔT) is equivalent to a matric suction of 1,000,000 kilopascals (kPa).
2. Submerge the matric suction sensors in de-aired water for 48 hours to completely saturate the sensor head. Measured ΔT is equivalent to a matric suction of 10 kPa.
3. Weigh 1 kilogram (kg) of each cover material into a zip-lock bag and add 100 millilitres (ml) of deionised (DI) water, mix well and allow the prepared mixture to come to equilibrium over 24 hours.
4. Bury each matric suction sensor in separate Falcon tubes with the selected cover material and allow them to reach equilibrium over 24 hours. Measured ΔT is equivalent to a matric suction between field capacity and permanent wilting point.
5. Repeat step 3 and step 4 with 50 ml of DI water.
6. At the end of step 4 measure total suction directly using a water potential dew-point meter.
7. At the end of step 4 measure the EC directly on a one-part cover material to five-parts DI water.

The matric suction can then be calculated from EQ A1 and EQ A2.

Total suction (kPa) = matric suction (kPa) + osmotic suction (kPa) [EQ A1]

Osmotic suction (kPa) = 0.36 * EC (dS/m) [EQ A2]

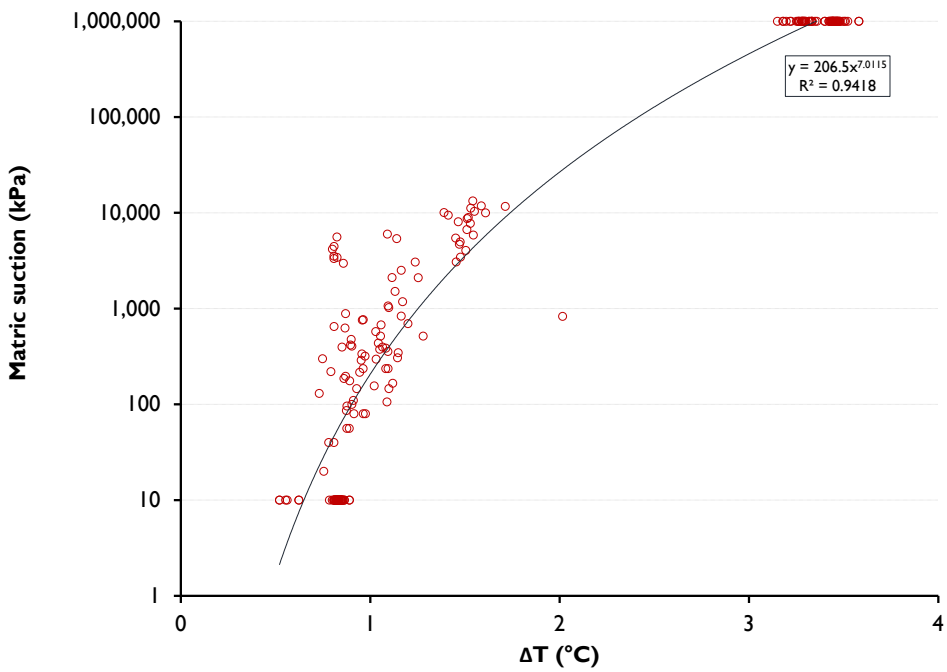

Figure 14 Soil / clay matric suction calibration function

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SGME was established to provide services in soil science, geochemistry, mine closure and Environmental management, planning & approvals cost efficiently. When you engage SGME you engage a partner to your business, priding themselves on:

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BARBARA COPPER-GOLD PROJECT

Rehabilitation Monitoring Program

Prepared for:

Aeris Resources
Mt Colin Mine off Barkly Hwy
Cloncurry
QLD 4824

SLR Ref: 628.30001.00000-R01
Version No: -v3.0
March 2023

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Aeris Resources (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

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CONTENTS

1 INTRODUCTION 5
1.1 Project background 5
1.2 Proposed post mine land uses 5
1.3 Regulatory context 5
1.3.1 Environmental authority 5
1.3.2 Progressive Rehabilitation and Closure Plan 7
1.4 Scope of works 8
2 EXISTING ENVIRONMENT 12
2.1 Regional context 12
2.2 Climate 12
2.3 Geology 13
2.4 Soils 13
2.5 Receiving waters 13
2.6 Vegetation communities 13
3 REHABILITATION MONITORING PROGRAM DESIGN 15
3.1 Purpose 15
3.2 Analogue sites 15
3.3 Rehabilitation sites 18
3.4 Monitoring timing and frequency 18
3.5 Vegetation monitoring 19
3.5.1 Transects and quadrats 19
3.5.2 Indices 20
3.5.3 Photographic monitoring 21
3.5.4 Data analysis 22
3.6 Fauna habitat monitoring 22
3.7 Soil monitoring 22
3.8 Erosion monitoring 23
3.9 Landscape function analysis 24
3.10 Safety and stability 25
3.10.1 Safety 25
3.10.2 Stability 25
3.10.2.1 Geotechnical Stability 25
3.10.2.2 Erosional Stability 26

CONTENTS

4 MILESTONE AND SUCCESS CRITERIA 27

4.1 Milestone Criteria 27

4.2 Success Criteria 28

5 REFERENCES 30

DOCUMENT REFERENCES

TABLES

Table 1 Regional ecosystems mapped by the Queensland Government in ML90241 (DES, 2022; DoR 2022) 14
Table 2 Analogue monitoring site locations 16
Table 3 Timeline for monitoring of analogue and rehabilitated sites 18
Table 4 Vegetation monitoring indices 20
Table 5 Information collected for each erosion feature 23
Table 6 Soil surface assessment calculations of the three indices for landscape function monitoring 25
Table 7 Rehabilitation milestones and criteria addressed in this RMP 27
Table 8 Draft success criteria for measured indices at rehabilitated sites 28

FIGURES

Figure 1 Project location 9
Figure 2 Project layout 10
Figure 3 Conceptual post mining land use 11
Figure 4 Annual rainfall and seasonal distribution for West Leichhardt Station (1955-2023) (BoM, 2022) 12
Figure 5 Analogue site locations 17
Figure 6 Representation of transect layout showing dimensions and quadrats 20

APPENDICES

Appendix A – Baseline data 2023
Appendix B – Land Function Analysis data
Appendix C – Flora species list
Appendix D – Representative photographs

1 Introduction

1.1 Project background

SLR Consulting Australia Pty Ltd (SLR) was commissioned by Aeris Resources Ltd (Aeris) to prepare a Rehabilitation Monitoring Program (RMP) for the Barbara Copper-Gold Project (BCP).

BCP is located in northwest Queensland within mining lease (ML) 90241 (**Figure 1**). The operation is owned by Aeris and operated under Environmental Authority (EA) permit EPML02840015. The 1,170ha ML area is located on the West Leichhardt Station, approximately 50km northeast of Mt Isa in the Northwest Highlands bioregion. Historical small-scale mining has previously occurred on the site and in the surrounding landscape. Currently the site consists of two pits (within the central southern area of the ML), a run of mine pad, maintenance workshop, waste rock dump, administration buildings, a haul road and water management infrastructure including a sediment dam, clean water diversions, and mine-impacted water drains. The surrounding landscape is used for low intensity cattle grazing. As of March 2021, active mining at the BCP concluded and the site was placed into care and maintenance.

1.2 Proposed post mine land uses

The current project layout and mine domains are presented on **Figure 2**. The proposed post mine land uses (PMLUs) for the mine domains at BCP following rehabilitation are presented on **Figure 3** and include the following:

- north pit and south pit – water storage for livestock
- sediment dam – water storage for livestock
- waste rock dump – native ecosystems
- ancillary infrastructure (run-of-mine (ROM) pad, roads and exploration) – low intensity grazing
- diversion drains (diversion drain and levee to the west of the north pit, diversion drain east of south pit and diversion drain east of the WRD sediment dam) – water management infrastructure.

1.3 Regulatory context

1.3.1 Environmental authority

The EA includes conditions regarding the rehabilitation of areas within the ML as follows.

- **Condition G1**: *'The environmental authority holder must rehabilitate all significantly disturbed land caused by the mining activities in a manner that ensures rehabilitated areas achieve the following rehabilitation objectives:*

  a) Safe for humans and wildlife;

  b) Non-polluting;

  c) Stable;

  d) Able to sustain a post-mining land-use agreed to by the administering authority and any underlying landholders;

  e) Revegetated with species endemic to the area with no declared pest species; and

f) Compliant with all conditions of this environmental authority.'

- **Condition G2:** '*Two years from commencement of mining*[1] *the environmental authority holder must develop and document a Post Mine Land-use Plan ('PMLUP') that describes how the rehabilitation objectives in condition G1 will be achieved. The PMLUP must at minimum include*:

a) Schematic representation of the proposed final land form inclusive of site drainage features;

b) Details of proposed slope design and erosion and sediment controls;

c) Proposed cover designs for encapsulation of waste material, including performance criteria;

d) Proposed re-vegetation methods inclusive of plant species selection, propagation methods and establishment of suitable plant growth medium (i.e. top soil);

e) Materials balance for all rehabilitation requirements including available top soil and material suitable for encapsulating waste in accordance with the proposed encapsulation methodology;

f) Geotechnical, geochemical and hydrological studies necessary to demonstrate likely success of proposed rehabilitation methodology to achieve the required rehabilitation outcomes;

g) An investigation of proposed residual voids including potential for generation/mobilisation of contaminants, potential pathways for release of contaminants to waters (including groundwater) and a long-term void water balance model; and

h) A rehabilitation monitoring program sufficient to identify if required rehabilitation outcomes have been achieved.'

- **Condition G3:** '*Rehabilitation must commence progressively in accordance with the Plan of Operations.*'

- **Condition H27**: '*After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria:*

a) the landform is safe for humans and fauna;

b) the landform is stable with no subsidence or significant erosion gullies for at least three (3) years;

c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated;

d) not allowing for acid mine drainage; or

e) there is no ongoing contamination to waters (including groundwater);

f) rehabilitation is undertaken in a manner such that any actual or potential acid sulfate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the Instructions for the treatment and management of acid sulfate soils (2001);

g) all significantly disturbed land is reinstated to the pre-disturbed soil suitability class;

h) for land that is not being cultivated by the landholder:

i. groundcover, that is not a declared pest species is established and self-sustaining,

ii. vegetation of similar species richness and species diversity to pre-selected analogue sites is established and suited to the post mine land use, and

[1] Commencement of mining is taken to be the date that extraction of material from the pit commences.

iii. the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the petroleum activity(ies).

i) *for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within 3 months of petroleum activities being completed*. '

1.3.2 Progressive Rehabilitation and Closure Plan

Progressive Rehabilitation and Closure Plan (PRCP) requirements for resource activities in Queensland took effect from 1 November 2019, meaning all mines with site-specific EAs must prepare a PRCP. The PRCP application for BCP was lodged on 28 July 2022 and is currently being assessed by the Queensland Government. The overarching objective of mine rehabilitation and closure at BCP is to achieve a safe, stable and non-polluting site which can sustain the agreed post mining land uses.

The current PRCP application sets out the following additional rehabilitation objectives for BCP, that have been designed to align with existing EA conditions.

1. Rehabilitation and closure are conducted in a planned, orderly and transparent manner.
2. Rehabilitation performance is assessed on the basis of reliable and scientifically valid evidence.
3. Closed project areas do not represent a danger to people or wildlife.
4. Agreed environmental and human use values of surface water systems are maintained.
5. Groundwater systems return to agreed beneficial uses.
6. Post-closure land capability is consistent with post-closure land uses agreed with landholders and other stakeholders.
7. Closure landforms are structurally and chemically safe and stable, with minimal requirement for ongoing maintenance or management.
8. Successful handover of selected infrastructure and removal of all other infrastructure associated with operations.
9. Achievement of agreed baseline for soil contamination.
10. Areas disturbed by mining activities are revegetated to an acceptable standard for the post-mine land use.
11. Closure landforms are visually compatible with the surrounding natural landscape.
12. Ongoing monitoring and maintenance of rehabilitated areas is appropriately resourced and implemented; accountabilities for post-closure management actions are clearly documented and agreed by responsible parties.
13. Closure is implemented to minimise adverse social and economic impacts on local communities.

The proposed rehabilitation milestones and milestone criteria for BCP can be found in the current PRCP.

1.4 Scope of works

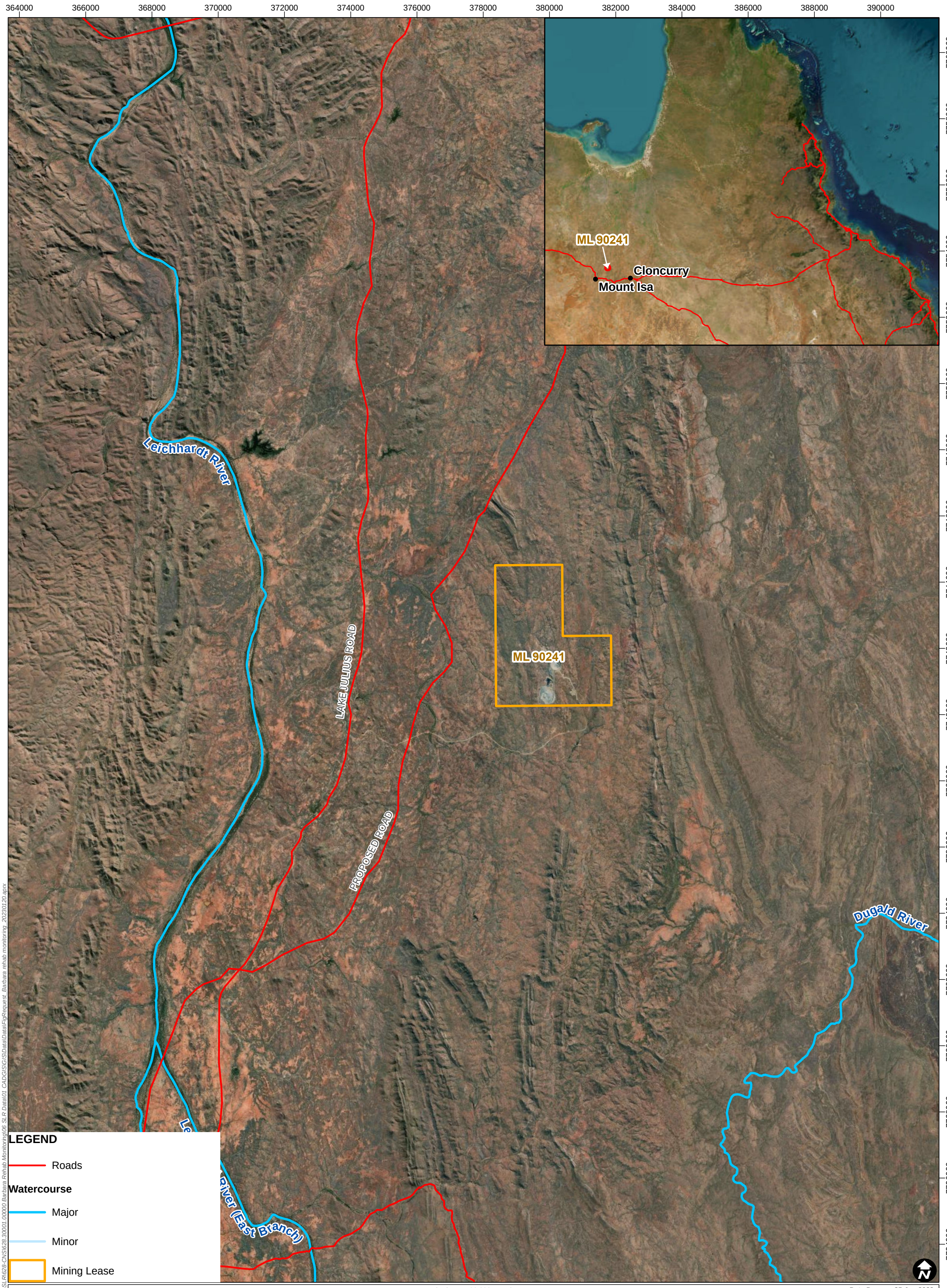
An information request from the Queensland Department of Environment and Science (DES) regarding the PRCP application was received on 7 September 2022. The following items in the information request are relevant to this scope of works:

- '*Provide information regarding the location of nominated analogue sites, their current condition regarding each of the milestone criteria that will be used for comparison and how the analogue sites are considered suitable for comparison*'.

SLR's scope of work was to prepare a Rehabilitation Monitoring Program (RMP) to assist in addressing condition G2(h) of the EA, and the PRCP application information request. This RMP may be updated following additional data collected from future monitoring events.

The RMP outlines the following:

- BCP Environmental Authority (EA) and PRCP requirements regarding rehabilitation and closure
- Details of BCP domains and post-mine land uses
- Locations and descriptions of analogue monitoring sites
- Rehabilitation monitoring methods (including the collection of data on vegetation, landform, erosion and soil characteristics for the development of rehabilitation success criteria)
- Frequency and timing of rehabilitation monitoring
- GIS mapping.



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Date Drawn: 25-Jan-2023
Project Number: 628.30001.00000

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Data Source: World Imagery: Earthstar Geographics(2020), Mining Lease, Roads datasets from QSpatial, DNRME (2023) Vegetation Management Watercourse dataset from QGOV, DES (2023).

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Project location

FIGURE 1

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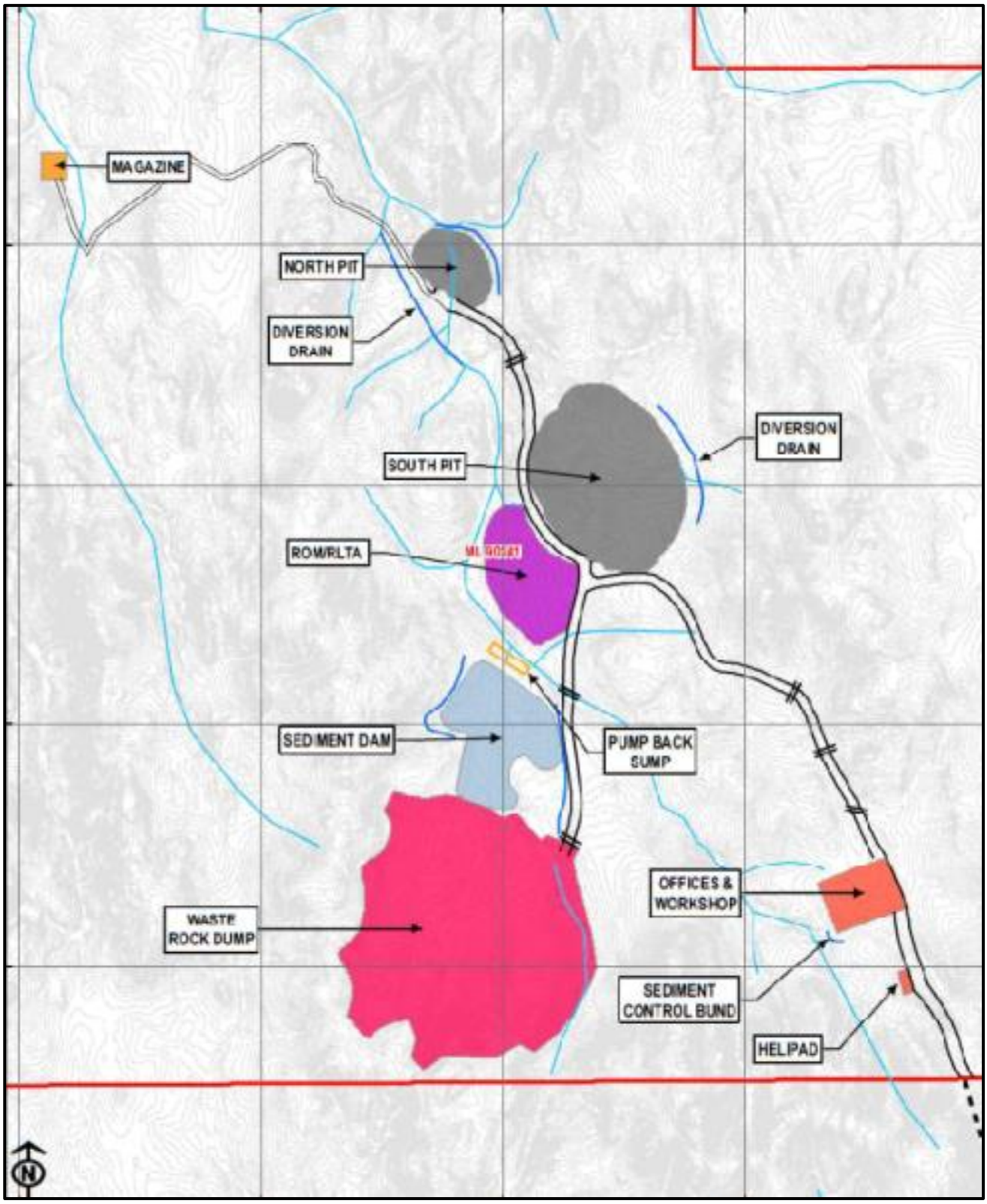


Figure 2 Project layout

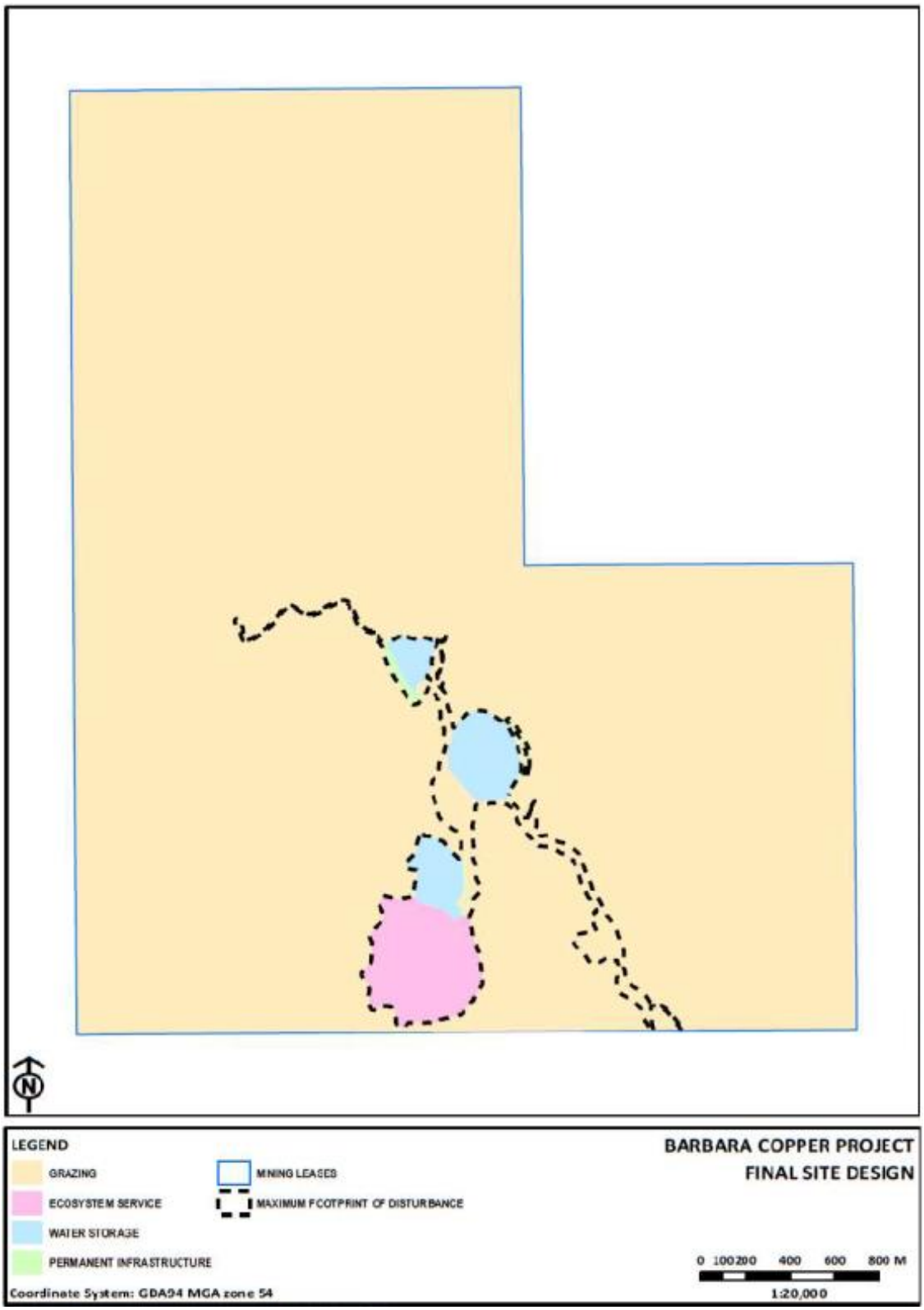


Figure 3 Conceptual post mining land use

2 Existing environment

2.1 Regional context

BCP is located in the Mount Isa Inlier subregion, of the Northwest Highlands bioregion, which is dominated by metamorphic and volcanic rocky hills, eroded sandstone platforms and limestone karst systems (DES, 2020). Land use in this bioregion is primarily agricultural (especially pastoral grazing) and extractive industries. Despite the lack of broadscale clearing in the region (approximately 99.5% of the vegetation in this sub-region is remnant), the condition of much of the remnant vegetation has been impacted from agriculture, mining, weeds and feral animals (DES, 2020).

2.2 Climate

The BCP area is characterised by hot summers and mild winters. The climate in the region is semi-arid and rainfall is highly seasonal, with the majority falling over a three-month period in the summer months. Meteorological data is available for several weather stations in the area and long-term rainfall data was sourced from the Bureau of Meteorology (BoM) West Leichhardt Station weather station (number 029121) approximately 27km from BCP (BoM, 2023).The local area typically experiences short, intense rainfall events which occur primarily between November to April (BoM, 2023; **Figure 4**). Average annual wet season rainfall over the 1955 to 2022 period is 358mm and the average annual dry season rainfall is 70mm (BoM, 2023).

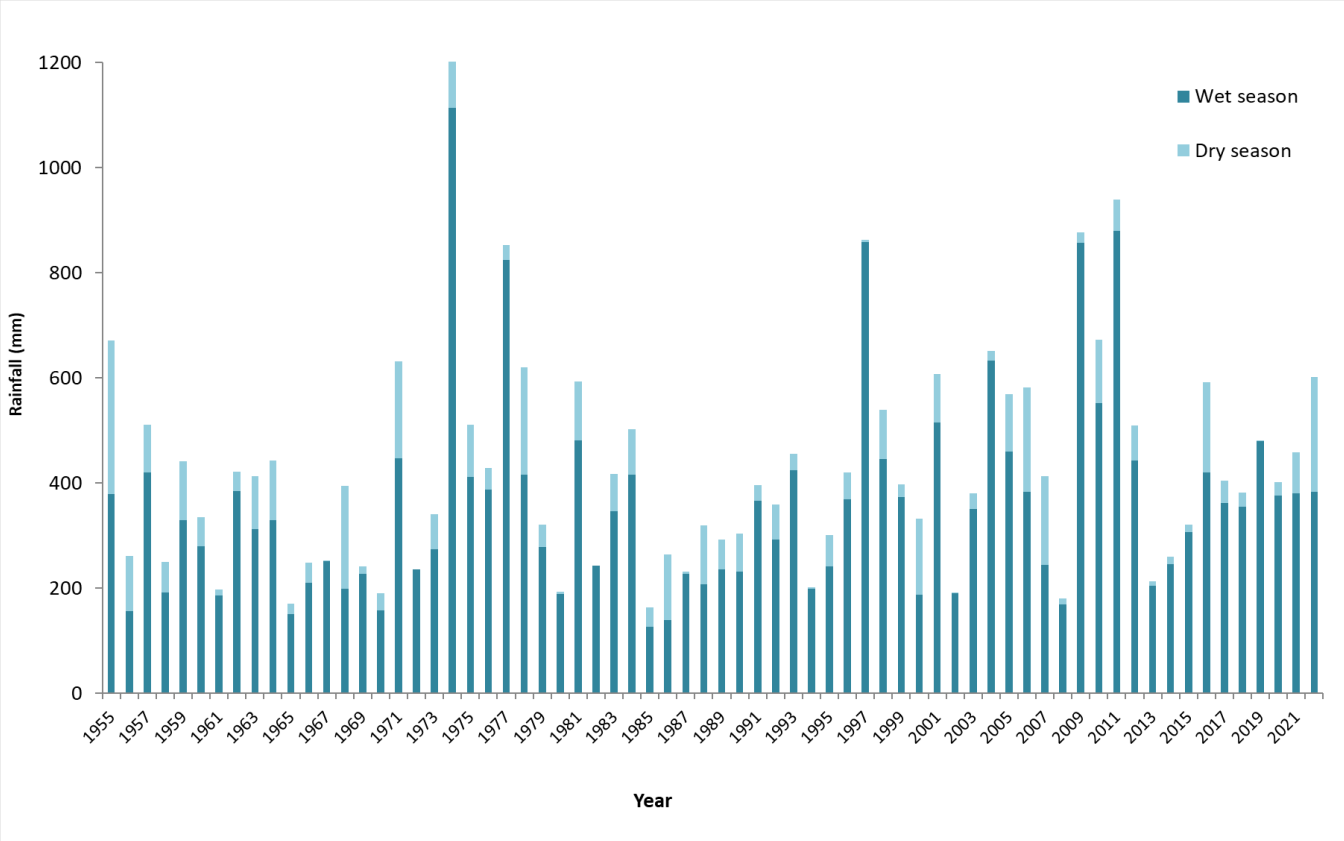


Figure 4 Annual rainfall and seasonal distribution for West Leichhardt Station (1955-2023) (BoM, 2022)

2.3 Geology

Bedrock geology in the area comprises Proterozoic rocks of the Mount Isa Inlier. Rock types at BCP include felsic volcanics (forming the hills), dolerite/amphibolite (in the drainages/valleys) and basalt (forming plateaus). The dominant rock type in the ML is the felsic volcanics. These rock types are resistant to weathering and extensive outcrops occur throughout the local area. Elevation within the ML ranges from 297m above sea level (ASL) in alluvial areas northwest of the mine footprint, to 390m ASL in rocky, hilly areas south and east of the mine footprint.

2.4 Soils

Three broad soil management units occur within the ML as follows (AARC, 2016).

- River red gum sands.
  - Sand textured soils, typically associated with drainage lines and watercourses. Soils are often deep and well-drained with a high gravel and cobble content.
- Cloncurry box drainage terrace.
  - Loamy to clayey sands occurring along terraces adjacent to open drainage depressions. These soils occur on relatively flat topography and are commonly intersected by drainage lines and rock outcrops. Course fragments (20-60mm) are present throughout the soil profile.
- Snappy gum slopes.
  - Clayey sands to sandy clay loams with moderate to high gravel content, occurring on steep lower slopes with extensive areas of rock outcrops. Soils vary in depth, with significant areas of shallow rocky substrate present.

2.5 Receiving waters

The landscape around BCP is composed primarily of rocky hills of folded siliceous metamorphosed sedimentary rock, and generally skeletal soils (including in watercourses). Average elevation is 350m above sea level and the site is traversed by a series of small ephemeral creeks and drainage lines. These meet a larger un-named watercourse which drains to the northwest and eventually flows into the Leichhardt River approximately 6km downstream of the project site. This unnamed creek runs through an area disturbed by historical mining activities which pre-date any Aeris activities on site.

2.6 Vegetation communities

Three different regional ecosystems (REs) are mapped by the Queensland Government (DES, 2022; DoR 2022) to occur within the BCP ML. These regional ecosystems comprise low open woodlands (often dominated by *Eucalyptus* or *Corymbia* species) on varying degrees of hills and slopes, with areas of sparse vegetation cover. Descriptions of each RE type and their conservation significance according to the Queensland *Vegetation Management Act* 1999 (VM Act) and the DES Biodiversity status (BD status), are present in **Table 1**. Mapped REs within the BCP ML are presented on **Figure 5**.

Table 1 Regional ecosystems mapped by the Queensland Government in ML90241 (DES, 2022; DoR 2022)

Regional Ecosystem (RE)	Description[1]	VM Act status[2]	BD status[3]
1.11.2	**1.11.2a:** *Eucalyptus leucophloia* low open woodland often with *Corymbia terminalis, Corymbia capricornia, Terminalia aridicola* and *Eucalyptus leucophylla* with shrub layer of *Acacia* spp. and ground layer of *Tr*iodia spp. Occurs on steep hills and strike ridges.	Least Concern	No concern at present
1.11.3	**1.11.3a:** *Eucalyptus leucophylla* low open woodland often with *Corymbia terminalis, C. aparrerinja, Eucalyptus leucophloi*a and *Atalaya hemiglauca* with scattered shrubs of *Acacia chisholmii* and a sparse ground layer of *Triodia pungens* and tussock grasses. Occurs on broad low hills; metamorphosed igneous rocks. **1.11.3b:** *Corymbia terminalis* and/or *Eucalyptus leucophylla* low open woodland, commonly with *Corymbia aparrerinja* and *Eucalyptus leucophloia* with a sparse shrub layer dominated by *Acacia chisholmii* and a sparse ground layer dominated by *Triodia pungens*. Occurs on hills, rises: metamorphosed igneous rocks.	Least Concern	No concern at present
1.11.8	*Terminalia aridicola* and/or *Corymbia aspera* low open woodland to low woodland, often with *Brachychiton collinus*, *Ficus* spp., *Alphitonia* spp. and *Trema tomentosa* with mid-dense shrub layer of *Acacia* spp. and/or *Calytrix brownii* and ground layer of mixed tussock grasses and *Triodia* spp. *Calytrix brownii* may be dominant on exposed rock faces. Occurs on rock outcrops on hills and ranges on strongly folded siliceous sedimentary and metamorphic pre-Cambrian rocks.	Least Concern	No concern at present

[1] Queensland Herbarium (2021).

[2] Status under the Queensland Vegetation Management Act 1999 (VM Act).

[3] Biodiversity status (BD status) according to the Queensland Department of Environment and Science (DES).

3 Rehabilitation monitoring program design

3.1 Purpose

This RMP addresses the proposed milestone criteria requirements provided in the PRCP Schedule, relevant to the monitoring of rehabilitated areas. This RMP addresses (in part) rehabilitation milestones RM5-RM11. Milestones/criteria and methodology relating to geotechnical, surface water or groundwater monitoring will be addressed in other monitoring programs.

This RMP provides a framework and methods to assess rehabilitated land at BCP. The aim of the RMP is as follows.

- Collect detailed, rigorous data at each of the analogue and rehabilitation sites to compare site performance against previous monitoring results and analogue sites.
- Assess the performance of rehabilitation activities against rehabilitation success criteria (described in **Section 4.2**) and the relevant rehabilitation milestone criteria outlined in PRCP Schedule.

Results from monitoring will assist in determining whether rehabilitated sites meet the goals of safe, stable, non-polluting and self-sustaining or if management intervention is required to achieve these goals.

3.2 Analogue sites

A desktop assessment was undertaken to assist in identifying appropriate analogue sites for this RMP. The methods and results of the desktop assessment are detailed in '*Barbara Copper-Gold Project: Rehabilitation Monitoring: Desktop Assessment*' (SLR, 2023). Following the desktop assessment, a ground-truthing survey was undertaken to establish permanent locations for analogue sites. An initial rehabilitation monitoring event was also undertaken at the sites to provide an indication of their condition.

Six analogue sites representative of the proposed final rehabilitated landform were established in the landscape surrounding BCP as follows.

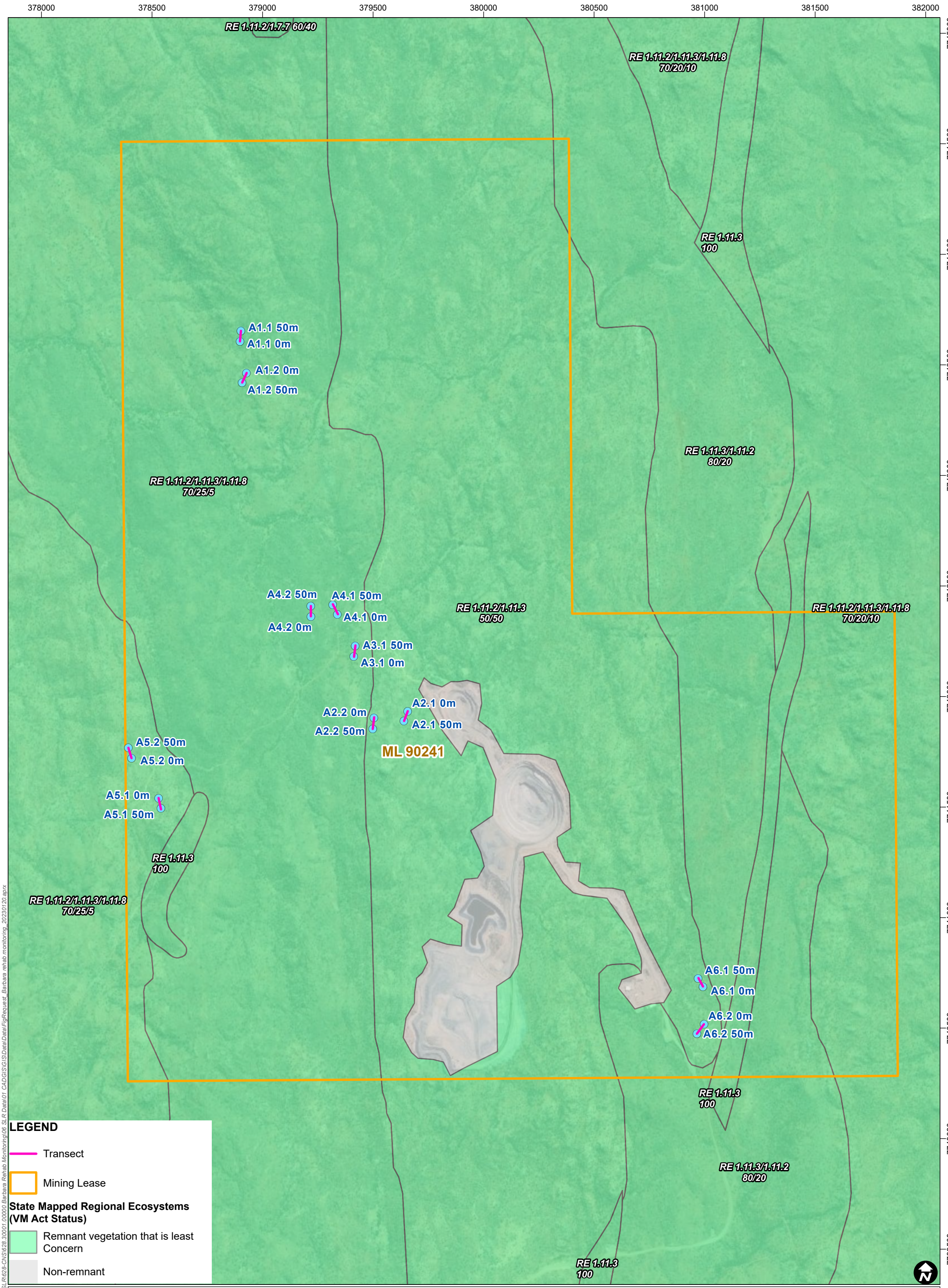
- Two replicate sites were established in areas field verified as RE 1.11.8, with steep slopes which are sparsely vegetated, representative of the side batters of the WRD (37 degrees).
- One replicate site, and one site with a single monitoring transect[2], were established in areas field verified as RE 1.11.2/1.11.3. Areas of flatter terrain were selected, representative of the cap of the WRD.
- Two replicate sites were established in areas field verified as RE 1.11.2/1.11.3. Areas of undulating terrain with native grass species (preferred by cattle) were selected, to represent low intensity grazing.
- Analogue monitoring sites representative of the 'water storage for livestock' and 'water management infrastructure' land uses, are not considered necessary or relevant; as water quality parameters at rehabilitated sites will be compared to published guideline values (rather than analogue site values).

[2] This landform was uncommon at BCP, therefore, a suitable location for a replicate transect at one of the sites could not be found.

A description of the characteristics of each analogue site, and the corresponding domain and PMLU is provided in **Table 2**, and site locations are presented on **Figure 5**. Monitoring data should continue to be collected from the sites and used to establish robust benchmarks against which future rehabilitation domains will be compared against. Data and representative photographs for each monitoring site from the initial monitoring event are provided in **Appendix A.**

Table 2 Analogue monitoring site locations

Domain(s)	Post-mine land use	Description	Analogue Site ID	Proposed location (GDA94)	
				Latitude	Longitude
Waste rock dump (WRD)	Native ecosystem	Areas field verified as RE 1.11.8, with steep slopes which are sparsely vegetated, representative of the side batters of the WRD (37 degrees).	A1.1	-20.401979	139.839381
			A1.2	-20.403388	139.839455
			A2.1	-20.417144	139.846550
			A2.2	-20.417395	139.845081
		Areas field verified as RE 1.11.2/1.11.3. Areas of flatter terrain will be selected, representative of the top of the WRD.	A3.1	-20.414892	139.844226
			A4.1	-20.413167	139.843531
			A4.2	-20.413241	139.842382
Ancillary infrastructure (ROM pad, roads, exploration)	Low intensity grazing	Areas field verified as RE 1.11.2/1.11.3. Areas of undulating terrain with native grass species (preferred by cattle) will be selected, to represent low intensity grazing.	A5.1	-20.420619	139.835723
			A5.2	-20.418974	139.834563
			A6.1	-20.428476	139.859263
			A6.2	-20.430010	139.859301
North pit, south pit, sediment dam	Water storage for livestock	NA – analogue site not required. Water quality parameters at rehabilitated sites will be compared to published guideline values.			
Diversion drains to be retained	Water management infrastructure	NA – analogue site not required.			



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Coordinate System: GDA 1994 MGA Zone 54

Date Drawn: 13-Mar-2023
Project Number: 628.30001.00000

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Data Source: World Imagery: Maxar(2020),
Mining Lease, Roads datasets from QSpatial, DNRME (2023),Biodiversity status of 2019 remnant regional ecosystems - © State of Queensland (Department of Environment and Science) 2023

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Analogue Site Locations

FIGURE 5

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3.3 Rehabilitation sites

Rehabilitation monitoring sites will be established in impacted areas as progressive rehabilitation is undertaken (*e.g.,* WRD, ROM pad). A minimum of two replicate rehabilitation sites per domain is proposed. The final number of rehabilitation sites for each area and domain required at BCP will be determined as rehabilitation works progress.

3.4 Monitoring timing and frequency

Monitoring of analogue and rehabilitation sites will be undertaken as close to the end of the wet season as possible, to allow for the identification of annual species and to assist with identification of species that require the presence of fertile material for accurate identification. It is recommended that dry season monitoring is also undertaken, to capture season variation in vegetation condition, and assist in developing more robust benchmark values.

Monitoring frequency for analogue and rehabilitation sites is summarised in **Table 3**.

Ground-truthing and collection of monitoring data from analogue sites will take place prior to the commencement of rehabilitation activities. Monitoring of analogue sites will occur annually until a robust dataset is considered to have been established.

Monitoring of rehabilitation sites will commence once initial rehabilitation activities have been completed at each domain, and will continue annually for five years post closure, which is when it is expected that there will be achievement of the final milestone and milestone criteria for the PMLUs. Once milestone criteria are met, progressive certification of the area would be expected to be applied for (under Chapter 5 of the Queensland *Environmental Protection Act 1994* (EP Act)). Monitoring should occur every five years until certification of each area is achieved; and every 10 years until surrender of the rehabilitation area from the EA (under Chapter 5 of the EP Act).

Table 3 Timeline for monitoring of analogue and rehabilitated sites

Monitoring sites	Years post rehabilitation						
	1	2	3	4	5	6 and beyond	
						Non-certified	Certified
Analogue site monitoring	Annually or bi-annually (until a robust dataset is established)						
Rehabilitation site monitoring	X	X	X	X	X	5-yearly	10-yearly

Where monitoring indicates areas of rehabilitation are not achieving outcomes to progress towards milestone criteria, remedial actions will be instigated as appropriate to the nature of the underperforming area. Examples of underperformance may include:

- limited germination and establishment of species from the applied seed mix
- erosion not stabilising
- persistence of surface crusting
- tree and shrub species not persisting and or no reproducing successional generations
- associated water quality is poor

- presence of weed species is evident.

3.5 Vegetation monitoring

Vegetation monitoring methodology is adapted from processes described in Queensland Herbarium guideline documents - *Methodology for survey and mapping of regional ecosystems and vegetation communities in Queensland* (Neldner *et al.*, 2022) and *BioCondition: A Condition Assessment Framework for Terrestrial Biodiversity in Queensland* (Eyre *et al*., 2015), and the Commonwealth *Vegetation Assessment Guide* (Commonwealth of Australia, 2013). Vegetation monitoring will be undertaken at each analogue and rehabilitation site.

3.5.1 Transects and quadrats

To collect data consistently and repeatedly, up to two permanent 50 m transect will be established at each analogue and rehabilitation site. Two transects are considered ideal at each site to account for spatial variation within sites; however, some analogue sites (and likely some rehabilitation sites) are spatially restricted and thus the appropriate number for each site will depend on its size and variability. Transects within each site will not overlap. For sites on sloping ground, transects will be run perpendicular to the slope.

The transect-based approach is currently considered most suitable as they are easily established, are scientifically robust, simple to execute and readily comparable between analogue and rehabilitation sites. A permanent marker (*e.g.,* star picket) will be placed at the 0 m and 50 m mark at the centre-line of the transect (using a measuring tape), and precise coordinates will be recorded, to ensure consistency between monitoring events. Several indices (detailed in **Section 3.5.2**) will be measured within 2.5 m or 10 m either side of the transect (in sub-plots) (**Figure 6**). Five 1 m x 1 m quadrats will be placed along the transect on alternating sides, starting on the right side at 0 m to measure ground cover indices (**Figure 6**). These will be placed at 0 – 1 m, 12 – 13 m, 25 – 26 m, 37 – 38 m and 49 – 50 m. Datasheets will record the site name, date, orientation of the transect, slope and photograph numbers taken.

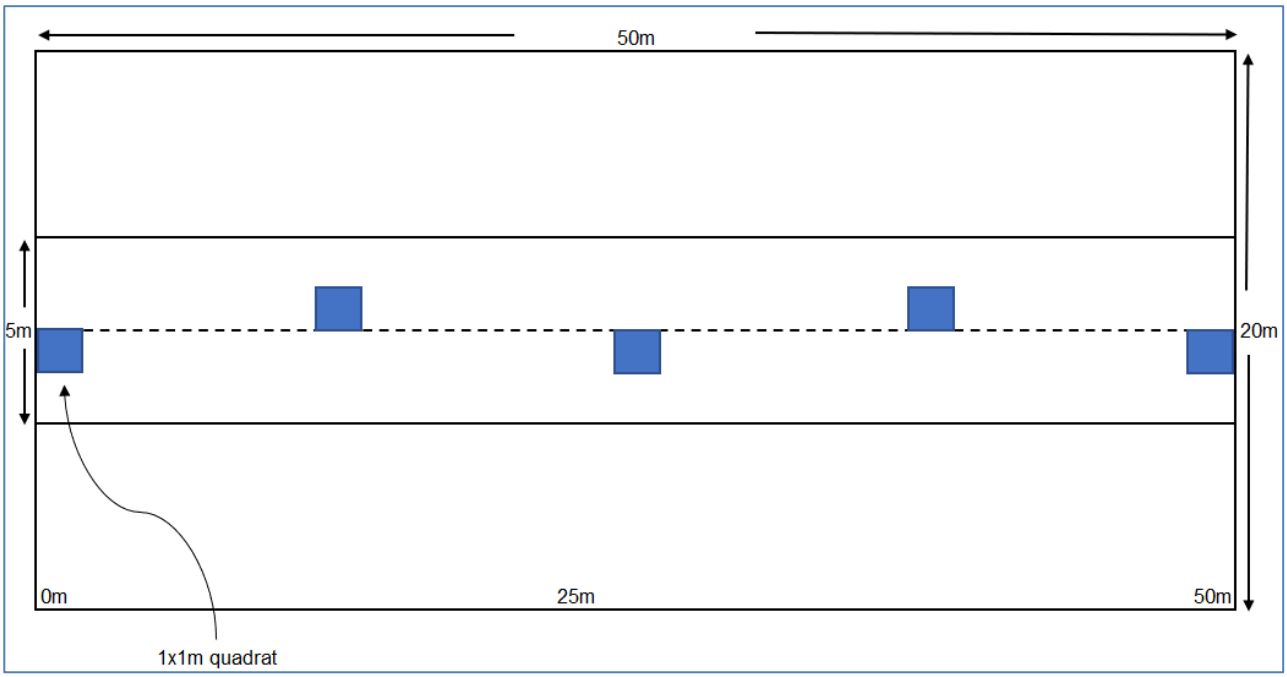

Figure 6 Representation of transect layout showing dimensions and quadrats

3.5.2 Indices

Vegetation indices measured along transects and within sub-plots and quadrats include the following. The methods for data collection of each index are provided in **Table 4**.

- Tree and shrub canopy cover.
- Tree and shrub species richness.
- Tree and shrub height.
- Tree and shrub density.
- Tree and shrub recruitment.
- Groundcover and ground layer species richness.
- Proportion of non-native flora species.
- Cover of 3P grasses (*i.e.,* palatable, perennial and productive).

Table 4 Vegetation monitoring indices

Sub-plot	Index	Method
50 m transect line	Tree and shrub canopy cover	Tree and shrub canopy cover will be measured for each vegetation layer along the transect using the canopy/line-intercept method (described in Neldner *et al.* (2022)). Data will be extrapolated, and a percent cover determined.

Sub-plot	Index	Method
		The percentage of non-native tree and shrub species canopy cover will be calculated for each vegetation layer. Weed status will be recorded, including if the species is classified as a weed of national significance (WoNS) or listed as declared, prohibited or restricted invasive plants under the Queensland *Biosecurity Act 2014* (Biosecurity Act).
50 x 20 m area	Tree and shrub species richness	Tree and shrub species richness will be recorded 2.5 m either side of each transect. A complete species lists will be developed. Weed status will be recorded.
	Tree and shrub height	A minimum of three tree and shrub individuals from each vegetation strata will be measured for height, where available. These heights will then be averaged for each layer.
	Tree and shrub density	Individuals of each tree and shrub species will be counted (*i.e.,* stem count) with results extrapolated to density per hectare. A basal area count (factor 0.5) of tree and shrub species (*i.e.,* woody stems) will be undertaken at the 25m point of the transect in line with the Bitterlich stick method presented in Neldner *et al.* (2022).
50 x 5 m area	Tree and shrub recruitment	The number of regenerating/sapling tree and shrub individuals of each species will be counted.
	Ground layer species richness	Species richness in the ground layer will be recorded.
1 x 1 m quadrats	Groundcover (including non-native species and 3P grasses)	Groundcover will include total cover inclusive of rock, bare ground, live vegetation and dead vegetation, litter, logs/woody debris which will each be separately measured and recorded. Live vegetation cover will be recorded as the percentage cover of each species. Weed status will be recorded. From this data, weed cover and 3P grass cover[1] will be calculated. Percentage rock cover will be recorded as follows: bedrock, boulder (>256 mm), cobble (64-256 mm), pebble (16-64 mm), gravel (4-16 mm) and sand (1-4 mm).

[1] 3P grass cover: 3P grasses are those that are palatable, perennial and productive. The type and abundance of grasses in a pasture can be used as an indicator of system health.

3.5.3 Photographic monitoring

Photographic monitoring is a useful tool for providing records of site conditions and allows for qualitative comparisons of vegetation progress over time. Photographs will be taken as follows.

- At the star pickets (0 m and 50 m) each end of the transect facing the alignment of the transect, towards the other star picket. The photograph will be taken directly above the star picket at chest height (approximately 110 cm above the ground).
- At the 25 m interval, four photographs will be taken, in four directions (along and at 90 degrees to the alignment of the transect).
- Photographs showing the general area surrounding the transect will also be taken for additional reference value.

3.5.4 Data analysis

Descriptive statistics will be used to compare vegetation indices at analogue sites to those at rehabilitation sites. Replicate transects at each site will be used to generate an average for each index. Where informative, medians, minimum and maximum values *etc.* for indices will also be calculated. Results at rehabilitation sites will also be compared over time (between monitoring events) to track progress towards the rehabilitation objectives/criteria.

3.6 Fauna habitat monitoring

Fauna habitat monitoring methodology is adapted from processes described in the *Terrestrial Vertebrate Fauna Survey Guidelines for Queensland* (Eyre *et al.,* 2022). Fauna habitat monitoring will be undertaken at each analogue and rehabilitation site. Data on the abundance of the following fauna habitat features will be collected, Abundance will be scored according to the following scale: 0 – nil, 1 – rare, 2 – occasional or 3 – common.

- Fallen logs (>10 cm in diameter).
- Decorticating bark.
- Course litter (>2 cm).
- Fine litter (<2 cm).
- Bare ground.
- Grass.
- Stones (20-60 cm).
- Boulders (61 cm-2 m).
- Large boulders (>2 m).
- Rock crevices.

3.7 Soil monitoring

Soil characterisation will be undertaken at analogue and rehabilitation sites to determine soil fertility and potential chemical constraints to growth and stability. A composite sample of approximately 500 g soil will be taken from each site; it will be collected from the top 10 cm at five locations, at 10 m intervals, along the transect (*i.e.,* at the 10, 20, 30, 40 and 50 m mark of each transect) using a hand trowel. The composite sample is then mixed and collected into a sample bag.

Soil samples will be analysed by a NATA accredited laboratory for chemical and physical properties including:

- pH
- electrical conductivity (EC)
- chloride
- exchange acidity
- exchangeable cations (calcium, magnesium, potassium, sodium and aluminium)
- cation exchange capacity (CEC)

- calcium/magnesium ration (Ca:Mg)
- exchangeable sodium percentage (ESP).
- total nitrogen, nitrite and nitrate
- total organic carbon (TOC)
- extractable potassium and phosphorous
- sulfate
- trace elements (copper, magnesium, zinc, iron and boron)
- moisture content
- Emerson aggregate stability test
- particle size analysis.

Additional parameters may be analysed if required. Soil moisture content will be measured for interpretive purposes only and will not be assessed in determining rehabilitation success. Soil analysis results from rehabilitation sites will be compared to analogue site values and relevant desirable ranges outlined in Hazelton and Murphy (2016) (as applicable), to provide an indication of soil quality at the time of sampling.

3.8 Erosion monitoring

The erosion monitoring methodology was developed with reference to the *Australian soil and land survey: field handbook* (MacDonald *et al.,* 1990). Erosion monitoring will be undertaken along permanent 50 m transects at each site (see **Section 3.5.1**). Transects will run perpendicular to the slope (if present).

The following types of erosion will be recorded along the transect:

- wind or sheet erosion (*i.e.,* a thin layer of topsoil is removed)
- signs of slumping (*i.e.,* movement of soil material downslope)
- rill erosion (*i.e.,* <30 cm deep, caused by run-off)
- gully erosion (*i.e.,* >30 cm deep, caused by run-off)
- tunnel erosion (*i.e.,* subsoil is removed).

The information that will be collected for each erosion feature is presented in **Table 5**.

Table 5 Information collected for each erosion feature

Feature	Information collected
Wind or sheet erosion	• Location along the transect (latitude, longitude) • Area of erosion intercepting the transect (using the line intercept method (described in Neldner *et al.* (2022)) • Photographs
Signs of slumping	
Rills	• Location along the transect (latitude, longitude) • Area of erosion intercepting the transect (using the line intercept method (described in Neldner *et al.* (2022))
Gullies	
Tunnels	

Feature	Information collected
	• Depth and width at the point of crossing the transect • Depth at the deepest point of the feature and width at the widest point of the feature • Total length of the feature up and down the slope • Photographs

3.9 Landscape function analysis

Landscape function analysis (LFA) is a monitoring procedure that uses rapidly acquired field-assessed indicators to assess the biogeochemical functioning of landscapes at the hillslope scale. This allows a landscape to be categorised along a spectrum from a highly functional to a highly dysfunctional system. The primary goal of rehabilitation monitoring using the LFA methods is to identify missing or ineffective processes in the landscape, so they can be restored or replaced.

The LFA analysis methodology from '*Landscape Function Analysis: Procedures for monitoring and assessing landscapes with species reference to mine sites and rangelands*' (Tongway and Hindley, 2004), is summarised below.

Along each permanent transect a soil surface assessment will be undertaken. Data on the following indicators will be collected.

- **Rain splash protection.** The degree to which physical surface cover and projected plant cover ameliorate the effect of raindrops impacting on the soil surface.
- **Perennial vegetation cover.** The "basal cover" of perennial grass and/or the density of canopy cover of trees and shrubs.
- **Litter.** The amount, origin and degree of decomposition of plant litter.
- **Cryptogram cover.** The cover of cryptogams visible on the soil surface.
- **Crust brokenness.** To what extent the surface crust is broken, leaving loosely attached soil material available for erosion.
- **Soil erosion type and severity. T**he type and severity of recent/current soil erosion *i.e.* soil loss from the transect.
- **Deposited materials.** The nature and amount of alluvium transported to and deposited on the transect.
- **Soil surface roughness.** The surface roughness for its capacity to capture and retain mobile resources such as water, propagules, topsoil and organic matter.
- **Surface nature.** The ease with which the soil can be mechanically disturbed to yield material suitable for erosion by wind or water.
- **Slake test.** The stability of natural soil fragments to rapid wetting.
- **Texture.** Classify the texture of the surface soil, and relate this to permeability.

These indicators will be used to calculate overall scores for stability, infiltration and nutrient cycling (as per Tongway and Hindley (2004)), presented in **Table 6**. This will allow comparison between analogue and rehabilitation sites.

Table 6 Soil surface assessment calculations of the three indices for landscape function monitoring

Parameter	Calculated from	Minimum score	Maximum score
Stability	Crust brokenness, surface resistance, slake test, erosion type and severity, deposited materials, cryptogram cover, rain splash protection and litter cover	8	40
Infiltration	Perennial vegetation cover, soil surface roughness, slake test, litter cover, origin and decomposition, and surface nature	6	57
Nutrient cycling status	Perennial vegetation cover, litter cover, origin and decomposition, cryptogram cover and soil surface roughness	4	43

3.10 Safety and stability

3.10.1 Safety

Human safety at mine sites is largely managed under the *Mining and Quarrying Safety and Health Act* 1999 and the *Coal Mining Safety and Health Act* 1999. Safety to fauna is not; however, covered in these Acts. When designing rehabilitation under environmental legislation, it is generally appropriate to consider both human and fauna safety. To achieve appropriate levels of safety, BCP will apply its risk management standards and procedures in the context of the agreed PMLU.

As such, rehabilitated land should pose no greater hazards, to humans and fauna, than the hazards currently present in the surrounding “unmined” landscape with the same land use.

The stability (both geotechnical and erosional) of the residual pit voids and retained water management infrastructure will be assessed by an appropriately qualified person. This assessment will identify the actions required to ensure that the land is left in a safe and stable condition and is appropriate for supporting the nominated PMLU.

3.10.2 Stability

3.10.2.1 Geotechnical Stability

Geotechnical stability refers to the stability of a slope against mass failure. Factors of Safety (FoS) against failure are generally defined as the ratio between restoring forces (strength) and disturbing forces (loading) within a slope. When a slope is at the point of failure, the restoring and disturbing forces are equal and the FoS is 1.0.

The Queensland Department of Mines and Energy (QDME) (1995) cite conventionally used FoS for temporary and permanent slopes of 1.2 and 1.5, respectively. This is aligned with advice from the Western Australian Department of Mines and Energy (WADME) (1999) which considered the consequence of failure in determining appropriate safety factors. When the consequence of failure and/or the level of uncertainty are high, designs should be more conservative.

3.10.2.2 Erosional Stability

Erosional stability is different to geotechnical stability but not less important in rehabilitation. A contemporary view is that erosion rates from rehabilitated landforms should be analogous to surrounding unmined areas. This would need to be demonstrated by monitoring of surrounding unmined areas, which is very difficult in practice.

While slope gradient will be used to select appropriate PMLU for different rehabilitation domains, it is not considered to be a useful indicator for rehabilitation success. Slope itself does not indicate if rehabilitation is safe, stable, non-polluting or useful. Research shows that high levels of vegetative cover reduces erosion to minimal levels, even on very steep slopes (Carroll and Tucker 2000; Carroll et. al., 2000). Carroll et. al., (2001) found rates of erosion on steep rehabilitation slopes from 10 % and 20 % gradient were reduced to < 1 t/ha/y with groundcover >50 %. In this context groundcover means anything in contact with the soil surface (*e.g.,* rocks, stones, sticks, leaves, grass).

4 Milestone and success criteria

4.1 Milestone Criteria

Milestone or completion criteria are defined by setting targets that will allow the fulfilment of closure objectives. Targets must be set to levels that make them attainable for the particular site, and within a specified timeframe. Equally, targets must be high enough to ensure that, once they are met, the risk of non-fulfilment of closure objectives is low or zero (Manero *et al.,* 2020).

The proposed rehabilitation milestone criteria for BCP are provided in the PRCP, those addressed in this RMP are provided in **Table 7**. These milestone criteria may require updating once the PRCP is finalised. Additional milestones and criteria not included in **Table 7** will be addressed in other management programs/documents and are not discussed further in this report.

Table 7 Rehabilitation milestones and criteria addressed in this RMP

Milestone reference	Rehabilitation milestone	Milestone criteria
RM5	Rehabilitation (Native Ecosystem) - WRD	• Stable landform of >1.5 factor of safety and angle of <25% for final landform design (WRD) assessed by suitably qualified person (*i.e.* Geotechnical).
RM6	Rehabilitation (Water Storage) - Residual Voids / Pits	• The voids have been certified as geotechnically stable by a suitably qualified person.
RM7	Rehabilitation (Low intensity grazing)	• Revegetation is to be equal or greater than 60% of comparable species richness and diversity to analogue site (consideration of alternate infill species will be undertaken, where required); • Percentage of ground cover (including trees, shrubs, forbs and grasses) is equal or greater than 60% of analogue site; • Native fauna identified at reference sites prior to mining are present or indicators of these species have been recorded; • Declared weed species composition of rehabilitated sites is not to exceed 10% more than the percentage cover of analogue sites.
RM8	Achievement of post mining land use (Levees and Diversions)	• Certification from an appropriately qualified person that the area has achieved a safe and stable condition.
RM9	Achievement of post mining land use (WRD / Native Ecosystem Services)	• Erosion assessment of final landform (no subsidence or significant erosion gullies for at least three (3) years); • The maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance.
RM10	Achievement of post mining land use (Water Storage)	• Certification from an appropriately qualified person that the water storages have achieved a safe and stable condition suitable for use as water storages.

Milestone reference	Rehabilitation milestone	Milestone criteria
RM11	Achievement of post mining land use (Low intensity grazing)	• Erosion assessment of final landform (no subsidence or significant erosion gullies for at least three (3) years); • Growth media and vegetation assessment demonstrates closure criteria have been met: - groundcover (pasture, naturalised and/or native species), that is not a declared weed species is established and self-sustaining - vegetation of similar species richness and species diversity to pre-selected analogue sites is established and suited to the post mine land use - the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance.

4.2 Success Criteria

Success criteria provide a set of benchmark values against which measurable indices can be compared. Success criteria are more detailed than milestone criteria, to enable an in-depth assessment of the indices and their progress towards meeting milestone criteria. Success criteria are non-binding, dynamic and may need to be revised as more data is collected from analogue and rehabilitation sites.

Draft success criteria developed for BCP rehabilitated areas are presented in **Table 8**. The benchmark values are derived from analogue sites and are particular to each PMLU. Benchmark values will be assigned to each success criterion once a robust dataset has been collected from the analogue sites. Benchmark values are based on the available research, applicable legislation and/or expert opinion. For example, benchmarks of 50 % or 70 % of the values recorded at analogue sites are provided for some of the indices (*e.g.,* tree/shrub canopy, tree height), based on the definition of remnant vegetation under the VM Act.

Successful rehabilitation requires a continuous improvement focus, site-specific knowledge, research and monitoring. The progressive rehabilitation at BCP will assist in building the knowledge and skills to deliver a sustainable outcome that meets success criteria. This RMP will monitor the success of vegetation establishment over time, evaluate potential threats to rehabilitated areas and record key rehabilitation information to ensure successful rehabilitation.

Table 8 Draft success criteria for measured indices at rehabilitated sites

Index	Post mine land use			
	Native ecosystems	Low intensity grazing	Water storage for livestock	Water management infrastructure
Tree species richness	50 % of the species richness recorded at analogue sites		NA	
Shrub species richness	50 % of the species richness recorded at analogue sites		NA	
Tree height	70 % of the canopy height recorded at analogue sites		NA	
Tree canopy cover	50 % of that recorded at analogue sites		NA	

Index	Post mine land use			
	Native ecosystems	Low intensity grazing	Water storage for livestock	Water management infrastructure
Shrub canopy cover	50 % of that recorded at analogue sites		NA	
Tree stem count	50 % of that recorded at analogue sites		NA	
Shrub stem count	50 % of that recorded at analogue sites		NA	
Ground cover richness	At least three of the characteristic species recorded at analogue sites are present		NA	
Percentage groundcover	50 % of the percentage groundcover recorded at analogue sites		NA	
Percentage 3P grass cover	NA	50 % of the percentage at analogue sites	NA	
Declared weeds	No more than 10% greater than the percentage cover at analogue sites		NA	
Fauna habitat features	Equivalent to analogue sites		NA	
Erosion	Where there are erosion features on a landform, they must not prevent reinstatement of the nominated post mining land use and be similar to reference sites. No active gullies > 1 m deep observed during rehabilitation monitoring		NA	
Soil parameters	Equivalent to analogue sites / within the desirable ranges outlined in Hazelton and Murphy (2016)		NA	
Stability (%)	LFA stability score of 80 % of that recorded at analogue sites		NA	
Infiltration (%)	LFA infiltration score of 80 % of that recorded at analogue sites		NA	
Nutrient cycling (%)	LFA nutrient cycling score of 80 % of that recorded at analogue sites		NA	
Safe to humans and wildlife	Safety hazards in rehabilitation are not significantly different to surrounding unmined landscapes subject to the same land use. No significant difference to surrounding similar land use (determined by Hazard assessment).			
Stable	Rehabilitation is geotechnically stable (factor of safety ≥1.5)			
	Rehabilitation is stable in terms of erosion (groundcover[1] >50 %).		NA	

[1] Groundcover includes anything in contact with the soil surface (*e.g.,* rocks, stones, sticks, leaves, grass).

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APPENDIX A

Baseline Data 2023

Table A1 Native tree and shrub cover (%) along a 50m transect from the 2023 wet season baseline survey

Landform	Site	Tree cover (%)	Shrub cover (%)
Waste rock dump (WRD)	A1.1	13	5
	A1.2	33.4	7.8
	A2.1	11.2	13.6
	A2.2	30.4	24.8
	A3.1	35.8	28.2
	A4.1	8.6	42.8
	A4.2	19	26.8
Ancillary infrastructure (ROM, roads, exploration)	A5.1	15.2	33.4
	A5.2	12.2	4.6
	A6.1	9.4	3.8
	A6.2	9.2	56.2

Table A2 Average tree and shrub height within each 50 X 20m plot

Landform	Site name	Tree height (m)	Shrub height (m)	Dominant species
Waste rock dump (WRD)	A1.1	4.9	2.1	*Terminalia aridicola, Tephrosia sp.*
	A1.2	5.3	1.2	*Terminalia aridicola, Tephrosia sp.*
	A2.1	6.2	2.2	*Eucalyptus leucipholia, Terminalia aridicola,*
	A2.2	5.8	2.5	*Eucalyptus leucipholia, Terminalia aridicola,*
	A3.1	10.3	3.6	*Eucalyptus leucipholia , Acacia phlebocarpa, Acacia melleodora*
	A4.1	4.7	1.9	*Eucalyptus leucipholia , Gossypium australe,*
	A4.2	5.2	1.7	*Grevillea wickhamii, Cajanus sp., Gossypium australe,*
Ancillary infrastructure (ROM, roads, exploration)	A5.1	5.6	1.2	*Eucalyptus leucipholia , Acacia phlebocarpa*

Landform	Site name	Tree height (m)	Shrub height (m)	Dominant species
	A5.2	5.2	1.3	*Eucalyptus leucipholia, Acacia holosericea*
	A6.1	5.7	1.1	*Eucalyptus leucipholia , Acacia phlebocarpa,*
	A6.2	4.9	1.6	*Eucalyptus leucipholia , Acacia phlebocarpa,*

Table A3 Fauna habitat features within each 50 X 20m plot

Domain	Site	Features						Overall Score
		Fallen logs (>10cm diameter)	Hollows	Stones (20-60cm)	Boulders (61cm-2m)	Large Boulders (>2m)	Rock Crevices	
Waste rock dump (WRD)	A1.1	1	1	3	3	2	3	13
	A1.2	1	1	3	3	3	3	14
	A2.1	1	1	3	3	3	3	14
	A2.2	1	1	3	3	3	3	14
	A3.1	2	0	1	0	0	0	3
	A4.1	0	1	1	0	1	2	5
	A4.2	0	0	1	1	0	2	4
Ancillary infrastructure (ROM, roads, exploration)	A5.1	0	2	1	0	0	1	4
	A5.2	0	2	1	1	0	1	5
	A6.1	0	1	2	2	0	3	8
	A6.2	0	1	1	1	0	3	6
Average		1	1	2	2	1	2	-

Scoring: 0= nil, 1= rare, 2 = occasional, 3 = common

Table A4 Disturbance observed within each 50 X 20m plot

Domains	Site	Disturbance Type					Overall Score
		Pest	Weed	Fire	Clearing	Cattle	
Waste rock dump (WRD)	A1.1	0	1	0	0	0	**1**
	A1.2	0	0	0	0	0	**0**
	A2.1	0	1	0	0	1	**2**
	A2.2	0	1	0	0	1	**2**
	A3.1	0	0	0	1	1	**2**
	A4.1	0	0	0	0	1	**1**
	A4.2	0	0	0	0	1	**1**
Ancillary infrastructure (ROM, roads, exploration)	A5.1	0	1	0	0	0	**1**
	A5.2	0	0	0	0	1	**1**
	A6.1	0	0	0	0	1	**1**
	A6.2	0	0	0	0	1	**1**
Average		**0**	**0**	**0**	**0**	**1**	-

Scoring: 0 = nil, 1 = minor, 2 = moderate, 3 = major

Table A5 Tree and shrub stem count and richness within a 50 X 5m plot

Domains	Site	Tree stem count	Shrub stem count	Recruits	Tree and shrub basal area (0.5 factor at 25m)	Dominant species
Waste rock dump (WRD)	A1.1	5	19	0	6	*Terminalia aridicola, Tephrosia sp., Acacia monticola*
	A1.2	4	34	0	5	*Terminalia aridicola Tephrosia sp., Clerodendrum sp.*
	A2.1	6	59	6	3	*Indigofera pratensis, Tephrosia sp., Eucalyptus leucipholia, Terminalia aridicola*
	A2.2	3	29	5	4	*Terminalia aridicola, Indigofera pratensis, Eucalyptus leucipholia*
	A3.1	5	59	19	2	*Eucalyptus leucipholia , Acacia phlebocarpa, Acacia melleodora*
	A4.1	5	78	5	0	Acacia phlebocarpa, Gossypium australe
	A4.2	5	52	14	0	*Cajanus sp., Gossypium australe, Grevillea wickhamii*
Ancillary infrastructure (ROM, roads, exploration)	A5.1	7	4	3	4	*Eucalyptus leucipholia , Indigofera hirsuta, Tephrosia sp.*
	A5.2	4	66	3	0	Tephrosia sp., *Acacia phlebocarpa, Gossypium australe*
	A6.1	1	12	8	4	Acacia phlebocarpa, Santalum lanceolatum
	A6.2	3	67	8	1	Eucalyptus leucipholia , Acacia phlebocarpa,
Average		**4.4**	**43.5**	**6.5**	**2.6**	

Table A6 Ground cover indices recorded during the 2023 wet season survey

Domain	Site	Bare (%)	Rock (%)	Logs / woody debris	Litter (%)		Flora cover (%)	Species richness	Dominant species
					Coarse litter (>2cm)	Fine litter (<2cm)			
Waste rock dump (WRD)	A1.1	7.8	60.2	0	2.5	4.8	25	19	*Triodia pungens, Eriachne mucronate*
	A1.2	2.2	54.4	0	2.4	17.2	23.8	11	*Enneapogon oblongus, Triodia pungens, Abultion sp.,*
	A2.1	3.4	42	0	2.8	18.4	33.4	15	*Glycine sp., Cenchrus ciliaris*
	A2.2	1	66	0	0.8	7.6	24.6	16	*Triodia pungens*
	A3.1	2.4	5.6	0	0.6	33	58.4	27	*Heteropogon contortus, Triodia pungens*
	A4.1	7	13.8	0	12	14.8	35.4	19	*Cymbopogon bombycinus, Triodia pungens*
	A4.2	2.4	17.2	0	0	23	51.4	14	*Cymbopogon bombycinus, Triodia pungens*
Ancillary infrastructure (ROM, roads, exploration)	A5.1	3.6	38	0	2	15	43	21	*Mnesitha farmmosa, Aristida lygrometrica*
	A5.2	3.6	39.4	0	0.8	5.2	51	18	*Triodia pungens, Eriachne sp.*
	A6.1	10	31	0	2	6	48	10	*Triodia pungens, Themeda triandra*
	A6.2	7	24	0	0.4	9.6	59	7	*Triodia pungens, Acacia phlebocarpa*

APPENDIX B

Land Function Analysis data

Table B1 LFA soil assessment scores of the 2023 wet season baseline survey

Domain	Site	Rainsplash protection	Surface roughness	Slake test	Crust brokenness	Surface nature	Cryptogram cover	Deposited material	Erosion	Perennial cover	Cover of plant material	Litter origin	Litter condition
Waste rock dump (WRD)	A1.1	5	1	3	0	5	1	4	4	4	1	l	n
	A1.2	5	1	1	0	5	0	3	4	4	1	l	n
	A2.1	5	2	2	0	3	1	3	4	4	2	l	n
	A2.2	5	2	2	0	3	1	3	4	4	2	l	s
	A3.1	5	3	3	0	3	1	3	3	4	3	l	s
	A4.1	5	2	2	0	3	1	4	4	4	2	l	n
	A4.2	5	2	3	0	3	1	3	4	4	2	l	n
Ancillary infrastructure (ROM, roads, exploration)	A5.1	4	2	3	0	3	2	4	4	4	1	l	n
	A5.2	5	2	2	0	3	2	4	4	4	1	l	n
	A6.1	5	2	4	0	3	1	4	4	4	1	l	n
	A6.2	5	1	3	0	3	1	3	4	4	2	l	s

LFA scoring of soil surface indicators are shown in table B2

Table B2 LFA soil surface indicators and interpretation

Indicator	Purpose of measurement	Indicator scores	Interpretation
Rain-splash protection	Assess the impact that rainfall will have on surface	1	<1% - No rain-splash protection: Bare, crusted soil, high run-off
		2	2 – 15% - Low rain-splash protection: some woody, stony or live plants will intercept some rain. Soil crusted
		3	16 – 30% - Moderate rain-splash protection: noticeable protective effect, but some soil crusting

Indicator	Purpose of measurement	Indicator scores	Interpretation
		4	31 – 50% - High rain-splash protection: crusting variable or weak
		5	>50% - Very high rain splash protection: soil surface not crusted
Litter cover	Assess the level of organic content in soil	1	<10% - Local derived from plants growing in very close proximity to the query zone and showing no signs of transport/ deposition by wind or water flows
		2	10 – 25% - Local derived from plants growing in very close proximity to the query zone and showing no signs of transport/ deposition by wind or water flows
		3	26 – 50% - Transported litter has clear signs of being washed or blown to the current location
		4	51 – 75% - Transported litter has clear signs of being washed or blown to the current location
		5	76 – 100% - Litter Cover
		6	100% up to 20mm thick – Nil decomposition the litter is loosely spread on the surface with few, if any, signs of decomposition and incorporation
		7	100% 21 – 70mm thick – Nil decomposition the litter is loosely spread on the surface with few, if any, signs of decomposition and incorporation
		8	100% 71 – 120mm thick – Slight decomposition litter Is broken down into small fragments and intimately in contact with the soil; some fragments may be partially buried
		9	100% 121 – 170mm thick – Slight decomposition litter Is broken down into small fragments and intimately in contact with the soil; some fragments may be partially buried
		10	100% >170mm thick – Moderate decomposition litter is in several distinct layers; some fungal attack is visible; the layer next to the soil is somewhat humified; some darkening of the soil to a depth of less than 10mm
Litter origin	The origin of litter on the content of sol	l	Local (l) derived from plants growing in very close promixity to the query zone showing no signs of transport/ deposition by wind or waterflows
		t	transported (t) litter has clear signs of being washed or blown to the current location
Litter condition	Decomposition state of litter	n	Nil decomposition (n) the litter is loosely spread on the surface with few, if any, signs of decomposition and incorporation

Indicator	Purpose of measurement	Indicator scores	Interpretation
		s	Slight decomposition (s) litter is broken down into small fragments and intimately in contact with the soil; some fragments may be partially buried.
		m	Moderate decomposition (m) litter is in several distinct layers; some fungal attack is visible; the layer next to the soil is somewhat humified; some darkening of the soil to a depth of less than 10mm
		e	Extensive decomposition (e) litter has at least three layers or stages in decomposition ranging from fresh material on top to 20mm or more of comprehensively humified (very dark, with no identifiable fragments) at the soil-litter interface. Mineral soil may have significant organic darkening in excess of 10mm.
Cryptogram cover	Assessment of cryptogams, an indicator of soil suitability	0	No stable soil surface present
		1	No contribution
		2	Slight contribution
		3	Moderate contribution
		4	Extensive contribution
Crust brokenness	Assess the crust stability and susceptibility to erosion	0	No crust present
		1	Crust present but extensively broken
		2	Crust present but moderately broken
		3	Crust present but slightly broken
		4	Crust present but intact and smooth
Deposited materials	Presence of organic material as erosion mitigation	1	Extensive amount present. Greater than 50% cover, several cm deep.
		2	Moderate amount of material present. 21 – 50% cover, significant depth
		3	Slight amount of material present. 6 – 20% cover
		4	None or small amount of material present. 0 – 5% cover or a dusting of loose material
		1	<1% - Very low root biomass likely

Indicator	Purpose of measurement	Indicator scores	Interpretation
Perennial cover	Assessment of biomass in vicinity for nutrient cycling and erosion mitigation	2	2 – 10% - Low root biomass due to a number of small plants
		3	11 – 20% - Moderate root biomass due to medium sized plants
		4	>20% - High root biomass due to present of large plants
Surface roughness	Assessment of stress application to soil surface	1	<3mm relief in soil surface. Smooth: little or no retained materials
		2	Shallow depression 3 – 8mm relief. Low visible retention.
		3	Deeper depressions 8 – 25mm or grass plants growing close together. Moderate to visible retention
		4	Deep depressions that have a visible base. Large visible retention
		5	Very deep depressions or cracks >100mm. Gilgai depressions. Extremely high retention
Surface nature	Assessment to which the soil can be mechanically disturbed	1	Loose, sandy surface – Surface is not crusted. Easily penetrated by finger pressure to about the second knuckle join. Sub-surface soil is non-coherent.
		2	Easily broken - Surface is easily penetrated with finger pressure to about the first knuckle joint. Surface may have a weak physical crust and sub-crust is non-coherent e.g. sandy.
		3	Moderately hard – Surface is moderately hard, may have a physical crust and needs a plastic tool (e.g. a pen top) to pierce, breaking into amorphous fragments or powder: the sub-crust is coherent.
		4	Crust is very hard and brittle – Needs a metal implement to break the surface, forming amorphous fragments or powder. The sub-crust is also very hard, coherent and brittle.
		5	Non-brittle – Shows some springiness when pressed with finger, or surface is a self-mulching clay or surface no physical crust and is under a dense, perennial grass sward (not just an isolated plant)

APPENDIX C

Flora Species List

Table D1 Flora species recorded during the 2023 baseline wet season survey

Family Name	Scientific name	Common name
Amaranthaceae	*Achyranthes aspera*	Chaff Flower
Amaranthaceae	*Aerva javanica*	Kapok Bush
Amaranthaceae	*Alternanthera nodiflora*	Common Joyweed
Amaranthaceae	*Gomphrena flaccida*	Pink Gem
Amaranthaceae	*Ptilotus fusiformis*	-
Apocynaceae	*Cynanchum viminale*	Caustic Bush
Asteraceae	*Bidens sp.*	Spanish Needles
Asteraceae	*Pterocaulon sp.*	-
Boraginaceae	*Heliotropium sp.*	-
Boraginaceae	*Heliotropium sp.*	-
Boraginaceae	*Trichodesma zeylanicum*	Camel Bush
Cleomaceae	*Cleome viscosa*	Tick-weed
Combretaceae	*Terminalia aridicola*	-
Convolvulaceae	*Bonamia media*	-
Convolvulaceae	*Bonamia sp.*	-
Convolvulaceae	*Evolvulus alsinoides*	Slender-dwarf Morning Glory
Convolvulaceae	*Xenostegia tridentata*	African Morning Vine
Cucurbitaceae	*Cucumis melo*	-
Cyperacea	*Cyperacea sp. 1*	Sedge
Cyperacea	*Cyperacea sp. 2*	Sedge
Cyperaceae	*Bulbostylis barbata*	-
Euphorbiaceae	*Euphorbia sp.*	-
Euphorbiaceae	*Euphorbia tannensis*	-
Fabaceae	*Acacia chisholmii*	Turpentine Bush
Fabaceae	*Acacia holosericea*	Strap Wattle
Fabaceae	*Acacia melleodora*	Sticky Wattle
Fabaceae	*Acacia monticola*	Red Wattle
Fabaceae	*Acacia phlebocarpa*	Table-top Wattle
Fabaceae	*Acacia sp.*	-
Fabaceae	*Cajanus sp.*	-
Fabaceae	*Crotalaria medicaginea*	Trefoil Rattlepod
Fabaceae	*Crotalaria novae-hollandiae*	Rattlepod
Fabaceae	*Glycine sp.*	-
Fabaceae	*Indigofera colutea*	Sticky Stylo

Family Name	Scientific name	Common name
Fabaceae	*Indigofera hirsuta*	Hairy Indigo
Fabaceae	*Indigofera linifolia*	-
Fabaceae	*Indigofera linnaei*	Birdsville Indigo
Fabaceae	*Indigofera pratensis*	Forest Indigo
Fabaceae	*Indigofera sp.*	-
Fabaceae	*Rhynchosia minima*	-
Fabaceae	*Senna planticola*	-
Fabaceae	*Senna sp.*	-
Fabaceae	*Sida sp.*	
Fabaceae	*Swainsona burkei*	-
Fabaceae	*Tephrosia brachyodon*	Pink Pea-bush
Fabaceae	*Tephrosia sp. 1*	-
Fabaceae	*Tephrosia sp. 2*	-
Fabaceae	*Zornia sp.*	-
Goodeniaceae	*Scaevola ovalifolia*	Bushy Fan-flower
Lamiaceae	*Clerodendrum sp.*	-
Lamiaceae	*Laminace sp*	-
Lamiaceae	*Ocimum tenuiflorum*	Holy Basil
Lauraceae	*Cassytha filiformis*	Love Vine
Malvaceae	*Abutilon sp.*	-
Malvaceae	*Corchorus sidoides*	-
Malvaceae	*Gossypium australe*	
Malvaceae	*Gossypium sp.*	-
Malvaceae	*Hibiscus sturtii*	Hill Hibiscus
Malvaceae	*Little abutilon*	-
Malvaceae	*Melhania oblongifolia*	Velvet Hibiscus
Malvaceae	*Triumfetta sp.*	-
Malvaceae	*Waltheria indica*	-
Menispermaceae	*Tinospora smilacina*	-
Myrtaceae	*Corymbia aparrerinja*	Ghost Gum
Myrtaceae	*Corymbia terminalis*	Bloodwood
Myrtaceae	*Eucalyptus leucipholia*	Snappy Gum
Nyctaginaceae	*Boerhavia sp.*	-
Orobanchaceae	*Buchnera linearis*	-
Phyllanthaceae	*Flueggea sp.*	-
Phyllanthaceae	*Flueggea virosa*	White-berry Bush

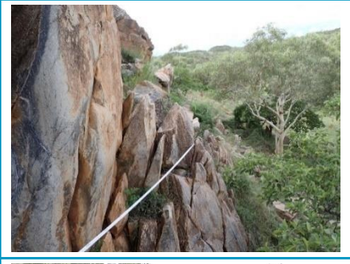
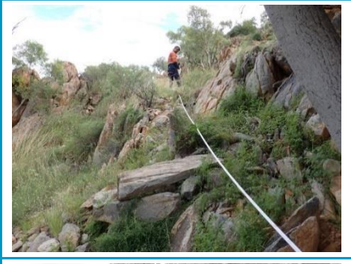
Family Name	Scientific name	Common name
Phyllanthaceae	*Phyllanthus maderaspatensis*	-
Poaceae	*Aristida calycina*	Dark Wiregrass
Poaceae	*Aristida hygrometrica*	-
Poaceae	*Bothriochloa ewartiana*	Desert Bluegrass
Poaceae	*Cenchrus ciliaris*	Buffel Grass
Poaceae	*Cymbopogon bombycinus*	-
Poaceae	*Digitaria brownii*	-
Poaceae	*Digitaria ctenantha*	Comb Finger Grass
Poaceae	*Digitaria sp.*	-
Poaceae	*Enneapogon oblongus*	Crown Nine Awn
Poaceae	*Enneapogon polyphyllus*	-
Poaceae	*Eragrostis leptocarpa*	Drooping Lovegrass
Poaceae	*Eragrostis sp.*	-
Poaceae	*Eriachne ciliata*	Slender Wanderrie Grass
Poaceae	*Eriachne mucronata*	Mountain Wanderrie Grass
Poaceae	*Heteropogon contortus*	Black Spear-grass
Poaceae	*Mnesithea formosa*	-
Poaceae	*Paspalidium constrictum*	Box Grass
Poaceae	*Perotis rara*	-
Poaceae	*Sehima nervosum*	White Grass
Poaceae	*Setaria surgens*	Pigeon Grass
Poaceae	*Themeda triandra*	Kangaroo Grass
Poaceae	*Triodia bitextura*	Curly Spinifex
Poaceae	*Triodia pungens*	Soft Spinifex
Proteaceae	*Grevillea wickhamii*	Holly-leaved Grevillea
Proteaceae	*Hakea lorea*	Bootlace Oak
Pteridaceae	*Cheilanthes brownii*	Woolly Resurrection Fern
Pteridaceae	*Cheilanthes sp.*	-
Rubiaceae	*Gardenia vilhelmii*	-
Rubiaceae	*Pavetta rupicola*	-
Rubiaceae	*Spermacoae stenophylla*	-
Santalaceae	*Santalum lanceolatum*	Sandalwood
Sapindaceae	*Atalaya hemiglauca*	Whitewood
Sapotaceae	*Sersalisia sericea*	Wild Prune
Scrophulariaceae	*Eremophila longifolia*	Berigan
Solanaceae	*Prostate solanum*	-

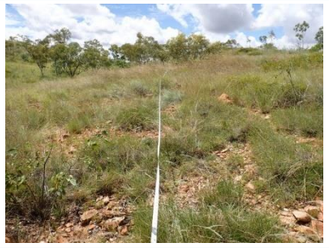
Family Name	Scientific name	Common name
Solanaceae	*Solanum echinatum*	-
Solanaceae	*Solanum ellipticum*	-
Stackhousiaceae	*Stackhousia sp.*	-
Sterculiaceae	*Brachychiton collinus*	Outcrop Kurrajong
Ulmaceae	*Trema tomentosa*	Poison Peach
Violaceae	*Afrohybanthus enneaspermus*	Spade Flower
Zygophyllaceae	*Tribulus sp.*	-

APPENDIX D

Representative Photographs

Table E1 Transect photos of the 2023 baseline wet season survey.

Site	Photographs along each transect					
	0M	25m	25m	25m	25m	50m
A1.1						
A1.2						
A2.1						
A2.2						

Site	Photographs along each transect					
	0M	25m	25m	25m	25m	50m
A3.1						
A4.1						
A4.2						
A5.1						
A5.2						

Site	Photographs along each transect					
	0M	25m	25m	25m	25m	50m
A6.1						
A6.2						

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REPORT

AERIS RESOURCES LIMITED

Barbara Copper Project
WMP Update for Underground Workings – Water Balance Model

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TAILINGS.WATER.WASTE.

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CONTENTS

1 INTRODUCTION 1

1.1 Background 1
1.2 Outcomes 1

2 WATER BALANCE MODEL 2

2.1 Water Balance Model Development 2
2.2 Model Structure and Inputs 2
2.2.1 Climatic Data 3
2.2.2 Catchment Delineation 3
2.2.3 Groundwater Inflows 4
2.2.4 Storage Curve Data and Initial Conditions 8
2.2.5 Initial Storage Conditions 12
2.2.6 Pump Transfers and Source Priority 12
2.2.7 Site Water Demands 12
2.2.8 South Pit and Underground Workings Interaction 13
2.2.9 Simulation Period 13
2.3 Model Development 13

3 RESULTS 15

3.1 South Pit 15
3.2 Underground Workings 17
3.3 North Pit 19
3.4 WRD Sediment Dam 21

4 SUMMARY AND CONCLUSION 24

REFERENCES 25

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TABLES

TABLE 1: SITE WATER BALANCE – RAINFALL AND EVAPORATION INPUT DATA 3
TABLE 2: CATCHMENT DETAILS 3
TABLE 3: NORTH PIT GROUNDWATER INFLOW ESTIMATES 5
TABLE 4: SOUTH PIT GROUNDWATER INFLOW ESTIMATES 6
TABLE 5: UNDERGROUND WORKINGS GROUNDWATER INFLOW ESTIMATES 7
TABLE 6: INITIAL WATER STORAGE INPUTS 12
TABLE 7: PUMP TRANSFER CONFIGURATION 12
TABLE 8: AWBM MODEL PARAMETERS 14

DIAGRAMS

DIAGRAM 1: WATER BALANCE MODEL PROCESS FLOW DIAGRAM 2
DIAGRAM 2: CATCHMENT DELINEATION 4
DIAGRAM 3: NORTH PIT STORAGE CURVE 9
DIAGRAM 4: SOUTH PIT STORAGE CURVE 9
DIAGRAM 5: WRD SEDIMENT DAM STORAGE CURVE 10
DIAGRAM 6: UNDERGROUND WORKINGS –ESTIMATED STORAGE CURVE 11
DIAGRAM 7: UNDERGROUND WORKINGS – NET STORAGE OVER TIME 11
DIAGRAM 8: AWBM FOR RUNOFF CALCULATIONS 13
DIAGRAM 9: SOUTH PIT WATER SURFACE ELEVATION (2025 TO 2050) 15
DIAGRAM 10: SOUTH PIT WATER SURFACE ELEVATION (2025 TO 2029) 16
DIAGRAM 11: SOUTH PIT ACCUMULATED GROUNDWATER INFLOWS 16
DIAGRAM 12: SOUTH PIT PUMP FLOW TO UG 17
DIAGRAM 13: UNDERGROUND WORKINGS ACCUMULATED VOLUMES 18
DIAGRAM 14: UNDERGROUND WORKINGS GROUNDWATER INFLOWS 18
DIAGRAM 15: NORTH PIT WATER SURFACE ELEVATION (2025 TO 2050) 19
DIAGRAM 16: NORTH PIT WATER SURFACE ELEVATION (2025 TO 2029) 20
DIAGRAM 17: NORTH PIT ACCUMULATED GROUNDWATER INFLOWS 20
DIAGRAM 19: NORTH PIT PUMP FLOWS TO UG 21
DIAGRAM 20: WRD SEDIMENT DAM WATER SURFACE ELEVATION (2025 T0 2050) 22
DIAGRAM 21: WRD SEDIMENT DAM WATER SURFACE ELEVATION (2025 T0 2029) 22
DIAGRAM 22: CUMMULATIVE PUMP FLOWS TO SOUTH PIT 23
DIAGRAM 23: WRD SEDIMENT DAMPUMP FLOWS TO UG 23

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1 INTRODUCTION

1.1 Background

The purpose of this report is to provide a summary of the operational water balance model (WBM) to support an EA amendment at the Barbara Copper Project (BCP). The BCP is currently in care and maintenance (C&M), pending technical investigations to allow for the re-commencement of mineral ore extraction by means of proposed new Underground Workings (UG). This would be accessed via a new portal located within the South Pit.

1.2 Outcomes

The intention of the operational WBM is to provide guidance on the following:

- Time taken to dewater to South Pit to allow for ore extraction at the base of the South Pit (Crown Pillar).
- Estimation of total groundwater entering the North Pit, South Pit and Underground Workings.
- Identify conditions under which the site has the potential to be in a water deficit.

2 WATER BALANCE MODEL

2.1 Water Balance Model Development

A water balance model was developed using GoldSim Pro (GoldSim V14.0) to assess the impacts of:

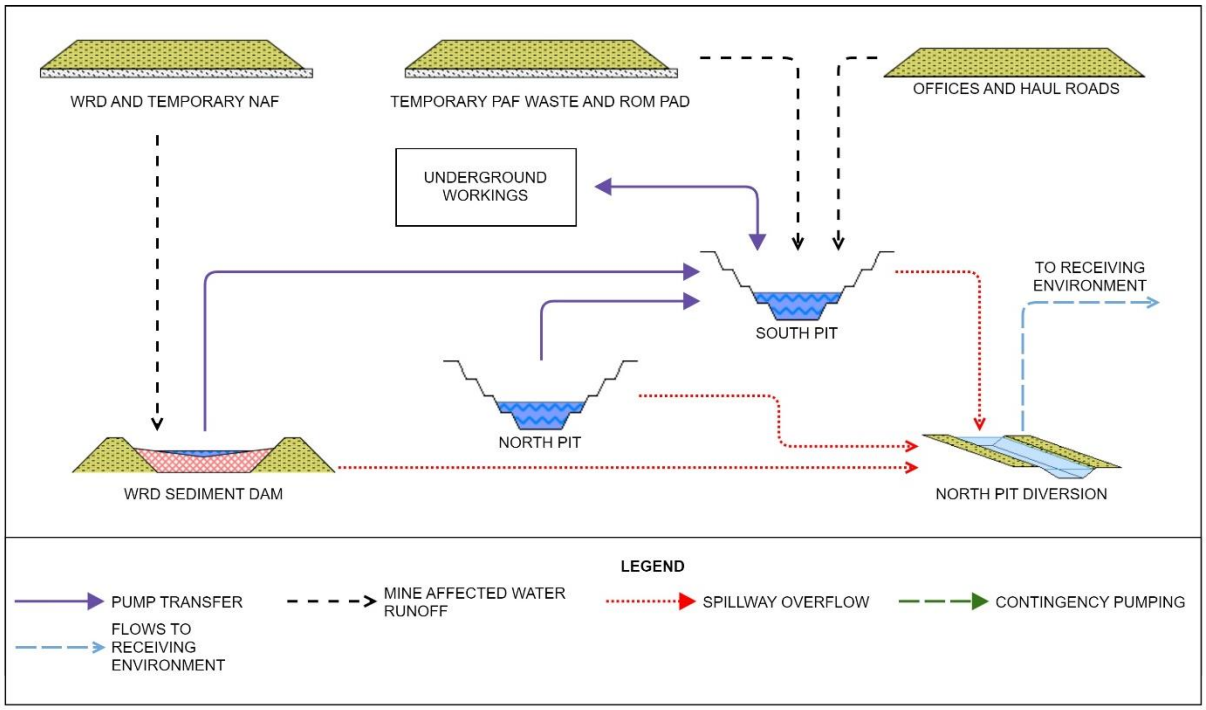
- surface water runoff, (both mine impacted and non-impacted).
- evaporation and groundwater inflows to the Pit.
- groundwater into the Underground Workings.
- surface water from the Pit to the underground working via the stopes at the base of the Pit and the backfilled Portal.

GoldSim is a dynamic probabilistic simulation program, which uses a range of parameters to represent the catchment surface water system. Simulations are then run using a time series of daily rainfall data to estimate the balance of water across the modelled water system over time and a range of climate conditions. The water balance model reflects the effects of stormwater runoff, evaporation, and groundwater inflows/outflows at the site.

2.2 Model Structure and Inputs

The process flow diagram for the BCP site is depicted in **Diagram 1,** representing the major water pathways at site. For clarity, **Diagram 1** does not depict rainfall, evaporation, or groundwater interactions, although these have been included in the modelling. Primary water balance inputs applying to each of the elements in the model development are described in the following sub-sections.

DIAGRAM 1: WATER BALANCE MODEL PROCESS FLOW DIAGRAM



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2.2.1 Climatic Data

Climate data specific to the site was obtained from the SILO Data-drill **[1]**. The key parameters from the data-drill are explained in **Table 1**.

TABLE 1: SITE WATER BALANCE – RAINFALL AND EVAPORATION INPUT DATA

Climate Data	Data Source	Comments
Daily Rainfall Rate (mm/day)	Rainfall data obtained from the SILO Data Drill Program for the Site Location (1889 - 2024)	Applied over dam surface areas, and as an input parameter for the estimation of surface runoff (AWBM).
Daily Evaporation Rate (mm/day)	Continuous record from SILO Data Drill formed by conjoining: CLIMARC estimates (1889 – 1957) and Class A Evaporation Data from proximate weather stations within the region (1889 – 2024).	Evaporation Data is scaled by evaporation factors for each site storage to reflect water storage conditions and expected water quality.
Daily Evapo-Transpiration Rate (mm/day)	As calculated by the FAO short crop reference methodology, assuming a wind speed of 2 m/s.	Potential evapo-transpiration is calculated based on temperature, vapour pressure and solar global exposure parameters derived from climatic data and is adopted as a reasonable estimate of potential evapotranspiration losses from ground surfaces within the model.

2.2.2 Catchment Delineation

Catchment delineation and estimation was performed using survey data and aerial photography. The catchments are depicted in **Diagram 2**. **Table 2** provides a summary of the catchment areas which were used to inform the AWBM generation of surface runoff volumes.

TABLE 2: CATCHMENT DETAILS

Surface Runoff Type	Catchments (ha)		
	North Pit	South Pit	WRD Sediment Dam
Natural (Undisturbed)	0.05	5.30	4.80
Disturbed	1.51	1.30	0.61
Hardstand	1.15	13.07	5.66
Open Cut	1.94	9.29	-
Waste	0.00	0.71	17.33
Surface Water Area (at full supply)	1.50	8.20	3.00
Catchment Area	4.65	29.68	28.41

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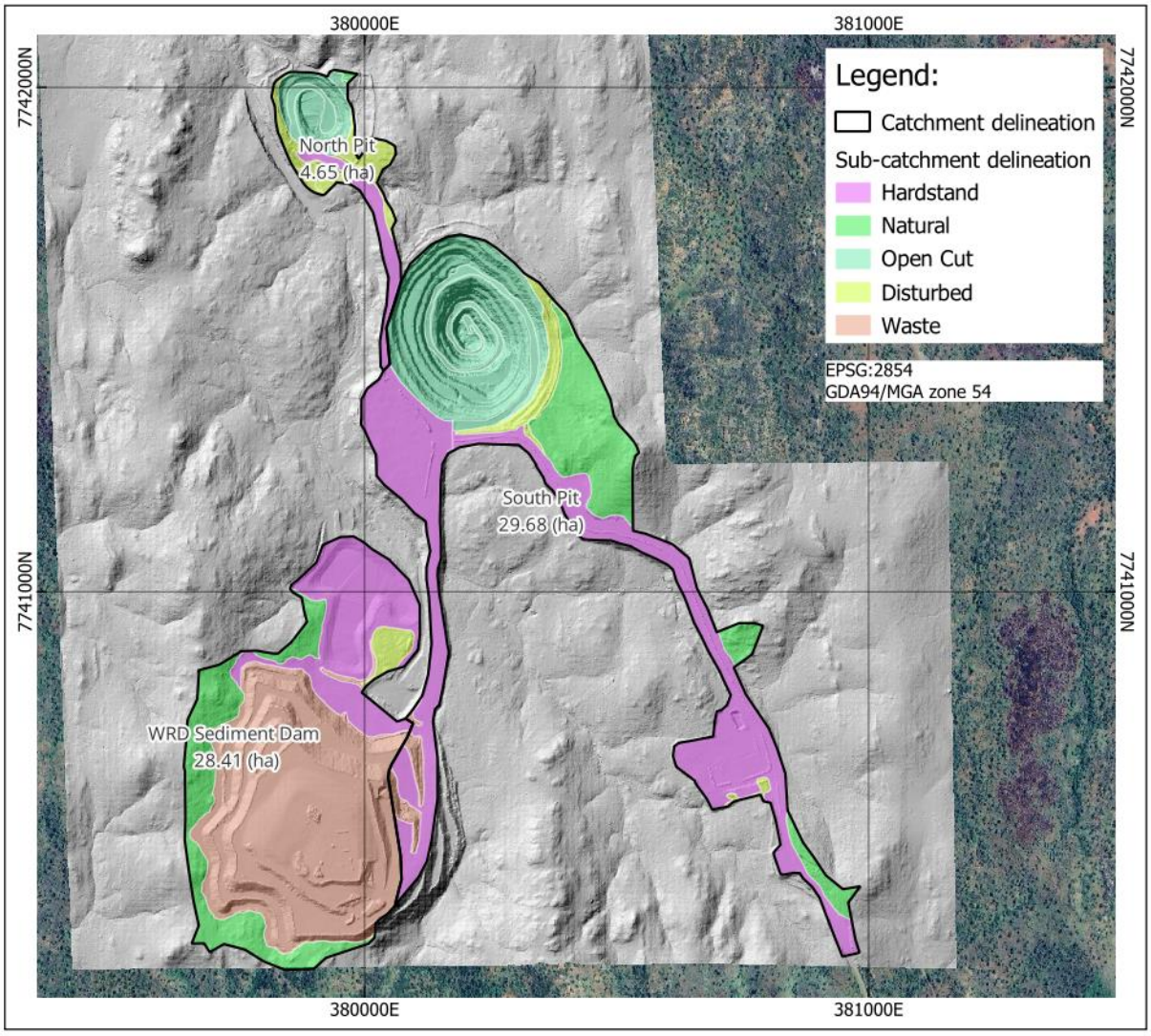
DIAGRAM 2: CATCHMENT DELINEATION



2.2.3 Groundwater Inflows

Groundwater interaction with the North Pit, South Pit and UG Workings is considered likely to occur. Inflows to the North Pit, South Pit and UG Workings from the surrounding groundwater systems could occur, with the direction of flow determined by the pit water level compared to the aquifer phreatic head. It is possible that the pit voids could spill during periods of significant rainfall, depending on their initial water level prior to the rainfall event/s.

Detailed groundwater inflow estimates were undertaken by WMV Environmental **[2]** for operational conditions, where active dewatering occurs, and under recovery conditions, where dewatering ceases and groundwater begins to return to 'pre-operational' levels.

Active dewatering occurs from 01/01/2025, when the Underground Workings will commence, to 31/10/2029, when the Underground Workings will cease, and the groundwater conditions will start recovering.

The groundwater flow estimates for the North Pit, South Pit and Underground Workings for operational and recovery scenarios are reproduced in **Table 3** to **Table 5**. Additionally, groundwater flow estimates for the Underground Workings (**Table 5**) contain the projected dates when these inflow rates are expected to occur. Full details can be found in WMV Environmental' s 'Groundwater Technical Report' **[3]**. The South Pit was determined to be a regional groundwater sink.

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As noted by WMV **[3]**, the estimates of groundwater inflow to the Pit and Underground Workings represent the groundwater that resided in the orebody prior to mining, with long term natural recharge expected to be much slower. As such, the inflows estimates are considered to be conservative.

TABLE 3: NORTH PIT GROUNDWATER INFLOW ESTIMATES

Elevation (m AHD)	Operational Conditions - Groundwater Inflow (L/s)	Recovery Conditions - Groundwater Inflow (L/s)
316	0.064	0.021
314	0.060	0.024
312	0.058	0.027
310	0.052	0.028
308	0.048	0.030
306	0.046	0.031
304	0.043	0.032
302	0.041	0.033
300	0.039	0.033
298	0.037	0.034
296	0.034	0.033
295	0.019	0.018

TABLE 4: SOUTH PIT GROUNDWATER INFLOW ESTIMATES

Elevation (m AHD)	Operational Conditions - Groundwater Inflow (L/s)	Recovery Conditions - Groundwater Inflow (L/s)
334	0.612	0.031
330	0.595	0.050
325	0.578	0.073
320	0.545	0.092
315	0.522	0.110
310	0.498	0.126
305	0.469	0.138
300	0.429	0.145
295	0.403	0.154
290	0.392	0.164
285	0.380	0.174
280	0.342	0.171
275	0.315	0.171
270	0.302	0.176
265	0.288	0.178
260	0.268	0.176
255	0.246	0.171
250	0.230	0.169
245	0.217	0.167
240	0.198	0.160
235	0.178	0.151
230	0.164	0.144
225	0.149	0.136
220	0.130	0.123
215	0.072	0.071
212	0.046	0.046

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TABLE 5: UNDERGROUND WORKINGS GROUNDWATER INFLOW ESTIMATES

Elevation (m AHD)	Projected Date	Operational Conditions - Groundwater Inflow (L/s)	Recovery Conditions - Groundwater Inflow (L/s)
306	1/01/2025	0.012	0.014
291	1/02/2025	0.016	0.021
265	1/03/2025	0.023	0.029
241	1/04/2025	0.031	0.036
221	1/05/2025	0.037	0.043
200	1/06/2025	0.048	0.050
193	1/09/2025	0.051	0.058
171	1/10/2025	0.057	0.063
153	1/11/2025	0.065	0.067
146	1/12/2025	0.072	0.072
146	1/01/2026	0.075	0.080
130	1/02/2026	0.079	0.081
125	1/03/2026	0.089	0.094
112	1/08/2026	0.095	0.099
101	1/09/2026	0.100	0.103
93	1/10/2026	0.104	0.107
85	1/11/2026	0.108	0.117
64	1/12/2026	0.116	0.120
55	1/01/2027	0.121	0.129
34	1/02/2027	0.128	0.131
26	1/03/2027	0.131	0.131
21	1/04/2027	0.138	0.146
2	1/05/2027	0.199	0.199

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2.2.4 Storage Curve Data and Initial Conditions

Storage curves were derived for both North Pit, South Pit and WRD Sediment Dam from the provided survey data. The resulting storage curves are depicted in **Diagram 3**, **Diagram 4** and **Diagram 5**.

The storage volume of the Underground Workings varies over the duration of the underground campaign. The development of the underground storage capacity over time is depicted in **DIAGRAM 6**: UNDERGROUND WORKINGS –ESTIMATED STORAGE CURVE

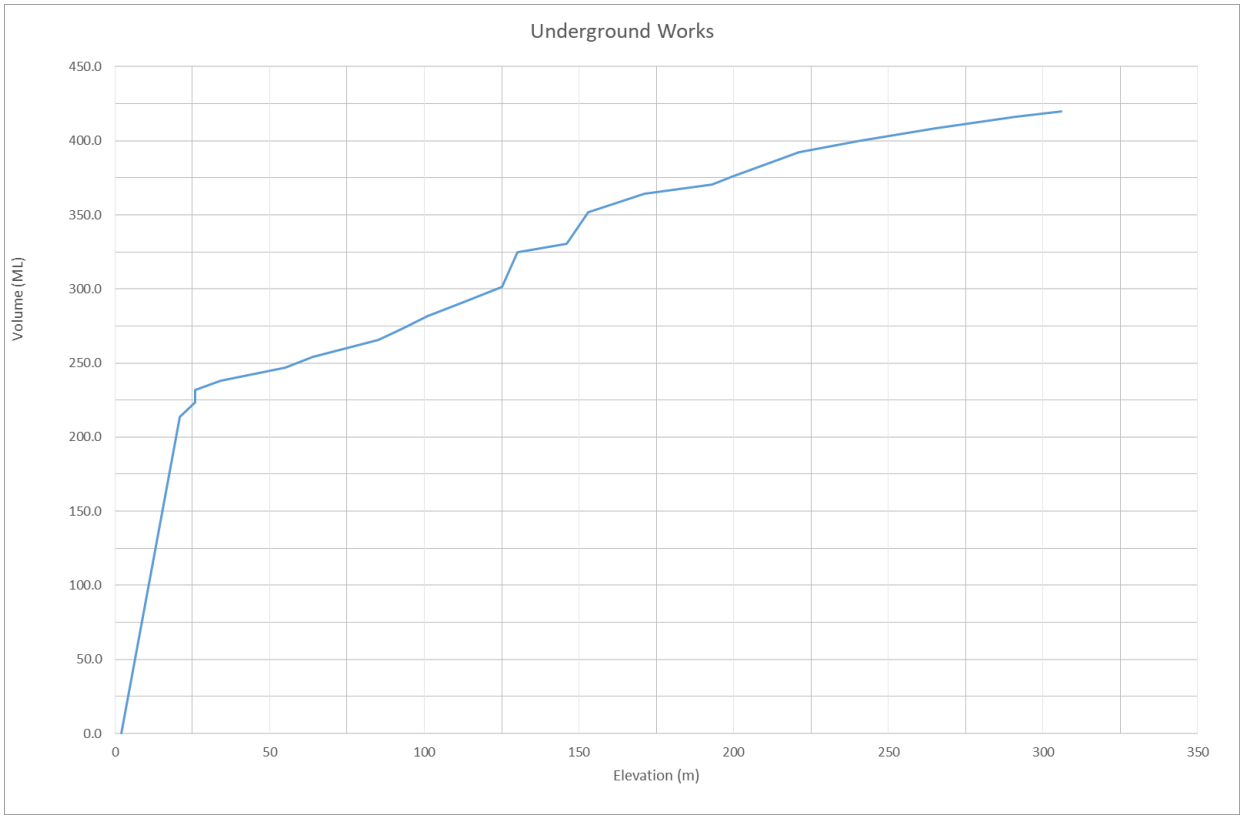

Diagram 7. The volume available in the Underground Workings comprises:

- backfilled stopes with a 30% voids ratio, representing the backfill conditions of crushed rock of various sizes. This will not occupy the entire backfilled area.
- open stopes, not backfilled with rock.

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DIAGRAM 3: NORTH PIT STORAGE CURVE

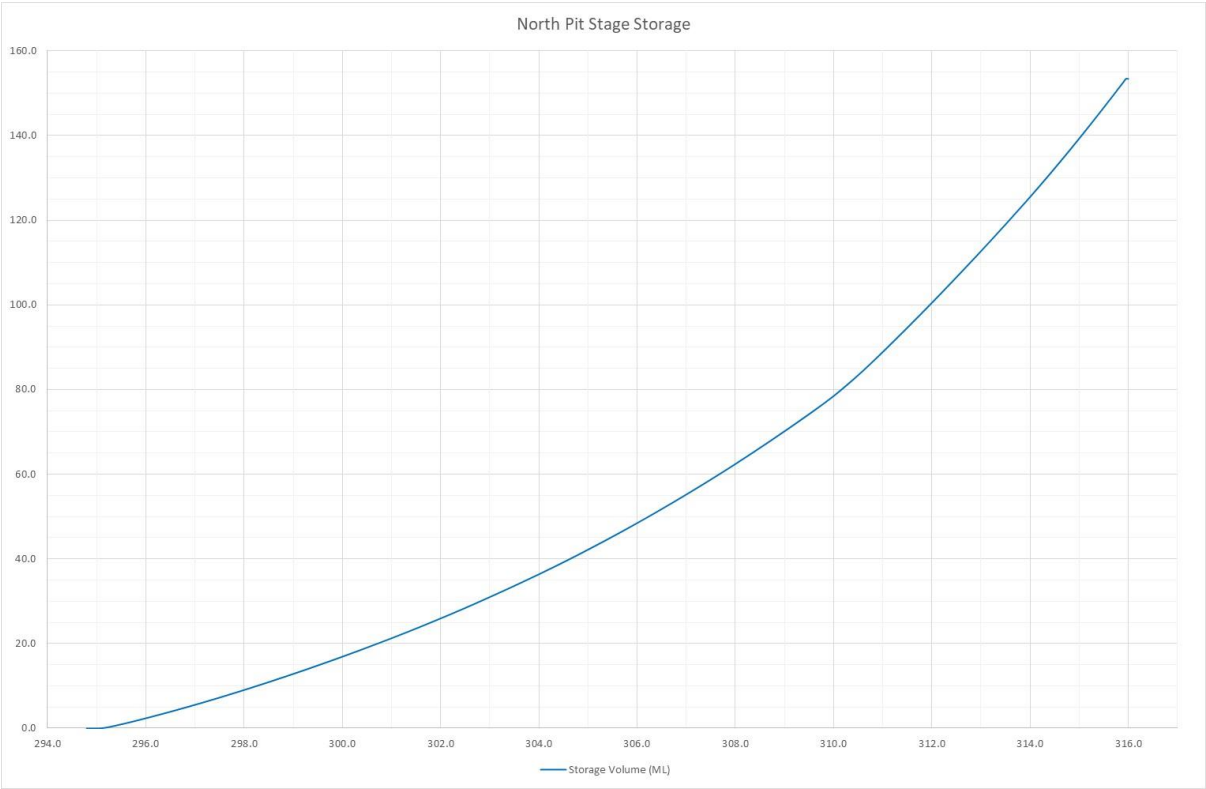

DIAGRAM 4: SOUTH PIT STORAGE CURVE

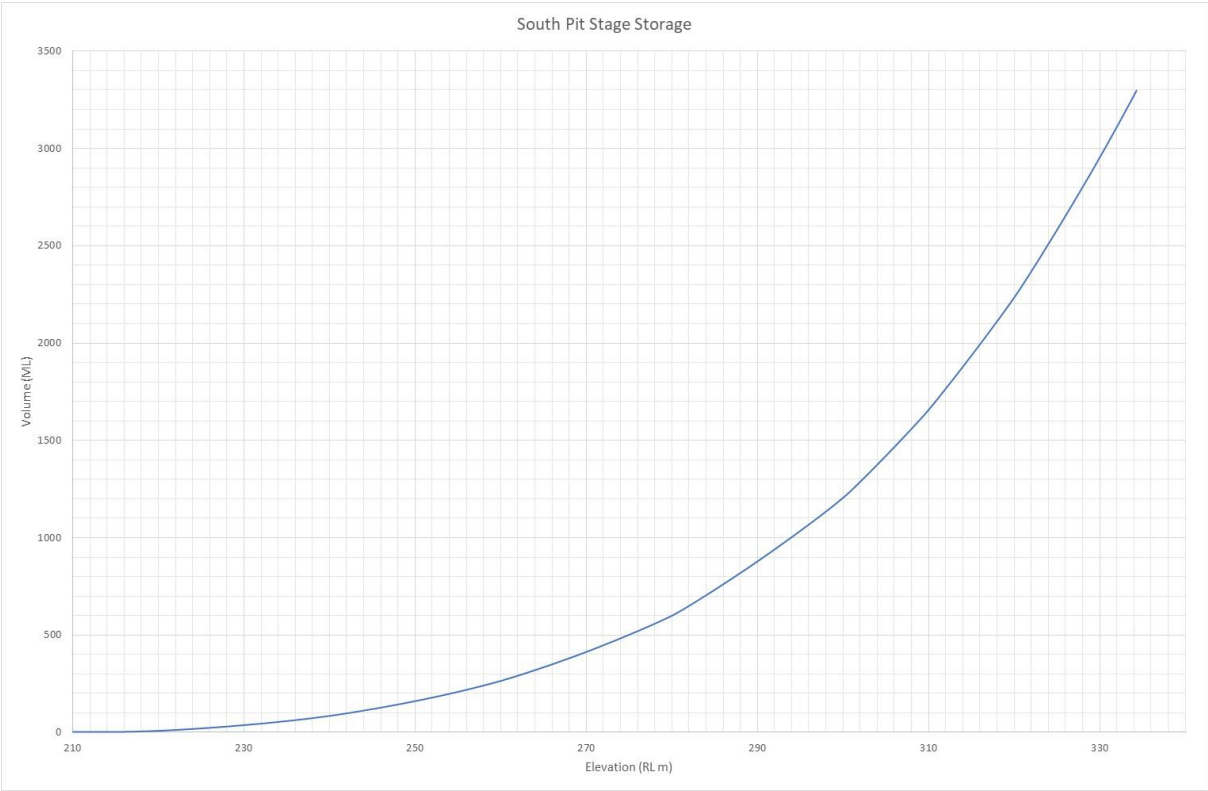

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DIAGRAM 5: WRD SEDIMENT DAM STORAGE CURVE

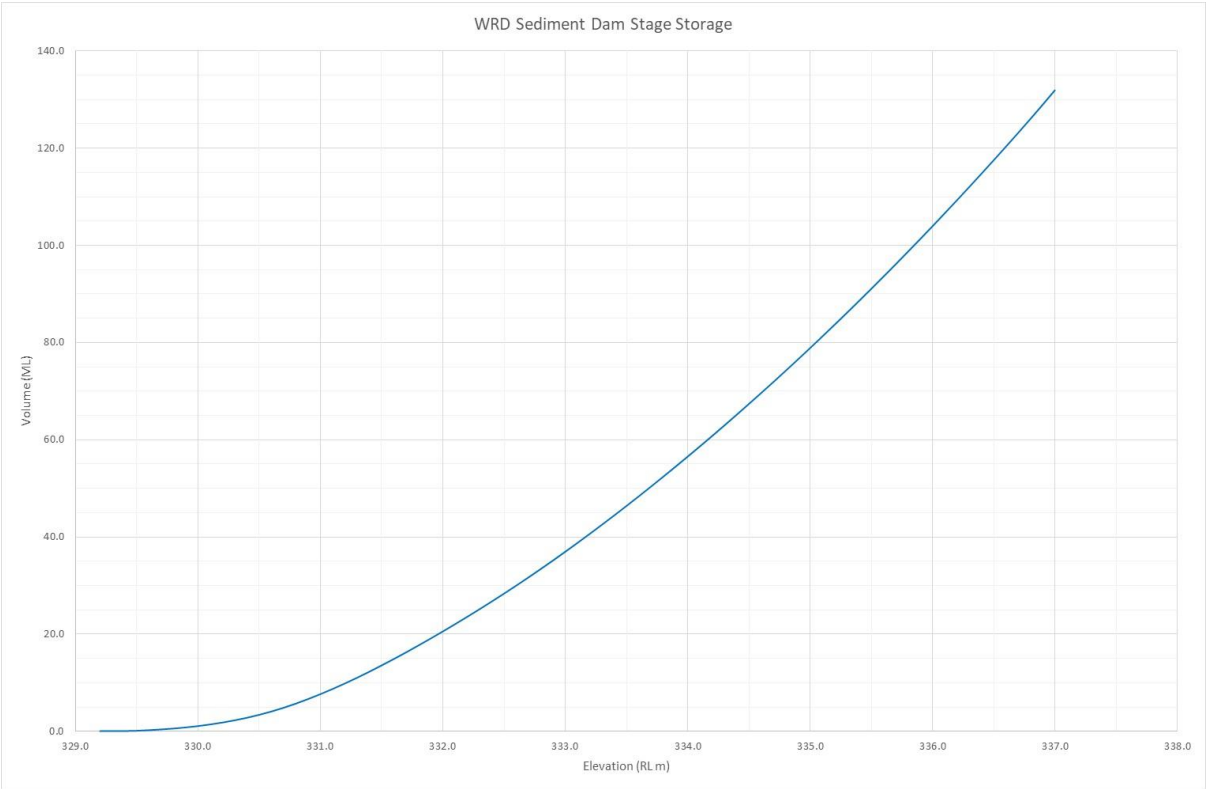

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DIAGRAM 6: UNDERGROUND WORKINGS –ESTIMATED STORAGE CURVE

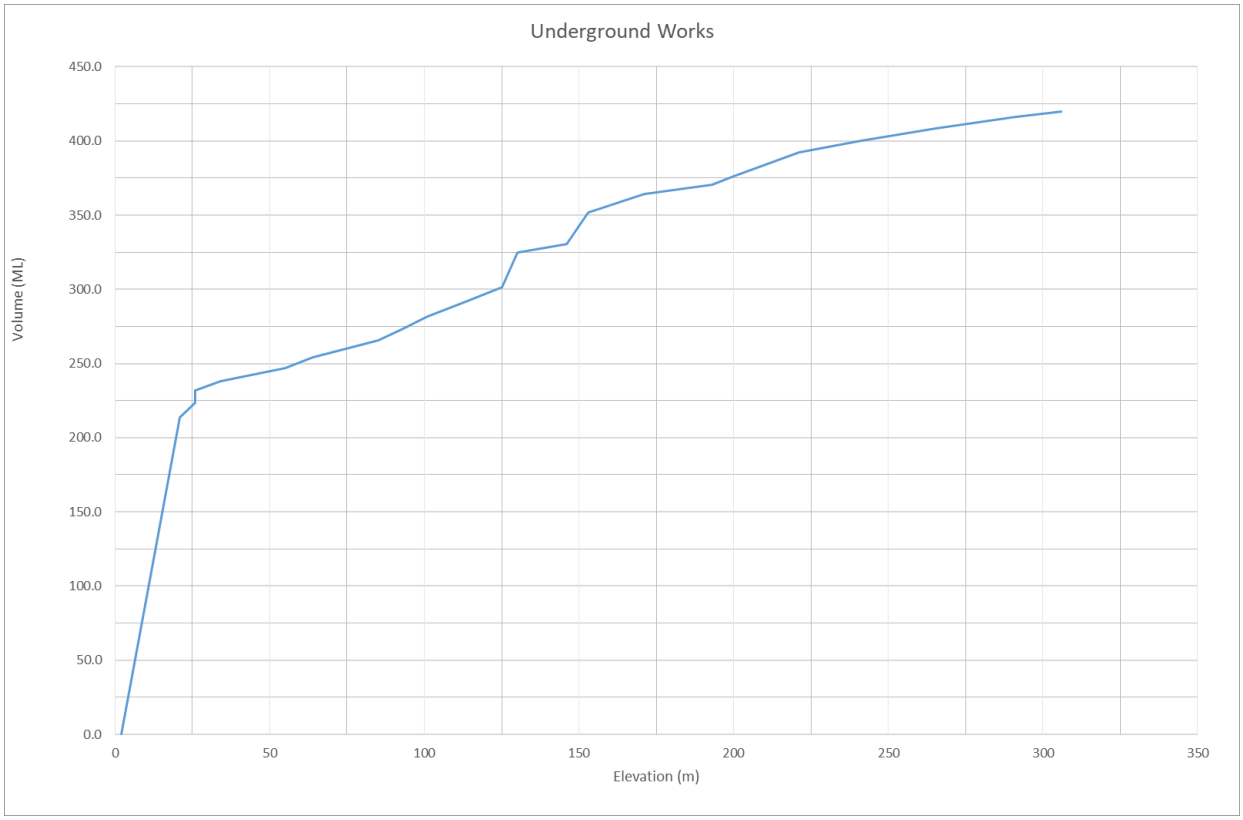
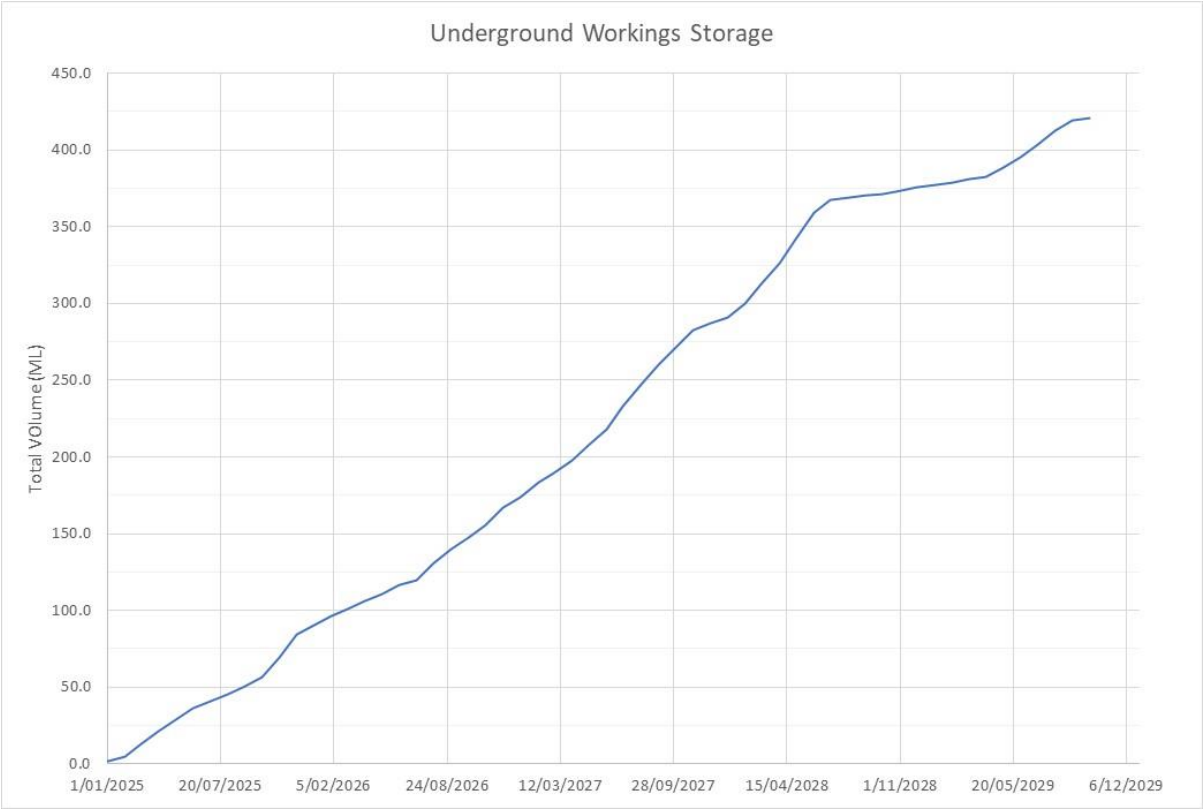


DIAGRAM 7: UNDERGROUND WORKINGS – NET STORAGE OVER TIME



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2.2.5 Initial Storage Conditions

Initial storage volumes were provided by Aeris, derived from water levels surveyed on 30 October 2023 **[4]** and are presented in **Table 6**. These values were applied at the simulation commencement of 01/01/2025.

TABLE 6: INITIAL WATER STORAGE INPUTS

Parameter	North Pit	South Pit	WRD Sediment Dam
Initial Volume* (ML)	67.0 (RL 308.58 m)	165.7 (RL 250.80 m)	44.4 (RL 333.38)
Total Capacity (ML)	131.0	3,296.4	153.3
Overflow Level (m)	RL 316.0 m	RL 334.3 m	RL 337.0 m

2.2.6 Pump Transfers and Source Priority

In discussion with Aeris, the following pumped transfer conditions and priorities were developed:

1st – Source water for the UG circuit and dust suppression directly from the South Pit. This will assist to dewater the South Pit to allow access to the ore at the base of the pit (crown pillar) approximately 18 months after operations recommence.

2nd – When the South Pit is sufficiently dewatered, water will be sourced from either the WRD Sediment Dam or North Pit based on which storage has the lowest available capacity remaining. Consideration is also given to the need to comply with Design Storage Allowance (DSA) requirements by 1 November each year.

3rd – Pump transfers from the North Pit and the WRD Sediment Dam will be initiated when water levels in these storages reach a critical water level. Pumping will be suspended once the water levels fall to a predetermined deactivation point. This arrangement is expected to remain operational for 2 years following the cessation of mining activities (until 31/12/2031). Details regarding activation/deactivation thresholds and pumping rates are provided in **Table 7**.

TABLE 7: PUMP TRANSFER CONFIGURATION

Source	Destination	Pump Transfer Rate	Activation Level	Deactivation Level	Destination Cease Pumping Level
North Pit	South Pit	66 L/s	RL 311 m	RL 310 m	RL 333 m
WRD Sediment Dam	South Pit	30 L/s	RL 334 m	RL 333 m	RL 333 m

2.2.7 Site Water Demands

There will be no on-site ore processing, and as such the primary uses for water onsite will be the UG circuit, and dust suppression on haul roads and the site access road. Aeris has confirmed that the UG circuit will consume approximately 0.35 ML/day, with dust suppression expected to consume approximately 5 ML/month (equating to approximately 0.2 ML/day). These estimates are based upon Aeris' experience at the Mt Colin site **[5]**.

2.2.8 South Pit and Underground Workings Interaction

In addition to groundwater inflows there is a potential for water ingress to the UG workings via the Portal and the Crown Pillar at the base of the Pit.

The portal is located at 310 m AHD and is located approximately 60 m above the latest recorded water level in the pit. The water level in the South Pit has never been above 250 m AHD. As the South Pit will be actively dewatered, the water level in the South Pit will be maintained well below the portal level. As such, interaction via the Portal is not considered to be likely.

The crown pillar at the base of the South Pit is the location of the richest ore deposit. Once the crown pillar is removed, the South Pit and Underground Workings become, in effect, a single storage. This has been represented in the model by allowing all runoff reporting to the South Put from 01/11/2029 to pass to the Underground. The Underground will have to fill to the level of 210 m AHD before the South Pit starts to fill.

2.2.9 Simulation Period

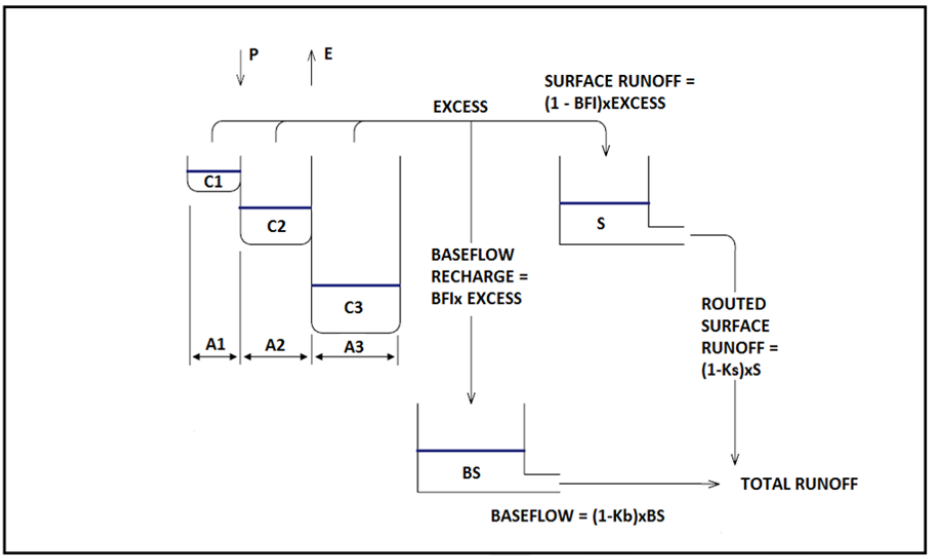
The model was run from the period 01/01/2025 to 31/10/2029, with the site under operational conditions, and from 01/11/2029 to 31/12/2050 to represent the closure conditions where groundwater levels recover to pre operational conditions.

2.3 Model Development

The Australian Water Balance Model (AWBM) was used to simulate daily runoff from rainfall, generated within the various sub-catchment types that are present on the project site. **Diagram 8** represents a schematic of the AWBM model, reproduced from Boughton (2004) **[6]**.

The catchment types and AWBM model parameters used to simulate these different catchment types and the average yields from these catchment areas are summarised in **Table 8**. Model parameters have been selected based on experience with similar water balance model studies and are considered to be conservative in the context of an uncalibrated model.

DIAGRAM 8: AWBM FOR RUNOFF CALCULATIONS



Where:

C1 - C3	= Surface Storage Capacities
A1 - A3	= Partial Areas Represented by Surface Storages
BFI	= Baseflow Index
K_b	= Daily Baseflow Recession Constant
BS	= Current Volume in Baseflow Store
K_s	= Daily Surface Flow Recession Constant
S	= Current Volume in Surface Store Routing

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TABLE 8: AWBM MODEL PARAMETERS

AWBM Parameters	Split Areas (sum=1.0)			Storage Capacities (mm)			Ks (day^{-1})	BFI	Kb (day^{-1})
	A1	A2	A3	C1	C2	C3			
Natural	0.13	0.43	0.43	12	120	250	0	0	1
Hardstand	1.00	0.00	0.00	10	0	0	0	0	1
Waste	0.20	0.80	0.00	10	300	300	0	0	1
Open Cut	0.10	0.90	0.00	5	20	20	0	0	1
Disturbed	0.10	0.30	0.60	20	55	100	0	0	1

3 RESULTS

The results of the WBM simulations are discussed in the following sections, for each structure at the BCP.

3.1 South Pit

The modelled water surface elevation in the South Pit is presented in **Diagram 9** (2025 to 2050) and **Diagram 10** (2025 to 2029). The following observations can be made in relation to **Diagram 9** and **Diagram 10:**

- Under median climatic conditions, the South Pit is rapidly dewatered by October 2025 to meet site water demands.
- Under median climatic conditions, the South Pit does not store any water until February 2041, as all rainfall and runoff enters the Underground Workings as the crown pillar has been removed.
- The maximum modelled water level in the South Pit is 290 m AHD, under the 99th percentile realisation. As the pit crest is 334 m AHD, this indicates the South Pit does not overtop or spill. The level of 290 m AHD is only reached in sequentially very wet years.
- The long term median water level in the South Pit is approximately 260 m AHD, approximately 10 metres above the current recorded water level.
- The South remains a groundwater sink, with no modelled outflows.

DIAGRAM 9: SOUTH PIT WATER SURFACE ELEVATION (2025 TO 2050)

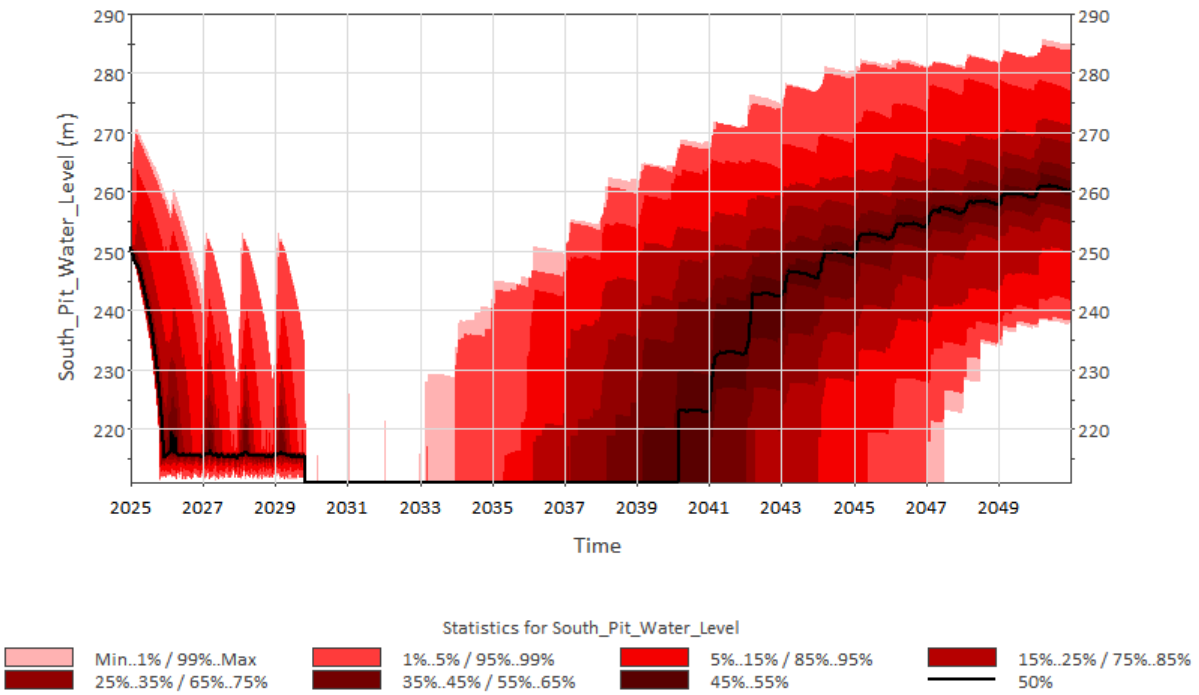

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DIAGRAM 10: SOUTH PIT WATER SURFACE ELEVATION (2025 TO 2029)

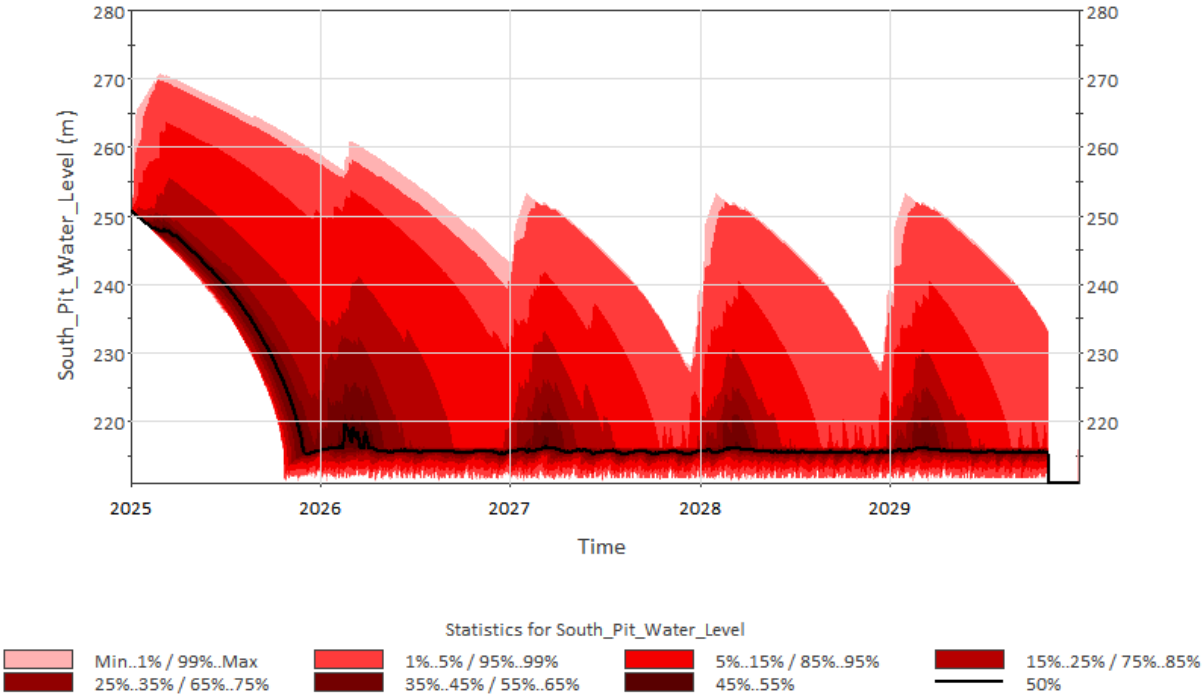
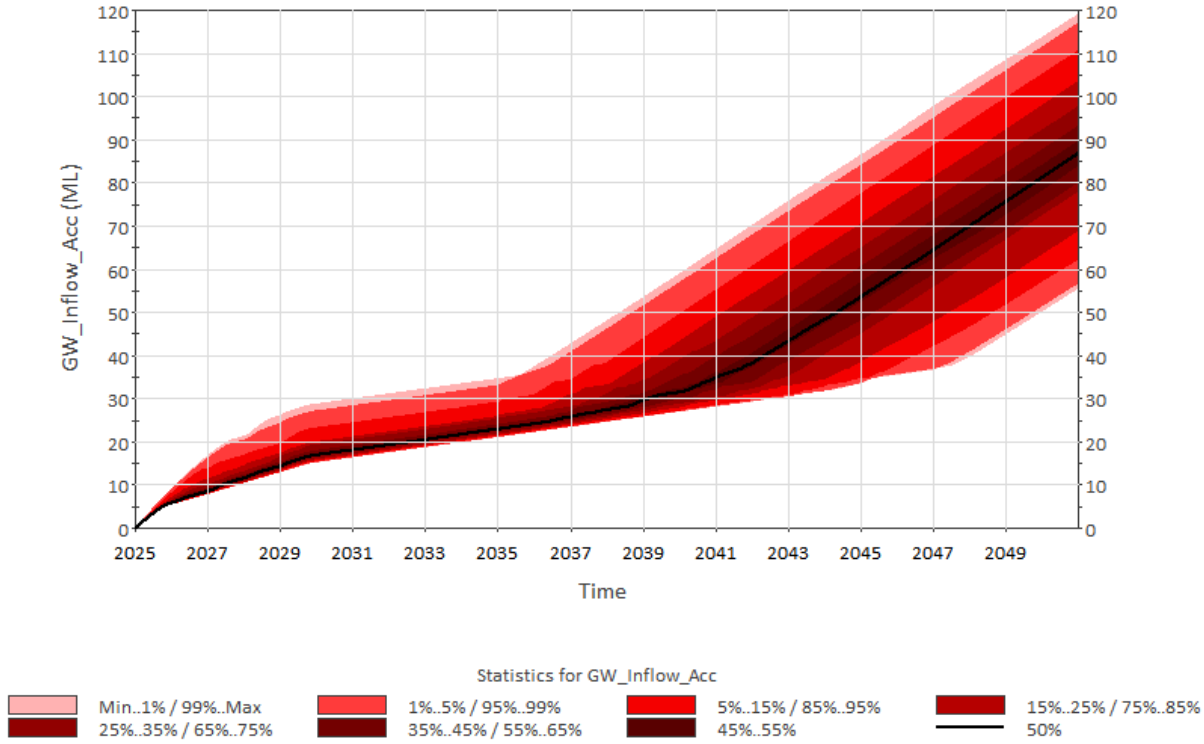


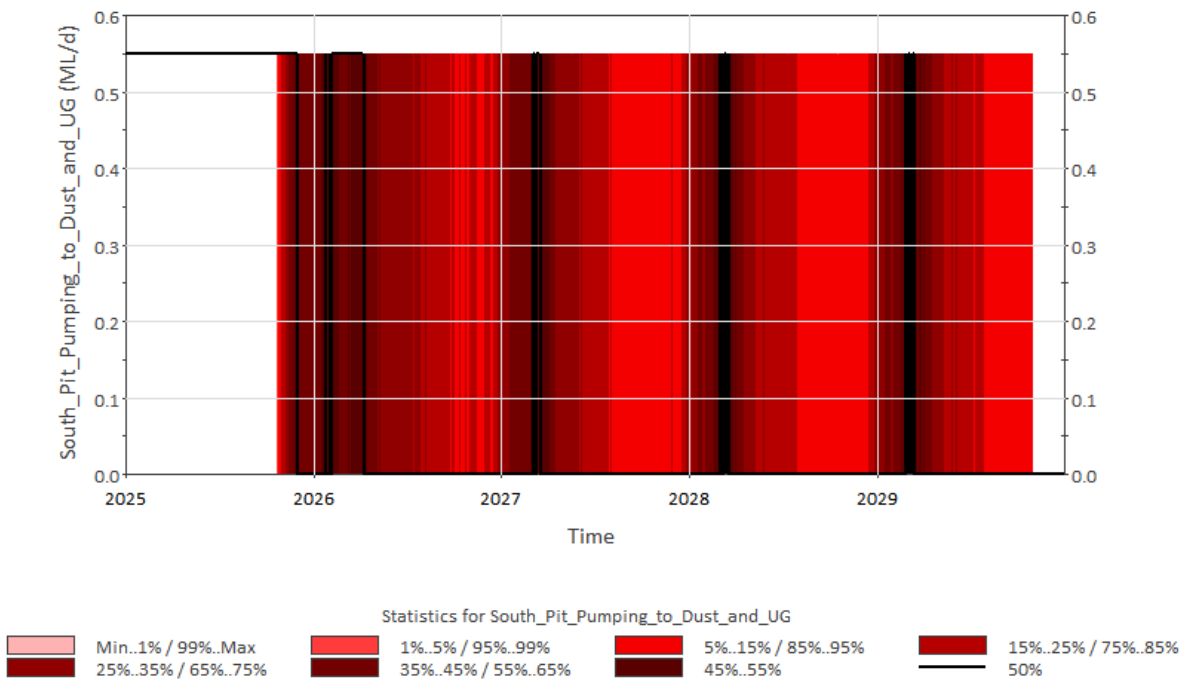
Diagram 11 illustrates the predicted accumulated groundwater inflow to the South Pit between 2025 and 2050. The median value is approximately 83 ML, or 3.32 ML/year.

DIAGRAM 11: SOUTH PIT ACCUMULATED GROUNDWATER INFLOWS



There were no modelled groundwater outflows from the South Pit as the South Pit is a regional groundwater sink. As can be seen in **Diagram 12**, the 0.55 ML/day of site water demands are met by the South Pit from January 2025 to October 2025. Beyond October 2025, the South Pit meets site water demands when water is available in the South Pit.

DIAGRAM 12: SOUTH PIT PUMP FLOW TO UG



3.2 Underground Workings

Diagram 13 depicts the accumulated volumes in the Underground. The following observations can be made in relation to **Diagram 13:**

- Under operational conditions the Underground Workings do not store any water between 2025 and 2029, as they are being actively dewatered.
- Under median climatic conditions the Underground Workings commence filling in 2030 and are completely filled by 2040. This is primarily driven by water ingress from the South Pit, connected to the Underground Workings via the removal of the crown pillar.

Diagram 14 depicts the variation in groundwater inflow over time. From this diagram, the following insights can be derived**:**

- Given the complexity of the Underground Workings, characterised by changes in available volume over time, the use of stage storage curves was not adopted in the WBM. Instead, the model incorporates projections of groundwater inflow over time as detailed in **Table 5**. This explains the lack of variability between the groundwater estimations of different realizations until the cease of mine operations (2029), as showed on **Diagram 14**. After the mine ceases its operations, the WBM calculates the groundwater inflows based on the estimated stage storage of UG Workings.
- The median accumulated groundwater inflow into the Underground Workings between 2025 and 2050 is approximately 20 ML, or 4.11 ML/year.
- The remainder of the water required to fill the Underground Workings is supplied by inflows from the South Pit.

DIAGRAM 13: UNDERGROUND WORKINGS ACCUMULATED VOLUMES

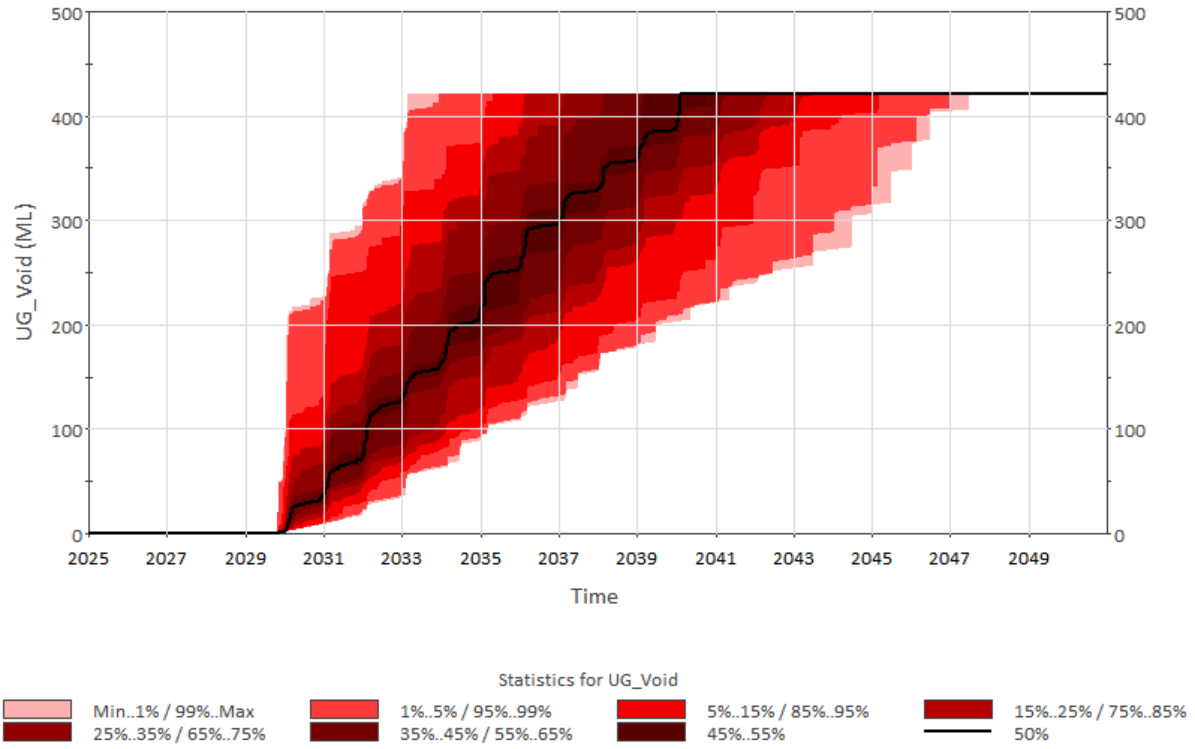
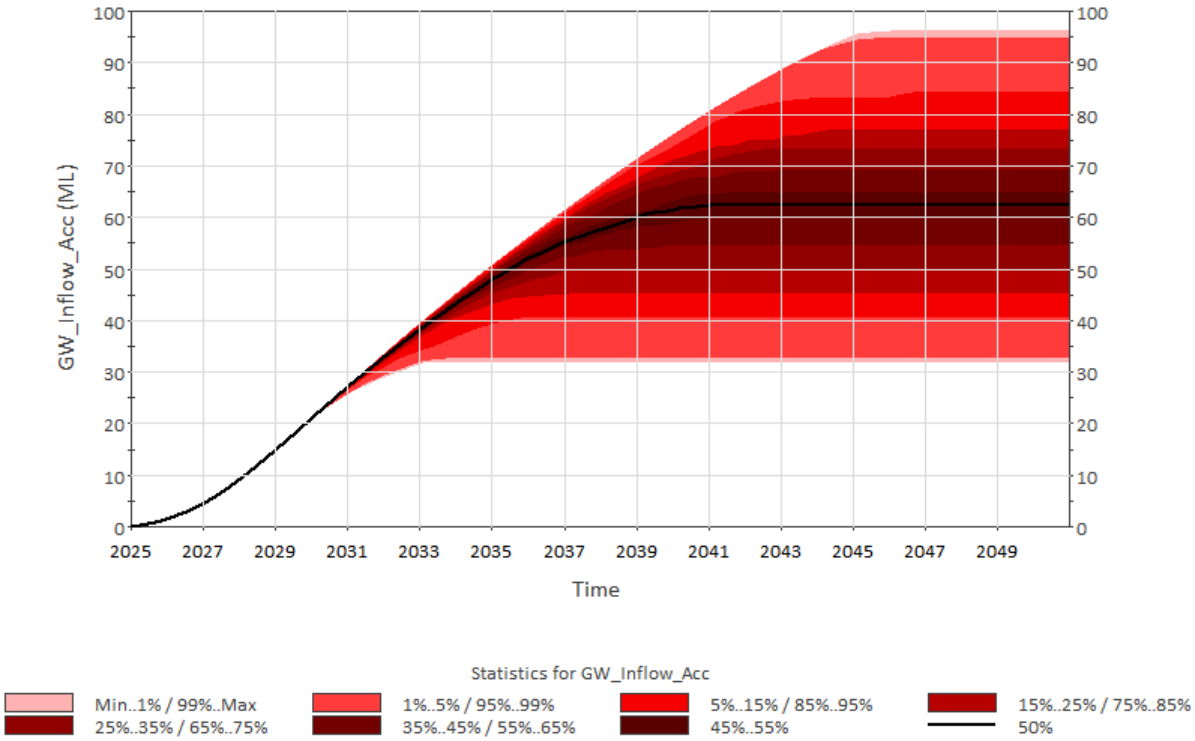


DIAGRAM 14: UNDERGROUND WORKINGS GROUNDWATER INFLOWS



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3.3 North Pit

Diagram 15 and **Diagram 16** depict the modelled water surface elevation in the South Pit. The following observations can be made in relation to **Diagram 15** and **Diagram 16:**

- Under median climatic conditions, the North Pit is rapidly dewatered by March 2026 to meet site water demands.
- Under median climatic conditions, between March 2026 and October 2029 (excluding the January-March period each year), the North Pit is dry, indicating the site may be in a net water deficit.
- The maximum modelled water level in the North Pit is 307 m AHD. As the pit crest is 316 m AHD, this indicates the North Pit does not overtop or spill. The level of 307 m AHD is only reached in sequentially very wet years.
- The long term median water level in the North Pit varies between 298 m AHD to 299 m AHD, approximately 10 metres below the current recorded water level.

DIAGRAM 15: NORTH PIT WATER SURFACE ELEVATION (2025 TO 2050)

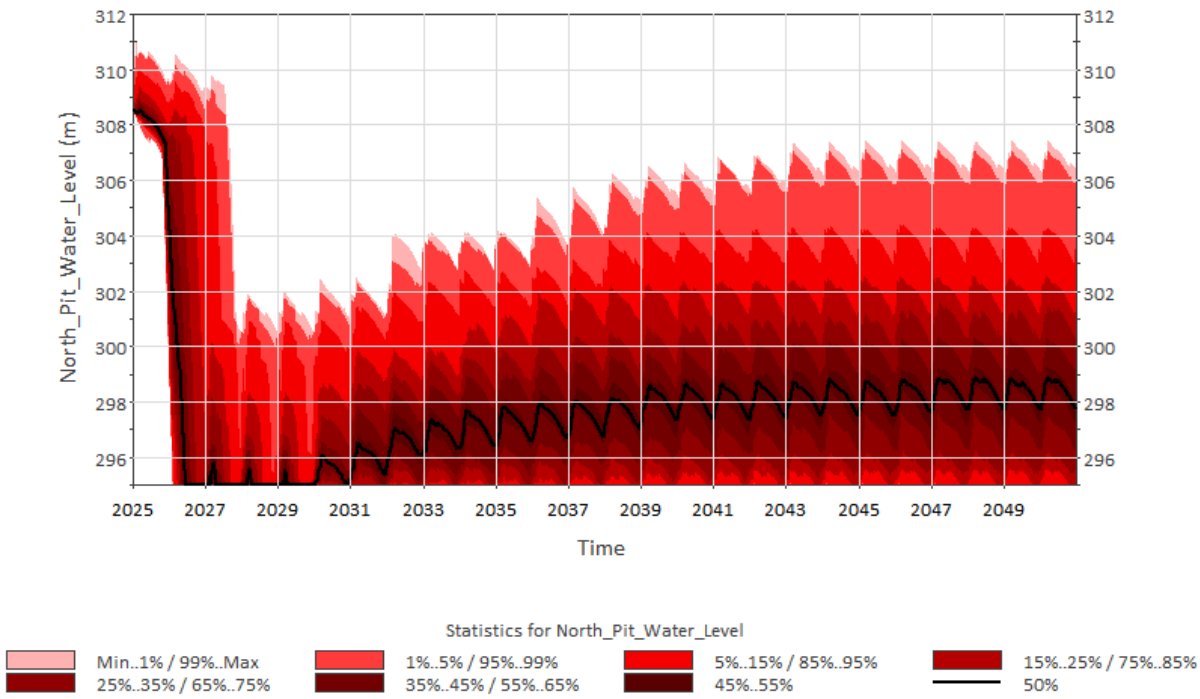

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DIAGRAM 16: NORTH PIT WATER SURFACE ELEVATION (2025 TO 2029)

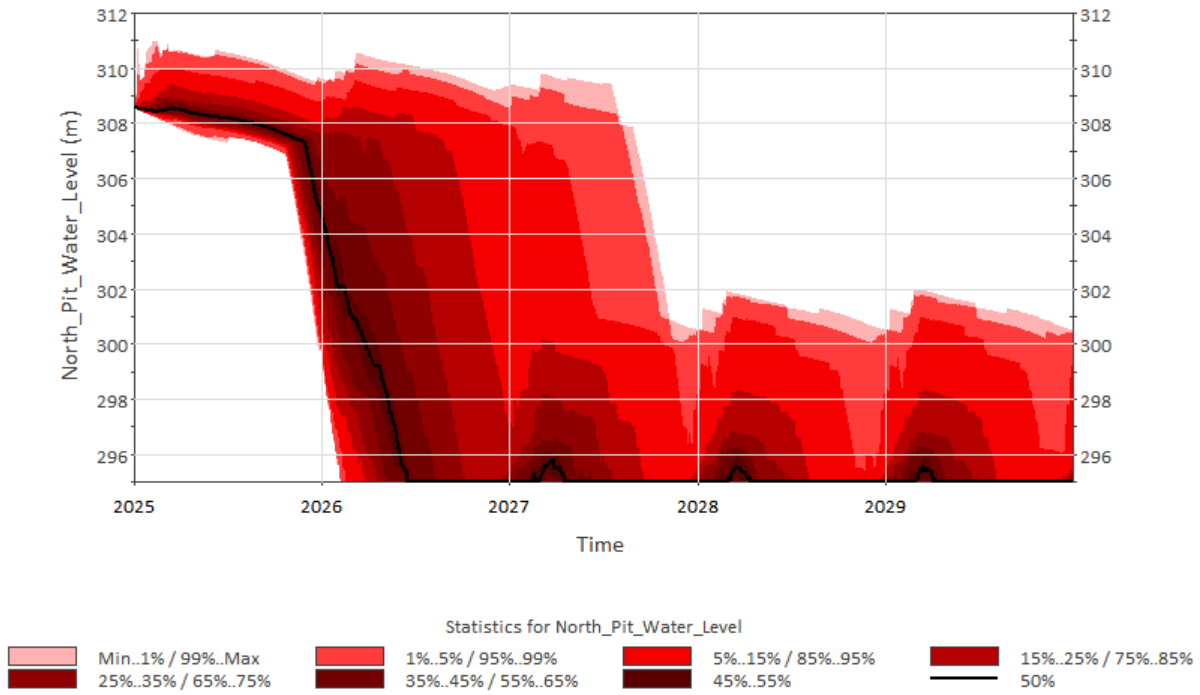
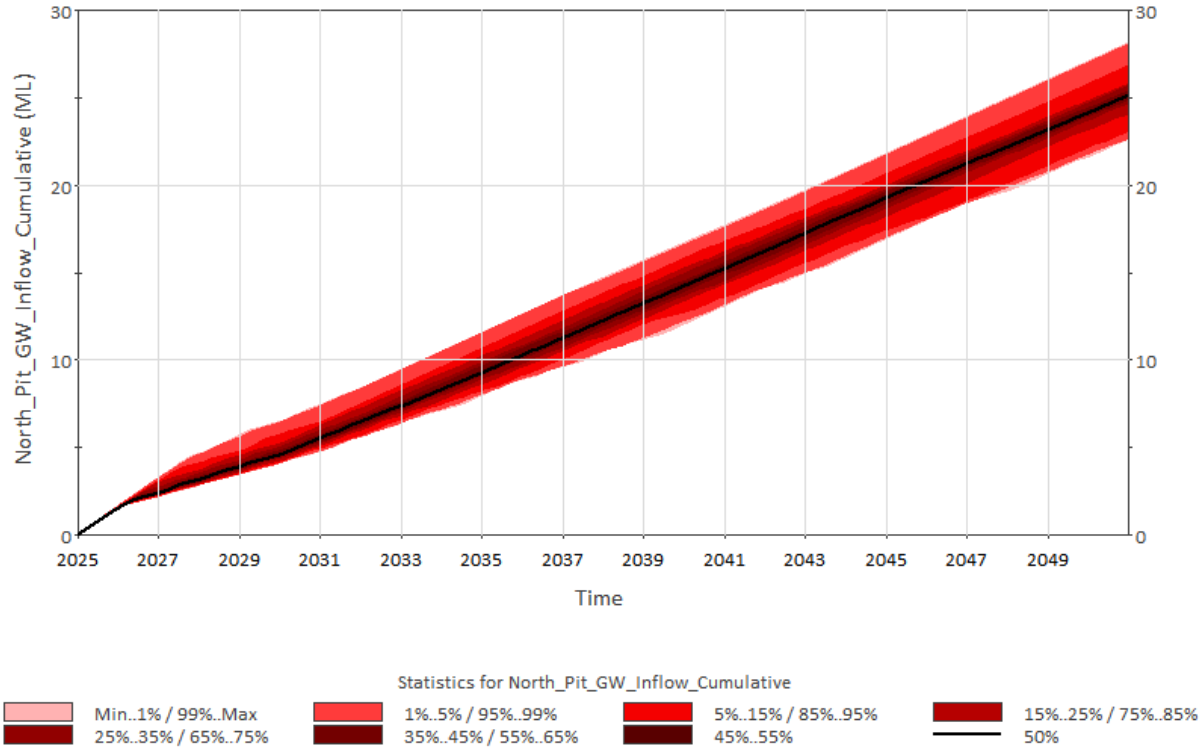


Diagram 17 illustrates that the median accumulated groundwater inflow into the North Pit between 2025 and 2050 is approximately 25 ML, or 1 ML/year.

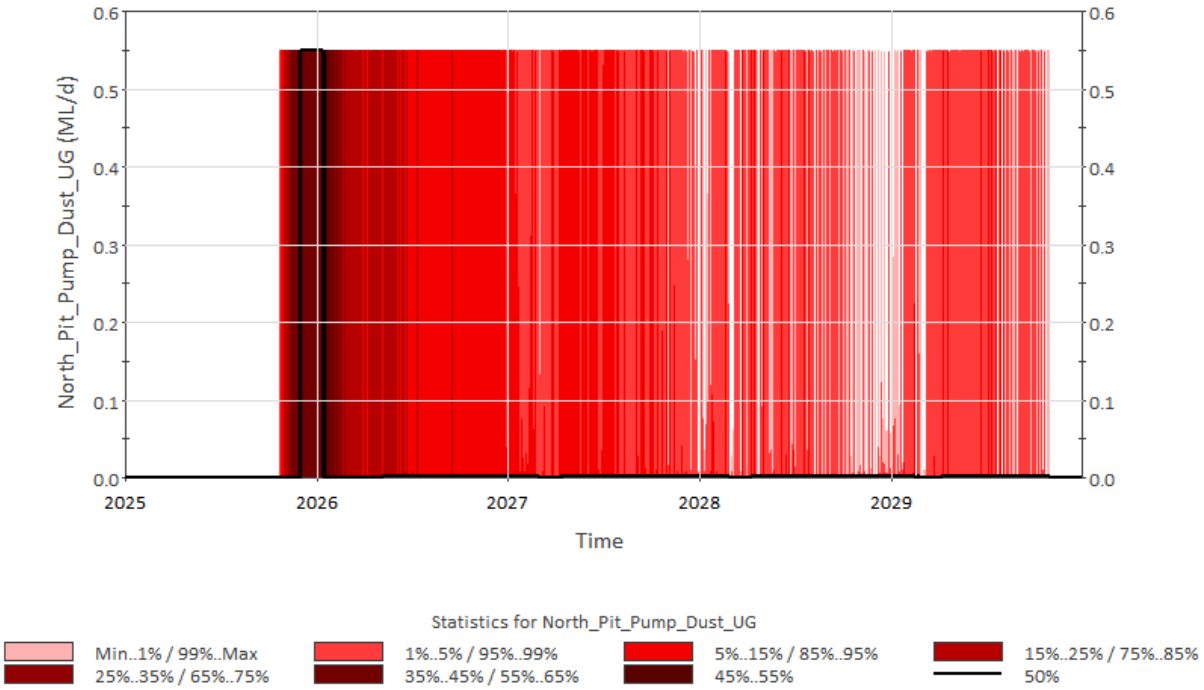
DIAGRAM 17: NORTH PIT ACCUMULATED GROUNDWATER INFLOWS



Additionally, under median climatic conditions there are no pump transfers from the North Pit to the South Pit. Pump transfers occur during three realisations where rainfall exceeds the median historical record.

Diagram 18 illustrates that under median climatic conditions, pump transfers from the North Pit assist in meeting site water demands beyond October 2025 (when the South Pit is effectively dewatered).

DIAGRAM 18: NORTH PIT PUMP FLOWS TO UG



3.4 WRD Sediment Dam

Diagram 19 and **Diagram 20** depicts the modelled water surface elevation in the WRD Sediment Dam. The following observations can be made in relation to **Diagram 19** and **Diagram 20:**

- Under median climatic conditions, the WRD Sediment Dam is dewatered by October 2026.
- Under median climatic conditions, between October 2026 and October 2029 (excluding January-March each year), there are periods where the WRD Sediment Dam dry, indicating the site may be in a net water deficit.
- The maximum modelled water level in the WRD Sediment Dam is 336.8 m AHD. The spillway level is at 336.8m AHD. There are 2 realisations where the WRD Sediment Dam spills. This only occurs in sequentially very wet years.
- The long term median water level in the WRD Sediment Dam varies between 330 m AHD to 331.2 m AHD, approximately 2.5 metres below the current recorded water level.

Due to the presence of the HDPE liner on the WRD Sediment Dam, no groundwater inflows or outflows were modelled.

DIAGRAM 19: WRD SEDIMENT DAM WATER SURFACE ELEVATION (2025 T0 2050)

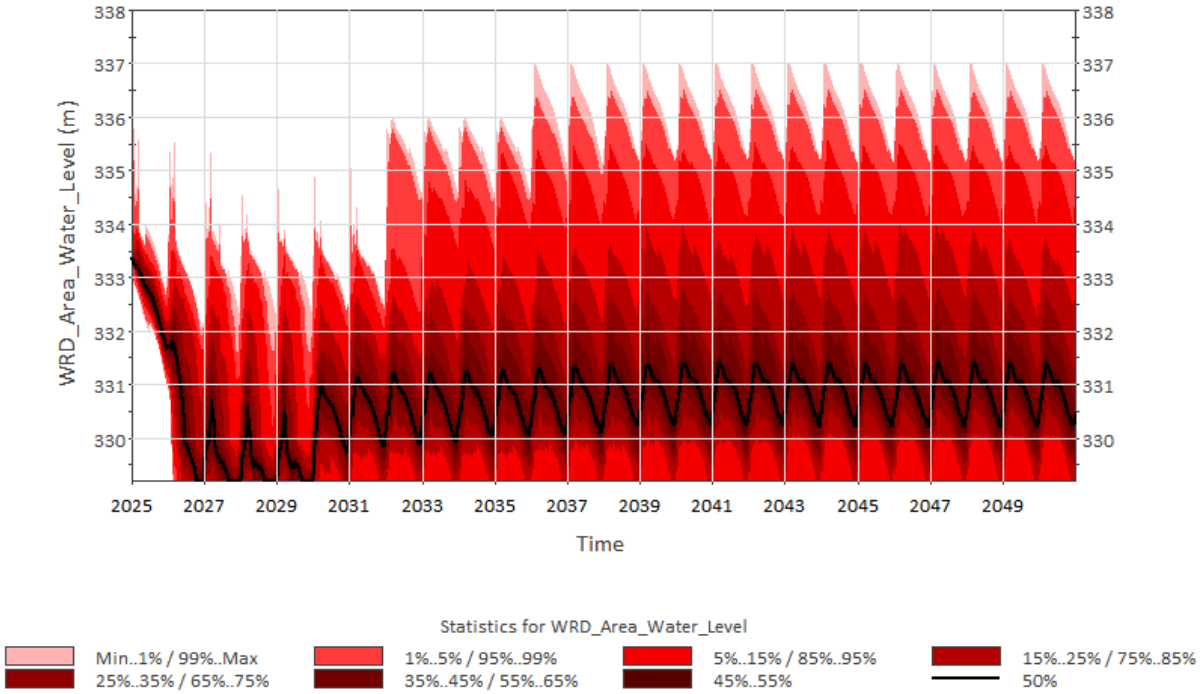


DIAGRAM 20: WRD SEDIMENT DAM WATER SURFACE ELEVATION (2025 T0 2029)

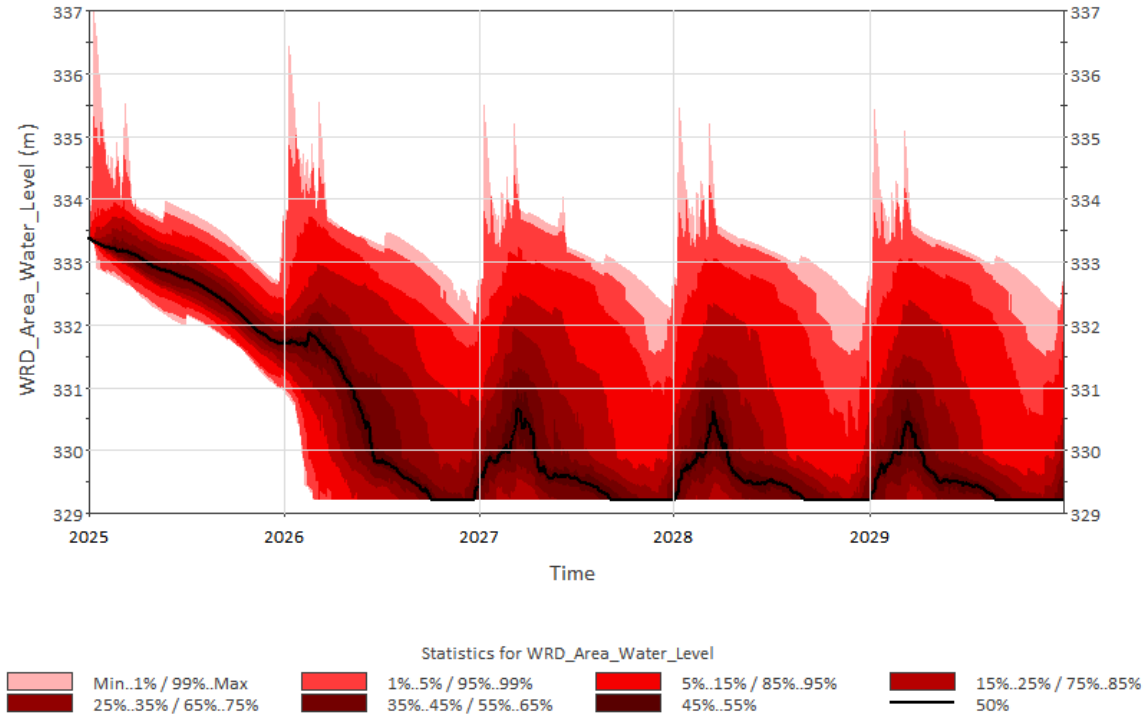


Diagram 21 illustrates that under median climatic conditions, there are no pump transfers from the WRD Sediment Dam to the South Pit. Pump transfers occurs in years where rainfall exceeds the median historical record.

TAILINGS.WATER.WASTE.

DIAGRAM 21: CUMMULATIVE PUMP FLOWS TO SOUTH PIT

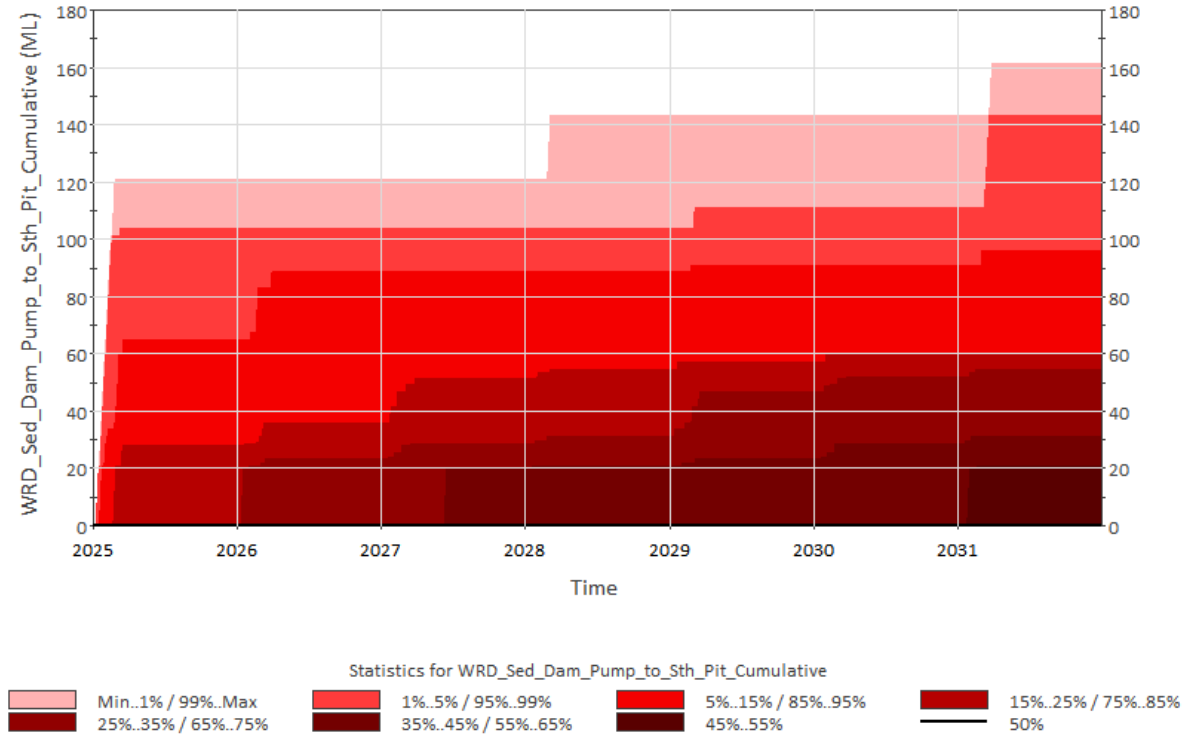
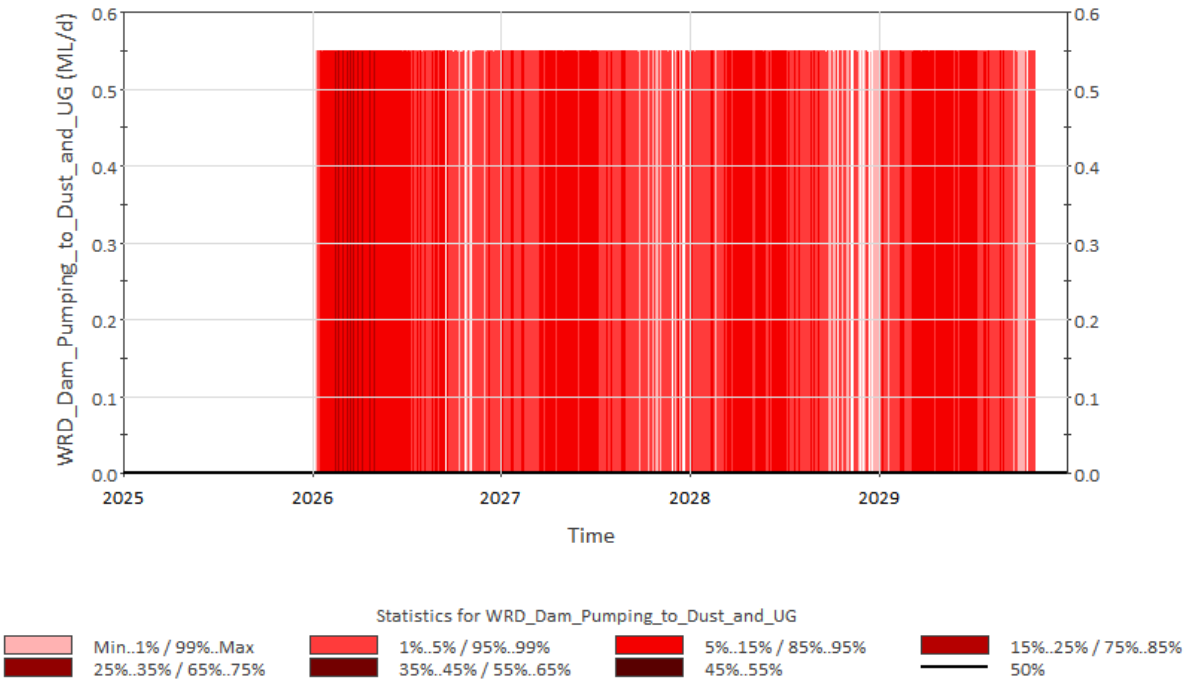


Diagram 22 illustrates that under median climatic conditions, pump transfers from the WRD Sediment Dam assist in meeting site water demands beyond October 2025 (when the South Pit is effectively dewatered).

DIAGRAM 22: WRD SEDIMENT DAMPUMP FLOWS TO UG



4 SUMMARY AND CONCLUSION

The results of the WBM undertaken as part of the assessment of the Underground Workings indicates the following:

The South Pit is rapidly dewatered by October 2025 to meet site water demands, whereupon the North Pit and WRD Sediment Dam are used as sources to meet the site water demands.

Modelling indicates that under median climatic conditions, the site may have the potential to be in a net water deficit in the dryer months of 2027, 2028 and 2029.

The Underground Workings receives all rainfall and runoff from the South Pit from 2029. Under median climatic conditions, the Underground Workings takes ten years from 2029 to 2039 to fill. After the Underground Workings fill, the South Pit then begins to fill.

By 2050, under median rainfall conditions, the South Pit water level reaches approximately 260 m AHD, which is approximately 75 m below the pit crest. During the 95th percentile wet years, the maximum modelled water level in the South Pit is approximately 290 m AHD, which is 45 m below the pit crest. Therefore, the South Pit is not predicted to overtop or spill during operations or closure conditions.

By 2050, under median rainfall conditions, the North Pit water level reaches approximately 298 m AHD to 299 m AHD, which is approximately 17 m below the pit crest. During the 95th percentile wet years, the maximum modelled water level in the North Pit is 307 m AHD, which is approximately 9 m below the pit crest. Therefore, the North Pit is not predicted to overtop or spill during operations or closure conditions.

The WRD Sediment Dam was observed to overtop in two realisations during operational conditions, with no overtopping occurring during closure conditions.

REFERENCES

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[2] WMV Environmental (2024a), 'BCP UG EA GW Inflow Calculations (v1.1 - 2024_02_19).xls', 19 February 2024.

[3] WMV Environmental (2024b), 'Barbara Copper Project UG EA Amendment . Groundwater Technical Report, February 2024.

[4] Aeris (2024). '231030_Barbara Dam Survey Information.xls', 30 October 2023.

[5] Eason, D. (2024) 'RE: Aeris Resources, Barbara Copper Project - underground EA amendment application',23rd January 2024.

[6] Boughton, W.C. (2004). 'The Australian Water Balance Model. Environmental Modelling & Software', Vol. 19, pp943-956.

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Memo

To:	Gemma Brown
Cc:	Cameron Schubert, Damon Newling, Tim Brettell, Max McInnis
Subject:	Geotechnical Assessment for the Barbara Underground -Subsidence risk
Date:	23 April 2024

1. BACKGROUND

A scoping study is currently underway to convert the Barbara Open Pit mines into an underground mine. Transitioning from Open Pit mining to underground requires EA amendment. Among other information, the Geotechnical assessment for the stability of the open pit because of underground mining needs to be completed. Geotechnical assessment to address the impact, the development of the underground workings will have on the stability of the north and south pits and the broader footprint of potential subsidence has been completed. As per Queensland Environmental Protection Act 1194 (EP Act), the EA will be subjected to an Assessment Level Decision (ALD) to determine environmental requirements to transition to underground mining.

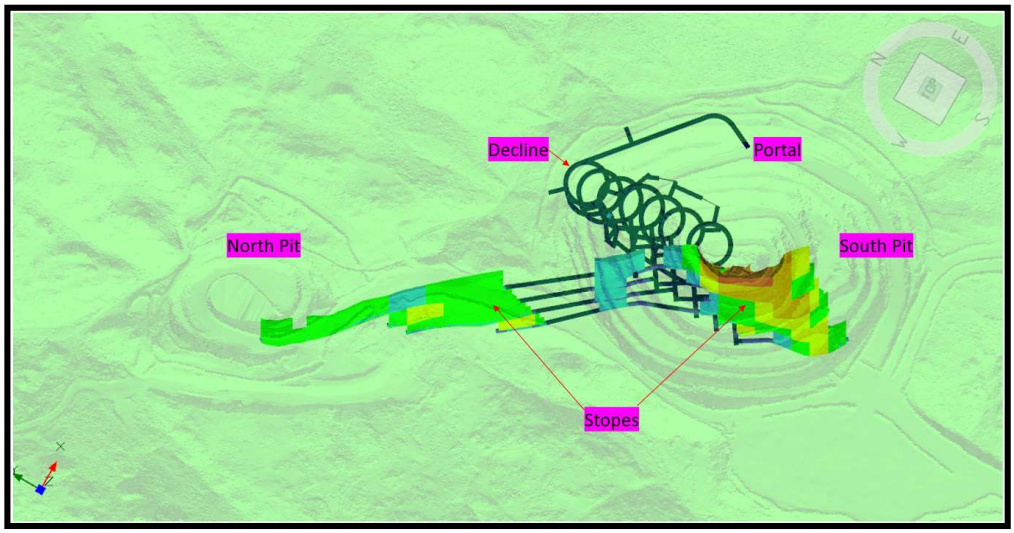

Figure 1: Barbara Copper Underground Project showing planned stopes (Plan view).

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2. INTRODUCTION

Barbara Copper mine comprises two open pits with the south pit mined deeper than the north Pit. Underground mining is being planned to commence at Barbara Copper Mine. This geotechnical report has been prepared to address the impact the development of the underground workings will have on the stability of the north and south pits and the broader footprint. Geotechnical assessment involved analysing the planned underground shapes and available structural model to analyze potential for the voids to breakthrough to surface.

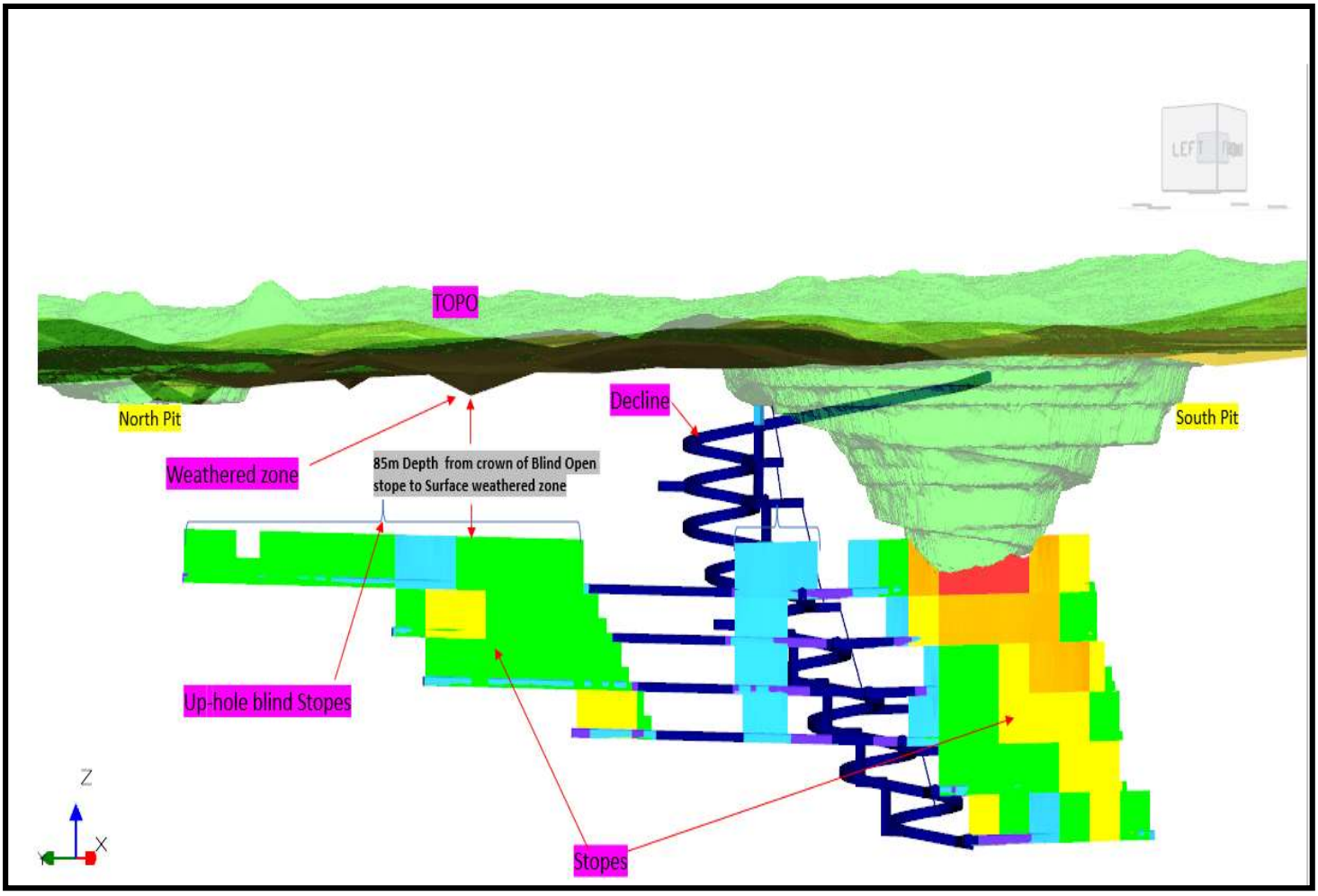

Figure 2: Barbara Copper Underground Project showing planned stopes (looking from South).

3. GEOLOGICAL AND GEOTECHNICAL DATA ANALYSIS

3.1 GEOLOGICAL SETTING

The Barbara Copper Project (BCP) orebody site is hosted within the Leichardt Metamorphics within the Kalkadoon-Leichhardt belt of the Mt Isa Inlier. The regional geology is structurally complex with structural repetition of stratigraphic units and wrench faulting common. Syndicated Metals Ltd (August 2014) describes the local geology of the Barbara Copper Project site as follows:
"*Bedrock geology in the area comprises Proterozoic rocks of the Mount Isa Inlier. Rock types at Barbara include felsic volcanics (forming the hills), dolerite/amphibolite (in the drainages/valleys) and basalt (forming plateaus). The felsic volcanics are the dominant rock type in the project area. The felsic and mafic volcanics dip at 60 degrees towards the northeast and the dolerites are subvertical within the project area. These three rock types are resistant to weathering and extensive outcrops occur throughout the area.*"

The orebody is located within what is informally termed as the Barbara Shear Zone (BSZ), which is a shear hosted deposit within the acid volcanics. The Northwest striking lode dips at approximately 60° to the southwest and varies from 2m to 30m true thickness.

3.2 GEOTECHNICAL DATA

3.2.1 STRESS REGIME

No local measurement of the pre-mining stress state has been undertaken at Barbara Copper project. In-situ stress datasets in the Mount Isa region indicate major stress are sub-horizontal and acting perpendicular to the strike of the orebody. Same with nearby Mount Colin Mine, no pre-mining stress state has been undertaken. No stress issues have been observed at Mount Colin owing to the shallow nature of the underground mine. The same can be said about the Barbara Copper Project. It is expected that that no stress issues will arise when underground mining commences as Barbara Underground Project is planned to be mined with the same configuration as Mount Colin in terms of depth and stope sizes. Mining induced stresses will most likely be rock mass relaxation in and around stoping areas.

3.2.2 ROCK PROPERTIES

The deposit is within the folded and faulted Leichardt Metamorphics unit. This unit mainly comprises felsic volcanics (Rhyolitic and Rhyodacitic units) that have been intruded by mafic dykes of amphibolite composition. Mafic schists (Dolerite/Biotite) occur along the margins of the dykes. The sulphide mineralisation is hosted within the BFZ zone that comprises schistose rock mass and sheared rhyodacite.

Table 1. Unconfined Compressive Strengths for Rhyodacite, Amphibolite and Mineralised zone

Rock Type	Unit Weight (t/m³)	Unconfined Compressive Strength (MPa)
Rhyodacite	2.68	162
Amphibolite	3.04	230
Mineralised zone (schist, dolerite, breccia)	2.91	86

3.2.3 STRUCTURAL DATA

PSM completed a campaign mapping of the south pit which included geological field and photogrammetric mapping. Major structures in the rock mass comprise foliation and faults/shears. Foliation forms a predominant defect within the schist rock mass, comprising two splays of the BFZ. Sporadic faults and shears may also be present within the rock mass. Minor structures in the rock mass are less continuous, mostly dominated by jointing.

Regional faulting is complex with numerous wrench faults and dip-slip normal fault evident. The Barbara Fault Zone (BFZ) is the main major regional structure which strikes northwest-southeast, dips steeply towards the west.

3.2.4 WEATHERING

Weathering profile range around 15m to 20m deep from surface. The weathering profile is very shallow in the South Pit west wall area with fresh rock approximately 5m to 10 m. In the North Pit depth of fresh rock is approximately 15 m to 20 m from both the west and east walls. Depth of weathering is significantly a key component for stope crown stability. For Barbara Copper Project, stope crowns are approximately 100 m deep from surface. With approximately 20 m weathered zone from surface, 80m fresh rock provides stope crown pillar stability. The stopes at the bottom of the south pit are all located in fresh rock.

3.2.5 GROUND WATER

Groundwater at the Barbara Copper Project site is primarily associated with the orebody (Rob Lait & Associates 2013). Flow of groundwater is from the west to east i.e., towards the orebody. Groundwater exists in fractured rock aquifer systems in the rhyodacite, schist and amphibolite units.

3.3 MINING METHOD

The Mining Method planned for the Barbara Copper Project is a Sub Level Open stope operation with waste backfill. Stopes have been designed with 25m sub-level intervals to a maximum stope height of 100 m. Sequnce of mining will be bottom-up to provide a working platform for subsequent stopes following waste backfilling process. A crown pillar is planned to be left at the pit bottom and will be mined last in the sequence. Some stopes have been designed to be mined as up-hole blind stopes with no filling horizon, thus will remain open and may present some stability issues but does not pose any subsidence risk due to a sizeable pillar (~85m from the stope crown to surface).

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4. UNDERGROUND MINING (SUBSIDENCE RISK)

4.1. STOPE STABILITY

PSM Consultants completed a scoping level underground geotechnical study. The study defined stope sizes based on the available geological / geotechnical information and completing empirical assessment using the modified Mathews Stability Graph (Mathews et al. 1981). Stopes have been designed with 25m sub-level intervals to a maximum stope height of 100 m. Stope spans range from 5 to 17m and strike lengths range from 50 to 100 m. Backfilling of stope voids improves stability and as such stope sizes have been designed to be stable with backfill and/or the need to have rib and sill pillars as required.

Hanging wall failure may occur in areas where weak ground conditions are encountered. Stopes will require to be backfilled with development waste immediately following stope completion to minimise hanging wall overbreak. The up-hole blind stopes will be left unfilled presenting a potential for excessive hanging wall and crown overbreak. For these up-hole blind stopes, it is likely that where poor ground conditions are encountered, hanging wall and crown may progressively fail until a stable arch is achieved. In some rare instances, hanging wall and crown progressive failure may continue to occur until void fill and choke void before reaching surface and remain stable. Even though blind stopes are going to remain open, there not expected to present subsidence risk due to a sizeable crown pillar. The stability of stopes at the Barbara Copper Project will depend on the need to ensure appropriate stope spans are used. As ground condition changes, the stope sizes will be re-designed accordingly to ensure stope stability.

4.2. STOPE CHIMNEY FAILURE POTENTIAL

Review of the mining design indicate the planned up-hole blind stopes have approximately 80 m of fresh cover from the crown to the weathered profile. Blind Up-hole stope voids are unlikely to breakthrough to surface. All the up-hole blind stopes are designed with sufficient cover and if any crown overbreak occurs, it is going to be restricted in the vicinity of the stopes and not expected to reach the weathered zone/ breakthrough to surface.

The weathering profile is shallow approximately 15 to 20 m depth. Up-hole blinds stopes will be left open, hanging wall and crown failure occurring over time is possible but it is highly unlikely any chimneying to surface would occur. The most likely mechanism is unravelling of the rock mass resulting in void overbreak on the crown and hanging wall until a stable arch had been achieved. In underground mines, chimneying to surface for up-hole blind stopes are likely to occur when these stopes intersect very weak and friable thin fault zones bounded by competent ground conditions on either side and the fault zone is modelled all the way to surface and/or weathered profile. Overtime failure will occur following the fault zone and create a chimney-like effect until breakthrough to surface occurs. For the Barbara Underground Copper mine, geological information interrogated from the south pit walls, refer to figure 4 and core photo logs does not indicate adverse weak

fault zones. Based on the available information which has been assessed, the chance of stope failure resulting in chimneying and breaking through to surface is highly unlikely.

Figure 3: Barbara South Pit, South Wall- Barbara Fault Zone -Ore Zone (looking South).

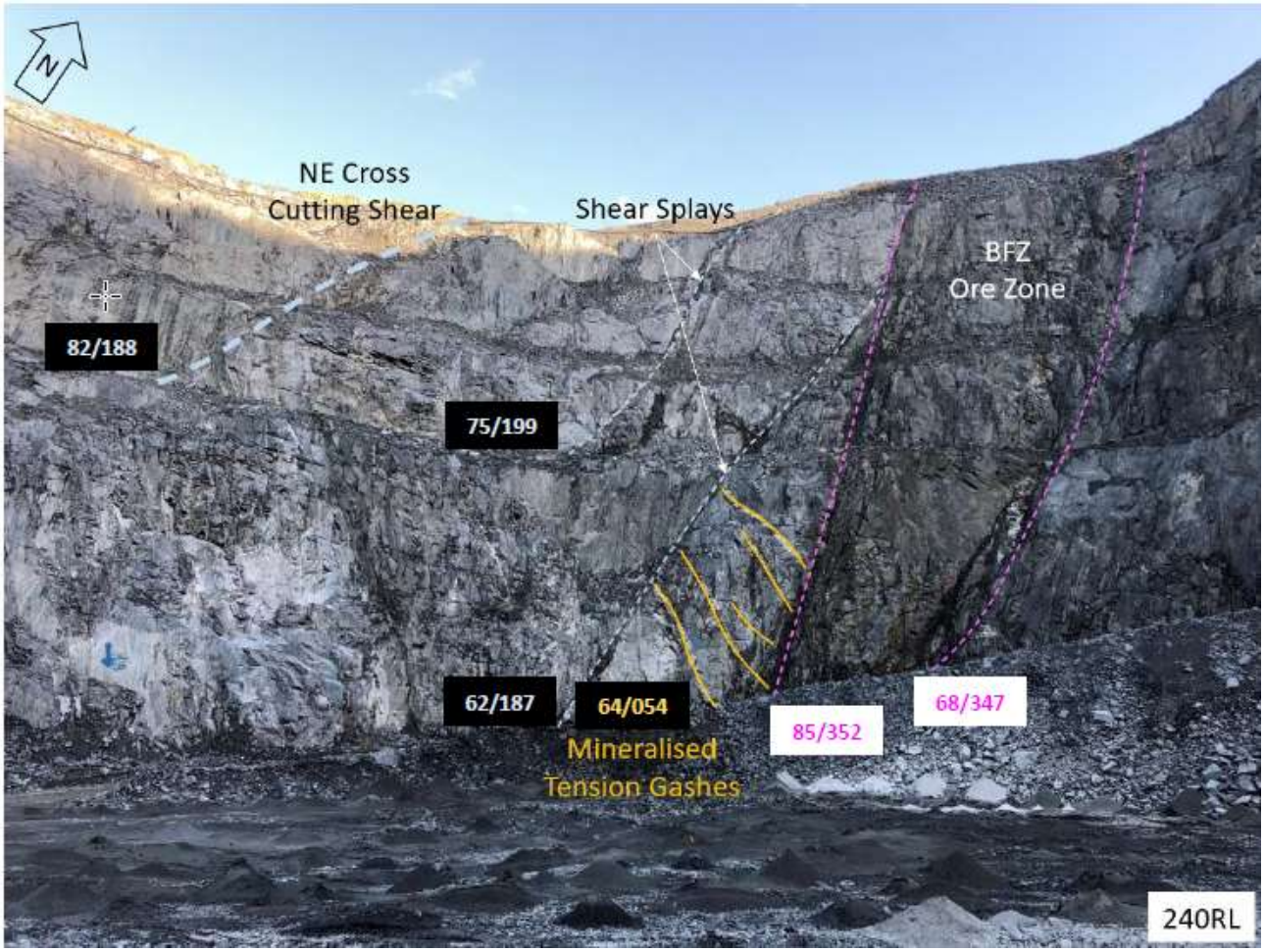

Figure 4: Barbara South Pit, Northern Wall- showing mapped Structures.

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5. SUBSIDENCE RISK

For the Barbara Underground Copper Project, the planned mining method is sub-level open stoping with waste backfill. The use of back fill is to stabilise the surrounding rock mass as well as provide working platform for subsequent stoping. Unlike cave mining methods used in base metal mines and longwall mining in coal, sublevel open stoping with backfill Mining method precludes caving thus subsidence risk is low. PSM preliminary assessment of stope stability conducted using the Mathews/Potvin Stability Graph Method indicate stable stopes are achievable thus are unlikely to cave to surface. The stopes in the proximity to the pit are planned to break through at the bottom of the Pit. Instability is going to be restricted in and around the pit bottom where a void is going to form while mining the pit crown stopes, thus no major surface disturbance is going to occur on surface. It should be mentioned that the existing south pit void does have more influence on surface disturbance than the planned underground stopes.

To identify surface disturbance due to the pit void, PSM Consultants completed a Mine closure Geotechnical study for Barbara Copper Project in 2020. The closure Geotechnical study was to fulfil a requirement for the Open Pit Progressive Rehabilitation and Closure Plan (PRCP). The analysis involved:

- Identification of the long -term stable pit crest location by assessing the extent of the "potential maximum failure "using appropriate stability analyses methods, which in this case included:
    - Limit Equilibrium (LE) stability analysis
    - Pit Geotechnical site inspection to identify potential structural failure mechanisms.
    - Use of approach as presented in the Western Australian guidelines for identification of a potentially unstable pit edge zone (DIR,1997) with a revised analysis to consider the long -term landforms evident in weathered materials.
- The "potential maximum failure" identified the long-term post closure conservative "potentially unstable zone" surrounding the pit voids.
- To ensure the long-term potentially unstable zone poses no risk to public safety, the zone was defined as an exclusion zone with a post closure abandonment bund installed to restrict public access. An additional 10m offset from the "potential maximum failure" boundary was then included for conservatism, refer to figure 5.

As indicated above, the underground mining excavations below pit, refer to figure 6, does not create any surface disturbance outside the current zone defined for the Barbara Open Pit Closure boundary bund.

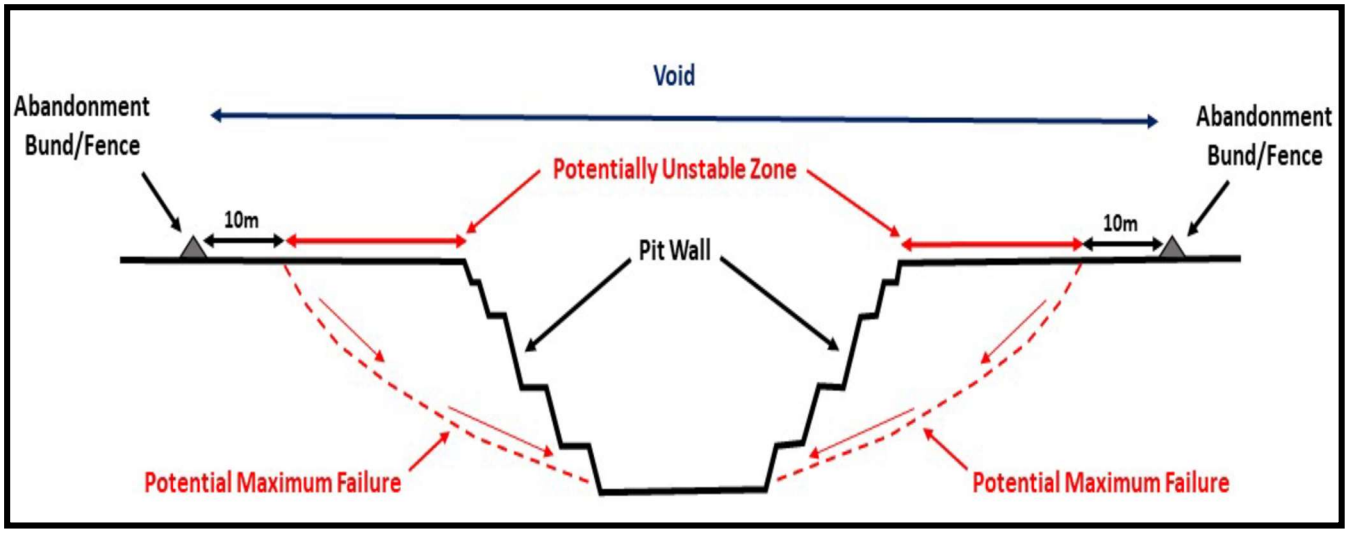

Figure 5: Schematic showing potentially unstable zone (PSM,2020)

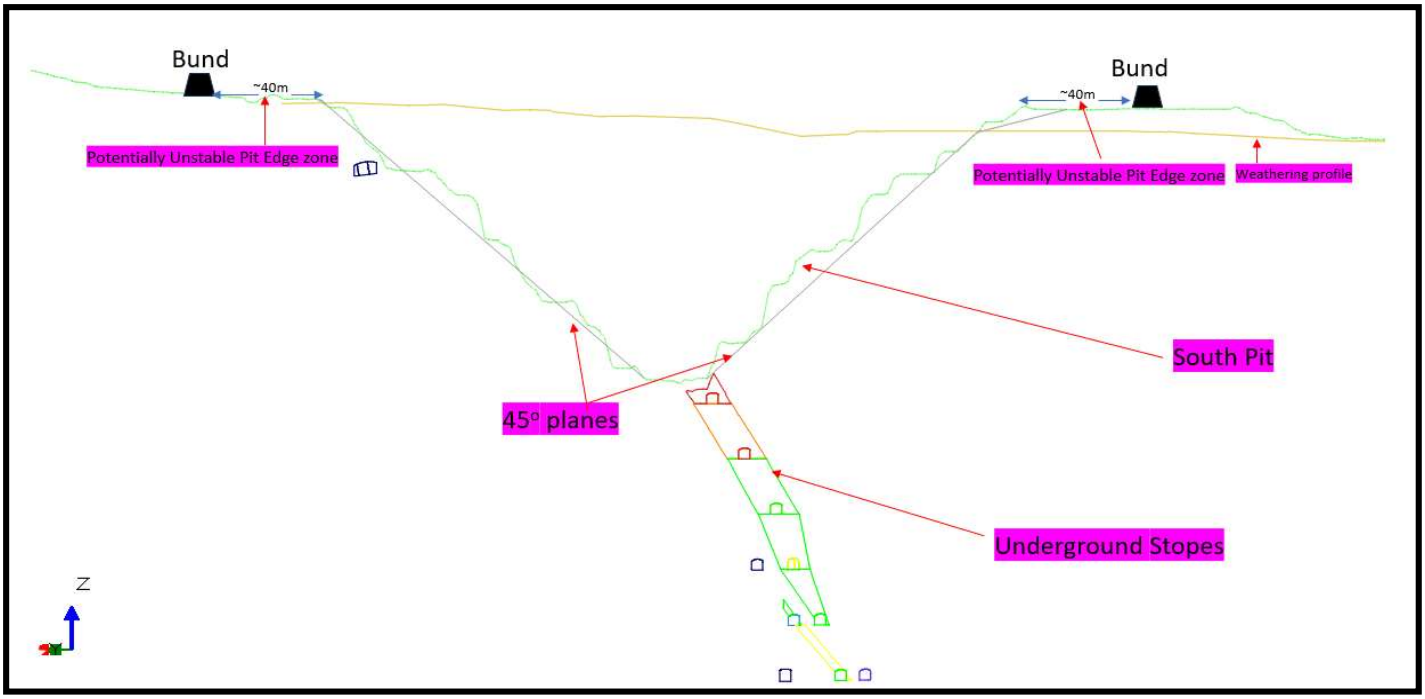

Figure 6: Barbara South Pit and underground stopes showing potentially unstable pit zone.

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6. SEALING OF SURFACE OPENINGS TO UNDERGROUND

Barbara Copper Project Main Portal will be backfilled with inert waste rock and a shotcrete bulkhead in front of the backfill. The waste rock backfill, and shotcrete bulkhead will be located approximately at least 50m down decline entrance in an area of good ground conditions. Shotcrete wall (Bulkhead) will be installed with drainage holes to allow for surface runoff to drain into the underground. The shotcrete plug will be installed as per standard bulkhead wall installation as per mine site bulkhead construction safe work instructions. Geotechnical assessment for shotcrete bulkhead construction will be undertaken prior to construction to decide location and size of the bulkhead. An inert bund will be installed just outside the portal entrance and a metal grate gate fitted at the portal. The inert bund walls should be constructed of minimum 2 meters height and 5 meters base width.

7. CONCLUSION

Geotechnical assessment to address the impact the development of underground workings will have on the stability of the north and south pits for potential subsidence of the Barbara Copper Project footprint has been completed. Planned underground voids beneath/surrounding the north and south pits pose a low risk of breakthrough to surface. Subsidence assessment indicates that the planned underground mining voids are highly unlikely to present any surface disturbance due to good ground conditions in and around the stope hanging wall and crown.

Stopes planned to be mined at Barbara Underground Project have been assessed to be stable with waste backfill used to provide passive support and as a working platform. Some up-hole blind stopes planned to be mined and left open are expected to be stable in the short term but may exhibit some instability in the long run due to time dependant deterioration of the rock mass. In other cases where poor ground conditions may be encountered on the hanging wall and crown, unravelling of the rock mass is likely to continue to occur until a stable arch has been achieved before reaching surface and remains stable. In other cases, continued unravelling of the hanging wall and crown may continue to occur with failed material filling and choking the void before reaching surface and remain stable.

It is envisioned that instability due to mining of the underground stopes will only be restricted to the pit bottom where the stopes interact with the pit void. Surface disturbance influence from the underground mining activities is minimal. Any disturbance arising from underground mining will be restricted to the ore zone and thus within the current surface disturbance zone defined for the south pit void.

Prepared By:

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Senior Geotechnical Engineer-Technical & Studies (Aeris Resources).

8. SUPPORTING REFERENCES

ATC Williams (ATCW) (2020) Barbara Copper Project- Post Mine land Plan Input

Barbara Copper Project Progressive Rehabilitation and Closure Plan – 20 July 2022

Depart of Environment and Science (DES) (2019), 'Guideline- Progressive Rehabilitation and Closure Plans',

Department of Industry and Resources (DIR) (1997) 'Guideline- Safety Bund Walls around abandoned Open Pit Mines.

PSM, Mne Closure Geotechnical Study, Barbara Copper Project-20 November 2020

PSM, Scoping Level Underground Geotechnical Study- 28 August 2020

PSM, Barbara Copper Project Geotechnical Feasibility Study – 2014

PSM, Mine Closure Geotechnical Study, Barbara Copper Project, 2020

Resolve Mining Solutions, Barbara Copper Project Completion Geology Report- 28 May 2021

Permit

Environmental Protection Act 1994

Environmental authority EPML02840015

This environmental authority is issued by the administering authority under Chapter 5 of the Environmental Protection Act 1994.

Environmental authority number: EPML02840015

Environmental authority takes effect on 30 September 2022

Environmental authority holder(s)

Name(s)	Registered address
ROUND OAK MINERALS PTY LIMITED	Level 10, 120 Edward Street BRISBANE QLD 4000

Environmentally relevant activity and location details

Environmentally relevant activity/activities	Location(s)
Schedule 3 17: Mining copper ore Schedule 3 18: Mining lead, silver or zinc seperately or in any combination Ancillary 08 - Chemical Storage 3: Storing more than 500 cubic metres of chemicals of class C1 or C2 combustible liquids under AS 1940 or dangerous goods class 3 under subsection (1)(c) Ancillary 15 - Fuel burning Using fuel burning equipment that is capable of burning at least 500kg of fuel in an hour	ML90241

ABN 46 640 294 485

Queensland Government

Schedule 3 16: Mining gold ore Schedule 3 19: Mining metal ore, other than a metal ore mentioned in itms 11, 12, 14, 15, 16,17 or 18 Schedule 3 14: Mining iron ore Ancillary 63 - Sewage Treatment 1: Operating sewage treatment works, other than no-release works, with a total daily peak design capacity of (a-i) 21 to 100EP if treated effluent is discharged from the works to an infiltration trench or through an irrigation scheme Ancillary 33 - Crushing, milling, grinding or screening Crushing, grinding, milling or screening more than 5000t of material in a year	

Additional information for applicants

Environmentally relevant activities

The description of any environmentally relevant activity (ERA) for which an environmental authority (EA) is issued is a restatement of the ERA as defined by legislation at the time the EA is issued. Where there is any inconsistency between that description of an ERA and the conditions stated by an EA as to the scale, intensity or manner of carrying out an ERA, the conditions prevail to the extent of the inconsistency.

An EA authorises the carrying out of an ERA and does not authorise any environmental harm unless a condition stated by the EA specifically authorises environmental harm.

A person carrying out an ERA must also be a registered suitable operator under the *Environmental Protection Act 1994* (EP Act).

Contaminated land

It is a requirement of the EP Act that an owner or occupier of contaminated land give written notice to the administering authority if they become aware of the following:

- the happening of an event involving a hazardous contaminant on the contaminated land (notice must be given within 24 hours); or
- a change in the condition of the contaminated land (notice must be given within 24 hours); or
- a notifiable activity (as defined in Schedule 3) having been carried out, or is being carried out, on the contaminated land (notice must be given within 20 business days);
- that is causing, or is reasonably likely to cause, serious or material environmental harm.

For further information, including the form for giving written notice, refer to the Queensland Government website www.qld.gov.au, using the search term 'duty to notify'.

Take effect

Please note that, in accordance with section 200 of the EP Act, an EA has effect:

a) if the authority is for a prescribed ERA and it states that it takes effect on the day nominated by the holder of the authority in a written notice given to the administering authority-on the nominated day; or

b) if the authority states a day or an event for it to take effect-on the stated day or when the stated event happens; or

c) otherwise-on the day the authority is issued.

However, if the EA is authorising an activity that requires an additional authorisation (a relevant tenure for a resource activity, a development permit under the *Sustainable Planning Act 2009* or an SDA Approval under the *State Development and Public Works Organisation Act 1971*), this EA will not take effect until the additional authorisation has taken effect.

If this EA takes effect when the additional authorisation takes effect, you must provide the administering authority written notice within 5 business days of receiving notification of the related additional authorisation taking effect.

If you have incorrectly claimed that an additional authorisation is not required, carrying out the ERA without the additional authorisation is not legal and could result in your prosecution for providing false or misleading information or operating without a valid environmental authority.

	30 September 2022
Signature	Date

Rebecca McAuley
Department of Environment and Science
Delegate of the administering authority
Environmental Protection Act 1994
Date issued: 30 September 2022

Enquiries:
Minerals Business Centre
Department of Environment and Science
Phone: 07 4222 5352
Email: ESCairns@des.qld.gov.au

Obligations under the *Environmental Protection Act 1994*

In addition to the requirements found in the conditions of this environmental authority, the holder must also meet their obligations under the EP Act, and the regulations made under the EP Act. For example, the holder must comply with the following provisions of the Act:

- general environmental duty (section 319)
- duty to notify environmental harm (section 320-320G)
- offence of causing serious or material environmental harm (sections 437-439)
- offence of causing environmental nuisance (section 440)
- offence of depositing prescribed water contaminants in waters and related matters (section 440ZG)
- offence to place contaminant where environmental harm or nuisance may be caused (section 443)

Schedule A – General

A1 This environmental authority authorises environmental harm referred to in the conditions. Where there is no condition or this environmental authority is silent on a matter, the lack of a condition or silence does not authorise environmental harm.

A2 Contaminants with the potential to cause environmental harm must not be released directly or indirectly to the receiving environment, except as permitted under the conditions of this environmental authority.

A3 The environmental authority holder must ensure that the activity is carried out in accordance with *Table A1* and *Schedule J – Map 1 Location of authorised disturbance*.

Table A1 - Authorised disturbance ('Table A1')

Name of disturbance area	Maximum area of disturbance (ha)	Mining Lease	Purpose
Run-of-mine (ROM) pad	3.0	ML90241	Temporary storage, crushing and handling of ore.
North Pit	3.3	ML90241	Mining of ore and site water management. Note: The North pit is a regulated dam with minimum hydraulic performance criteria detailed in *Table H1* of this environmental authority.
South pit	10.2	ML90241	Mining of ore and site water management. Note: The North pit is a regulated dam with minimum hydraulic performance criteria detailed in *Table H1* of this environmental authority.
Abandonment bund	1.7	ML90241	
Waste rock dump (WRD)	23.4	ML90241	Storage and disposal of waste rock.
WRD dam	6.0	ML90241	Water management for stormwater runoff from the WRD area.
Diversion drain	1.4	ML90241	Water management to prevent stormwater runoff entering mine workings.
Access Road, Haul Roads and tracks	11.0	ML90241	Site access.
Light Infrastructure Area: including Administration buildings, Fuel storage, Power facility, sewage treatment, and Workshop area.	2.7	ML90241	Site administration, Fuel storage and power generation, Maintenance and storage.

A4 The holder of this environmental authority must:

a) Install all measures, plant and equipment necessary to ensure compliance with the conditions of this environmental authority;

b) Maintain such measures, plant and equipment in a proper and efficient condition;

c) Operate such measures, plant and equipment in a proper and efficient manner; and

d) Ensure all instruments and devices used for the measurement or monitoring of any parameter under any condition of this environmental authority are properly calibrated.

Monitoring

A5 Except where specified in another condition of this environmental authority, all monitoring data, records and reports required by this environmental authority or related to environmental management of the activities must be:

a) Carried out by an appropriately qualified person;

b) Kept for a period of not less than five years; and

c) Provided to the administering authority in the specified format within 10 business days of a request.

A6 The following information must be recorded in relation to all monitoring required under a condition of this environmental authority:

a) The date and time when the sample was taken;

b) The location where the sample was taken; and

c) Any other pertinent details of relevance to interpreting the sampling results (*i.e.* stream flow, wind conditions or any unusual observations such as odour or colouration).

Risk management

A7 The holder of this environmental authority must develop and implement a risk management system for mining activities which mirrors the content requirement of the Standard for Risk Management (ISO31000:2009), or the latest edition of an Australian standard for risk management, to the extent relevant to environmental management, by 5 October 2016.

Notification of emergencies, incidents and exceptions

A8 The holder of this environmental authority must notify the administering authority by written notification within 24 hours, after becoming aware of any emergency or incident which results in the release of contaminants not in accordance, or reasonably expected to be not in accordance with, the conditions of this environmental authority.

A9 Within 10 business days following the initial notification of an emergency or incident, or receipt of monitoring results, whichever is the latter, further written advice must be provided to the administering authority, including the following:

a) Results and interpretation of any samples taken and analysed;

b) Outcomes of actions taken at the time to prevent or minimise unlawful environmental harm; and

c) Proposed actions to prevent a recurrence of the emergency or incident.

Complaints

A10 The holder of this environmental authority must record all environmental complaints received about the mining activities including:

a) Name, address and contact number for of the complainant;

b) Time and date of complaint;

c) Reasons for the complaint;

d) Investigations undertaken;

e) Conclusions formed;

f) Actions taken to resolve the complaint;

g) Any abatement measures implemented; and

h) Person responsible for resolving the complaint.

A11 The holder of this environmental authority must, when requested by the administering authority, undertake relevant specified monitoring within a reasonable timeframe nominated or agreed to by the administering authority to investigate any complaint of environmental harm. The results of the investigation (including an analysis and interpretation of the monitoring results) and abatement measures, where implemented, must be provided to the administering authority within 10 business days of completion of the investigation, or no later than 10 business days after the end of the timeframe nominated by the administering authority to undertake the investigation.

Third-party reporting

A12 The holder of this environmental authority must:

a) Within one (1) year of the commencement of this environmental authority, obtain from an appropriately qualified person a report on compliance with the conditions of this environmental authority;

b) Obtain further such reports at regular intervals, not exceeding three (3) yearly intervals, from the completion of the report referred to above; and

c) Provide each report to the administering authority within 90 days of its completion.

A13 Where a condition of this environmental authority requires compliance with a standard, policy or guideline published externally to this environmental authority and the standard is amended or changed subsequent to the issue of this environmental authority, the holder of this environmental authority must:

a) Comply with the amended or changed standard, policy or guideline within two years of the amendment or change being made, unless a different period is specified in the amended standard or relevant legislation, or where the amendment or change relates specifically to regulated structures referred to in Schedule I, the time specified in that condition; and

b) Until compliance with the amended or changed standard, policy or guideline is achieved, continue to remain in compliance with the corresponding provision that was current immediately prior to the relevant amendment or change.

Exploration

A14 All exploration activities carried out on the mining lease must comply with each of the standard environmental conditions contained in the latest version of the *Eligibility criteria and standard conditions for exploration and mineral development projects.*

END OF CONDITIONS FOR SCHEDULE A

Schedule B – Air

B1 The activities must not cause an exceedance of the air quality objectives specified in *Table B1* beyond the boundaries of any mining lease/s listed on this environmental authority.

Table B1 - Air quality objectives ('Table B1')

Contaminant	Measurement period	Air Quality Objective
Dust Deposition		
Arsenic and its compounds as arsenic[3]	Annual average over the calendar year	Must not exceed background concentration[4]
Cadmium and its compounds as cadmium[3]		
Copper and its compounds as copper[3]		
Lead and its compounds as lead[3]		250 µg/m^2/day
Dust deposition (total insoluble matter)[1]		120 mg/m^2/day

[1] The dust deposition limit is calculated over a nominal month as per AS/NZS3580.10.1 of 2003 (or more recent editions) unless an appropriately qualified person recommends and justifies an alternative frequency.

[3] Metal analysis is to be carried out in accordance with a methodology, sufficient to produce representative results capable of comparison against the respective trigger values.

[4] The background concentration must be determined in accordance with condition B2 of this environmental authority and include sufficient background dust deposition monitoring locations that are not potentially impacted by the mining activities.

B2 Prior to commencing the mining activity, the environmental authority holder must ensure that an air quality monitoring program is developed and implemented by an appropriately qualified person that is capable of determining compliance with condition B1 of this environmental authority.

END OF CONDITIONS FOR SCHEDULE B

Schedule C - Waste management

C1 All waste generated as part of the mining activities must be disposed of in a lawful manner at an off-site facility, with the exception of:

a) Treated sewage effluent, which may only be released via sub-surface infiltration trench and must be undertaken in accordance with condition C2 of this environmental authority; and

b) Waste rock, which must be characterised, handled and disposed of in accordance with condition C3 of this environmental authority.

C2 The only contaminant permitted to be released to land is treated sewage effluent released in accordance with condition C1 (a) and the release limits specified in *Table C1.*

Table C1 - Contaminant release limits to land ('Table C1')

Contaminant	Unit	Release Limit	Limit Type	Frequency
5 day Biochemical oxygen demand (BOD)1	mg/L	20	Maximum	Monthly
Total suspended solids	mg/L	30	Maximum	Monthly
Nitrogen	mg/L	30	Maximum	Monthly
Phosphorus	mg/L	15	Maximum	Monthly
E-coli	Organisms/100ml	1000	Maximum	Monthly
pH	pH units	6.0-9.0	Range	Monthly

C3 All potentially acid forming waste rock must be:

(a) Identified and disposed of in a manner that minimises the potential generation and/or release of contaminants to the receiving environment;

(b) Where the characteristics of waste rock in regards to acid producing potential is uncertain, this material must be treated as potentially acid forming until demonstrated otherwise; and

(c) Details pertaining to meeting the requirements of this condition must be recorded and retained until this environmental authority is surrendered.

END OF CONDITIONS FOR SCHEDULE C

Schedule D – Noise

Noise limits

D1 The holder of this environmental authority must ensure that noise generated by the mining activities does not cause the criteria in *Table D1* to be exceeded at a sensitive place or commercial place.

Table D1 – Noise limits ('Table D1')

Sensitive place						
Noise level dB(A) measured as:	**Monday to Saturday**			**Sundays and public holidays**		
	7am to 6pm	**6pm to 10pm**	**10pm to 7am**	**9am to 6pm**	**6pm to 10pm**	**10pm to 9am**
$L_{Aeq, adj, 15 mins}$	CV = 50 AV = 5	CV = 45 AV = 5	CV = 40 AV = 0	CV = 45 AV = 5	CV = 40 AV = 5	CV = 35 AV = 0
$L_{A1, adj, 15 mins}$	CV = 55 AV = 10	CV = 50 AV = 10	CV = 45 AV = 5	CV = 50 AV = 10	CV = 45 AV = 10	CV = 40 AV = 5

Notes:

a) CV: Critical Value, AV: Adjustment Value
b) To calculate noise limits;
If bg ≤ (CV-AV): Noise limit = bg + AV
If (CV-AV) < bg ≤ CV: Noise limit = CV
If bg > CV: Noise limit = bg+0
c) In the event that measured bg (LA90,adj, 15 mins) is less than 30 dB(A), then 30 dB(A) can be substituted for the measured background level.
d) Bg = background noise level (LA90, adj, 15 mins) measured over 3 – 5 days at the nearest sensitive receptor.
e) If the project is unable to meet the noise limits as calculated above alternative limits may be calculated using the process outlined in the 'Planning for Noise Control' guideline.

Airblast overpressure nuisance

D2 The holder of this environmental authority must ensure that blasting does not cause the limits for peak particle velocity and air blast overpressure in *Table D2* to be exceeded at a sensitive place or commercial place.

Table D2 – Blasting noise limits ('Table D2')

Blasting noise limits	Sensitive or commercial blasting noise limits place limits	
	7am to 6pm	**6pm to 7am**
Airblast overpressure	115 dB (Linear) Peak for 9 out of 10 consecutive blasts initiated and not greater than 120 dB (Linear) Peak at any time	No blasting
Ground vibration peak particle velocity	5mm/second peak particle velocity for 9 out of 10 consecutive blasts and not greater than 10 mm/second peak particle velocity at any time	No blasting

Monitoring and reporting

D3 Noise monitoring and recording must include the following descriptor characteristics and matters:

a) $L_{AN,T}$ (where N equals the statistical levels of 1, 10 and 90 and T = 15 mins)

b) background noise LA90

c) the level and frequency of occurrence of impulsive or tonal noise and any adjustment and penalties to statistical levels

d) atmospheric conditions including temperature, relative humidity and wind speed and directions

e) effects due to any extraneous factors such as traffic noise

f) location, date and time of monitoring

g) if the complaint concerns low frequency noise, Max LpLIN,T and one third octave band measurements in dB(LIN) for centre frequencies in the 10 – 200 Hz range.

END OF CONDITIONS FOR SCHEDULE D

Schedule E – Water

Contaminant release

E1 Contaminants must not be released to receiving waters unless there are natural flows in the receiving water of at least twenty times the volume of the release.

E2 Contaminants may only be released to receiving waters from a location specified in *Table E1* and must not exceed any release limit specified in *Table E2*.

Table E1 – Authorised contaminant release points ('Table E1')

Release point	Location		Release source	Monitoring Point	Receiving waters description
	Easting (GDA94 – Zone 54)	Northing (GDA94 – Zone 54)			
RP01	379862	7742050	North Pit (Mine water dam)	Pit	Drainage of unnamed tributary
RP02	380153	7741260	South Pit	Pit	Drainage of unnamed tributary
RP03	380007	7741120	WRD Dam	Dam Spillway	Drainage of unnamed tributary

E3 Contaminated water released from a release point specified in *Table E1* must be monitored at the release point for all contaminants and at the frequency specified in *Table E2*.

Table E2 – Contaminant release limits ('Table E2)

Contaminant	Release limit[1, 2]	Monitoring frequency
pH (pH units)	6.0 or 20th percentile[3] of reference site[4] value, whichever is lower	- One sample must be taken within 2 hours of any release event commencing; and - For release events with duration of greater than twenty-four hours, samples must be taken daily for one week and once a week thereafter until the release event ceases.
	7.5 or 80th percentile[3] of reference site[4] value, whichever is higher	
EC (µs/cm)	1,500 or 20 times the 80th percentile[3] of reference site value[4], whichever is higher	
Turbidity (NTU)	20 x 80th percentile of reference site value[3]	
Sulfate	1,000 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Fluoride	2 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Arsenic	0.14 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Barium	20 x 80th percentile[3] of reference site[4] concentration	
Bismuth	20 x 80th percentile[3] of reference site[4] concentration	
Chromium	0.02 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Cobalt	0.056 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Copper	0.028 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Molybdenum	0.15 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Nickel	0.22 or 20 x 80th or percentile[3] of reference site[4] concentration, whichever is higher	

Selenium	0.22 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	
Uranium	0.4 or 20 x 80th percentile[3] of reference site[4] concentration, whichever is higher	

[1] All metals and metalloids must be measured as both 'total' (from analysis of an unfiltered sample) and 'dissolved' (from analysis of a field filtered sample).

[2] Measured and reported in mg/L unless specified otherwise.

[3] The relevant reference site is specified in *Table E3*.

[4] Site-specific trigger levels and water quality objectives for water quality (20th, 80th and 95th percentile of reference site concentration) must be calculated in accordance with QWQG (2009) and ANZECC (2000) methodology if sufficient monitoring data is available. The environmental authority holder must maintain a database documenting all relevant water quality monitoring data and calculation of percentiles adopted as water quality trigger levels and water quality objectives.

E4 The environmental authority holder must notify the administering authority within twenty-four hours of any contaminant release commencing or ceasing.

Surface waters

E5 The quality of receiving waters must be monitored at the locations specified in *Table E3,* for the contaminants and at the frequency specified in *Table E4.*

Table E3 - Receiving waters reference and compliance monitoring sites ('Table E3')

Monitoring sites	Monitoring site description and purpose	Location	
		Easting (GDA94 – Zone 54)	Northing (GDA94 – Zone 54)
Reference sites			
BASW09	Drainage feature outside and northeast of disturbance footprint catchment	377540	7738673
BASW05	Drainage feature southwest and outside of disturbance footprint catchment	380736	7742273
Compliance sites			
BASW01	Watercourse at Mining Lease west boundary	378513	7743286
BASW04	Watercourse downstream of North Pit	379491	7742440
BASW08	Drainage feature at the top of catchment (Mining Lease entry)	380776	7740396
BASW11	Drainage feature upstream of junction with watercourse	379884	7743040

Table E4 - Receiving waters trigger levels and quality objectives ('Table E4')

Contaminant	Water quality[1, 3]		Sediment quality[7, 4]		Monitoring frequency
	Trigger levels	Water quality objectives	Trigger levels[2]	Sediment quality objectives[2]	
pH (pH units)	6.0 (minimum)	5.0 (minimum)	Not applicable		- For water quality: a) At least daily during release events, the first sample must be taken within two hours of the release event commencing; and b) At least once every three months (if surface water is present). - For sediment quality, at least twice per year, once at the end of the wet season and once at the end of the dry season.
	7.5 (maximum)	9.0 (maximum)	Not applicable		
Electrical conductivity (µS/cm)	500 or 80th percentile[6] of reference site[5], whichever is higher	1,000 or 95th percentile[6] of reference site[5], whichever is lower	Not applicable		
Turbidity (NTU)	80th percentile[6] of reference site[5]	25 or 95th percentile[6] of reference site[5], whichever is lower	Not applicable		
Sulfate	80th percentile[6] of reference site[5]	1,000 or 95th percentile[6] of reference site[5], whichever is lower	Not applicable		
Fluoride	80th percentile[6] of reference site[5]	2 or 95th percentile[6] of reference site[5], whichever is lower	Not applicable		
Arsenic	0.007 or 80th percentile[6] of reference site[5], whichever is higher	0.5 (total) or 95th percentile[6] of reference site[5] (dissolved), whichever is lower	20 or two times the reference site[5] value, whichever is higher	70 or two times the reference site[5] value, whichever is lower	
Barium	80th percentile of reference site[5]	95th percentile[6] of reference site[5] (dissolved)	Two times the reference site[5] value	Three times the reference site[5] value	
Bismuth	80th percentile[6] of reference site[5]	95th percentile[6] of reference site[5] (dissolved)	Two times the reference site[5] value	Three times the reference site[5] value	
Cobalt	0.0028 or 80th percentile[6] of reference site[5], whichever is higher	1 (total) or 95th percentile[6] of reference site[5] (dissolved), whichever is lower	Two times the reference site[5] value	Three times the reference site[5] value	
Chromium	0.001 or 80th percentile[6] of reference site[5], whichever is higher	1 (total) or 95th percentile[6] of reference site[5] (dissolved), whichever is lower	80 or two times the reference site[5] value, whichever is higher	370 or two times the reference site[5] value, whichever is lower	
Copper	0.0014 or 80th percentile[6] of reference site[5], whichever is higher	1 or (total) or 95th percentile[6] of reference site[5] (dissolved), whichever is lower	65 or two times the reference site[5] value, whichever is higher	270 or two times the reference site[5] value, whichever is lower	
Molybdenum	0.034 or 80th percentile[6] of reference site[5], whichever is higher	0.15 (total) and 95th percentile[6] of reference site[5] (dissolved), whichever is lower	Two times the reference site[5] value	Three times the reference site[5] value	
Nickel	0.011 or 80th percentile[6] of reference site[5], whichever is higher	1 (total) or 95th percentile[6] of reference site[5] (dissolved), whichever is lower	21 or two times the reference site[5] value, whichever is higher	52 or two times the reference site[5] value, whichever is lower	
Selenium	0.011 or 80th percentile[6] of reference site[5], whichever is higher	0.02 (total) and 95th percentile[6] of reference site[5] (dissolved), whichever is lower	Two times the reference site[5] value	Three times the reference site[5] value	

Uranium	0.02 or 80th percentile[6] of reference site[5], whichever is higher	0.2 (total) or 95th percentile[6] of reference site[5] (dissolved), whichever is lower	Two times the reference site[5] value, whichever is higher	Three times the reference site[5] value, whichever is lower
Major cations	For interpretation only		Not applicable	
Major anions	For interpretation only		Not applicable	
Total hardness	For interpretation only		Not applicable	
Total organic carbon	Not applicable		For interpretation only	

[1] For water quality, all metals and metalloids must be measured as both 'total' (from analysis of an unfiltered sample) and 'dissolved' (from analysis of a field filtered sample). All trigger levels are based on dissolved metal concentrations; for water quality objectives, the relevant method is specified in brackets for each contaminant where applicable.

[2] Analysis for metals/metalloids concentrations in sediment must be conducted on the <2mm fraction of the sample and measured as a dilute acid extractable concentration in a manner consistent with the *Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines*, CSIRO (May 2013).

[3] Measured and reported in mg/L unless specified otherwise.

[4] Measured and reported in mg/kg dry weight.

[5] The relevant reference site is specified in *Table E3*.

[6] Site-specific trigger levels and water quality objectives for water quality (80th and 95th percentile of reference site concentration) must be calculated in accordance with QWQG (2009) and ANZECC (2000) methodology if sufficient monitoring data is available. The environmental authority holder must maintain a database documenting all relevant water quality monitoring data and calculation of percentiles adopted as water quality trigger levels and water quality objectives.

[7] For sediment quality, compliance site monitoring results are to be compared:

a) Directly to the guideline values from the *Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines*, CSIRO (May 2013), if insufficient reference site monitoring data is available; or

b) The relevant reference site monitoring data, which must be normalised to account for any difference in particle size distribution (*i.e.* conduct a fractionated sediment analysis based on comparing the metals concentrations of the <63µm sediment fraction with the >63µm to <2mm sediment fraction).

E6 The contaminant concentrations measured in receiving waters including any compliance site specified in *Table E3* must not exceed a water quality objective or sediment quality objective specified in *Table E4*.

E7 If a contaminant concentration measured at a compliance site specified in *Table E3* exceeds any trigger level specified in *Table E4*, the environmental authority holder must compare this result to the applicable reference site; and

a) If the contaminant concentration measured at the compliance site is equal to or less than the contaminant concentration measured at the applicable reference site, no further action is required for this event; or

b) If the contaminant concentration measured at the compliance site is greater than the contaminant concentration measured at the applicable reference site:

i. Notify the administering authority within twenty-four hours of becoming aware of the trigger level exceedance; and

ii. Undertake further sampling of potentially impacted receiving waters for all contaminants specified in *Table E4*; and

iii. Complete an investigation into the potential for environmental harm to occur in accordance with ANZECC (2000) methodology, within three months of identifying this exceedance or the alternative timeframe specified by the administering authority; and

iv. Within one week of completing the investigation, provide a written report to the administering authority detailing all pertinent aspects of the investigation (such as objectives, applied methodology, investigation outcomes, assumptions relied upon and justification for any assertions made) and any actions undertaken and/or proposed to prevent or minimise environmental harm.

Note: Where a contaminant trigger level exceedance has occurred and is under investigation in accordance with condition E7, no further reporting is required for subsequent exceedance events of that contaminant during the course of the investigation.

Groundwater

E8 The holder of this environmental authority must not release contaminants to groundwater.

E9 The extraction of groundwater must not cause environmental harm to any groundwater dependent ecosystems.

E10 Groundwater quality and levels must be monitored:

a) at the locations specified in *Table E5 (Groundwater monitoring bore locations); and*

b) at the frequencies specified in *Table E5 (Groundwater monitoring bore locations); and*

c) for the quality characteristics identified in *Table E6 (Groundwater Quality Objectives)*.

Table E5 - Groundwater monitoring bore locations ('Table E5')

Monitoring Point	Location (GDA94 – Zone 54)		Surface RL (m)[1]	Total Depth (mbgl[2])	Screened interval (mbgl)	Monitoring Frequency	
	Easting	Northing				Standing water level	Groundwater quality
Compliance bores							
BAWB05	380948	7740252	377.32	102	35-102	Monthly	3 monthly
Bore E	380022	7738827	334.23	85	28-83		
BAWB01	380432	7742097	352.68	104	20-101	Monthly	3 monthly
BAWB02	379480	7742395	310.59	104	96-102		
BAWB03	379834	7741692	329.50	104	50-102		
BAWB04	380043	7742054	329.14	100	94-100		
BAWB07	379849	7741936	328.74	127	18-146		
BAWBR1	380292	7740939	334.49	14	5-6		
BAWBR2	379912	7741279	322.98	14	2-3		
BAWBR3	379991	7741485	326.02	14	3-4		
Seepage monitoring bores							
Seepage Bore 1a	380084	7741046	336.819	6	1-5	Monthly	3 monthly
Seepage Bore 1b	380084	7741048	336.487	16	5-15		

Seepage Bore 2a	380025	7741117	331.218	6	1-5		
Seepage Bore 2b	380023	7741116	331.342	16	5-15		
Seepage Bore 3a	379985	7741133	332.189	6	1-5		
Seepage Bore 3b	379986	7741135	331.962	16	5-15		
Seepage Bore 4a	380711	7740798	355.061	6	1-5		
Seepage Bore 4b	380711	7740800	355.111	16	5-15		

Notes:
1. RL must be measured to the nearest 5cm from the top of the bore casing.
2. Metres below ground level

Table E6 – Groundwater quality objectives ('Table E6')

Contaminant[1]	Units	Limit type	Bore(s)	Limit A[3]	Limit B[4]
pH	pH	Range	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	7.0-8.5
Electrical conductivity (EC)	µS/cm	Maximum	BAWB01, BAWB02, BAWB07	1260	1365
			BAWB03, BAWB04, BAWB05, BAWBR1, BAWBR2, BAWBR3, Bore E	950	1010
Sulfate	mg/L	Maximum	BAWB01, BAWB03, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	65	73
			BAWB02	190	200
			BAWB04	16	21
Fluoride	mg/L	Maximum	BAWB02, BAWB03, BAWB04, BAWB05, BAWBR1, BAWBR2, BAWBR3	0.8	0.9
			BAWB01, BAWB07, Bore E	1.6	1.7
Arsenic	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.013[2]
Barium	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	0.140	0.170
			BAWB04	0.400	0.420
			BAWB05	0.2	0.3
Bismuth	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.0007[5]
Cobalt	mg/L	Maximum	BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.0014[5]
			BAWB01	-	0.0028

Chromium	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.001[2]
Copper	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	0.003	0.008
Molybdenum	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.034[2]
Nickel	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.011[2]
Selenium	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	-	0.011[2]
Uranium	mg/L	Maximum	BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	0.006	0.007
Major cations			BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	For interpretation only	
Major anions			BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	For interpretation only	
Total Hardness			BAWB01, BAWB02, BAWB03, BAWB04, BAWB05, BAWB07, BAWBR1, BAWBR2, BAWBR3, Bore E	For interpretation only	

Notes:

1. All metals and metalloids must be measured as 'dissolved' (from analysis of a field filtered sample)
2. Contaminant limit based on ANZECC (2000), Table 3.4.1, 95% aquatic species protection level for slightly to moderately disturbed ecosystem.
3. Derived from site-specific values, based off dissolved concentration of metals (80th percentiles).
4. Derived from site-specific values, based off dissolved concentration of metals (95th percentiles).
5. Based off ANZECC (2000) low reliability metals and metalloids, Section 8.3.7.1

E11 Groundwater measured from any compliance bore specified in **Table E5** must not exceed the corresponding Limit A specified in **Table E6** on any five consecutive sampling occasions**.**

E12 Groundwater measured from any compliance bore specified in **Table E5** must not exceed the corresponding Limit B specified in **Table E6** on any three consecutive sampling occasions**.**

E13 If groundwater measured from any compliance bore specified in **Table E5** exceeds the corresponding Limit B specified in **Table E6** on any one sampling occasion the environmental authority holder must resample the groundwater within the compliance bore for all exceeding parameters within ten business days of receipt of results.

Bore construction and maintenance and decommissioning

E14 The construction, maintenance and decommissioning of groundwater monitoring bores must be undertaken in a manner that:

a) prevents contaminants entering the groundwater; and

b) ensures the integrity of the bores to obtain representative groundwater samples from the target aquifer; and

c) maintains the hydrogeological environment within the aquifer.

E15 A bore drill log must be kept for each reference, compliance and observation groundwater monitoring bore which includes:

a) bore identification reference and geographic coordinate location;

b) specific construction information including but not limited to depth of bore, depth and length of casing, depth and length of screening and bore sealing details;

c) standing groundwater level and water quality parameters including physical parameters and results of laboratory analysis for the possible trigger parameters;

d) lithological data and stratigraphic interpretation by an appropriately qualified person to identify important features associated with groundwater monitoring; and

e) target aquifer formation of the bore.

Groundwater Management Program

E16 A Groundwater Management Program must be developed, documented and implemented by appropriately qualified persons.

E17 The Groundwater Management Program required by Condition E16 must:

a) identify potential sources of contamination to groundwater from the activity; and

b) ensure that all potential groundwater impacts due to the activity are identified, monitored and mitigated; and

c) document sampling and monitoring methodology; and

d) ensure that adequate groundwater monitoring and data analysis is undertaken to achieve the following objectives:

i. detect any impacts to groundwater levels due to the activity;

ii. detect any impacts to groundwater quality due to the activity;

iii. determine compliance with condition E11 and E12; and

iv. determine trends in groundwater quality; and

e) include an appropriate quality assurance and quality control program; and

f) include a conceptual groundwater model; and

g) include a review process to identify improvements to the program that includes addresses any comments provided by the administering authority.

E18 The Groundwater Management Program must be reviewed on an annual basis by an appropriately qualified person to determine if it continues to meet the requirements stated in condition E17.

E19 Monitoring and sampling must be carried out in accordance with written procedures and must address the requirements of the latest version of the following documents unless otherwise approved by the administering authority:

a) for waters and aquatic environments, the Queensland Government's Monitoring and Sampling Manual – Environmental Protection (Water) Policy;

b) for groundwater, Groundwater Sampling and Analysis – A Field Guide (2009:27 GeoCat#6890.1) and Australian Standard AS/NZS 5667.11:1998 Water Quality – Sampling – Guidance on sampling of groundwaters;

c) for subterranean aquatic fauna, the Guideline for the Environmental Assessment of Subterranean Aquatic Fauna.

Receiving environment monitoring program

E20 The environmental authority holder must develop, document and implement a Receiving Environment Monitoring Program (REMP) to monitor, identify and describe any adverse impacts to environmental values of receiving waters by 5 October 2016. The REMP must include at minimum:

a) Monitoring the effects of the mining activities on the receiving environment periodically under natural flow conditions and while contaminants are being released (if applicable);

b) Encompass the waters of Leichardt River and connected or surrounding waterways within 10km downstream of the mining activities;

c) Identification of all environmental values of receiving waters;

d) An assessment of background reference water quality, the condition of downstream water quality compared against water quality objectives, and the suitability of current environmental authority conditions to protect downstream environmental values; and

e) Application of biological monitoring if required to determine whether the mining activities are being conducted in a manner that enhances or protects the environmental values of receiving waters;

E21 A report outlining the findings of the REMP that addresses all requirements specified under condition E20, including all monitoring results and any interpretations or assumptions relied upon, must be completed annually.

Water management

E22 A Water Management Plan must be developed by an appropriately qualified person, documented and implemented for all stages of the mining activity.

Erosion and sediment control

E23 An Erosion and Sediment Control Plan must be developed, documented and implemented by an appropriately qualified person for all stages of the mining activities to minimise erosion and the release of sediment to receiving waters.

END OF CONDITIONS FOR SCHEDULE E

Schedule F – Biodiversity

Biodiversity offsets

F1 Impacts to prescribed environmental matters, other than by low impact activities, are only authorised to occur if the impacts do not exceed the maximum extent of impact specified for that prescribed environmental matter specified in *Table F1 – Authorised impacts to prescribed environmental matters*.

F2 An environmental offset made under the *Environmental Offsets Act 2014* must be delivered for each impact specified in *Table F1 – Authorised impacts to prescribed environmental matters* as requiring an environmental offset.

F3 A notice of election must be provided to the administering authority no less than three months before the proposed commencement of the prescribed activities.

Table F1 – Authorised impacts to prescribed environmental matters ('Table F1')

Prescribed environmental matter	Location of prescribed environmental matter (GDA94 – Zone 54)	Maximum extent of impact	Environmental offset required
Protected wildlife habitat			
Habitat for an animal that is vulnerable wildlife – Purple-necked rock wallaby *Petrogale purpuriecollis*	379910 E, 7740390 N	5 ha	Yes

F4 Prior to the commencement of any impacts to a prescribed environmental matter for which an offset is required by condition F2, the authority holder must enter into an Agreed Delivery Arrangement with the administering authority

END OF CONDITIONS FOR SCHEDULE F

Schedule G – Land and Rehabilitation

G1 The environmental authority holder must rehabilitate all significantly disturbed land caused by the mining activities in a manner that ensures rehabilitated areas achieve the following rehabilitation objectives:

a) Safe for humans and wildlife;

b) Non-polluting;

c) Stable;

d) Able to sustain a post-mining land-use agreed to by the administering authority and any underlying landholders;

e) Revegetated with species endemic to the area with no declared pest species; and

f) Compliant with all conditions of this environmental authority.

G2 Two years from commencement of mining[1] the environmental authority holder must develop and document a Post Mine Land-use Plan ('PMLUP') that describes how the rehabilitation objectives in condition G1 will be achieved. The PMLUP must at minimum include:

a) Schematic representation of the proposed final land form inclusive of site drainage features;

b) Details of proposed slope design and erosion and sediment controls;

c) Proposed cover designs for encapsulation of waste material, including performance criteria;

d) Proposed re-vegetation methods inclusive of plant species selection, propagation methods and establishment of suitable plant growth medium (*i.e.* top soil);

e) Materials balance for all rehabilitation requirements including available top soil and material suitable for encapsulating waste in accordance with the proposed encapsulation methodology;

f) Geotechnical, geochemical and hydrological studies necessary to demonstrate likely success of proposed rehabilitation methodology to achieve the required rehabilitation outcomes;

g) An investigation of proposed residual voids including potential for generation/mobilisation of contaminants, potential pathways for release of contaminants to waters (including groundwater) and a long-term void water balance model; and

h) A rehabilitation monitoring program sufficient to identify if required rehabilitation outcomes have been achieved.

Note: Commencement of mining is taken to be the date that extraction of material from the pit commences.

G3 Rehabilitation must commence progressively in accordance with the Plan of Operations.

G4 Residual voids (including open pits and underground workings) must not cause any serious or material environmental harm, other than the environmental harm constituted by the existence of the residual void itself, subject to any other condition within this environmental authority.

G5 All explosives, flammable or corrosive substances, hazardous chemicals, toxic substances, gases and dangerous goods must be stored and handled in accordance with:

a) The current Australian Standard where applicable; or

b) Where no relevant Australian Standard exists, store such materials within an on-site containment system sufficient to prevent release to the receiving environment.

END OF CONDITIONS FOR SCHEDULE G

Schedule H – Regulated Dams

H1 The consequence category of any structure must be assessed by a suitably qualified and experienced person in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* at the following times:

a) prior to the design and construction of the structure, if it is not an existing structure; or

b) if it is an existing structure, prior to the adoption of this schedule; or

c) prior to any change in its purpose or the nature of its stored contents.

H2 A consequence assessment report and certification must be prepared for each structure assessed and the report may include a consequence assessment for more than one structure.

H3 Certification must be provided by the suitably qualified and experienced person who undertook the assessment, in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

Design and construction of a regulated structure

H4 Conditions H5 to H9 inclusive do not apply to existing structures.

H5 All regulated structures must be designed by, and constructed[5] under the supervision of, a suitably qualified and experienced person in accordance with the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

H6 Construction of a regulated structure is prohibited unless the holder has submitted a consequence category assessment report and certification to the administering authority has been certified by a suitably qualified and experienced person for the design and design plan and the associated operating procedures in compliance with the relevant condition of this authority.

H7 Certification must be provided by the suitably qualified and experienced person who oversees the preparation of the design plan in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*, and must be recorded in the Regulated Dams/Levees register.

H8 Regulated structures must:

a) be designed and constructed in accordance with and conform to the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635);*

b) be designed and constructed with due consideration given to ensuring that the design integrity would not be compromised on account of:

i) floodwaters from entering the regulated dam from any watercourse or drainage line; and

ii) possible erosion by floodwaters arising from any watercourse or drainage line.

H9 Certification by the suitably qualified and experienced person who supervises the construction must be submitted to the administering authority on the completion of construction of the regulated structure, and state that:

a) the 'as constructed' drawings and specifications meet the original intent of the design plan for that regulated structure;

b) construction of the regulated structure is in accordance with the design plan.

Operation of a regulated structure

H10 Operation of a regulated structure**,** except for an existing structure, is prohibited unless:

a) the holder has submitted to the administering authority:

i) one paper copy and one electronic copy of the design plan and certification of the 'design plan' in accordance with condition H8, and

ii) a set of 'as constructed' drawings and specifications, and

iii) certification of those 'as constructed drawings and specifications' in accordance with condition H9, and

iv) where the regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, a copy of the certified system design plan.

v) the requirements of this authority relating to the construction of the regulated structure have been met;

vi) the holder has entered the details required under this authority, into a Register of Regulated Dams; and

vii) there is a current operational plan for the regulated structures.

H11 Each regulated structure must be maintained and operated, for the duration of its operational life until decommissioned and rehabilitated, in a manner that is consistent with the current operational plan and, if applicable, the current design plan and associated certified 'as constructed' drawings.

Mandatory reporting level

H12 Conditions H14 to H17 inclusive only apply to Regulated Structures which have not been certified as low consequence category for 'failure to contain – overtopping'.

H13 The Mandatory Reporting Level (the MRL) specified in *Table H1* must be marked on a regulated dam in such a way that during routine inspections of that dam, it is clearly observable.

H14 The holder must, as soon as practical and within forty-eight (48) hours of becoming aware, notify the administering authority when the level of the contents of a regulated dam reaches the MRL.

H15 The holder must, immediately on becoming aware that the MRL has been reached, act to prevent the occurrence of any unauthorised discharge from the regulated dam.

H16 The holder must record any changes to the MRL in the Register of Regulated Structures.

Design storage allowance

H17 The holder must assess the performance of each regulated dam or linked containment system over the preceding November to May period based on actual observations of the available storage in each regulated dam or linked containment system taken prior to 1 July of each year.

H18 By 1 November of each year, storage capacity must be available in each regulated dam (or network of linked containment systems with a shared DSA volume), to meet the Design Storage Allowance (DSA) volume for the dam (or network of linked containment systems), as specified in *Table H1*.

H19 The holder must, as soon as possible and within forty-eight (48) hours of becoming aware that the regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on 1 November of any year, notify the administering authority.

H20 The holder must, immediately on becoming aware that a regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on 1 November of any year, act to prevent the occurrence of any unauthorised discharge from the regulated dam or linked containment systems.

Annual inspection report

H21 Each regulated structure must be inspected each calendar year by a suitably qualified and experienced person.

H22 At each annual inspection, the condition and adequacy of all components of the regulated structure must be assessed and a suitably qualified and experienced person must prepare an annual inspection report containing details of the assessment and include recommended actions to ensure the integrity of the regulated structure.

H23 The suitably qualified and experienced person who prepared the annual inspection report must certify the report in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

H24 The holder must:

a) Within 20 business days of receipt of the annual inspection report, provide to the administering authority:

   i) The recommendations section of the annual inspection report; and

   ii) If applicable, any actions being taken in response to those recommendations; and

b) If, following receipt of the recommendations and (if applicable) actions, the administering authority requests a full copy of the annual inspection report from the holder, provide this to the administering authority within 10 business days[6] of receipt of the request.

Transfer arrangements

H25 The holder must provide a copy of any reports, documentation and certifications prepared under this authority, including but not limited to any Register of Regulated Structures, consequence assessment, design plan and other supporting documentation, to a new holder on transfer of this authority.

Decommissioning and rehabilitation

H26 Dams must not be abandoned but be either:

a) decommissioned and rehabilitated to achieve compliance with condition H27; or

b) be left in-situ for a beneficial use(s) provided that:

i) it no longer contains contaminants that will migrate into the environment; and

ii) it contains water of a quality that is demonstrated to be suitable for its intended beneficial use(s); and

iii) the administering authority, the holder of the environmental authority and the landholder agree in writing that the dam will be used by the landholder following the cessation of the environmentally relevant activity(ies).

H27 After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria:

a) the landform is safe for humans and fauna;

b) the landform is stable with no subsidence or significant erosion gullies for at least three (3) years;

c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated;

d) not allowing for acid mine drainage; or

e) there is no ongoing contamination to waters (including groundwater);

f) rehabilitation is undertaken in a manner such that any actual or potential acid sulfate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the Instructions for the treatment and management of acid sulfate soils (2001);

g) all significantly disturbed land is reinstated to the pre-disturbed soil suitability class;

h) for land that is not being cultivated by the landholder:

i. groundcover, that is not a declared pest species is established and self-sustaining

ii. vegetation of similar species richness and species diversity to pre-selected analogue sites is established and suited to the post mine land use, and

iii. the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the petroleum activity(ies).

i) for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within 3 months of petroleum activities being completed.

Register of Regulated Dams

H30 A Register of Regulated Dams must be established and maintained by the holder for each regulated dam.

H31 The holder must provisionally enter the required information in the Register of Regulated Dams when a design plan for a regulated dam is submitted to the administering authority.

H32 The holder must make a final entry of the required information in the Register of Regulated Dams once compliance with condition H10 and H11 has been achieved.

H33 The holder must ensure that the information contained in the Register of Regulated Dams is current and complete on any given day.

H34 All entries in the Register of Regulated Dams must be approved by the chief executive officer for the holder of this authority, or their delegate, as being accurate and correct.

H35 The holder must, at the same time as providing the annual return, supply to the administering authority a copy of the records contained in the Register of Regulated Dams, in the electronic format required by the administering authority.

Hydraulic performance of regulated dams

H36 All regulated dams must meet the hydraulic performance criteria specified in *Table H1*.

Table H1 – Hydraulic performance criteria ('Table H1')

Name of dam	Consequence category	Hydraulic performance criteria		
		Spillway capacity	Design Storage Allowance	Mandatory Reporting Level
North Pit	Significant	1:100 to 1:1000 AEP 72 hour duration storm event	1:20 AEP 2 month wet season	1:10 AEP 72 hour duration storm event
South Pit	Significant	1:100 to 1:1000 AEP72 hour duration storm event	1:20 AEP 2 month wet season	1:10 AEP 72 hour duration storm event
WRD Dam	Significant	1:100 to 1:1000 AEP72 hour duration storm event	1:20 AEP 2 month wet season	1:10 AEP 72 hour duration storm event

END OF CONDITIONS FOR SCHEDULE H

Schedule I – Definitions

Definitions
Key terms and/or phrases used in this document are defined in this section and bolded throughout this document. Applicants should note that where a term is not defined, the definition in the *Environmental Protection Act 1994*, its regulations or environmental protection policies must be used. If a word remains undefined it has its ordinary meaning.

Acid rock drainage means any contaminated discharge emanating from a mining activity formed through a series of chemical and biological reactions, when geological strata is disturbed and exposed to oxygen and moisture.

Administering Authority is the agency that administers the environmental authority provisions under the *Environmental Protection Act 1994*.

Affected person is someone whose drinking water can potentially be impacted as a result of discharges from a dam or their life can be put at risk due to dwellings or workplaces being in the path of a dam break flood.

Airblast overpressure means energy transmitted from the blast site within the atmosphere in the form of pressure waves. The maximum excess pressure in this wave, above ambient pressure is the peak airblast overpressure measured in decibels linear (dBL).

Annual inspection report means an assessment prepared by a suitably qualified and experienced person containing details of the assessment against the most recent consequence assessment report and design plan (or system design plan);

(a) against recommendations contained in previous annual inspections reports;

(b) against recognised dam safety deficiency indicators;

(c) for changes in circumstances potentially leading to a change in consequence category;

(d) for conformance with the conditions of this authority;

(e) for conformance with the ‘as constructed’ drawings;

(f) for the adequacy of the available storage in each regulated dam, based on an actual observation or observations taken after 31 May each year but prior to 1 November of that year, of accumulated sediment, state of the containment barrier and the level of liquids in the dam (or network of linked containment systems);

(g) for evidence of conformance with the current operational plan.

Annual exceedance probability or AEP the probability that at least one event in excess of a particular magnitude will occur in any given year.

Appropriately qualified person means a person who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relating to the subject matter using the relevant protocols, standards, methods or literature.

Assessed or **assessment** by a suitably qualified and experienced person in relation to a consequence assessment of a dam, means that a statutory declaration has been made by that person and, when taken

together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit of the assessment:

(a) exactly what has been assessed and the precise nature of that determination;

(b) the relevant legislative, regulatory and technical criteria on which the assessment has been based;

(c) the relevant data and facts on which the assessment has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and

(d) the reasoning on which the assessment has been based using the relevant data and facts, and the relevant criteria.

Associated works in relation to a dam, means:

(a) operations of any kind and all things constructed, erected or installed for that dam; and

(b) any land used for those operations.

Authority means an environmental authority or a development approval.

Background, with reference to the water schedule means the average of samples taken prior to the commencement of mining from the same waterway that the current sample has been taken.

Blasting means the use of explosive materials to fracture:

(a) rock, coal and other minerals for later recovery, or

(b) structural components or other items to facilitate removal from a site or for reuse.

Certification means assessment and approval must be undertaken by a suitably qualified and experienced person in relation to any assessment or documentation required by this Manual, including design plans, 'as constructed' drawings and specifications, construction, operation or an annual report regarding regulated structures, undertaken in accordance with the Board of Professional Engineers of Queensland Policy Certification by RPEQs (ID: 1.4 (2A)).

Certification, Certifying or **Certified** by an appropriately qualified and experienced person in relation to a design plan or an annual report regarding dams/structures, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit at any time:

a) exactly what is being certified and the precise nature of that certification

b) the relevant legislative, regulatory and technical criteria on which the certification has been based

c) the relevant data and facts on which the certification has been based, the source of that material, and the efforts made to obtain all relevant data and facts

d) the reasoning on which the certification has been based using the relevant data and facts, and the relevant criteria.

Chemical means:

a) an agricultural chemical product or veterinary chemical product within the meaning of the Agricultural and *Veterinary Chemicals Code Act 1994* (Commonwealth), or

b) a dangerous good under the Australian Code for the Transport of Dangerous Goods by Road and Rail approved by the Australian Transport Council, or

c) a lead hazardous substance within the meaning of the Workplace Health and Safety Regulation 1997, or

d) a drug or poison in the Standard for the Uniform Scheduling of Drugs and Poisons prepared by the Australian Health Ministers' Advisory Council and published by the Commonwealth, or

e) any substance used as, or intended for use as:

   i. a pesticide, insecticide, fungicide, herbicide, rodenticide, nematocide, miticide, fumigant or related product, or

   ii. a surface active agent, including, for example, soap or related detergent, or

   iii. a paint solvent, pigment, dye, printing ink, industrial polish, adhesive, sealant, food additive, bleach, sanitiser, disinfectant, or biocide, or

   iv. a fertiliser for agricultural, horticultural or garden use, or

   v. a substance used for, or intended for use for mineral processing or treatment of metal, pulp and paper, textile, timber, water or wastewater, or

   vi. manufacture of plastic or synthetic rubber.

Commercial place means a workplace used as an office or for business or commercial purposes, which is not part of the mining activity and does not include employees' accommodation or public roads.

Construction or constructed in relation to a regulated structure includes building a new regulated structure and lifting or otherwise modifying an existing regulated structure, but does not include investigations and testing necessary for the purpose of preparing a design plan.

Coal seam gas water means groundwater that is necessarily or unavoidably brought to the surface in the process of coal seam gas exploration or production.

Coal seam gas water concentrate means the concentrated saline water waste stream from a water treatment process that does not exceed a total dissolved solid concentration of 40 000 mg/L.

Coal seam gas evaporation dam is defined as a impoundment, enclosure or structure that is designed to be used to hold coal seam gas water for evaporation.

Consequence in relation to a structure as defined, means the potential for environmental harm resulting from the collapse or failure of the structure to perform its primary purpose of containing, diverting or controlling flowable substances.

Consequence category means a category, either low, significant or high, into which a dam is assessed as a result of the application of tables and other criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

Dam means a land-based structure or a void that contains, diverts or controls flowable substances, and includes any substances that are thereby contained, diverted or controlled by that land-based structure or void and associated works.

Dam crest volume means the volume of material (liquids and/or solids) that could be within the walls of a dam at any time when the upper level of that material is at the crest level of that dam. That is, the instantaneous maximum volume within the walls, without regard to flows entering or leaving (for example, via spillway).

Design plan is a document that contains the design, operation, monitoring and revegetation criteria of a watercourse diversion that addresses the outcomes stated in conditions on the environmental authority relating to the diversion. The document should include, but not be limited to:

a) required information under a functional design
b) the location, function and description of geomorphic and riparian vegetation features within the proposed watercourse diversion
c) results from hydrologic, hydraulic and sediment transportation modelling used in the design of the diversion
d) a revegetation and vegetation management plan (a revegetation plan) for the diversion
e) engineering drawings depicting the physical attributes and dimensions of the diversion
f) (if relevant) the staged development of a permanent watercourse diversion including the proposed use of temporary watercourse diversions with identified lifespans
g) all investigation and other reports relied on by the design
h) plans and specifications sufficient to complete construction and revegetation in accordance with the design.

Design storage allowance or DSA means an available volume, estimated in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority, must be provided in a dam as at 1 November each year in order to prevent a discharge from that dam to an annual exceedance probability (AEP) specified in that Manual.

Designer for the purposes of a regulated dam, means the certifier of the design plan for the regulated dam.

Development approval means a development approval under the *Integrated Planning Act 1997* or the *Sustainable Planning Act 2009* in relation to a matter that involves an environmentally relevant activity under the *Environmental Protection Act 1994*.

Disturbance of land includes:

a) compacting, removing, covering, exposing or stockpiling of earth
b) removal or destruction of vegetation or topsoil or both to an extent where the land has been made susceptible to erosion
c) carrying out mining within a watercourse, waterway, wetland or lake
d) the submersion of areas by tailings or hazardous contaminant storage and dam/structure walls
e) temporary infrastructure, including any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc) which is to be removed after the mining activity has ceased
f) releasing of contaminants into the soil, or underlying geological strata.

However, the following areas are not included when calculating areas of ‘disturbance’:

a) areas off lease (e.g. roads or tracks which provide access to the mining lease)
b) areas previously disturbed which have achieved the rehabilitation outcomes

c) by agreement with the administering authority, areas previously disturbed which have not achieved the rehabilitation objective(s) due to circumstances beyond the control of the mine operator (such as climatic conditions)

d) areas under permanent infrastructure. Permanent infrastructure includes any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc) which is to be left by agreement with the landowner

e) disturbance that pre-existed the grant of the tenure.

EC means electrical conductivity.

Effluent treated waste water released from sewage treatment plants.

Emergency action plan means documentation forming part of the operational plan held by the holder or a nominated responsible officer, that identifies emergency conditions that sets out procedures and actions that will be followed and taken by the dam owner and operating personnel in the event of an emergency. The actions are to minimise the risk and consequences of failure, and ensure timely warning to downstream communities and the implementation of protection measures. The plan must require dam owners to annually update contact.

Equilibrium: A state where 'balance' is achieved despite changing variables.

Existing structure means a structure that was in existence prior to the adoption of this schedule of conditions under the authority.

Extreme Storm Storage – means a storm storage allowance determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority

Flare pit means containment area where any hydrocarbon that is discovered in an over-pressured reservoir during a drilling operation is diverted to, and combusted. The flare pit is only used during the drilling and work over process on a petroleum well.

Flowable substance means matter or a mixture of materials which can flow under any conditions potentially affecting that substance. Constituents of a flowable substance can include water, other liquids fluids or solids, or a mixture that includes water and any other liquids fluids or solids either in solution or suspension.
Functional design is a document that contains 'conceptual' information about the design, operation and revegetation criteria of a watercourse diversion that addresses the outcomes stated in the conditions on the environmental authority relating to the diversion. The document should include, but not be limited to:

a) geomorphic and vegetation assessment of the existing watercourse

b) hydrologic conditions of the existing watercourse

c) the proposed watercourse diversion route

d) results from hydrologic, hydraulic and sediment transportation modelling used in the design of the diversion.

Functionality: the purpose that something is designed or expected to fulfil.

Holder means:

a) where this document is an environmental authority, any person who is the holder of, or is acting under, that environmental authority; or

b) where this document is a development approval, any person who is the registered operator for that development approval.

Hazard category means a category, either low significant or high, into which a dam is assessed as a result of the application of tables and other criteria in 'Manual for Assessing Hazard Categories and Hydraulic Performance of Dams'.

Holder, for a mining tenement, means a holder of the tenement under the *Mineral Resources Act 1989*, and the holder of the associated environmental authority under the *Environmental Protection Act 1994.*

Hydraulic performance means the capacity of a regulated dam to contain or safely pass flowable substances based on the design criteria specified for the relevant consequence category in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

Infrastructure means water storage dams, levees,, roads and tracks, buildings and other structures built for the purpose of the mining activity.

Land in the 'land schedule' of this document means land excluding waters and the atmosphere, that is, the term has a different meaning from the term as defined in the *Environmental Protection Act 1994*. For the purposes of the *Acts Interpretation Act 1954*, it is expressly noted that the term 'land' in this environmental authority relates to physical land and not to interests in land.

Land use means the selected post mining use of the land, which is planned to occur after the cessation of mining operations.

Leachate means a liquid that has passed through or emerged from, or is likely to have passed through or emerged from, a material stored, processed or disposed of at the operational land, which contains soluble, suspended or miscible contaminants likely to have been derived from the said material.

Levee means an embankment that only provides for the containment and diversion of stormwater or flood flows from a contributing catchment, or containment and diversion of flowable materials resulting from releases from other works, during the progress of those stormwater or flood flows or those releases; and does not store any significant volume of water or flowable substances at any other times.

Licensed place means the mining activities carried out at the mining tenements.

Low consequence dam means any dam that is not a high or significant consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.
Low impact activities means activities which do not result in the clearing of native vegetation, cause disruption to soil profiles through earthworks or excavation, or result in significant disturbance to land which cannot be rehabilitated immediately using hand tools after the activity is completed. Examples of such activities include but are not necessarily limited to soil surveys (excluding test pits), topographic surveys, cadastral surveys and ecological surveys, the installation of monitoring equipment provided that it is within the meaning of low impact and traversing land by car or foot via existing access tracks or routes or in such a way that does not result in permanent damage to vegetation.

Mandatory reporting level or MRL means a warning and reporting level determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

Manual means the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

Maximum extent of impacts means the total maximum, unabated, impact to a prescribed environmental matter that could to occur over the whole-of-project life.

Minimise is to reduce to the smallest possible amount or degree.

Modification or modifying (see definition of 'construction')

NATA means National Association of Testing Authorities, Australia.

Natural flow means the flow of water through waters caused by natural processes (*i.e.* rainfall in the catchment area and subsequent runoff into watercourses).

Non polluting means having no adverse impacts upon the receiving environment.

Notice of election has the meaning in section 18(2) *Environmental Offsets Act 2014* by which an authority holder elects to deliver an environmental offset.

Operational plan includes:

(a) Normal operating procedures and rules (including clear documentation and definition of process inputs in the DSA allowance);

(b) Contingency and emergency action plans including operating procedures designed to avoid and/or minimise environmental impacts including threats to human life resulting from any overtopping or loss of structural integrity of the regulated structure.

Peak particle velocity (ppv) means a measure of ground vibration magnitude which is the maximum rate of change of ground displacement with time, usually measured in millimetres/second (mm/s).

Permanent watercourse diversion is a man-made structure that incorporates the geomorphologic, hydraulic, hydrologic and ecological components of a local watercourse and is designed, constructed, operated and maintained according to an engineering standard that ultimately achieves a self-sustaining watercourse able to function without features or characteristics that rely on ongoing maintenance or that impose a financial or other burden on the proponent, government or the community.

Pre-existing watercourse is the section of watercourse from which the flow of water will be diverted as a result of the construction and operation of a watercourse diversion.

Prescribed environmental matters has the meaning in section 10 of the *Environmental Offsets Act 2014*, limited to the matters of State environmental significant listed in schedule 2 of the *Environmental Offsets Regulation 2014*.

Protected area means – a protected area under the *Nature Conservation Act 1992*, or

a) a marine park under the *Marine Parks Act 1992*, or

b) a World Heritage Area.

Receiving environment in relation to an activity that causes or may cause environmental harm, means the part of the environment to which the harm is, or may be, caused. The receiving environment includes (but is not limited to):

a) Waters;

b) Land;

c) Air; and

d) Any area that is not specified in Table A1 of this environmental authority.

Receiving waters means the waters into which this environmental authority authorises releases of contaminated water.

Regulated dam means any dam in the significant or high consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

Register of Regulated Dams includes**:**

a) Date of entry in the register;

b) Name of the dam, its purpose and intended/actual contents;

c) The consequence category of the dam as assessed using the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635);

d) Dates, names, and reference for the design plan plus dates, names, and reference numbers of all document(s) lodged as part of a design plan for the dam;

e) Name and qualifications of the suitably qualified and experienced person who certified the design plan and 'as constructed' drawings;

f) For the regulated dam, other than in relation to any levees –

   i. The dimensions (metres) and surface area (hectares) of the dam measured at the footprint of the dam;

   ii. Coordinates (latitude and longitude in GDA94) within five metres at any point from the outside of the dam including its storage area

   iii. Dam crest volume (megalitres);

   iv. Spillway crest level (metres AHD).

   v. Maximum operating level (metres AHD);

   vi. Storage rating table of stored volume versus level (metres AHD);

   vii. Design storage allowance (megalitres) and associated level of the dam (metres AHD);

   viii. Mandatory reporting level (metres AHD);

g) The design plan title and reference relevant to the dam;

h) The date construction was certified as compliant with the design plan;

i) The name and details of the suitably qualified and experienced person who certified that the constructed dam was compliant with the design plan;

j) Details of the composition and construction of any liner;

k) The system for the detection of any leakage through the floor and sides of the dam;

l) Dates when the regulated dam underwent an annual inspection for structural and operational adequacy, and to ascertain the available storage volume for 1 November of any year;

m) Dates when recommendations and actions arising from the annual inspection were provided to the administering authority;

n) Dam water quality as obtained from any monitoring required under this authority as at 1 November of each year.

Regulated structure includes land-based containment structures, levees, bunds and voids, but not a tank or container designed and constructed to an Australian Standard that deals with strength and structural integrity.

Rehabilitation means the process of reshaping and revegetating land to restore it to a stable landform.

Release event means a discharge of water contaminated by the mining activity.

Representative means a sample set which covers the variance in monitoring or other data either due to natural changes or operational phases of the mining activities.

Residual drilling material means waste drilling materials including muds and cuttings or cement returns from well holes and which have been left behind after the drilling fluids are pumped out.

Revegetation is the re-establishment of vegetation[1] of a species and density of cover similar to surrounding undisturbed areas or the landform that existed before mining activities on soil surfaces associated with the construction or rehabilitation of a watercourse diversion.

RL means reduced level, relative to mean sea level as distinct from depths to water.

Saline drainage The movement of waters, contaminated with salts, as a result of the mining activity.

Self-sustaining means not requiring on-going intervention and maintenance to maintain functional riverine processes and characteristics

Sensitive place means:

a) a dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises, or

b) a motel, hotel or hostel, or

c) an educational institution, or

d) a medical centre or hospital, or

e) a protected area under the *Nature Conservation Act 1992*, the *Marine Parks Act 1992* or a World Heritage Area, or

f) a public park or gardens.

Significant residual impact has the meaning in section 8 *Environmental Offsets Act 2014.*

Spillway means a weir, channel, conduit, tunnel, gate or other structure designed to permit discharges form the dam, normally under flood conditions or in anticipation of flood conditions.

Structure means dam or levee.

Suitably qualified and experienced person in relation to regulated structures means a person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the *Professional Engineers Act 2002*, and has demonstrated competency and relevant experience:

- for regulated dams, an RPEQ who is a civil engineer with the required qualifications in dam safety and dam design.
- for regulated levees, an RPEQ who is a civil engineer with the required qualifications in the design of flood protection embankments.

Note: It is permissible that a suitably qualified and experienced person obtain subsidiary certification from an RPEQ who has demonstrated competence and relevant experience in either geomechanics, hydraulic design or engineering hydrology.

System design plan means a plan that manages an integrated containment system that shares the required DSA and/or ESS volume across the integrated containment system.

Temporary watercourse diversion is a man-made structure that may incorporate geomorphologic, hydraulic, hydrologic and ecological components of a local watercourse and is designed, constructed, operated and maintained to an engineering standard that ensures the diversion does not compromise the equilibrium and performance of the diversion and adjoining watercourses. A temporary diversion is replaced by a permanent diversion, or the re-establishment of the pre-existing watercourse, within the timeframe specified in the design plan.

the Act means the *Environmental Protection Act 1994*.

Void means any constructed, open excavation in the ground.

Water is defined under Schedule 4 of the *Water Act 2000.*

Watercourse has the meaning in Schedule 4 of the *Environmental Protection Act 1994* and means a river, creek or stream in which water flows permanently or intermittently—

(a) in a natural channel, whether artificially improved or not; or

(b) in an artificial channel that has changed the course of the watercourse.

Watercourse includes the bed and banks and any other element of a river, creek or stream confining or containing water.

Water quality means the chemical, physical and biological condition of water.

Waters includes all or any part of a river, stream, lake, lagoon, pond, swamp, wetland, unconfined surface water, unconfined water in natural or artificial watercourses, bed and banks of a watercourse, dams, non-tidal or tidal waters (including the sea), stormwater channel, stormwater drain, roadside gutter, stormwater run-off, and groundwater.

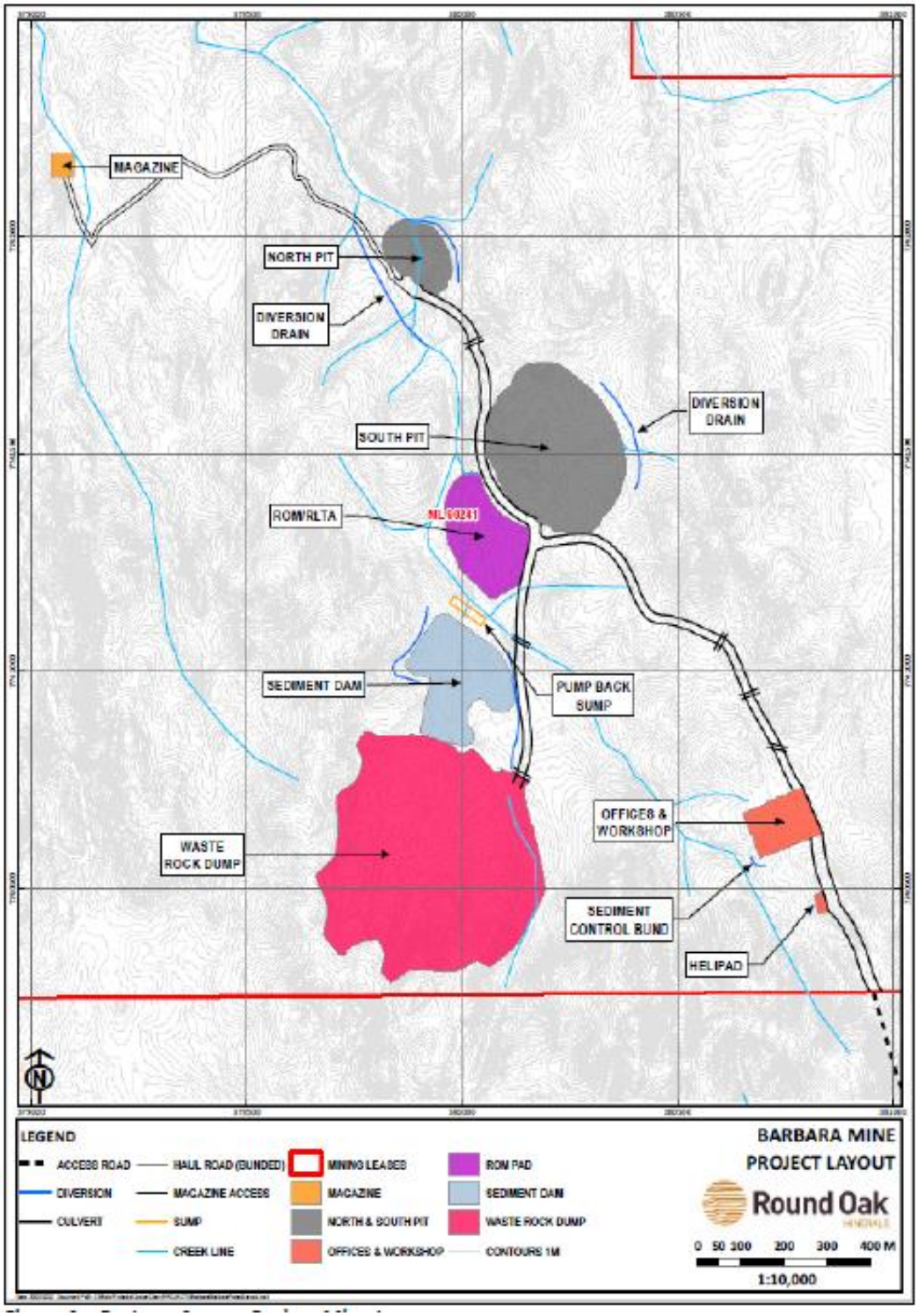
Water year means the 12-month period from 1 July to 30 June.

Wet season means the time of year, covering one or more months, when most of the average annual rainfall in a region occurs. For the purposes of DSA determination this time of year is deemed to extend from 1 November in one year to 31 May in the following year inclusive.

END OF SCHEDULE I

Schedule J – Maps and Plans

Map 1 – Location of authorised disturbance



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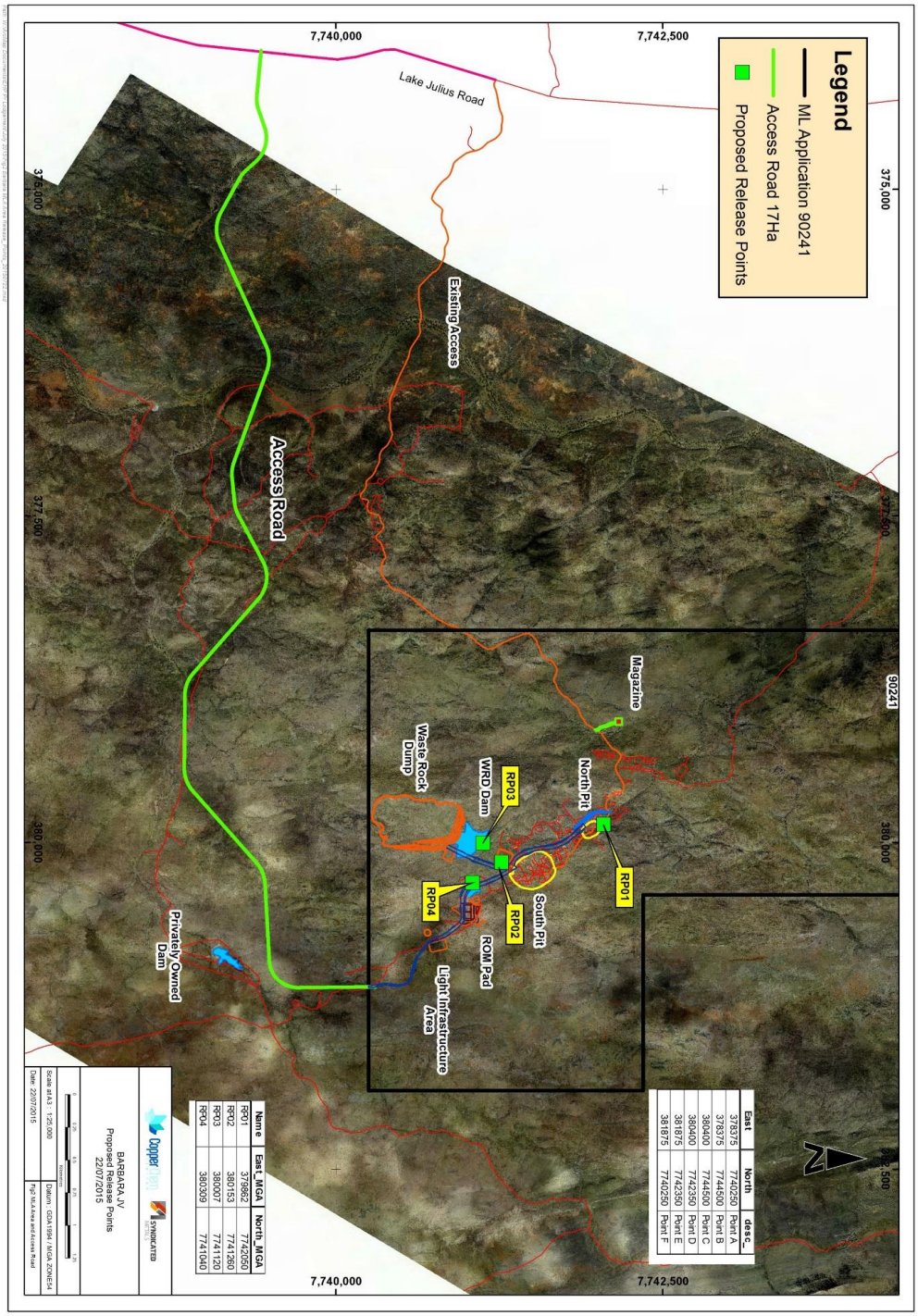
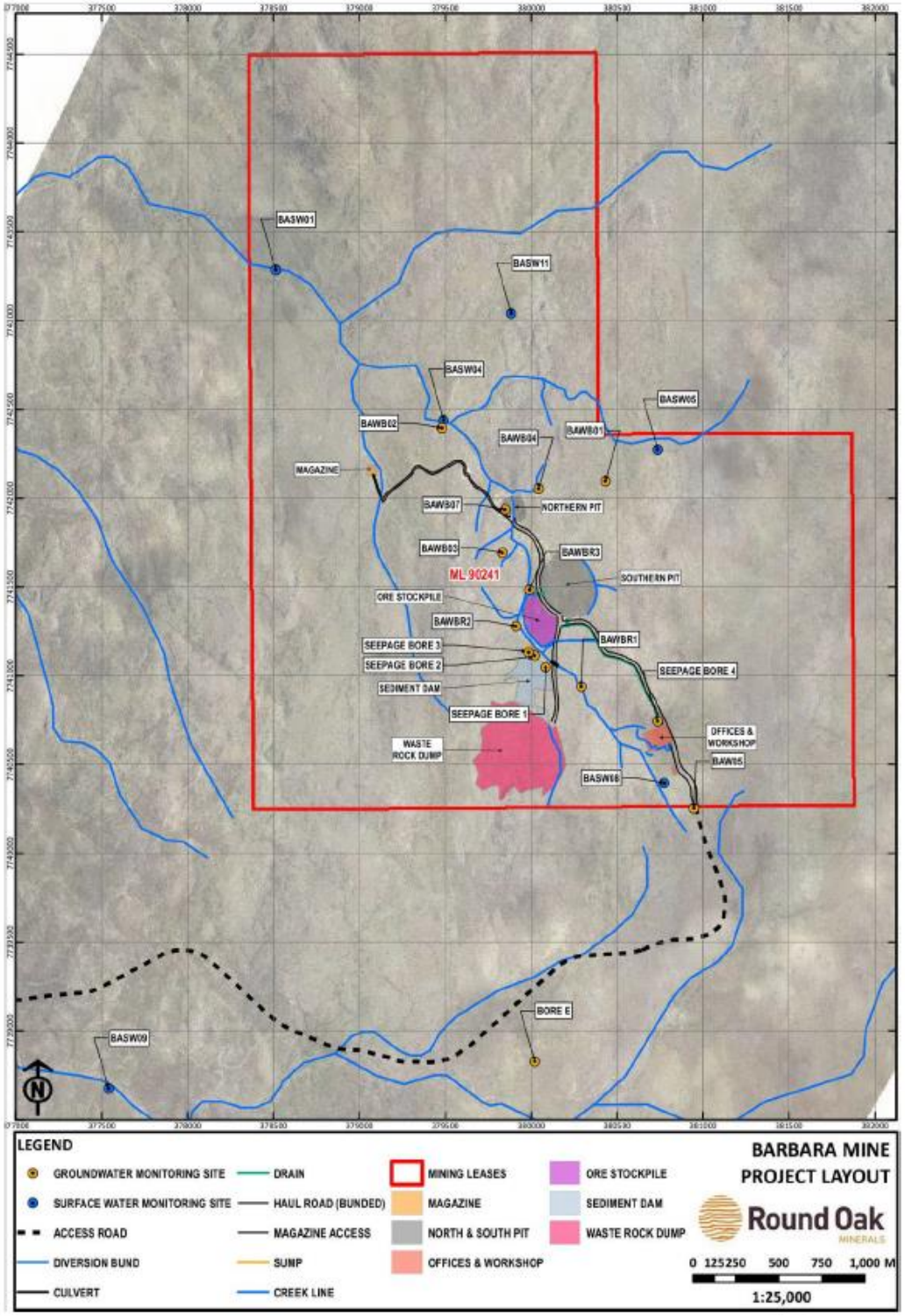
Map 2—Release points



Map 3—Monitoring and reference sites



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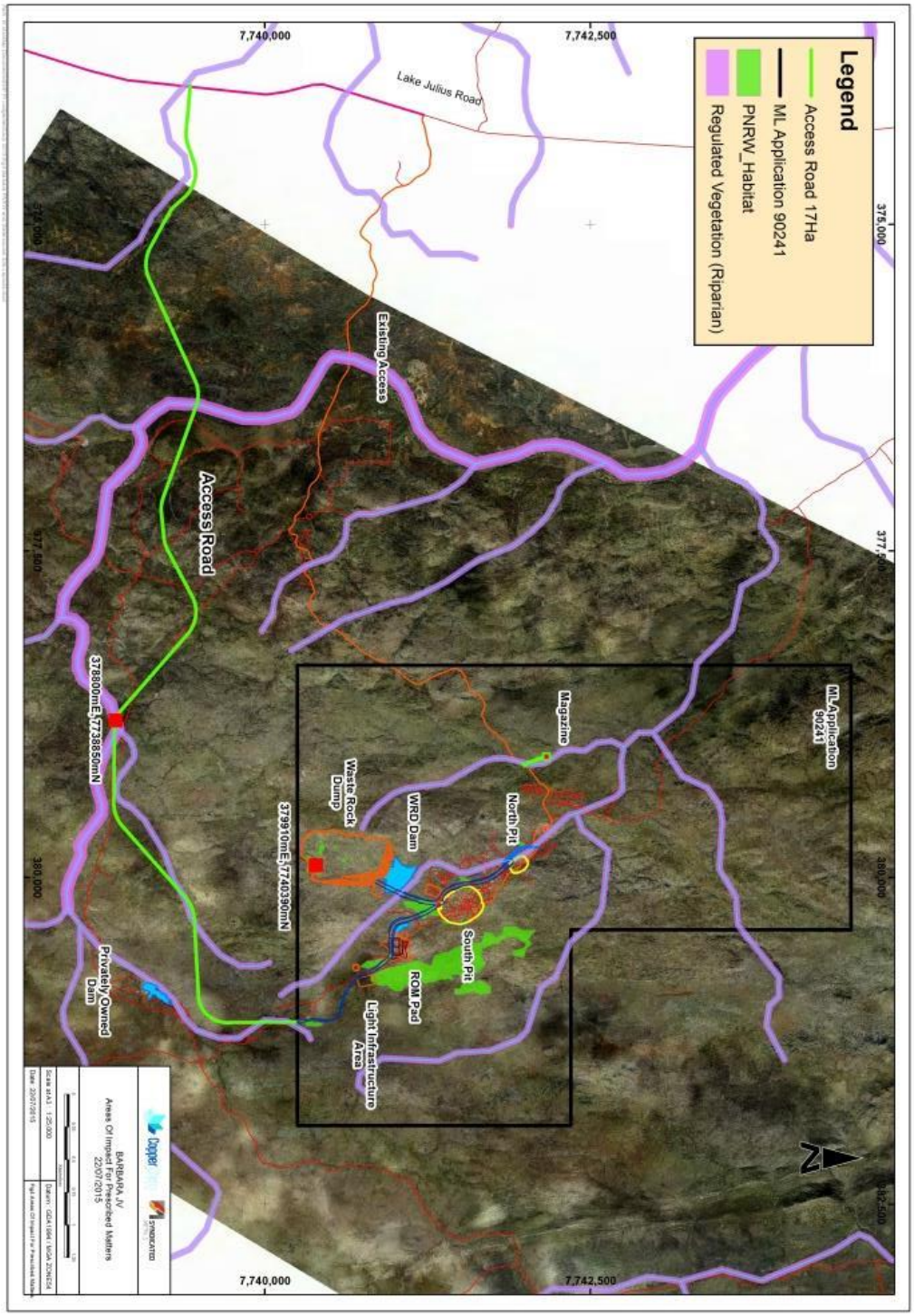
Map 4—Areas of impact for prescribed matters



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End of Schedule J

END OF PERMIT

Post Mine Land Use Plan

Round Oak Minerals

Barbara Copper Project

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Revision History

Revision	Author	Changes	Date	Approved By	Date
Draft	AARC	Update to original document	18/01/2022	E&C Coordinator	
Final	Julie Byrd	Amendments to draft	09/06/2021	Damon Newling	

CONTENTS

1	**Introduction**	**6**
	1.1 Objectives	6
	1.2 Project Location	7
	1.3 Project Description	9
	1.4 Current Infrastructure	9
2	**Existing Environment**	**11**
	2.1 Vegetation	11
	2.2 Soil	17
	2.3 Geology	19
	2.4 Hydrology	19
	2.5 Surface Water Quality	19
3	**Pre and Post Mine Land Use**	**22**
	3.1 Land Suitability Classification	22
4	**Geochemical Characterisation**	**24**
	4.1 2014 Geochemical Characterisation	24
	4.2 2020 Geochemical Characterisation	30
5	**Rehabilitation Requirements**	**39**
	5.1 Rehabilitation Areas	39
	5.2 Rehabilitation Goals	40
	5.3 Rehabilitation Objectives	40
	5.4 Completion Criteria	41
	5.5 Rehabilitation Indicators	41
	5.6 Assessing Rehabilitation Success	41
	5.7 Rehabilitation Success	0
6	**Rehabilitation Plan and Landform Design**	**2**
	6.1 Final Voids	2
	6.2 Waste Rock Dumps	11
	6.3 Bunds, Levees, Diversion Drains and Dams	13

6.4 Ancillary Infrastructure, Roads & ROM Pad 16
6.5 Exploration 16
6.6 Vegetation Removal and Topsoil Stripping 16
6.7 Erosion and Sediment Control 16
7 Revegetation Methods 18
7.1 Cover Soil Suitability and Management 18
7.2 Growth Media Availability 19
7.3 Growth Media Preparation 20
7.4 Surface Preparation 20
7.5 Growth Media Placement 21
7.6 Species Selection 21
7.7 Propagation 23
7.8 Maintenance 26
8 Rehabilitation Monitoring Program 28
8.1 Vegetation Monitoring 28
8.2 Photographic Monitoring 33
8.3 Erosion Monitoring 33
8.4 Topsoil Monitoring 34
8.5 Waste Rock Dump Monitoring 35
8.6 Groundwater Monitoring 35
8.7 Receiving Water Monitoring 35
8.8 Rehabilitation Success 35
9 Research Programs and Associated Milestones 36
10 References 37

LIST OF TABLES

LIST OF FIGURES

Figure 1 Project Location 7
Figure 2 BCO Mining Lease and Accessibility 8
Figure 3 Barbara Mine Project Layout 10
Figure 4 Vegetation Communities within the study area (AARC, 2014) 11
Figure 5 Distribution of Soil Management Units within the Study Area 17
Figure 6 Aquatic Monitoring Site Locations 20
Figure 7 Temporal Comparison of Total and Dissolved Copper in Surface Water 21
Figure 8 Acid Rock Drainage Characterisation of BCO Samples (EGi, 2014) 26
Figure 9 Summary of EC Values for All Rock Units Within Barbara Drill Core Samples 29
Figure 10 Acid Rock Drainage Plot for Barbara Waste Rock and ROM Oxide 31
Figure 11:ARD Classification 32
Figure 12 Sulphur Speciation in Column Leach Test Samples 33
Figure 13 Monitored NAG pH Profiles for PAF Waste Rock and Low-grade Ore Samples 34
Figure 14 Comparison of Carbonate Neutralising Value and Acid Neutralising Capacity 35
Figure 15:Acid Buffer Characteristics Curve for Sample NAF4 36
Figure 16 Bund Location for the North Pit 4
Figure 17 Bund Location for the South Pit 5
Figure 18 North and South Pit Post-Closure Catchment Areas 8
Figure 19 Modelled Storage Volume - North Pit 9
Figure 20 Modelled Water Surface Elevation – North Pit 10
Figure 21 Modelled Storage Volume - South Pit 10
Figure 22 Modelled Water Surface Elevation – South Pit 11
Figure 23 Waste Rock Dump Sensitivity Stability Analysis (ATC Williams, 2019) 13
Figure 24 Barbara Diversion Drains 15
Figure 26 Transect Area and Layout 30
Figure 26 Guide to Estimating Ground Cover Percentage (Eyre *et al.* 2017) 32

LIST OF ABBREVIATIONS

AARC	AARC Environmental Solutions Pty Ltd
AEP	Annual Exceedance Probability
AMD	Acid Mine Drainage
ANC	Acid neutralising capacity
AWBM	Australian Water Balance Model
BCO	Barbara Copper Project
CNV	Carbonate Neutralising Value
DBH	Diameter at breast height
DSA	Design storage allowance
EA	Environmental Authority
EC	Electrical conductivity
ESP	Exchangeable sodium percent
GAI	Geochemical abundance index
GPS	Global Positioning System
LOR	Limit of Reporting
MAW	Mine Affected Water
ML	Mining Lease
NAF	Non-Acid-Forming
NAG	Net Acid Generation
NAPP	Net Acid Producing Potential
PAF	Potentially Acid Forming
PAWC	Plant available water capacity
PMLUP	Post Mining Land Use Plan
RMP	Rehabilitation monitoring program
ROM	Run of mine
SLSA	Soil and Land Suitability Assessment
SMU	Soil Mapping unit
WRD	Waste Rock Dump

1 Introduction

This Post Mine Land Use Plan (PMLUP) has been developed by AARC Environmental Solutions Pty Ltd (AARC) on behalf of Round Oak Minerals Pty Ltd (Round Oak Minerals) for the Barbara Copper Project (BCO).

1.1 Objectives

This PMLUP describes how the rehabilitation objectives outlined in condition G1 of Environmental Authority (EA) EPML02840015 for the BCO will be achieved. This PMLUP has been completed in accordance with the requirements of condition G2 of the EA, which states that:

Two years from commencement of mining the environmental authority holder must develop and document a Post Mine Land Use Plan ('PMLUP') that describes how the rehabilitation objectives in condition G1 will be achieved. The PMLUP must at minimum include:

a) *Schematic representation of the proposed final landform inclusive of site drainage features;*
b) *Details of proposed slope design and erosion and sediment controls;*
c) *Proposed cover designs for encapsulation of waste material, including performance criteria;*
d) *Proposed revegetation methods inclusive of plant species selection, propagation methods and establishment of suitable plant growth medium (i.e. top soil);*
e) *Materials balance for all rehabilitation requirements including available top soil and material suitable for encapsulating waste in accordance with the proposed encapsulation methodology;*
f) *Geotechnical, geochemical and hydrological studies necessary to demonstrate likely success of proposed rehabilitation methodology to achieve the required rehabilitation outcomes;*
g) *An investigation of proposed residual voids including potential for generation/mobilisation of contaminants, potential pathways for release of contaminants to waters (including groundwater) and a long-term void water balance model; and*
h) *A rehabilitation monitoring program sufficient to identify if required rehabilitation outcomes have been achieved.*

The PMLUP aims to comply with this condition through the application of best practice methodologies, resulting in environmental outcomes which satisfy the rehabilitation objectives of G1 in the EA. Existing rehabilitation indicators and completion criteria provided in the BCO Plan of Operations 2019 – 2022 (Round Oak Minerals 2019) have been reviewed and a complete set of site-specific rehabilitation goals, objectives, indicators and completion criteria developed. In accordance with condition G2 (h), the PMLUP includes a rehabilitation monitoring program designed to enable future monitoring to assess whether rehabilitation outcomes have been achieved.

1.2 Project Location

The Project is situated in north-west Queensland, 50 kilometres (km) north-east of Mount Isa and as such, is situated within the Mt Isa local government area (Figure 1). The BCO is consists of Mining Lease (ML) ML90241, which is accessible via the Lake Julius / Kajabbi Road (Figure 2). The operation is in care and maintenance, having completed open pit extraction of the copper and gold ore. All ore excavated from the two mine pits was trucked to Mount Isa for processing.

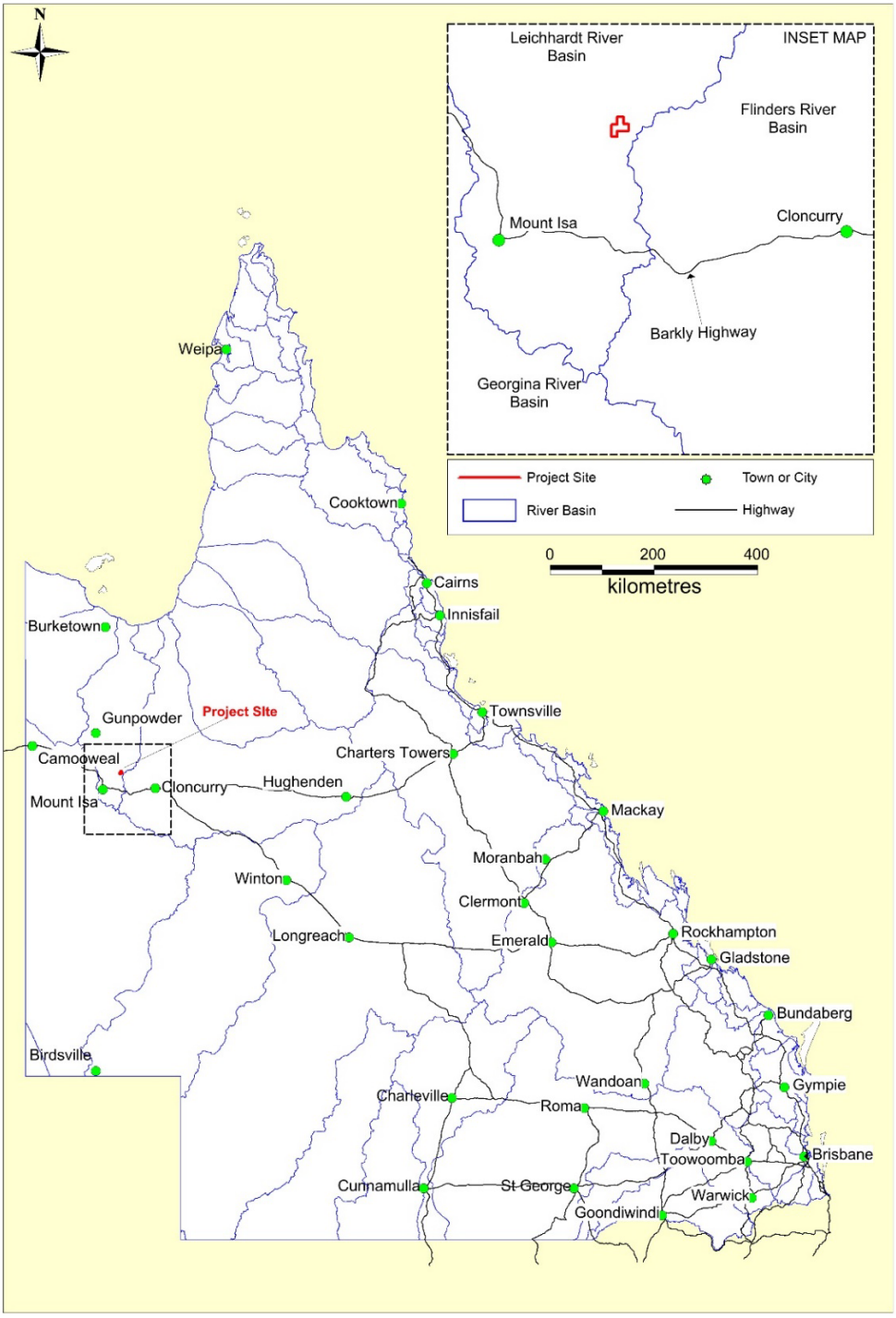


Figure 1 Project Location

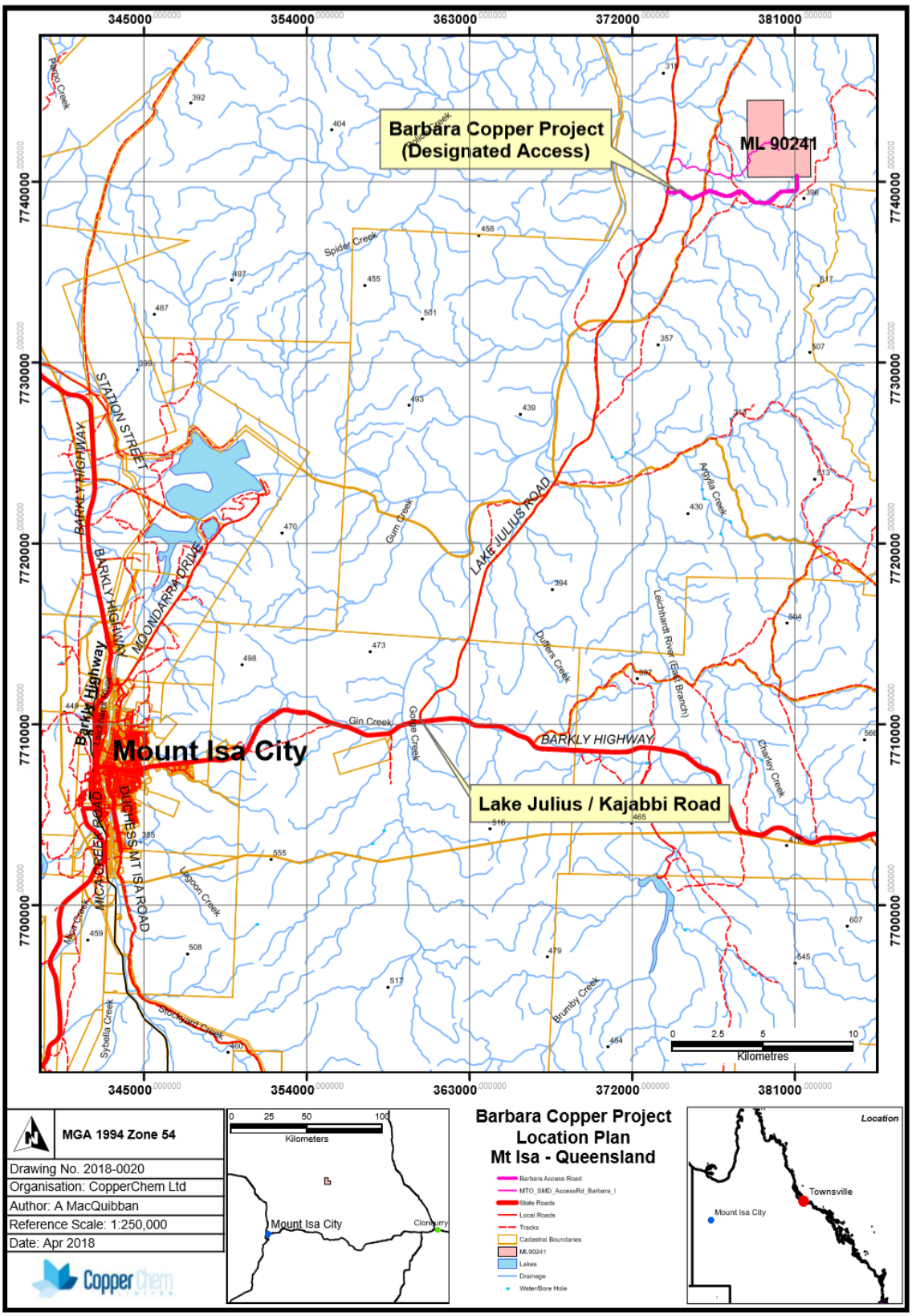


Figure 2 BCO Mining Lease and Accessibility

1.3 Project Description

The BCO operated as an open cut copper mine producing approximately 772,000 tonnes ore over 18 months with a copper (Cu) grade of 2.0 %, gold (Au) at 0.16 grams/tonne (g/t) and silver (Ag) at 3g/t. There are two completed open pits; North Pit approximately 60m deep and South Pit approximately 150m deep. The total disturbance footprint is approximately 7.5 ha. All ore was transported off site by road train for processing at a third-party processing facility in the region. The site is under care and maintenance while further exploration is conducted to establish the viability of an underground extension of mining.

1.4 Current Infrastructure

The current disturbance on the Project site subject to rehabilitation is presented in Table 1 below and illustrated in Figure 3.

Table 1 Infrastructure Disturbance Area

Infrastructure area	Maximum licensed area of disturbance (ha)
North Pit	1.5
South Pit	6
Waste Rock Dump (WRD)	23
WRD Sediment Dam	4
Run of Mine (ROM) Pad	3.5
Topsoil Stockpiles	2.5
Light Infrastructure Area	2.5
Sewage Treatment Facility	0.5
Explosive Magazine	0.5
Road Train Loading Area	1
Access Road, Haul Roads and Tracks	20.5
Diversion Drain	0.5

Table 1 is adapted from Table A1 of EA EPML02840015 (2019).

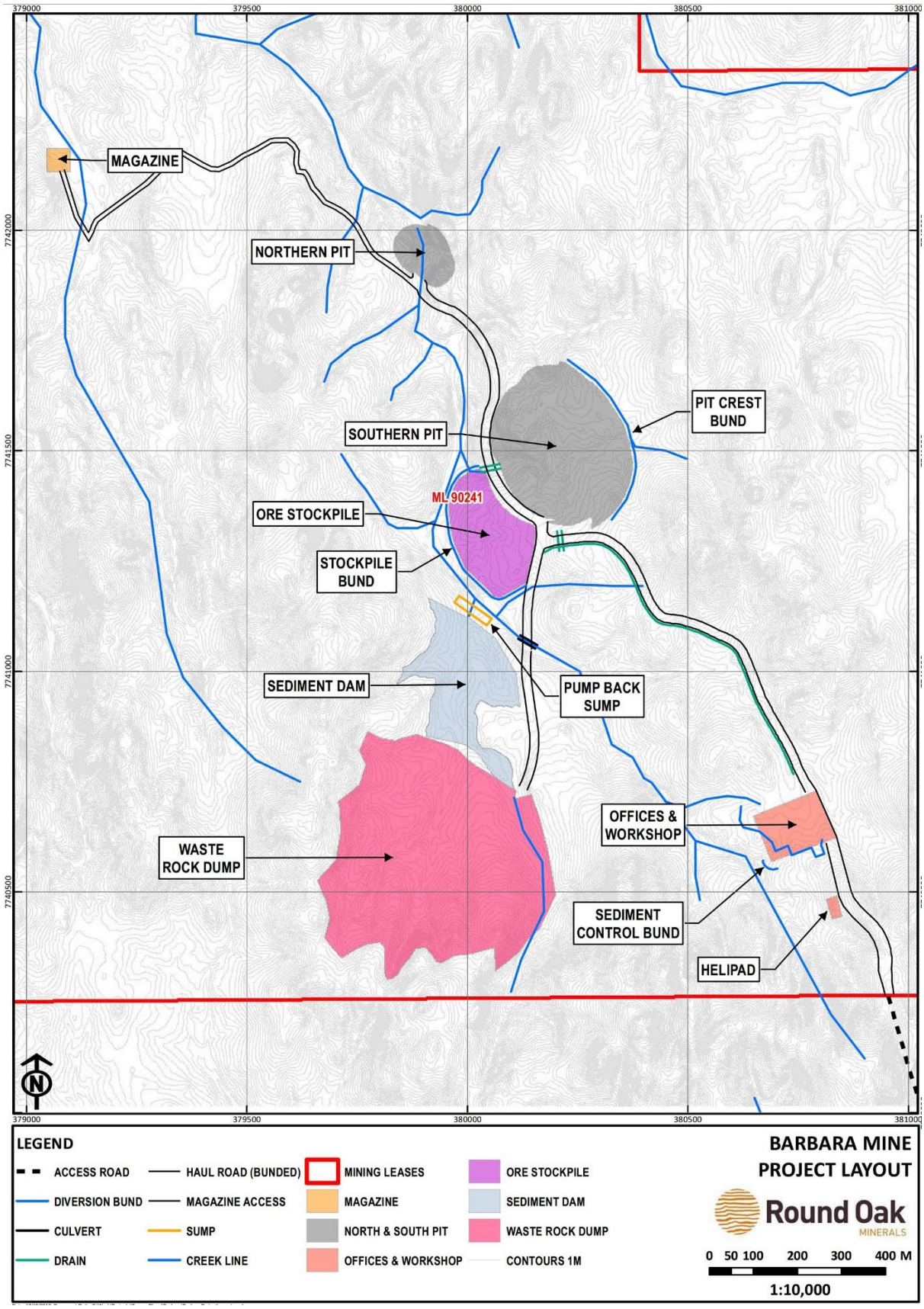


Figure 3 Barbara Mine Project Layout

2 Existing Environment

2.1 Vegetation

To determine the pre-mining plant communities within the BCO site, flora surveys were conducted to assess vegetation communities and ecological values. Survey timing was selected in accordance with the '*Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland*' (Neldner *et al*., 2012). Seven vegetation communities were identified across the BCO site, all of which are classified as remnant vegetation. A summary of each vegetation community is provided in Table 2 The location and extent of each vegetation community on the BCO site are presented in Figure 4. Full descriptions and photographs of the vegetation communities are provided in '*Barbara Copper Project: Terrestrial Flora and Fauna Assessment*' (AustralAsian Resource Consultants, 2014).

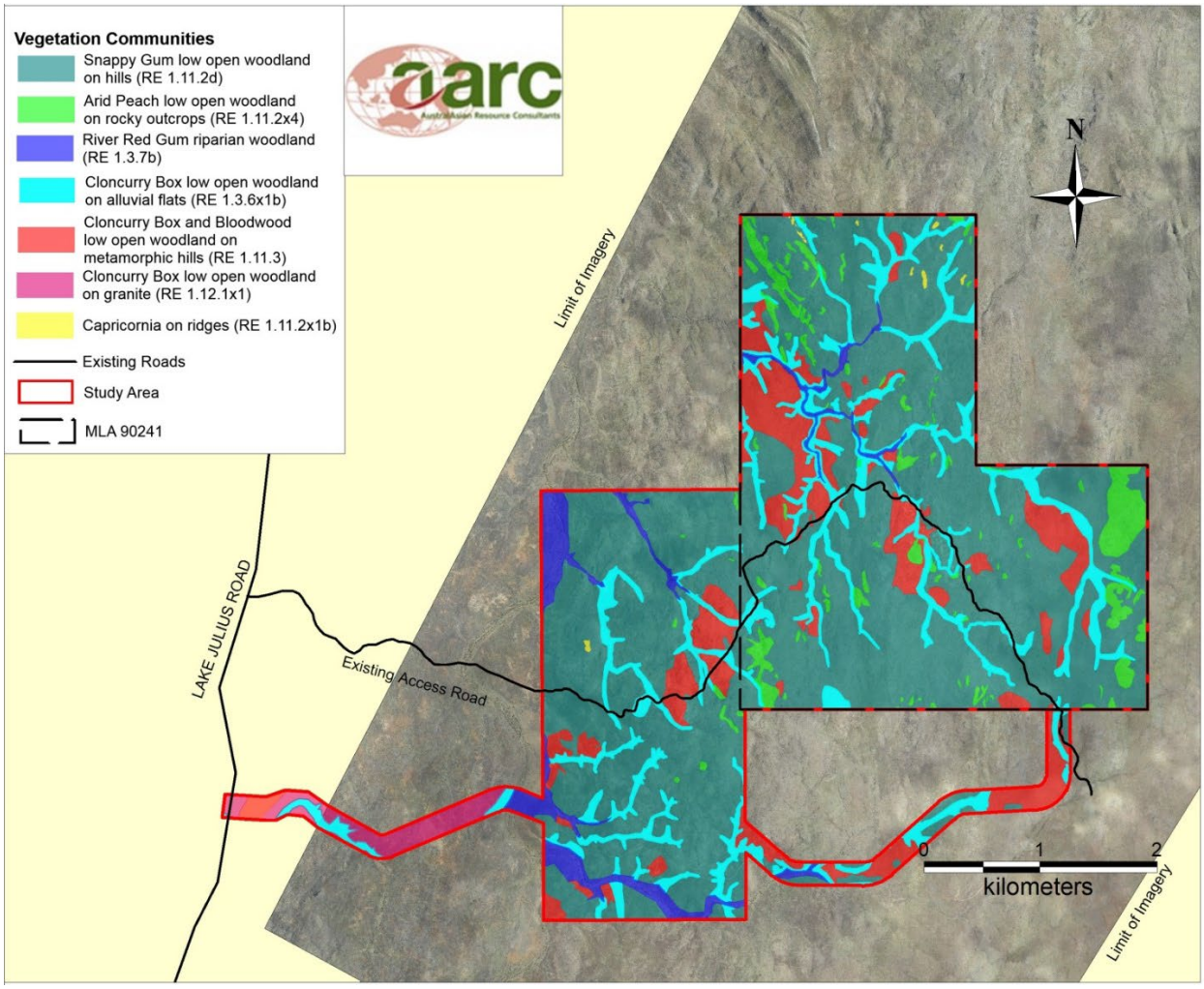


Figure 4 Vegetation Communities within the study area (AARC, 2014)

Table 2 Pre-mining Vegetation Community Descriptions

Community No.	Community 1	Community 2	Community 3	Community 4	Community 5	Community 6	Community 7
Community Name	**Low Open Woodland of Snappy Gum**	**Low Open Woodland of Cloncurry Box and Bloodwood**	**Low Open Woodland of Cloncurry Box on Alluvial Flats**	**River Red Gum and Northern Swamp Box Riparian Woodland**	**Low Open Woodland of Arid Peach on Rocky Outcrops**	**Capricornia Ridges**	**Low Open Woodland and Bloodwood on Granites**
Regional Ecosystem	1.11.2d	1.11.3	1.3.6X1b	1.3.7b	1.11.2X4	1.11.2X1b	1.12.1X1
Area (ha)	1,348	236.8	163.5	75.2	81.1	1.92	38.26
EPBC Status	Not Listed	Not Listed	Not listed	Not listed	Not Listed	Not Listed	Not Listed
VM Status	Least Concern	Least Concern	Least Concern	Least Concern	Least Concern	Least Concern	Least Concern
Biodiversity Status	No concern at present	No concern at present	Of Concern	Endangered	No concern at present	No concern at present	No concern at present
Tree Layer	*Eucalyptus leucophloia (D), Corymbia terminalis (A), Terminalia aridicola (A), Brachychiton collinus (A), Corymbia aparrerinja (O), Corymbia capricornia (O), Eucalyptus leucophylla (O)*	*E. leucophylla (CD), C. terminalis (CD), E. leucophloia (A), Terminalia aridicola (A), Atalaya hemiglauca (O), Brachychiton collinus (O)*	*E. leucophylla (D), Lophostemon grandiflorus (A), C. terminalis (O),*	*Eucalyptus camaldulensis (CD), Lophostemon grandiflorus (CD)*	*Terminalia aridicola (D), Brachychiton collinus (SD), E. leucophloia (A)*	*Corymbia capricornia (D), Eucalyptus leucophloia (A), Alphitonia excelsa (A), Terminalia aridicola (A)*	*Eucalyptus leucophylla (CD), C. terminalis (CD), Atalaya hemiglauca (A)*
Shrub Layer	*Acacia phlebocarpa (D), Acacia chisholmii (SD), Acacia holosericea (A), Acacia monticola (A), Acacia melleodora (A)*	*A. holosericea (CD), A. Chisholmii (CD), A. phlebocarpa (A), A. meleodora (A), Gossypium australe (A).*	*A. holosericea (D), Terminalia aridicola (A), A. Chisholmii (A), Melaleuca bracteata (A), A. phlebocarpa (A), Flueggea virosa subsp. melanthesoides (O), Gossypium australe (O)*	*Melaleuca bracteata (CD), Sesbania javanica (CD), A. holosericea (A), Flueggea virosa subsp. melanthesoides (O)*	*Trema tomentosa (D), A. phlebocarpa (A), A. chisholmii (A)*	*Acacia monticola (A), A. orthocarpa (A)*	*Acacia chisholmii (D), Carissa lanceolata (A)*
Ground Layer	*Triodia pungens (D)*	*Triodia pungens (D)*	*Triodia pungens (D)*	*Cenchrus ciliaris (D)*	*Triodia pungens (D), Cymbopogon bombycinus (A), Sehima nervosum (A)*	*Triodia bitextura (D), Cymbopogon bombycinus (A)*	*Triodia spp. (D)*

Community No.	Community 1	Community 2	Community 3	Community 4	Community 5	Community 6	Community 7
Community Name	**Low Open Woodland of Snappy Gum**	**Low Open Woodland of Cloncurry Box and Bloodwood**	**Low Open Woodland of Cloncurry Box on Alluvial Flats**	**River Red Gum and Northern Swamp Box Riparian Woodland**	**Low Open Woodland of Arid Peach on Rocky Outcrops**	**Capricornia Ridges**	**Low Open Woodland and Bloodwood on Granites**
Weed Species	*Cenchrus ciliaris (O), Vachellia farnesiana (O), Aerva javanica (O)*	*C. ciliaris (O), V. farnesiana (O), A. javanica (O)*	*C. ciliaris (O), V. farnesiana (O), A. javanica (O)*	*Cenchrus ciliaris (O), V. farnesiana (O)*	*Cenchrus ciliaris (O)*	N/A	N/A
Landform Description	Low open woodland on rock outcrops with a very sparse shrub layer of Acacia spp. and a sparse to very sparse ground layer of *Triodia pungens*. Occurs on steep rocky slopes and crests on metamorphosed igneous rocks.	Low open woodland with Acacia spp. dominated shrub layer and ground layer of Triodia spp. and/or tussock grasses. Occurs on metabasalts and dolerites; skeletal soils, some shallow loams.	Floodplain (other than floodplain wetlands). woodland with a mid-dense ground layer dominated by tussock grasses. Occurs on narrow terraces.	Riverine wetland or fringing riverine wetland. Fringing woodland. Occurs on recent levees and channel deposits of medium and smaller tributaries which are dry for most of the year; alluvial soils.	Low open woodland with mid-dense shrub layer and ground layer of mixed tussock grasses. Occurs on rock outcrops on hills and ranges on strongly folded siliceous sedimentary and metamorphic pre-Cambrian rocks.	This community occurs on small, isolated ridges that form a distinct change in ecotone as the terrain rises sharply and the geology becomes dominated by quartz rock.	Low open woodland and occurs on ranges and stony hills and rises on igneous rocks; skeletal soils and some shallow red earths.
Vegetation Condition	Evidence of low intensity cattle grazing was observed throughout this community with visible impacts limited to faecal evidence. Weed diversity and abundance is relatively low within this RE. Seed dispersal vectors likely include wind transport as well as cattle and avian dispersal. Introduced flora species Buffel Grass (*Pennesetum ciliare*) and Kapok (*Aerva javanica*) were observed to be widespread throughout the	Typically subject to low intensity cattle grazing, the impacts were more prominent in areas adjacent to watercourses. As a result of increased grazing pressure, these areas exhibit greater disturbance and weed abundances. Buffel Grass was occasionally observed in high densities and was recorded as co-dominant with Soft Spinifex in areas adjacent to ephemeral watercourses. Introduced	Healthy, with a relatively high diversity of flora species. This is one of the most fertile habitats on the property and is susceptible to greater weed invasion. Introduced species recorded within this community include Mimosa (V. *farnesiana*), Buffel Grass and Kapok. On some drainage lines, Buffel was recorded as co-dominant with native grasses. Kapok was found to occur sporadically	This riparian community (RE 1.3.7b) is subject to invasion by introduced species that are known to occur commonly throughout the region including Buffel Grass, Red Natal Grass (*Melinis repens*) and Mimosa. No weed species, listed under the LP Act or listed as of national significance, were observed within the riparian community. This zone was dominated mostly by native vegetation with only low	Native flora species dominated the dry rocky outcrops with only a scattered presence and low abundance of the introduced Buffel Grass recorded. No weed species listed under the LP Act or listed as Weeds of National Significance were recorded from this community.	A low diversity and density of introduced species was recorded in association with the Capricornia ridges. Weed species recorded in low densities included including Buffel Grass and Beggar's Ticks (*Bidens bipinnata*). No weed species, listed under the LP Act or listed as of national significance, were observed within the	This community occurs as part of a large patch of remnant vegetation. Previous disturbance within this community is limited to low intensity cattle grazing activities.

Community No.	Community 1	Community 2	Community 3	Community 4	Community 5	Community 6	Community 7
Community Name	**Low Open Woodland of Snappy Gum**	**Low Open Woodland of Cloncurry Box and Bloodwood**	**Low Open Woodland of Cloncurry Box on Alluvial Flats**	**River Red Gum and Northern Swamp Box Riparian Woodland**	**Low Open Woodland of Arid Peach on Rocky Outcrops**	**Capricornia Ridges**	**Low Open Woodland and Bloodwood on Granites**
	community, however, present in low densities.	flora species were otherwise found to have a sparse presence within this community. Native species tended to dominate the drier open plains and lower slopes of the surrounding hills.	throughout the community.	levels of introduced species found in the dry waterways and across stream banks. Overall, the condition of this RE on the Project site is good with only a low diversity of introduced species recorded throughout.		Capricornia ridges community.	
Habitat Value	Provides habitat for macropods, small mammals, reptiles and open woodland birds.	Provides good habitat variety for birds, large macropods and reptiles in particular through the provision of rocky substrates, leaf litter, fallen timber and Spinifex tussocks.	Provides an abundance of habitat suited to reptiles. This community also provides habitat for birds and large macropods as well as amphibians during wet periods.	Provides good habitat variety for reptiles, amphibians, birds and mammals through the presence of hollow bearing trees, rocky substrates, leaf litter and fallen timber as well as temporary aquatic habitats.	Provides plentiful habitat value for birds, reptiles and rock-dwelling mammals (e.g. Rock Rats and Purple-necked Rock-wallabies) in particular.	This community occupies very small areas of rocky quartz ridges, which are likely to provide limited habitat value for reptiles, birds and mammals.	Provides good habitat variety for birds, large macropods and reptiles in particular through the provision of rocky substrates, fallen timber and Spinifex tussocks. The small rocky hills and low rock outcrops are likely to support reptiles and small mammals. Highly mobile species such as birds and macropods are likely to utilise this community as forage habitat.

Key: D = Dominant, CD = Co-dominant, SD = Sub-dominant, A = Associated, O = Occasional

2.2 Soil

A Soil and Land Suitability Assessment (SLSA) was conducted by AustralAsian Resource Consultants Pty Ltd (AustralAsian Resource Consultants) to classify soil types, assess the suitability of topsoil material and identify potential management limitations associated with soil characteristics. Based on field observations and laboratory analysis, three broad soil management units were confirmed within the study area. A description of the dominant soil types identified in each management unit, together with typical chemical characteristics, is included in the following section. The distribution of these soil management units has been mapped at a semi-detailed scale representation of 1:50,000 (McKenzie et.al., 2008) in Figure 5.

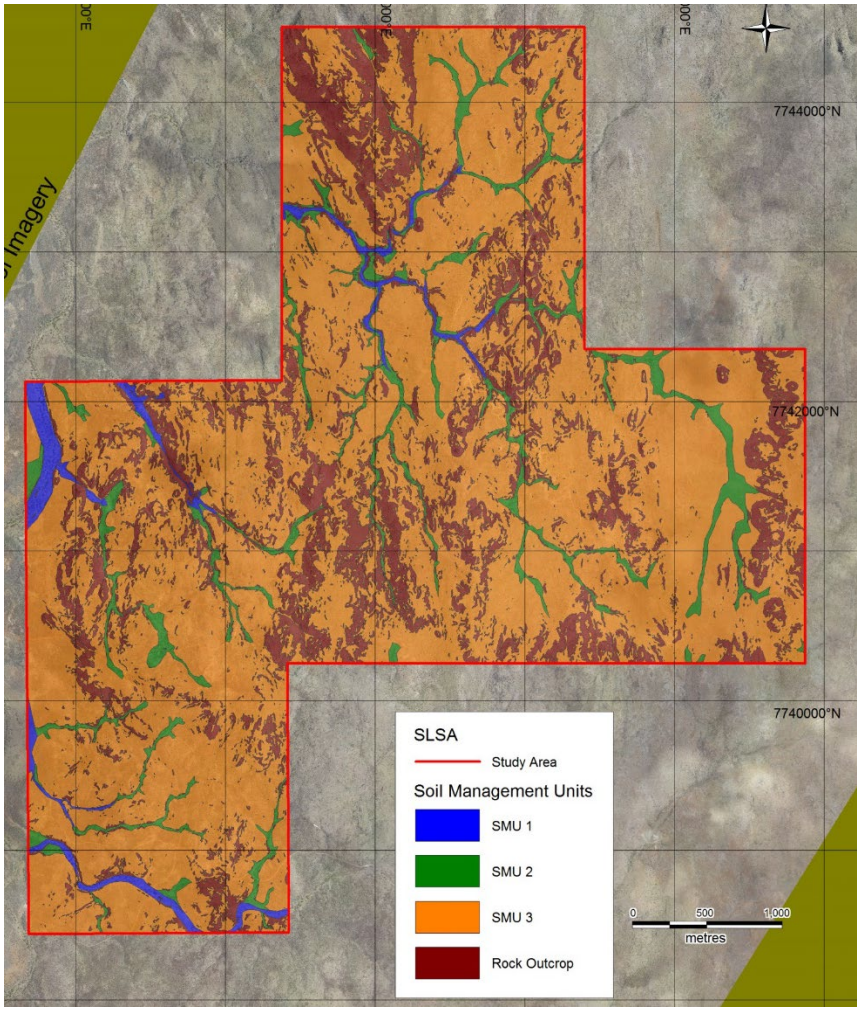


Figure 5 Distribution of Soil Management Units within the Study Area

2.2.1 SMU 1 – River Red Gum Sands

SMU 1, identified as the River Red Gum Sands, consists of sand textured soil and is typically associated with higher order drainage lines and ephemeral watercourses. These soils are often deeper and well-draining although soil depths may become shallow in upper tributaries where rocky parent material occurs within 0.5m of the surface (sometimes present on the surface).

These soils have a high gravel and cobble content, with an abundance of rounded coarse fragments and a loose surface. Finer stream sediments are removed via alluvial action with occasional evidence of distinct depositional horizons associated with stream-flow and regular inundation. These areas are sparsely covered with surface vegetation but are associated with larger river red gum and riverine species.

Soil chemistry indicates deficiencies in major soil nutrients with very low levels of nitrogen, phosphorus, and potassium. pH is neutral and within the preferred range for most plant species. This soil constitutes a Tenosol under the Australian Soils Classification (Isbell, 2016).

2.2.2 SMU2 – Cloncurry Box Drainage Terraces

SMU2, identified as the Cloncurry Box Drainage Terraces, consists of loamy to clayey sands along terraces adjacent to open drainage depressions. These soils occur on relatively flat topography (1-2%) in isolated areas of greater deposition within the undulating topography found on site. Areas of SMU2 are commonly intersected by thin drainage lines of SMU1 and areas of rock outcrops. Soils of SMU2 typically have lower fine gravel content but larger (20-60+ mm) sub-rounded to rounded coarse fragments present throughout profile. This soil constitutes a Tenosol under the Australian Soils Classification (Isbell, 2016).

Within this SMU there is evidence of very minor areas of gully erosion associated with the ephemeral watercourses which transect SMU2, although soil chemistry suggests soil is not prone to erosivity or dispersion.

Typically, soil chemistry indicates deficiency in major soil nutrients with very low to low levels of nitrogen and phosphorus. Levels of exchangeable potassium are moderate, higher than those observed in the other SMU's within the study area. Soil pH is neutral, bordering on mildly alkaline, but still within the preferred range for most plant species.

An individual observation located within the SMU returned laboratory results of unexpectedly high pH, high electrical conductivity (EC) and high exchangeable sodium percent (ESP). However, it was noted that this site was situated near extensive disturbance from historic mine workings. Subsequently, these observations have been noted, but the data excluded from further analysis as being atypical of the area.

2.2.3 SMU3 – Snappy Gum Slopes

SMU3, identified as the Snappy Gum Slopes, consist of slopes of clayey sands to sandy clay loams with moderate to high gravel content (Coarse Fragment Size: 6-20 mm and 20-60 mm; Shape: angular) on steep lower slopes. These areas are often dominated on the steeper slopes by extensive areas of rock outcrop (as mapped in Figure 4). Slopes within the SMU vary from 0 – 20+% with an average of 6%.

Soils of SMU3 vary considerably in depth, with significant areas of shallow rocky substrate encountered within 15-70 cm of the surface across the study area. Soil chemistry indicates deficiencies in major soil nutrients with very low to low levels of nitrogen, low to moderate levels of phosphorus, and low levels of exchangeable potassium. Soil pH varies slightly across the study area but is typically neutral, bordering on mildly alkaline, but still within the preferred range for most plant species. This soil constitutes a Tenosol under the Australian Soils Classification (Isbell, 2016).

2.3 Geology

Bedrock geology in the area comprises Proterozoic rocks of the Mount Isa Inlier. Rock types at Barbara include felsic volcanics (forming the hills), dolerite/amphibolite (in the drainages/valleys) and basalt (forming plateaus). The felsic volcanics are the dominant rock type in the Project area. The felsic and mafic volcanics dip at 60 degrees towards the northeast and the dolerites are sub-vertical within the Project area. These three rock types are resistant to weathering and extensive outcrops occur throughout the area.

The copper sulphide in the area can occur close to surface with a maximum thickness of 45 metres and consisting of massive sulphide through to stringer veins within an alteration zone of biotite, tourmaline and quartz. The weathering profile averages around 15 m deep. The near-surface copper mineralisation is recoverable through open pit mining. However, the higher-grade material is below the limits of an open pit, but potentially recoverable by underground mining methods.

2.4 Hydrology

The Project area is crossed by numerous small, unnamed first- and second-order drainage lines. One larger, third-order watercourse flows through the south-western and north-western areas of the Project area. These waterways drain north-west to form an unnamed third-order creek which flows into the Leichhardt River and subsequently north into the Gulf of Carpentaria. The waterways are ephemeral and flow only after heavy rainfall. There are no wetlands within the Project area boundary. Lake Julius, a large lacustrine wetland listed on the Directory of Important Wetlands in Australia, is located approximately 17 kilometres downstream of the Project.

2.5 Surface Water Quality

A receiving environment monitoring program (REMP) has been implemented annually at the BCO to monitor surface water quality during wet and dry seasons over time. The most recent annual report for the Project was prepared in 2020 for surveys undertaken from 3 to 4 March 2020 (wet season survey) and 23 August 2020 (dry season survey).

There are ten established monitoring sites within the REMP (Figure 6), however, only four sites had sufficient water for sampling during the 2020 wet season survey, while only one site had sufficient water during the 2020 dry season survey. Water quality data collected during each survey is assessed against the ANZECC and ARMCANZ (2000) guidelines for tropical Australia upland streams, QWQG regional guideline values for the Gulf Rivers (EHP, 2009), and Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018). Data is also compared against results from previous surveys to identify any changes in water quality that may be attributed to mine operations, although it is acknowledged that limited data availability across all monitoring sites over time constrains this ability.

Water quality characteristics for the BCO are discussed in Section 2.5.1. Further detail can be sourced from the Barbara Copper Project: REMP annual report (SLR 2020).

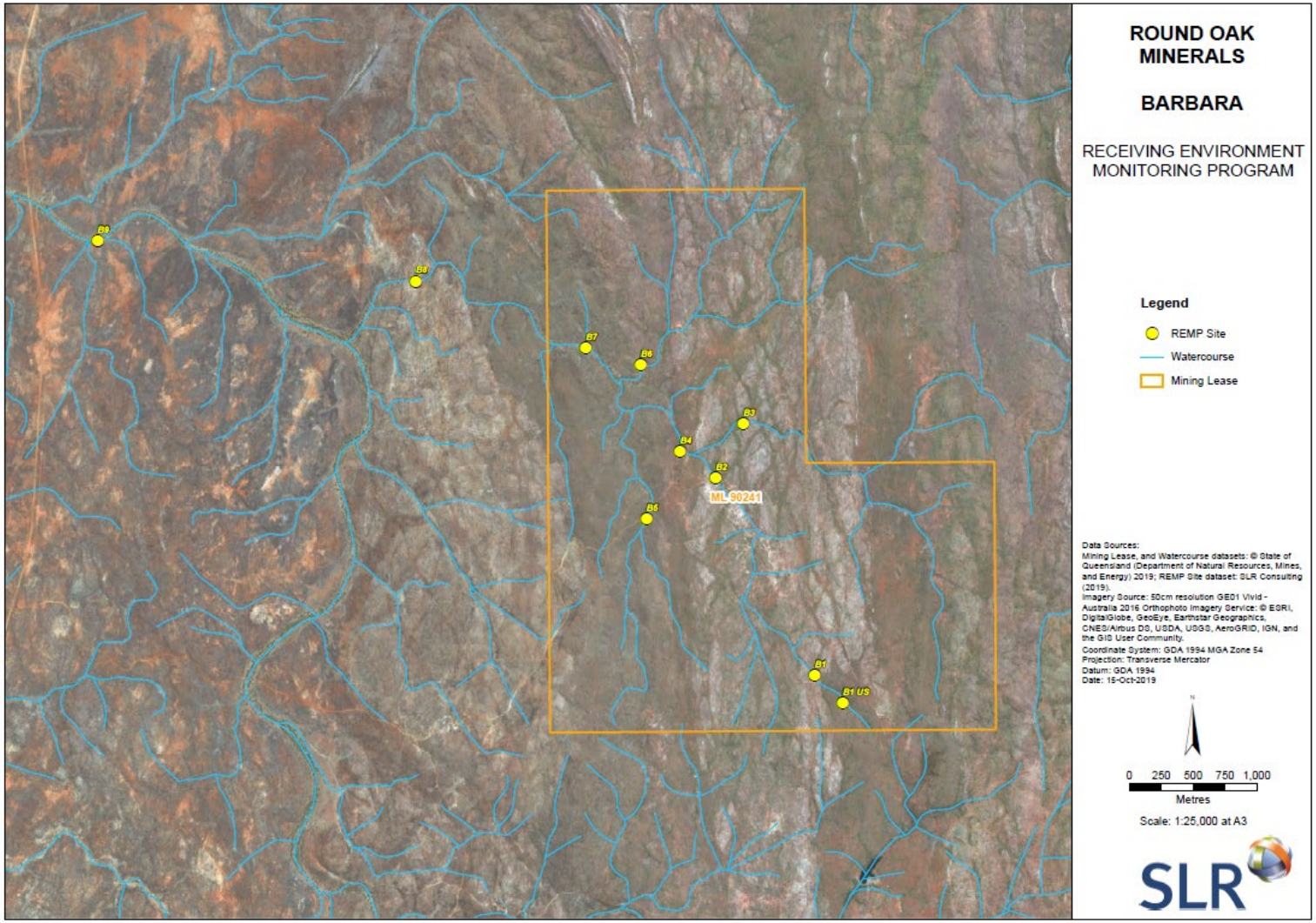


Figure 6 Aquatic Monitoring Site Locations

2.5.1 Surface Water Quality Characteristics

Monitoring of physiochemical characteristics for receiving waters of the BCO indicates pH is typically above the ANZECC high guideline value, while dissolved oxygen is below. Water turbidity was determined to be higher than the ANZECC guidelines at downstream sites B7 and B9 during the wet season and B3 during the dry season.

The concentration of heavy metals in surface water is typically within the limits defined by the ANZG guidelines, although exceedances for total and dissolved copper have been recorded at sites B3, B7, and B9 since the REMP was established at the BCO in 2018. Dissolved and total copper concentrations for these three sites are displayed in Figure 7 and are presented against the ANZG limit for comparison. One exceedance of total and dissolved cobalt was recorded at site B3 during the dry season 2020.

The cause of these heavy metal exceedances, particularly for copper is not known. However, as increases in copper concentrations have been recorded at upstream and downstream monitoring sites, this may be attributed to the highly mineralised local landscape and historical mine activity.

Macroinvertebrates observed at BCO provides an indication of water quality and is generally reflective of the highly ephemeral nature of receiving waters in the local region. The macroinvertebrates community consists largely of tolerant taxa and few PET taxa, thereby achieving low SIGNAL 2 scores. Due to inconsistent sampling, it is not possible to establish a temporal trend.

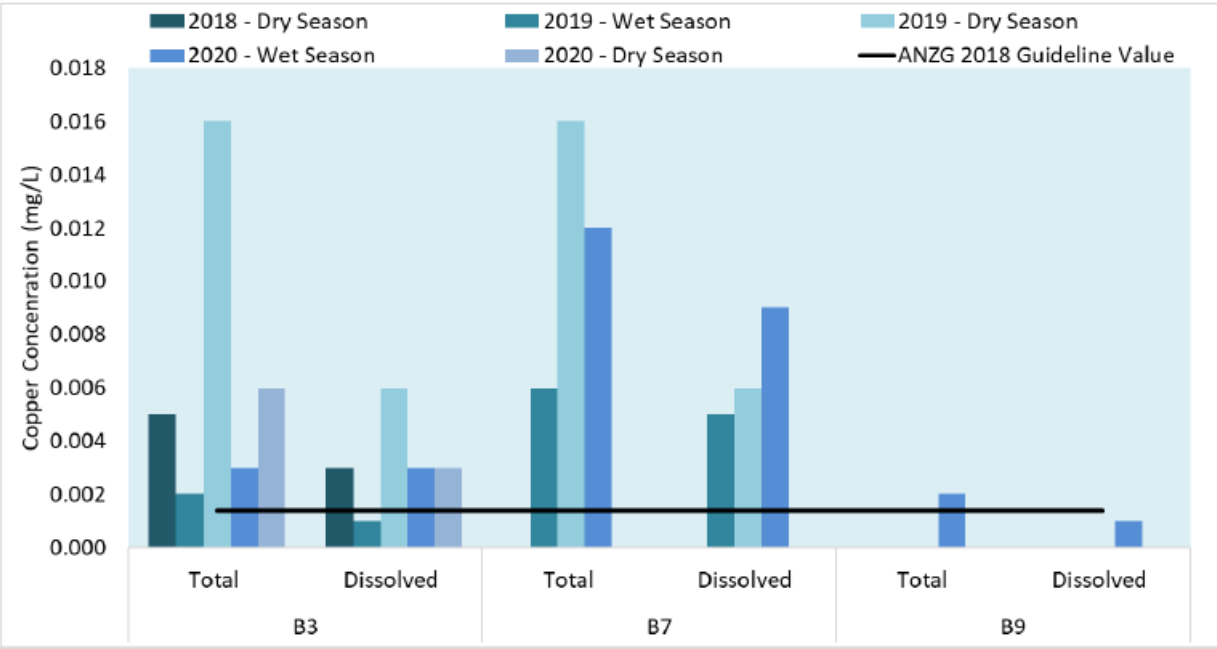


Figure 7 Temporal Comparison of Total and Dissolved Copper in Surface Water

3 Pre and Post Mine Land Use

Current land uses on the Project site include low intensity cattle grazing and mineral exploration activities. Historically, mining activities and cattle grazing have been the predominant land use; with evidence of this noted throughout the site, with fences, cattle grids, and disused mine shafts.

Where possible, rehabilitation aims to return the Project area to its former land use of low intensity grazing. Unless agreed to in writing by the post mining landowner/holder, all infrastructure, including water storage structures, will be removed from the site prior to ML surrender.

3.1 Land Suitability Classification

Land suitability classes refer to the capacity of the land resources to sustain land use such as cattle grazing, broadacre cropping, and conservation. These classes are derived through qualitative and quantitative interpretation of the data collected on the physical, chemical, and nutritional characteristics of the soil. The classification system ranks land suitability according to a five-class system. The classes are described in the Technical Guidelines (QDME 1995) as:

Class 1 Suitable land with negligible limitations which is well suited to a proposed use.

Class 2 Suitable land with minor limitations which is suited to a proposed use, but which may require minor changes in management to sustain use.

Class 3 Suitable land with moderate limitations which is moderately suited to a proposed use, but which requires significant inputs to ensure sustainable use.

Class 4 Marginal land with severe limitations which is marginally suited for a proposed use and would require major inputs to ensure sustainability. These inputs may not be justified by the benefits to be obtained in using the land for a particular purpose and is hence considered presently unsuitable.

Class 5 Unsuitable land with extreme limitations which preclude its sustainable use for the proposed purpose.

Land suitability for the Project area was determined from a SLSA conducted in 2014. The outcome of this SLSA for beef cattle grazing and rain-fed broadacre cropping are summarised in Section 3.1.1 and 3.1.2 respectively.

3.1.1 Beef Cattle Grazing

The most significant limitation to beef cattle grazing on the Project site is the soils' plant available water capacity (PAWC) and general nutrient deficiency of the soils within the study area. PAWC limitations stem from shallow soil resources. All soil management units were assessed as having a suitability class of 4 for grazing (Table 3).

Notwithstanding the classification derived from this assessment, grazing has been carried out on the lands within the area for many years.

Table 3 Land Suitability Classes for Beef cattle Grazing

Soil Management Unit	Most Limiting Factor/s	Land Suitability Class
SMU1	PAWC, Nutrient deficiency	4
SMU2	PAWC Nutrient deficiency	4
SMU3	PAWC, Nutrient deficiency	4

3.1.2 Rain-fed Broadacre Cropping

4 Geochemical Characterisation

In accordance with Condition G2 (f) of the EA, information regarding the geochemical characterisation of both waste rock material and ore material has been included as part of this PMLUP. Geochemical investigations were completed to assess the acid forming potential of waste rock and the potential release of metals and metalloids (particularly copper and sulphur) from the BCO waste rock. This will inform the environmental risk associated with waste rock and advise on appropriate waste rock management to ensure rehabilitated landforms achieve the required rehabilitation outcomes.

In 2014, geochemical characterisation of the waste rock at BCO was completed by Environmental Geochemistry International Pty Ltd (EGi). This study analysed 121 drill core samples from 14 drill holes across the North and the South Pit footprint. Standard geochemical analyses of drill samples were undertaken by EGi., with outcomes categorised based upon a 0.5% Copper (Cu) grade cut-off threshold for ore. In total, 27 samples were classified as ore, and 94 samples were classified as waste. Results from the 2014 geochemical testing are discussed in Section 1.

Additional geochemical characterisation of waste rock and ROM oxide was undertaken by EGi in 2020. Several geochemical analyses including kinetic column leach testing were conducted on a total of six samples collected from the South Pit. The outcome of the kinetic column leach testing from 2020 is detailed in Section 1.

4.1 2014 Geochemical Characterisation

4.1.1 Initial Drainage

Initial drainage tests were also performed by EGi, to provide an indication of the pH level expected from runoff reporting from waste and ore surfaces. The test method is designed to emulate 'first flush' runoff water quality, based upon a short duration contact time between rainwater and waste/ore.

The initial drainage analyses undertaken indicate that first flush surface runoff was expected to be circum-neutral to slightly alkaline (pH generally ≥ 7.5). It was concluded that the acidity/alkalinity of the initial drainage was not likely to be a significant water quality issue.

4.1.2 Acid Rock Drainage Classifications

Characterisation of Net Acid Producing Potential (NAPP) and Net Acid Generation (NAG) properties of the samples was undertaken to examine the potential for Acid Mine Drainage (AMD). AMD is the process by which sulphides oxidise when in contact with water and oxygen and form sulphuric acid. AMD is generally released over the longer term and is considered separately to 'first flush' runoff water quality. Some materials may exhibit both the capacity to generate acid, and to neutralise acid (Acid Neutralising Capacity or ANC), with the final classification based on the overall properties of the sample (rather than sulphide content independently).

Based upon the analyses undertaken, the samples were classified by EGi into the following classes:

- Non-Acid-Forming (NAF): the sample is not expected to generate acid in excess of the available ANC.

- Potentially Acid Forming (PAF): the sample may form sulphuric acid when in prolonged contact with water and oxygen.
- Uncertain (UC): the sample may or may not form acid.

Based upon the acid forming properties of the material, water which remains in contact for medium to long-term durations, may exhibit AMD.

NAPP and NAG characterisation demonstrates most waste rock samples are NAF, while ore samples are distributed between NAF and PAF (). An AMD classification plot displaying the concurrence of NAPP and NAG test results is provided in .

Table 4 Waste Rock Classification (ATCW, 2019)

Waste/Ore	Classification	Number of Analyte Results	Proportion
Waste Rock (Cu ≤ 0.5% Grade)	PAF	7	7%
	NAF	83	89%
	UC	4	4%
Ore (Cu > 0.5% Grade)	PAF	15	56%
	NAF	12	44%

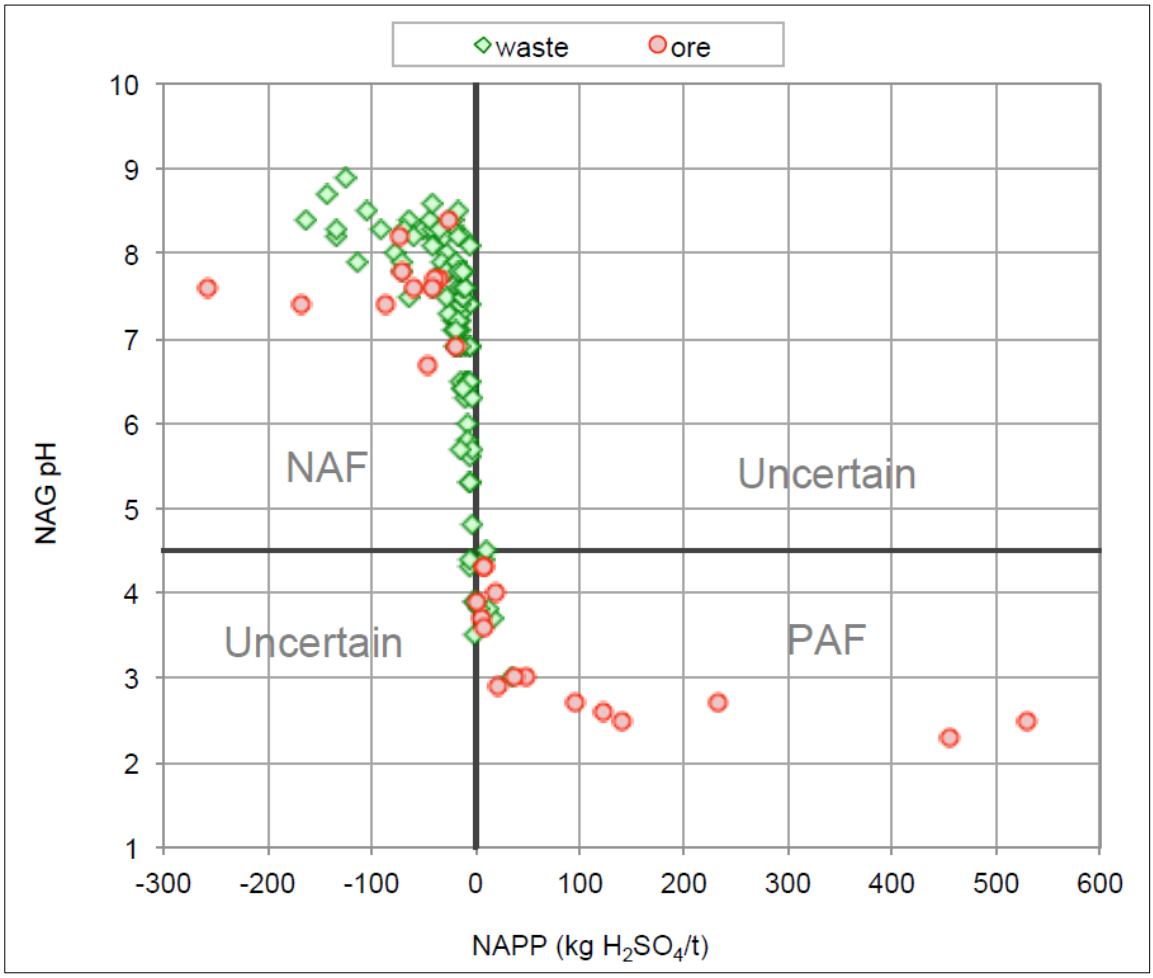


Figure 8 Acid Rock Drainage Characterisation of BCO Samples (EGi, 2014)

4.1.3 Reactivity of PAF Rock

Additional kinetic NAG analyses were conducted for five samples (three waste, two ore) of PAF rock, to provide an indication of the lag time before significant acid generation occurs. Accordingly, the five samples analysed were PAF samples. The determined outcomes are presented in .

Table 5 Acid Rock Drainage Samples - Acid Generation Lag Time (EGi, 2014)

Sample	Final pH	Lag Time
Ore #8050	3.1	Weeks to months
Ore #8112	2.7	At least a year to several years
Waste #8066	4.7	At least a year to several years
Waste #8092	3.0	Several years
Waste #8072	6.3	At least a year to several years

Overall, lag times for samples classified as PAF were significant, and likely to exceed a year.

Of the two analysed PAF ore samples, one was highly reactive (Ore #8050), with generation of acid expected to occur within weeks of being exposed to atmospheric conditions (water and oxygen).

NAF waste rock materials exhibited limited ANC, consequently blending of NAF and PAF samples may not result in significant changes to acid generation characteristics of the blended material, compared to the PAF material alone.

Additionally, sulphur speciation was conducted on the five samples used in the kinetic NAG analyses to determine the forms of sulphur present in rock. This revealed very minimal sulphate-sulphur present in rock with most sulphur present as sulphide-sulphur.

4.1.4 Acid Neutralising Capacity

The ANC of ore and waste rock was determined using the Sobek procedure. Results demonstrated ore samples having a moderate to high ANC with the median ANC for NAF ore samples at 98 kg H_2SO_4/t (10% $CaCO_3$ equivalent) and the median ANC for PAF ore samples lower at 47 kg H_2SO_4/t. The ANCs of waste rock samples was typically lower ranging from 13 to 49 kg H_2SO_4/t with a median of 21 kg H_2SO_4/t. Although ANCs for waste rock samples is lower than ore samples, kinetic NAG tests suggest waste rock ANC should still provide a reasonable lag if the rock is exposed to conditions conducive to sulphide oxidation.

4.1.5 Elemental Characterisation

Characterisation of the elements within each sample was undertaken using a geochemical abundance index (GAI) approach. Under this approach, the abundance of minerals within a sample is compared to reference materials which do not feature abundance or enrichment of specific elements.

The elements analysed included: Al, As, Ba, Be, Bi, Cu, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Sn, Sr, Th, U and Zn.

All elements detected in the waste rock and ore samples that are considered to be of minor (GAI = 1-2) to significant enrichment (GAI ≥ 3) are listed in and .

Table 6 Elemental Ore Characteristics

Material	Element	Abundance (Ration of Sample: Reference Material)	GAI	Description
Ore	Copper	≥24	≥3	Abundant
	Sulphur	≥24	≥3	Abundant
	Selenium	12 - 24	3	Significant Enriched
	Bismuth	12 - 24	3	Significant Enriched
	Cobalt	12 - 24	3	Significant Enriched
	Arsenic	12 - 24	3*	Significant Enriched
	Nickel	6 - 12	2**	Minor Enriched

**1 of 7 ore samples was classified as having a GAI of 3 for Arsenic, with 6/7 samples classified as having a GAI of 0 (Little to no enrichment)*
***2 of 7 ore samples were classified as having a GAI of 2 for Nickel, with 5/7 samples classified as having a GAI of 0 (Little to no enrichment)*

Table 7 Elemental Waste Characteristics

Material	Element	Abundance (Ration of Sample: Reference Material)	GAI	Description
Waste	Copper	12 - 24	3	Significant Enriched
	Sulphur	12 - 24	3	Significant Enriched
	Selenium	12 - 24	3	Significant Enriched
	Bismuth	6 - 12	2	Minor Enrichment
	Cobalt	6 -12	2	Minor Enrichment

4.1.6 Water Extractable Elements

The elemental characterisation provides an indication of elements enriched in the solid rock material, however, may not be indicative of the potential for metal leaching to water. The leaching potential of ore and waste rock was, therefore, determined using an extraction with deionised water. The composition of water extract is representative of the state of chemical equilibration between the liquid and solid phase at the natural pH of the material. Results from the water extraction test suggest drainage from freshly mined waste rock is typically slightly alkaline (median pH = 9.0) and has low concentrations of soluble salts (median EC = 200 µS/cm). Furthermore, concentrations of metals of environmental importance are considered low and are as follows:

- ≤ 0.0001 mg/L Hg, Cd
- ≤ 0.001 mg/L Cr, Co, Mn, Ni, Pb, Sb, Sn
- ≤ 0.002 mg/L As, Cu
- ≤ 0.005 mg/L Mo, Zn
- ≤ 0.01 mg/L Se

Similarly, it is expected that the drainage from stockpiles of recently mined ore would be alkaline and have low concentrations of dissolved metals. However, there is potential for leaching of sulphate from high grade ores.

4.1.7 Saline Drainage

Analyses of EC were performed to provide an indirect measure of the soluble salt content of mined rock and to assess the potential for saline drainage if material is exposed to atmospheric conditions. provides a summary of EC values per rock unit.

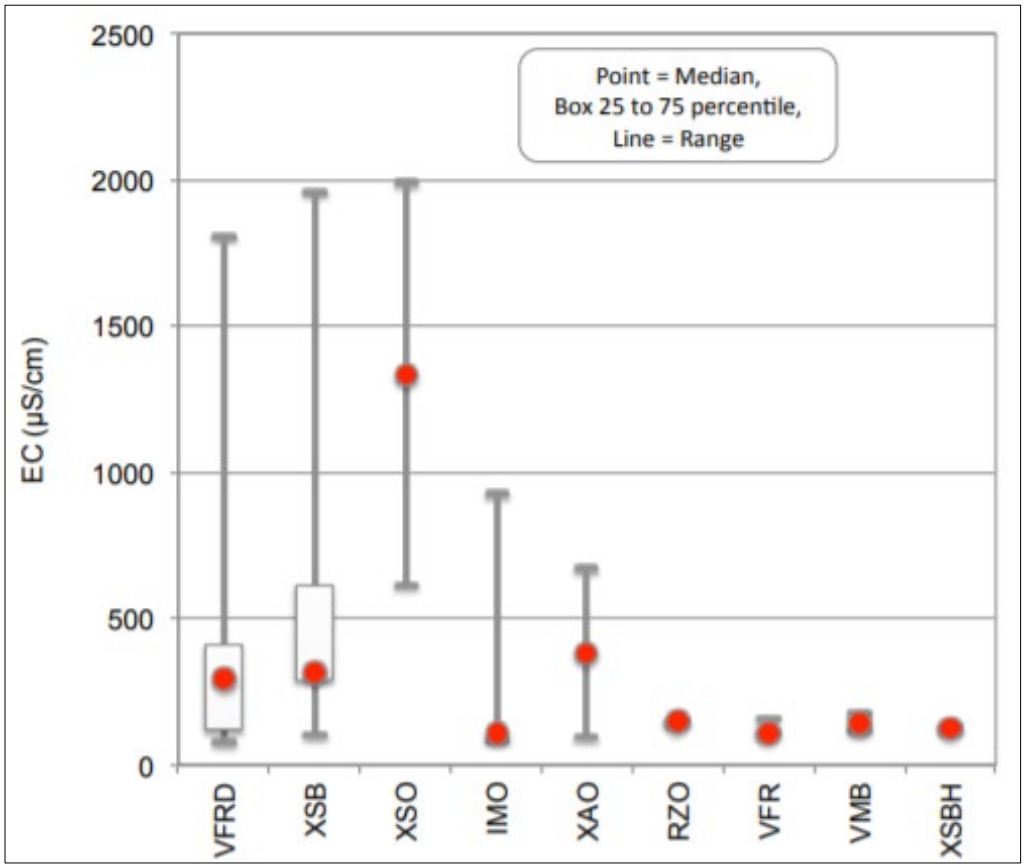


Figure 9 Summary of EC Values for All Rock Units Within Barbara Drill Core Samples

From the results presented in , the following outcomes can be determined:

- 72% of the 87 VRFD analyses - generally comprising of the predominant waste rock unit (Porphyritic Rhyolite), resulted in an EC of less than 400 µS/cm, representative of 'non-saline water'.
- 21% of the 87 VRFD analyses resulted in an EC between 400 and 800 µS/cm, representative of 'slightly saline water'.
- 13 of the 121 drill core analyses conducted were classified indirectly as 'saline' (≥800 µS/cm). It is noted that 12 of the 13 analyses resulting in a 'saline' classification comprised high sulphur ore materials.

Based upon the EGi (2014) results, it was concluded that saline drainage was not considered a significant water quality issue, with respect to waste rock materials. Drainage from ore materials may be saline.

4.1.8 Summary of Potential Contaminants

4.1.8.1 *Waste Rock*

Potential contaminants at the BCO predominantly relate to the mineral extraction activities within the North and South Pit.

Based upon the geochemistry investigation conducted by EGi (2014), potential water quality issues and contaminants relating to waste rock material may include the following:

- Copper, sulphur, selenium (Significantly Enriched Elements); and
- Bismuth, cobalt (Enriched Elements).

Regarding the acid generation capacity of waste rock, most samples tested were NAF, however, approximately 10% of samples tested were classified as PAF. Lag times for significant acid generation to occur (based on 3 samples) are expected to exceed one (1) year. Additionally, suspended sediment levels of runoff generated from waste surfaces is likely to become elevated.

4.1.8.2 *Ore Material*

Water quality issues may relate to the ore streams extracted from the North and South Pit developments, as follows:

- Copper, sulphur (Abundant Elements);
- Selenium, bismuth, cobalt, arsenic (Significantly Enriched Elements); and
- Nickel (Minor enrichment).

With respect to the acid generation capacity of ore material, 56% of the ore samples tested were classified as PAF. Lag times for significant acid generation (based on 2 samples) varied from 'weeks' to 'years'.

4.2 2020 Geochemical Characterisation

The six samples were collected from various geological units according to geochemical characteristics. One sample was considered PAF, three samples represented NAF waste rock and the remaining two samples represented ROM oxide.

4.2.1 Acid Forming Characteristics

Chemical characterisation of three of the NAF samples and the two ROM oxide samples indicate NAF characteristics. One NAF sample recorded significant sulphide concentration, although this sample also presented moderate to high ANC which resulted in a negative NAPP test and was subsequently confirmed to be NAF. The PAF Sample recorded a positive NAPP result and acidified during the NAG test. The acid forming characteristics of samples are summarised in and .

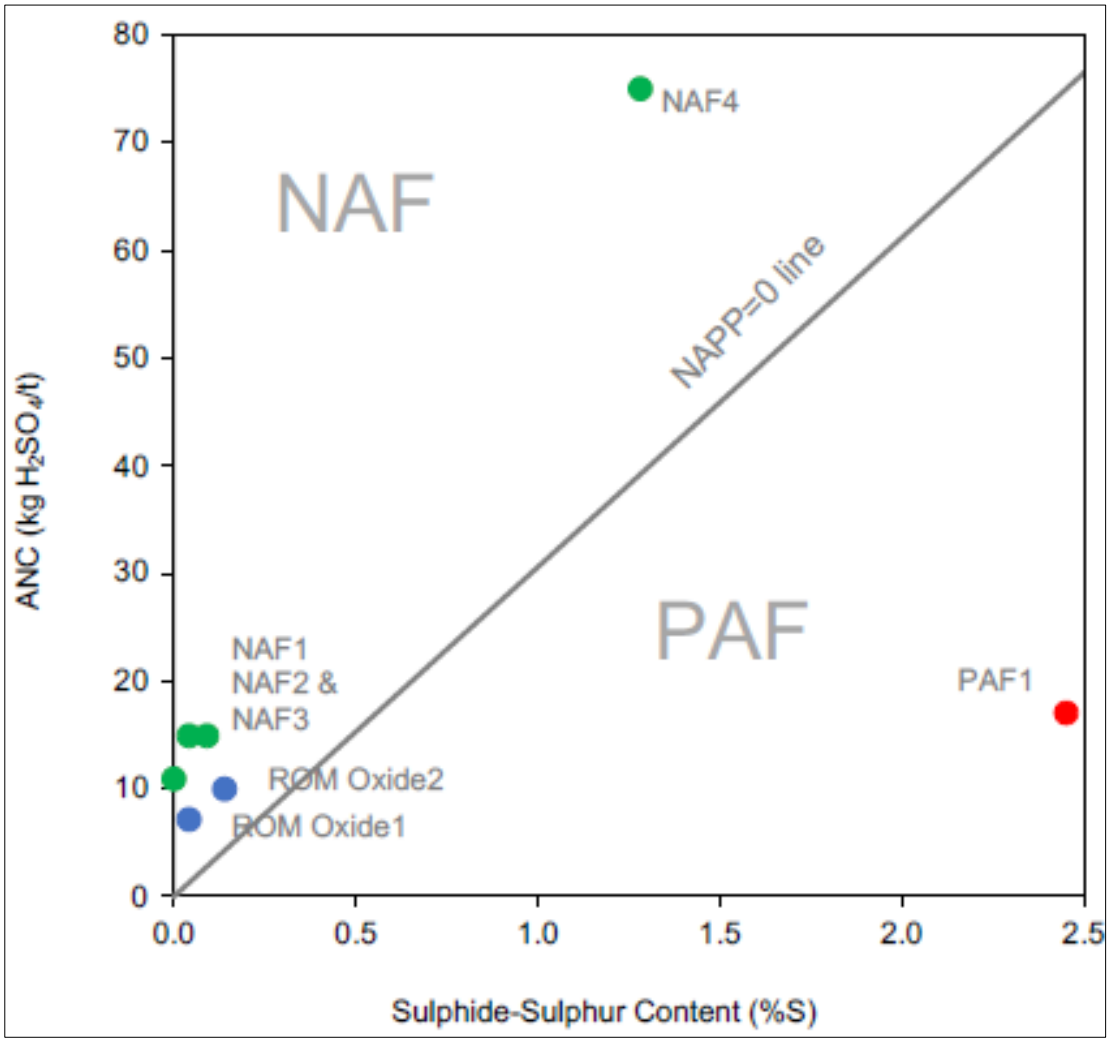


Figure 10 Acid Rock Drainage Plot for Barbara Waste Rock and ROM Oxide

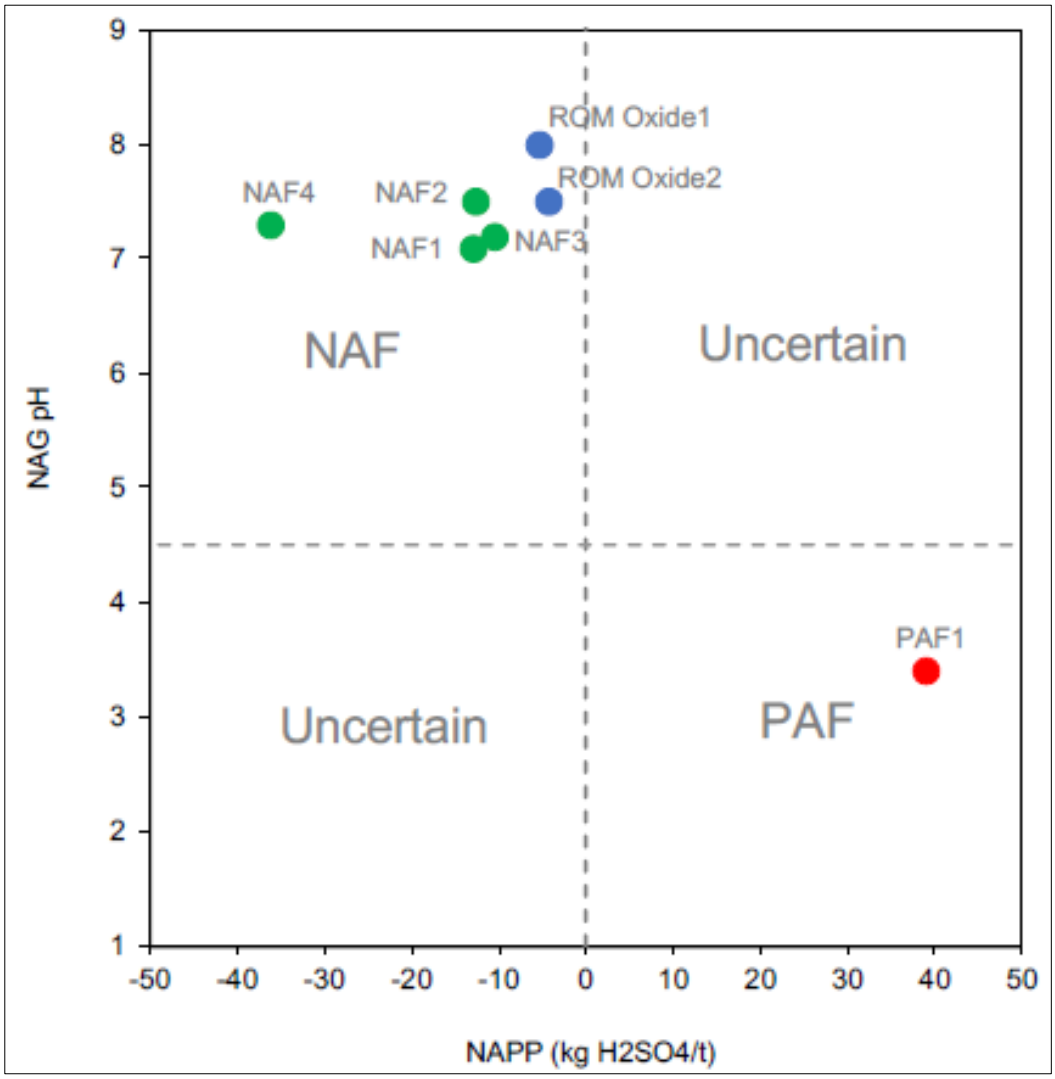


Figure 11:ARD Classification

4.2.2 Sulphur Speciation and Reactivity

Sulphur speciation was undertaken on samples to differentiate between sulphide and sulphate, that is, species of sulphur that are acid forming and non-acid forming.

Two samples, one NAF and one PAF presented significant sulphide content. Although, both samples had elevated copper which indicates the process of copper sulphide mineralisation.

The PAF sample recorded a sulphide content of 2.45%. Based on the copper content of 0.79%Cu, it is estimated that approximately two-thirds of sulphur exists as pyrite, with the remaining third existing as chalcopyrite. The NAF sample recorded a sulphide content of 1.32% and a copper content of 1.05%Cu. Based on this sulphide and copper concentration, it was determined that 1.06%S of sulphide exists as chalcopyrite, with 0.22%S is present as pyrite. Sample composition is presented in .

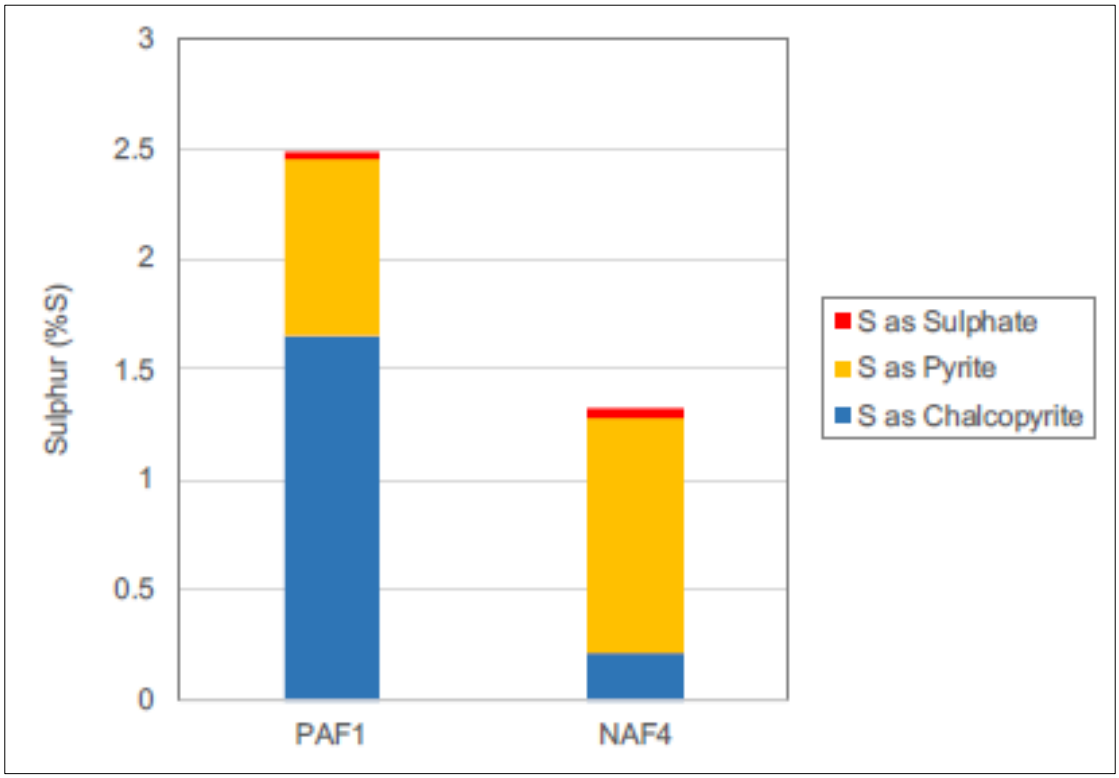


Figure 12 Sulphur Speciation in Column Leach Test Samples

4.2.3 Sulphur Reactivity

The reactivity of sulphides in the PAF sample was assessed during a monitored NAG test. The monitored NAG test revealed an initial lag in acidification, attributed to the acid neutralising capacity of the rock material. After the lag period, pH began to decline while temperature increase as sulphidic material was oxidised. The results of the monitored NAG test are presented in and indicate the sulphidic mineralisation is reactive, however, the lag period suggests acidification will only occur after many months or years under field conditions.

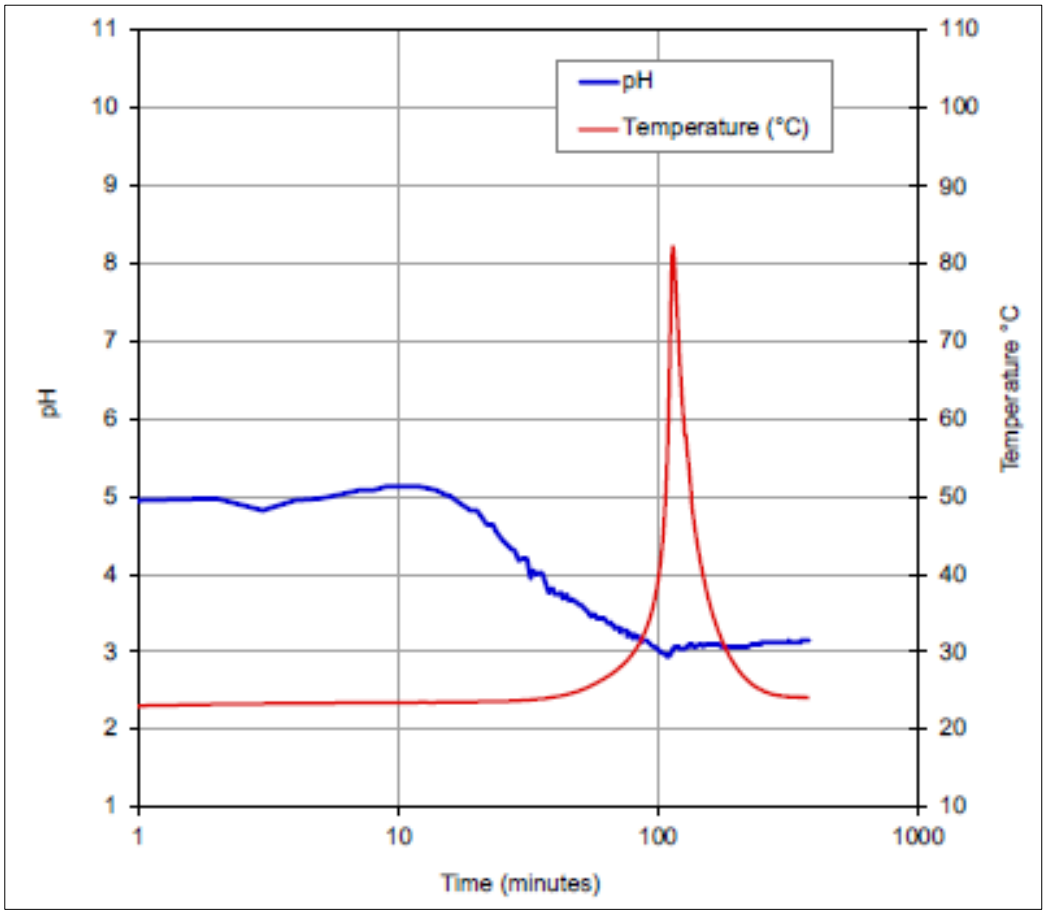


Figure 13 Monitored NAG pH Profiles for PAF Waste Rock and Low-grade Ore Samples

4.2.4 Carbonate Neutralising Value

Two assessments for acid neutralising potential were conducted on samples, namely ANC and carbonate neutralising value (CNV). Results are presented in . For all samples, CNVs were below ANC values. This suggests most acid neutralising capacity in rock is a result of carbonate mineralisation. This is particularly true for sample NAF4 which has the highest ANC. It is anticipated that for samples with very low ANCs, some acid neutralising may be derived from gangue minerals such as silicates.

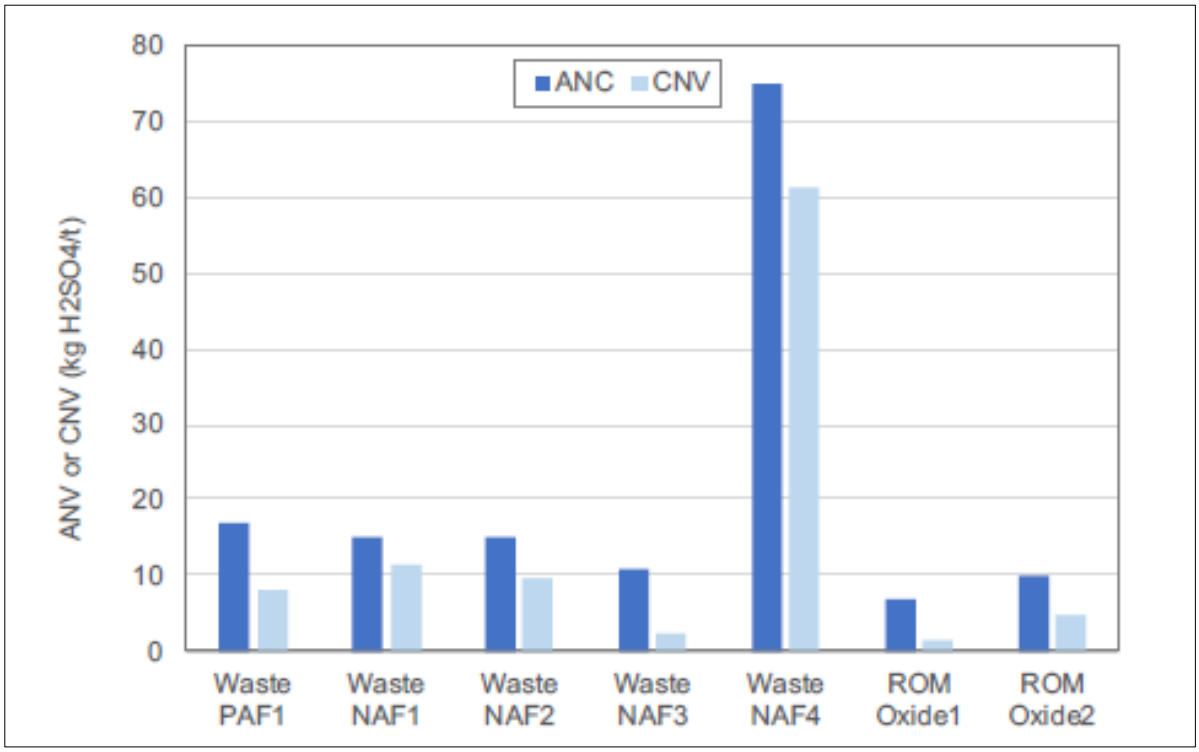


Figure 14 Comparison of Carbonate Neutralising Value and Acid Neutralising Capacity

4.2.5 Acid Buffer Characteristics

An acid buffer curve was developed for sample NAF4 as this sample presented significant ANC and high copper sulphide content. The outcome provides a measure of the buffering provided by more soluble carbonates within a sample. The buffer curve is presented in against buffer curves of reference samples (limestone, dolomite, ferroan-dolomite, magnesite and siderite). The buffer curve indicates limestone is readily available for neutralisation. Dolomite is also reactive; however, the reactivity may decline when there is significant iron substitution resulting in the formation of ferroan dolomite. The buffer curve indicates sample NAF4 aligns closely with ferroan-dolomite.

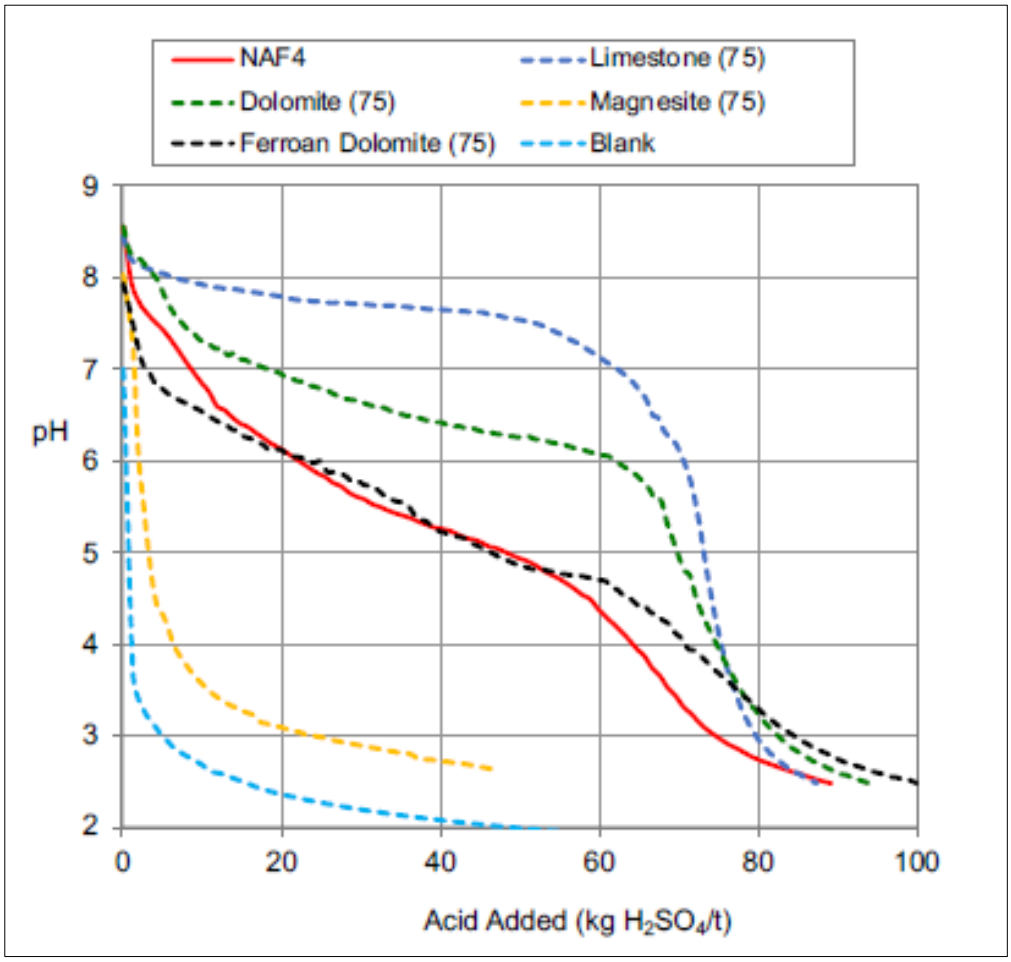


Figure 15:Acid Buffer Characteristics Curve for Sample NAF4

4.2.6 Multi-elemental Analysis of Solids

Elemental analysis of solids was undertaken to determine if particular elements occur at a concentration significantly greater than median background soil abundance values. As expected, all samples recorded copper contents higher than the median copper concentration in soil. Several additional elements were detected at higher concentrations relative to background soil abundance which may be environmentally significant, these are presented in .

Table 8:Minor and Significant Elements of Geochemical Abundance

Sample ID	Significant (GAI≥3)	Minor (GAI 1 or 2)
PAF1	Cu, Co, Se, s	As, Mg, Ni
NAF1	-	Cu
NAF2	-	Cu, As, Co, Cr, Mg
NAF3	Cu	Co, Mg
NAF4	Cu, S	Co, Mg, Se

Sample ID	Significant (GAI≥3)	Minor (GAI 1 or 2)
ROM Oxide 1	Cu	Co, Mg, Se
ROM Oxide 2	Cu	Co, Mg, Se

4.2.7 Column Leach Test

A column leach test was conducted to assess the kinetic geochemistry of waste rock. The column leach test occurred for one-year under conditions amenable to sulphide oxidation. The column was flushed every three weeks with the leachate collected for elemental analysis.

The first-flush leachate collected from all samples was found to be alkaline, low in soluble salts, contained only trace concentrations of aluminium, iron and manganese. Dissolved metal concentrations were generally below the limits of analytical detection.

A summary of chemical characteristics for the leachate produced from each sample for weeks 4-52 is provided in .

Table 9: Summary of Leachate Analysis from Week 4 to 52

Sample ID	Leachate Characteristics
PAF1	pH remained circum-neutral signifying the sample was in lag phase. Release of sulphate remained relatively low – ranging between 155 to 334 mg/L which indicates slow rate of sulphide oxidation. No leaching of iron or copper as a result of slow rates of pyrite and chalcopyrite oxidation. Despite significant enrichment of cobalt and selenium and minor enrichment of arsenic and nickel in the sample, arsenic concentration was below detection limits while only trace concentrations of cobalt, nickel and selenium were present in leachate. Only minor leaching of manganese and aluminium were recorded.
NAF 1 and NAF2	pH of leachate remained alkaline. Sulphate concentrations remain very low for the duration of the column leach (NAF1 average of 20 mg/L and NAF2 average of 47 mg/L. Results indicate sulphide oxidation is near non-existent. Calcium was recorded as a major cation in leachate with the average calcium concentration of 11 mg/L and 21 mg/L in NAF1 and NAF2 respectively. Concentration of copper, cobalt and chromium indicates no significant leaching of these metals. NAF2 presented minor leach of arsenic with concentrations in leachate increasing in the first six months before stabilising at 0.03 mg/L.

Sample ID	Leachate Characteristics
NAF4	pH of leachate remained slightly alkaline for the duration of the column test. Although leachate remained alkaline, there was a significant release of sulphate during the test with and average sulphate concentration of 452 mg/L at a release rate of 32 mg/kg/week. This corresponds to an IOR of $4.8x10^{-8}$ kg/O_2/m^3/sec. which is in the moderate range for sulphidic rock. Significant leaching of calcium was detected which reflects the carbonate minerals within sample reacting with the acidity generated by sulphide oxidation. Release of magnesium was also reported, suggesting carbonate mineralisation may have been partially dolomitic. Although the sample had a high copper content, the concentration of copper in leachate was minor at around 0.01 to 0.04 mg/L. It is thought that copper released during oxidation likely reprecipitated as copper oxyhydroxide. No significant leaching of iron, manganese, or any other element of environmental significance was detected.
Oxide ROM1 and ROM2	Both ROM oxide samples remains circum-neutral during the column leach test. Release of sulphate occurred during the first few months of the test, however this decreased thereafter. The copper concentration of leachate indicates some evidence of copper leaching, although results indicate a pH-dependent solubility control for copper release. As such, copper leaching is expected to remain constant as a result of circum-neutral pH. No significant leaching of cobalt or other metals of environmental significance was detected.

5 Rehabilitation Requirements

As per condition G3, rehabilitation will be undertaken progressively within a reasonable timeframe in accordance with the Plan of Operations. Each disturbance area within the mine footprint will form unique rehabilitation areas with a post-mining land use and defined rehabilitation goals, objectives, indicators, and completion criteria, to ensure that rehabilitation works are completed in an appropriate manner.

5.1 Rehabilitation Areas

Each disturbance area requires a specific approach to rehabilitation with consideration for both the rehabilitation hierarchy and rehabilitation goals. Each mine domain will be rehabilitated unless stipulated by the landholder.

In general, the site will be rehabilitated as follows:

- buildings and equipment will be dismantled and removed from site;
- internal access roads and tracks will be ripped and revegetated;
- where drains or bunding are not required for flood and/or erosion protection they will be levelled or used as fill;
- sediments will be cleaned from dams and sumps, regraded and revegetated; and
- materials that can be recycled and/or reused will be removed from site and directed to appropriate contractors for reprocessing or taken to a waste transfer station.

Disturbance areas associated with the Project site, as defined in Table A1 (Authorised Mining Activities) of the EA are outlined in Table 11. In total, there are four main types of disturbance associated with the Project, comprising of ten disturbance areas.

Table 10 Disturbance Areas for Rehabilitated (adapted from EA EPML02840015 Table A1

Disturbance Type	Disturbance Area Name	Disturbance Area (ha)
Mining Area / Void	North Pit	1.5
	South Pit	6
Waste	WRD	23
Ancillary Infrastructure, ROM, Exploration	ROM Pad & ore stockpiles	3.0
	Site Roads	20.5
	Light infrastructure area: Administration buildings, fuel storage, power facility, workshop area, concrete mixing	2.7
	Sewage Treatment Facility	Nil, included in administration buildings above
	Explosives Magazine	0.5
	WRD Sediment Dam	4
Diversions	Diversion Drains	0.5
Total Disturbance		61.7

5.2 Rehabilitation Goals

Mine rehabilitation is a requirement under the EP Act. Amendments to the EP Act in late 2018 implemented key elements of the State Government's Mined Land Rehabilitation Policy (Queensland Government 2018). These broad rehabilitation goals are reflected in the BCOs existing rehabilitation objectives under the EA (Section 5.3).

The three general rehabilitation goals for all areas disturbed by mining in Queensland are:

- The land is safe and structurally stable;
- There is no environmental harm being caused by anything on or in the land; and
- The land can sustain a post-mining land use (section 111A of the EP Act).

5.3 Rehabilitation Objectives

As mentioned above, the BCOs current EA details site-specific rehabilitation objectives that align with the general rehabilitation goals defined by the Queensland Government. Condition G1 of the EA requires rehabilitated land to achieve the following rehabilitation objectives:

- Safe for humans and wildlife;
- Non-polluting;
- Stable;
- Able to sustain an agreed post-mining land use agreed to by the administrating authority and any underlying landholders;

- Revegetated with species endemic to the area with no declared pest species; and
- Compliant with all conditions of the EA.

5.4 Completion Criteria

Completion criteria are a set of measurable benchmarks that provide a clear definition of rehabilitation success for each disturbance area. These benchmarks can be compared against the rehabilitation indicators (Section 5.5) to determine whether rehabilitation objectives are being met. Completion criteria for the Project are provided in Table 12, Section 5.6.

5.5 Rehabilitation Indicators

Rehabilitation indicators are being used to provide a measurement of progress towards rehabilitation objectives. In some instances, several indicators will be relevant for one objective, and one indicator may have relevance for more than one objective.

Rehabilitation indicators for the Project are provided in Table 12, Section 5.6.

5.6 Assessing Rehabilitation Success

The rehabilitation objectives for each mine domain and the corresponding completion criteria and rehabilitation indicators are outlined in Table 12.

The rehabilitation monitoring program (described in detail in Section 8) will provide evidence of the completion criteria success. The domains within the Project site are deemed to be successfully rehabilitated when completion criteria for each rehabilitation goal and objective have been achieved within an appropriate timeframe and determined appropriate to the level of environmental risk presented by the final landform.

Table 11 Mine Domains with Corresponding Rehab Objectives, Indicators and Completion Criteria

Mine Domain	Rehabilitation Objective	Indicators	Completion Criteria
Voids	Safe for humans and wildlife	Engineered structures and signage to preclude humans and animals (e.g., safety bund wall, signage at entrance and access roads blocked off).	Rehabilitation report: that all safety precautions have been taken in accordance with the relevant legislation – Signs comply with AS 1319:1994 – Safety Signs for the Occupational Environment.
		Safety assessment of final landform by suitably qualified person (i.e. geotechnical assessment with photographic evidence).	Rehabilitation report: geotechnical assessment to determine risk of wall failure / suitable extent of safety bund wall.
	Non-polluting	Contamination assessment of final landforms by suitably qualified person (i.e. grade control and waste rock management).	Rehabilitation report: certification of assessment and any remedial work.
		Monitoring (void water quality, surface water, groundwater and stream sediment) to meet site-specific water quality objectives and limits.	Rehabilitation report: assessment and certification of analytical results within applicable guideline values.
	Stable	Geotechnical assessment of risk on final voids with photographic evidence.	Rehabilitation report: geotechnical assessment on risk of wall failure.
		Residual risk assessment of final landforms.	Rehabilitation report: residual risk assessment and control measures.
Waste Rock Dumps / Sediment Dam	Safe for humans and wildlife	Safety assessment of final landform by suitably qualified person.	Rehabilitation report: certification structurally safe for post mine land use.
	Non-polluting	Contamination assessment of final landforms by suitably qualified person (i.e. grade control, waste rock management).	Rehabilitation report: post closure monitoring shows the final landform is compliant with established and applicable limits.

Mine Domain	Rehabilitation Objective	Indicators	Completion Criteria
		Contamination assessment of final landforms by suitably qualified person (i.e. grade control and waste rock placement).	Rehabilitation report: certification that the waste rock dumps have an adequate landform design and construction to prevent any release or seepage of hazardous or contaminated material.
		Rehabilitation monitoring plan in place to monitor receiving environment (i.e. downstream surface water /groundwater).	Rehabilitation report: monitoring data demonstrates the landform is benign and functioning to prevent release or seepage of hazardous or contaminated material to the receiving environment.
	Stable	Geotechnical assessment of final landforms.	Rehabilitation report: geotechnical assessment to determine landform stability.
	Able to sustain a post-mining land use agreed to by the administering authority and any underlying landholders	Residual risk assessment of final landforms.	Rehabilitation report: appropriate risk assessment and control measures.
	Revegetated with species endemic to the area with no declared pest species	Vegetation assessment percentage of cover.	Rehabilitation report: Equal or greater than 60% of comparable species to the analogue site.
		Abundance of weeds.	Rehabilitation report: Weeds not to exceed 10% more than percentage cover of analogue site.
Ancillary Infrastructure, Roads & Exploration Areas	Safe for humans and wildlife	Safety assessment of final landform by suitably qualified person.	Rehabilitation report: Certification structurally sound and safe.
	Non-polluting	Contaminated land assessment.	Evidence of remediated landform in a contaminated land assessment report.
		Rehabilitation monitoring plan in place to monitor downstream surface/groundwater.	Rehabilitation report: monitoring data meets specified contaminant and trigger levels that ensure environmental values are not being compromised.

Mine Domain	Rehabilitation Objective	Indicators	Completion Criteria
	Stable	Engineers' assessment of design and construction of structures to control water flow.	Rehabilitation report: Engineer certification that infrastructure sites (both remaining and decommissioned) have the required structures to control water flow and runoff.
	Revegetated with species endemic to the area with no declared pest species	Vegetation assessment percentage of cover.	Rehabilitation report: Equal or greater than 60% of comparable species to the analogue site.
		Abundance of weeds.	Rehabilitation report: Weeds not to exceed 10% more than percentage cover of analogue site.
Water Infrastructure	Safe for humans and wildlife	Safety assessment of final landform by suitably qualified person. Safety barriers and signage.	Rehabilitation report: Certification structurally sound and safe, all precautions implemented.
	Non-polluting	Rehabilitation monitoring plan in place to monitor water in the ponds and downstream surface/groundwater.	Rehabilitation report: post closure monitoring (water quality) is compliant with established and applicable limits.
	Stable	Geotechnical studies of final landforms.	Rehabilitation report: geotechnical studies to determine whether final landform is stable.
		Risk assessment of final landform.	Rehabilitation report: appropriate risk assessment and control measures have been undertaken.
	Revegetated with species endemic to the area with no declared pest species	Vegetation assessment percentage of cover.	Rehabilitation report: Equal or greater than 60% of comparable species to the analogue site.
		Abundance of weeds.	Rehabilitation report: Weeds not to exceed 10% more than percentage cover of analogue site.

5.6.1 Revegetation Completion Criteria

Revegetation completion criteria have been developed to measure revegetation progress. Once rehabilitated sites have achieved the revegetation completion criteria (typically three years), it is reasonable to assume that these sites are capable of self-sustaining natural vegetation or habitat.

Proposed revegetation completion criteria are presented in Table 13 and are used to compare the success of rehabilitation sites against analogue monitoring sites described in Section 8.

Table 12 Revegetation Completion Criteria

Criteria	Revegetation Completion Criteria
Vegetation Density / Percentage of Ground Cover	Equal or greater than 60% of comparable species to the analogue site
Abundance of Weeds	Weeds not to exceed 10% more than percentage cover of analogue site

5.7 Rehabilitation Success

Rehabilitation success criteria that have been adopted for the Project are described in Table 14 and will be used to demonstrate disturbed and constructed landforms meet post-mine land use (PMLU).

Table 13 Rehabilitation Success Criteria

Criteria	Rehabilitation Success Criteria
Landforms	Non-polluting, safe and stable with no rill erosion deeper than 50 cm
Landform Design	WRD batter slopes – <36 degrees to the angle of repose Residual Voids – Restricted access by means of either fence, abandonment bund or a combination
Land Capability	WRD – Land Class VIII – not suitable for agricultural purposes, PMLLU of Native Ecosystem Services Residual Void – Land Class VIII – ,PMLU of Water Storage Mine Infrastructure Areas - Land Class VI, PMLU of Low Intensity Grazing

Monitoring of the rehabilitation areas will be undertaken (Section 8) annually to provide data that substantiates the performance of the rehabilitation from completion of rehabilitation activities to relinquishment. If during a subsequent monitoring event, a rehabilitation area fails to meet the success criteria or the area is not trending towards the success criteria, the following steps will be undertaken:

- An investigation into the reasons for failure or regression of rehabilitation. In some cases, the cause may be a naturally occurring event, such as a fire event, and not due to the failure of the rehabilitation method;
- If necessary, a risk assessment to determine whether remedial actions are required. This may occur when the ground cover is not sufficient to prevent erosion of the rehabilitation area; and

- The decision to conduct remedial actions will be undertaken through the close liaison with regulatory authorities to identify the best approach. Possible remediation activities may include the use of fire, thinning or the additional seeding of areas.

Upon identification of the cause of failure to comply with rehabilitation success criteria and the completion of remedial activities (if required), the area of rehabilitation will be monitored annually until the criteria have been met.

6 Rehabilitation Plan and Landform Design

Rehabilitation strategies and methods for the Project have been developed in accordance with the guideline *Rehabilitation Requirements for Mining Resource Activities* (DES, 2014).

The rehabilitation hierarchy, in order of decreasing capacity to prevent or minimise environmental harm, is as follows:

1. Avoid disturbance that will require rehabilitation;
2. Reinstate a "natural" ecosystem as similar as possible to the original;
3. Develop an alternative outcome with a higher economic value than the previous land use;
4. Reinstate previous land use;
5. Develop a lower value land use; and
6. Leave the site in an unusable condition or with a potential to generate future pollution or adversely affect environmental values.

The hierarchy allows for lower values to be acceptable when they will be appropriate to the stakeholders or when higher values are impractical. However, leaving the site in an unusable condition or with the potential to cause further environmental harm is not considered acceptable and has not been proposed for the Project.

The following sections detail the final landform design of each disturbance type. The outcome from several geotechnical, groundwater and surface water technical studies have been incorporated into the final landform design to be implemented at the BCO.

6.1 Final strati

Both Pits will achieve the PMLU of Water Storage for post closure. To ensure the final voids achieve the nominated rehabilitation objectives (Table 12), the North and South Pit areas have been subject to detailed geotechnical assessment by Pells Sullivan Meynink Consult Pty Ltd (PSM 2020).

The structural model developed for voids at the BCO is based on mapping completed by PSM and ROM within the South Pit during the Quarterly Geotechnical Inspections. The structural database consists of data from field mapping undertaken by ROM and additional field and photogrammetric mapping undertaken by PSM. Structural data from geotechnical investigations show major structures in the rock mass comprise of foliation and faults/shears:

- Foliation is identified as the predominant defect within the schist rock mass, compromising two splays of the Barbara Fault Zone (BFZ)), and is also present in localised zones of weakly foliated felsic volcanics adjacent to the schist; and
- Other sporadic faults and shears that may also be present within the rock mass.

Structural data also demonstrates minor structures in the rock mass that are less continuous with jointing the main defect type (PSM 2020).

Five domains have been mapped across the structural model from the South Pit. Structural integrity of each domain has been summarised by PSM as follows (PSM 2020):

- Domain 1 and Domain 2 (east wall of the South pit):
    - Most joint defects dip greater than 60° towards the west. Joints mapped in the north-east part of the East wall, Domain 2, are slightly rotated likely due to the proximity to the BFZ.
    - Faults and shears are present in Domain 1 and Domain 2. These are generally moderately to steeply dipping (greater than 55°) but some moderately to shallow dipping faults and shears are also present.
- Domain 3, Domain 4, and Domain 5 (west wall of the South pit):
    - Most defects dip greater than 75° towards the east, except for a cluster of joints exposed in Domain 4 that dip between 30° and 50° towards north-northeast (NNE).
    - The shallow defect set dipping towards the NNE is evident within Domain 4, and typically have a persistence of less than 5 m.

The North Pit presents similar structural characteristics, although PSM also note:

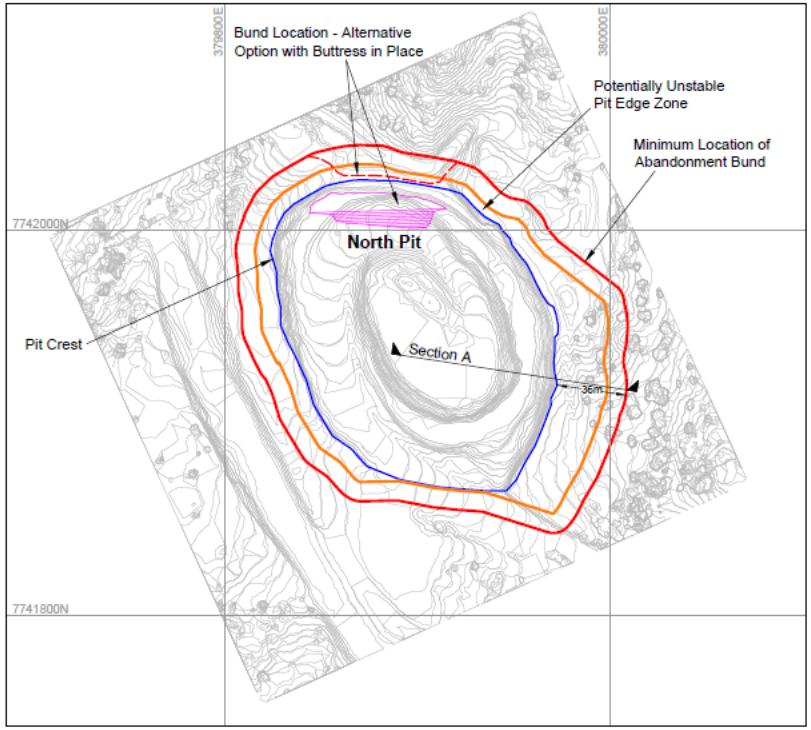
- Joint sets form cubic blocks, resulting in a blocky to very blocky character; and,
- Poorer structural conditions are associated with the BFZ as dilation and poorer rock mass have been observed around this zone.

The primary objective of the mine closure assessment undertaken by PSM was to identify the most stable long-term crest location and to demarcate an appropriate exclusion zone around the perimeter of each final void based on the predicted long-term slope stability. This will inform planning for the abandonment bund to prevent access to the void.

The location of the abandonment bund for the North Pit is presented in Figure 16. Following the assessment of slope stability, the suitable location for the abandonment bund typically varies between 15 to 20 m from the pit permitter, except for in the south-east (the assessed potentially unstable pit edge zone delineated by Section A in Figure 16) where it should be located 36 m behind the pit crest due to a deeper weathering profile.

The location of the abandonment bund for the South Pit is presented in Figure 17. Due to the potentially unstable pit edge zones delineated by Section B and Section C in Figure 17, the minimum location of the bund has been determined at 14 m and 32 m behind the pit crest respectively.

Signs that communicate the risk to public safety and prohibit public access are erected at suitable locations. A security gate prevents unauthorised access to the mine site. Seeding along the external edge of the bund will be established where practicable to reduce the visual impact of the bund.



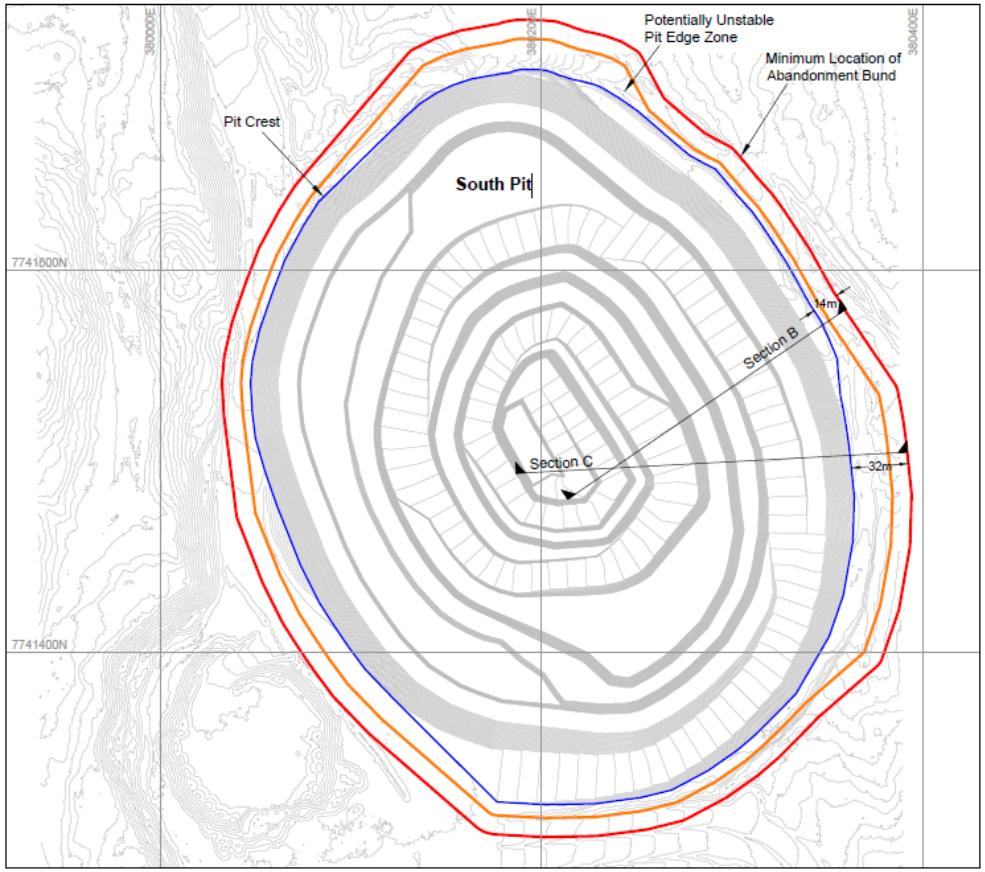
0 50 100
Scale (m)

Round Oak Minerals
Barbara Copper Project
Mine Closure Geotechnical Study

NORTH PIT BUND LOCATION

PSM2319-041L | Figure 3

Figure 16 Bund Location for the North Pit



0 50 100
Scale (m)

Round Oak Minerals
Barbara Copper Project
Mine Closure Geotechnical Study

SOUTH PIT BUND LOCATION

PSM2319-041L | Figure 6

Figure 17 Bund Location for the South Pit

6.1.1 Long-term Water Balance

A water balance model was developed by ATC Williams (2020) to determine potential projected future void water levels for both open cut pits. The water balance model was run deterministically for a 30-year period with a daily time-step. The model assumes that all previously disturbed areas have been successfully rehabilitated and removed from the mine water management system. Modelling inputs are detailed below.

The pit configuration as at the end of mining was adopted with the storage characteristics detailed in Table 15.

Table 14 Pit Configuration

Parameter	North Pit	South Pit
Crest Elevation (m RL)	316	334
Storage Capacity (ML)	153	3,526
Surface Area (ha)	1.5	7.4

Climatic data used for the model was sourced from SILO and is summarised in Table 16.

Table 15 Rainfall and Evaporation Inputs

Climate Data	Data Source	Comments
Daily Rainfall Rate (mm/day)	Rainfall data obtained from SILO Data Drill Program for the site location for the period 1889 – 2018)	Applied to dam surface areas and as an input parameter for surface runoff estimation.
Daily Evaporation Rate (mm/day)	Continuous record from SILO Data Drill formed by conjoining CLIMARC estimates (1889 – 1957) and Class A Evaporation Data from proximate weather stations within the region (1889 – 2018)	Evaporation Data is scaled by evaporation factors for each site storage to reflect water storage conditions and expected water quality.
Daily Evapotranspiration Rate (mm/day)	As calculated by FAO short crop reference methodology, assuming a wind speed of 2 m/s	PET is calculated based on temperature, vapour pressure and solar global exposure parameters derived from climatic data and is adopted as a reasonable estimate of potential evapotranspiration losses from ground surfaces within the surface runoff model.

The Australian Water Balance Model (AWBM) was used to simulate runoff volume post rainfall events. Details relating to catchment types on site and additional AWBM input parameters adopted for the model are detailed in Table 17, Table 18 and Figure 18.

Table 16 Water Balance - Rainfall and Evaporation Data

Catchment Type	Split area (Sum =1)			Storage Capacities (mm)			Surface recession constant (Ks) day^{-1}	Base flow Index (BFI)	Baseflow Recession Constant (Kb)
	A1	A2	A3	A1	A2	A3			
Natural	13.4	43.3	43.3	12	120	250	0	0	1
Hardstand	10	0	0	10	-	-	0	0	1
Open Cut	10	90	0	5	20	-	0	0	1

Table 17 Total Catchment Areas

North Pit	South Pit
4.2 ha	44.1 ha

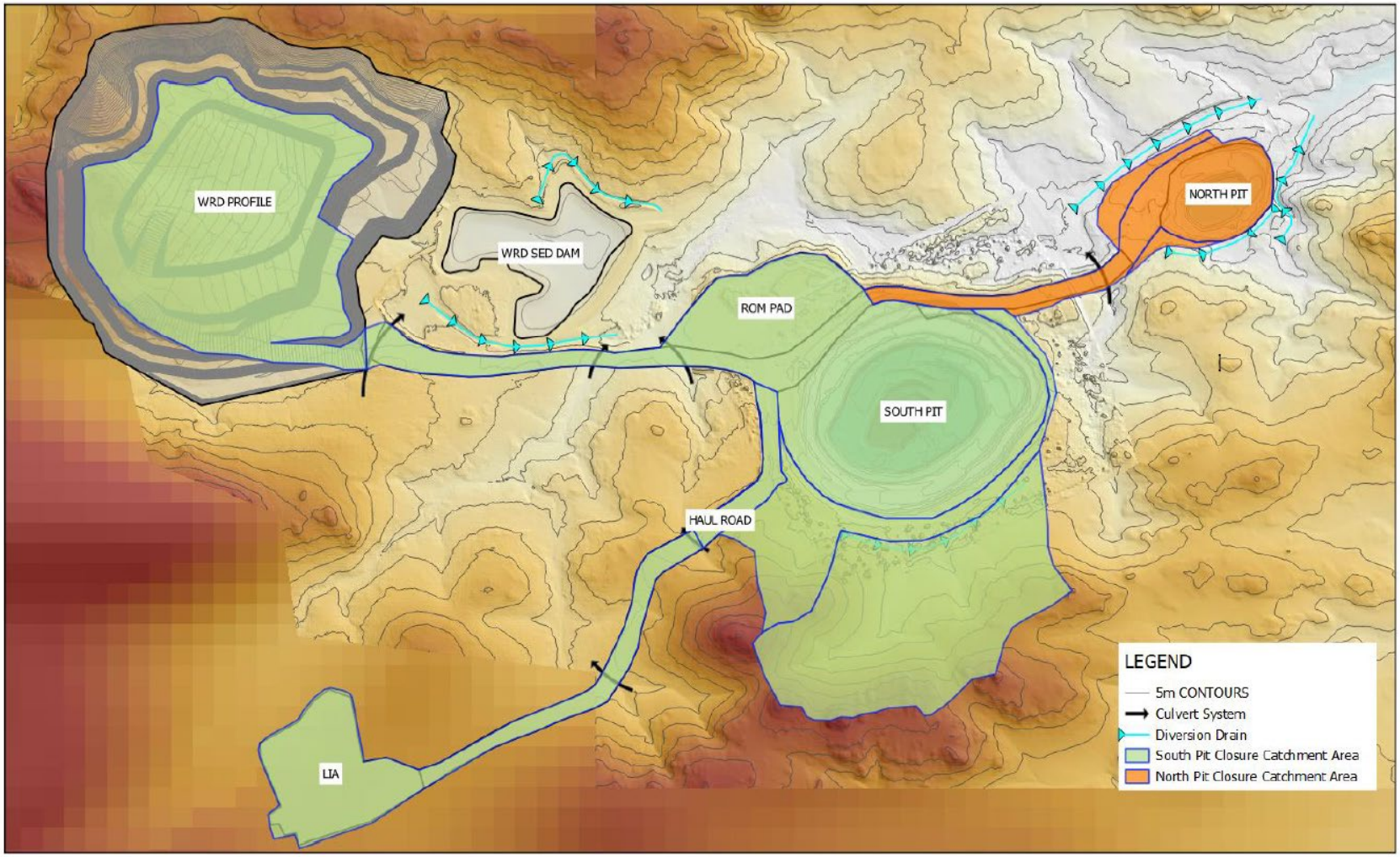


Figure 18 North and South Pit Post-Closure Catchment Areas

Pit inflows are generally comprised of surface run-off and groundwater inflows, however, to date no groundwater inflows have been detected at either of the North Pit and South Pit voids. Therefore, no groundwater inputs have been incorporated in the model.

Modelling results for the North Pit and South Pit post mining were as follows:

North Pit: Long-term modelling demonstrates the mean surface elevation is approximately 303 m with an anticipated long-term volume of 30 ML. The risk of overtopping post-closure is low.

South Pit: A long-term surface elevation of 290 m is estimated with a long-term volume of 1,150 ML. The risk of overtopping post-closure is low.

The results of water balance modelling for the North and South Pit are displayed in Figure 19 to Figure 22.

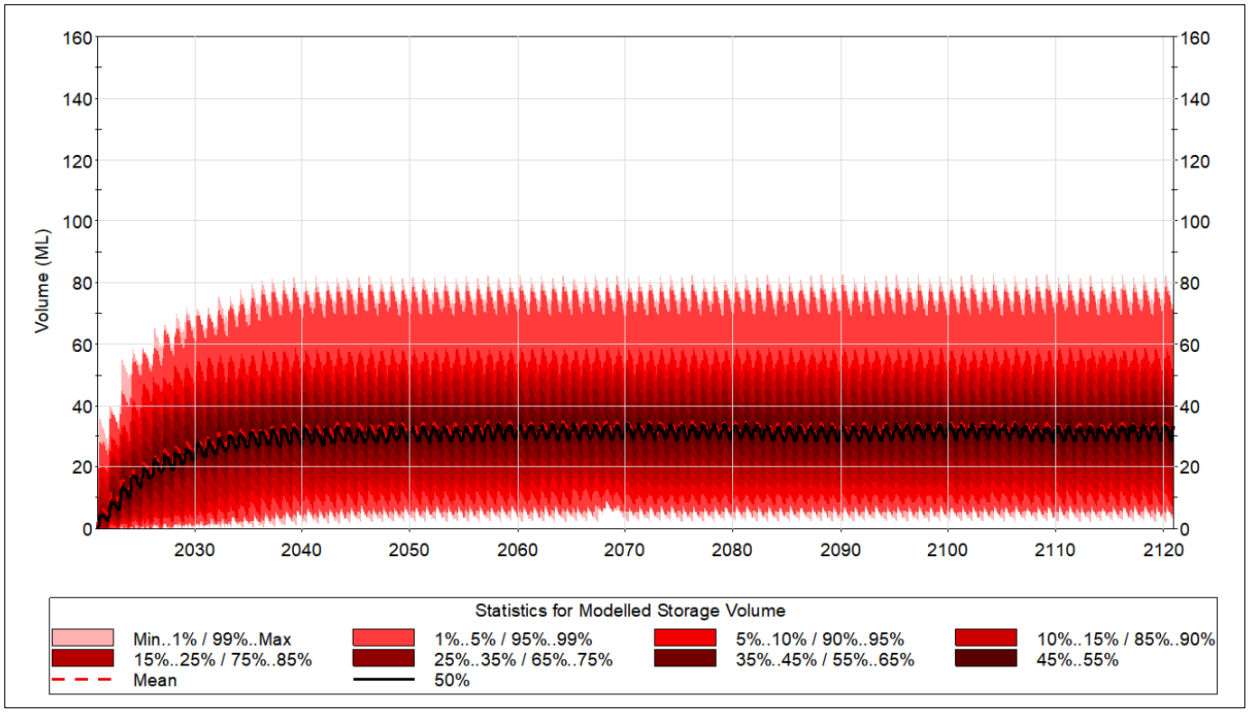


Figure 19 Modelled Storage Volume - North Pit

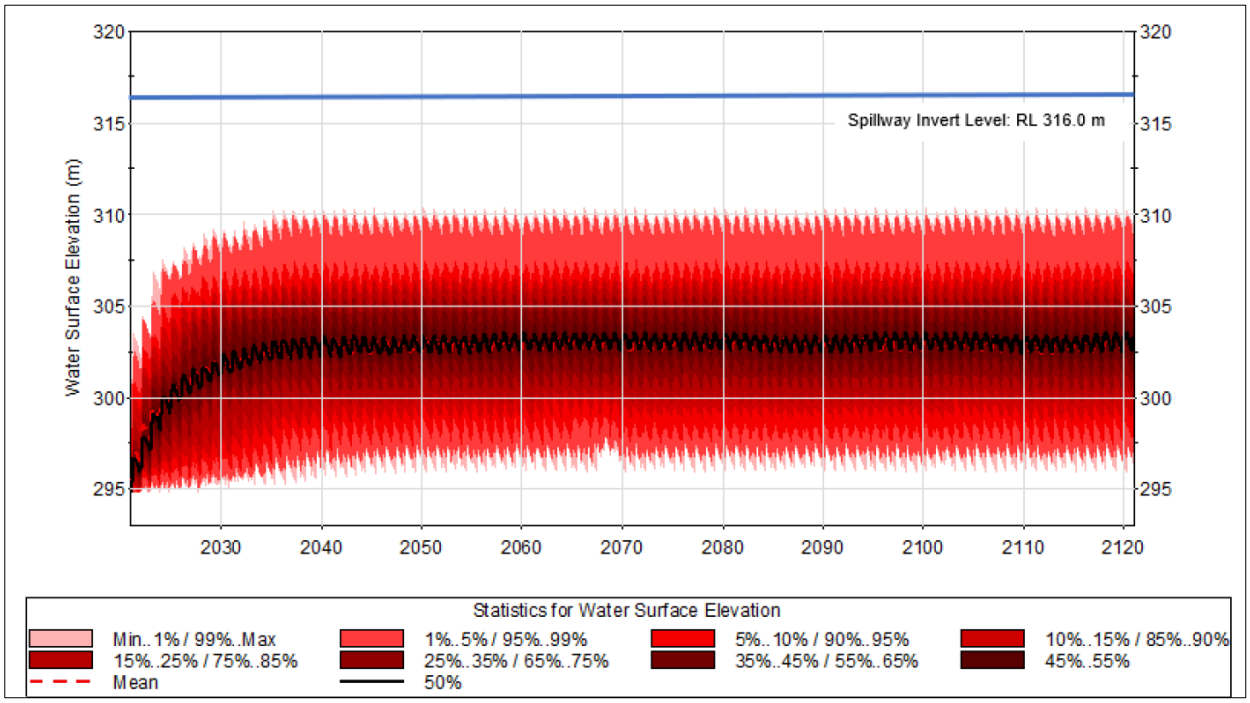


Figure 20 Modelled Water Surface Elevation – North Pit

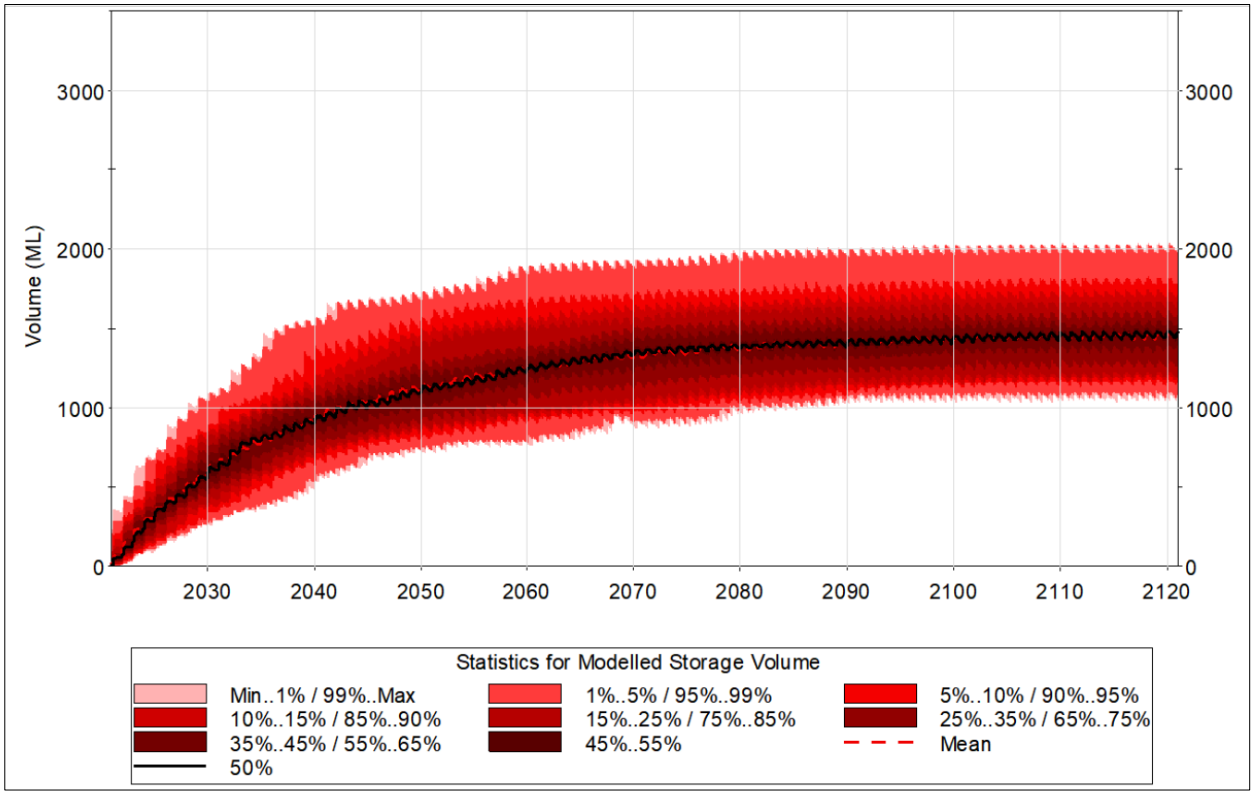


Figure 21 Modelled Storage Volume - South Pit

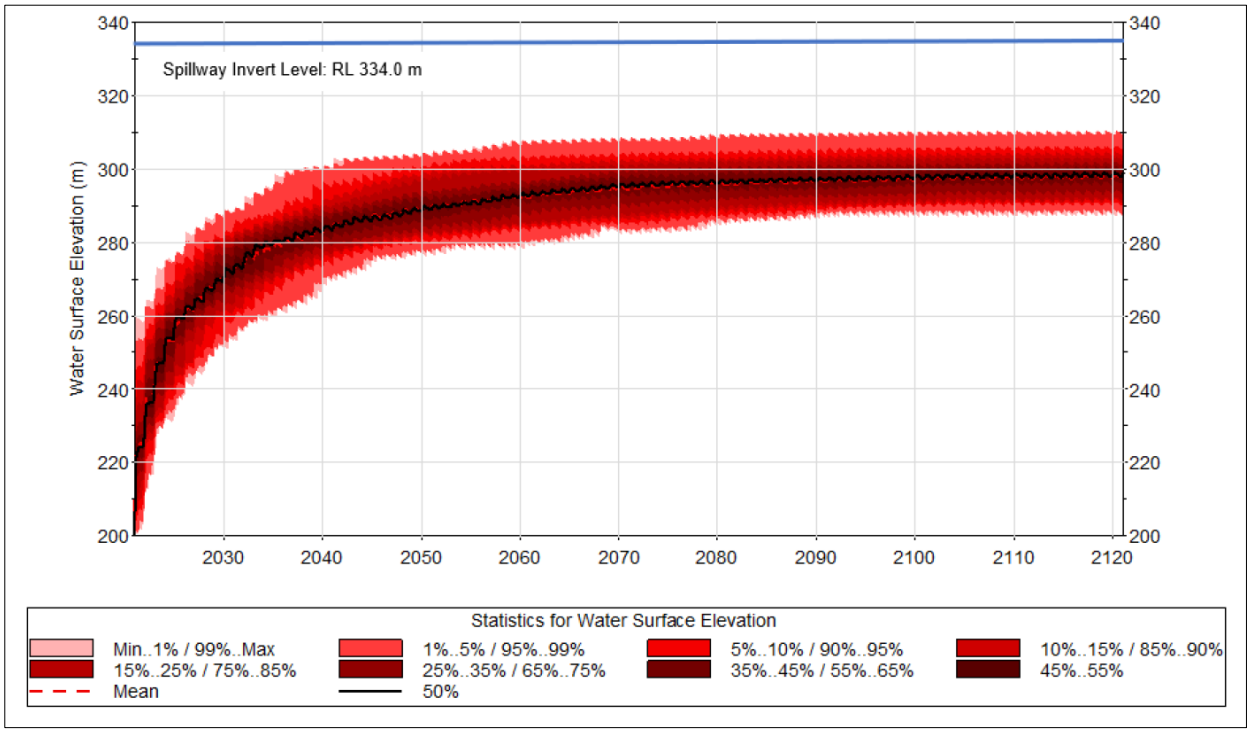


Figure 22 Modelled Water Surface Elevation – South Pit

6.1.2 Groundwater Risk Assessment

A risk assessment was undertaken by Rob Lait and Associates Pty Ltd (RLA) in 2014 to assess the impact of voids on ground water and surface water environmental values. The risk of contaminant migration to regional groundwater systems was determined to be low, as:

- The local aquifer is confined. Any Mine Affected Water (MAW) stored in the void is unlikely to have an impact on regional groundwater values; and
- Due to high evaporation rates and low rainfall experienced in the BCO region, pits will likely be groundwater sinks with no outflow of MAW to groundwater systems.

6.1.3 Surface Water Risk Assessment

The risk of mobilisation of contaminants to surface water is considered low, as the risk of overtopping at the North and South voids is predicted to be low with a 1% probability of the water surface reaching the eventual weathered zones of RL 305m (North Pit) and RL 270m (South Pit). Furthermore, as MAW is unlikely to impact groundwater systems, the risk of MAW impacted groundwater expressing to surface water and thus degrading surface water quality is low (RLA, 2014).

6.2 Waste Rock Dumps

As an interim measure, prior to closure, the WRD has been capped to be a water shedding feature to prevent infiltration into the PAF cell. A compacted NAF material barrier layer of 5 m thickness has been placed over the bounded PAF cell, followed by a compacted and rolled crushed non-mineralised rock layer of 50mm (nominal) thickness. The average gradient on the upper surfaces is 3% to facilitate rapid runoff and avoid pooling. Drainage from the WRD discharges to the Sediment Dam.

Post-closure, the WRD is designed to be safe, stable and non-polluting. To achieve the rehabilitation goals and objectives the closure design includes a water shedding cover system and revegetation elements in a layered sequence to limit erosion and infiltration and topsoil to promote growth of native vegetation. The final capping design is yet to be completed, with cover trials being set up and run in columns, with oversight from a suitability qualified environmental geochemist.

The total disturbance footprint of the WRD will be approximately 23 ha. The angle of repose of the side batters will be 37 degrees. The natural rill of the batters will create natural rock armouring / outcropping and potential habitat for the Purple-Necked Rock-Wallaby, to assist in achieving a PMLU of Native Ecosystem Services.

A surface water management system will convey runoff to the Sediment Dam and South Pit. At closure, the Sediment Dam would be either rehabilitated fully or utilised for stock water purposes, with the WRD runoff reporting to either South Pit or into the receiving environment.

The geotechnical stability of the WRD design was assessed by ATC Williams in 2019. Slope stability was assessed using GeoStudio, SLOPE.W software. The proposed geometric configuration of the WRD is as follows:

- Batter slopes: 37 degrees (angle of repose);
- Batter height: 10 metres (m);
- Bench width: 12 m; and
- Average batter slope: 1V:2.5H

Model parameters for WRD material properties and foundation have been sourced from the Sediment Dam Detailed Design Report (Ref: 118131-02R002) (ATCW, 2019) and are detailed in Table 19.

Table 18 Adopted Material Characteristics

Layer Description	Bulk Density (Y) (kN/m^3)	Effective Strength Parameters	
		Cohesion (C^I) (kPa)	Friction Angle ($Ø^I$) (degrees)
Fractured Rock	20	0	45*
Fresh Rock	20	0	45*
Gravelly Clayey Sand	18	0	28*
WRD Material	20	0	37**

**ATCW, 2019*
***PSM, 2019*

Modelling suggests the waste rock landform meets the required factors of safety for long-term geotechnical stability. An output from the stability analysis, for a direct shear case along the base of the WRD (worst case) is displayed in Figure 23. A sensitivity analysis of friction angles for the waste rock given the use of angle of repose batters was undertaken. This shows the global stability of the landform is acceptable, with a safety factor of 1.83 (Figure 23). Therefore, an outer batter slope of 1V:2.5H is proposed as part of the final landform.

It should be noted that this assessment considers global failure assuming competent foundation sequences. Localised slip failures could still occur on the batters of WRD placed at the angle of repose. As discussed above, as the characteristics of rock material are unknown. If weak, loose, or compressible soils are present under the waste rock, a potential slip face between underlying sequences could develop. However, fauna and human access will be minimised and the effects of localised failure will, therefore, be low.

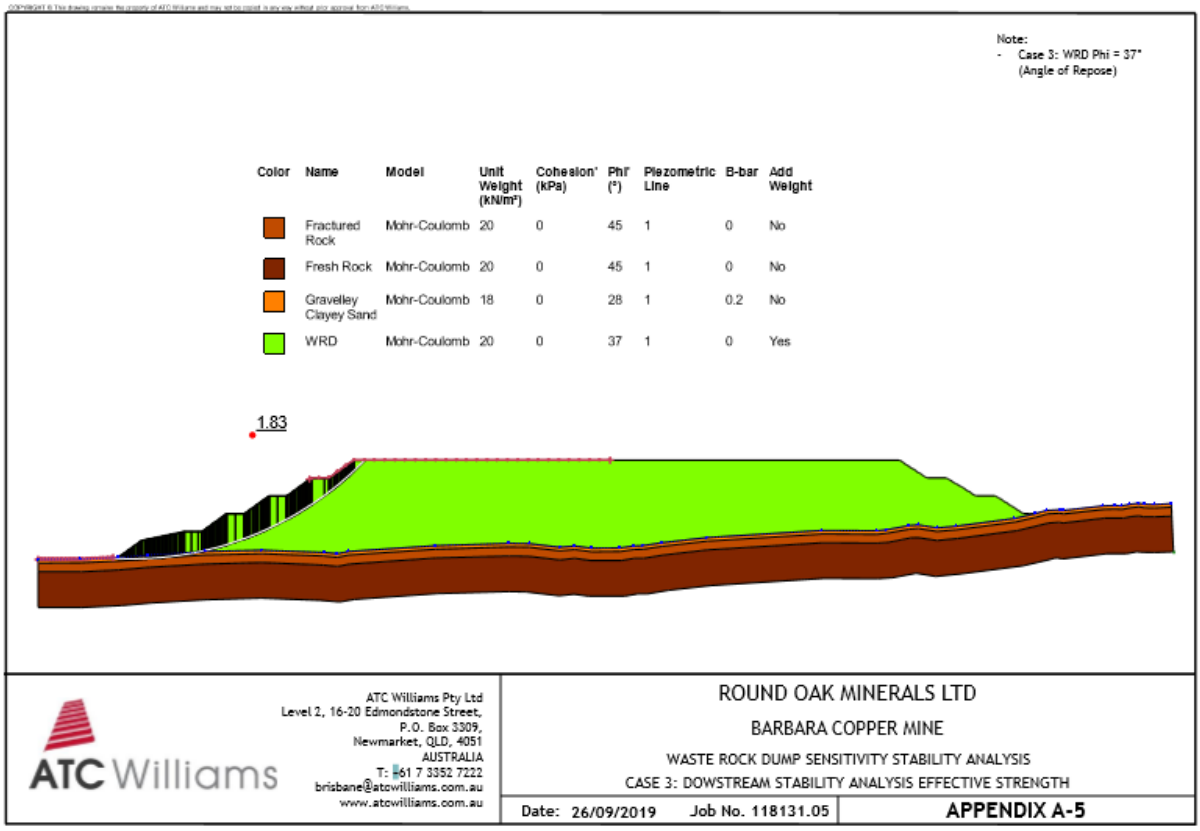


Figure 23 Waste Rock Dump Sensitivity Stability Analysis (ATC Williams, 2019)

6.3 Bunds, Levees, Diversion Drains and Dams

Several diversion drains, bunds and culverts have been constructed to manage local runoff by preventing backflow into mining operational areas and mine impacted run-off from entering the receiving environment. The location of diversion drains and culverts are displayed in Figure 24. The Eastern and Western diversion drains have been constructed as temporary diversion drains that are not required post closure once the WRD has been decommissioned. The North Pit Creek Diversion and Levee will remain post-closure to reduce pit inflows, with other diversions being removed, to facilitate inflows to South and North Pit, with the final land use being water storage for the property owner.

As per the EA criteria and the consequence category of the pits, the Creek Diversion and Levee and the East Creek Diversion have been designed to convey a peak flow for a 1:1,000-year annual exceedance probability (AEP) rainfall event. Rock armouring of the diversion drains was not required as diversions were formed from competent rock. The current design of these diversions satisfies relinquishment requirements. Therefore, no further work is needed at closure.

Initially, the Sediment Dam will be retained to evaporate stormwater runoff from the rehabilitated WRD. The Sediment Dam will subsequently be reconfigured as a sediment catch dam unless otherwise stipulated by the landowner. Water quality monitoring will be ongoing to determine the quality of the water in the pits and Sediment Dam prior to decommissioning.

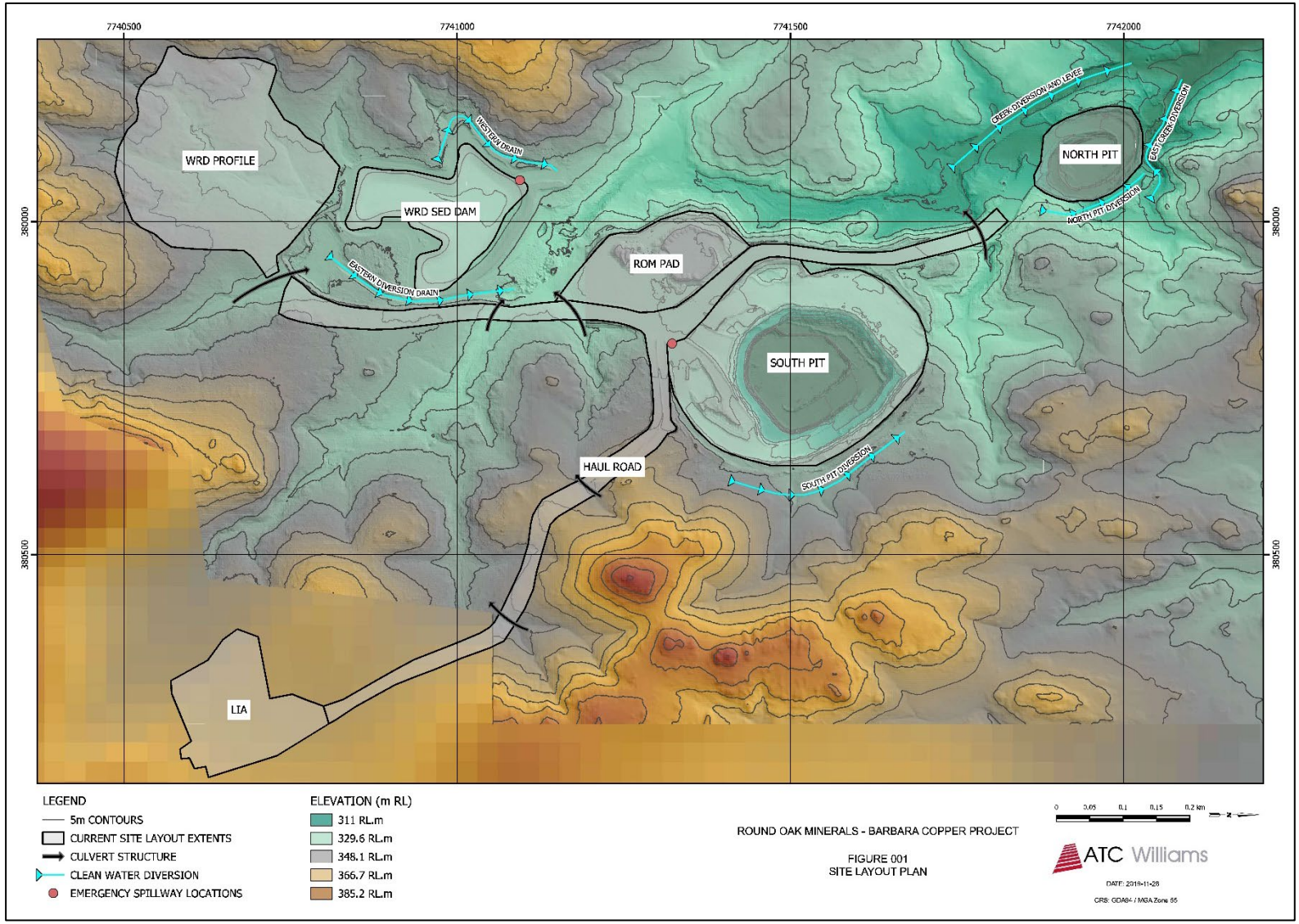


Figure 24 Barbara Diversion Drains

6.4 Ancillary Infrastructure, Roads & ROM Pad

All crushing plant, associated buildings and equipment will be dismantled and removed from the site upon cessation of the Project, unless required by the landholder.

All access tracks and haul roads on the Project will be ripped and revegetated (Section 7) unless they are required by the landholder.

The ROM pad will be excavated to a depth of 0.5 m, or refusal, to ensure the removal of ore and any potentially contaminated materials. Benign material will be used either as capping material or regraded and revegetated (Section 7).

The remaining disturbed areas will be reshaped where required, deep ripped to remove compaction and revegetated using the methods described in Section 7 of this document.

The PMLU for ancillary infrastructure, ROM pad and roads will be low intensity grazing.

6.5 Exploration

Exploration disturbances have been rehabilitated in accordance with the Code of Environmental Compliance for Exploration and Mineral Development Projects:

- Drill holes will be immediately capped;
- Once dry the sump will be backfilled;
- Holes will be grout filled or capped at a depth >0.5 m; and
- Disturbed areas will be scarified to encourage revegetation.

Should natural regeneration not be successful, native seed will be sown prior to the wet season.

6.6 Vegetation Removal and Topsoil Stripping

The Project has resulted in in land disturbance (clearing) for the mining pits and mine infrastructure. Land disturbance has been restricted to the minimum possible footprints and where feasible, the BCO had utilised areas (roads and drill pads) previously cleared for exploration activities.

Prior to development, topsoil and ground cover vegetation has been progressively removed from each disturbance footprint, however, due to the rocky structure of BCO, no topsoil has been stockpiled for use during rehabilitation.

6.7 Erosion and Sediment Control

The objective of the final landform design is to produce a stable landform able to resist erosion caused by surface water runoff. Throughout the Project, progressive rehabilitation and revegetation (Section 7) will reduce the presence of bare earth areas and mitigate the potential for erosion and sediment transport.

The following actions will be taken to ensure maximum potential for revegetation of areas:

- Seeding activities will be timed to ensure promote high germination rates are achieved;

- Sediment fences and temporary perimeter banks will be used for short term bare earth areas;
- Sediment and erosion control structures will not be removed until disturbed areas have been stabilised;
- Exposed surfaces will be ripped and left with sufficient surface roughness to minimise the potential for erosion;
- Bunds and check dams will be implemented across contours in order to capture and slow runoff; and,
- Disturbed areas will be contoured to ensure all runoff is directed through erosion and sediment controls and onsite water management systems.

7 Revegetation Methods

After appropriate surface preparation, growth media will be spread to support the growth of vegetation (where applicable), reducing erosion and helping to sustain the desired post mine land use.

The rehabilitation strategy for various disturbance areas such as the WRD and ROM pad will be tailored to address specific risks associated with those disturbance types. That is, specialised management strategies will be implemented as deemed necessary to prevent environmental harm.

Following surface amendments, selected domains will be revegetated as follows:

- Where available/practicable, growth media will be spread over the area to be rehabilitated;
- The area will be deep ripped where required to alleviate compaction;
- Fertiliser and additional growth media will be spread at an appropriate rate (if required) based on the nutrient status of the surface material, and requirements of the vegetation species that will be established. Assessment of fertiliser requirements will occur during topsoil (or topsoil substitute) placement; and
- Selected native tree, shrub and pasture grass species will be sown (seeds and/or tube stock).

7.1 Cover Soil Suitability and Management

Typically, topsoil resources within the study area have poor nutrient availability and very low levels of organic matter. Notwithstanding this, their suitability for topsoil stripping and re-use in rehabilitation efforts will be most limited by the practicality of removal and stockpiling, given the degree of rock outcropping and the inherently shallow soil resource.

Soils within SMU1 consist primarily of coarsely textured material of low water holding capacity and poor nutrient availability. These soils are, therefore, less suited to pre-stripping and stockpiling before mine activity.

Soils within SMUs 2 and 3 are more suitable for stripping and stockpiling for later use in rehabilitation efforts due to their physicochemical properties. Soils of SMU2 report higher levels of major soil nutrients, however, application of a suitable soil ameliorants will still improve these soils as a growth medium.

Where practicable, topsoil should be stripped to a maximum depth of 300 mm. Due to the inherently low levels of major plant nutrients, this soil may require specific inputs to improve the soil as a growth medium for rehabilitation. It should be noted that shallow rocky substrate in localised areas has prevented stripping to a full recommended depth of 300 mm.

Minor variation in topsoil characteristics occur within the soil types of each of the management units particularly in respect to the location of rocky outcrops and shallow rock substrate. Consequently, it is recommended that monitoring of soil type variability be undertaken during the ongoing operational phases of the Project to ensure that the maximum quantity and quality of usable topsoil resources is recovered.

7.2 Growth Media Availability

Where possible, stripped rocky substrate has been salvaged for use in rehabilitation. The SLSA for the BCO indicates 0.3 m as the suitable stripping depth for each SMU, should topsoil stripping and stockpiling be feasible during future disturbance (AustralAsian Resource Consultants 2014).

For rehabilitation, 19,650 m^3 of growth media will be required to rehabilitate the WRD and ROM pads across the Project site (Table 20). It is anticipated that benign rocky substrate will be sourced from the Project site for rehabilitation of the WRD and ROM pad. This will create naturally draining rocky outcrops on the rehabilitated landforms, which is characteristic of natural landforms within the region.

Table 19 Rocky Substrate Volumetric Requirements for Rehabilitation of the Project

Disturbance			Rocky Substrate Requirement	
Mine Feature Name	**Area (ha)**	**Area (m^2)**	**Thickness (m)**	**Volume (m^3)**
North Pit	1.5	15,000	N/A	N/A
South Pit	6	60,000	N/A	N/A
Waste Rock Dump	12.5	125,000	0.15	18,750
ROM Pad & ore stockpiles	0.6	6,000	0.15	900
Total Volume Required (m^3)				**19,650**

In addition to growth media, capping materials will be required to adequately rehabilitate the WRD on the Project site (refer to Table 21). The maximum disturbance area for the WRD will be 12.5 ha, however, it is not yet known how much of this disturbance area will require capping for PAF and NAF material respectively. To calculate the volume of materials required, a 12.5 ha footprint has been assumed as the maximum area requiring capping for both PAF and NAF material (although growth medium has only been included in the materials balance once). It is estimated that a maximum of 62,500 m^3 of low permeability barrier material will be required to prevent seepage of contaminants and provide extra stability, to effectively rehabilitate the Project site. Additionally, 50,000 m^3 of rock mulch and 18,750 m^3 of growth media will be required irrespective of the underlying waste rock (NAF or PAF).

Table 20 Capping Volumetric Requirements for Rehabilitation of Project

Mine Feature	Max. Disturbance Area (ha)	Capping Material	Capping Thickness (m)	Maximum Capping Volume (m^3)
PAF WRD	12.5	Low Permeability Barrier	0.5	62,500
		Rock Mulch	0.4	50,000
		Rocky Substrate Growth media	0.15	18,750
NAF WRD And Berms	12.5	Rocky Substrate Growth media	0.15	-

Following geochemical characterisation, benign rock fill may also be acquired from the Project site for use during rehabilitation.

7.3 Growth Media Preparation

If rocky substrate sourced from site is used as growth media in rehabilitation activities, incorporation of a conditioning agent will be considererd. This activity is particularly important where the rocky substrate has been stored for over six months.

In addition to the conditioning agent, the addition of an organic blend to this material would further improve its quality as a growth media. The recommended agents for conditioning of rocky substrate material are outlined in Table 22.

Table 21 Recommended Conditioning Rates for Topsoil Prior to Placement

Conditioning Agent	Application Rate
Feedlot Manure (organic matter)	10 tonnes per hectare
Urea (nitrogen)	100kg per hectare

7.4 Surface Preparation

7.4.1 Natural Surfaces

Prior to the spreading of rocky growth media, disturbed areas will undergo surface contouring and ripping. Surface contouring will be undertaken to minimise erosion and maximise water retention The spacing between rip lines is determined by the slope of the land, which acts to reduce soil erosion and increase plant establishment rates (refer to Table 23). Where soils are particularly compacted, a ripping depth of 300 mm should be employed.

Table 22 Design of Ripping Operations for Post-disturbance Surface Preparation

Slope	Ripping Depth	Tyne Spacing
>10%	200mm	<1.5m
5 – 10%	200mm	<2.5m
<5%	200mm	<5m

7.4.2 Constructed Landforms

Following placement of growth media, constructed landforms such as the ROM pad will be contoured to resemble the original local topography as far as practicable, in accordance with the landform design described in Section 4.

Landforms shall be deep ripped where required to alleviate compaction prior to seeding.

7.5 Growth Media Placement

Placement of rocky growth media at a thickness of approximately 0.15 m has been recommended across the rehabilitated area to create a growth medium of sufficient depth to hold water and support revegetation.

Typically, the process of rocky growth media placement would include:

- Surface roughening by dozer or other tracked machines;
- Application of rocky growth media by placement from the embankment crest on batters, or from the edge of the area to adjacent areas. Care should be taken not to compact the surface roughened areas;
- Spreading of the placed rocky growth media (and mulched vegetation, as applicable) to the desired thickness using low ground pressure plant; and
- Deep ripping of rocky growth media prior to seeding.

Grass and woody vegetation remaining after land clearing can be incorporated into the rehabilitated surface at strategic locations to help limit runoff/erosion (by slowing down overland flow), retain active biological activity, and provide habitat for returning fauna. Additionally, mulched organic material incorporated into the rocky growth media will increase organic carbon levels over time, further stabilising the soil and landscape, providing more exchange sites for necessary cations, increasing water holding capacity, and ensuring less organic matter is oxidised (Smith et. al., 2018).

7.6 Species Selection

Revegetation of disturbed areas will occur by direct seed application using either manual or mechanical techniques. Species have been chosen based on the most dominant vegetation communities (Section 2) mapped across the Project area pre-mining, or through the selected post-mine land use for each domain.

A recommended grass and pasture species seed list is outlined in Table 24. These species are suitable for use in low intensity grazing areas as well as on rehabilitated structures where the establishment of deep-rooted trees is unsuitable (waste rock dumps). Where appropriate, planting of native tree and shrub seeds may be incorporated into low intensity grazing areas to improve water holding capacity of land and provide shade for cattle. Suggested tree and shrub species are provided in Table 25.

Where appropriate, fencing, stability controls, and erosion controls should be implemented to protect revegetation areas following soil preparation/seeding to ensure that plant establishment is not compromised.

Table 23 Recommended Seeding Mix for the Rehabilitation of the Project Site

Scientific Name	Common Name	Note
Triodia pungens (D)	Soft Spinifex	Community 1 (RE 1.11.2d), Community 2 (RE 1.11.3), Community 3 (RE 1.3.6x1b)
Cymbopogon bombycinus (A)	Citronella Grass	Community 5 (RE 1.11.2x4) – rocky outcrops
Triodia bitextura (D)	Feathertop Spinifex	Community 6 (RE 1.11.2x1b)
Eriachne mucronata	N/A	Native species
Themeda triandra	Kangaroo Grass	Native pasture species
Dicanthium sericium	Queensland Bluegrass	Native pasture species
Sorghum spp.	Annual Sorghum	Single-generation quick establishing groundcover
Rhynchosia minima	Least snout-bean	Legume suited to north-west Queensland
Vigna savi	Cowpea	Legume suited to north-west Queensland

Key: D = Dominant, A = Associated

Table 24 Recommended Tree and Shrub Species

Scientific Name	Common Name	Note
Tree Layer		
Eucalyptus leucophloia (D)	Snappy Gum	Community 1 (RE 1.11.2d), Community 2 (RE 1.11.3),
Corymbia terminalis (A)	Western Bloodwood	Community 1 (RE 1.11.2d), Community 2 (RE 1.11.3), Community 3 (RE 1.3.6x1b)
Terminalia aridicola (A)	Arid Peach	Community 1 (RE 1.11.2d), Community 2 (RE 1.11.3),
Eucalyptus leucophylla (O)	Cloncurry box	Community 1 (RE 1.11.2d), Community 2 (RE 1.11.3), Community 3 (RE 1.3.6x1b)
Corymbia aparrerinja (O)	Ghost Gum	Community 1 (RE 1.11.2d),
Atalaya hemiglauca	Whitewood	Suited to north-west Queensland
Shrub Layer		
Acacia holosericea (D/A)	Soapbush Wattle	Community 1 (RE 1.11.2d), Community 2 (RE 1.11.3), Community 3 (RE 1.3.6x1b)

Acacia phlebocarpa (D)	Tabletop Wattle	Community 1 (RE 1.11.2d), Community 2 (RE 1.11.3),
Acacia chisholmii (SD)	Turpentine	Community 1 (RE 1.11.2d), Community 2 (RE 1.11.3), Community 3 (RE 1.3.6x1b)
Senna artmeisiodes subsp. *helmsii*	Crinkled Cassia	Suited to north-west Queensland
Senna artemisioides subsp. *oligophylla*	Limestone Cassia	Suited to north-west Queensland
Senna notabilis	Cockroach Bush	Suited to north-west Queensland

Key: D = Dominant, SD = Sub-dominant, A = Associated

7.7 Propagation

To successfully rehabilitate the BCO, selected plant species will be either directly seeded into rehabilitated areas.. The method of planting, germination, and propagation varies based on company requirements, rehabilitation design, and the needs of individual species. Seeds of selected species must be treated in a specific manner to allow for successful revegetation. Table 26 shows the propagation method associated with each plant seed to ensure successful germination and plant survival.

Closer to the initiation of revegetation, Round Oak Minerals will nominate a contractor to complete the revegetation tasks associated with the Project, or alternatively, employ a specialised workforce. It should be noted that the listed species represent a guide only.

As stated in the Operations Completion Criteria (Table 12), rehabilitation success is based on the completion criteria of 60% comparable species to the analogue site. Therefore, not all species identified will be added to the final species list. Species chosen for rehabilitation purposes will be based on suitability and availability, at the discretion of Round Oak Minerals and the chosen rehabilitation contractor. It is also expected that some in situ revegetation will occur over time from neighbouring vegetated areas, as the rehabilitation develops.

Table 25 Recommended Propagation Methods for Selected Species

Common Name	Scientific Name	Propagation Method
Tree Species		
Snappy Gum	*Eucalyptus leucophloia*[1]	This species can be directly seeded. Seed is separated into seed and chaff, with no listed pre-treatment. Generally, 25-30% of seed produced is viable, with this species having 375 viable seeds per gram. Seeds should be directly planted with 3-4 seeds per pot or can be field planted at 10-100 g/km^2. Seeds can be stored for 4-5 years, or longer at low temperatures.
Western Bloodwood	*Corymbia terminalis*[1]	This species can be directly seeded. Seed is separated into seed and chaff, with no listed pre-treatment. Generally, 25-30% of seed produced is viable, with this species having 37 viable seeds per gram. Seeds should be directly planted with 3-4 seeds per pot or can be field planted at 10-100 g/km^2. Seeds can be stored for 4-5 years, or longer at low temperatures.

Common Name	Scientific Name	Propagation Method
Cloncurry box	*Eucalyptus leucophylla*[1]	This species can be directly seeded. Seed is separated into seed and chaff, with no listed pre-treatment. Generally, 25-30% of seed produced is viable. Seeds should be directly planted with 3-4 seeds per pot or can be field planted at 10-100 g/km^2. Seeds can be stored for 4-5 years, or longer at low temperatures.
Ghost Gum	*Corymbia aparrerinja*[1]	Seed is separated into seed and chaff, with no listed pre-treatment. Generally, 25-30% of seed produced is viable. Seeds should be directly planted with 3-4 seeds per pot or can be field planted at 10-100 g/km^2. Seeds can be stored for 4-5 years, or longer at low temperatures.
Arid Peach	*Terminalia aridicola*	Variable results from seed between species. Seeds may benefit from treatment by soaking seed in water for 16 hours or gentle cracking of the seed case. Germination usually occurs in 40-60 days but can take 3-6 months. Sow seeds fresh. Warmer temperatures give best results.
Whitewood	*Atalaya hemiglauca*[1]	Grown from seed and should be sown fresh. *A. hemiglauca* has moderate results from seed and is quick to germinate. Remove the wings from the seed and sow at 25 – 30 °C. Hot water treatment can be used to improve germination.
Shrub Species		
Turpentine	*Acacia chisholmii*[1]	Hard seed coat and may benefit from treatment with dry heat (80-100 °C). Seeds should be mixed with sand or seed raising media spread to 1-2cm thickness on metal trays. Timing trials will need to be conducted to determine the most effective dry heat application. Seeds should be germinated in trays, then transferred to pots after germination. Alternatively, this species can be directly seeded in the field. 79 to 200 g of seed should be used per km^2.
Soapbush	*Acacia holosericea*[1]	Hard seed coat and may benefit from treatment with dry heat (80-100 degrees). Seeds should be mixed with sand or seed raising media spread to 1-2cm thickness on metal trays. Timing trials will need to be conducted to determine the most effective dry heat application. Seeds should be germinated in trays, then transferred to pots after germination. Alternatively, this species can be directly seeded in the field. 79 to 200 g of seed should be used per km^2, with approximately 56-86 viable seeds calculated per gram.
Tabletop Wattle	*Acacia phlebocarpa*	Hard seed coat and may benefit from treatment. Several treatments can be used to break dormancy. Pouring boiling water over seed and allowing to soak for 12-15 hours is the most widely used method. Although trials should be undertaken to determine if temperature needs to be varied. Seeds sown in trays are easiest to handle as seedlings. Seed usually germinates in 3-10 weeks with seedlings usually growing quickly. Seeding rates of 70 – 200g per km^2 are required to achieve a natural bush effect.
Crinkled Cassia	*Senna artmeisiodes* subsp. *helmsii*[1]	Seed known to have hard coats. Hot water treatment is recommended (95 °C for two minutes). Seedlings usually

Common Name	Scientific Name	Propagation Method
Limestone Cassia	*Senna artemisioides* subsp. *oligophylla*[1]	begin germination within 2-7 weeks. Most species are suited to direct seeding in pots or in the field. *S. helmsii* may not require hot water treatment.
Cockroach Bush	*Senna notabilis*[1]	
Grass Species		
Feathertop Spinifex	*Triodia bitextura*[1]	This species likely has after-ripening period, though the timing of this period is unknown. Smoke treatment can improve germination results. Division may also be a successful method of propagation, though will result in low species diversity. Non-dormant seeds should germinate within 1-4 weeks.
Soft Spinifex	*Triodia pungens*[1]	This species likely has after-ripening period, though the timing of this period is unknown. Smoke treatment can improve germination results.
Citronella Grass	*Cymbopogon bombycinus*[1]	This species can be grown from seed and is unlikely to have an after-ripening period. The removal of husk can improve germination. Smoke germination also improved germination, but not significantly.
N/A	*Eriachne mucronata*[1]	This species has an after-ripening period and requires 12 months dry storage after picking.
Kangaroo grass	*Themeda triandra*[1]	This species has an after-ripening period of up to 11 months (found in Alice springs, Canberra and Townsville samples). To reduce seed dormancy, several temperature treatments have been found to be effective. These treatments should be completed over one month, and include either 60° storage, 45°-day 20°-night storage, or constant 3-5° storage. Gibberellic acid treatment has also been found to be effective. Germination should be 2-4 weeks in non-dormant seeds.
Queensland Bluegrass	*Dicanthium sericium*	This species has an after-ripening period. Seed collected from coastal areas are less likely to be dormant. Seeds sourced from inland areas likely require 2-24 months dry storage. Smoke treatment, chilling of seed (5°C for 1 week) and dry heat (80°C for 15 minutes) all helped improve germination rates.
Annual Sorghum	*Sorghum spp.*[3]	Best sowing rate for this species within a seed mixture under dryland conditions is between 2-6 kg/ha. Ideal sowing time occurs when soil temperature reaches 16°C.
Least snout-bean	*Rhynchosia minima*[1]	Grown from seed. Seeds generally have hard coats and will benefit from treatment. Hot or boiling water is a commonly used treatment. Treatment temperatures usually range from 70 – 100 °C. The standard treatment method is to pour hot/boiling water over seeds, allow to soak for 4-8 hours. Germination usually occurs in 3-6 weeks. Seed can be prone to rotting, caution should be taken not to over water.

Common Name	Scientific Name	Propagation Method
		Seeds suited to direct sowing in the field or direct seeded in pots (if limited availability).
Cowpea	*Vigna savi*[1]	Methods described for *R. minima* can be used for *V. savi.*

1 – Growing Australian Native Plants from Seed, Murry Ralph (2009)
2 – South Australian Seed Conservation Centre, Botanic Gardens of South Australia (2018)
3 – Pastures Australia, GRDC (2010)

7.7.1 Direct Seeding

Direct seeding should be used in areas where consistent dispersal over a relatively large area is required. Seeds utilised for this process should be available in large quantities, suited to direct seeding (see Table 26) and have undergone all necessary pre-treatments prior to dispersal. If the seed is robust, agricultural machinery may be used for this purpose, dictated by the size of the area and ease of access (Native Vegetation Guide for the Riverina, 2002).

7.8 Maintenance

7.8.1 Weed Control

Following revegetation, rehabilitated areas should be checked for weed proliferation. Maximum allowable targets are outlined in Table 13 and indicate that rehabilitated sites should have equal or greater than 60% of comparable species to the analogue site, with weeds not exceeding 10% of analogue site cover.

Weed control incorporates:

- Preventing the introduction of exotic/invasive weeds (through the use of seed-free topsoil and appropriate washdown procedures);
- Minimising the spread of existing weeds (removing weeds prior to seed formation, ensuring known weed infestations are avoided on foot and in vehicles); and
- Controlling weed infestations using either mechanical or herbicidal treatments (targeted chain-sawing, mulching, soil solarisation, weed pulling, or use of handheld weed sprayers).

The first few years following planting are the most important for controlling the spread of invasive species. As weeds behave as pioneer species, weeds tend to out-compete native species on exposed soils before native species can become established across the rehabilitated area. During the first three growing seasons, botanical surveys and hand removal of weeds or targeted herbicide applications should be undertaken as necessary.

Rehabilitated areas will be monitored for weed proliferation during qualitative monitoring periods (Section8). Maximum allowable weed cover targets set in the EA should be adopted as performance indicators for revegetated areas, with areas not meeting the set criteria managed appropriately.

7.8.2 Reparation

Should rehabilitated areas exhibit loss of vegetation, erosion, or weed infestations, reparation will be required to ensure the success of the area. Depending on the specific issue, reparation may include:

- Replanting failed/unsatisfactory areas;
- Repairing eroded areas
- Pest and weed control);
- Fertiliser applications;
- Watering plants in drier areas, especially during the establishment phase; and
- Visual inspection of revegetated areas should be undertaken regularly to determine maintenance requirements.

In addition to this, Table 12 outlines the completion criteria for vegetation establishment throughout the various domains on the Project site.

8 Rehabilitation Monitoring Program

8.1 Vegetation Monitoring

A rehabilitation monitoring program (RMP) will be conducted annually to analyse the progress of rehabilitated areas against undisturbed reference (analogue) sites. Monitoring will be undertaken as close to the end of the wet season as possible, to allow for the identification of annual species and to assist with identification of species that require the presence of flowers/fruiting material for accurate identification.

The aims of the RMP are to:

- Collect detailed information at each of the analogue and rehabilitation sites, including species composition, density, richness, and percentage ground cover to compare site performance against previous monitoring results and analogue sites; and
- Assess the performance of rehabilitation activities against the rehabilitation criteria outlined in Landform Completion Criteria and Revegetation Completion Criteria and Rehabilitation Requirements nominated by this PMLUP.

Annual rehabilitation monitoring throughout the life of the mine shall provide sufficient replication to enable statistical analysis of results at an acceptable power. Analogue sites need to be protected against mining disturbance to provide valuable data to assist rehabilitation success criteria.

8.1.1 Analogue Sites

Rehabilitation involves the revegetation of areas disturbed by mining that are no longer required for operational purposes. These areas need to be subsequently monitored to track their annual progress towards a self-sustaining ecosystem. This is done by comparing rehabilitated site data to reference data from an undisturbed area, known as a reference or analogue site.

The nominated reference sites apply to all rehabilitation monitoring at the Barbara Project site. Permanent reference sites should be established during the first round of monitoring under this RMP. Reference sites should be established in locations that reflect the post-mining rehabilitation goals of the respective disturbance areas. Factors to consider include slope/landform characteristics, pre-clearing vegetation and landuse. This will allow rehabilitation sites to be paired with an appropriate reference site.

Indicative locations (transect starting point) for reference monitoring sites are listed in Table 27.

Table 26 Proposed Analogue Site Locations on the Project Site

Site ID	Reference Site to Disturbance Type	Analogue Sites	
		Easting	Northing
Analogue 1	WRD (37° rocky side slopes)	TBD	TBD
Analogue 2	ROM Pad	TBD	TBD
Analogue 3	Infrastructure	TBD	TBD
Analogue 4	Drainage	TBD	TBD

TBD = To be determined

8.1.2 Rehabilitation Sites

Rehabilitation monitoring sites will be established in impacted areas as progressive rehabilitation is undertaken across the Project. Once rehabilitation has been undertaken, each domain should contain a minimum of three permanent sampling sites to be compared with reference sites as a part of the RMP.

Rehabilitation site sampling density should be based on the sum of all disturbance areas within a particular domain (e.g. total area occupied by all dams belonging to the water storage domain). The sampling densities proposed are designed to enable the RMP to be statistically robust.

Currently, four rehabilitation sites are proposed for the Project site outlined in Table 28. As rehabilitation progresses throughout the Project site supplementary rehabilitation sites may be established as part of this RMP and assessed against analogue sites within the appropriate RE settings.

Table 27 Proposed Rehabilitation Site Monitoring Locations

Site ID	Disturbance Type	Rehabilitation Sites	
		Easting	Northing
Rehabilitation 1	WRD	TBD	TBD
Rehabilitation 2	ROM Pad	TBD	TBD
Rehabilitation 3	Infrastructure	TBD	TBD
Rehabilitation 4	Drainage	TBD	TBD

Note: TBD = To be determined following completion of landform

8.1.3 Experimental Design

8.1.4 *Monitoring Methods*

Rehabilitation monitoring will compare the progress of rehabilitated sites to reference site data by assessing the following characteristics:

- Ground cover percentage;
- Canopy cover;
- Species richness;

- Woody stem density;
- Recruitment;
- Weed disturbance;
- Photographic monitoring;
- Landform evolution modelling;
- Soil Moisture Characteristic Curves;
- Soil permeability/matrix suction;
- Erosion monitoring; and
- Soil sampling and topsoil depth (every 2-3 years).

These methods are further described in the following sections.

8.1.5 *Permanent Vegetation Monitoring Transects*

This method involves the collection of quantitative data on groundcover cover, canopy cover, species richness and woody stem density/recruitment. At each monitoring site a 50 m tape is extended, with the coordinates of each end recorded, to establish a permanent 50 m transect. A star picket is installed at each end of the transect to identify the exact transect location during each monitoring period. The transect area extends 5 m on either side of the 50 m tape, with 1 m quadrants placed every 5 m on alternating sides (see Figure 26).

The permanent vegetation monitoring methodology follows the *Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland* (Version 4.0). Results from this survey will be used to compare plant communities between analogue and rehabilitated sites, including percentages of native species and weeds referred to in Table 14 completion criteria.

The permanent location of these monitoring transects will be decided during the first annual RMP, with coordinates to be included in the PMLUP before the next annual monitoring occurs.

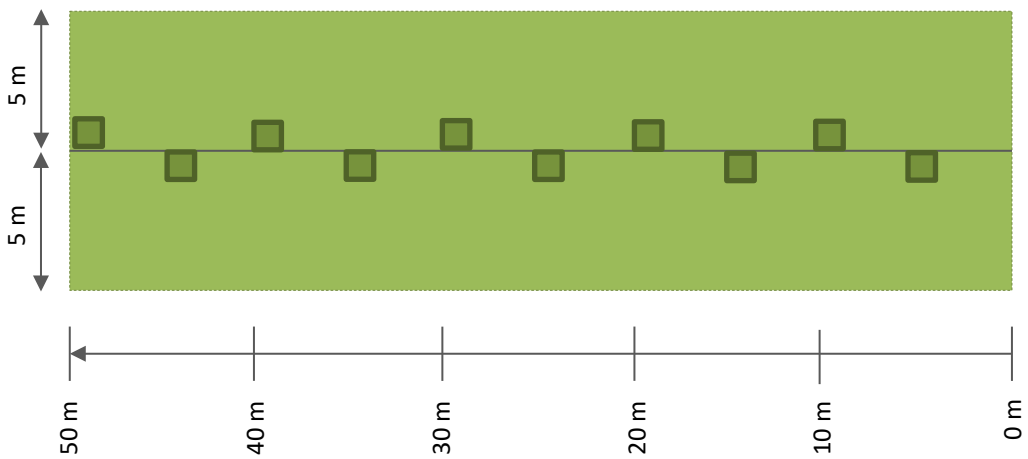


Figure 25 Transect Area and Layout

8.1.6 *Ground Cover Percentage*

Ground cover percentage for each site is recorded within the ten 1 m x 1 m quadrats. The quadrats are placed every 5 m on alternating sides along the 50 m transect, as described in section 8.1.5. In each quadrat the percentage cover of:

- Rock;
- Bare ground;
- Organic litter;
- Cryptogams (lichens and bryophytes); and
- Plant species.

Figure 26 giving guidance on percentage estimation. For reporting purposes, plant species are classified into one of the following six groups:

- Native pasture species;
- Exotic pasture species;
- Shrubs;
- Forbs; and
- Noxious weeds.

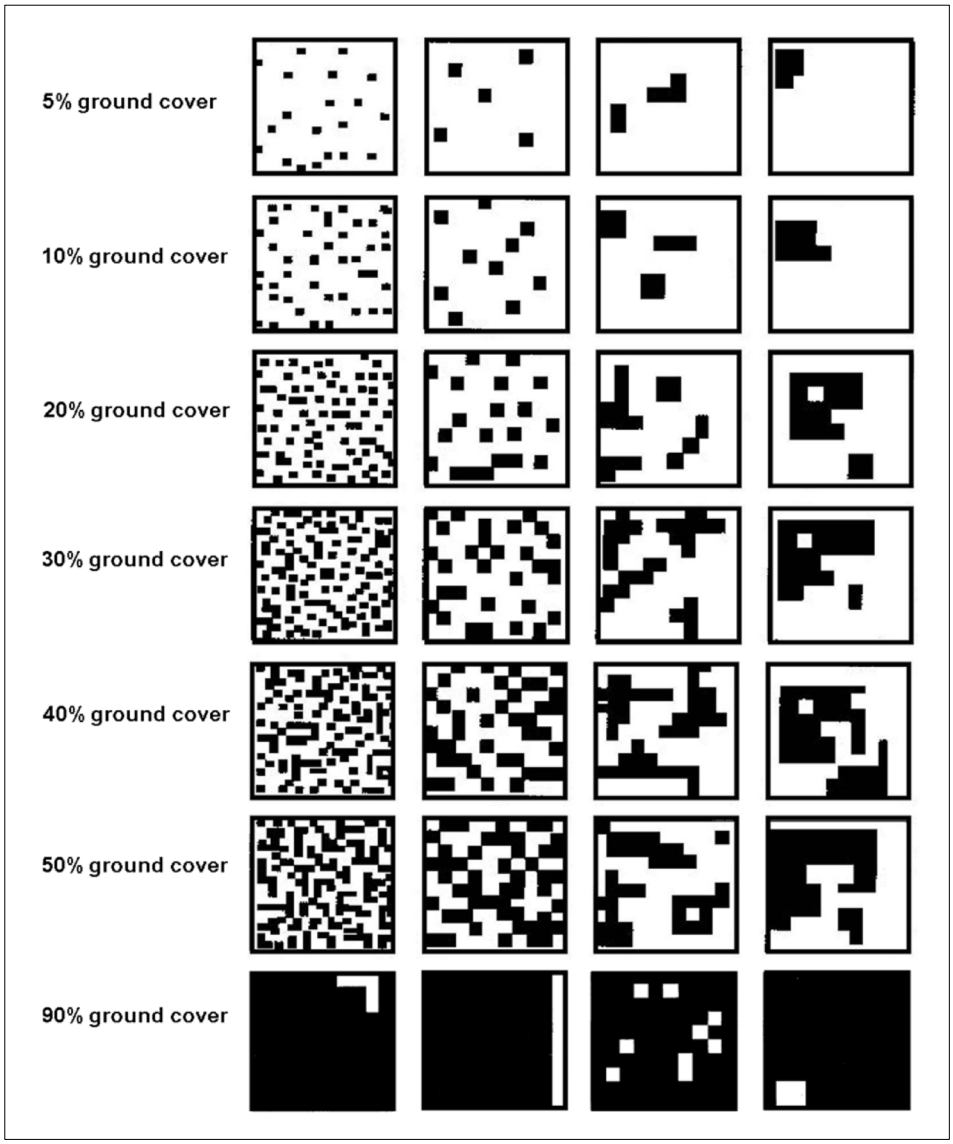


Figure 26 Guide to Estimating Ground Cover Percentage (Eyre *et al.* 2017)

8.1.6.1 *Species Richness*

To measure species richness, all vascular plants occurring within the 10 m x 50 m plot area are recorded (as seen in Figure 26) Any species unable to be identified in the field are collected for later identification. In addition to this, all tree and shrub species within the 10 m x 50 m plot are counted. This allows for the calculation of the total density of trees and shrubs as well as the density of each species.

8.1.6.2 *Recruitment*

Recruitment is assessed over the 10 m x 50 m plot (see Figure 26). Within this plot, the proportion of dominant species found to be regenerating are counted. A regenerating individual is identified as a woody stem species with a diameter at breast height (DBH) of <5 cm. For each dominant canopy species present, at least one individual must be present as a sapling or seedling for the species to be considered as regenerating. The presence of all dominant species in the regenerative state would make up 100% of recruitment.

8.1.7 Statistical Analysis

Average species richness will be calculated from the data obtained using the *Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland*. Data recorded for each site will be collated and averaged to obtain an indication of the species richness and type that the rehabilitation strategy is aiming to achieve.

Tree and shrub, and ground cover densities will be calculated from both the stem counts in the *Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland* and the species counts within the Ground Cover Percentage Method. These densities and percentages will then be averaged as described above for species richness and used to compare with completion criteria listed in Table 13.

8.2 Photographic Monitoring

Photographic monitoring provides a visual record of the vegetation, ground cover, erosion and general appearance of each rehabilitation and reference site, allowing comparisons to be made over time.

A digital camera is used to take the photos so that a permanent record can be kept for each site. The process of taking the monitoring photos is as follows:

1. The person taking the photograph stands at the star picket that marks the beginning of the 50 m transects for each of the sites.
2. The camera is then aimed directly towards the end of the 50 m transect and a photograph is taken.
3. The person then stands at the star picket which marks the end of the 50 m transects for each of the sites.
4. The camera is then aimed directly toward the start of the 50 m transect and a photograph is taken.
5. The digital photographs are then downloaded and stored for future reference.

8.3 Erosion Monitoring

Erosion at the survey sites is monitored through a visual assessment over time. Assessment is undertaken by traversing the 50 m transects described in Section 8.1.5, and recording the number and average depth of any erosion features or rill lines. Table 29 is used to record and classify these observations.

Table 28 Erosion Classifications

Erosion Classification	Minor	Moderate	Severe	Extreme
No. of rills	<15	15-30	31-50	>50
Average depth (cm)	<10	10-30	30-60	>60

The location of any severe erosion outside the transect (i.e. tunnels, mass wasting, large gullies) is also recorded and marked with a handheld Global Positioning System (GPS).

The following information is recorded at each site:

- GPS reading of location;
- General description of type of erosion (gully, rill line, circular failure, tunnelling, etc.) and possible causes;
- Depth of erosion;
- Width of erosion;
- Length of erosion;
- Where eroded material is being deposited; and
- Whether the erosion line is being stabilised by vegetation.

8.4 Topsoil Monitoring

It is recommended that sampling of growth media/rocky substrate along the transects should occur every 2-3 years to monitor plant growth conditions across the rehabilitated areas. Sampling of growth media is conducted by collecting a 200 g sample from the surface 10 cm with a clean plastic trowel and bucket every 10 m along the 50 m transect. These five samples are then mixed in the bucket before a 200 g soil sample is taken from the mix and placed into a plastic sample bag. Samples are sent to a National Association of Testing Authorities certified laboratory for chemical analysis including:

- pH;
- Electrical conductivity;
- Soluble chloride;
- Moisture content;
- Emerson Aggregate Stability test;
- Particle size analysis;
- Exchange acidity;
- Exchangeable cations (Calcium, Magnesium, Potassium, Sodium and Aluminium);
- Cation Exchange Capacity (CEC);
- Calcium / magnesium ratio (Ca:Mg);
- Exchangeable sodium percentage (ESP);
- Total nitrogen, nitrite & nitrate;
- Sulphate;
- Extractable Potassium and Phosphorous (Colwell);
- Total organic carbon and organic matter; and
- Trace elements (Copper, Manganese, Zinc, Iron and Boron).

Soil moisture content shall be measured for interpretive purposes only and will not be assessed in determining rehabilitation success.

Ideally, rehabilitation site data should reflect that of reference sites, though variable data may be sufficient in supporting the chosen post-mining land use.

8.5 Waste Rock Dump Monitoring

A description of the proposed instrumentation, monitoring and maintenance program is provided below. The monitoring program is required to assess the performance of the constructed capping system against the closure objectives.

Revision of the monitoring program may be required as added information becomes available or performance issues identified during regular inspections.

Instrumentation is proposed for the waste rock surface to monitor the performance of the capping system against rehabilitation objectives. Instrumentation proposed to be installed on the WRD are as follows:

- Weather station – Climatic data will be useful for calibrating vadose models and for analysis of matric suction measurements. Rainfall, temperature, and wind speed will be monitored;
- Matric suction sensors – a thermal conductivity sensor measures matric suction. Measurement of matric suction in the cover system will provide an indication of the fate of moisture within the cover system. At the recommended location, nodes will be placed in the surface of the cover soil and surface of waste rock material; and
- Settlement monitoring plates - Settlement monitoring plates installed on the WRD will be used for monitoring settlement and geotechnical stability on annual basis.

Monitoring of the overall condition of the WRD and presence (and cause) of surface settlement /displacement/erosion/ disturbance will occur on an annual basis for a five-year timeframe.

8.6 Groundwater Monitoring

Groundwater monitoring will be conducted on a biannual basis. Samples will be collected by a suitably trained person, and the samples must be analysed by a NATA accredited laboratory. Monitoring locations are set forth in the EA.

8.7 Receiving Water Monitoring

Receiving water monitoring will be conducted at a frequency consistent with other monitoring events conducted at the site (once following a significant rainfall event (>50 mm), for a period of five years. Samples must be collected by a suitably trained person, and the samples must be analysed by a NATA accredited laboratory. Monitoring locations are set forth in the EA.

Receiving water samples should be retrieved from the internal drains (when flow is available), at points located immediately upstream of the outlet point. Field analysis of pH, temperature, electrical conductivity and dissolved oxygen is recommended, as well as laboratory analysis of surface water analytes consistent with set forth in the EA.

8.8 Rehabilitation Success

Once rehabilitation success criteria have been met, for the specified amount of time, application for certification of rehabilitated land can be made before relinquishment.

9 Research Programs and Associated Milestones

The rehabilitation program should be considered as an ongoing trial, whereby, if research and monitoring identify the potential for improvements in rehabilitation methods and techniques, these will be incorporated into successive rehabilitation programs. The PMLUP should be updated when necessary, or when a change in monitoring methodology or rehabilitation strategy occurs.

To facilitate and ensure the continual improvement of rehabilitation methods over the life of the Project, reporting should be conducted on the outcomes of the monitoring program on a three-yearly basis from the commencement of this PMLUP. The timing of this milestone will ensure successive years of rehabilitation will generate meaningful and comparable results and allow for the incorporation of any developments in best practice environmental management from across the mining sector.

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BARBARA

Receiving Environment Monitoring Program
Annual Report 2020

Prepared for:

Round Oak Minerals

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Round Oak Minerals (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
623.20018.20211-R01-v2.0	18 November 2020	Larissa Gross	Scott Harte	Dave Hall

EXECUTIVE SUMMARY

Introduction to the Barbara Receiving Environment Monitoring Program (REMP)

Monitoring and reporting on ecosystem health within the receiving environment is a requirement for the Barbara Copper Project (Barbara), under Schedule E of Environmental Authority EPML02840015. The purpose of a REMP is to provide a periodic assessment of the overall health of the receiving environment at the site and examine for potential presence, cause, extent and effects of any mining-related impacts.

Site Conditions for the 2020 REMP Surveys

This report outlines the results of the 2020 REMP surveys for the wet and dry season, conducted 3 to 4 March 2020 and 23 August 2020, respectively. Prior to the wet season survey, rainfall was above average with high rainfall occurring during the survey; however, due to the ephemeral nature of the area water sampling was only possible at four sites and macroinvertebrate sampling at three sites. Very little rainfall was recorded between March and August of 2020, hence the majority of sites were dry during the August survey with only one site holding sufficient water for surface water sampling and for a one-bed macroinvertebrate sample. All sites were analysed for stream sediment quality during both surveys. B8 was not accessible during both survey due to overgrown tracks and was not sampled.

Surface Water Data

Surface water quality was found to be typical of water in stagnant pools, with low DO and high pH values slightly outside aquatic ecosystem guideline values. Turbidity concentrations were reflective of sediment suspended during rain events and wildlife/livestock trampling the stream bank.

Metal and metalloid concentrations were within guideline values aside from copper during both surveys and cobalt during the dry season survey. Exceedances of total and dissolved copper at reference site B3 were within the previously recorded range and are likely caused from a combination of natural mineralisation and historical mining impacts. Total and dissolved copper concentrations have been higher during each survey at downstream site B7 yet there is limited data from which to draw conclusions. At the furthest downstream site, B9, dissolved copper was below the guideline value while total copper was slightly above. This indicates that copper is decreasing throughout the system and likely to have limited impacts upon the receiving environment.

Total and dissolved cobalt were above the guideline value at B3; however, this is an upstream site and an exceedance in cobalt was recorded during the baseline survey, thus this is likely natural mineralisation or from historical activities in the local area.

Stream sediment quality

Exceedance of stream sediment guideline values were restricted to copper and nickel. Whole and fine fraction copper at upstream site B1US has increased in concentration over time, and for the first-time exceeded concentrations recorded at B1. There is limited temporal data available for B1US to allow robust conclusions and there are no further upstream sites to compare results against. Continued monitoring is required for substantial conclusions. At the other sites where exceedances occurred, B2, B4 and B7, copper concentrations were similar to previously recorded results.

EXECUTIVE SUMMARY

Whole and fine fraction nickel have been a common exceedance at Barbara. At B1US whole fraction and fine fraction nickel have been above the DGV for each survey and it is unknown if this is reflective of baseline conditions as no data were obtained for this site in the baseline survey. At the other upstream sites, B3, B5 and B6, fine fraction nickel has increased over time and whilst the cause is unknown. It unlikely to be from current operations as these sites are upstream of any mining activity. At downstream sites nickel concentrations have persistently been above the DGV yet no increase over time is evident.

At the furthest downstream site, B9, whole fraction copper and whole and fine fraction nickel recorded concentrations below the DGV, and fine fraction copper only slightly exceeded it. This indicates that any potential impacts to the receiving environment decrease with distance from areas of high concentration.

Macroinvertebrate assemblages

Macroinvertebrate indices were typical of an ephemeral system with low habitat heterogeneity. A large proportion of the macroinvertebrate communities consisted of tolerant taxa, no sensitive taxa and very few PET taxa recorded during both surveys and SIGNAL2 scores were low. Indices results are within previous ranges with no temporal changes observed. AusRivAS banding, available for this region for the first time in 2020, reported that upstream site B3 (the sole permanent waterhole within the span of sample sites) is a Band A (similar to model reference) whereas downstream sites B6 and B7 were rated Band B (significantly impaired). Temporal comparisons could not be completed for AusRivAS banding as this was the first year the model was available for the Barbara area.

CONTENTS

1 INTRODUCTION 8
1.1 Barbara Copper Project 8
1.2 The Receiving Environment Monitoring Program (REMP) 8
1.3 Objectives 8
1.3.1 Climate 9
1.3.2 Description of Receiving Waters 9
1.3.3 Environmental Values 9
1.3.4 Potential Impacts to Environmental Values 10
1.3.5 Water Quality Objectives 11
2 METHODOLOGY 12
2.1 Receiving Environment Monitoring Program 12
2.2 2020 Wet and Dry Season Sampling Events 12
2.3 Sampling Sites 12
2.4 Surface Water Quality 13
2.4.1 Field Collection 13
2.4.2 Laboratory Analysis 14
2.4.3 Guideline Values 14
2.4.4 Quality Assurance for Surface Water 15
2.5 Stream Sediment Quality Sampling and Analysis 16
2.5.1 Field Collection 16
2.5.2 Laboratory Analysis 16
2.5.3 Guideline Values 16
2.5.4 Quality Assurance for Stream Sediment 17
2.6 Aquatic Macroinvertebrates 17
2.6.1 Stream and Habitat Assessment 17
2.6.2 Field Collection 19
2.6.3 Data Analysis 20
2.6.4 Quality Assurance 22
3 RESULTS 23
3.1 Surface water quality 23
3.1.1 Wet Season 2020 23
3.1.2 Dry Season 2020 23
3.2 Stream Sediment Quality 24
3.2.1 Wet Season 2020 24
3.2.2 Dry Season 2020 25

CONTENTS

3.3 Macroinvertebrates 28
3.3.1 Wet Season 2020 28
3.3.2 Dry Season 2019 32
4 DISCUSSION AND RECOMMENDATIONS 35
4.1 Surface Water Quality 35
4.2 Stream Sediment Quality 35
4.3 Macroinvertebrates 37
5 RECOMMENDATIONS AND CONCLUSION 38
6 REFERENCES 39

DOCUMENT REFERENCES

TABLES

Table 1 REMP monitoring sites for the 2020 wet and dry season surveys 13
Table 2 Sediment fraction size ranges for particle size distribution 16
Table 3 Variables evaluated in the habitat assessment and descriptions of the scoring system applied for each variable* 18
Table 4 Key to AusRivAS habitat assessment scores (DNRM, 2001) 19
Table 5 Overview of indices used to assess macroinvertebrate assemblages and stream health 20
Table 6 Division of observed (O) vs. expected (E) taxa into bands 22
Table 7 Habitat assessment scores for sample sites during the wet season 28
Table 8 AusRivAS macroinvertebrate banding for bed and edge samples 31
Table 9 Temporal comparison of sites sampled during the 2020 wet season which were also sampled in the 2019 wet season 32
Table 10 Habitat assessment scores for dry season sample sites 32
Table 11 Temporal comparisons of macroinvertebrate assemblage indices at site B3 between dry season monitoring events 34

FIGURES

Figure 1 Annual rainfall (1893 to 2020) divided between wet and dry season records from the West Leichardt Station weather station (BoM, 2020) 9
Figure 2 Mean monthly rainfall recorded from the West Leichardt Station weather station from 1893 to 2020, compared with monthly rainfall from September 2019 to August 2020 (BoM, 2020) 9
Figure 3 Temporal comparison of total and dissolved copper in surface water at Barbara monitoring sites 24
Figure 4 Particle size distribution of stream sediments recorded during the 2020 wet season survey 25
Figure 5 Particle size distribution of stream sediments recorded during the 2020 dry season survey 26

CONTENTS

Figure 6 Temporal comparison of fine fraction copper in the stream sediment 27
Figure 7 Temporal comparison of fine fraction nickel in the stream sediment 28
Figure 8 Abundance of taxa collected at Barbara during the 2020 wet season 29
Figure 9 Taxa richness for sites sampled at Barbara during the 2020 wet season 30
Figure 10 Percent tolerant taxa at Barbara during the 2020 wet season 30
Figure 11 SIGNAL 2 scores for Barbara sites sampled during the 2020 wet season survey 31
Figure 12 Abundance of taxa collected at Barbara during the 2020 dry season 33

APPENDICES

Appendix A Map

Appendix B Site Photographs and Field Sheets

Appendix C Surface Water Data

Appendix D Stream Sediment Data

Appendix E Macroinvertebrate Data

Appendix F Quality Assurance

Appendix G SGS Chain of Custody

Appendix H SGS Laboratory Results

Appendix I SGS Laboratory Reports

1 Introduction

1.1 Barbara Copper Project

The Barbara copper-gold project is located in far north Queensland within mining lease (ML) 90241. The operation is owned by Round Oak Minerals Pty Ltd (ROM) and operated under Environmental Authority (EA) permit EPML02840015. The 1,170ha ML area is located on the West Leichhardt Station, approximately 50km northeast of Mt Isa in the Northwest Highlands bioregion. Historical small-scale mining has previously occurred on the site and in the surrounding landscape. Currently the site consists of two pits (within the central southern area of the ML), a run of mine pad, maintenance workshops, administration buildings, a haul road and water management infrastructure including a sediment dam, clean water diversions and mine impacted water drains. The surrounding landscape is used for low intensity cattle grazing.

1.2 The Receiving Environment Monitoring Program (REMP)

The REMP program includes sampling of surface waters, stream sediments, habitat assessments and macroinvertebrate bioindicators at ten sites in the Barbara receiving environment during the wet and dry season. Through analysis of these aspects of the receiving environment, the monitoring program is designed to monitor, identify and describe adverse impacts to environmental values of receiving waters. The objectives of the REMP in the context of satisfying the requirements of the EA are outlined below.

1.3 Objectives

The current EA outlines several conditions that must be met to ensure protection of environmental values (EV's) as follows:

- Condition E20 – The environmental authority holder must develop, document and implement a Receiving Environment Monitoring Program (REMP) to monitor, identify and describe any adverse impacts to environmental values of receiving waters by 5 October 2016. The REMP must include at minimum:
  - Monitoring the effects of the mining activities on the receiving environment periodically under natural flow conditions and while contaminants are being release (if applicable)
  - Encompass the waters of Leichardt River and connected or surrounding waterways withing 10km downstream of the mining activities
  - Identification of all environmental values of receiving waters
  - An assessment of background reference water quality, the condition of downstream water quality compared against water quality objectivise, and the suitability of current environmental authority conditions to protect downstream environmental values; and
  - Application of biological monitoring if required to determine whether the mining activities are being conducted in a manner that enhances or protects the environmental values of receiving waters.
- Condition E21 – A report outlining the finding of the REMP that addresses all requirements specified under condition E20, including all monitoring results and any interpretations or assumptions relied upon, must be completed annually.

The objectives of the aquatic ecology monitoring survey were as follows:

- To satisfy conditions E20 and E21 of the sites EA;
- To determine the current condition of aquatic ecosystems within the receiving environment by assessing aquatic macroinvertebrate, surface water and stream sediment quality results; and
- To identify the nature and extent of any potential impacts on the aquatic environment by comparison of site data from the 2020 wet and dry season surveys with data available from previous years.

To achieve the objectives of this survey, aquatic macroinvertebrates, surface water and stream sediment samples were collected from sites within the Barbara project area receiving environment during the 2020 wet and dry season surveys.

1.3.1 Climate

The Barbara area is characterised by hot summers and mild winters. Meteorological data is available for a number of weather stations in the area and long-term rainfall data was sourced from the West Leichardt Station weather station (number 029121) approximately 27km from the mine (BoM, 2020).

The local area typically experiences short, intense rainfall events that primarily occur during the wet season from November to March (BoM, 2020; **Figure 1**). Annual wet season rainfall can vary significantly, as show in **Figure 2**, which depicts the high variability of precipitation since 1893. Average annual wet season precipitation over this period is 356mm, and the average dry season precipitation is 66.9mm.

Rainfall in the wet season, prior to sampling, was slightly above average for the same period (November through to February), largely due to a large rainfall event from 26 to 31 January, which resulted in watercourses flushing and instigating the wet season survey. After January, drier than average conditions persisted in the area prior to the August dry season survey, with no rainfall recorded since May.

Figure 1 Annual rainfall (1893 to 2020) divided between wet and dry season records from the West Leichardt Station weather station (BoM, 2020)Figure 2 Mean monthly rainfall recorded from the West Leichardt Station weather station from 1893 to 2020, compared with monthly rainfall from September 2019 to August 2020 (BoM, 2020)Description of Receiving Waters

The landscape at the site is composed primarily of rocky hills of folded siliceous metamorphosed sedimentary rock, with generally skeletal soils (including in watercourses). Average elevation is 350m above sea level and the site is traversed by a series of small ephemeral creeks and drainage lines. These meet a larger un-named watercourse draining to the northwest and eventually flow into the Leichardt River approximately 6km downstream of the project site. This un-named creek runs through an area disturbed by historical mining activities that predate any ROM activities on site.

1.3.3 Environmental Values

EV's are qualities that require protection to support healthy aquatic ecosystems and safe community use (DES, 2019). To protect the water environment while allowing for ecologically sustainable development a framework exists to aid identification of EV's, which states that all tidal and non-tidal waters have EV's (DES, 2019).

The Barbara site falls within the Leichardt River catchment in the Southern Gulf Catchments region, as relevant to the EPP Water (DES, 2019), for which specific water and wetland EV's attribution and water quality planning is currently under development. However, EV's can be estimated by referring to the framework (DES, 2019) and analysing the surrounding landscape.

A search of groundwater bores on Queensland Globe indicates that multiple bores are scattered within the Barbara ML; however, there are no homesteads within the immediate area that would rely on these for drinking water or domestic use. Some of these bores are groundwater monitoring bores for the mine and others were pre-existing. These bores are likely utilised for any of the following:

- Stock watering
- Agricultural use
- Environmental monitoring; and
- Dewatering bores for in-pit mining activities.

The Barbara site is not situated near any township, and the surrounding landscape is therefore not likely to be utilised by the public for recreational purposes. There are no aquaculture practices or industrial activities occurring in the surrounding landscape, apart from the mine which does not use water on an industrial level. Lake Julius is a man-made feature constructed in 1976 and is located approximately 30km downstream. Environmental values associated with this lake are drinking water, recreation, agricultural, and possibly industrial uses.

Given the above, EV's applicable to the project under the EPP Water (DES, 2019):

- *Aquatic ecosystems – slightly disturbed waters – the biological integrity of high ecological value waters with slightly modified physical or chemical indicators but effectively unmodified biological indicators*
- *Stock watering – suitability of water supply for production of healthy livestock;* and
- *Cultural and spiritual values – custodial, spiritual, cultural and traditional heritage, hunting, gathering and ritual responsibilities*.

1.3.4 Potential Impacts to Environmental Values

Surface Water

The potential surface water quality impacts from activities on the project include:

- Potential metalliferous, saline or sediment laden runoff; and
- Overflows from North or South Pit and sediment dam.

Adverse surface water quality conditions have the potential to impact on flora and fauna that are reliant on the creek system and there is the potential for works close to creek systems to significantly alter the hydrological regimes.

Stream Sediment

Potential stream sediment related impacts associated with the project include increased sediment runoff from the project that can result in increased turbidity of affected waterways and introduce toxins (i.e. increased metal concentrations). This can affect aspects of the instream fauna through feeding and respiration.

Groundwater

The potential groundwater impacts from the project activities could include:

- Drawdown of groundwater potentially impacting on other users of the groundwater in the vicinity of the project.
- Leaching of metals and metalloids into the shallow ephemeral groundwater aquifers.

1.3.5 Water Quality Objectives

Watercourses in the Barbara region are poorly studied— as stated in the previous section, waterways associated with the Leichardt River are not listed in Schedule 1 of the EPP water; thus, no Water Quality Objectives currently exist for the aquatic environments at Barbara.

2 Methodology

2.1 Receiving Environment Monitoring Program

The objectives of the REMP are to provide a dataset with which to establish the overall health of the aquatic receiving environment and provide a point of comparison for any future assessments of mine-related disturbance on water quality.

Ongoing assessments of water and sediment quality and macroinvertebrate assemblages are recommended during both wet and dry seasons to provide a dataset that reflects seasonal variation in the physical, chemical and ecological characters of watercourses. The timing of the wet season survey is subject to rainfall and streamflow conditions and is generally undertaken after rapid creek flows have ceased and surface water pools remain. These conditions ensure aquatic macroinvertebrate communities can establish after watercourses have flushed. Dry season monitoring is typically undertaken during drier conditions at the end of winter in absence of any significant rain events that would flush the watercourses.

The current REMP for Barbara includes sampling at ten sites relevant to the Barbara project area, including four upstream sites and six downstream sites. The sampling methods are designed to determine the current condition of aquatic ecosystems within the receiving environment, incorporating aquatic macroinvertebrates, surface water and stream sediments. The condition of these parameters at downstream sites are compared with upstream sites that represent the condition of the receiving environment in the absence of mining-related disturbance.

2.2 2020 Wet and Dry Season Sampling Events

This report describes stream sediment, surface water and aquatic macroinvertebrate sampling undertaken at sites during the 2020 wet and dry season sampling events at Barbara.

The 2020 wet season survey was conducted 3 to 4 March 2020. Downstream site B8 was inaccessible during this survey due to the access track being significantly overgrown. Heavy rainfall occurred during the survey, yet despite this, several monitoring points remained dry. As watercourses in this area are naturally ephemeral and drain rapidly, only four sites contained sufficient water for water sampling and three were sampled for macroinvertebrates. All sites were sampled for stream sediment quality.

The 2020 dry season survey was conducted on the 23 August 2020 following several months of dry conditions and below average dry season rainfall. Of the ten sampling sites only one (B3) had sufficient water for surface water and one macroinvertebrate bed samples. Downstream site B8 remained inaccessible during this survey due to the access track being significantly overgrown. All accessible sites were sampled for stream sediment quality.

2.3 Sampling Sites

The monitoring sites surveyed during 2020 surveys are depicted in the monitoring locations map in **Appendix A** and described in **Table 1**. Survey site descriptions, habitat assessments, sketches and datasheets have been compiled and are provided in **Appendix B**.

Based on recommendations made in the 2019 wet season survey an additional two sites (B1US and B9) were identified and added to the REMP survey to elucidate the origin and persistence of heavy metals in the receiving environment. Site B1 has previously been considered an upstream site as it is above previous historical workings; however, due to clearing occurring adjacent to this site in early 2019 it can no longer be considered as a site upstream from disturbance. An additional site upstream of B1 and current operations was established during the 2019 dry season survey (B1US), representing the furthest upstream monitoring point on the main tributary. However, this site is ~30m downstream of the haul road and thus interpreting data from B1US as an upstream site must be undertaken with caution. Site B9 was established during the 2019 dry season sampling to represent the furthest downstream monitoring site, located just east of Lake Julius Rd on the main watercourse. Currently, B9 is sampled only for surface water and stream sediment.

Table 1 REMP monitoring sites for the 2020 wet and dry season surveys

Stream	Site	Sampling regime	Description	Easting	Northing
Leichardt River tributary	B1US	Upstream of current activities	Furthest upstream site on the main watercourse.	380677	7740482
	B1	Adjacent to current disturbance	Previously furthest upstream site prior to current infrastructure development and establishment of B1US.	380436	7740728
	B2	Downstream of historical disturbance	Approximately 1.8km downstream from B1 on the main watercourse.	379678	7742242
	B3	Upstream of historical disturbance	Eastern tributary of the main watercourse.	379897	7742670
	B4	Downstream of historical disturbance	On the main watercourse, below the confluence of the eastern tributary. Approximately 370m downstream of B2.	379398	7742448
	B5	Upstream of historical disturbance	Southern tributary of the main watercourse.	379136	7741925
	B6	Upstream of historical disturbance	Eastern tributary of the main watercourse.	379089	7743128
	B7	Downstream of historical disturbance	On the main watercourse, below the confluence of all tributaries. Approximately 1.3km downstream of B4.	378660	7743261
	B8	Downstream of historical disturbance	Previously furthest downstream site prior to establishment of B9. Approximately 1.6km downstream of B7.	377326	7743786
	B9	Downstream of historical disturbance	Furthest downstream site on the main watercourse, positioned approximately 500m east of Lake Julius Road and 3.1km downstream of B8.	374831	7744106

Coordinates provided in GDA94, Zone 54

2.4 Surface Water Quality

2.4.1 Field Collection

In-situ physico-chemical water quality data was recorded for each sample site where sufficient water was available. Water temperature, pH, electrical conductivity (EC), dissolved oxygen (DO) and turbidity were recorded using a multi-parameter water quality meter, according to manufacturer's specifications.

Sampling methods followed those outlined in the Monitoring and Sampling Manual 2018 (Department of Environment and Science, 2018) and are summarised below:

- Operators familiarised themselves with site locations and issues relating to sampling prior to the sampling event
- Photographs were taken of each site, facing upstream and downstream
- An *in-situ* water quality meter was used to take field physico-chemical parameters and was used according to the manufacturer's instructions, while also ensuring the meter was properly maintained and calibrated
- Operators stood at the sample location and submerged the water quality meter into the water, in an upstream direction; and
- Operators waited until physico-chemical parameters stabilised. These data were recorded on the field datasheet.

Water quality samples were taken at the same time as the *in-situ* measurements and sent to the laboratory for processing of further water quality information. Water samples were taken directly from the water column while wearing clean disposable gloves, facing upstream, in sample containers provided by NATA accredited laboratory, SGS Australia Pty Ltd (SGS). Field filtered water samples were collected for dissolved metals using 0.45µm polyethersulfone filters. Samples were preserved by placing them on ice or in refrigerated conditions until received by the SGS laboratory in Cairns.

2.4.2 Laboratory Analysis

The water samples were analysed by the laboratory for water hardness (as calcium carbonate), sulfate, fluoride and total and dissolved metals (arsenic, barium, bismuth, chromium, cobalt, copper, molybdenum, nickel, selenium and uranium).

2.4.3 Guideline Values

Surface water quality data were compared to published guideline values to assess the condition of water and assist in interpretation of aquatic macroinvertebrate results. Published guidelines were used as a guide to depict water quality and the effects it may be having on the aquatic ecosystems.

There are currently no Queensland Water Quality Guidelines (QWQG; Department of Environment and Heritage Protection (EHP), 2009) for the Gulf region, therefore water quality data were compared to the following guidelines:

- Australian and New Zealand Environmental Conservation Council (ANZECC & ARMCANZ, 2000) tropical Australia upland streams guideline values were used for pH, turbidity, and dissolved oxygen (DO)
- QWQG (EHP, 2009) regional guideline values for the Gulf Rivers – upland streams – Gulf salinity zone for electrical conductivity (EC); and
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) default guideline values (DGV's) for heavy metals (recognised as toxicants in ANZG) for the protection of slightly to moderately disturbed systems (95% protection for aquatic organisms) for total and dissolved metals.

Water hardness plays an important role in contaminant toxicity as it limits the bioavailability of certain heavy metals to aquatic organisms (ANZG, 2018). If metal concentrations exceeded ANZG (2018) trigger values, the hardness modified trigger values (HMTV) were calculated where applicable (cadmium, chromium, nickel, lead, and zinc) as per Table 3.4.3 in ANZG (2018). HMTVs were not applied if total dissolved solids (TDS) levels exceeded 2,500ppm. If values exceeded HMTVs for these metals, or if HMTVs were not applicable, the following method of interpretation was used:

- Results that were elevated above ANZG (2018) values were compared to results from relevant upstream sites to assess any potential impacts from upstream in the receiving environment on the macroinvertebrate assemblage present.

The analysis of toxicants in aquatic ecosystems is focused on the interpretation of dissolved metal concentrations. Dissolved metal concentrations are considered more pertinent to the management of water quality as they are more bioavailable to uptake by organisms, therefore emphasis was given to comparison of dissolved heavy metals in water samples (ANZG, 2018).

2.4.4 Quality Assurance for Surface Water

For quality assurance, a duplicate water sample was collected from one site to confirm the analytical reliability of laboratory results (site B3 for both wet and dry sampling events). This sample was collected following the same methodology as above; however, duplicate sample bottles were labelled QA to ensure the laboratory did not know which site was used for quality assurance purposes. The quality assurance site was recorded on the field datasheet.

Interpretation was based on the reproducibility assessment method, which provides a measure of precision. The analytical values from the sample and its replicate are compared by calculating the relative per cent difference (RPD) for each parameter as follows:

$$RPD\ (\%) = \frac{[X]_{sample} - [X]_{replicate}}{[X]_{\ mean\ of\ sample\ and\ replicate}} \times 100$$

The RPD then uses the limit of reporting (LOR) to identify thresholds for valid reproducibility. These include:

- Mean of sample and replicate <10x LOR: There is no RPD limit (i.e. reproducibility is valid);
- 10x LOR < Mean of sample and replicate <20x LOR: The RPD range limit is 0%–50% for a valid duplicate; and
- Mean of sample and replicate >20x LOR: The RPD range limit is 0%–20% for a valid duplicate.

A blank water sample was also taken to confirm contamination was not introduced during field handling. Results of the quality assurance and blank water sample analyses are provided in **Appendix F** of this report.

2.5 Stream Sediment Quality Sampling and Analysis

2.5.1 Field Collection

Field collection of stream sediments was completed using the sediment quality assessment guidelines outlined in Simpson *et al.* (2005) and the Australian Standard (AS/NZS 5667.12:1999) for *Water quality sampling-Guidelines on sampling of bottom sediments*. Stream sediment samples were collected from the streambed at each monitoring site and analysed in the laboratory for physical and chemical properties. Surface sediments were taken from the top 10cm, where most biological activity occurs (Simpson *et al.*, 2005) and composite samples were taken along a streambed length of 10m using a hand trowel. Approximately 500g of sediment was taken from each site. The composite sample was mixed and collected into a sediment sample bag. The potential for cross contamination between sample sites was minimised by the cleaning of sampling equipment with deionised water and sample site water between each site.

2.5.2 Laboratory Analysis

Stream sediment samples were analysed by NATA accredited laboratory SGS for chemical and physical properties. Chemical analyses were undertaken on the whole sediment fraction (<2mm) and the fine sediment fraction (<63µm) for arsenic, barium, bismuth, chromium, cobalt, copper, molybdenum, nickel, selenium and uranium. The particle size distribution was determined for each sample to describe the proportions of stream sediments that occur across the sediment size classes (**Table 2**). Copies of the chain of custody forms, laboratory receipts and analytical reports can be found in the appendices of this report.

Table 2 Sediment fraction size ranges for particle size distribution

Size Class	Fraction Size Range
Gravel	>2mm
Coarse Sand	600µm–2mm
Large Medium Sand	300–600µm
Small Medium Sand	212–300µm
Fine Sand	63–212µm
Silt and Clay	<63µm (fine fraction for metals analysis)

2.5.3 Guideline Values

Chemical results were compared to relevant sediment quality guidelines to provide an indication of sediment quality at the time of sampling. Results were compared to default guideline values (DGV) and high guideline values (GV-high) (ANZG, 2018) for the whole sediment fraction. The DGVs are considered trigger values and concentrations of contaminants below this value are expected to cause a very low frequency of adverse biological effects. All concentrations above the DGV trigger were reported as exceedances. The GV-high represents a concentration above which adverse biological effects are expected to occur more frequently. Where exceedances occurred, this value was utilised to interpret the likelihood that the observed concentrations would cause biological harm. DGV and GV-high correspond to the effects range low and median values outlined in Long *et al*. (1995). The fine sediment fraction represents the most bioavailable component of the stream sediments, and analysis of the fine sediment fraction is considered the most accurate representation of materials that are likely to be ingested by aquatic organisms (Minshall, 1984; Simpson *et al.,* 2013).

2.5.4 Quality Assurance for Stream Sediment

For quality assurance purposes, a duplicate sediment sample was collected from one site to confirm analytical reliability of laboratory results (site B3 for both surveys). The quality assurance sediment sample was collected in the usual manner, except approximately 1kg of sediment was collected, mixed thoroughly, one of the corners of the sample bag was cut and the sediment was poured into a cone shape on clean paper, flattened and divided into quarters with a clean trowel. The top left and bottom right quarters were extracted into a clean sediment bag and labelled with the site name, while the top right and bottom left quarters were extracted into a clean sediment bag and labelled 'QA'. The quality assurance site was recorded on the field datasheet. Results of the quality assurance were analysed using the methods outlined in Section 2.4.4. Results of the quality assurance analyses are provided in the appendices of this report.

2.6 Aquatic Macroinvertebrates

Macroinvertebrates are organisms that lack a backbone (invertebrate) and can easily be seen with the naked eye (macro). These animals include insects, crustaceans, molluscs, arachnids and annelids. They inhabit all types of running waters for all or part of their lives and their survival is related to the quality of the water they inhabit. Aquatic macroinvertebrates are easily sampled due to their limited functional mobility and are typically used to provide an integrated measure of stream health in favour of other aquatic organisms. Macroinvertebrate assemblages may be influenced by the quality of the surrounding habitat at sampling sites (Connolly *et al.,* 2007). An integrated approach considering habitat quality in conjunction with macroinvertebrate indices is therefore the most robust method for assessing macroinvertebrate assemblages and stream health. The sections below outline the methodology used to assess habitat quality and calculate macroinvertebrate indices for this report.

2.6.1 Stream and Habitat Assessment

At each site, a stream assessment was undertaken prior to sampling of sites to determine the most suitable location for macroinvertebrate sampling. Typically, sites are sampled within the same 100m reach as the previous survey, to allow easy and consistent comparison of data. At times, however, this is not possible (e.g. when sedimentation changes the watercourse structure over time or when the ephemeral nature of waterways results in isolated pools). In this case, samples were taken as close to the previous sample location as possible. The assessment conducted for this report required operators to walk 50m in each direction from the monitoring site to determine the best habitat to sample. Within this 100m reach, two suitable bed habitats were found and sampled.

Habitat characteristics at sampling sites may have a strong influence on aquatic macroinvertebrate assemblages. To determine the influence of habitat on macroinvertebrate assemblage structure and indices, a habitat assessment was taken at all sites containing sufficient water for macroinvertebrate sampling. Habitat assessments were focused on evaluating the structure of the surrounding physical habitat, which may influence the quality of the water resource and the condition of the resident aquatic macroinvertebrate community (**Table 3**). This assessment considers the variety and quality of the substrate, channel morphology, bank structure and riparian vegetation. Individual scores are given to each habitat variable and summed to calculate the overall habitat assessment score. Habitat assessment is given a score out of 135 and divided into four habitat categories: poor, fair, good or excellent, based on Department of Natural Resources and Mines methodology (DNRM, 2001). A high score indicates a stream with a complex habitat structure typically favoured by aquatic macroinvertebrates, whereas a low score represents a very simple unfavourable stream habitat (**Table 4**). This information, used in conjunction with water quality and stream sediment quality results, can help interpret aquatic macroinvertebrate results.

Table 3 Variables evaluated in the habitat assessment and descriptions of the scoring system applied for each variable*

Habitat Variable	Category			
	Excellent	Good	Fair	Poor
1. Bottom substrate/ available cover	Greater than 50% rubble, gravel, submerged logs, undercut banks or other stable habitat.	30%–50% rubble, gravel or other stable habitat.	10%–30% rubble, gravel, or other stable habitat. Habitat availability less than desirable.	Less than 10% rubble, gravel or stable habitat. Lack of habitat is obvious.
	20, 19, 18, 17, 16	15, 14, 13, 12, 11	10, 9, 8, 7, 6	5, 4, 3, 2, 1
2. Embeddedness	Gravel, cobble and boulder particles are between 0% and 25% surrounded by fine sediment.	Gravel, cobble and boulder particles are between 25% and 50% surrounded by fine sediment.	Gravel, cobble and boulder particles are between 50% and 75% surrounded by fine sediment.	Gravel, cobble and boulder particles are between 75% and 100% surrounded by fine sediment.
	20, 19, 18, 17, 16	15, 14, 13, 12, 11	10, 9, 8, 7, 6	5, 4, 3, 2, 1
3. Velocity/depth category	Slow deep, slow shallow, fast deep, fast shallow, habitats all present.	Only 3 of the 4 habitat categories present (missing riffles/runs receive lower score).	Only 2 of the 4 habitat categories present (missing riffles/runs receive lower score).	Dominated by one velocity/depth category (usually pool).
	20, 19, 18, 17, 16	15, 14, 13, 12, 11	10, 9, 8, 7, 6	5, 4, 3, 2, 1
4. Channel alteration	Little or no enlargement of islands or point bars and/or no channelisation.	Some new increase in bar formation mostly from coarse gravel, and/or some channelisation present.	Moderate deposition of new gravel, coarse sand on old and new bars, pools partly filled with silt, and/or embankments on both banks.	Heavy deposits of fine materials increased bar development, most pools filled with silt, and/or extensive channelisation.
	15, 14, 13, 12	11, 10, 9, 8	7, 6, 5, 4	3, 2, 1, 0
5. Bottom scouring and deposition	Less than 5% of the bottom affected by scouring and deposition.	5%–30% affected. Scours at constrictions and where grades steepen, some deposition in pools.	30%–50% affected. Deposits and scours at obstructions and bends. Some deposition in pools.	More than 50% of the bottom changing nearly year long. Pools almost absent due to deposition. Only large rocks in riffles exposed.
	15, 14, 13, 12	11, 10, 9, 8	7, 6, 5, 4	3, 2, 1, 0
6. Pool/riffle, run/band ratio	0–7 Variety of habitat. Deep riffles and pools.	7–15 Adequate depth in pools and riffles. Bends provide habitat.	15–25 Occasional riffle/bend. Bottom contours provide habitat.	>25 Essentially a straight stream. All flat water. Poor habitat.
	15, 14, 13, 12	11, 10, 9, 8	7, 6, 5, 4	3, 2, 1, 0
7. Bank stability	Stable, no evidence of erosion or bank failure. Side slopes generally <30%. Little potential for future problem.	Moderately stable. Infrequent, small areas of erosion mostly healed over. Side slopes to 40% on bank.	Moderately unstable. Moderate frequency and size of erosional areas. Side slopes to 60% on banks.	Unstable. Many eroded areas. Side slopes >60% common. Bare areas frequent along straight sections and bends.
	10, 9	8, 7, 6	5, 4, 3	2, 1, 0

Habitat Variable	Category			
	Excellent	Good	Fair	Poor
8. Bank vegetative stability	Over 80% of the streambank surfaces covered by vegetation or boulders and cobble.	50%–79% of the streambank surfaces covered by vegetation, gravel or larger material.	25%–49% of the streambank covered by vegetation, gravel or larger material.	<35% of the streambank surfaces covered by vegetation, gravel or larger material.
	10, 9	8, 7, 6	5, 4, 3	2, 1, 0
9. Streamside cover	Dominant vegetation is of tree form.	Dominant vegetation is shrub.	Dominant vegetation is grass, sedge, ferns.	>50% stream bank = no vegetation.
	10, 9	8, 7, 6	5, 4, 3	2, 1, 0

* Scores for each habitat variable provide a numerical assessment of habitat quality. Low scores indicate poor habitat, and high scores indicate favourable habitat for macroinvertebrates.

Table 4 Key to AusRivAS habitat assessment scores (DNRM, 2001)

Habitat Assessment Score	Interpretation
0–35	**Habitat quality is poor** There is limited availability for in-stream habitat. There is little variation in velocity and depth of water, and the creek bed is dominated by fine sediment types. The water body typically consists of a small, shallow pool. Streamside vegetation, if present, consists of grasses and sedges. There is moderate to significant bank erosion.
36–70	**Habitat quality is fair** There is some availability of rubble, gravel or other stable habitat. The streamside vegetation consists mainly of grasses and sedges. There is moderate evidence of bank erosion and the percentage of vegetation cover on banks is less than 50 per cent.
71–105	**Habitat quality is good** The bank is moderately stable, there is variety in depth and velocity categories within the water body, and the substrate type is variable and tending towards gravel, cobble and boulders. Streamside vegetation dominated by shrubs, adding to bank stability. The percentage of streamside cover of vegetation is between 50% and 79%.
106–135	**Habitat quality is excellent** There is no bank erosion and the dominant vegetation is in the tree form. There is great variability in depth and velocity, and the habitat is relatively complex, offering favourable conditions for macroinvertebrates. Habitat usually contains submerged logs, undercut banks or other stable habitat.

2.6.2 Field Collection

Australian River Assessment System (AusRivAS) standardised assessments in Queensland use bed and edge habitat of streams to monitor freshwater macroinvertebrates (DNRM, 2001). However, in ephemeral streams, edge habitat is typically unavailable or only available for short periods of time at the peak of the wet season. To overcome a number of obstacles relating to the use of this AusRivAS sampling methodology in north Queensland stream environments, SLR uses an alternative methodology using replicate bed samples. This is a robust approach as it allows replicate samples to be obtained within bed habitats.

Sampling within a pool habitat requires disturbance of the substratum by the sampler using their feet to kick substrate material. Two replicate kick samples within bed habitats were collected from each site where sufficient water was present. Appropriately trained personnel conducted the sampling and live picking. Aquatic macroinvertebrates were collected from each site and were live picked in the field. Samples were collected using the following methods:

- Each site was located using GPS and the coordinates provided
- Each site was photographed (upstream and downstream)
- Water and stream sediment samples were collected following the methodology provided within the relevant sections of this report
- Aquatic macroinvertebrate samples were taken from two bed locations, keeping samples separate. Each kick sample was undertaken for two minutes over a length of 10m, keeping the net (250µm mesh aperture) downstream of the plume to collect dislodged macroinvertebrates. If there is no flow, a short sweeping action of the net is used to capture any dislodged macroinvertebrates. The suspended macroinvertebrates are captured as the net sweeps through the cloud of suspended matter.
- The material collected from each kick sample was emptied into separate white sorting trays
- The two macroinvertebrate samples were live picked in the field for 30 minutes. Samples were transferred from the sorting trays to a solution of pure ethanol
- For quality assurance purposes, the residuals of each sample at one site were collected after live picking and placed in 100% ethanol for validation of the sampling and analysis process in the laboratory to quantify any errors in sampling
- The rapid biophysical assessment datasheets were completed for each of the two bed habitats sampled at each site and included data such as water depth, substrate composition, flow, occurrence of overhanging and trailing riparian vegetation, along with longitudinal and cross-section diagrams taken of the 100m stream reach. This information assists with interpretation of macroinvertebrate assemblage post laboratory identification; and
- All macroinvertebrate and quality assurance samples were sent to the laboratory for identification to appropriate taxa level.

2.6.3 Data Analysis

Macroinvertebrate indices

Guidelines for the assessment of macroinvertebrate assemblages in Queensland are based on a number of sensitivity indices, which are outlined in **Table 5**. The comparison of indices between sites and years can provide an indication of stream health; however, differences in habitat characteristics between sites should be taken into account when interpreting indices. To limit interpretational errors based on the sole use of a particular index, a variety of indices were calculated for each macroinvertebrate sample and considered in conjunction with habitat scores. These indices were used to interpret macroinvertebrate results from the 2020 surveys.

Table 5 Overview of indices used to assess macroinvertebrate assemblages and stream health

Index	Description
Taxa richness	Taxa richness is the number of aquatic macroinvertebrate taxa collected within a sample. Changes in taxa richness are likely the result of some change in the condition of a site or some change from reference condition.

Index	Description
PET taxa richness	PET taxa richness refers to the number of taxa of Plectopera (Stoneflies), Ephemeroptera (Mayflies) and Trichoptera (Caddisflies) taxa within a sample. These three orders of insects are considered sensitive to changes in their environment, and therefore PET taxa richness can be used as an indication of stream health.
% Sensitive/ tolerant taxa	The relative percentage of tolerant and sensitive taxa within a sample can be an indication of water quality. Taxa are categorised as sensitive if they have a sensitivity grade of 8–10, and tolerant if they have a sensitivity grade of 1–3 (EHP, 2009). Taxa with a sensitivity grade of 4–7 are considered neither tolerant nor sensitive. The percentages of tolerant and sensitive taxa were calculated for each macroinvertebrate assemblage at each site.
SIGNAL 2 Scores	The SIGNAL (Stream Invertebrate Grade Number - Average Level) score can be used as an indicator of water quality (Chessman, 2003; EHP, 2009). Each macroinvertebrate family has been allocated a sensitivity grade based on relative sensitivity to pollutants and other physico-chemical factors. SIGNAL scores were calculated by taking the average sensitivity scores of taxa present within a sample, and weighting this by the abundance of each taxon using a weight factor as follows: $$\frac{\sum (SIGNAL\ grade\ \times\ weight\ factor)}{total\ weight\ factor}$$ Further information on the calculation of SIGNAL 2 scores (weighted for abundance) can be found in Chessman (2003).

Macroinvertebrate guideline values

Macroinvertebrates have been used throughout Australia to biologically assess stream health. EHP guidelines on macroinvertebrate assessments are still in their developmental stages for several regions within Queensland. The Barbara project is located within the Gulf River catchment and there are currently no guideline values for the Gulf region (EHP, 2009). Therefore, the primary interpretation of the indices mentioned above and AusRivAS modelling will be used for the comparison of results in the downstream environment with upstream sites.

AusRivAS modelling

Standardised macroinvertebrate sampling, using the methodology as per this study, has been used to assess the biological health of waterways since the development of the AusRivAS methodology under the National River Health Program in 1994. Under AusRivAS, macroinvertebrate results together with physico-chemical and habitat data are entered into appropriate models to determine the health of the streams sampled. AusRivAS methodology uses predictive model software to analyse macroinvertebrate results and predict which taxa should occur at that site in the absence of environmental damage.

The model uses taxa calculated to have a 50% or greater probability of occurring at each site, based on reference site data collected to establish the model. This reduces the occurrence of low probability taxa while maintaining sufficient analytical resolution to detect significant changes in species composition. The output from the model divides each site into bands based on macroinvertebrate taxa that were observed (O) and those that were expected (E) if the site was in pristine condition (O/E taxa). There are five bands, each are described in **Table 6**. A series of models have been developed for each habitat (edge, pool (bed) and riffle) in regional Queensland. Macroinvertebrates assemblages from the 2019 dry season sampling event were not compared to the AusRivAS model as it was not a requirement of the previous REMP design.

Table 6 Division of observed (O) vs. expected (E) taxa into bands

Band	Description	O/E Taxa	Potential Interpretation of Results
X	More biologically diverse than reference	O/E > 90th percentile of reference sites used to create the model	More families found than expected. Potential biodiversity 'hotspot' or mild organic enrichment Continuous irrigation flow in normally intermittent stream
A	Similar to reference	O/E within range of central 80th percentile of reference sites used to create the model	Expected number of families within the range found at 80% of the reference sites
B	Significantly impaired	O/E< 10th percentile of reference sites used to create the model	Fewer families than expected Potential impact either on water and/or habitat resulting in a loss of families
C	Severely impaired	O/E below Band B, same width as Band A	Many fewer families than expected Loss of families from substantial impairment of expected biota caused by water and/or habitat quality
D	Extremely impaired	O/E below Band C to zero	Few of the expected families and only the hardy, pollution tolerant families remain Severe impairment

2.6.4 Quality Assurance

For quality assurance, the residuals of each of the two bed samples at one site (site B3 in both seasons of survey) were collected after live picking to determine the accuracy of live picking by each operator. These residual samples were placed in a separate container to the picked macroinvertebrates, both of which were placed in 100% ethanol. Both samples were sent to a third-party macroinvertebrate identification specialist to quantify any errors in live picking. All macroinvertebrate and quality assurance samples were sent to Benthic Australia Pty Ltd, for identification to appropriate taxonomic levels and determination of any missed taxa in the samples. The results of the macroinvertebrate quality assurance samples are provided in **Appendix F**.

3 Results

3.1 Surface water quality

Four of the of the nine accessible sites had sufficient water during the 2020 wet season survey for surface water sampling: two upstream sites (sites B3 and B6), and two downstream sites (sites B7 and B9). Only one site (site B3) had surface water available for sample collection during the dry season. Surface water quality results from *in-situ* readings and laboratory analyses are provided in **Appendix C** and are compared to the most relevant published guidelines.

3.1.1 Wet Season 2020

Physico-chemical parameters

The following physico-chemical parameters exceeded relevant guidelines:

- pH was elevated above the ANZECC high guideline value at all sites
- DO was below the ANZECC low guideline value at all sites; and
- Turbidity was slightly above the ANZECC guideline value at downstream sites B7 and B9.

Metals

There was only one metal that exceeded ANZG (2018) guideline values. Total copper at B3, B7 and B9 was above the ANZG (2018) GV, and dissolved copper was above the GV at B3 and B7.

The LOR for bismuth and uranium was above the respective guidelines for all sites and this is not considered an exceedance. All other physico-chemical parameters and metal concentrations were below published guideline values.

3.1.2 Dry Season 2020

Physico-chemical parameters

The following physico-chemical parameters exceeded relevant guideline values at site B3:

- pH exceeded the upper ANZECC (2000) guideline;
- DO was below the lower ANZECC (2000) guideline; and
- Turbidity was above the ANZECC (2000) guideline.

Metals

Total and dissolved cobalt and copper exceeded the ANZG (2018) guideline values at site B3.

The LOR for bismuth and uranium was above the respective guidelines for B3 and this is not considered an exceedance. All other physico-chemical parameters and metal concentrations were below published guideline values.

Temporal Comparison

Total and dissolved copper has been above guideline values at various upstream and downstream sites since the original REMP survey conducted in the 2018 dry season survey (**Figure 3**) which was prior to any construction activities. Total and dissolved copper at B3 and B7 were above guideline values during every survey to date where surface water was present (with the exception of dissolved copper during the 2019 wet season survey). B9, the relatively new site, has only held sufficient water for sampling during the 2020 wet season survey and thus a temporal comparison is not possible.

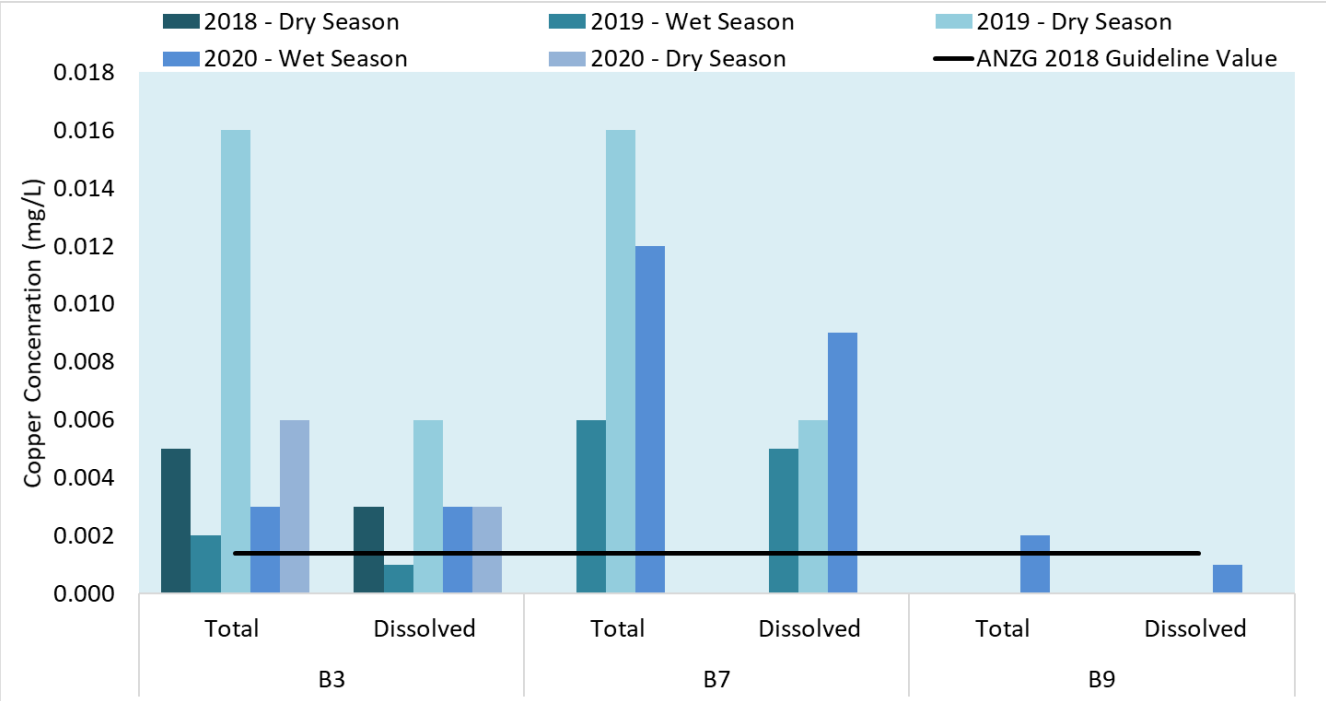

Figure 3 Temporal comparison of total and dissolved copper in surface water at Barbara monitoring sites

3.2 Stream Sediment Quality

3.2.1 Wet Season 2020

Particle size distribution

Particle size distribution varied little between sites and the majority of sample locations were dominated by coarser sediments in the 300µm to >2mm range (74%–94%; **Figure 4**). B1US had remarkedly lower percentage of coarse sediment at 25%. Moderate size fractions represented 4%–19% of stream sediment per site, and fine sediments (<63µm) constituted 2% to 23% of total stream sediment at the majority of sites. Site B1US was again the exception, with 58% fine fraction sediment.

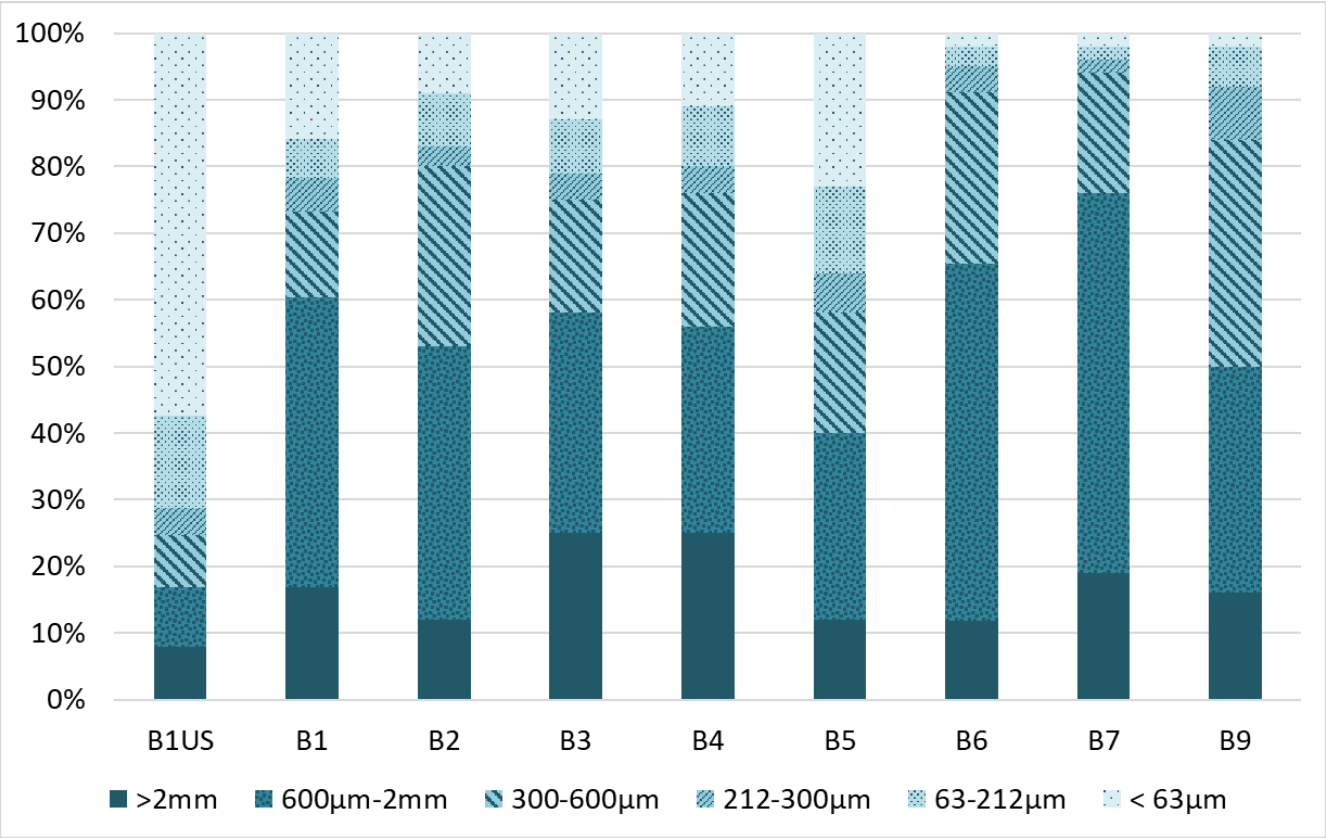

Figure 4 Particle size distribution of stream sediments recorded during the 2020 wet season survey

Metal analysis

Laboratory results of stream sediment quality are shown in **Appendix D** and are compared to ANZG (2018) guideline values where available. There were few exceedances of metals during the 2020 wet survey, as follows:

- Whole fraction copper exceeded the DGV at B1US, B1 and B4, and the GV-High at B2;
- Fine fraction copper exceeded the DGV at B1US, B6, B4, B7 and B9, and the GV-High at B3, B5 and B1;
- Whole fraction nickel exceeded the DGV at B1US and B5; and
- Fine fraction nickel exceeded the DGV at all sites except for B4 and B9.

All other metals were within guideline values.

3.2.2 Dry Season 2020

Particle size distribution

Particle size distribution was fairly consistent amongst sites and the majority of sample locations were dominated by coarser sediments in the 300µm–2mm range (66%–88%; **Figure 5**), with the exception being B1US which had 54% coarse sediment. Moderate size fractions represented 9%–26% of stream sediment per site, and fine sediments (<63µm) constituted 2% to 10% of total stream sediment at majority of sites. Site B1US contained the highest percent of the fine sediment fraction (28%).

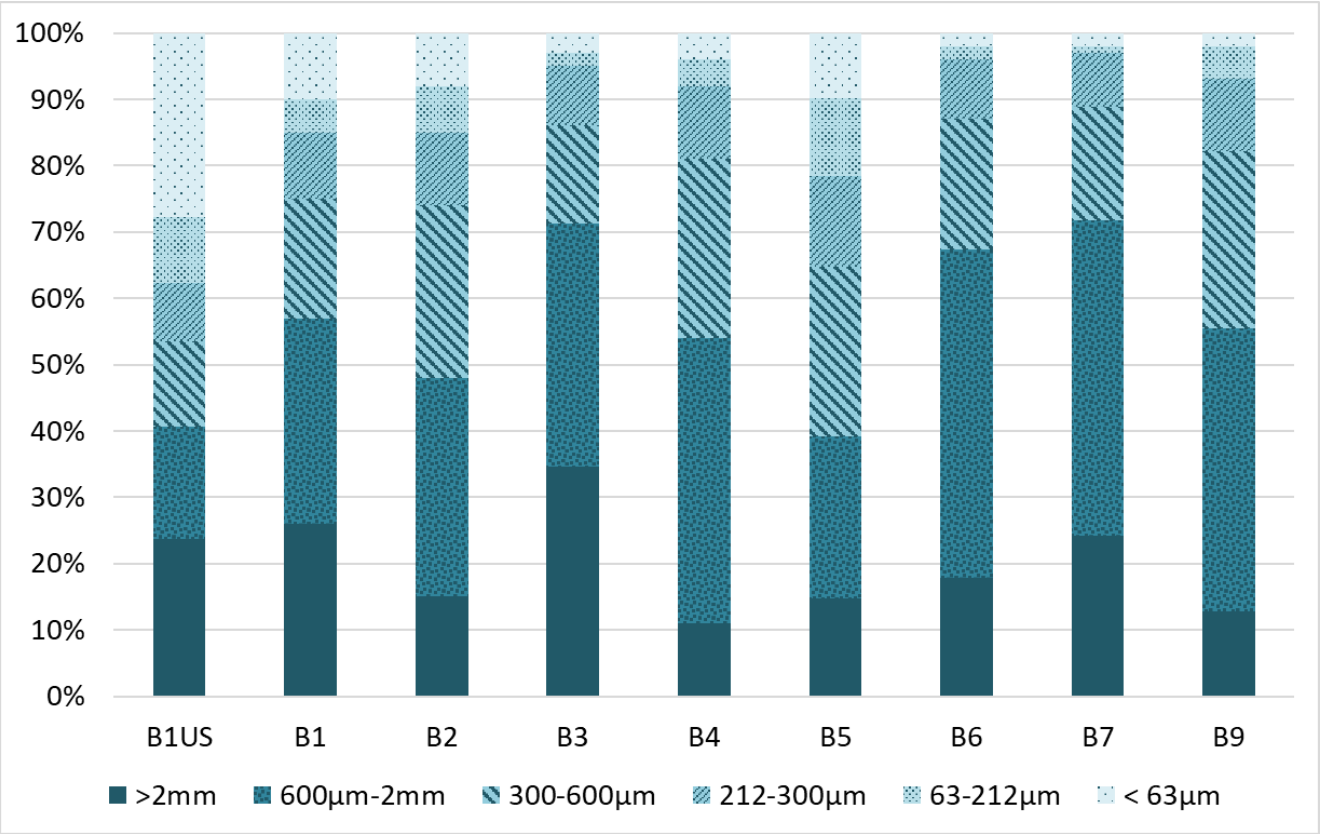

Figure 5 Particle size distribution of stream sediments recorded during the 2020 dry season survey

Metal analysis

Laboratory results of stream sediment quality are shown in **Appendix D** and are compared to ANZG (2018) trigger values where available. There were few exceedances of metals during the 2020 dry season survey as shown below:

- Whole fraction copper exceeded the DGV at B1US, B1 and B4, and the GV-High at B2;
- Fine fraction copper exceeded the DGV at B1US, B3, B5 and B9, and exceeded the GV-High at B6, B1, B2, B4 and B7;
- Whole fraction nickel exceeded the DGV at B1US and B2; and
- Fine fraction nickel exceeded the DGV at every site except B9.

All other metals were within guideline values.

Temporal Comparison

The fine fraction has been focused upon for temporal comparison as it has the highest potential of impacting the macroinvertebrate community.

A temporal comparison reveals that copper concentrations have exceeded guideline values in the fine fraction at downstream sites since the 2018 dry season survey (**Figure 6**). In contrast, there previously has not been any copper exceedances at upstream sites. There is a trend for copper to increase between B1 and B2 and then progressively decrease downstream. Copper concentrations at B1US, B6 and B7 have tended to be in greater concentration with each survey.

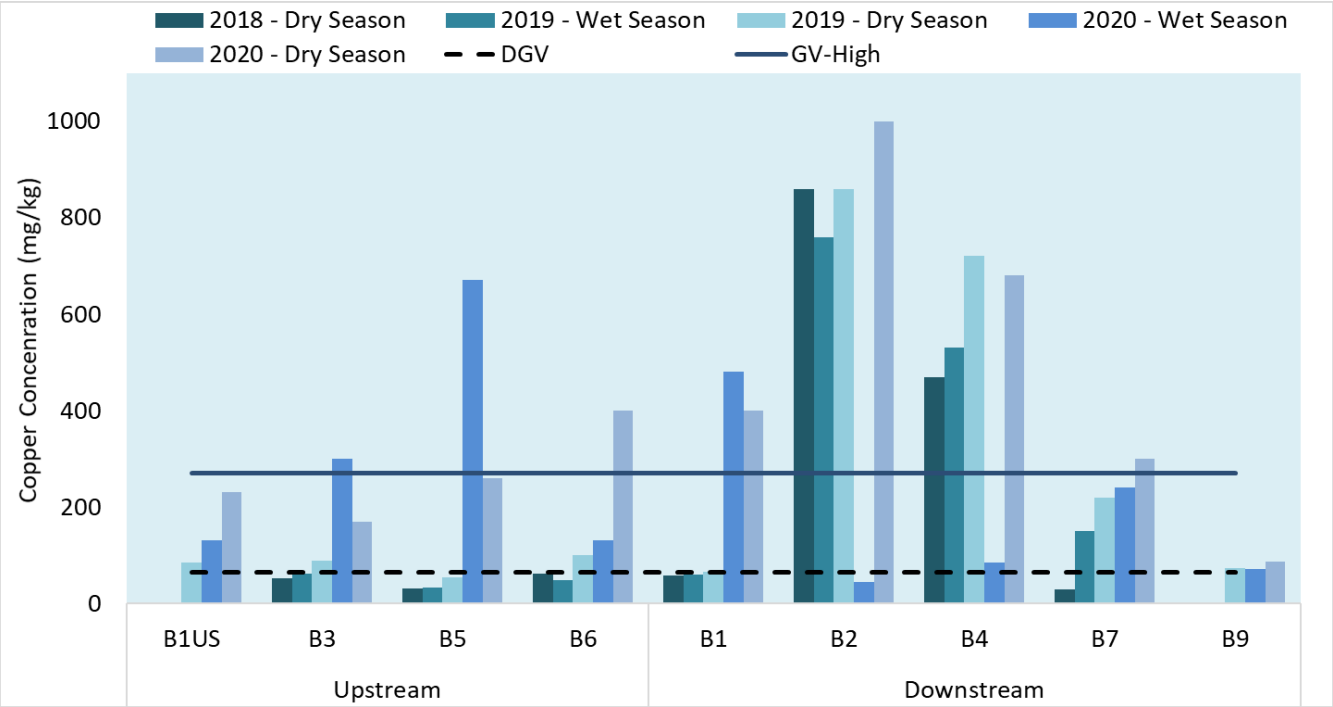

Figure 6 Temporal comparison of fine fraction copper in the stream sediment

Fine fraction nickel has consistently been above the DGV at the majority of sites and overall, results from the 2020 surveys appeared relatively stable (**Figure 7**). There is a slight trend of an increase in nickel concentration within the fine fraction at upstream sites and fluctuation in concentration at downstream sites.

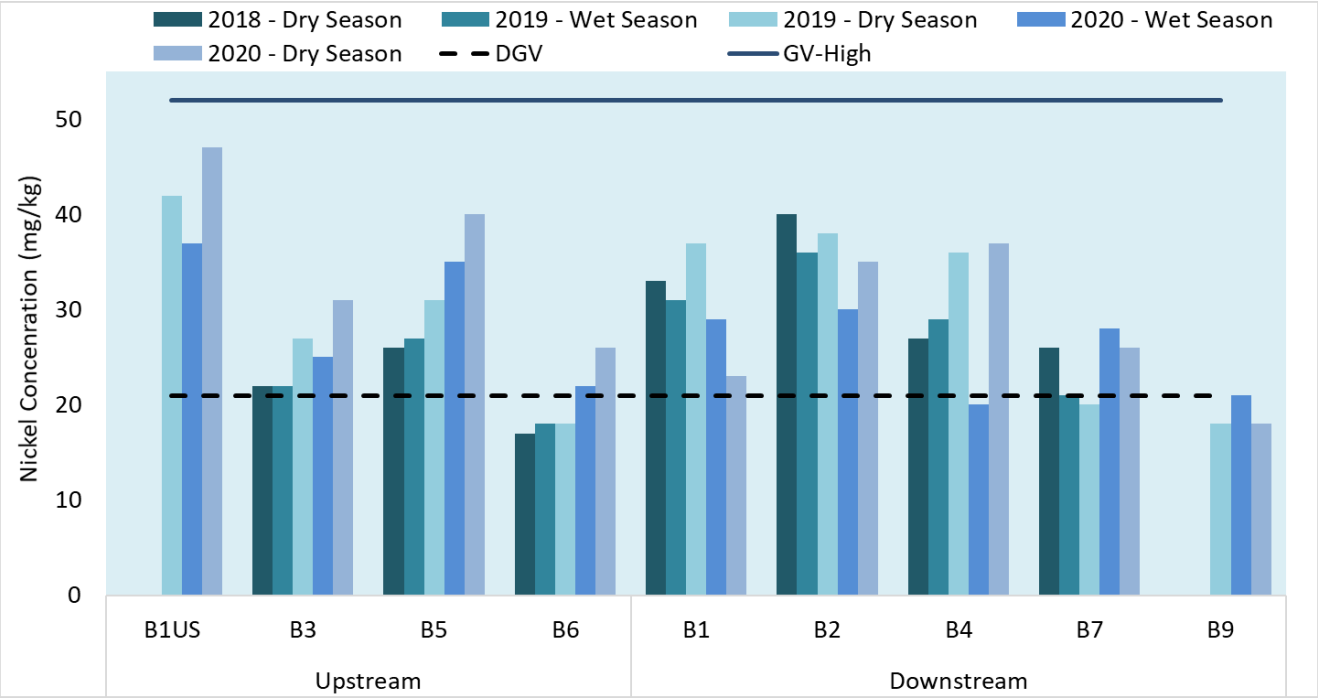

Figure 7 Temporal comparison of fine fraction nickel in the stream sediment

3.3 Macroinvertebrates

3.3.1 Wet Season 2020

Habitat assessment

Three sites contained sufficient water for macroinvertebrate sampling during the 2020 wet season survey. A comprehensive list of aquatic macroinvertebrate taxa recorded during the survey is provided in **Appendix E**. Surface water pools ranged from 2-10m wide and 50-90cm deep. Habitat quality was highest at upstream site B3, slightly lower at B6 and lowest at B7 (**Table 7**). Surface water at all sites was reduced to pools and flow had ceased. The primary difference in habitat quality between sites was in variability of the substrate habitat and bank vegetation cover. The pools sampled at B3 and B6 contained angular bedrock, which provided some habitat heterogeneity, and a high percentage of bank vegetation, while the bed sampled at B7 had slightly less substrate variation and bank vegetation.

Table 7 Habitat assessment scores for sample sites during the wet season

Site	Habitat score	Interpretation
B3	99	Good
B6	94	Good
B7	92	Good

Abundance in collected samples

A total of 1,193 individuals from 20 macroinvertebrate taxa were found during the 2020 wet season survey (**Figure 7**). The majority of macroinvertebrates sampled were Water Fleas (Family Cladocera) which made up 43% of all collected individuals. 14 taxa were comprised of a comparatively small proportion of overall abundance, with recorded taxa represented by <50 individuals. Far more individual macroinvertebrates were recorded at site B7 (847) than the other sites (<235).

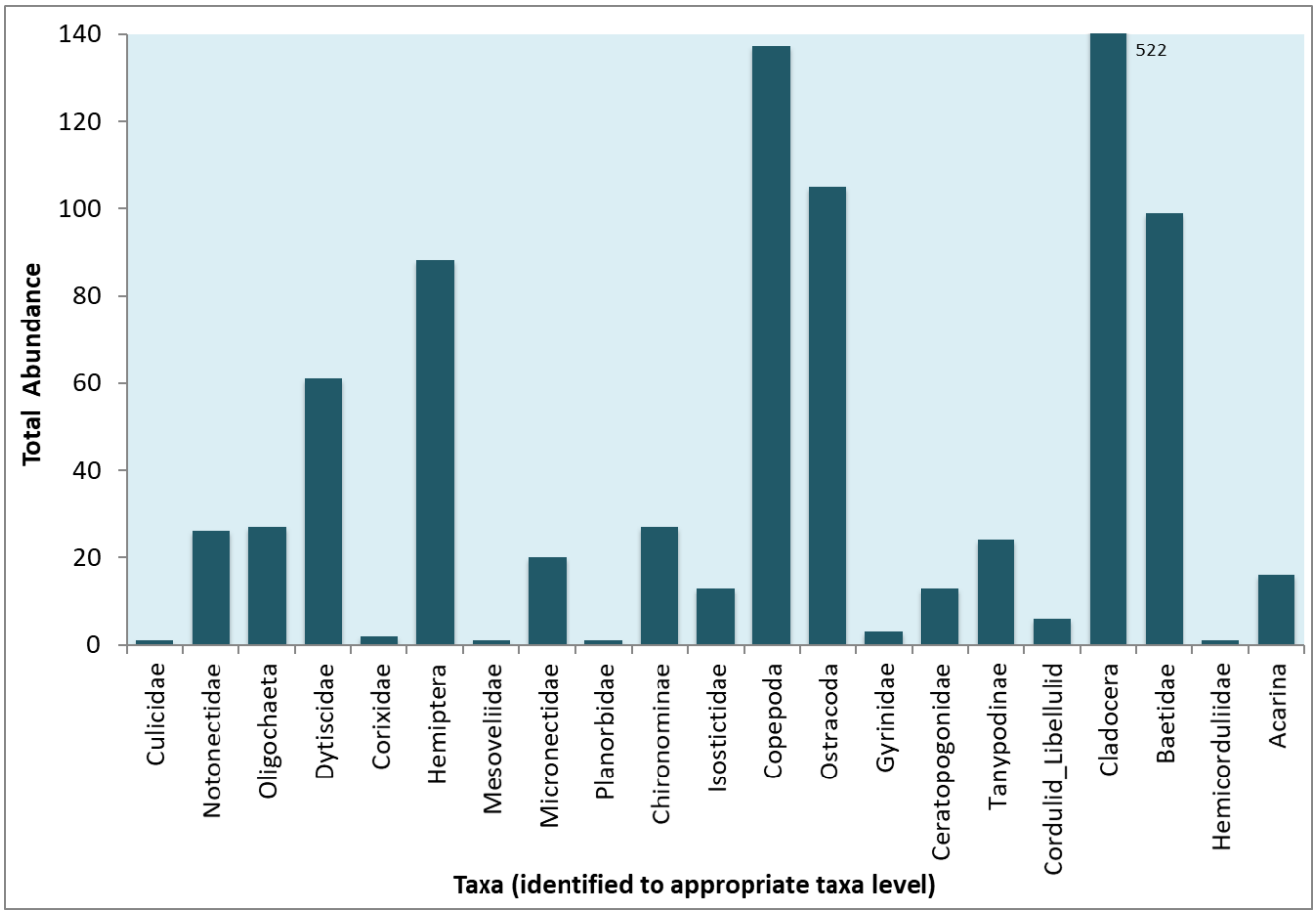

Figure 8 Abundance of taxa collected at Barbara during the 2020 wet season

Macroinvertebrate indices

Taxa richness

Average taxa richness ranged from 7.5 to 14.5 between sites and richness was higher at site B3 than the other sites (**Figure 6**). B3 and B6 had similar richness, whilst B7 had notably lower richness. A single PET taxon was sampled during the 2020 wet season survey, from class Ephemeroptera (Mayflies), which was present at all sites thus there was equal PET species richness between sites.

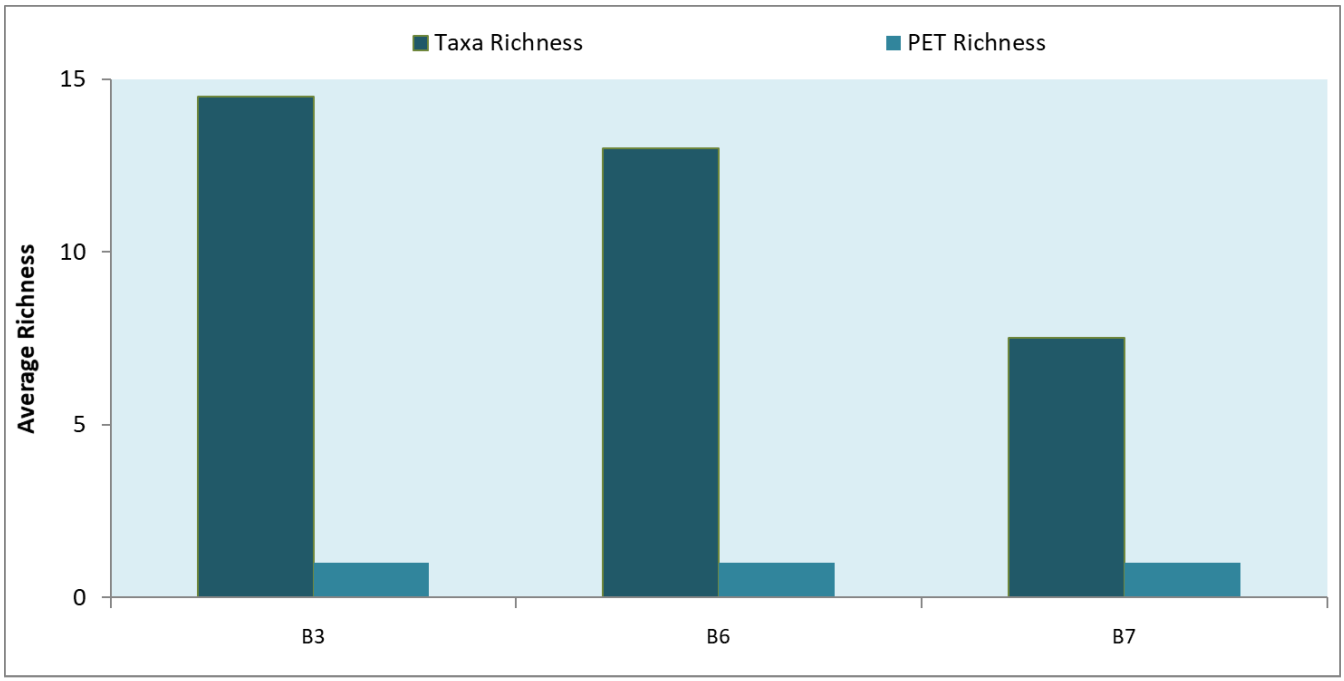

Figure 9 Taxa richness for sites sampled at Barbara during the 2020 wet season

Sensitive and tolerant taxa

No sensitive taxa were recorded during the 2020 wet season survey. The percentage of tolerant taxa was highest at site B7 (55.2%), slightly lower at B6 and lowest at B3 (45.0%; **Figure 7**).

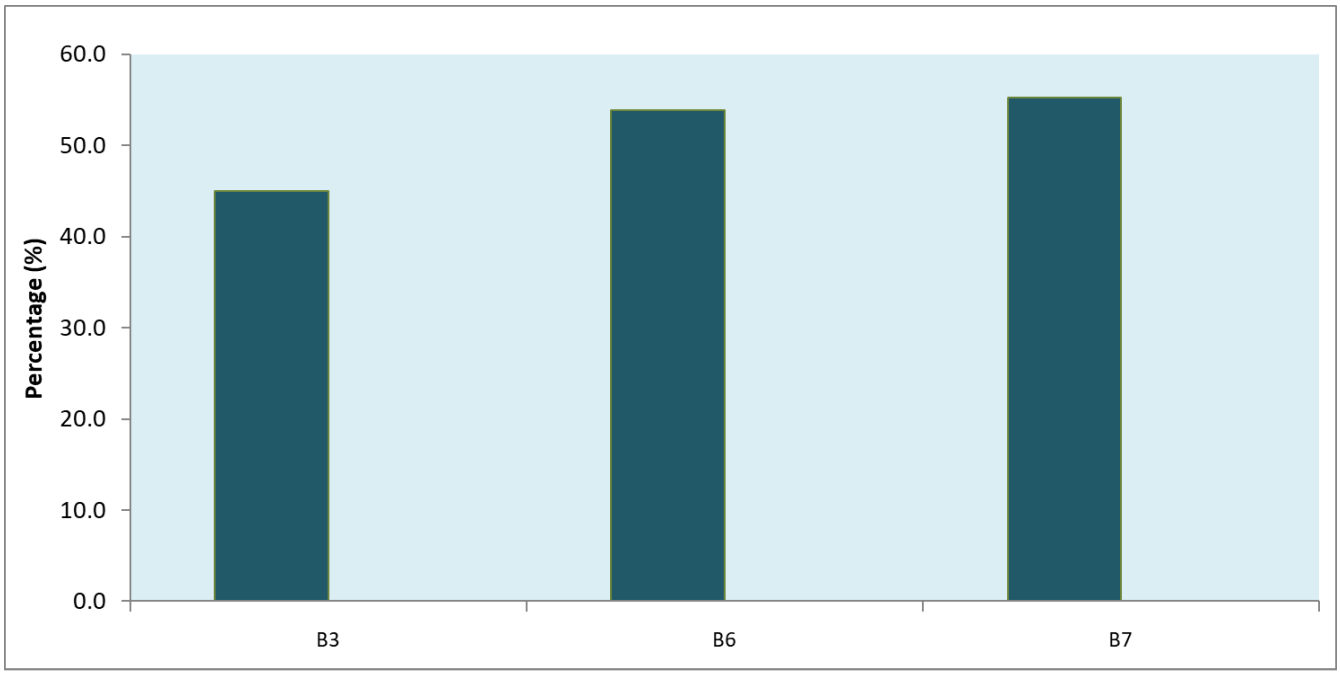

Figure 10 Percent tolerant taxa at Barbara during the 2020 wet season

SIGNAL 2 scores

Average SIGNAL 2 scores were moderate and similar between sites (**Figure 8**), ranging from 3.27 to 3.59 (B6 and B3, respectively). Upstream site B3 was only slightly higher than furthest downstream site B7 (3.59 and 3.38, respectively).

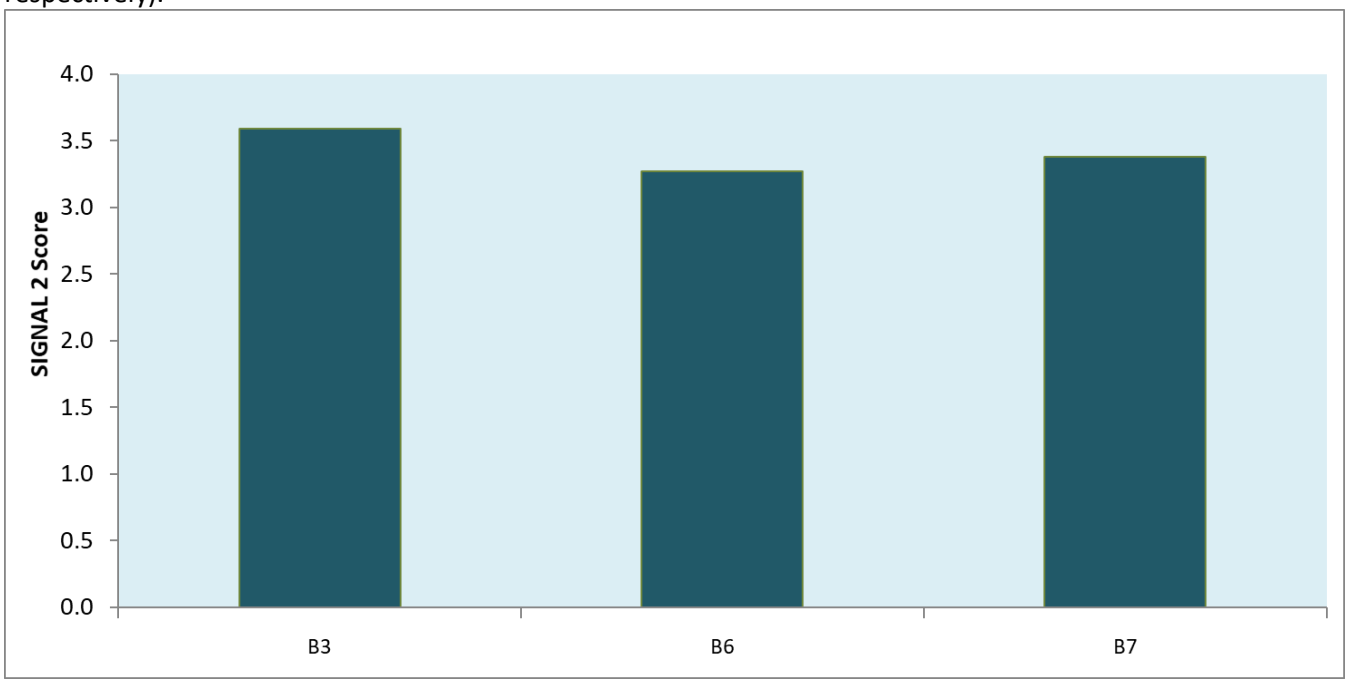

Figure 11 SIGNAL 2 scores for Barbara sites sampled during the 2020 wet season survey

AusRivAS banding

AusRivAS banding results indicated that B3 contained similar taxa than expected and B6 and B7 contained less taxa than expected (**Table 8**). AusRivAS modelling only became available for western Queensland in 2020 and therefore comparison to previous surveys is not possible.

Table 8 AusRivAS macroinvertebrate banding for bed and edge samples

Site	Habitat	Band	Description
B3	Pool	A	Similar to reference
B6	Pool	B	Significantly impaired
B7	Pool	B	Significantly impaired

Temporal comparison

B3 and B7 are the only sites that have been sampled during the 2019 and 2020 wet season. A temporal comparison of these sites determined that indices had been quite similar, although both B3 and B7 had a relatively large increase in percentage of temporal taxa (**Table 9**).

Table 9 Temporal comparison of sites sampled during the 2020 wet season which were also sampled in the 2019 wet season

Site	Macroinvertebrate index	2019	2020
B3	Taxa Richness (average)	14.5	14.5
	PET Taxa Richness (average)	1.0	1.0
	Tolerant Taxa (%)	21.5	45.0
	Signal 2 score	3.57	3.59
B7	Taxa Richness (average)	10.0	7.5
	PET Taxa Richness (average)	1.0	1.0
	Tolerant Taxa (%)	36.0	55.2
	Signal 2 score	3.16	3.38

3.3.2 Dry Season 2019

Habitat assessment

Only one site (B3) contained sufficient water for macroinvertebrate sampling during the 2020 dry season survey, and only one macroinvertebrate sweep was possible, compared to the normal two-bed sweep. A comprehensive list of aquatic macroinvertebrate taxa recorded for B3 during dry season sampling is provided in **Appendix E**. Habitat quality was recorded as good based on DNRM (2001) habitat quality criteria (**Table 10**).

Table 10 Habitat assessment scores for dry season sample sites

Site	Habitat Score	Interpretation
B3	77	Good

Abundance in collected samples

A total of 140 individuals from 12 macroinvertebrate taxa were collected during the 2020 dry season survey (**Figure 12**). The majority of macroinvertebrates sampled were non-biting midges (Tanypodinae) which accounted for 45% of all collected individuals. 11 taxa were comprised of a comparatively small proportion of overall abundance, with recorded taxa represented by <10 individuals.

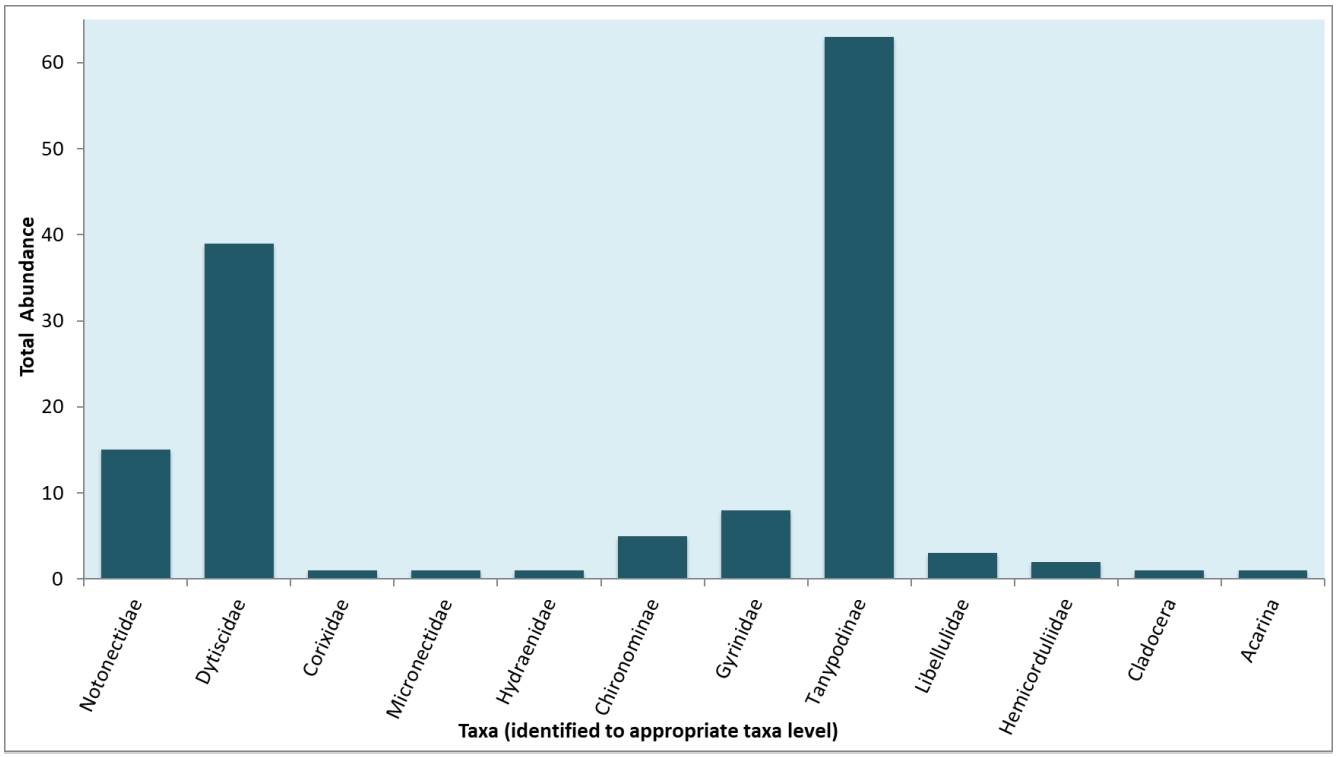

Figure 12 Abundance of taxa collected at Barbara during the 2020 dry season

Macroinvertebrate indices

Taxa richness

Taxa richness was similar between the 2018 and 2020 dry season surveys (**Table 11**). No PET taxa were detected during the 2020 dry season survey, which was in contrast with previous dry season surveys.

Sensitive and tolerant taxa

No sensitive taxa have been recorded at Barbara during the dry season surveys (**Table 11**). There was a large increase in the percentage of tolerant taxa at B3 between the 2019 dry season and 2020 dry season survey yet was similar to the amount recorded in 2018.

SIGNAL 2 scores

The current Signal 2 score was lower than the previous year but similar to that of 2018 (**Table 11**).

AusRivAS banding

AusRivAS banding results indicated that B3 contained similar taxa to expected (**Table 11**). AusRivAS modelling only became available for western Queensland in 2020 and therefore comparison to previous surveys is not possible.

Table 11 Temporal comparisons of macroinvertebrate assemblage indices at site B3 between dry season monitoring events

Macroinvertebrate index	2018	2019	2020
Taxa Richness (average)	11.5	13.5	12
PET Taxa Richness (average)	1.5	1.5	0
Tolerant Taxa (%)	46.6	10.5	50
Signal 2 score	3.10	3.74	3.07
AusRivAS banding	-	-	A- Similar to reference

4 Discussion and Recommendations

4.1 Surface Water Quality

Water quality at the sites sampled during the 2020 wet and dry season surveys exhibited few exceedances of guideline values. Measurements of pH, DO and turbidity were outside guideline values at multiple sites during both surveys. pH is one of three toxic stressors that are naturally highly variable in systems (ANZECC & ARMCANZ, 2000) and only an extreme pH (less than five or greater than nine) is considered to be potentially toxic to aquatic organisms, as some waterways and ecosystems adapt to extremes (EHP, 2009). The water at these sites had either ceased flowing or was reduced to a small flow, and it is noted in the QWQG that "*DO guidelines (% saturation) for freshwaters should only be applied to flowing waters, including those with significant sub-surface flows. Stagnant pools in intermittent streams naturally experience values of DO below 50% saturation*". It is possible that moderate turbidity has affected DO levels, as suspended particulate matter may restrict the amount of light that penetrates the water column, thereby impacting macrophytes and oxygen production (DES, 2005). High turbidity is likely due to the small pools and rainfall which occurred during the survey.

There were two metals that exceeded guideline values during the 2020 surveys. Total and dissolved copper concentrations were above the guideline value at sites B3, B7 and B9 (except for dissolved copper at B9) during the 2020 wet season survey and at B3 during the 2020 dry season survey. Operations at Barbara commenced after the 2018 dry season survey was conducted and total and dissolved copper were above guideline values at B3 at that time. Total and dissolved copper at B3 have fluctuated over the past three years and the concentrations recorded during the 2020 surveys are within the previous range recorded. Additionally, as B3 is upstream of activities undertaken by ROM these exceedances cannot be attributed to mining activities and are likely due to historic impacts and/or natural mineralisation.

Similarly, at B7 total and dissolved copper has been above guidelines each survey where surface water was present, although total copper has reported higher concentrations with each subsequent survey. There is no baseline surface water data for B7 as there was insufficient water during baseline surveys, and as only one site further upstream held surface water for comparison it is difficult to determine the origins of high copper concentration. The high concentrations of copper at upstream sites over time indicates that copper is abundant in the surrounding landscape and highly variable. Whilst it is possible that copper concentrations may be influenced by mining activities, other factors such as natural mineralisation and historic mining activities are likely the contributors to the higher concentrations recorded at this site. Continued monitoring will assist in determining whether increased copper at this site is temporary and spatially restricted. Copper concentrations decreased throughout the system, and at B9 copper was just above the guideline value, indicating copper is decreasing with distance from areas with high concentrations.

The only other exceedance during the current surveys was total and dissolved cobalt at B3. Cobalt has been above the guideline value during the original 2018 dry survey, and as previously mentioned this is an upstream site and exceedances at this site cannot be attributed to ROM mining activities.

4.2 Stream Sediment Quality

Stream sediment quality results were similar to previous surveys and exceedances of guideline values for copper and nickel in the whole and fine fraction were common.

B1US site was introduced to the sampling regime when it was noted during the 2019 wet season survey that activities were occurring adjacent to B1. The proximity to activities resulted in B1 being reclassified from an upstream site to a downstream site and B1US being introduced as an upstream site. B1US lies at the beginning of the tributary which originates below the haul road; therefore, despite being unable to classify B1US a true upstream site it is not possible to implement any alternative upstream sites.

Copper in the whole and fine fraction sediment at B1US has exceeded the DGV for the past three surveys and has been recorded in a higher concentration with each survey. Due to B1US being a relatively new site, data must be interpreted with caution; however, it is possible that the haul road may be a contributing factor. Site B1 is located immediately downstream of B1US and had not recorded any copper exceedances prior to 2020. During both REMP surveys for the current annual reporting period whole fraction copper was above the DGV at site B1 and fine fraction copper was above the GV-High. While the whole fraction copper concentration was slightly lower at B1 compared to B1US, fine fraction copper concentrations were over three times higher at B1 during the wet season and twice as high in the dry season compared to B1US. There are no further upstream sites within this watercourse for comparison and B1US does not have any baseline data available. The cause of the copper exceedances in both the whole and fine sediment fraction is unknown, but ongoing monitoring is warranted given the trend of increasing concentrations.

During the baseline REMP conducted in the 2018 dry season, whole fraction copper exceeded and has consistently exceeded, the GV-High at B2 and B4. Fine fraction copper has also frequently been above the GV-High at B2 and B4 and above the DGV at B7 over time. The area around B2 and B4 has been subjected to extensive historical mining activities, and coupled with the naturally mineral-rich area, is the likely cause for the exceedances recorded in the baseline assessment. Given the identification of exceedances of guideline values at these sites prior to the commencement of the current operation, it is considered likely to occur in subsequent surveys. There is a temporal anomaly for the whole and fine fraction for copper during the 2020 wet season survey, where copper concentrations at B2 and B4 were significantly lower in concentration compared to other surveys. Prior to and during the 2020 wet season survey, large amounts of rainfall occurred in the Barbara landscape which may have dispersed and diluted mineral-rich sediments. Sampling sites were originally selected by identifying areas where surface water is likely to persist, and due to the ephemeral nature of the landscape these pools become smaller through evaporation over time. It is likely that during the majority of surveys, metals precipitate out of the water column and settle in stream sediments increasing copper concentrations. During rain events metals can become resuspended in the water column and diluted with fresh water.

Despite copper being recorded in high concentrations prior to current mining activities commencing, there is currently potential for toxicity impacts upon local EV's and an increased likelihood of negative biological effects (ANZG, 2018) at sites B2 and B4. Although these sites recorded high metal concentrations, they only recorded a small percentage of fine sediment fraction and it is unlikely that this is bioavailable to macroinvertebrate communities. Copper concentration within stream sediment decreases rapidly downstream of B4, and at the furthest downstream site, B9, whole copper is below the DGV, and fine fraction copper only slightly exceeds the DGV and appears stable.

Whole fraction nickel concentrations at B1US have been above the DGV during every survey and sporadically at other sites. Fine fraction nickel concentrations have been above the DGV at the majority of sites across all surveys. During the 2018 dry season survey, whole fraction nickel concentrations were below the DGV at all sites and fine fraction nickel concentrations were above the DGV at all sites except B6 and B8. This indicates that nickel is abundant in the Barbara landscape, either natural or remnant from historical activities. The addition of B1US determined that nickel concentrations are higher in the upstream environment; however, as there is no background data from this site it cannot be determined whether this is pre-existing or if there is any contribution from the haul road. At upstream sites B3, B5 and B6 whole fraction nickel has fluctuated whilst fine fraction has been at a higher concentration with each sampling event. As these are upstream sites this cannot be attributed to ROM activities and demonstrates the naturally mineral rich environment around Barbara. At downstream sites whole and fine fraction nickel appear stable, and at B9 are below the DGV.

Particle size distribution analyses revealed that sites were dominated by coarse-grained sediments, with a small proportion of fine sediments represented at sites (aside from B1US, as previously discussed). The fine fraction sediment represents the most bioavailable component of stream sediments. The low percentage of fine fraction sediment indicates low bioavailability of comparatively high metal concentrations to the macroinvertebrate community.

Overall, similar results have been reported in previous studies; therefore, it is likely that comparatively high concentrations of metals in the fine sediment fraction are a result of natural mineralisation and/or historical disturbance at the majority of sites. It is possible the haul road above B1US and activities adjacent to B1 are influencing copper levels at these sites; however, there is not enough data to clearly determine if there is any influence from the haul road at site B1US as sampling at this site did not occur prior to current mining activities commencing. B1US is situated at the beginning of the tributary and thus it is not possible to identify another upstream site.

4.3 Macroinvertebrates

A large proportion of the macroinvertebrate community present consisted of tolerant taxa, with few PET taxa and no sensitive taxa recorded and low SIGNAL 2 scores. This community of hardier macroinvertebrates has been described in previous REMP reports for Barbara and is reflective of highly ephemeral systems. The Barbara landscape does not experience long-term flow without sustained rainfall and subsequently dries out rapidly. Most macroinvertebrates require four to six weeks to establish in a watercourse, by which time surface water at Barbara has likely diminished to the point at which habitat heterogeneity is decreased. Lack of habitat features such as running water, log jams, boulders and cobble, and leaf litter reduces the suitability of the watercourse for many taxa. Habitat at the sites sampled consisted of little to no macrophytes (aquatic flora), overhanging vegetation, biological litter or debris. Thus, macroinvertebrate assemblages at Barbara are characterised by an abundance of tolerant taxa with terrestrial and/or desiccation-resistant life stages.

There has been inconsistent sampling of macroinvertebrate communities at each site over time due to environmental conditions. B3 is the only site that has been sampled for macroinvertebrates each survey, and whilst there have been fluctuations in indices, the results from the 2020 wet and dry season surveys are very similar to those in the 2018 dry season. B7, the only other site sampled in 2020 that has been sampled prior (in the 2019 wet season) and was mostly similar with an increase recorded in the percentage of tolerant taxa (from 36.0 to 55.2%) and a higher SIGNAL 2 score. AusRivAS modelling was available for the first time in this region in 2020, thus a temporal comparison is not possible. Upstream site B3 was rated similar to reference in the 2020 wet and dry season surveys and the two downstream sites, B6 and B7, were rated significantly impaired in the 2020 wet season survey.

Macroinvertebrate comparisons at Barbara are hindered by the ephemeral nature of the landscape as few sites have been sampled multiple times. Future surveys, particularly those undertaken during the wet season, will enable greater spatial and temporal analysis of macroinvertebrate assemblages at Barbara by enabling a point of comparison for sites that have not been sampled multiple times, and particularly in relation to AusRivAS banding.

5 Recommendations and Conclusion

The limited number of surveys conducted at Barbara limits the interpretation of variation in spatial and temporal data. Between the 2018 dry season and 2019 wet and dry season surveys construction activities commenced and there was an increase in some metal concentrations. The cause for increased metal concentrations in the Barbara region is unknown; however, as increases have been recorded at both upstream and downstream monitoring sites it is likely representative of natural processes occurring in the landscape. The results of this study suggest that historical mining activities conducted at Barbara and the highly mineralised local landscape are likely influencing the receiving environment, particularly with regards to copper and nickel concentrations.

Concentrations of copper in the sediments at sites B1US and B1 during the current reporting period have increased in comparison to prior monitoring events. Natural mineralisation and historical mining impacts may be compounded from the haul road upstream, although interpretation is inhibited by the lack of a true upstream site above B1US and B1. As a precaution, it is recommended that disturbance activities near watercourses are limited and adequately controlled, and that appropriate erosion and sediment control measures are continually monitored adjacent to disturbance areas. Dust suppression regimes for access and hauls roads should also be reviewed and updated where necessary. These precautions would minimise any migration of disturbed sediment into the watercourses and would assist the assessment of natural surface water quality characteristics within the vicinity of the Barbara Copper Project.

Site B8 has remained inaccessible the past three REMP surveys and it is recommended that vegetation is cleared to allow collection of data which will allow more robust interpretations of changes.

Water quality, stream sediments and macroinvertebrates should continue to be monitored bi-annually in the wet and dry seasons to provide sufficient data to derive site-specific trigger values for the area. Continued monitoring of the same sites will allow for the accurate comparison of changes in the receiving environment conditions over time and will provide an indication of the nature and extent of any future impacts.

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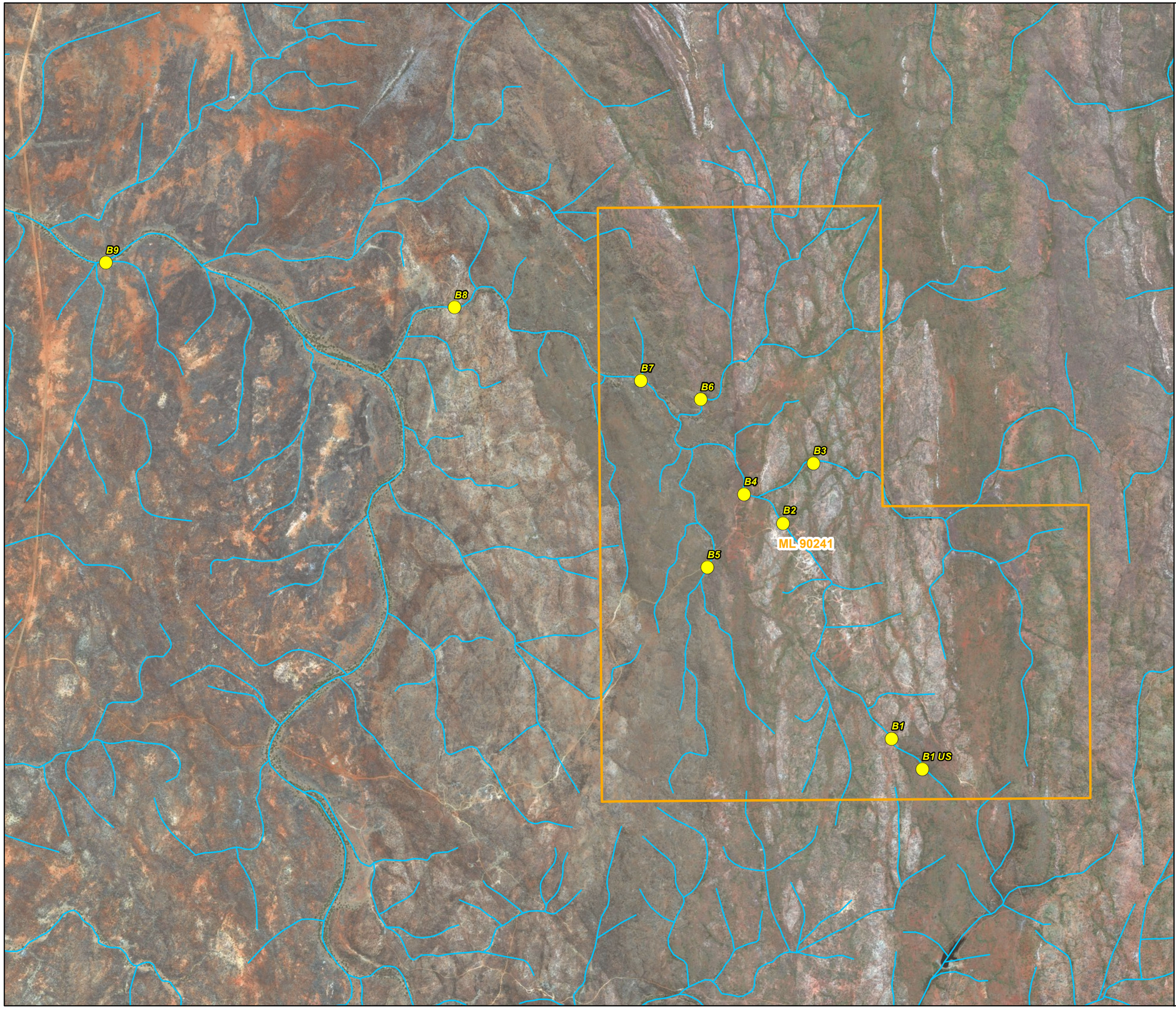
APPENDIX A

Map



ROUND OAK MINERALS

BARBARA

RECEIVING ENVIRONMENT MONITORING PROGRAM

Legend

- REMP Site
- Watercourse
- Mining Lease

Data Sources:
Mining Lease, and Watercourse datasets: © State of Queensland (Department of Natural Resources, Mines, and Energy) 2019; REMP Site dataset: SLR Consulting (2019).
Imagery Source: 50cm resolution GE01 Vivid - Australia 2016 Orthophoto Imagery Service: © ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994
Date: 15-Oct-2019

N

0 250 500 750 1,000
Metres

Scale: 1:25,000 at A3

SLR

APPENDIX B

Site Photographs and Field Sheets

Wet Season Survey 2020

B1US—UPSTREAM

UPSTREAM

DOWNSTREAM

HABITAT ASSESSMENT

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

LONGITUDINAL/CROSS-SECTION SKETCH

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

Project Name: Barbara

Site name/number: B1US **Collected by:** TJ, MMM **Date:** 4/3/20

Photos: Upstream: 337 Downstream: 338 **Time:** 9:40

QA sample taken: (circle) YES (NO) sediment water quality macroinvertebrates

Rain in the past week: Moderate

Weather: no rain (showers) heavy rain sunny some cloud (overcast) calm strong wind

Flow: (nil) low moderate high **Bars:** 100 %

Bank erosion: (nil) low moderate high

BED 1	BED 2
Velocity Min: Max:	**Velocity** Min: Max:
Mean depth:	**Mean depth:**
Mean channel width:	**Mean channel width:**
Canopy Cover: %	**Canopy Cover:** %
Width of riparian zone	**Width of riparian zone**
Left Bank: Right Bank:	Left Bank: Right Bank:
Composition of riparian zone	**Composition of riparian zone**
Native: % Exotic: %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: % Shrubs: %	Grass: % Shrubs: %
Trees: <10m: % >10m: %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock %	Bedrock %
Boulder (>256mm) %	Boulder (>256mm) %
Cobble (64-256mm) %	Cobble (64-256mm) %
Pebble (16-64mm) %	Pebble (16-64mm) %
Gravel (4-16mm) %	Gravel (4-16mm) %
Sand (1-4mm) %	Sand (1-4mm) %
Silt/Clay (<1mm) %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton 0 1 2 3 4	Periphyton 0 1 2 3 4
Moss 0 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 1 2 3 4	Filamentous algae 0 1 2 3 4
Detritus 0 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes 0 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
nil slight mod extensive	nil slight mod extensive

DRY

Adjacent land use: Mining ~50m upslope is Admin infrastructure

Upstream land use: " , Pastoral , Haul Rd.

Percent of habitats in 100m reach

Riffle: 0 % Run: 0 % Pool (rocky): 0 % Pool (sandy): 0 % Dry: 100 % Edge: 0 % Macrophytes: 0 %

Water odour: N/A	**Impact from animals:** Macropod trails
Water foaming:	**Human activity:** Mine site - Admin upslope
Plume:	**Aquatic animal life:** N/A
Sediment oils: Nil	**Additional notes:** –
Sediment odour: Nil	

B1- DOWNSTREAM

UPSTREAM

DOWNSTREAM

HABITAT ASSESSMENT

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

LONGITUDINAL/CROSS-SECTION SKETCH

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

Project Name: Barbara

Site name/number: B1 **Collected by:** TJ, MM **Date:** 4.3.20

Photos: Upstream: 339 Downstream: 340 **Time:** 9:50

QA sample taken: (circle) YES (NO) sediment water quality macroinvertebrates

Rain in the past week: Moderate

Weather: no rain (showers) heavy rain sunny some cloud (overcast) (calm) strong wind

Flow: Nil (nil) low moderate high **Bars:** 100 %

Bank erosion: Nil (nil) low moderate high

BED 1	BED 2
Velocity Min: Max:	**Velocity** Min: Max:
Mean depth:	**Mean depth:**
Mean channel width:	**Mean channel width:**
Canopy Cover: %	**Canopy Cover:** %
Width of riparian zone	**Width of riparian zone**
Left Bank: Right Bank:	Left Bank: Right Bank:
Composition of riparian zone	**Composition of riparian zone**
Native: % Exotic: %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: % Shrubs: %	Grass: % Shrubs: %
Trees: <10m: % >10m: %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock %	Bedrock %
Boulder (>256mm) %	Boulder (>256mm) %
Cobble (64-256mm) %	Cobble (64-256mm) %
Pebble (16-64mm) %	Pebble (16-64mm) %
Gravel (4-16mm) %	Gravel (4-16mm) %
Sand (1-4mm) %	Sand (1-4mm) %
Silt/Clay (<1mm) %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton 0 1 2 3 4	Periphyton 0 1 2 3 4
Moss 0 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 1 2 3 4	Filamentous algae 0 1 2 3 4
Detritus 0 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes 0 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
nil slight mod extensive	nil slight mod extensive

Adjacent land use: Mining, pastoral

Upstream land use: " "

Percent of habitats in 100m reach

Riffle: 0 % Run: 0 % Pool (rocky): 0 % Pool (sandy): 0 % Dry: 100 % Edge: 0 % Macrophytes: 0 %

Water odour: N/A
Water foaming:
Plume:

Impact from animals: Cattle tracks, macropod scats
Human activity: Nil
Aquatic animal life: N/A

Sediment oils: Nil
Sediment odour: Nil

Additional notes: Downslope behind mine Admin area.

B2—DOWNSTREAM

UPSTREAM

DOWNSTREAM

HABITAT ASSESSMENT

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

LONGITUDINAL/CROSS-SECTION SKETCH

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore sketches not completed.

Project Name: Barbara			
Site name/number: B2	**Collected by:**		**Date:** 4/3/20
Photos: Upstream: 335	Downstream: 336		**Time:** 9:20
QA sample taken: (circle) YES (NO) sediment water quality macroinvertebrates			
Rain in the past week: Moderate			
Weather: no rain (showers) heavy rain sunny some cloud (overcast) (calm) strong wind			
Flow: Nil	(nil) low moderate high		**Bars:** 100 %
Bank erosion:	(nil) low moderate high		

BED 1	BED 2
Velocity Min: Max:	**Velocity** Min: Max:
Mean depth:	**Mean depth:**
Mean channel width:	**Mean channel width:**
Canopy Cover: %	**Canopy Cover:** %
Width of riparian zone	**Width of riparian zone**
Left Bank: Right Bank:	Left Bank: Right Bank:
Composition of riparian zone	**Composition of riparian zone**
Native: % Exotic: %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: % Shrubs: %	Grass: % Shrubs: %
Trees: <10m: % >10m: %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock %	Bedrock %
Boulder (>256mm) %	Boulder (>256mm) %
Cobble (64-256mm) %	Cobble (64-256mm) %
Pebble (16-64mm) %	Pebble (16-64mm) %
Gravel (4-16mm) %	Gravel (4-16mm) %
Sand (1-4mm) %	Sand (1-4mm) %
Silt/Clay (<1mm) %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton 0 1 2 3 4	Periphyton 0 1 2 3 4
Moss 0 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 1 2 3 4	Filamentous algae 0 1 2 3 4
Detritus 0 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes 0 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
nil slight mod extensive	nil slight mod extensive

Adjacent land use: Mining downstream & east
Upstream land use: Pastoral

Percent of habitats in 100m reach
Riffle: 0 % Run: 0 % Pool (rocky): 0 % Pool (sandy): 0 % Dry: 100 % Edge: 0 % Macrophytes: 0 %

Water odour: N/A	**Impact from animals:** track ~50m upslope
Water foaming:	**Human activity:** cattle trails, macropod tracks
Plume:	**Aquatic animal life:** N/A
Sediment oils: Nil	**Additional notes:** Nil
Sediment odour: Nil	

B3—UPSTREAM

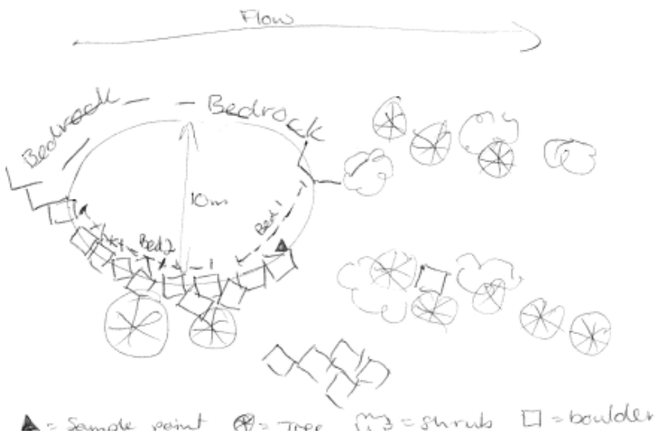
UPSTREAM

DOWNSTREAM

HABITAT ASSESSMENT

Habitat variable	Category	Score
1. Bottom substrate/ available cover	Excellent	19
2. Embeddedness	Excellent	18
3. Velocity/depth category	Poor	0
4. Channel alteration	Excellent	14
5. Bottom scouring and deposition	Excellent	14
6. Pool/riffle, run/band ratio	Fair	7
7. Bank stability	Excellent	9
8. Bank vegetative stability	Excellent	9
9. Streamside cover	Excellent	9
Total Score	**Good**	**99**

LONGITUDINAL SKETCH



CROSS-SECTION SKETCH

Project Name: Barbara

Site name/number: B3 | **Collected by:** TJ, MM | **Date:** 3.3.20

Photos: Upstream: 331 Downstream: 332 | **Time:** 15:15

QA sample taken: (circle) YES (NO) sediment water quality macroinvertebrates

Rain in the past week: Moderate

Weather: (no rain) showers heavy rain sunny some cloud (overcast) (calm) strong wind

Flow: (nil) low moderate high | **Bars:** 70 %

Bank erosion: (nil) low moderate high

BED 1	BED 2
Velocity Min: – Max: –	**Velocity** Min: – Max: –
Mean depth: 70cm	**Mean depth:** 50
Mean channel width: 10	**Mean channel width:** 10
Canopy Cover: 0 %	**Canopy Cover:** %
Width of riparian zone	**Width of riparian zone**
Left Bank: 1 Right Bank: 1	Left Bank: 1 Right Bank: 1
Composition of riparian zone	**Composition of riparian zone**
Native: 70% Exotic: 30%	Native: 70 % Exotic: 30 %
Riparian Vegetation	**Riparian Vegetation**
Grass: 50% Shrubs: 50%	Grass: 50% Shrubs: 50 %
Trees: <10m: 50 % >10m: 0 %	Trees: <10m: 50 % >10m: 0 %
Substrate Description	**Substrate Description**
Bedrock 5 %	Bedrock 0 %
Boulder (>256mm) 0 %	Boulder (>256mm) 80 %
Cobble (64-256mm) 15 %	Cobble (64-256mm) 2 %
Pebble (16-64mm) 10 %	Pebble (16-64mm) 0 %
Gravel (4-16mm) 10 %	Gravel (4-16mm) 0 %
Sand (1-4mm) 10 %	Sand (1-4mm) 5 %
Silt/Clay (<1mm) 5 %	Silt/Clay (<1mm) 5 %
Substrate Cover	**Substrate Cover**
Periphyton 0 (1) 2 3 4	Periphyton 0 (1) 2 3 4
Moss (0) 1 2 3 4	Moss (0) 1 2 3 4
Filamentous algae (0) 1 2 3 4	Filamentous algae (0) 1 2 3 4
Detritus (0) 1 2 3 4	Detritus (0) 1 2 3 4
Macrophytes (0) 1 2 3 4	Macrophytes (0) 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
(nil) slight mod extensive	nil slight (mod) extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
(nil) slight mod extensive	(nil) slight mod extensive

Adjacent land use: Mining downstream to SSE

Upstream land use: Pastoral

Percent of habitats in 100m reach

Riffle: 0% Run: 0% Pool (rocky): 75 % Pool (sandy): 25 % Dry: 0 % Edge: 0 % Macrophytes: 0 %

Water odour: Nil	**Impact from animals:** Cattle tracks, scats, trails
Water foaming: Nil	**Human activity:** Nil
Plume: Moderate	**Aquatic animal life:** Tadpoles, freshwater mussels
Sediment oils: Nil	**Additional notes:** Cattle dung in water.
Sediment odour: Nil	Bed 2 just amongst rocks as pool too deep, not ideal habitat but not safe elsewhere

B4—DOWNSTREAM

UPSTREAM

DOWNSTREAM

HABITAT ASSESSMENT

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

LONGITUDINAL/CROSS-SECTION SKETCH

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore sketches not completed.

Project Name: Berbera.

Site name/number: B4 **Collected by:** TS/MM **Date:** 3/3/20

Photos: Upstream: 329 Downstream: 332 **Time:** 14:40

QA sample taken: (circle) YES (NO) sediment water quality macroinvertebrates

Rain in the past week: Slight

Weather: no rain showers heavy rain sunny some cloud overcast calm strong wind

Flow: (nil) low moderate high **Bars:** 100%

Bank erosion: nil (low) moderate high

DRY

BED 1	BED 2
Velocity Min: Max:	**Velocity** Min: Max:
Mean depth:	**Mean depth:**
Mean channel width:	**Mean channel width:**
Canopy Cover: %	**Canopy Cover:** %
Width of riparian zone	**Width of riparian zone**
Left Bank: Right Bank:	Left Bank: Right Bank:
Composition of riparian zone	**Composition of riparian zone**
Native: % Exotic: %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: % Shrubs: %	Grass: % Shrubs: %
Trees: <10m: % >10m: %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock %	Bedrock %
Boulder (>256mm) %	Boulder (>256mm) %
Cobble (64-256mm) %	Cobble (64-256mm) %
Pebble (16-64mm) %	Pebble (16-64mm) %
Gravel (4-16mm) %	Gravel (4-16mm) %
Sand (1-4mm) %	Sand (1-4mm) %
Silt/Clay (<1mm) %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton 0 1 2 3 4	Periphyton 0 1 2 3 4
Moss 0 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 1 2 3 4	Filamentous algae 0 1 2 3 4
Detritus 0 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes 0 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
nil slight mod extensive	nil slight mod extensive

Adjacent land use: Cattle grazing

Upstream land use: Mining.

Percent of habitats in 100m reach

Riffle: % Run: % Pool (rocky): % Pool (sandy): % Dry: 100% Edge: % Macrophytes: %

Water odour:	**Impact from animals:** Cattle impacts (slight)
Water foaming: Nil.	**Human activity:** Cattle grazing.
Plume:	**Aquatic animal life:** Nil
Sediment oils:	**Additional notes:**
Sediment odour: No.	

B5—UPSTREAM

UPSTREAM

DOWNSTREAM

HABITAT ASSESSMENT

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

LONGITUDINAL/CROSS-SECTION SKETCH

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore sketches not completed.

Project Name: Barbara			
Site name/number: B5	Collected by: D, MM		Date: 4/3/20
Photos: Upstream: 333	Downstream: 334		Time: 9:00am
QA sample taken: (circle) YES NO	sediment	water quality	macroinvertebrates
Rain in the past week: Moderate			
Weather: no rain (showers) heavy rain sunny some cloud (overcast) calm strong wind			
Flow: (nil) low moderate high			Bars: 100 %
Bank erosion: N (nil) low moderate high			

BED 1	BED 2
Velocity Min: – Max: –	Velocity Min: Max:
Mean depth:	Mean depth:
Mean channel width:	Mean channel width:
Canopy Cover: %	Canopy Cover: %
Width of riparian zone	**Width of riparian zone**
Left Bank: Right Bank:	Left Bank: Right Bank:
Composition of riparian zone	**Composition of riparian zone**
Native: % Exotic: %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: % Shrubs: %	Grass: % Shrubs: %
Trees: <10m: % >10m: %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock %	Bedrock %
Boulder (>256mm) %	Boulder (>256mm) %
Cobble (64-256mm) %	Cobble (64-256mm) %
Pebble (16-64mm) %	Pebble (16-64mm) %
Gravel (4-16mm) %	Gravel (4-16mm) %
Sand (1-4mm) %	Sand (1-4mm) %
Silt/Clay (<1mm) %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton 0 1 2 3 4	Periphyton 0 1 2 3 4
Moss 0 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 1 2 3 4	Filamentous algae 0 1 2 3 4
Detritus 0 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes 0 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
nil slight mod extensive	nil slight mod extensive

DRY

Adjacent land use: Mining downstream to east	
Upstream land use: Pastoral	
Percent of habitats in 100m reach	
Riffle: 0 % Run: 0 % Pool (rocky): 0 % Pool (sandy): 0 % Dry: 100 % Edge: 0 % Macrophytes: 0 %	
Water odour:	Impact from animals: Cattle trails
Water foaming:	Human activity: Nil but track ~50m downstream
Plume:	Aquatic animal life: N/A
Sediment oils: Nil	Additional notes: NIL.
Sediment odour: Nil	

B6— UPSTREAM

UPSTREAM

DOWNSTREAM

HABITAT ASSESSMENT

Habitat variable	Category	Score
1. Bottom substrate/ available cover	Excellent	18
2. Embeddedness	Excellent	18
3. Velocity/depth category	Poor	1
4. Channel alteration	Excellent	14
5. Bottom scouring and deposition	Excellent	14
6. Pool/riffle, run/band ratio	Fair	6
7. Bank stability	Excellent	10
8. Bank vegetative stability	Good	10
9. Streamside cover	Excellent	9
Total Score	**Good**	**100**

LONGITUDINAL SKETCH

CROSS-SECTION SKETCH

Project Name: Barbara

Site name/number: B6 | **Collected by:** TJ, MM | **Date:** 3.3.20

Photos: Upstream: 327 Downstream: 328 | **Time:** 13:30

QA sample taken: (circle) YES (NO) sediment water quality macroinvertebrates

Rain in the past week: Moderate ~ 1 week ago

Weather: (no rain) showers heavy rain sunny some cloud (overcast) (calm) strong wind

Flow: Nil (nil) low moderate high | **Bars:** 2 %

Bank erosion: Nil (nil) low moderate high

BED 1	BED 2
Velocity Min: – Max: –	**Velocity** Min: – Max: –
Mean depth: 1.4m	**Mean depth:**
Mean channel width: 2	**Mean channel width:** 2
Canopy Cover: 0 %	**Canopy Cover:** %
Width of riparian zone	**Width of riparian zone**
Left Bank: 0 Right Bank: 1	Left Bank: – Right Bank: 1
Composition of riparian zone	**Composition of riparian zone**
Native: 98 % Exotic: 2 %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: 15 % Shrubs: 20 %	Grass: % Shrubs: %
Trees: <10m: 10 % >10m: 0 %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock 20 %	Bedrock %
Boulder (>256mm) 50 %	Boulder (>256mm) %
Cobble (64-256mm) 5 %	Cobble (64-256mm) %
Pebble (16-64mm) 5 %	Pebble (16-64mm) %
Gravel (4-16mm) 10 %	Gravel (4-16mm) %
Sand (1-4mm) 8 %	Sand (1-4mm) %
Silt/Clay (<1mm) 2 %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton (0) 1 2 3 4	Periphyton 0 1 2 3 4
Moss (0) 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 (1) 2 3 4	Filamentous algae 0 1 2 3 4
Detritus (0) 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes (0) 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
(nil) slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
(nil) slight mod extensive	nil slight mod extensive

Adjacent land use: Mining to south, downstream

Upstream land use: Pastoral

Percent of habitats in 100m reach

Riffle: % (0) Run: (%) Pool (rocky): % (8) Pool (sandy): % (2) Dry: % (90) Edge: % (0) Macrophytes: % (0)

Water odour: Nil	**Impact from animals:** Nil
Water foaming: Nil	**Human activity:** Nil except old track ~100m downstream
Plume: Slight	**Aquatic animal life:** tadpoles
Sediment oils: Nil	**Additional notes:** Slight amount of algae. Small pool rocky gorge Majority of pool too deep to sample
Sediment odour: Nil	

B7—DOWNSTREAM

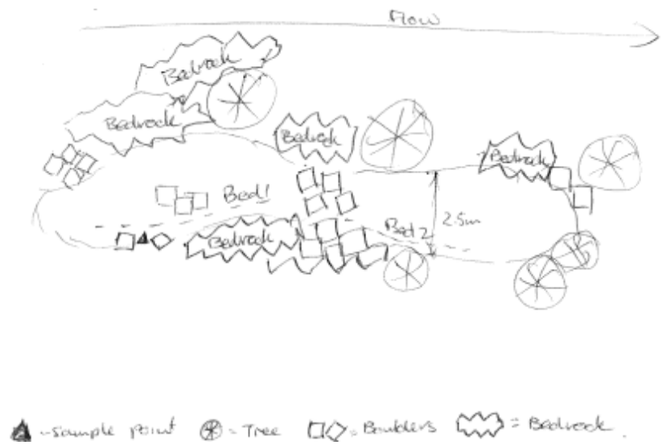
UPSTREAM

DOWNSTREAM

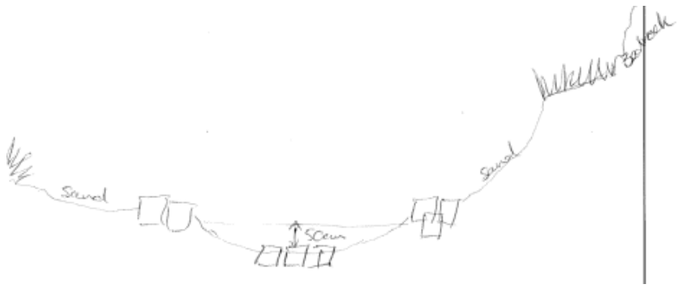
HABITAT ASSESSMENT

Habitat variable	Category	Score
1. Bottom substrate/ available cover	Good	13
2. Embeddedness	Excellent	18
3. Velocity/depth category	Poor	1
4. Channel alteration	Excellent	14
5. Bottom scouring and deposition	Excellent	15
6. Pool/riffle, run/band ratio	Fair	5
7. Bank stability	Excellent	9
8. Bank vegetative stability	Good	8
9. Streamside cover	Excellent	9
Total Score	**Good**	**92**

LONGITUDINAL SKETCH



CROSS-SECTION SKETCH



Project Name: Barbara

Site name/number: B7	Collected by: D, MM	Date: 3.3.20
Photos: Upstream: 325	Downstream: 326	Time: 11:15

QA sample taken: (circle) YES NO sediment water quality macroinvertebrates

Rain in the past week: Moderate ~1 wk ago

Weather: no rain showers heavy rain sunny some cloud overcast calm strong wind

Flow: Nil — nil low moderate high

Bank erosion: Low — nil low moderate high

Bars: 50 %

BED 1	BED 2
Velocity Min: – Max: –	Velocity Min: – Max: –
Mean depth: 50	Mean depth: 90
Mean channel width: 2.5	Mean channel width: 2.5
Canopy Cover: 5 %	Canopy Cover: 0 %
Width of riparian zone	**Width of riparian zone**
Left Bank: 2 Right Bank: 2	Left Bank: 2 Right Bank: 2
Composition of riparian zone	**Composition of riparian zone**
Native: 90 % Exotic: 10 %	Native: 90 % Exotic: 10 %
Riparian Vegetation	**Riparian Vegetation**
Grass: 90 % Shrubs: 10 %	Grass: 90 % Shrubs: 10 %
Trees: <10m: NA % 15 >10m: NA % 15	Trees: <10m: 15 % >10m: 15 %
Substrate Description	**Substrate Description**
Bedrock 10 %	Bedrock 5 %
Boulder (>256mm) 40 %	Boulder (>256mm) 40 %
Cobble (64-256mm) 5 %	Cobble (64-256mm) 15 %
Pebble (16-64mm) 5 %	Pebble (16-64mm) 5 %
Gravel (4-16mm) 10 %	Gravel (4-16mm) 15 %
Sand (1-4mm) 25 %	Sand (1-4mm) 15 %
Silt/Clay (<1mm) 5 %	Silt/Clay (<1mm) 5 %
Substrate Cover	**Substrate Cover**
Periphyton 0 (1) 2 3 4	Periphyton 0 (1) 2 3 4
Moss (0) 1 2 3 4	Moss (0) 1 2 3 4
Filamentous algae (0) 1 2 3 4	Filamentous algae (0) 1 2 3 4
Detritus 0 (1) 2 3 4	Detritus 0 (1) 2 3 4
Macrophytes (0) 1 2 3 4	Macrophytes (0) 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil (slight) mod extensive	(nil) slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
(nil) slight mod extensive	(nil) slight mod extensive

Adjacent land use: Mine to south, pastoral land.

Upstream land use: Pastoral

Percent of habitats in 100m reach

0 Riffle: 0% Run: 0% Pool (rocky): 20 % Pool (sandy): 20 % Dry: 60 Edge: 0% Macrophytes: 0%

Water odour: Nil	Impact from animals: Cattle tracks
Water foaming: Nil	Human activity: Track (dirt) ~100m upstream
Plume: Moderate	Aquatic animal life: Tadpoles
Sediment oils: Nil	Additional notes: –
Sediment odour: Detritus	

B9—DOWNSTREAM

UPSTREAM

DOWNSTREAM

HABITAT ASSESSMENT

Site is a surface water and sediment site only, therefore a habitat assessment was not completed.

LONGITUDINAL/CROSS-SECTION SKETCH

Site is a surface water and sediment site only, therefore sketches were not completed.

Project Name: Barbara		
Site name/number: B9	**Collected by:** TJ, MM	**Date:** 4/3/20
Photos: 241, 242 Upstream:	Downstream:	**Time:** 10:40
QA sample taken: (circle) YES (NO) sediment water quality macroinvertebrates		
Rain in the past week: Moderate		
Weather: no rain (showers) heavy rain sunny some cloud (overcast) (calm) strong wind		
Flow: (nil) low moderate high		**Bars:** 95 %
Bank erosion: nil (low) moderate high		

NOT MACRO SITE

BED 1	BED 2
Velocity Min: Max:	**Velocity** Min: Max:
Mean depth:	**Mean depth:**
Mean channel width:	**Mean channel width:**
Canopy Cover: %	**Canopy Cover:** %
Width of riparian zone	**Width of riparian zone**
Left Bank: Right Bank:	Left Bank: Right Bank:
Composition of riparian zone	**Composition of riparian zone**
Native: % Exotic: %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: % Shrubs: %	Grass: % Shrubs: %
Trees: <10m: % >10m: %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock %	Bedrock %
Boulder (>256mm) %	Boulder (>256mm) %
Cobble (64-256mm) %	Cobble (64-256mm) %
Pebble (16-64mm) %	Pebble (16-64mm) %
Gravel (4-16mm) %	Gravel (4-16mm) %
Sand (1-4mm) %	Sand (1-4mm) %
Silt/Clay (<1mm) %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton 0 1 2 3 4	Periphyton 0 1 2 3 4
Moss 0 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 1 2 3 4	Filamentous algae 0 1 2 3 4
Detritus 0 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes 0 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
nil slight mod extensive	nil slight mod extensive

Adjacent land use: Pastoral	
Upstream land use: Pastoral	
Percent of habitats in 100m reach	
Riffle: 0 % Run: 0 % Pool (rocky): 2 % Pool (sandy): 3 % Dry: 75 % Edge: 0 % Macrophytes: 0 %	
Water odour: Cattle odour	**Impact from animals:** Very heavily cattle affected pool (scats, tracks, trails)
Water foaming: Nil	**Human activity:** Nil
Plume:	**Aquatic animal life:**
Sediment oils: Nil	**Additional notes:** Site is listed as "dry season regime" in RMP design, but SOD and SW collected.
Sediment odour: Nil (other than cattle urine)	

Dry Season Survey 2020

B1US—UPSTREAM

UPSTREAM

HABITAT ASSESSMENT

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

DOWNSTREAM

LONGITUDINAL/CROSS-SECTION SKETCH

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

Project Name: Barbara.			
Site name/number: B1US.	Collected by: cl/mm		Date: 23/8/20.
Photos: Upstream: 446	Downstream: 447.		Time: 14:30.
QA sample taken: (circle) YES (NO)	sediment	water quality	macroinvertebrates
Rain in the past week: NO.			
Weather: no rain showers heavy rain (sunny) some cloud overcast calm strong wind			
Flow: (nil) low moderate high		Bars: %	
Bank erosion: nil (low) moderate high			

BED 1	BED 2
Velocity Min: Max:	Velocity Min: Max:
Mean depth:	Mean depth:
Mean channel width:	Mean channel width:
Canopy Cover: %	Canopy Cover: %
Width of riparian zone	**Width of riparian zone**
Left Bank: Right Bank:	Left Bank: Right Bank:
Composition of riparian zone	**Composition of riparian zone**
Native: % Exotic: %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: % Shrubs: %	Grass: % Shrubs: %
Trees: <10m: % >10m: %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock %	Bedrock %
Boulder (>256mm) %	Boulder (>256mm) %
Cobble (64-256mm) %	Cobble (64-256mm) %
Pebble (16-64mm) %	Pebble (16-64mm) %
Gravel (4-16mm) %	Gravel (4-16mm) %
Sand (1-4mm) %	Sand (1-4mm) %
Silt/Clay (<1mm) %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton 0 1 2 3 4	Periphyton 0 1 2 3 4
Moss 0 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 1 2 3 4	Filamentous algae 0 1 2 3 4
Detritus 0 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes 0 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
nil slight mod extensive	nil slight mod extensive

DRY.

Adjacent land use: Cattle grazing, mining.	
Upstream land use: " " "	
Percent of habitats in 100m reach	
Riffle: % Run: % Pool (rocky): % Pool (sandy): % Dry: 100% Edge: % Macrophytes: %	
Water odour:	Impact from animals: No.
Water foaming: N/A.	Human activity: NO.
Plume:	Aquatic animal life: N/A.
Sediment oils: NO	Additional notes:
Sediment odour: NO.	

B1- DOWNSTREAM

UPSTREAM

DOWNSTREAM

HABITAT ASSESSMENT

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

LONGITUDINAL/CROSS-SECTION SKETCH

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

Project Name: Barbara.			
Site name/number: B1	Collected by: CL/MM		Date: 23/8/20
Photos: Upstream: 498		Downstream: 499	Time: 14:35
QA sample taken: (circle) YES (NO) sediment water quality macroinvertebrates			
Rain in the past week: Nil			
Weather: no rain showers heavy rain (sunny) some cloud overcast calm strong wind			
Flow: (nil) low moderate high			Bars: %
Bank erosion: nil (low) moderate high			

BED 1	BED 2
Velocity Min: Max:	Velocity Min: Max:
Mean depth:	Mean depth:
Mean channel width:	Mean channel width:
Canopy Cover: %	Canopy Cover: %
Width of riparian zone	**Width of riparian zone**
Left Bank: Right Bank:	Left Bank: Right Bank:
Composition of riparian zone	**Composition of riparian zone**
Native: % Exotic: %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: % Shrubs: %	Grass: % Shrubs: %
Trees: <10m: % >10m: %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock %	Bedrock %
Boulder (>256mm) %	Boulder (>256mm) %
Cobble (64-256mm) %	Cobble (64-256mm) %
Pebble (16-64mm) %	Pebble (16-64mm) %
Gravel (4-16mm) %	Gravel (4-16mm) %
Sand (1-4mm) %	Sand (1-4mm) %
Silt/Clay (<1mm) %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton 0 1 2 3 4	Periphyton 0 1 2 3 4
Moss 0 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 1 2 3 4	Filamentous algae 0 1 2 3 4
Detritus 0 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes 0 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
nil slight mod extensive	nil slight mod extensive

DRY

Adjacent land use: Cattle grazing, mining	
Upstream land use: " "	
Percent of habitats in 100m reach	
Riffle: % Run: % Pool (rocky): % Pool (sandy): % Dry: 100% Edge: % Macrophytes: %	
Water odour:	Impact from animals: NO
Water foaming: N/A.	Human activity: NO.
Plume:	Aquatic animal life: NO.
Sediment oils: NO	Additional notes:
Sediment odour: NO.	

B2—DOWNSTREAM

UPSTREAM

DOWNSTREAM

HABITAT ASSESSMENT

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

LONGITUDINAL/CROSS-SECTION SKETCH

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore sketches not completed.

Project Name: Barbara.			
Site name/number: B2	**Collected by:** CC/MM	**Date:** 23/8/20	
Photos: Upstream: 494	Downstream: 495	**Time:** 13:00.	
QA sample taken: (circle) YES (NO) sediment water quality macroinvertebrates			
Rain in the past week: Nil			
Weather: no rain showers heavy rain (sunny) some cloud overcast calm strong wind			
Flow: (nil) low moderate high		**Bars:** %	
Bank erosion: nil (low) moderate high			

BED 1	BED 2
Velocity Min: Max:	**Velocity** Min: Max:
Mean depth:	**Mean depth:**
Mean channel width:	**Mean channel width:**
Canopy Cover: %	**Canopy Cover:** %
Width of riparian zone	**Width of riparian zone**
Left Bank: Right Bank:	Left Bank: Right Bank:
Composition of riparian zone	**Composition of riparian zone**
Native: % Exotic: %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: % Shrubs: %	Grass: % Shrubs: %
Trees: <10m: % >10m: %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock %	Bedrock %
Boulder (>256mm) %	Boulder (>256mm) %
Cobble (64-256mm) %	Cobble (64-256mm) %
Pebble (16-64mm) %	Pebble (16-64mm) %
Gravel (4-16mm) %	Gravel (4-16mm) %
Sand (1-4mm) %	Sand (1-4mm) %
Silt/Clay (<1mm) %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton 0 1 2 3 4	Periphyton 0 1 2 3 4
Moss 0 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 1 2 3 4	Filamentous algae 0 1 2 3 4
Detritus 0 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes 0 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
nil slight mod extensive	nil slight mod extensive

DRY

Adjacent land use: Cattle Grazing.	
Upstream land use: " " , Mining.	
Percent of habitats in 100m reach	
Riffle: % Run: % Pool (rocky): % Pool (sandy): % Dry: 100 % Edge: % Macrophytes: %	
Water odour:	**Impact from animals:** slight cattle & macropod
Water foaming: N/A.	**Human activity:** No
Plume:	**Aquatic animal life:** N/A.
Sediment oils: No	**Additional notes:**
Sediment odour: No.	

B3—UPSTREAM

UPSTREAM

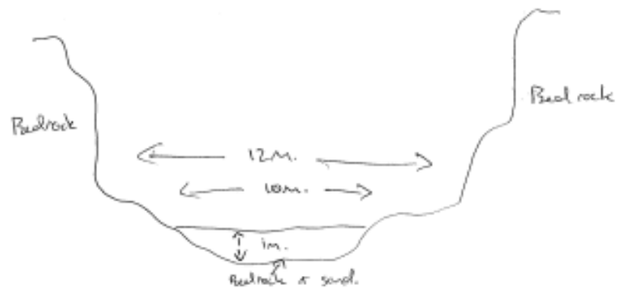
DOWNSTREAM

HABITAT ASSESSMENT

Habitat variable	Category	Score
1. Bottom substrate/ available cover	Good	11
2. Embeddedness	Good	11
3. Velocity/depth category	Poor	5
4. Channel alteration	Excellent	12
5. Bottom scouring and deposition	Good	11
6. Pool/riffle, run/band ratio	Fair	4
7. Bank stability	Excellent	9
8. Bank vegetative stability	Fair	5
9. Streamside cover	Excellent	9
Total Score	**Good**	**77**

LONGITUDINAL SKETCH

CROSS-SECTION SKETCH



Project Name:	Barbara.		
Site name/number:	B3	Collected by: CC/MM	Date: 28/8/20
Photos:	Upstream: 490	Downstream: 491	Time: 09:20.
QA sample taken: (circle)	(YES) NO	sediment water quality macroinvertebrates	
Rain in the past week:	Nil		
Weather:	no rain showers heavy rain (sunny) some cloud overcast calm strong wind		
Flow:	(nil) low moderate high		Bars: 20. %
Bank erosion:	nil (low) moderate high		

BED 1		BED 2	
Velocity Min:	Max: Nil	Velocity Min:	Max:
Mean depth:	~~[illegible]~~ 1m.	Mean depth:	
Mean channel width:	12m.	Mean channel width:	
Canopy Cover:	0 %	Canopy Cover:	%
Width of riparian zone		**Width of riparian zone**	
Left Bank:	1m Right Bank: 5m.	Left Bank:	Right Bank:
Composition of riparian zone		**Composition of riparian zone**	
Native:	95 % Exotic: 5 %	Native:	% Exotic: %
Riparian Vegetation		**Riparian Vegetation**	
Grass:	10 % Shrubs: 10 %	Grass:	% Shrubs: %
Trees: <10m:	30 % >10m: 40. %	Trees: <10m:	% >10m: %
Substrate Description		**Substrate Description**	
Bedrock	45 %	Bedrock	%
Boulder (>256mm)	0 %	Boulder (>256mm)	%
Cobble (64-256mm)	5 %	Cobble (64-256mm)	%
Pebble (16-64mm)	5 %	Pebble (16-64mm)	%
Gravel (4-16mm)	20 %	Gravel (4-16mm)	%
Sand (1-4mm)	15 %	Sand (1-4mm)	%
Silt/Clay (<1mm)	10 %	Silt/Clay (<1mm)	%
Substrate Cover		**Substrate Cover**	
Periphyton	0 1 (2) 3 4	Periphyton	0 1 2 3 4
Moss	(0) 1 2 3 4	Moss	0 1 2 3 4
Filamentous algae	(0) 1 2 3 4	Filamentous algae	0 1 2 3 4
Detritus	0 (1) 2 3 4	Detritus	0 1 2 3 4
Macrophytes	(0) 1 2 3 4	Macrophytes	0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%		0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	
Bank Overhang Vegetation		**Bank Overhang Vegetation**	
(nil) slight mod extensive		nil slight mod extensive	
Trailing Bank Vegetation? tick		**Trailing Bank Vegetation?** tick	
(nil) slight mod extensive		nil slight mod extensive	

Adjacent land use:	Cattle grazing
Upstream land use:	" "

Percent of habitats in 100m reach

Riffle: 0 % Run: 0 % Pool (rocky): 20 % Pool (sandy): 10 % Dry: 70 % Edge: 0 % Macrophytes: 0 %

Water odour:	Low poo	Impact from animals:	Heavy cattle impacts.
Water foaming:	No	Human activity:	No.
Plume:	Heavy.	Aquatic animal life:	No.
Sediment oils:	No.	Additional notes:	
Sediment odour:	Low poo		

B4—DOWNSTREAM

UPSTREAM

DOWNSTREAM

HABITAT ASSESSMENT

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

LONGITUDINAL/CROSS-SECTION SKETCH

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore sketches not completed.

Project Name: Barbara.			
Site name/number: B4	**Collected by:** CC/MM	**Date:** 23/8/20.	
Photos: Upstream: 486	Downstream: 489.	**Time:**	
QA sample taken: (circle) YES	(NO) sediment	water quality	macroinvertebrates
Rain in the past week: Nil			
Weather: no rain showers heavy rain (sunny) some cloud overcast calm strong wind			
Flow: (nil) low moderate high		**Bars:** %	
Bank erosion: nil (low) moderate high			

BED 1	BED 2
Velocity Min: Max:	**Velocity** Min: Max:
Mean depth:	**Mean depth:**
Mean channel width:	**Mean channel width:**
Canopy Cover: %	**Canopy Cover:** %
Width of riparian zone	**Width of riparian zone**
Left Bank: Right Bank:	Left Bank: Right Bank:
Composition of riparian zone	**Composition of riparian zone**
Native: % Exotic: %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: % Shrubs: %	Grass: % Shrubs: %
Trees: <10m: % >10m: %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock %	Bedrock %
Boulder (>256mm) %	Boulder (>256mm) %
Cobble (64-256mm) %	Cobble (64-256mm) %
Pebble (16-64mm) %	Pebble (16-64mm) %
Gravel (4-16mm) %	Gravel (4-16mm) %
Sand (1-4mm) %	Sand (1-4mm) %
Silt/Clay (<1mm) %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton 0 1 2 3 4	Periphyton 0 1 2 3 4
Moss 0 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 1 2 3 4	Filamentous algae 0 1 2 3 4
Detritus 0 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes 0 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
nil slight mod extensive	nil slight mod extensive

DRY.

Adjacent land use: Cattle grazing	
Upstream land use: " " Mining	
Percent of habitats in 100m reach	
Riffle: % Run: % Pool (rocky): % Pool (sandy): % Dry: 100 % Edge: % Macrophytes: %	
Water odour:	**Impact from animals:** NO
Water foaming:	**Human activity:** NO
Plume: N/A.	**Aquatic animal life:** N/A.
Sediment oils: NO	**Additional notes:**
Sediment odour: NO.	

B5—UPSTREAM

UPSTREAM

DOWNSTREAM

HABITAT ASSESSMENT

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

LONGITUDINAL/CROSS-SECTION SKETCH

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore sketches not completed.

Project Name: Barbara.			
Site name/number: B5	**Collected by:** CL/MM.		**Date:** 23/8/20.
Photos: Upstream: 442	Downstream: 443.		**Time:** 12:45
QA sample taken: (circle) YES (NO) sediment water quality macroinvertebrates			
Rain in the past week: NO			
Weather: no rain showers heavy rain (sunny) some cloud overcast calm strong wind			
Flow: (nil) low moderate high			**Bars:** %
Bank erosion: nil (low) moderate high			

BED 1	BED 2
Velocity Min: Max:	**Velocity** Min: Max:
Mean depth:	**Mean depth:**
Mean channel width:	**Mean channel width:**
Canopy Cover: %	**Canopy Cover:** %
Width of riparian zone	**Width of riparian zone**
Left Bank: Right Bank:	Left Bank: Right Bank:
Composition of riparian zone	**Composition of riparian zone**
Native: % Exotic: %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: % Shrubs: %	Grass: % Shrubs: %
Trees: <10m: % >10m: %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock %	Bedrock %
Boulder (>256mm) %	Boulder (>256mm) %
Cobble (64-256mm) %	Cobble (64-256mm) %
Pebble (16-64mm) %	Pebble (16-64mm) %
Gravel (4-16mm) %	Gravel (4-16mm) %
Sand (1-4mm) %	Sand (1-4mm) %
Silt/Clay (<1mm) %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton 0 1 2 3 4	Periphyton 0 1 2 3 4
Moss 0 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 1 2 3 4	Filamentous algae 0 1 2 3 4
Detritus 0 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes 0 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
nil slight mod extensive	nil slight mod extensive

DRY.

Adjacent land use: Cattle grazing	
Upstream land use: " "	
Percent of habitats in 100m reach	
Riffle: % Run: % Pool (rocky): % Pool (sandy): % Dry: % (100) Edge: % Macrophytes: %	
Water odour:	**Impact from animals:** slight cattle impacts.
Water foaming: N/A.	**Human activity:** NO.
Plume:	**Aquatic animal life:** N/A.
Sediment oils: NO	**Additional notes:**
Sediment odour: NO.	

B6— UPSTREAM

UPSTREAM

HABITAT ASSESSMENT

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

DOWNSTREAM

LONGITUDINAL/CROSS-SECTION SKETCH

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore sketches not completed.

Project Name: Barbara.			
Site name/number: B6.	Collected by: CC/MM		Date: 23/8/20.
Photos:	Upstream: 486	Downstream: 487	Time:
QA sample taken: (circle)	YES	(NO).	sediment water quality macroinvertebrates
Rain in the past week:	Nil		
Weather: no rain showers heavy rain (sunny) some cloud overcast calm strong wind			
Flow:	(nil) low moderate high		Bars: %
Bank erosion:	nil (low). moderate high		

BED 1	BED 2
Velocity Min: Max:	Velocity Min: Max:
Mean depth:	Mean depth:
Mean channel width:	Mean channel width:
Canopy Cover: %	Canopy Cover: %
Width of riparian zone	**Width of riparian zone**
Left Bank: Right Bank:	Left Bank: Right Bank:
Composition of riparian zone	**Composition of riparian zone**
Native: % Exotic: %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: % Shrubs: %	Grass: % Shrubs: %
Trees: <10m: % >10m: %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock %	Bedrock %
Boulder (>256mm) %	Boulder (>256mm) %
Cobble (64-256mm) %	Cobble (64-256mm) %
Pebble (16-64mm) %	Pebble (16-64mm) %
Gravel (4-16mm) %	Gravel (4-16mm) %
Sand (1-4mm) %	Sand (1-4mm) %
Silt/Clay (<1mm) %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton 0 1 2 3 4	Periphyton 0 1 2 3 4
Moss 0 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 1 2 3 4	Filamentous algae 0 1 2 3 4
Detritus 0 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes 0 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
nil slight mod extensive	nil slight mod extensive

DRY

Adjacent land use:	Cattle grazing
Upstream land use:	" "

Percent of habitats in 100m reach

Riffle: % Run: % Pool (rocky): % Pool (sandy): % Dry: 100 % Edge: % Macrophytes: %

Water odour:	N/A.	Impact from animals:	NO.
Water foaming:		Human activity:	NO
Plume:		Aquatic animal life:	N/A.
Sediment oils:	NO	Additional notes:	
Sediment odour:	NO.		

B7—DOWNSTREAM

UPSTREAM

DOWNSTREAM

HABITAT ASSESSMENT

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore a habitat assessment was not completed.

LONGITUDINAL/CROSS-SECTION SKETCH

Site contained insufficient water for collection of aquatic macroinvertebrates at the time of samping, therefore sketches not completed.

Project Name: Barbara.			
Site name/number: B7	**Collected by:** CL/MM		**Date:** 23/8/20.
Photos: Upstream: 484	Downstream: 485		**Time:**
QA sample taken: (circle) YES (NO)	sediment	water quality	macroinvertebrates
Rain in the past week: Nil			
Weather: no rain showers heavy rain (sunny) some cloud overcast calm strong wind			
Flow: (nil) low moderate high			**Bars:** %
Bank erosion: nil (low) moderate high			

BED 1	BED 2
Velocity Min: Max:	**Velocity** Min: Max:
Mean depth:	**Mean depth:**
Mean channel width:	**Mean channel width:**
Canopy Cover: %	**Canopy Cover:** %
Width of riparian zone	**Width of riparian zone**
Left Bank: Right Bank:	Left Bank: Right Bank:
Composition of riparian zone	**Composition of riparian zone**
Native: % Exotic: %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: % Shrubs: %	Grass: % Shrubs: %
Trees: <10m: % >10m: %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock %	Bedrock %
Boulder (>256mm) %	Boulder (>256mm) %
Cobble (64-256mm) %	Cobble (64-256mm) %
Pebble (16-64mm) %	Pebble (16-64mm) %
Gravel (4-16mm) %	Gravel (4-16mm) %
Sand (1-4mm) %	Sand (1-4mm) %
Silt/Clay (<1mm) %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton 0 1 2 3 4	Periphyton 0 1 2 3 4
Moss 0 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 1 2 3 4	Filamentous algae 0 1 2 3 4
Detritus 0 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes 0 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
nil slight mod extensive	nil slight mod extensive

DRY.

Adjacent land use: Cattle grazing	
Upstream land use: " " , Mining.	
Percent of habitats in 100m reach	
Riffle: % Run: % Pool (rocky): % Pool (sandy): % Dry: 100 % Edge: % Macrophytes: %	
Water odour:	**Impact from animals:** Slight cattle impacts.
Water foaming: N/A.	**Human activity:** NO.
Plume:	**Aquatic animal life:** N/A.
Sediment oils: NO	**Additional notes:**
Sediment odour: NO.	

B9—DOWNSTREAM

UPSTREAM

DOWNSTREAM

HABITAT ASSESSMENT

Site is a surface water and sediment site only, therefore a habitat assessment was not completed.

LONGITUDINAL/CROSS-SECTION SKETCH

Site is a surface water and sediment site only, therefore sketches were not completed.

Project Name: Barbara.			
Site name/number: B9.	**Collected by:** CC/MM		**Date:** 23/8/20
Photos: Upstream: 500	Downstream: 501		**Time:** 16:50
QA sample taken: (circle)	YES	(NO)	sediment water quality macroinvertebrates
Rain in the past week: Nil			
Weather: no rain showers heavy rain (sunny) some cloud overcast calm strong wind			
Flow:	(nil) low moderate high		**Bars:** %
Bank erosion:	nil (low) moderate high		

BED 1	BED 2
Velocity Min: Max:	**Velocity** Min: Max:
Mean depth:	**Mean depth:**
Mean channel width:	**Mean channel width:**
Canopy Cover: %	**Canopy Cover:** %
Width of riparian zone	**Width of riparian zone**
Left Bank: Right Bank:	Left Bank: Right Bank:
Composition of riparian zone	**Composition of riparian zone**
Native: % Exotic: %	Native: % Exotic: %
Riparian Vegetation	**Riparian Vegetation**
Grass: % Shrubs: %	Grass: % Shrubs: %
Trees: <10m: % >10m: %	Trees: <10m: % >10m: %
Substrate Description	**Substrate Description**
Bedrock %	Bedrock %
Boulder (>256mm) %	Boulder (>256mm) %
Cobble (64-256mm) %	Cobble (64-256mm) % DRY.
Pebble (16-64mm) %	Pebble (16-64mm) %
Gravel (4-16mm) %	Gravel (4-16mm) %
Sand (1-4mm) %	Sand (1-4mm) %
Silt/Clay (<1mm) %	Silt/Clay (<1mm) %
Substrate Cover	**Substrate Cover**
Periphyton 0 1 2 3 4	Periphyton 0 1 2 3 4
Moss 0 1 2 3 4	Moss 0 1 2 3 4
Filamentous algae 0 1 2 3 4	Filamentous algae 0 1 2 3 4
Detritus 0 1 2 3 4	Detritus 0 1 2 3 4
Macrophytes 0 1 2 3 4	Macrophytes 0 1 2 3 4
0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%	0=<10% 1=10-35% 2=35-65% 3=65-90% 4=>90%
Bank Overhang Vegetation	**Bank Overhang Vegetation**
nil slight mod extensive	nil slight mod extensive
Trailing Bank Vegetation? tick	**Trailing Bank Vegetation?** tick
nil slight mod extensive	nil slight mod extensive

Adjacent land use: Cattle grazing	
Upstream land use: " " , Mining.	
Percent of habitats in 100m reach	
Riffle: % Run: % Pool (rocky): % Pool (sandy): % Dry: 100 % Edge: % Macrophytes: %	
Water odour:	**Impact from animals:** Cattle tracks, scats + dead
Water foaming: N/A.	**Human activity:** No. body nearby.
Plume:	**Aquatic animal life:** N/A.
Sediment oils: No	**Additional notes:**
Sediment odour: No.	

APPENDIX C

Surface Water Data

Table C1 Surface water results for Barbara taken in 2020 wet season with exceedances of the guideline values highlighted in red, orange indicates where the limit of reporting was above the guideline value

Parameter		Unit	GV	Upstream		Downstream	
				B3	B6	B7	B9
pH		pH units	6.0-7.5[1]	8.2	7.9	8.5	7.7
EC		µs/cm	500[2]	154	303	350	393
DO		%Sat	90-120[1]	49.2	58.1	58	18.4
Temperature		°C	-	30.78	30.09	28.73	26.43
Turbidity		NTU	15[1]	9.7	5.2	32.6	40.4
Sulfate		mg/L	-	2.3	3.4	5.9	1.7
Fluoride		mg/L	-	0.1	0.1	0.2	0.1
Hardness		mg $CaCO_3$/L	-	39	79	79	120
Arsenic	Total	mg/L	0.013[3]	<0.003	<0.003	<0.003	<0.003
	Dissolved	mg/L	0.013[3]	<0.003	<0.003	<0.003	<0.003
Barium	Total	mg/L	-	0.022	0.024	0.048	0.044
	Dissolved	mg/L	-	0.020	0.022	0.044	0.036
Bismuth	Total	mg/L	0.0007[4]	<0.001	<0.001	<0.001	<0.001
	Dissolved	mg/L	0.0007[4]	<0.001	<0.001	<0.001	<0.001
Chromium	Total	mg/L	0.0033[3]	<0.0005	<0.0005	<0.0005	<0.0005
	Dissolved	mg/L	0.0033[3]	<0.0005	<0.0005	<0.0005	<0.0005
Cobalt	Total	mg/L	0.0014[3]	<0.001	<0.001	<0.001	0.001
	Dissolved	mg/L	0.0014[3]	<0.001	<0.001	<0.001	<0.001
Copper	Total	mg/L	0.0014[3]	0.003	0.001	0.012	0.002
	Dissolved	mg/L	0.0014[3]	0.003	0.001	0.009	0.001
Molybdenum	Total	mg/L	0.034[3]	<0.0005	0.0008	0.0011	0.0012
	Dissolved	mg/L	0.034[3]	<0.0005	0.0008	0.0010	0.0012
Nickel	Total	mg/L	0.011[3]	<0.001	<0.001	<0.001	<0.001
	Dissolved	mg/L	0.011[3]	<0.001	<0.001	<0.001	<0.001

Parameter		Unit	GV	Upstream		Downstream	
				B3	B6	B7	B9
Selenium	Total	mg/L	0.011[3]	<0.002	<0.002	<0.002	<0.002
	Dissolved	mg/L	0.011[3]	<0.002	0.003	<0.002	0.003
Uranium	Total	mg/L	0.0005[3]	<0.001	<0.001	<0.001	<0.001
	Dissolved	mg/L	0.0005[3]	<0.001	<0.001	<0.001	<0.001

1 Indicates where Australian and New Zealand Environmental Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC & ARMCANZ, 2000) tropical Australia upland streams guideline values were used. There are currently no QWQG (EHP, 2009) guideline values for the Gulf region for pH, turbidity, and DO.

2 Indicates where QWQG (EHP, 2009) regional guideline values for the Gulf rivers – upland streams – Gulf salinity zone used for EC (75th percentile).

3 Indicates where ANZG (2018) trigger values for toxicants for the protection of slightly to moderately disturbed systems (95% protection for aquatic ecosystems) were used for total and dissolved metals.

4 Indicates where Environmental Concern Level was used (ANZECC, 2000).

Table C2 Surface water results for Barbara taken in 2020 dry season with exceedances of the guideline values highlighted in red, orange indicates where the limit of reporting was above the guideline value

Parameter		Unit	GV	Upstream
				B3
pH		pH units	6.0-7.5[1]	8.3
EC		µs/cm	500[2]	433
DO		%Sat	90-120[1]	14.5
Temperature		°C	-	15.54
Turbidity		NTU	15[1]	399
Sulfate		mg/L	-	3.5
Fluoride		mg/L	-	0.2
Hardness		mg $CaCO_3$/L	-	100
Arsenic	Total	mg/L	0.013[3]	0.004
	Dissolved	mg/L	0.013[3]	<0.003
Barium	Total	mg/L	-	0.26
	Dissolved	mg/L	-	0.088
Bismuth	Total	mg/L	0.0007[4]	<1
	Dissolved	mg/L	0.0007[4]	<1
Chromium	Total	mg/L	0.0033[3]	<0.0005
	Dissolved	mg/L	0.0033[3]	<0.0005
Cobalt	Total	mg/L	0.0014[3]	0.006
	Dissolved	mg/L	0.0014[3]	0.002
Copper	Total	mg/L	0.0014[3]	0.006
	Dissolved	mg/L	0.0014[3]	0.003
Molybdenum	Total	mg/L	0.034[3]	0.0009
	Dissolved	mg/L	0.034[3]	0.0012
Nickel	Total	mg/L	0.011[3]	0.002
	Dissolved	mg/L	0.011[3]	0.001

Parameter		Unit	GV	Upstream
				B3
Selenium	Total	mg/L	0.011[3]	0.002
	Dissolved	mg/L	0.011[3]	0.003
Uranium	Total	mg/L	0.0005[3]	<0.001
	Dissolved	mg/L	0.0005[3]	<0.001

1 Indicates where Australian and New Zealand Environmental Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC & ARMCANZ, 2000) tropical Australia upland streams guideline values were used. There are currently no QWQG (EHP, 2009) guideline values for the Gulf region for pH, turbidity, and DO.

2 Indicates where QWQG (EHP, 2009) regional guideline values for the Gulf rivers – upland streams – Gulf salinity zone used for EC (75th percentile).

3 Indicates where ANZG (2018) trigger values for toxicants for the protection of slightly to moderately disturbed systems (95% protection

4 Indicates where Environmental Concern Level was used (ANZECC, 2000).

APPENDIX D

Stream Sediment Data

Table D1 Stream sediment results for Barbara taken in 2020 wet season (exceedances above DVG guideline values shaded in pale red, exceedances above GV-High guideline values shaded in dark red)

Parameter	Fraction	Units	ANZG trigger value		Upstream				Downstream				
			DGV	GV-High	B1US	B3	B5	B6	B1	B2	B4	B7	B9
Arsenic	Whole	mg/kg	20	70	3.5	2.5	2.9	4.1	6.5	6.5	4.9	3.5	2.5
	Fine	mg/kg	20	70	3.8	6.8	9.1	3.3	6.0	3.0	3.9	4.3	3.9
Barium	Whole	mg/kg	-	-	140	53	100	43	69	56	47	43	37
	Fine	mg/kg	-	-	170	140	140	130	120	210	120	150	120
Bismuth	Whole	mg/kg	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	Fine	mg/kg	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chromium	Whole	mg/kg	80	370	50	18	31	16	23	18	21	16	13
	Fine	mg/kg	80	370	56	36	30	30	36	34	32	35	31
Cobalt	Whole	mg/kg	-	-	31	15	26	14	19	29	44	17	9.7
	Fine	mg/kg	-	-	31	23	41	22	52	26	22	26	19
Copper	Whole	mg/kg	65	270	83	38	26	19	71	350	160	37	24
	Fine	mg/kg	65	270	130	300	670	130	480	45	85	240	71
Molybdenum	Whole	mg/kg	-	-	<0.5	<0.5	<0.5	<0.5	0.7	0.5	<0.5	<0.5	<0.5
	Fine	mg/kg	-	-	<0.5	0.8	0.6	<0.5	0.7	<0.5	0.8	0.6	0.6
Nickel	Whole	mg/kg	21	52	32	12	24	9.7	18	21	17	12	8.3
	Fine	mg/kg	21	52	37	25	35	22	29	30	20	28	21
Selenium	Whole	mg/kg	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Fine	mg/kg	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Uranium	Whole	mg/kg	-	-	0.5	0.6	0.8	0.7	0.6	0.7	0.7	0.6	0.6
	Fine	mg/kg	-	-	0.6	0.9	1.2	0.9	1.1	1.2	1.3	1.2	1.2

Note: Fine Fraction = <63µm and whole fraction = <2mm.

Table D2 Stream sediment results for Barbara taken in 2020 dry season (exceedances above DVG guideline values shaded in pale red, exceedances above GV-High guideline values shaded in dark red)

Parameter	Fraction	Units	ANZG trigger value		Upstream				Downstream				
			DGV	GV-High	B1US	B3	B5	B6	B1	B2	B4	B7	B9
Arsenic	Whole	mg/kg	20	70	3.7	3.1	2.3	3.9	7.6	7.4	6.2	3.9	1.9
	Fine	mg/kg	20	70	3.6	6.1	<0.5	6.3	6.0	8.5	5.8	4.7	3.2
Barium	Whole	mg/kg	-	-	120	44	81	45	70	60	40	39	31
	Fine	mg/kg	-	-	220	190	230	410	120	140	150	200	120
Bismuth	Whole	mg/kg	-	-	<3	<3	<3	<3	<3	<3	<3	<3	<3
	Fine	mg/kg	-	-	5	3	<3	<3	<3	<3	<3	<3	<3
Chromium	Whole	mg/kg	80	370	43	15	24	15	24	17	20	15	12
	Fine	mg/kg	80	370	59	39	42	35	32	34	45	31	26
Cobalt	Whole	mg/kg	-	-	29	14	20	15	19	28	29	16	11
	Fine	mg/kg	-	-	39	35	34	40	18	34	47	25	17
Copper	Whole	mg/kg	65	270	110	32	43	28	70	450	140	44	25
	Fine	mg/kg	65	270	230	170	260	400	400	1000	680	300	87
Molybdenum	Whole	mg/kg	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Fine	mg/kg	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Nickel	Whole	mg/kg	21	52	29	11	20	10	20	22	17	12	8.3
	Fine	mg/kg	21	52	47	31	40	26	23	35	37	26	18
Selenium	Whole	mg/kg	-	-	<3	<3	<3	<3	<3	<3	<3	<3	<3
	Fine	mg/kg	-	-	<3	<3	<3	<3	<3	<3	<3	<3	<3
Uranium	Whole	mg/kg	-	-	0.6	0.6	0.8	0.6	0.5	0.7	0.6	0.6	0.6
	Fine	mg/kg	-	-	0.8	1.1	1.1	1.2	0.7	1.1	1.2	1.2	1.3

Note: Fine Fraction = <63µm and whole fraction = <2mm.

APPENDIX E

Macroinvertebrate Data

Table E1 List of macroinvertebrate taxa collected and abundance per sample during the 2020 wet season aquatic ecology survey

Higher order	Taxon	SIGNAL 2 score	Upstream			Downstream		Total
			B3		B6	B7		
			Bed 1	Bed 2	Bed 1	Bed 1	Bed 2	
Acarina	Acarina	6	10	4	0	0	2	**16**
Oligochaeta	Oligochaeta	2	2	5	12	4	4	**27**
Cladocera	Cladocera	5	7	15	11	281	208	**522**
Copepoda	Copepoda	4	39	3	6	52	37	**137**
Ostracoda	Ostracoda	4	15	16	33	18	23	**105**
Coleoptera	Dytiscidae	2	14	10	10	14	13	**61**
Coleoptera	Gyrinidae	4	3	0	0	0	0	**3**
Diptera	Ceratopogonidae	4	1	1	1	5	5	**13**
Diptera	Chironominae	3	7	5	6	3	6	**27**
Diptera	Tanypodinae	4	5	10	9	0	0	**24**
Diptera	Culicidae	1	0	1	0	0	0	**1**
Ephemeroptera	Baetidae	5	11	13	6	22	47	**99**
Hemiptera	Corixidae	2	0	2	0	0	0	**2**
Hemiptera	Hemiptera	2	11	0	4	15	58	**88**
Hemiptera	Mesoveliidae	2	0	0	0	1	0	**1**
Hemiptera	Micronectidae	2	9	0	2	5	4	**20**
Hemiptera	Notonectidae	1	1	3	8	4	10	**26**
Odonata	Cordulid_Libellulid	4	4	0	0	0	2	**6**
Odonata	Hemicorduliidae	5	0	0	0	1	0	**1**
Odonata	Isostictidae	3	0	7	4	1	1	**13**
Gastropoda	Planorbidae	2	0	0	0	0	1	**1**
Total Bed Taxa			**139**	**95**	**112**	**426**	**421**	**1193**

Table E2 List of macroinvertebrate taxa collected and abundance per sample during the 2020 dry season aquatic ecology survey

Higher order	Taxon	SIGNAL 2 score	Upstream	Total
			B3	
			Bed 1	
Acarina	Acarina	6	1	**1**
Cladocera	Cladocera	5	1	**1**
Coleoptera	Dytiscidae	2	39	**39**
Coleoptera	Gyrinidae	4	8	**8**
Coleoptera	Hydraenidae	3	1	**1**
Diptera	Chironominae	3	5	**5**
Diptera	Tanypodinae	4	63	**63**
Hemiptera	Corixidae	2	1	**1**
Hemiptera	Hemiptera	2	6	**6**
Hemiptera	Micronectidae	2	1	**1**
Hemiptera	Notonectidae	1	15	**15**
Odonata	Hemicorduliidae	5	2	**2**
Odonata	Libellulidae	4	3	**3**
Total Bed Taxa				**146**

APPENDIX F

Quality Assurance

Wet Season Survey 2020

Surface water

Reproducibility

Replicate water quality data and corresponding precision estimates are provided in **Table F1**. All parameters reported valid reproducibility, indicating that the sampling and laboratory procedures were accurate and repeatable.

Table F1 Reproducibility of surface water quality assurance data.

Parameter		Unit	LOR	B7	QA	RPD (%)	Threshold (%)	Reproducibility
Sulfate		mg/L	0.5	5.9	77	1.681	0-50	OK
Fluoride		mg/L	0.1	0.2		0.000	NO THRESHOLD	OK
Hardness		mgCaCO3/L	1	79	11	0.000	NO THRESHOLD	OK
Arsenic	Total	mg/L	0.003	0.003	0.003	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.003	0.003	0.003	0.000	NO THRESHOLD	OK
Barium	Total	mg/L	0.005	0.048	0.046	4.255	NO THRESHOLD	OK
	Dissolved	mg/L	0.005	0.044	0.044	0.000	NO THRESHOLD	OK
Bismuth	Total	mg/L	0.001	0.001	0.001	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.001	0.001	0.001	0.000	NO THRESHOLD	OK
Chromium	Total	mg/L	0.0005	0.0005	0.0005	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.0005	0.0005	0.0005	0.000	NO THRESHOLD	OK
Cobalt	Total	mg/L	0.001	0.001	0.001	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.001	0.001	0.001	0.000	NO THRESHOLD	OK
Copper	Total	mg/L	0.001	0.012	0.011	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.001	0.009	0.009	0.000	NO THRESHOLD	OK
Molybdenum	Total	mg/L	0.0005	0.0011	0.0011	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.0005	0.0010	0.0011	0.000	NO THRESHOLD	OK
Nickel	Total	mg/L	0.001	0.001	0.001	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.001	0.001	0.001	0.000	NO THRESHOLD	OK
Selenium	Total	mg/L	0.002	0.002	0.002	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.002	0.002	0.002	0.000	NO THRESHOLD	OK
Uranium	Total	mg/L	0.001	0.001	0.001	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.001	0.001	0.001	0.000	NO THRESHOLD	OK

QA: quality assurance

RPD: relative per cent difference

LOR: limit of reporting

Contamination

The potential for water sample contamination due to field sampling techniques and/or sample handling was measured by analysis of a blank sample of deionised water taken in the field at the time of sampling. All parameters in the field blank sample reported concentrations less than the LOR (**Table F2**).

Table F2 Assessment of blank water sample results

Parameter		Unit	LOR	Blank	Pass
Sulfate		mg/L	1	<1	OK
Fluoride		mg/L	0.1	<0.1	OK
Hardness		mg CaCO3/L	0.5	<0.5	OK
Arsenic	Total	mg/L	0.003	<0.003	OK
	Dissolved	mg/L	0.003	<0.003	OK
Barium	Total	mg/L	0.005	<0.005	OK
	Dissolved	mg/L	0.005	<0.005	OK
Bismuth	Total	mg/L	0.001	<0.001	OK
	Dissolved	mg/L	0.001	<0.001	OK
Chromium	Total	mg/L	0.0005	<0.0005	OK
	Dissolved	mg/L	0.0005	<0.0005	OK
Cobalt	Total	mg/L	0.001	<0.001	OK
	Dissolved	mg/L	0.001	<0.001	OK
Copper	Total	mg/L	0.001	<0.001	OK
	Dissolved	mg/L	0.001	<0.001	OK
Molybdenum	Total	mg/L	0.0005	<0.0005	OK
	Dissolved	mg/L	0.0005	<0.0005	OK
Nickel	Total	mg/L	0.001	<0.001	OK
	Dissolved	mg/L	0.001	<0.001	OK
Selenium	Total	mg/L	0.002	<0.002	OK
	Dissolved	mg/L	0.002	<0.002	OK
Uranium	Total	mg/L	0.001	<0.001	OK
	Dissolved	mg/L	0.001	<0.001	OK

LOR: limit of reporting

Stream sediments

Replicate sediment data and corresponding precision estimates are provided in **Table F3**. All parameters reported valid reproducibility, indicating that the sampling and laboratory procedures were accurate and repeatable.

Table F3 Reproducibility of stream sediment quality assurance data

Parameter	Fraction	Unit	LOR	B7	QA	RPD (%)	Threshold (%)	Reproducibility
Arsenic	Whole	mg/kg	0.5	3.5	3.6	2.817	NO THRESHOLD	OK
	Fine	mg/kg	0.5	4.3	4.7	0.000	NO THRESHOLD	OK
Barium	Whole	mg/kg	0.5	43	44	2.299	0-20	OK
	Fine	mg/kg	0.5	150	150	0.000	NO THRESHOLD	OK
Bismuth	Whole	mg/kg	0.5	0.5	0.7	33.333	NO THRESHOLD	OK
	Fine	mg/kg	0.5	0.5	0.5	0.000	NO THRESHOLD	OK
Chromium	Whole	mg/kg	0.5	16	16	0.000	NO THRESHOLD	OK
	Fine	mg/kg	0.5	35	35	0.000	NO THRESHOLD	OK
Cobalt	Whole	mg/kg	0.5	17	15	12.500	0-20	OK
	Fine	mg/kg	0.5	26	26	0.000	NO THRESHOLD	OK
Copper	Whole	mg/kg	0.5	37	38	2.667	0-20	OK
	Fine	mg/kg	0.5	240	260	0.000	NO THRESHOLD	OK
Molybdenum	Whole	mg/kg	0.5	0.5	0.6	18.182	NO THRESHOLD	OK
	Fine	mg/kg	0.5	0.6	0.6	0.000	NO THRESHOLD	OK
Nickel	Whole	mg/kg	0.5	12	12	0.000	NO THRESHOLD	OK
	Fine	mg/kg	0.5	28	28	0.000	NO THRESHOLD	OK
Selenium	Whole	mg/kg	1	1	1	0.000	NO THRESHOLD	OK
	Fine	mg/kg	1	1	1	0.000	NO THRESHOLD	OK
Uranium	Whole	mg/kg	0.1	0.6	0.6	0.000	NO THRESHOLD	OK
	Fine	mg/kg	0.1	1.2	1.2	0.000	NO THRESHOLD	OK

Note: fine fraction refers to silt and clay (<63µm) and whole fraction refers to all sediment <2mm.

QA: quality assurance

RPD: relative per cent difference

LOR: limit of reporting

Aquatic macroinvertebrates

Site B7 was nominated as the quality assurance sample site and all bed samples from this site were tested for live picking error. Analyses of the residual samples indicated that one taxon from Bed 1 was missed (**Table F4**). This taxon was Acarina, which is not a sensitive or PET taxon and thus unlikely to have a significant impact on results.

Table F4 Live picking error data at the residual sample site B7

Site	Sample	Taxa collected	Taxa missed	Percentage error
B7	Bed 1	14	1	7.14%
	Bed 2	15	0	0%

Information provided by Benthic Australia Pty Ltd

Dry Season 2020

Surface water

Reproducibility

Replicate water quality data and corresponding precision estimates are provided in **Table F5**. All parameters reported valid reproducibility, indicating that the sampling and laboratory procedures were accurate and repeatable.

Table F5 Reproducibility of surface water quality assurance data.

Parameter		Unit	LOR	B3	QA	RPD (%)	Threshold (%)	Reproducibility
Sulfate		mg/L	0.5	3.5	3.6	2.817	NO THRESHOLD	OK
Fluoride		mg/L	0.1	0.2	0.2	0.000	NO THRESHOLD	OK
Hardness		mgCaCO3/L	1	100	100	0.000	NO THRESHOLD	OK
Arsenic	Total	mg/L	0.003	0.004	0.004	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.003	0.003	0.003	0.000	NO THRESHOLD	OK
Barium	Total	mg/L	0.005	0.26	0.26	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.005	0.088	0.080	9.524	0-50	OK
Bismuth	Total	mg/L	1	1	1	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	1	1	1	0.000	NO THRESHOLD	OK
Chromium	Total	mg/L	0.0005	0.0005	0.0005	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.0005	0.0005	0.0005	0.000	NO THRESHOLD	OK
Cobalt	Total	mg/L	0.001	0.006	0.006	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.001	0.002	0.002	0.000	NO THRESHOLD	OK
Copper	Total	mg/L	0.001	0.006	0.007	15.385	NO THRESHOLD	OK
	Dissolved	mg/L	0.001	0.003	0.003	0.000	NO THRESHOLD	OK
Molybdenum	Total	mg/L	0.0005	0.0009	0.0009	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.0005	0.0012	0.0012	0.000	NO THRESHOLD	OK
Nickel	Total	mg/L	0.001	0.002	0.002	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.001	0.001	0.001	0.000	NO THRESHOLD	OK
Selenium	Total	mg/L	0.002	0.002	0.002	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.002	0.003	0.003	0.000	NO THRESHOLD	OK
Uranium	Total	mg/L	0.001	0.001	0.001	0.000	NO THRESHOLD	OK
	Dissolved	mg/L	0.001	0.001	0.001	0.000	NO THRESHOLD	OK

QA: quality assurance

RPD: relative per cent difference

LOR: limit of reporting

Contamination

The potential for water sample contamination due to field sampling techniques and/or sample handling was measured by analysis of a blank sample of deionised water taken in the field at the time of sampling. All parameters in the field blank sample reported concentrations less than the LOR (**Table F6**).

Table F6 Assessment of blank water sample results

Parameter		Unit	LOR	Blank	Pass
Sulfate		mg/L	0.5	<0.5	OK
Fluoride		mg/L	0.1	<0.1	OK
Hardness		mg CaCO3/L	1	<1	OK
Arsenic	Total	mg/L	0.003	<0.003	OK
	Dissolved	mg/L	0.003	<0.003	OK
Barium	Total	mg/L	0.005	<0.005	OK
	Dissolved	mg/L	0.005	<0.005	OK
Bismuth	Total	mg/L	1	<1	OK
	Dissolved	mg/L	1	<1	OK
Chromium	Total	mg/L	0.0005	<0.0005	OK
	Dissolved	mg/L	0.0005	<0.0005	OK
Cobalt	Total	mg/L	0.001	<0.001	OK
	Dissolved	mg/L	0.001	<0.001	OK
Copper	Total	mg/L	0.001	<0.001	OK
	Dissolved	mg/L	0.001	<0.001	OK
Molybdenum	Total	mg/L	0.0005	<0.0005	OK
	Dissolved	mg/L	0.0005	<0.0005	OK
Nickel	Total	mg/L	0.001	<0.001	OK
	Dissolved	mg/L	0.001	<0.001	OK
Selenium	Total	mg/L	0.002	<0.002	OK
	Dissolved	mg/L	0.002	<0.002	OK
Uranium	Total	mg/L	0.001	<0.001	OK
	Dissolved	mg/L	0.001	<0.001	OK

LOR: limit of reporting

Stream sediments

Replicate sediment data and corresponding precision estimates are provided in **Table F7**. All parameters reported valid reproducibility, indicating that the sampling and laboratory procedures were accurate and repeatable.

Table F7 Reproducibility of stream sediment quality assurance data

Parameter	Fraction	Unit	LOR	B3	QA	RPD (%)	Threshold (%)	Reproducibility
Arsenic	Whole	mg/kg	0.5	3.1	2.9	6.667	NO THRESHOLD	OK
	Fine	mg/kg	0.5	6.1	7.0	13.740	0-50	OK
Barium	Whole	mg/kg	0.5	44	42	4.651	0-20	OK
	Fine	mg/kg	0.5	190	200	5.128	0-20	OK
Bismuth	Whole	mg/kg	3	3	3	0.000	NO THRESHOLD	OK
	Fine	mg/kg	3	3	3	0.000	NO THRESHOLD	OK
Chromium	Whole	mg/kg	0.5	15	14	6.897	0-20	OK
	Fine	mg/kg	0.5	39	39	0.000	NO THRESHOLD	OK
Cobalt	Whole	mg/kg	0.5	14	14	0.000	NO THRESHOLD	OK
	Fine	mg/kg	0.5	35	37	5.556	0-20	OK
Copper	Whole	mg/kg	0.5	32	31	3.175	0-20	OK
	Fine	mg/kg	0.5	170	160	6.061	0-20	OK
Molybdenum	Whole	mg/kg	1	1	1	0.000	NO THRESHOLD	OK
	Fine	mg/kg	1	1	1	0.000	NO THRESHOLD	OK
Nickel	Whole	mg/kg	0.5	11	11	0.000	NO THRESHOLD	OK
	Fine	mg/kg	0.5	31	31	0.000	NO THRESHOLD	OK
Selenium	Whole	mg/kg	3	3	3	0.000	NO THRESHOLD	OK
	Fine	mg/kg	3	3	3	0.000	NO THRESHOLD	OK
Uranium	Whole	mg/kg	0.1	0.6	0.6	0.000	NO THRESHOLD	OK
	Fine	mg/kg	0.1	1.1	1.1	0.000	NO THRESHOLD	OK

Note: fine fraction refers to silt and clay (<63µm) and whole fraction refers to all sediment <2mm.

QA: quality assurance

RPD: relative per cent difference

LOR: limit of reporting

Aquatic macroinvertebrates

Site B3 was nominated as the quality assurance sample site and all bed samples from this site were tested for live picking error. Analyses of the residual samples indicated that no taxon were missed (**Table F8**).

Table F8 Live picking error data at the residual sample site B3

Site	Sample	Taxa collected	Taxa missed	Percentage error
B3	Bed 1	13	0	0%

Information provided by Benthic Australia Pty Ltd

APPENDIX G

SGS Chain of Custody

source: Cairns_20200826121136662.pdf page: 1 SGS Ref: CE147942_COC

SGS EHS Cairns COC

CE147942

CHAIN OF CUSTODY & ANALYSIS REQUEST

Job Reference Number: CE147942

(SGS use only)

		Sample Date	Matrix: SOIL	Matrix: WATER	Matrix: OTHER		Preservation Method: NONE	Preservation Method: ICE	Preservation Method: ACID	Preservation Method: OTHER		Analysis Required: Particle Size	As, Ba, Bi,	Co, Cr, Cu,	Mo, Ni, Se, U.	Z.				Total organic carbon		Comments:
1	QA	23-08-2020	X				X					X	X	X	X	X				X		PSD Fractions: 2.00mm, 600µm, 300µm, 212µm, 63µm Please perform metals analysis on 63µm and <2mm fraction for all sample.
2	B1US	23-08-2020	X				X					X	X	X	X	X				X		
3	B1	23-08-2020	X				X					X	X	X	X	X				X		
4	B2	23-08-2020	X				X					X	X	X	X	X				X		
5	B3	23-08-2020	X				X					X	X	X	X	X				X		
6	B4	23-08-2020	X				X					X	X	X	X	X				X		
7	B5	23-08-2020	X				X					X	X	X	X	X				X		
8	B6	23-08-2020	X				X					X	X	X	X	X				X		
9	B7	23-08-2020	X				X					X	X	X	X	X				X		
~~10~~	~~B8~~	~~23-08-2020~~	~~X~~				~~X~~					~~X~~	~~X~~	~~X~~	~~X~~	~~X~~				~~X~~		
11	B9	23-08-2020	X				X					X	X	X	X	X				X		
12	BASW01	23-08-2020	X				X					X	X	X	X	X				X		
13	BASW02	23-08-2020	X				X					X	X	X	X	X				X		
14	BASW03	23-08-2020	X				X					X	X	X	X	X				X		

Company Name: SLR Consulting
Address: 12 Cannan Street, South Townsville, QLD 4810
Contact Name: Caitlin Cross, Matthew McIntosh
Email address: APAC_NorthEcologyData@slrconsulting.com; ccross@slrconsulting.com
Telephone: 47228000 **Facsimile:**

Client Order Number:
Project Name: Barbara REMP DS 2020
Project Number: 623.20018.20211
Results Required By:

Laboratory Contact: Cameron Talbot
Total Number of Containers/Bottles: 13x soil
Total Number of Samples/Sites:

Relinquished by: **Date:** **Time:** **Received by:** **Date:** 26/8/2020 **Time:** 11:30a

Relinquished by: **Date:** **Time:** **Received by:** **Date:** **Time:**

* Circle whichever is applicable

Sample Cooler Sealed: YES/NO*	Samples Intact: YES/NO*	Correct Sample Bottles Used: YES/NO*	Temperature: AMBIENT/CHILLED*

CHAIN OF CUSTODY & ANALYSIS REQUEST

Job Reference Number: CE147942A
(SGS use only)

Laboratory ID	Client SAMPLE ID	Sample Date	Matrix: SOIL	Matrix: WATER	Matrix: OTHER		Preservation Method: NONE	Preservation Method: ICE	Preservation Method: ACID	Preservation Method: OTHER		Analysis Required: Total Hardness	Total organic carbon	Major ions	Tot & Diss-Al	As, Ba, Bi,	Co, Cr, Cu,	Mo, Ni, Se, U.		SO4, Fluoride		Explosive suite	Comments:
1	QA			X				X				X	X	X	X	X	X	X		X			
2	Blank			X				X				X	X	X	X	X	X	X		X			
3	B1US																						
4	~~B1~~																						
5	~~B2~~																						
6	B3			X				X				X	X	X	X	X	X	X		X			Metals for both unfiltered and filtered samples
7	~~B4~~																						
8	~~B5~~																						
9	~~B6~~																						
10	~~B7~~																						
11	~~B8~~																						
12	~~B9~~																						

Company Name: SLR Consulting
Address: 12 Cannan Street, South Townsville, QLD 4810
Contact Name: Caitlin Cross
Email address: APAC_NorthEcologyData@slrconsulting.com; ccross@slrconsulting.com
Telephone: 47228000 **Facsimile:**

Client Order Number:
Project Name: Barbara REMP DS 2020
Project Number: 623.20018.20211
Results Required By:

Laboratory Contact: Cameron Talbot
Total Number of Containers/Bottles: 3x500NP 6x125AW
Total Number of Samples/Sites:

Relinquished by: **Date:** **Time:** **Received by:** **Date:** 26/8/2020 **Time:** 11:30a

Relinquished by: **Date:** **Time:** **Received by:** **Date:** **Time:**

* Circle whichever is applicable

Sample Cooler Sealed: YES/NO*	Samples Intact: YES/NO*	Correct Sample Bottles Used: YES/NO*	Temperature: AMBIENT/CHILLED*

Comments including subcontracting details:

Please provide client with details X
Consent given for subcontracting

source: MFP_M630_SR20200306125716.pdf page: 1 SGS Ref: CE144943_COC

CHAIN OF CUSTODY & ANALYSIS REQUEST

SGS Cairns Environmental

CE144943 COC
Received: 06 – Mar – 2020

Job Reference Number: .....
(SGS use only)

		le Date	Matrix: SOIL	Matrix: WATER	Matrix: OTHER		Preservation Method: NONE	ICE	ACID	OTHER		Analysis Required: Particle Size ✓	As, Ba, Bi, ✓	Co, Cr, Cu, ✓	Mo, Ni, Se, U. ✓	Z. ✓				Total organic carbon ✓		Comments:
1	QA	3/3/20	X				X					X	X	X	X	X				X		PSD Fractions: 2.00mm, 600µm, 300µm, 212µm, 63µm Please perform metals analysis on 63µm and <2mm fraction for all sample.
2	B1US	4/3/20	X				X					X	X	X	X	X				X		
3	B1	4/3/20	X				X					X	X	X	X	X				X		
4	B2	4/3/20	X				X					X	X	X	X	X				X		
5	B3	3/3/20	X				X					X	X	X	X	X				X		
6	B4	3/3/20	X				X					X	X	X	X	X				X		
7	B5	4/3/20	X				X					X	X	X	X	X				X		
8	B6	3/3/20	X				X					X	X	X	X	X				X		
9	B7	3/3/20	X				X					X	X	X	X	X				X		
~~10~~	~~B8~~		~~X~~				~~X~~					~~X~~	~~X~~	~~X~~	~~X~~	~~X~~				~~X~~		
10	B9	4/3/20.	X				X					X	X	X	X	X				X		

Company Name: SLR Consulting
Address: 12 Cannan Street, South Townsville, QLD 4810
Contact Name: Terri Jones
Email address: APAC_NorthEcologyData@slrconsulting.com; tcjones@slrconsulting.com
Telephone: 47228000 **Facsimile:** .....

Client Order Number: .....
Project Name: Barbara REMP WS 2020
Project Number: 623.20018.0040
Results Required By: .....

Laboratory Contact: Cameron Talbot
Total Number of Containers/Bottles: 10
10XSOIL.
Total Number of Samples/Sites: 10

Relinquished by: Matt M Intosh **Date:** 5/3/20. **Time:** ..... **Received by:** J.NICOL **Date:** 5 MAR 2020 **Time:** 14:35

Relinquished by: ..... **Date:** ..... **Time:** ..... **Received by:** DH **Date:** 6/3/20 **Time:** 11AM.

* Circle whichever is applicable

Sample Cooler Sealed: YES/NO*	Samples Intact: YES/NO*	Correct Sample Bottles Used: YES/NO*	Temperature: AMBIENT/CHILLED*

Comments including subcontracting details:

Please provide client with details X
Consent given for subcontracting

source: MFP_M630_SR20200306143125.pdf page: 1 SGS Ref: CE144955_COC

SGS Cairns Environmental

CE144955 COC
Received: 06 – Mar – 2020

F CUSTODY & ANALYSIS REQUEST

Job Reference Number: .....
(SGS use only)

	SAMPLE ID	Sample Date	Matrix: SOIL	Matrix: WATER	Matrix: OTHER		Preservation Method: NONE	Preservation Method: ICE	Preservation Method: ACID	Preservation Method: OTHER		Analysis Required: Total Hardness	Total organic carbon	Major ions	Tot & Diss-Al	As, Ba, Bi,	Co, Cr, Cu,	Mo, Ni, Se, U.		SO4, Fluoride			Comments:
1	QA	3/3/20		X				X				X	X	X	X	X	X	X		X			
2	Blank	5/3/20		X				X				X	X	X	X	X	X	X		X			
~~3~~	~~B1US~~	~~[illegible]~~																					
~~4~~	~~B1~~																						
~~5~~	~~B2~~																						
6	B3	3/3/20		X				X				X	X	X	X	X	X	X	X	X			Metals for both unfiltered and filtered samples
~~7~~	~~B4~~																						
~~8~~	~~B5~~																						
9	B6	3/3/20		X				X				X	X	X	X	X	X	X	X	X			
10	B7	3/3/20		X				X				X	X	X	X	X	X	X	X	X			
~~11~~	~~B8~~																						
12	B9	4/3/20		X				X				X	X	X	X	X	X	X	X	X			

Company Name: SLR Consulting
Address: 12 Cannan Street, South Townsville, QLD 4810
Contact Name: Terri Jones
Email address: APAC_NorthEcologyData@slrconsulting.com; tcjones@slrconsulting.com
Telephone: 47228000 **Facsimile:**

Client Order Number:
Project Name: Barbara REMP WS 2020
Project Number: 623.20018.0040
Results Required By:

Laboratory Contact: Cameron Talbot
6x500NP
Total Number of Containers/Bottles: 18.
6x125AW T
Total Number of Samples/Sites: 6
6x125AW F.

Relinquished by: Matt McIntosh **Date:** 5/3/20. **Time:** **Received by:** J. NICOL **Date:** 5 MAR 2020 **Time:** 14:35

Relinquished by: **Date:** **Time:** **Received by:** **Date:** **Time:**

* Circle whichever is applicable

Sample Cooler Sealed: YES/NO*	Samples Intact: YES/NO*	Correct Sample Bottles Used: YES/NO*	Temperature: AMBIENT/CHILLED*

Comments including subcontracting details:

Please provide client with details X
Consent given for subcontracting

APPENDIX H

SGS Laboratory Receipts

SAMPLE RECEIPT ADVICE

CE147942

CLIENT DETAILS

Contact	Matthew McIntosh
Client	SLR CONSULTING AUSTRALIA PTY LTD
Address	LEVEL 1, 514 STURT STREET TOWNSVILLE QLD 4810
Telephone	0400 985 407
Facsimile	07 4722 8001
Email	mmcintosh@slrconsulting.com
Project	**623.20018.20211 Barbara REMP DS 2020**
Order Number	(Not specified)
Samples	39

LABORATORY DETAILS

Manager	Anthony Nilsson
Laboratory	SGS Cairns Environmental
Address	Unit 2, 58 Comport St Portsmith QLD 4870
Telephone	+61 07 4035 5111
Facsimile	+61 07 4035 5122
Email	AU.Environmental.Cairns@sgs.com
Samples Received	Wed 26/8/2020
Report Due	Fri 11/9/2020
SGS Reference	**CE147942**

SUBMISSION DETAILS

This is to confirm that 39 samples were received on Wednesday 26/8/2020. Results are expected to be ready by COB Friday 11/9/2020. Please quote SGS reference CE147942 when making enquiries. Refer below for details relating to sample integrity upon receipt.

Samples clearly labelled	Yes	Complete documentation received	Yes
Sample container provider	SGS	Sample cooling method	None
Samples received in correct containers	Yes	Sample counts by matrix	13 Soil
Date documentation received	26/8/2020	Type of documentation received	COC
Number of eskies/boxes received	1	Samples received in good order	Yes
Samples received without headspace	Yes	Sample temperature upon receipt	Ambient
Sufficient sample for analysis	Yes	Turnaround time requested	Standard

Unless otherwise instructed, water and bulk samples will be held for one month from date of report, and soil samples will be held for two months.

COMMENTS

SAMPLE BASW02 IS LABELLED BASW05 ON BAGS
SAMPLE BASW03 IS LABELLED BASW09 ON BAGS

TOC DONE ON ORIGINAL SAMPLE.

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SAMPLE RECEIPT ADVICE

CE147942

CLIENT DETAILS

Client SLR CONSULTING AUSTRALIA PTY LTD

Project 623.20018.20211 Barbara REMP DS 2020

SUMMARY OF ANALYSIS

No.	Sample ID	Moisture Content	Particle sizing of soils by sieving	Total Organic Carbon by Heanes Oxidation	Total Recoverable Elements in Soil/Waste	Total Recoverable Metals in Soil by ICPMS
001	QA	1	10	2	-	-
002	B1US	1	10	2	-	-
003	B1	1	10	2	-	-
004	B2	1	10	2	-	-
005	B3	1	10	2	-	-
006	B4	1	10	2	-	-
007	B5	1	10	2	-	-
008	B6	1	10	2	-	-
009	B7	1	10	2	-	-
010	B9	1	10	2	-	-
011	BASW01	1	10	2	-	-
012	BASW05	1	10	2	-	-
013	BASW09	1	10	2	-	-
014	QA_<2mm	-	-	-	10	1
015	B1US_<2mm	-	-	-	10	1
016	B1_<2mm	-	-	-	10	1
017	B2_<2mm	-	-	-	10	1
018	B3_<2mm	-	-	-	10	1
019	B4_<2mm	-	-	-	10	1
020	B5_<2mm	-	-	-	10	1
021	B6_<2mm	-	-	-	10	1
022	B7_<2mm	-	-	-	10	1
023	B9_<2mm	-	-	-	10	1
024	BASW01_<2mm	-	-	-	10	1

CONTINUED OVERLEAF

The above table represents SGS' interpretation of the client-supplied Chain Of Custody document.
The numbers shown in the table indicate the number of results requested in each package.
Please indicate as soon as possible should your request differ from these details .
Testing as per this table shall commence immediately unless the client intervenes with a correction .

SAMPLE RECEIPT ADVICE

CE147942

CLIENT DETAILS

Client SLR CONSULTING AUSTRALIA PTY LTD

Project 623.20018.20211 Barbara REMP DS 2020

SUMMARY OF ANALYSIS

No.	Sample ID	Total Recoverable Elements in Soil/Waste	Total Recoverable Metals in Soil by ICPMS
025	BASW05_<2mm	10	1
026	BASW09_<2mm	10	1
027	QA_<63um	10	1
028	B1US_<63um	10	1
029	B1_<63um	10	1
030	B2_<63um	10	1
031	B3_<63um	10	1
032	B4_<63um	10	1
033	B5_<63um	10	1
034	B6_<63um	10	1
035	B7_<63um	10	1
036	B9_<63um	10	1
037	BASW01_<63um	10	1
038	BASW05_<63um	10	1
039	BASW08_<63um	10	1

The above table represents SGS' interpretation of the client-supplied Chain Of Custody document.
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Please indicate as soon as possible should your request differ from these details .
Testing as per this table shall commence immediately unless the client intervenes with a correction .

SAMPLE RECEIPT ADVICE

CE144943

CLIENT DETAILS

Contact	Terri Jones
Client	SLR CONSULTING AUSTRALIA PTY LTD
Address	LEVEL 1, 514 STURT STREET TOWNSVILLE QLD 4810
Telephone	07 4722 8000
Facsimile	07 4722 8001
Email	tcjones@slrconsulting.com
Project	**623.20018.0040 Barbara REMP WS 2020**
Order Number	**7535**
Samples	30

LABORATORY DETAILS

Manager	Anthony Nilsson
Laboratory	SGS Cairns Environmental
Address	Unit 2, 58 Comport St Portsmith QLD 4870
Telephone	+61 07 4035 5111
Facsimile	+61 07 4035 5122
Email	AU.Environmental.Cairns@sgs.com
Samples Received	Fri 6/3/2020
Report Due	Fri 20/3/2020
SGS Reference	**CE144943**

SUBMISSION DETAILS

This is to confirm that 30 samples were received on Friday 6/3/2020. Results are expected to be ready by COB Friday 20/3/2020. Please quote SGS reference CE144943 when making enquiries. Refer below for details relating to sample integrity upon receipt.

Samples clearly labelled	Yes	Complete documentation received	Yes
Sample container provider	SGS	Sample cooling method	Ice Bricks
Samples received in correct containers	Yes	Sample counts by matrix	10x Sediment
Date documentation received	6/3/2020	Type of documentation received	COC
Number of eskies/boxes received	1	Samples received in good order	Yes
Samples received without headspace	Yes	Sample temperature upon receipt	Chilled
Sufficient sample for analysis	Yes	Turnaround time requested	Standard

Unless otherwise instructed, water and bulk samples will be held for one month from date of report, and soil samples will be held for two months.

COMMENTS

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SAMPLE RECEIPT ADVICE

CE144943

CLIENT DETAILS

Client SLR CONSULTING AUSTRALIA PTY LTD

Project 623.20018.0040 Barbara REMP WS 2020

SUMMARY OF ANALYSIS

No.	Sample ID	Moisture Content	Particle sizing of soils by sieving	Total Organic Carbon by Heanes Oxidation	Total Recoverable Elements in Soil/Waste	Total Recoverable Metals in Soil by ICPMS
001	QA	1	10	2	-	-
002	B1US	1	10	2	-	-
003	B1	1	10	2	-	-
004	B2	1	10	2	-	-
005	B3	1	10	2	-	-
006	B4	1	10	2	-	-
007	B5	1	10	2	-	-
008	B6	1	10	2	-	-
009	B7	1	10	2	-	-
010	B9	1	10	2	-	-
011	QA_<2mm	-	-	-	10	2
012	B1US_<2mm	-	-	-	10	2
013	B1_<2mm	-	-	-	10	2
014	B2_<2mm	-	-	-	10	2
015	B3_<2mm	-	-	-	10	2
016	B4_<2mm	-	-	-	10	2
017	B5_<2mm	-	-	-	10	2
018	B6_<2mm	-	-	-	10	2
019	B7_<2mm	-	-	-	10	2
020	B9_<2mm	-	-	-	10	2
021	QA_<63um	-	-	-	10	2
022	B1US_<63um	-	-	-	10	2
023	B1_<63um	-	-	-	10	2
024	B2_<63um	-	-	-	10	2

CONTINUED OVERLEAF

The above table represents SGS' interpretation of the client-supplied Chain Of Custody document.
The numbers shown in the table indicate the number of results requested in each package.
Please indicate as soon as possible should your request differ from these details .
Testing as per this table shall commence immediately unless the client intervenes with a correction .

SAMPLE RECEIPT ADVICE

CE144943

CLIENT DETAILS

Client SLR CONSULTING AUSTRALIA PTY LTD

Project 623.20018.0040 Barbara REMP WS 2020

SUMMARY OF ANALYSIS

No.	Sample ID	Total Recoverable Elements in Soil/Waste	Total Recoverable Metals in Soil by ICPMS
025	B3_<63um	10	2
026	B4_<63um	10	2
027	B5_<63um	10	2
028	B6_<63um	10	2
029	B7_<63um	10	2
030	B9_<63um	10	2

The above table represents SGS' interpretation of the client-supplied Chain Of Custody document.
The numbers shown in the table indicate the number of results requested in each package.
Please indicate as soon as possible should your request differ from these details .
Testing as per this table shall commence immediately unless the client intervenes with a correction .

SAMPLE RECEIPT ADVICE

CE144955

CLIENT DETAILS

Contact	Terri Jones
Client	SLR CONSULTING AUSTRALIA PTY LTD
Address	LEVEL 1, 514 STURT STREET TOWNSVILLE QLD 4810
Telephone	07 4722 8000
Facsimile	07 4722 8001
Email	tcjones@slrconsulting.com
Project	**Barbara REMP WS 2020 623.20018.0040**
Order Number	(Not specified)
Samples	6

LABORATORY DETAILS

Manager	Anthony Nilsson
Laboratory	SGS Cairns Environmental
Address	Unit 2, 58 Comport St Portsmith QLD 4870
Telephone	+61 07 4035 5111
Facsimile	+61 07 4035 5122
Email	AU.Environmental.Cairns@sgs.com
Samples Received	Fri 6/3/2020
Report Due	Tue 17/3/2020
SGS Reference	**CE144955**

SUBMISSION DETAILS

This is to confirm that 6 samples were received on Friday 6/3/2020. Results are expected to be ready by COB Tuesday 17/3/2020. Please quote SGS reference CE144955 when making enquiries. Refer below for details relating to sample integrity upon receipt.

Samples clearly labelled	Yes	Complete documentation received	Yes
Sample container provider	SGS	Sample cooling method	Ice Bricks
Samples received in correct containers	Yes	Sample counts by matrix	6 Water
Date documentation received	6/3/2020	Type of documentation received	COC
Number of eskies/boxes received	1	Samples received in good order	Yes
Samples received without headspace	Yes	Sample temperature upon receipt	Chilled
Sufficient sample for analysis	Yes	Turnaround time requested	Standard

Unless otherwise instructed, water and bulk samples will be held for one month from date of report, and soil samples will be held for two months.

COMMENTS

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SAMPLE RECEIPT ADVICE

CE144955

CLIENT DETAILS

Client SLR CONSULTING AUSTRALIA PTY LTD

Project Barbara REMP WS 2020 623.20018.0040

SUMMARY OF ANALYSIS

No.	Sample ID	Alkalinity	Chloride by Discrete Analyser in Water	Fluoride by Ion Selective Electrode in Water	Forms of Carbon	Metals in Water (Total) by ICPOES	Metals in Water (Dissolved) by ICPOES	Metals in Water (Dissolved) by	Metals in Water (Total) by ICPOES-USN
001	QA	4	1	1	1	2	12	7	7
002	Blank	4	1	1	1	2	12	7	7
003	B3	4	1	1	1	2	12	7	7
004	B6	4	1	1	1	2	12	7	7
005	B7	4	1	1	1	2	12	7	7
006	B9	4	1	1	1	2	12	7	7

CONTINUED OVERLEAF

The above table represents SGS' interpretation of the client-supplied Chain Of Custody document.
The numbers shown in the table indicate the number of results requested in each package.
Please indicate as soon as possible should your request differ from these details .
Testing as per this table shall commence immediately unless the client intervenes with a correction .

SAMPLE RECEIPT ADVICE

CE144955

CLIENT DETAILS

Client SLR CONSULTING AUSTRALIA PTY LTD

Project Barbara REMP WS 2020 623.20018.0040

SUMMARY OF ANALYSIS

No.	Sample ID	Calculation of Anion-Cation Balance	Trace Metals (Dissolved) in Water by ICPMS	Trace Metals (Total) in Water by ICPMS
001	QA	3	2	2
002	Blank	3	2	2
003	B3	3	2	2
004	B6	3	2	2
005	B7	3	2	2
006	B9	3	2	2

The above table represents SGS' interpretation of the client-supplied Chain Of Custody document.
The numbers shown in the table indicate the number of results requested in each package.
Please indicate as soon as possible should your request differ from these details .
Testing as per this table shall commence immediately unless the client intervenes with a correction .

APPENDIX I

SGS Laboratory Reports

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Matthew McIntosh	Manager	Anthony Nilsson
Client	SLR CONSULTING AUSTRALIA PTY LTD	Laboratory	SGS Cairns Environmental
Address	LEVEL 1, 514 STURT STREET TOWNSVILLE QLD 4810	Address	Unit 2, 58 Comport St Portsmith QLD 4870
Telephone	0400 985 407	Telephone	+61 07 4035 5111
Facsimile	07 4722 8001	Facsimile	+61 07 4035 5122
Email	mmcintosh@slrconsulting.com	Email	AU.Environmental.Cairns@sgs.com
Project	**623.20018 20211 Barbara REMP DS 2020**	SGS Reference	**CE147942A R0**
Order Number	(Not specified)	Date Received	27 Aug 2020
Samples	3	Date Reported	08 Sep 2020

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(3146/19038)

SIGNATORIES

Alyson BERGAMO
Senior Laboratory Technician

Anthony NILSSON
Operations Manager

Jon Dicker
Manager Northern QLD

Maristela GANZAN
Metals Team Leader

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name	CE147942A.001 Water 23 Aug 2020 QA	CE147942A.002 Water Blank	CE147942A.003 Water 23 Aug 2020 B3
pH in water Method: AN101 Tested: 27/8/2020						
pH**	pH Units	0.1		7.9	6.5	7.8
Conductivity and TDS by Calculation - Water Method: AN106 Tested: 27/8/2020						
Conductivity @ 25 C	µS/cm	5		460	<5	450
Alkalinity Method: AN135 Tested: 27/8/2020						
Total Alkalinity as CaCO3	mg/L	5		210	<5	210
Bicarbonate Alkalinity as CaCO3	mg/L	5		210	<5	210
Carbonate Alkalinity as CaCO3	mg/L	5		<5	<5	<5
Hydroxide Alkalinity as CaCO3	mg/L	5		<5	<5	<5
Chloride by Discrete Analyser in Water Method: AN274 Tested: 28/8/2020						
Chloride, Cl	mg/L	1		20	<1	21
Fluoride by Ion Selective Electrode in Water Method: AN141 Tested: 27/8/2020						
Fluoride by ISE	mg/L	0.1		0.2	<0.1	0.2
Calculation of Anion-Cation Balance (SAR Calc) Method: AN121 Tested: 8/9/2020						
Sum of Cation Milliequivalents*	meq/L	-		4.38	0.001	4.41
Sum of Anion Milliequivalents*	meq/L	-		4.83	0.046	4.79
Anion-Cation Balance	%	-100		-4.9	-97	-4.1

Parameter	Units	LOR	CE147942A.001	CE147942A.002	CE147942A.003
		Sample Number	CE147942A.001	CE147942A.002	CE147942A.003
		Sample Matrix	Water	Water	Water
		Sample Date	23 Aug 2020	Blank	23 Aug 2020
		Sample Name	QA		B3
Forms of Carbon Method: AN190 Tested: 7/9/2020					
Total Organic Carbon as NPOC	mg/L	0.2	**55**	**1.0**	**54**
Metals in Water (Dissolved) by ICPOES Method: AN320 Tested: 3/9/2020					
Aluminium, Al	mg/L	0.005	**0.007**	<0.005	**0.008**
Barium, Ba	mg/L	0.005	**0.080**	<0.005	**0.088**
Calcium, Ca	mg/L	0.1	**21**	<0.1	**21**
Magnesium, Mg	mg/L	0.1	**12**	<0.1	**12**
Potassium, K	mg/L	0.1	**38**	<0.1	**38**
Sodium, Na	mg/L	0.5	**32**	<0.5	**33**
Sulfur asSulfate, SO4	mg/L	0.5	**3.6**	<0.5	**3.5**
Total Hardness by Calculation	mg CaCO3/L	1	**100**	<1	**100**
Metals in Water (Total) by ICPOES Method: AN022/AN320 Tested: 3/9/2020					
Total Aluminium	mg/L	0.005	**0.20**	<0.005	**0.22**
Total Barium	mg/L	0.005	**0.26**	<0.005	**0.26**
Metals in Water (Dissolved) by ICPOES-USN Method: AN320/AN322 Tested: 3/9/2020					
Arsenic, As	mg/L	0.003	<0.003	<0.003	<0.003
Chromium, Cr	mg/L	0.0005	<0.0005	<0.0005	<0.0005
Cobalt, Co	mg/L	0.001	**0.002**	<0.001	**0.002**
Copper, Cu	mg/L	0.001	**0.003**	<0.001	**0.003**
Molybdenum, Mo	mg/L	0.0005	**0.0012**	<0.0005	**0.0012**
Nickel, Ni	mg/L	0.001	**0.001**	<0.001	**0.001**
Selenium, Se	mg/L	0.002	**0.003**	<0.002	**0.003**
Metals in Water (Total) by ICPOES-USN Method: AN320/AN322 Tested: 3/9/2020					
Total Arsenic, As	mg/L	0.003	**0.004**	<0.003	**0.004**
Total Chromium, Cr	mg/L	0.0005	<0.0005	<0.0005	<0.0005
Total Cobalt, Co	mg/L	0.001	**0.006**	<0.001	**0.006**
Total Copper, Cu	mg/L	0.001	**0.007**	<0.001	**0.006**
Total Molybdenum, Mo	mg/L	0.0005	**0.0009**	<0.0005	**0.0009**
Total Nickel, Ni	mg/L	0.001	**0.002**	<0.001	**0.002**
Total Selenium, Se	mg/L	0.002	<0.002	<0.002	**0.002**
Trace Metals (Dissolved) in Water by ICPMS Method: AN318 Tested: 1/9/2020					
Bismuth, Bi	µg/L	1	<1	<1	<1
Uranium, U	µg/L	1	<1	<1	<1

Parameter	Units	LOR	CE147942A.001	CE147942A.002	CE147942A.003
		Sample Number	CE147942A.001	CE147942A.002	CE147942A.003
		Sample Matrix	Water	Water	Water
		Sample Date	23 Aug 2020	Blank	23 Aug 2020
		Sample Name	QA		B3
Trace Metals (Total) in Water by ICPMS Method: AN022/AN318 Tested: 1/9/2020					
Total Bismuth	µg/L	1	<1	<1	<1
Total Uranium	µg/L	1	<1	<1	<1

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Alkalinity Method: ME-(AU)-[ENV]AN135

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Alkalinity as CaCO3	LB081785	mg/L	5	<5	0 - 1%	107%
Bicarbonate Alkalinity as CaCO3	LB081785	mg/L	5	<5		
Carbonate Alkalinity as CaCO3	LB081785	mg/L	5	<5		
Hydroxide Alkalinity as CaCO3	LB081785	mg/L	5	<5		

Chloride by Discrete Analyser in Water Method: ME-(AU)-[ENV]AN274

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Chloride, Cl	LB081800	mg/L	1	<1	0 - 9%	109%

Conductivity and TDS by Calculation - Water Method: ME-(AU)-[ENV]AN106

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Conductivity @ 25 C	LB081785	µS/cm	5	<5	0 - 1%	99 - 100%

Fluoride by Ion Selective Electrode in Water Method: ME-(AU)-[ENV]AN141

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery	MS %Recovery
Fluoride by ISE	LB081785	mg/L	0.1	<0.1	106 - 108%	117%

Forms of Carbon Method: ME-(AU)-[ENV]AN190

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Organic Carbon as NPOC	LB082055	mg/L	0.2	<0.2	0%	96%

Metals in Water (Total) by ICPOES Method: ME-(AU)-[ENV]AN022/AN320

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Aluminium	LB081967	mg/L	0.005	<0.005	0 - 10%	106%
Total Barium	LB081967	mg/L	0.005	<0.005	0%	101%

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Metals in Water (Dissolved) by ICPOES Method: ME-(AU)-[ENV]AN320

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Aluminium, Al	LB081966	mg/L	0.005	<0.005	0%	104%	117%
Barium, Ba	LB081966	mg/L	0.005	<0.005	0 - 1%	97%	
Calcium, Ca	LB081966	mg/L	0.1	<0.1	0%	110%	110%
Magnesium, Mg	LB081966	mg/L	0.1	<0.1	0 - 1%	97%	112%
Potassium, K	LB081966	mg/L	0.1	<0.1	0 - 1%	99%	
Sodium, Na	LB081966	mg/L	0.5	<0.5	0 - 1%	101%	
Sulfur asSulfate, SO4	LB081966	mg/L	0.5	<0.5			
Total Hardness by Calculation	LB081966	mg CaCO3/L	1	<1			

Metals in Water (Dissolved) by ICPOES-USN Method: ME-(AU)-[ENV]AN320/AN322

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Arsenic, As	LB081970	mg/L	0.003	<0.003	1 - 2%	111%	105%
Chromium, Cr	LB081970	mg/L	0.0005	<0.0005	0%	105%	104%
Cobalt, Co	LB081970	mg/L	0.001	<0.001	0 - 5%	106%	103%
Copper, Cu	LB081970	mg/L	0.001	<0.001	0 - 1%	102%	120%
Molybdenum, Mo	LB081970	mg/L	0.0005	<0.0005	3 - 4%	103%	
Nickel, Ni	LB081970	mg/L	0.001	<0.001	0%	110%	103%
Selenium, Se	LB081970	mg/L	0.002	<0.002	15 - 17%	88%	

Metals in Water (Total) by ICPOES-USN Method: ME-(AU)-[ENV]AN320/AN322

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Total Arsenic, As	LB081972	mg/L	0.003	<0.003	3 - 7%	107%	108%
Total Chromium, Cr	LB081972	mg/L	0.0005	<0.0005	0%	105%	104%
Total Cobalt, Co	LB081972	mg/L	0.001	<0.001	1 - 3%	107%	105%
Total Copper, Cu	LB081972	mg/L	0.001	<0.001	0%	104%	122%
Total Molybdenum, Mo	LB081972	mg/L	0.0005	<0.0005	7 - 14%	105%	
Total Nickel, Ni	LB081972	mg/L	0.001	<0.001	0%	109%	101%
Total Selenium, Se	LB081972	mg/L	0.002	<0.002	0 - 7%	86%	

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

pH in water Method: ME-(AU)-[ENV]AN101

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
pH**	LB081785	pH Units	0.1	5.8 - 7.6	0 - 5%	101%	NA

Trace Metals (Dissolved) in Water by ICPMS Method: ME-(AU)-[ENV]AN318

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Bismuth, Bi	LB081900	µg/L	1	<1	0%	108%
Uranium, U	LB081900	µg/L	1	<1	0%	99%

Trace Metals (Total) in Water by ICPMS Method: ME-(AU)-[ENV]AN022/AN318

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Bismuth	LB081897	µg/L	1	<1	0%	108%
Total Uranium	LB081897	µg/L	1	<1	0%	99%

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN022/AN318	Following acid digestion of un filtered sample, determination of elements at trace level in waters by ICP-MS technique, referenced to USEPA 6020B and USEPA 200.8 (5.4).
AN022/AN320	Total (acid soluble) Metals by ICP-OES: Samples are digested in nitric or nitric and hydrochloric acids prior to analysis for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components.
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode (glass plus reference electrode) and is calibrated against 3 buffers purchased commercially. For soils, an extract with water is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Total Dissolved Salts can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. SGS use 0.6. Reference APHA 2510 B.
AN106	Salinity may be calculated in terms of NaCl from the sample conductivity. This assumes all soluble salts present, measured by the conductivity, are present as NaCl.
AN121	This method is used to calculation the balance of major Anions and Cations in water samples and converts major ion concentration to milliequivalents and then summed. Anions sum and Cation sum is calculated as a difference and expressed as a percentage.
AN135	Alkalinity (and forms of) by Titration: The sample is titrated with standard acid to pH 8.3 (P titre) and pH 4.5 (T titre) and permanent and/or total alkalinity calculated. The results are expressed as equivalents of calcium carbonate or recalculated as bicarbonate, carbonate and hydroxide. Reference APHA 2320. Internal Reference AN135
AN141	Determination of Fluoride by ISE: A fluoride ion selective electrode and reference electrode combination, in the presence of a pH/complexation buffer, is used to determine the fluoride concentration. The electrode millivolt response is measured logarithmically against fluoride concentration. Reference APHA F- C.
AN190	TOC and DOC in Water: A homogenised micro portion of sample is injected into a heated reaction chamber packed with an oxidative catalyst that converts organic carbon to carbon dioxide. The CO2 is measured using a non-dispersive infrared detector. The process is fully automated in a commercially available analyser. If required a sugar value can be calculated from the TOC result. Reference APHA 5310 B.
AN190	Chemical oxygen demand can be calculated/estimated based on the O2/C relation as 2.67*NPOC (TOC). This is an estimate only and the factor will vary with sample matrix so results should be interpreted with caution.
AN274	Chloride by Discrete Analyse: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Reference APHA 4500Cl-
AN318	Determination of elements at trace level in waters by ICP-MS technique,, referenced to USEPA 6020B and USEPA 200.8 (5.4).
AN320	Metals by ICP-OES: Samples are preserved with 10% nitric acid for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components .

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN320	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B.
AN320/AN322	ICP-OES (Ultrasonic Nebuliser): After preservation with 10% nitric acid, a wide range of metals and some non-metals in solution can be measured by ICP- Ultrasonic nebulisation. Solutions are aspirated using an ultrasonic nebuliser into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components.
AN320/AN322	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B
AN322	ICP-OES (Ultrasonic Nebuliser): After preservation with 10% nitric acid, a wide range of metals and some non-metals in solution can be measured by ICP- Ultrasonic nebulisation. Solutions are aspirated using an ultrasonic nebuliser into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components.
AN322	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B
Calculation	Free and Total Carbon Dioxide may be calculated using alkalinity forms only when the samples TDS is <500mg/L. If TDS is >500mg/L free or total carbon dioxide cannot be reported. APHA4500CO2 D.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
**	Indicative data, theoretical holding time exceeded.	QFL	QC result is below the lower tolerance
***	Indicative data, theoretical holding time exceeded and NATA accreditation does not cover the performance of this service.	-	The sample was not analysed for this analyte
		NVL	Not Validated

Unless it is reported that sampling has been performed by SGS, the samples have been analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC and MU criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here: www.sgs.com.au/en-gb/environment-health-and-safety.

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ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Terri Jones	Manager	Anthony Nilsson
Client	SLR CONSULTING AUSTRALIA PTY LTD	Laboratory	SGS Cairns Environmental
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Project	**Barbara REMP WS 2020 623.20018.0040**	SGS Reference	**CE144955 R0**
Order Number	(Not specified)	Date Received	06 Mar 2020
Samples	6	Date Reported	18 Mar 2020

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(3146).

SIGNATORIES

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Parameter	Units	LOR	CE144955.001	CE144955.002	CE144955.003	CE144955.004
		Sample Number	CE144955.001	CE144955.002	CE144955.003	CE144955.004
		Sample Matrix	Water	Water	Water	Water
		Sample Date	03 Mar 2020	05 Mar 2020	03 Mar 2020	03 Mar 2020
		Sample Name	QA	Blank	B3	B6
Alkalinity Method: AN135 Tested: 9/3/2020						
Total Alkalinity as CaCO3	mg/L	5	170	<5	69	150
Bicarbonate Alkalinity as CaCO3	mg/L	5	170	<5	69	150
Carbonate Alkalinity as CaCO3	mg/L	5	<5	<5	<5	<5
Hydroxide Alkalinity as CaCO3	mg/L	5	<5	<5	<5	<5
Chloride by Discrete Analyser in Water Method: AN274 Tested: 10/3/2020						
Chloride, Cl	mg/L	1	16	<1	6	12
Fluoride by Ion Selective Electrode in Water Method: AN141 Tested: 9/3/2020						
Fluoride by ISE	mg/L	0.1	0.3	<0.1	0.1	0.1
Forms of Carbon Method: AN190 Tested: 13/3/2020						
Total Organic Carbon as NPOC	mg/L	0.2	15	1.3	8.1	11
Metals in Water (Dissolved) by ICPOES Method: AN320 Tested: 12/3/2020						
Aluminium, Al	mg/L	0.02	<0.02	<0.02	<0.02	<0.02
Barium, Ba	mg/L	0.005	0.044	<0.005	0.020	0.022
Calcium, Ca	mg/L	0.2	18	<0.2	9.5	18
Magnesium, Mg	mg/L	0.1	8.1	<0.1	3.8	8.5
Potassium, K	mg/L	0.1	7.1	<0.1	4.4	5.3
Sodium, Na	mg/L	0.5	39	<0.5	14	29
Sulfur asSulfate, SO4	mg/L	0.5	6.0	<0.5	2.3	3.4
Sulfur, S	mg/L	0.1	2.0	<0.1	0.8	1.1
Total Hardness by Calculation	mg CaCO3/L	1	79	<1	39	79
Metals in Water (Total) by ICPOES Method: AN022/AN320 Tested: 12/3/2020						
Total Aluminium	mg/L	0.02	0.06	<0.02	0.03	<0.02
Total Barium	mg/L	0.005	0.046	<0.005	0.022	0.024

Parameter	Units	LOR	CE144955.001	CE144955.002	CE144955.003	CE144955.004
		Sample Number	CE144955.001	CE144955.002	CE144955.003	CE144955.004
		Sample Matrix	Water	Water	Water	Water
		Sample Date	03 Mar 2020	05 Mar 2020	03 Mar 2020	03 Mar 2020
		Sample Name	QA	Blank	B3	B6
Metals in Water (Dissolved) by ICPOES-USN Method: AN320/AN322 Tested: 12/3/2020						
Arsenic, As	mg/L	0.003	**0.003**	<0.003	<0.003	<0.003
Chromium, Cr	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cobalt, Co	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Copper, Cu	mg/L	0.001	**0.009**	<0.001	**0.003**	**0.001**
Molybdenum, Mo	mg/L	0.0005	**0.0011**	<0.0005	<0.0005	**0.0008**
Nickel, Ni	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Selenium, Se	mg/L	0.002	**0.002**	<0.002	<0.002	**0.003**
Metals in Water (Total) by ICPOES-USN Method: AN320/AN322 Tested: 12/3/2020						
Total Arsenic, As	mg/L	0.003	<0.003	<0.003	<0.003	<0.003
Total Chromium, Cr	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Total Cobalt, Co	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Total Copper, Cu	mg/L	0.001	**0.011**	<0.001	**0.003**	**0.001**
Total Molybdenum, Mo	mg/L	0.0005	**0.0011**	<0.0005	<0.0005	**0.0008**
Total Nickel, Ni	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Total Selenium, Se	mg/L	0.002	<0.002	<0.002	<0.002	<0.002
Trace Metals (Dissolved) in Water by ICPMS Method: AN318 Tested: 9/3/2020						
Bismuth, Bi	µg/L	1	<1	<1	<1	<1
Uranium, U	µg/L	1	<1	<1	<1	<1
Trace Metals (Total) in Water by ICPMS Method: AN022/AN318 Tested: 9/3/2020						
Total Bismuth	µg/L	1	<1	<1	<1	<1
Total Uranium	µg/L	1	<1	<1	<1	<1
Calculation of Anion-Cation Balance (SAR Calc) Method: AN121 Tested: 18/3/2020						
Sum of Cation Milliequivalents*	meq/L	-	**3.47**	**0.001**	**1.50**	**2.98**
Sum of Anion Milliequivalents*	meq/L	-	**3.95**	**0.045**	**1.61**	**3.43**
Anion-Cation Balance	%	-100	**-6.4**	-	**-3.5**	**-7.0**

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name	CE144955.005 Water 03 Mar 2020 B7	CE144955.006 Water 05 Mar 2020 B9
Alkalinity Method: AN135 Tested: 9/3/2020					
Total Alkalinity as CaCO3	mg/L	5		**170**	**190**
Bicarbonate Alkalinity as CaCO3	mg/L	5		**170**	**190**
Carbonate Alkalinity as CaCO3	mg/L	5		<5	<5
Hydroxide Alkalinity as CaCO3	mg/L	5		<5	<5
Chloride by Discrete Analyser in Water Method: AN274 Tested: 10/3/2020					
Chloride, Cl	mg/L	1		**15**	**14**
Fluoride by Ion Selective Electrode in Water Method: AN141 Tested: 9/3/2020					
Fluoride by ISE	mg/L	0.1		**0.2**	**0.1**
Forms of Carbon Method: AN190 Tested: 13/3/2020					
Total Organic Carbon as NPOC	mg/L	0.2		**15**	**16**
Metals in Water (Dissolved) by ICPOES Method: AN320 Tested: 12/3/2020					
Aluminium, Al	mg/L	0.02		<0.02	<0.02
Barium, Ba	mg/L	0.005		**0.044**	**0.036**
Calcium, Ca	mg/L	0.2		**18**	**25**
Magnesium, Mg	mg/L	0.1		**8.1**	**13**
Potassium, K	mg/L	0.1		**7.2**	**13**
Sodium, Na	mg/L	0.5		**39**	**29**
Sulfur asSulfate, SO4	mg/L	0.5		**5.9**	**1.7**
Sulfur, S	mg/L	0.1		**2.0**	**0.6**
Total Hardness by Calculation	mg CaCO3/L	1		**79**	**120**
Metals in Water (Total) by ICPOES Method: AN022/AN320 Tested: 12/3/2020					
Total Aluminium	mg/L	0.02		**0.10**	**0.10**
Total Barium	mg/L	0.005		**0.048**	**0.044**

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name	CE144955.005 Water 03 Mar 2020 B7	CE144955.006 Water 05 Mar 2020 B9
Metals in Water (Dissolved) by ICPOES-USN Method: AN320/AN322 Tested: 12/3/2020					
Arsenic, As	mg/L	0.003		<0.003	<0.003
Chromium, Cr	mg/L	0.0005		<0.0005	<0.0005
Cobalt, Co	mg/L	0.001		<0.001	<0.001
Copper, Cu	mg/L	0.001		**0.009**	**0.001**
Molybdenum, Mo	mg/L	0.0005		**0.0010**	**0.0012**
Nickel, Ni	mg/L	0.001		<0.001	<0.001
Selenium, Se	mg/L	0.002		<0.002	**0.003**
Metals in Water (Total) by ICPOES-USN Method: AN320/AN322 Tested: 12/3/2020					
Total Arsenic, As	mg/L	0.003		<0.003	<0.003
Total Chromium, Cr	mg/L	0.0005		<0.0005	<0.0005
Total Cobalt, Co	mg/L	0.001		<0.001	**0.001**
Total Copper, Cu	mg/L	0.001		**0.012**	**0.002**
Total Molybdenum, Mo	mg/L	0.0005		**0.0011**	**0.0012**
Total Nickel, Ni	mg/L	0.001		<0.001	<0.001
Total Selenium, Se	mg/L	0.002		<0.002	<0.002
Trace Metals (Dissolved) in Water by ICPMS Method: AN318 Tested: 9/3/2020					
Bismuth, Bi	µg/L	1		<1	<1
Uranium, U	µg/L	1		<1	<1
Trace Metals (Total) in Water by ICPMS Method: AN022/AN318 Tested: 9/3/2020					
Total Bismuth	µg/L	1		<1	<1
Total Uranium	µg/L	1		<1	<1
Calculation of Anion-Cation Balance (SAR Calc) Method: AN121 Tested: 18/3/2020					
Sum of Cation Milliequivalents*	meq/L	-		**3.46**	**3.93**
Sum of Anion Milliequivalents*	meq/L	-		**3.89**	**4.33**
Anion-Cation Balance	%	-100		**-5.9**	**-4.8**

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Alkalinity Method: ME-(AU)-[ENV]AN135

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Alkalinity as CaCO3	LB076803	mg/L	5	<5	1 - 3%	104 - 105%
Bicarbonate Alkalinity as CaCO3	LB076803	mg/L	5	<5		
Carbonate Alkalinity as CaCO3	LB076803	mg/L	5	<5		
Hydroxide Alkalinity as CaCO3	LB076803	mg/L	5	<5		

Chloride by Discrete Analyser in Water Method: ME-(AU)-[ENV]AN274

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Chloride, Cl	LB076842	mg/L	1	<1	0 - 3%	106 - 107%

Fluoride by Ion Selective Electrode in Water Method: ME-(AU)-[ENV]AN141

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Fluoride by ISE	LB076803	mg/L	0.1	<0.1	1%	101 - 104%	109%

Forms of Carbon Method: ME-(AU)-[ENV]AN190

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Organic Carbon as NPOC	LB076986	mg/L	0.2	<0.2	1%	105%

Metals in Water (Total) by ICPOES Method: ME-(AU)-[ENV]AN022/AN320

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Total Aluminium	LB076900	mg/L	0.02	<0.02	0%	99%	123%
Total Barium	LB076900	mg/L	0.005	<0.005	0%	103%	

Metals in Water (Dissolved) by ICPOES Method: ME-(AU)-[ENV]AN320

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Aluminium, Al	LB076899	mg/L	0.02	<0.02	0%	99%	109%
Barium, Ba	LB076899	mg/L	0.005	<0.005	0%	102%	
Calcium, Ca	LB076899	mg/L	0.2	<0.2	0%	100%	101%
Magnesium, Mg	LB076899	mg/L	0.1	<0.1	1%	103%	106%
Potassium, K	LB076899	mg/L	0.1	<0.1	0 - 1%	97%	94%
Sodium, Na	LB076899	mg/L	0.5	<0.5	0%	103%	102%
Sulfur asSulfate, SO4	LB076899	mg/L	0.5	<0.5			
Sulfur, S	LB076899	mg/L	0.1	<0.1	0 - 1%	98%	
Total Hardness by Calculation	LB076899	mg CaCO3/L	1	<1			

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Metals in Water (Dissolved) by ICPOES-USN Method: ME-(AU)-[ENV]AN320/AN322

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Arsenic, As	LB076901	mg/L	0.003	<0.003	1 - 10%	98%	111%
Chromium, Cr	LB076901	mg/L	0.0005	<0.0005	0%	99%	
Cobalt, Co	LB076901	mg/L	0.001	<0.001	0 - 1%	100%	103%
Copper, Cu	LB076901	mg/L	0.001	<0.001	1 - 2%	98%	118%
Molybdenum, Mo	LB076901	mg/L	0.0005	<0.0005	6%	101%	
Nickel, Ni	LB076901	mg/L	0.001	<0.001	0 - 4%	102%	100%
Selenium, Se	LB076901	mg/L	0.002	<0.002	11%	85%	

Metals in Water (Total) by ICPOES-USN Method: ME-(AU)-[ENV]AN320/AN322

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Total Arsenic, As	LB076902	mg/L	0.003	<0.003	12 - 17%	91%	118%
Total Chromium, Cr	LB076902	mg/L	0.0005	<0.0005	0%	104%	
Total Cobalt, Co	LB076902	mg/L	0.001	<0.001	9 - 13%	104%	102%
Total Copper, Cu	LB076902	mg/L	0.001	<0.001	1 - 2%	104%	123%
Total Molybdenum, Mo	LB076902	mg/L	0.0005	<0.0005	9%	106%	
Total Nickel, Ni	LB076902	mg/L	0.001	<0.001	0 - 3%	105%	100%
Total Selenium, Se	LB076902	mg/L	0.002	<0.002	0%	105%	

Trace Metals (Dissolved) in Water by ICPMS Method: ME-(AU)-[ENV]AN318

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Bismuth, Bi	LB076767	µg/L	1	<1	0%	90%
Uranium, U	LB076767	µg/L	1	<1	0%	90%

Trace Metals (Total) in Water by ICPMS Method: ME-(AU)-[ENV]AN022/AN318

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Bismuth	LB076768	µg/L	1	<1	0%	90%
Total Uranium	LB076768	µg/L	1	<1	0%	99%

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN022/AN318	Following acid digestion of un filtered sample, determination of elements at trace level in waters by ICP-MS technique, referenced to USEPA 6020B and USEPA 200.8 (5.4).
AN022/AN320	Total (acid soluble) Metals by ICP-OES: Samples are digested in nitric or nitric and hydrochloric acids prior to analysis for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components.
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode (glass plus reference electrode) and is calibrated against 3 buffers purchased commercially. For soils, an extract with water is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Total Dissolved Salts can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. SGS use 0.6. Reference APHA 2510 B.
AN106	Salinity may be calculated in terms of NaCl from the sample conductivity. This assumes all soluble salts present, measured by the conductivity, are present as NaCl.
AN121	This method is used to calculation the balance of major Anions and Cations in water samples and converts major ion concentration to milliequivalents and then summed. Anions sum and Cation sum is calculated as a difference and expressed as a percentage.
AN135	Alkalinity (and forms of) by Titration: The sample is titrated with standard acid to pH 8.3 (P titre) and pH 4.5 (T titre) and permanent and/or total alkalinity calculated. The results are expressed as equivalents of calcium carbonate or recalculated as bicarbonate, carbonate and hydroxide. Reference APHA 2320. Internal Reference AN135
AN141	Determination of Fluoride by ISE: A fluoride ion selective electrode and reference electrode combination, in the presence of a pH/complexation buffer, is used to determine the fluoride concentration. The electrode millivolt response is measured logarithmically against fluoride concentration. Reference APHA F- C.
AN190	TOC and DOC in Water: A homogenised micro portion of sample is injected into a heated reaction chamber packed with an oxidative catalyst that converts organic carbon to carbon dioxide. The CO2 is measured using a non-dispersive infrared detector. The process is fully automated in a commercially available analyser. If required a sugar value can be calculated from the TOC result. Reference APHA 5310 B.
AN190	Chemical oxygen demand can be calculated/estimated based on the O2/C relation as 2.67*NPOC (TOC). This is an estimate only and the factor will vary with sample matrix so results should be interpreted with caution.
AN274	Chloride by Discrete Analyse: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Reference APHA 4500Cl-
AN318	Determination of elements at trace level in waters by ICP-MS technique,, referenced to USEPA 6020B and USEPA 200.8 (5.4).
AN320	Metals by ICP-OES: Samples are preserved with 10% nitric acid for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components .

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN320	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B.
AN320/AN322	ICP-OES (Ultrasonic Nebuliser): After preservation with 10% nitric acid, a wide range of metals and some non-metals in solution can be measured by ICP- Ultrasonic nebulisation. Solutions are aspirated using an ultrasonic nebuliser into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components.
AN320/AN322	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B
AN322	ICP-OES (Ultrasonic Nebuliser): After preservation with 10% nitric acid, a wide range of metals and some non-metals in solution can be measured by ICP- Ultrasonic nebulisation. Solutions are aspirated using an ultrasonic nebuliser into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components.
AN322	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B
Calculation	Free and Total Carbon Dioxide may be calculated using alkalinity forms only when the samples TDS is <500mg/L. If TDS is >500mg/L free or total carbon dioxide cannot be reported. APHA4500CO2 D.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
**	Indicative data, theoretical holding time exceeded.	QFL	QC result is below the lower tolerance
		-	The sample was not analysed for this analyte
		NVL	Not Validated

Unless it is reported that sampling has been performed by SGS, the samples have been analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC and MU criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here: www.sgs.com.au/en-gb/environment-health-and-safety.

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ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS		LABORATORY DETAILS	
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Project	**623.20018.20211 Barbara REMP DS 2020**	SGS Reference	**CE147942 R0**
Order Number	(Not specified)	Date Received	26 Aug 2020
Samples	39	Date Reported	22 Sep 2020

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(3146/19038)

SIGNATORIES

Anthony NILSSON
Operations Manager

Jon Dicker
Manager Northern QLD

Parameter	Units	LOR	CE147942.001	CE147942.002	CE147942.003	CE147942.004
Sample Number			CE147942.001	CE147942.002	CE147942.003	CE147942.004
Sample Matrix			Soil	Soil	Soil	Soil
Sample Date			23 Aug 2020	23 Aug 2020	23 Aug 2020	23 Aug 2020
Sample Name			QA	B1US	B1	B2
Moisture Content Method: AN002 Tested: 3/9/2020						
% Moisture	%w/w	0.5	15	1.3	0.7	<0.5
Particle sizing of soils by sieving Method: AN005 Tested: 22/9/2020						
Passing 2.00mm	%w/w	1	67	76	74	85
Retained 2.00mm	%w/w	1	33	24	26	15
Passing 600µm	%w/w	1	30	59	43	52
Retained 600µm	%w/w	1	38	17	31	33
Passing 300µm	%w/w	1	14	46	25	26
Retained 300µm	%w/w	1	16	13	18	26
Passing 212µm	%w/w	1	5	37	16	15
Retained 212µm	%w/w	1	9	9	10	11
Passing 63µm	%w/w	1	3	28	10	8
Retained 63µm	%w/w	1	2	10	5	7
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 11/9/2020						
Arsenic, As	mg/kg	0.5	-	-	-	-
Barium, Ba	mg/kg	0.5	-	-	-	-
Bismuth, Bi*	mg/kg	3	-	-	-	-
Cobalt, Co	mg/kg	0.5	-	-	-	-
Chromium, Cr	mg/kg	0.5	-	-	-	-
Copper, Cu	mg/kg	0.5	-	-	-	-
Molybdenum, Mo	mg/kg	1	-	-	-	-
Nickel, Ni	mg/kg	0.5	-	-	-	-
Selenium, Se	mg/kg	3	-	-	-	-
Zinc, Zn	mg/kg	0.5	-	-	-	-
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 11/9/2020						
Bismuth, Bi*	mg/kg	0.5	-	-	-	-
Uranium, U	mg/kg	0.1	-	-	-	-
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 9/9/2020						
Total Organic Carbon	%w/w	0.05	0.20	1.9	0.54	0.35
Organic Matter	%w/w	0.1	0.34	3.2	0.94	0.61

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name	CE147942.005 Soil 23 Aug 2020 B3	CE147942.006 Soil 23 Aug 2020 B4	CE147942.007 Soil 23 Aug 2020 B5	CE147942.008 Soil 23 Aug 2020 B6
Moisture Content Method: AN002 Tested: 3/9/2020							
% Moisture	%w/w	0.5		15	<0.5	0.5	<0.5
Particle sizing of soils by sieving Method: AN005 Tested: 22/9/2020							
Passing 2.00mm	%w/w	1		66	89	85	83
Retained 2.00mm	%w/w	1		35	11	15	18
Passing 600µm	%w/w	1		28	46	61	33
Retained 600µm	%w/w	1		37	43	25	50
Passing 300µm	%w/w	1		13	19	35	13
Retained 300µm	%w/w	1		15	27	26	20
Passing 212µm	%w/w	1		4	8	21	3
Retained 212µm	%w/w	1		9	11	14	9
Passing 63µm	%w/w	1		3	4	10	2
Retained 63µm	%w/w	1		2	4	12	2
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 11/9/2020							
Arsenic, As	mg/kg	0.5		-	-	-	-
Barium, Ba	mg/kg	0.5		-	-	-	-
Bismuth, Bi*	mg/kg	3		-	-	-	-
Cobalt, Co	mg/kg	0.5		-	-	-	-
Chromium, Cr	mg/kg	0.5		-	-	-	-
Copper, Cu	mg/kg	0.5		-	-	-	-
Molybdenum, Mo	mg/kg	1		-	-	-	-
Nickel, Ni	mg/kg	0.5		-	-	-	-
Selenium, Se	mg/kg	3		-	-	-	-
Zinc, Zn	mg/kg	0.5		-	-	-	-
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 11/9/2020							
Bismuth, Bi*	mg/kg	0.5		-	-	-	-
Uranium, U	mg/kg	0.1		-	-	-	-
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 9/9/2020							
Total Organic Carbon	%w/w	0.05		0.25	0.24	0.58	0.37
Organic Matter	%w/w	0.1		0.43	0.40	1.0	0.64

Parameter	Units	LOR	CE147942.009	CE147942.010	CE147942.011	CE147942.012
Sample Number			CE147942.009	CE147942.010	CE147942.011	CE147942.012
Sample Matrix			Soil	Soil	Soil	Soil
Sample Date			23 Aug 2020	23 Aug 2020	23 Aug 2020	23 Aug 2020
Sample Name			B7	B9	BASW01	BASW05
Moisture Content Method: AN002 Tested: 3/9/2020						
% Moisture	%w/w	0.5	<0.5	<0.5	<0.5	1.3
Particle sizing of soils by sieving Method: AN005 Tested: 22/9/2020						
Passing 2.00mm	%w/w	1	76	87	82	86
Retained 2.00mm	%w/w	1	24	13	18	14
Passing 600µm	%w/w	1	29	44	34	63
Retained 600µm	%w/w	1	47	43	48	23
Passing 300µm	%w/w	1	11	18	12	32
Retained 300µm	%w/w	1	17	27	22	30
Passing 212µm	%w/w	1	3	7	4	18
Retained 212µm	%w/w	1	8	11	8	15
Passing 63µm	%w/w	1	2	2	2	8
Retained 63µm	%w/w	1	1	5	2	9
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 11/9/2020						
Arsenic, As	mg/kg	0.5	-	-	-	-
Barium, Ba	mg/kg	0.5	-	-	-	-
Bismuth, Bi*	mg/kg	3	-	-	-	-
Cobalt, Co	mg/kg	0.5	-	-	-	-
Chromium, Cr	mg/kg	0.5	-	-	-	-
Copper, Cu	mg/kg	0.5	-	-	-	-
Molybdenum, Mo	mg/kg	1	-	-	-	-
Nickel, Ni	mg/kg	0.5	-	-	-	-
Selenium, Se	mg/kg	3	-	-	-	-
Zinc, Zn	mg/kg	0.5	-	-	-	-
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 11/9/2020						
Bismuth, Bi*	mg/kg	0.5	-	-	-	-
Uranium, U	mg/kg	0.1	-	-	-	-
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 9/9/2020						
Total Organic Carbon	%w/w	0.05	0.21	0.18	0.24	1.8
Organic Matter	%w/w	0.1	0.36	0.31	0.41	3.1

Parameter	Units	LOR	CE147942.013	CE147942.014	CE147942.015	CE147942.016
Sample Number			CE147942.013	CE147942.014	CE147942.015	CE147942.016
Sample Matrix			Soil	Soil	Soil	Soil
Sample Date			23 Aug 2020	23 Aug 2020	23 Aug 2020	23 Aug 2020
Sample Name			BASW09	QA_<2mm	B1US_<2mm	B1_<2mm
Moisture Content Method: AN002 Tested: 3/9/2020						
% Moisture	%w/w	0.5	7.2	-	-	-
Particle sizing of soils by sieving Method: AN005 Tested: 22/9/2020						
Passing 2.00mm	%w/w	1	85	-	-	-
Retained 2.00mm	%w/w	1	15	-	-	-
Passing 600µm	%w/w	1	62	-	-	-
Retained 600µm	%w/w	1	24	-	-	-
Passing 300µm	%w/w	1	36	-	-	-
Retained 300µm	%w/w	1	26	-	-	-
Passing 212µm	%w/w	1	21	-	-	-
Retained 212µm	%w/w	1	15	-	-	-
Passing 63µm	%w/w	1	10	-	-	-
Retained 63µm	%w/w	1	11	-	-	-
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 11/9/2020						
Arsenic, As	mg/kg	0.5	-	2.9	3.7	7.6
Barium, Ba	mg/kg	0.5	-	42	120	70
Bismuth, Bi*	mg/kg	3	-	<3	<3	<3
Cobalt, Co	mg/kg	0.5	-	14	29	19
Chromium, Cr	mg/kg	0.5	-	14	43	24
Copper, Cu	mg/kg	0.5	-	31	110	70
Molybdenum, Mo	mg/kg	1	-	<1	<1	<1
Nickel, Ni	mg/kg	0.5	-	11	29	20
Selenium, Se	mg/kg	3	-	<3	<3	<3
Zinc, Zn	mg/kg	0.5	-	23	33	24
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 11/9/2020						
Bismuth, Bi*	mg/kg	0.5	-	-	-	-
Uranium, U	mg/kg	0.1	-	0.6	0.6	0.5
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 9/9/2020						
Total Organic Carbon	%w/w	0.05	1.7	-	-	-
Organic Matter	%w/w	0.1	2.9	-	-	-

Parameter	Units	LOR	CE147942.017	CE147942.018	CE147942.019	CE147942.020
Sample Number			CE147942.017	CE147942.018	CE147942.019	CE147942.020
Sample Matrix			Soil	Soil	Soil	Soil
Sample Date			23 Aug 2020	23 Aug 2020	23 Aug 2020	23 Aug 2020
Sample Name			B2_<2mm	B3_<2mm	B4_<2mm	B5_<2mm
Moisture Content Method: AN002 Tested: 8/9/2020						
% Moisture	%w/w	0.5	-	-	-	-
Particle sizing of soils by sieving Method: AN005 Tested: 22/9/2020						
Passing 2.00mm	%w/w	1	-	-	-	-
Retained 2.00mm	%w/w	1	-	-	-	-
Passing 600µm	%w/w	1	-	-	-	-
Retained 600µm	%w/w	1	-	-	-	-
Passing 300µm	%w/w	1	-	-	-	-
Retained 300µm	%w/w	1	-	-	-	-
Passing 212µm	%w/w	1	-	-	-	-
Retained 212µm	%w/w	1	-	-	-	-
Passing 63µm	%w/w	1	-	-	-	-
Retained 63µm	%w/w	1	-	-	-	-
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 10/9/2020						
Arsenic, As	mg/kg	0.5	7.4	3.1	6.2	2.3
Barium, Ba	mg/kg	0.5	60	44	40	81
Bismuth, Bi*	mg/kg	3	<3	<3	<3	<3
Cobalt, Co	mg/kg	0.5	28	14	29	20
Chromium, Cr	mg/kg	0.5	17	15	20	24
Copper, Cu	mg/kg	0.5	450	32	140	43
Molybdenum, Mo	mg/kg	1	<1	<1	<1	<1
Nickel, Ni	mg/kg	0.5	22	11	17	20
Selenium, Se	mg/kg	3	<3	<3	<3	<3
Zinc, Zn	mg/kg	0.5	11	24	18	17
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 11/9/2020						
Bismuth, Bi*	mg/kg	0.5	-	-	-	-
Uranium, U	mg/kg	0.1	0.7	0.6	0.6	0.8
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 10/9/2020						
Total Organic Carbon	%w/w	0.05	-	-	-	-
Organic Matter	%w/w	0.1	-	-	-	-

Parameter	Units	LOR	CE147942.021	CE147942.022	CE147942.023	CE147942.024
Sample Number			CE147942.021	CE147942.022	CE147942.023	CE147942.024
Sample Matrix			Soil	Soil	Soil	Soil
Sample Date			23 Aug 2020	23 Aug 2020	23 Aug 2020	23 Aug 2020
Sample Name			B6_<2mm	B7_<2mm	B9_<2mm	BASW01_<2mm
Moisture Content Method: AN002 Tested: 8/9/2020						
% Moisture	%w/w	0.5	-	-	-	-
Particle sizing of soils by sieving Method: AN005 Tested: 22/9/2020						
Passing 2.00mm	%w/w	1	-	-	-	-
Retained 2.00mm	%w/w	1	-	-	-	-
Passing 600µm	%w/w	1	-	-	-	-
Retained 600µm	%w/w	1	-	-	-	-
Passing 300µm	%w/w	1	-	-	-	-
Retained 300µm	%w/w	1	-	-	-	-
Passing 212µm	%w/w	1	-	-	-	-
Retained 212µm	%w/w	1	-	-	-	-
Passing 63µm	%w/w	1	-	-	-	-
Retained 63µm	%w/w	1	-	-	-	-
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 10/9/2020						
Arsenic, As	mg/kg	0.5	**3.9**	**3.9**	**1.9**	**3.6**
Barium, Ba	mg/kg	0.5	**45**	**39**	**31**	**38**
Bismuth, Bi*	mg/kg	3	<3	<3	<3	<3
Cobalt, Co	mg/kg	0.5	**15**	**16**	**11**	**15**
Chromium, Cr	mg/kg	0.5	**15**	**15**	**12**	**15**
Copper, Cu	mg/kg	0.5	**28**	**44**	**25**	**46**
Molybdenum, Mo	mg/kg	1	<1	<1	<1	<1
Nickel, Ni	mg/kg	0.5	**10**	**12**	**8.3**	**11**
Selenium, Se	mg/kg	3	<3	<3	<3	<3
Zinc, Zn	mg/kg	0.5	**19**	**14**	**13**	**16**
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 11/9/2020						
Bismuth, Bi*	mg/kg	0.5	-	-	-	-
Uranium, U	mg/kg	0.1	**0.6**	**0.6**	**0.6**	**0.6**
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 10/9/2020						
Total Organic Carbon	%w/w	0.05	-	-	-	-
Organic Matter	%w/w	0.1	-	-	-	-

Parameter	Units	LOR	CE147942.025	CE147942.026	CE147942.027	CE147942.028
Sample Number			CE147942.025	CE147942.026	CE147942.027	CE147942.028
Sample Matrix			Soil	Soil	Soil	Soil
Sample Date			23 Aug 2020	23 Aug 2020	23 Aug 2020	23 Aug 2020
Sample Name			BASW05_<2mm	BASW09_<2mm	QA_<63um	B1US_<63um
Moisture Content Method: AN002 Tested: 8/9/2020						
% Moisture	%w/w	0.5	-	-	-	-
Particle sizing of soils by sieving Method: AN005 Tested: 22/9/2020						
Passing 2.00mm	%w/w	1	-	-	-	-
Retained 2.00mm	%w/w	1	-	-	-	-
Passing 600µm	%w/w	1	-	-	-	-
Retained 600µm	%w/w	1	-	-	-	-
Passing 300µm	%w/w	1	-	-	-	-
Retained 300µm	%w/w	1	-	-	-	-
Passing 212µm	%w/w	1	-	-	-	-
Retained 212µm	%w/w	1	-	-	-	-
Passing 63µm	%w/w	1	-	-	-	-
Retained 63µm	%w/w	1	-	-	-	-
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 10/9/2020						
Arsenic, As	mg/kg	0.5	2.0	2.2	7.0	3.6
Barium, Ba	mg/kg	0.5	34	45	200	220
Bismuth, Bi*	mg/kg	3	<3	<3	<3	5
Cobalt, Co	mg/kg	0.5	11	11	37	39
Chromium, Cr	mg/kg	0.5	12	19	39	59
Copper, Cu	mg/kg	0.5	17	17	160	230
Molybdenum, Mo	mg/kg	1	<1	<1	<1	<1
Nickel, Ni	mg/kg	0.5	7.9	11	31	47
Selenium, Se	mg/kg	3	<3	<3	<3	<3
Zinc, Zn	mg/kg	0.5	17	12	68	56
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 11/9/2020						
Bismuth, Bi*	mg/kg	0.5	-	-	-	-
Uranium, U	mg/kg	0.1	0.5	0.7	1.1	0.8
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 10/9/2020						
Total Organic Carbon	%w/w	0.05	-	-	-	-
Organic Matter	%w/w	0.1	-	-	-	-

Parameter	Units	LOR	CE147942.029	CE147942.030	CE147942.031	CE147942.032
Sample Number			CE147942.029	CE147942.030	CE147942.031	CE147942.032
Sample Matrix			Soil	Soil	Soil	Soil
Sample Date			23 Aug 2020	23 Aug 2020	23 Aug 2020	23 Aug 2020
Sample Name			B1_<63um	B2_<63um	B3_<63um	B4_<63um
Moisture Content Method: AN002 Tested: 8/9/2020						
% Moisture	%w/w	0.5	-	-	-	-
Particle sizing of soils by sieving Method: AN005 Tested: 22/9/2020						
Passing 2.00mm	%w/w	1	-	-	-	-
Retained 2.00mm	%w/w	1	-	-	-	-
Passing 600µm	%w/w	1	-	-	-	-
Retained 600µm	%w/w	1	-	-	-	-
Passing 300µm	%w/w	1	-	-	-	-
Retained 300µm	%w/w	1	-	-	-	-
Passing 212µm	%w/w	1	-	-	-	-
Retained 212µm	%w/w	1	-	-	-	-
Passing 63µm	%w/w	1	-	-	-	-
Retained 63µm	%w/w	1	-	-	-	-
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 10/9/2020						
Arsenic, As	mg/kg	0.5	6.0	8.5	6.1	5.8
Barium, Ba	mg/kg	0.5	120	140	190	150
Bismuth, Bi*	mg/kg	3	<3	<3	3	<3
Cobalt, Co	mg/kg	0.5	18	34	35	47
Chromium, Cr	mg/kg	0.5	32	34	39	45
Copper, Cu	mg/kg	0.5	400	1000	170	680
Molybdenum, Mo	mg/kg	1	<1	<1	<1	<1
Nickel, Ni	mg/kg	0.5	23	35	31	37
Selenium, Se	mg/kg	3	<3	<3	<3	<3
Zinc, Zn	mg/kg	0.5	33	22	66	36
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 11/9/2020						
Bismuth, Bi*	mg/kg	0.5	-	-	-	-
Uranium, U	mg/kg	0.1	0.7	1.1	1.1	1.2
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 10/9/2020						
Total Organic Carbon	%w/w	0.05	-	-	-	-
Organic Matter	%w/w	0.1	-	-	-	-

Parameter	Units	LOR	CE147942.033	CE147942.034	CE147942.035	CE147942.036
Sample Number			CE147942.033	CE147942.034	CE147942.035	CE147942.036
Sample Matrix			Soil	Soil	Soil	Soil
Sample Date			23 Aug 2020	23 Aug 2020	23 Aug 2020	23 Aug 2020
Sample Name			B5_<63um	B6_<63um	B7_<63um	B9_<63um
Moisture Content Method: AN002 Tested: 8/9/2020						
% Moisture	%w/w	0.5	-	-	-	-
Particle sizing of soils by sieving Method: AN005 Tested: 22/9/2020						
Passing 2.00mm	%w/w	1	-	-	-	-
Retained 2.00mm	%w/w	1	-	-	-	-
Passing 600µm	%w/w	1	-	-	-	-
Retained 600µm	%w/w	1	-	-	-	-
Passing 300µm	%w/w	1	-	-	-	-
Retained 300µm	%w/w	1	-	-	-	-
Passing 212µm	%w/w	1	-	-	-	-
Retained 212µm	%w/w	1	-	-	-	-
Passing 63µm	%w/w	1	-	-	-	-
Retained 63µm	%w/w	1	-	-	-	-
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 10/9/2020						
Arsenic, As	mg/kg	0.5	<0.5	6.3	4.7	3.2
Barium, Ba	mg/kg	0.5	230	410	200	120
Bismuth, Bi*	mg/kg	3	<3	<3	<3	<3
Cobalt, Co	mg/kg	0.5	34	40	25	17
Chromium, Cr	mg/kg	0.5	42	35	31	26
Copper, Cu	mg/kg	0.5	260	400	300	87
Molybdenum, Mo	mg/kg	1	<1	<1	<1	<1
Nickel, Ni	mg/kg	0.5	40	26	26	18
Selenium, Se	mg/kg	3	<3	<3	<3	<3
Zinc, Zn	mg/kg	0.5	40	46	31	31
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 11/9/2020						
Bismuth, Bi*	mg/kg	0.5	-	-	-	-
Uranium, U	mg/kg	0.1	1.1	1.2	1.2	1.3
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 10/9/2020						
Total Organic Carbon	%w/w	0.05	-	-	-	-
Organic Matter	%w/w	0.1	-	-	-	-

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name	CE147942.037 Soil 23 Aug 2020 BASW01_<63um	CE147942.038 Soil 23 Aug 2020 BASW05_<63um	CE147942.039 Soil 23 Aug 2020 BASW08_<63um
Moisture Content Method: AN002 Tested: 8/9/2020						
% Moisture	%w/w	0.5	-	-	-	-
Particle sizing of soils by sieving Method: AN005 Tested: 22/9/2020						
Passing 2.00mm	%w/w	1	-	-	-	-
Retained 2.00mm	%w/w	1	-	-	-	-
Passing 600µm	%w/w	1	-	-	-	-
Retained 600µm	%w/w	1	-	-	-	-
Passing 300µm	%w/w	1	-	-	-	-
Retained 300µm	%w/w	1	-	-	-	-
Passing 212µm	%w/w	1	-	-	-	-
Retained 212µm	%w/w	1	-	-	-	-
Passing 63µm	%w/w	1	-	-	-	-
Retained 63µm	%w/w	1	-	-	-	-
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 10/9/2020						
Arsenic, As	mg/kg	0.5	**8.2**	**2.9**	**3.7**
Barium, Ba	mg/kg	0.5	**250**	**140**	**150**
Bismuth, Bi*	mg/kg	3	<3	<3	<3
Cobalt, Co	mg/kg	0.5	**35**	**17**	**23**
Chromium, Cr	mg/kg	0.5	**40**	**26**	**44**
Copper, Cu	mg/kg	0.5	**400**	**65**	**69**
Molybdenum, Mo	mg/kg	1	<1	<1	<1
Nickel, Ni	mg/kg	0.5	**34**	**19**	**27**
Selenium, Se	mg/kg	3	<3	<3	<3
Zinc, Zn	mg/kg	0.5	**46**	**49**	**33**
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 11/9/2020						
Bismuth, Bi*	mg/kg	0.5	-	-	-
Uranium, U	mg/kg	0.1	**1.4**	**1.1**	**1.1**
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 10/9/2020						
Total Organic Carbon	%w/w	0.05	-	-	-
Organic Matter	%w/w	0.1	-	-	-

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Total Organic Carbon by Heanes Oxidation **Method: ME-(AU)-[ENV]AN273**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Total Organic Carbon	LB082120	%w/w	0.05	<0.05	23 - 24%	98%	100%
Organic Matter	LB082120	%w/w	0.1	<0.10	23 - 24%	NA	NA

Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES **Method: ME-(AU)-[ENV]AN040/AN320**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Arsenic, As	LB082143	mg/kg	0.5	<0.5	1 - 41%	108 - 112%	
Barium, Ba	LB082143	mg/kg	0.5	<0.5	2 - 3%	98 - 99%	
Bismuth, Bi*	LB082143	mg/kg	3	<3	0 - 2%	NA	92%
Cobalt, Co	LB082143	mg/kg	0.5	<0.5	0 - 5%	90 - 94%	92%
Chromium, Cr	LB082143	mg/kg	0.5	<0.5	1 - 3%	99 - 102%	94%
Copper, Cu	LB082143	mg/kg	0.5	<0.5	2 - 6%	102 - 110%	118%
Molybdenum, Mo	LB082143	mg/kg	1	<1	0%	102 - 105%	
Nickel, Ni	LB082143	mg/kg	0.5	<0.5	3 - 4%	98 - 101%	92%
Selenium, Se	LB082143	mg/kg	3	<3	0%	94 - 97%	87%
Zinc, Zn	LB082143	mg/kg	0.5	<0.5	3 - 8%	99 - 102%	94%

Total Recoverable Metals in Soil by ICPMS **Method: ME-(AU)-[ENV]AN041/AN318**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Uranium, U	LB082188	mg/kg	0.1	<0.1	2%	NA

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN002	The test is carried out by drying (at either 40°C or 105°C) a known mass of sample in a weighed evaporating basin. After fully dry the sample is re-weighed. Samples such as sludge and sediment having high percentages of moisture will take some time in a drying oven for complete removal of water.
AN005	The particle size distribution of a soil is determined by wet sieving, using a maximum of 900 mL of deionised water to sieve all fractions down to 75 µm. Referenced to AS1289.3.6.1 and AS1141.11.
AN040/AN320	A portion of sample is digested with nitric acid to decompose organic matter and hydrochloric acid to complete the digestion of metals. The digest is then analysed by ICP OES with metals results reported on the dried sample basis. Based on USEPA method 200.8 and 6010C.
AN041/AN318	Determination of elements at trace level in soil digest by ICP-MS technique, referenced to USEPA 6020B and USEPA 200.8 (5.4).
AN273	The sample is digested in Dichromate / Sulfuric Acid to oxidise the organic carbon. The determination is completed colourimetrically by Aquakem Discrete Analyser at 600 nm. Based on Rayment & Higginson 6B1.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
		QFL	QC result is below the lower tolerance
**	Indicative data, theoretical holding time exceeded.	-	The sample was not analysed for this analyte
***	Indicates that both * and ** apply.	NVL	Not Validated

Unless it is reported that sampling has been performed by SGS, the samples have been analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC and MU criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here: www.sgs.com.au/en-gb/environment-health-and-safety.

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ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Terri Jones	Manager	Anthony Nilsson
Client	SLR CONSULTING AUSTRALIA PTY LTD	Laboratory	SGS Cairns Environmental
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Project	**623.20018.0040 Barbara REMP WS 2020**	SGS Reference	**CE144943 R0**
Order Number	(Not specified)	Date Received	06 Mar 2020
Samples	30	Date Reported	23 Mar 2020

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(3146).

SIGNATORIES

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Senior Laboratory Technician

Anthony NILSSON
Operations Manager

Jon Dicker
Lab Manager

Maristela GANZAN
Metals Team Leader

Parameter	Units	LOR	CE144943.001	CE144943.002	CE144943.003	CE144943.004
		Sample Number	CE144943.001	CE144943.002	CE144943.003	CE144943.004
		Sample Matrix	Sediment	Sediment	Sediment	Sediment
		Sample Date	03 Mar 2020	04 Mar 2020	04 Mar 2020	04 Mar 2020
		Sample Name	QA	B1US	B1	B2
Moisture Content Method: AN002 Tested: 6/3/2020						
% Moisture	%w/w	0.5	16	23	18	6.9
Particle sizing of soils by sieving Method: AN005 Tested: 23/3/2020						
Passing 2.00mm	%w/w	1	76	92	83	88
Retained 2.00mm	%w/w	1	24	8	17	12
Passing 600µm	%w/w	1	20	84	39	47
Retained 600µm	%w/w	1	56	9	44	41
Passing 300µm	%w/w	1	6	76	27	20
Retained 300µm	%w/w	1	14	8	13	27
Passing 212µm	%w/w	1	3	72	22	17
Retained 212µm	%w/w	1	3	4	5	3
Passing 63µm	%w/w	1	1	58	16	9
Retained 63µm	%w/w	1	2	14	6	8
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 13/3/2020						
Total Organic Carbon	%w/w	0.05	0.29	3.3	3.7	0.35
Organic Matter	%w/w	0.1	0.50	5.6	6.4	0.60
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 19/3/2020						
Arsenic, As	mg/kg	0.5	-	-	-	-
Copper, Cu	mg/kg	0.5	-	-	-	-
Nickel, Ni	mg/kg	0.5	-	-	-	-
Zinc, Zn	mg/kg	0.5	-	-	-	-
Lead, Pb	mg/kg	0.5	-	-	-	-
Barium, Ba	mg/kg	0.5	-	-	-	-
Cobalt, Co	mg/kg	0.5	-	-	-	-
Chromium, Cr	mg/kg	0.5	-	-	-	-
Molybdenum, Mo	mg/kg	0.5	-	-	-	-
Selenium, Se	mg/kg	1	-	-	-	-
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 20/3/2020						
Bismuth, Bi*	mg/kg	0.5	-	-	-	-
Uranium, U	mg/kg	0.1	-	-	-	-

Parameter	Units	LOR	CE144943.005	CE144943.006	CE144943.007	CE144943.008
Sample Number			CE144943.005	CE144943.006	CE144943.007	CE144943.008
Sample Matrix			Sediment	Sediment	Sediment	Sediment
Sample Date			03 Mar 2020	03 Mar 2020	04 Mar 2020	03 Mar 2020
Sample Name			B3	B4	B5	B6
Moisture Content Method: AN002 Tested: 6/3/2020						
% Moisture	%w/w	0.5	18	0.6	8.1	18
Particle sizing of soils by sieving Method: AN005 Tested: 23/3/2020						
Passing 2.00mm	%w/w	1	75	75	88	88
Retained 2.00mm	%w/w	1	25	25	12	12
Passing 600µm	%w/w	1	42	45	60	34
Retained 600µm	%w/w	1	33	31	28	54
Passing 300µm	%w/w	1	25	25	42	8
Retained 300µm	%w/w	1	17	20	18	26
Passing 212µm	%w/w	1	21	20	36	5
Retained 212µm	%w/w	1	4	4	6	4
Passing 63µm	%w/w	1	13	11	23	2
Retained 63µm	%w/w	1	8	9	13	3
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 13/3/2020						
Total Organic Carbon	%w/w	0.05	0.75	0.59	1.1	0.37
Organic Matter	%w/w	0.1	1.3	1.0	1.9	0.63
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 19/3/2020						
Arsenic, As	mg/kg	0.5	-	-	-	-
Copper, Cu	mg/kg	0.5	-	-	-	-
Nickel, Ni	mg/kg	0.5	-	-	-	-
Zinc, Zn	mg/kg	0.5	-	-	-	-
Lead, Pb	mg/kg	0.5	-	-	-	-
Barium, Ba	mg/kg	0.5	-	-	-	-
Cobalt, Co	mg/kg	0.5	-	-	-	-
Chromium, Cr	mg/kg	0.5	-	-	-	-
Molybdenum, Mo	mg/kg	0.5	-	-	-	-
Selenium, Se	mg/kg	1	-	-	-	-
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 20/3/2020						
Bismuth, Bi*	mg/kg	0.5	-	-	-	-
Uranium, U	mg/kg	0.1	-	-	-	-

Parameter	Units	LOR	CE144943.009	CE144943.010	CE144943.011	CE144943.012
Sample Number			CE144943.009	CE144943.010	CE144943.011	CE144943.012
Sample Matrix			Sediment	Sediment	Sediment	Sediment
Sample Date			03 Mar 2020	04 Mar 2020	QA_<2mm	B1US_<2mm
Sample Name			B7	B9		
Moisture Content Method: AN002 Tested: 6/3/2020						
% Moisture	%w/w	0.5	14	19	-	-
Particle sizing of soils by sieving Method: AN005 Tested: 23/3/2020						
Passing 2.00mm	%w/w	1	81	84	-	-
Retained 2.00mm	%w/w	1	19	16	-	-
Passing 600µm	%w/w	1	24	50	-	-
Retained 600µm	%w/w	1	57	34	-	-
Passing 300µm	%w/w	1	7	16	-	-
Retained 300µm	%w/w	1	18	34	-	-
Passing 212µm	%w/w	1	4	8	-	-
Retained 212µm	%w/w	1	2	8	-	-
Passing 63µm	%w/w	1	2	2	-	-
Retained 63µm	%w/w	1	2	6	-	-
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 13/3/2020						
Total Organic Carbon	%w/w	0.05	0.41	0.59	-	-
Organic Matter	%w/w	0.1	0.70	1.0	-	-
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 19/3/2020						
Arsenic, As	mg/kg	0.5	-	-	3.6	3.5
Copper, Cu	mg/kg	0.5	-	-	38	83
Nickel, Ni	mg/kg	0.5	-	-	12	32
Zinc, Zn	mg/kg	0.5	-	-	17	44
Lead, Pb	mg/kg	0.5	-	-	3.1	7.3
Barium, Ba	mg/kg	0.5	-	-	44	140
Cobalt, Co	mg/kg	0.5	-	-	15	31
Chromium, Cr	mg/kg	0.5	-	-	16	50
Molybdenum, Mo	mg/kg	0.5	-	-	0.6	<0.5
Selenium, Se	mg/kg	1	-	-	<1	<1
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 20/3/2020						
Bismuth, Bi*	mg/kg	0.5	-	-	0.7	<0.5
Uranium, U	mg/kg	0.1	-	-	0.6	0.5

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name	CE144943.013 Sediment B1_<2mm	CE144943.014 Sediment B2_<2mm	CE144943.015 Sediment B3_<2mm	CE144943.016 Sediment B4_<2mm
Moisture Content Method: AN002 Tested: 12/3/2020							
% Moisture	%w/w	0.5		-	-	-	-
Particle sizing of soils by sieving Method: AN005 Tested: 23/3/2020							
Passing 2.00mm	%w/w	1		-	-	-	-
Retained 2.00mm	%w/w	1		-	-	-	-
Passing 600µm	%w/w	1		-	-	-	-
Retained 600µm	%w/w	1		-	-	-	-
Passing 300µm	%w/w	1		-	-	-	-
Retained 300µm	%w/w	1		-	-	-	-
Passing 212µm	%w/w	1		-	-	-	-
Retained 212µm	%w/w	1		-	-	-	-
Passing 63µm	%w/w	1		-	-	-	-
Retained 63µm	%w/w	1		-	-	-	-
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 17/3/2020							
Total Organic Carbon	%w/w	0.05		-	-	-	-
Organic Matter	%w/w	0.1		-	-	-	-
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 20/3/2020							
Arsenic, As	mg/kg	0.5		6.5	6.5	2.5	4.9
Copper, Cu	mg/kg	0.5		71	350	38	160
Nickel, Ni	mg/kg	0.5		18	21	12	17
Zinc, Zn	mg/kg	0.5		26	11	29	18
Lead, Pb	mg/kg	0.5		4.6	3.1	3.3	3.3
Barium, Ba	mg/kg	0.5		69	56	53	47
Cobalt, Co	mg/kg	0.5		19	29	15	44
Chromium, Cr	mg/kg	0.5		23	18	18	21
Molybdenum, Mo	mg/kg	0.5		0.7	0.5	<0.5	<0.5
Selenium, Se	mg/kg	1		<1	<1	<1	<1
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 9/3/2020							
Bismuth, Bi*	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5
Uranium, U	mg/kg	0.1		0.6	0.7	0.6	0.7

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name	CE144943.017 Sediment B5_<2mm	CE144943.018 Sediment B6_<2mm	CE144943.019 Sediment B7_<2mm	CE144943.020 Sediment B9_<2mm
Moisture Content Method: AN002 Tested: 12/3/2020							
% Moisture	%w/w	0.5		-	-	-	-
Particle sizing of soils by sieving Method: AN005 Tested: 23/3/2020							
Passing 2.00mm	%w/w	1		-	-	-	-
Retained 2.00mm	%w/w	1		-	-	-	-
Passing 600µm	%w/w	1		-	-	-	-
Retained 600µm	%w/w	1		-	-	-	-
Passing 300µm	%w/w	1		-	-	-	-
Retained 300µm	%w/w	1		-	-	-	-
Passing 212µm	%w/w	1		-	-	-	-
Retained 212µm	%w/w	1		-	-	-	-
Passing 63µm	%w/w	1		-	-	-	-
Retained 63µm	%w/w	1		-	-	-	-
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 17/3/2020							
Total Organic Carbon	%w/w	0.05		-	-	-	-
Organic Matter	%w/w	0.1		-	-	-	-
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 20/3/2020							
Arsenic, As	mg/kg	0.5		**2.9**	**4.1**	**3.5**	**2.5**
Copper, Cu	mg/kg	0.5		**26**	**19**	**37**	**24**
Nickel, Ni	mg/kg	0.5		**24**	**9.7**	**12**	**8.3**
Zinc, Zn	mg/kg	0.5		**23**	**17**	**18**	**14**
Lead, Pb	mg/kg	0.5		**4.2**	**3.2**	**3.2**	**3.0**
Barium, Ba	mg/kg	0.5		**100**	**43**	**43**	**37**
Cobalt, Co	mg/kg	0.5		**26**	**14**	**17**	**9.7**
Chromium, Cr	mg/kg	0.5		**31**	**16**	**16**	**13**
Molybdenum, Mo	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5
Selenium, Se	mg/kg	1		<1	<1	<1	<1
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 9/3/2020							
Bismuth, Bi*	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5
Uranium, U	mg/kg	0.1		**0.8**	**0.7**	**0.6**	**0.6**

Parameter	Units	LOR	CE144943.021 Sediment QA_<63um	CE144943.022 Sediment B1US_<63um	CE144943.023 Sediment B1_<63um	CE144943.024 Sediment B2_<63um
Sample Number			CE144943.021	CE144943.022	CE144943.023	CE144943.024
Sample Matrix			Sediment	Sediment	Sediment	Sediment
Sample Name			QA_<63um	B1US_<63um	B1_<63um	B2_<63um
Moisture Content Method: AN002 Tested: 12/3/2020						
% Moisture	%w/w	0.5	-	-	-	-
Particle sizing of soils by sieving Method: AN005 Tested: 23/3/2020						
Passing 2.00mm	%w/w	1	-	-	-	-
Retained 2.00mm	%w/w	1	-	-	-	-
Passing 600µm	%w/w	1	-	-	-	-
Retained 600µm	%w/w	1	-	-	-	-
Passing 300µm	%w/w	1	-	-	-	-
Retained 300µm	%w/w	1	-	-	-	-
Passing 212µm	%w/w	1	-	-	-	-
Retained 212µm	%w/w	1	-	-	-	-
Passing 63µm	%w/w	1	-	-	-	-
Retained 63µm	%w/w	1	-	-	-	-
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 17/3/2020						
Total Organic Carbon	%w/w	0.05	-	-	-	-
Organic Matter	%w/w	0.1	-	-	-	-
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 20/3/2020						
Arsenic, As	mg/kg	0.5	4.7	3.8	6.8	9.1
Copper, Cu	mg/kg	0.5	260	130	300	670
Nickel, Ni	mg/kg	0.5	28	37	25	35
Zinc, Zn	mg/kg	0.5	42	47	38	21
Lead, Pb	mg/kg	0.5	7.4	8.4	8.9	4.8
Barium, Ba	mg/kg	0.5	150	170	140	140
Cobalt, Co	mg/kg	0.5	26	31	23	41
Chromium, Cr	mg/kg	0.5	35	56	36	30
Molybdenum, Mo	mg/kg	0.5	0.6	<0.5	0.8	0.6
Selenium, Se	mg/kg	1	<1	<1	<1	<1
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 9/3/2020						
Bismuth, Bi*	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5
Uranium, U	mg/kg	0.1	1.2	0.6	0.9	1.2

Parameter	Units	LOR	CE144943.025 Sediment B3_<63um	CE144943.026 Sediment B4_<63um	CE144943.027 Sediment B5_<63um	CE144943.028 Sediment B6_<63um
Sample Number			CE144943.025	CE144943.026	CE144943.027	CE144943.028
Sample Matrix			Sediment	Sediment	Sediment	Sediment
Sample Name			B3_<63um	B4_<63um	B5_<63um	B6_<63um
Moisture Content Method: AN002 Tested: 12/3/2020						
% Moisture	%w/w	0.5	-	-	-	-
Particle sizing of soils by sieving Method: AN005 Tested: 23/3/2020						
Passing 2.00mm	%w/w	1	-	-	-	-
Retained 2.00mm	%w/w	1	-	-	-	-
Passing 600µm	%w/w	1	-	-	-	-
Retained 600µm	%w/w	1	-	-	-	-
Passing 300µm	%w/w	1	-	-	-	-
Retained 300µm	%w/w	1	-	-	-	-
Passing 212µm	%w/w	1	-	-	-	-
Retained 212µm	%w/w	1	-	-	-	-
Passing 63µm	%w/w	1	-	-	-	-
Retained 63µm	%w/w	1	-	-	-	-
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 17/3/2020						
Total Organic Carbon	%w/w	0.05	-	-	-	-
Organic Matter	%w/w	0.1	-	-	-	-
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 20/3/2020						
Arsenic, As	mg/kg	0.5	3.3	6.0	3.0	3.9
Copper, Cu	mg/kg	0.5	130	480	45	85
Nickel, Ni	mg/kg	0.5	22	29	30	20
Zinc, Zn	mg/kg	0.5	50	28	34	39
Lead, Pb	mg/kg	0.5	5.9	5.4	5.6	7.0
Barium, Ba	mg/kg	0.5	130	120	210	120
Cobalt, Co	mg/kg	0.5	22	52	26	22
Chromium, Cr	mg/kg	0.5	30	36	34	32
Molybdenum, Mo	mg/kg	0.5	<0.5	0.7	<0.5	0.8
Selenium, Se	mg/kg	1	<1	<1	<1	<1
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 9/3/2020						
Bismuth, Bi*	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5
Uranium, U	mg/kg	0.1	0.9	1.1	1.2	1.3

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name	CE144943.029 Sediment B7_<63um	CE144943.030 Sediment B9_<63um
Moisture Content Method: AN002 Tested: 12/3/2020					
% Moisture	%w/w	0.5		-	-
Particle sizing of soils by sieving Method: AN005 Tested: 23/3/2020					
Passing 2.00mm	%w/w	1		-	-
Retained 2.00mm	%w/w	1		-	-
Passing 600µm	%w/w	1		-	-
Retained 600µm	%w/w	1		-	-
Passing 300µm	%w/w	1		-	-
Retained 300µm	%w/w	1		-	-
Passing 212µm	%w/w	1		-	-
Retained 212µm	%w/w	1		-	-
Passing 63µm	%w/w	1		-	-
Retained 63µm	%w/w	1		-	-
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 17/3/2020					
Total Organic Carbon	%w/w	0.05		-	-
Organic Matter	%w/w	0.1		-	-
Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES Method: AN040/AN320 Tested: 20/3/2020					
Arsenic, As	mg/kg	0.5		**4.3**	**3.9**
Copper, Cu	mg/kg	0.5		**240**	**71**
Nickel, Ni	mg/kg	0.5		**28**	**21**
Zinc, Zn	mg/kg	0.5		**39**	**35**
Lead, Pb	mg/kg	0.5		**6.9**	**7.2**
Barium, Ba	mg/kg	0.5		**150**	**120**
Cobalt, Co	mg/kg	0.5		**26**	**19**
Chromium, Cr	mg/kg	0.5		**35**	**31**
Molybdenum, Mo	mg/kg	0.5		**0.6**	**0.6**
Selenium, Se	mg/kg	1		<1	<1
Total Recoverable Metals in Soil by ICPMS Method: AN041/AN318 Tested: 9/3/2020					
Bismuth, Bi*	mg/kg	0.5		<0.5	<0.5
Uranium, U	mg/kg	0.1		**1.2**	**1.2**

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Total Organic Carbon by Heanes Oxidation **Method: ME-(AU)-[ENV]AN273**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Total Organic Carbon	LB076992	%w/w	0.05	<0.05	0 - 1%	99%	95%
Organic Matter	LB076992	%w/w	0.1		0 - 1%		

Total Recoverable Elements in Soil/Waste Solids/Materials by ICPOES **Method: ME-(AU)-[ENV]AN040/AN320**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Arsenic, As	LB077210	mg/kg	0.5	<0.5	6 - 8%	97%	96%
Copper, Cu	LB077210	mg/kg	0.5	<0.5	1%	96%	96%
Nickel, Ni	LB077210	mg/kg	0.5	<0.5	2%	96%	90%
Zinc, Zn	LB077210	mg/kg	0.5	<0.5	0 - 3%	92%	89%
Lead, Pb	LB077210	mg/kg	0.5	<0.5	4 - 6%	95%	89%
Barium, Ba	LB077210	mg/kg	0.5	<0.5	0%	110%	95%
Cobalt, Co	LB077210	mg/kg	0.5	<0.5	1 - 3%	100%	94%
Chromium, Cr	LB077210	mg/kg	0.5	<0.5	1 - 2%	100%	95%
Molybdenum, Mo	LB077210	mg/kg	0.5	<0.5	0%	100%	94%
Selenium, Se	LB077210	mg/kg	1	<1	0%	95%	87%

Total Recoverable Metals in Soil by ICPMS **Method: ME-(AU)-[ENV]AN041/AN318**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Bismuth, Bi*	LB076753	mg/kg	0.5	<0.5	0 - 18%	NA
Uranium, U	LB076753	mg/kg	0.1	<0.1	0 - 2%	NA

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN002	The test is carried out by drying (at either 40°C or 105°C) a known mass of sample in a weighed evaporating basin. After fully dry the sample is re-weighed. Samples such as sludge and sediment having high percentages of moisture will take some time in a drying oven for complete removal of water.
AN005	The particle size distribution of a soil is determined by wet sieving, using a maximum of 900 mL of deionised water to sieve all fractions down to 75 µm. Referenced to AS1289.3.6.1 and AS1141.11.
AN040/AN320	A portion of sample is digested with nitric acid to decompose organic matter and hydrochloric acid to complete the digestion of metals. The digest is then analysed by ICP OES with metals results reported on the dried sample basis. Based on USEPA method 200.8 and 6010C.
AN041/AN318	Determination of elements at trace level in soil digest by ICP-MS technique, referenced to USEPA 6020B and USEPA 200.8 (5.4).
AN273	The sample is digested in Dichromate / Sulfuric Acid to oxidise the organic carbon. The determination is completed colourimetrically by Aquakem Discrete Analyser at 600 nm. Based on Rayment & Higginson 6B1.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
**	Indicative data, theoretical holding time exceeded.	QFL	QC result is below the lower tolerance
		-	The sample was not analysed for this analyte
		NVL	Not Validated

Unless it is reported that sampling has been performed by SGS, the samples have been analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC and MU criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here: www.sgs.com.au/en-gb/environment-health-and-safety.

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Barbara Copper Project

Terrestrial Flora and Fauna Assessment

Prepared for:
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AustralAsian Resource Consultants

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TABLE OF CONTENTS

EXECUTIVE SUMMARY 1

1.0 INTRODUCTION 4

1.1 SCOPE OF STUDY 4

2.0 PROJECT DESCRIPTION 5

2.1 PROJECT LOCATION 5

2.2 LOCAL WATERWAYS AND TOPOGRAPHY 7

2.3 GEOLOGY 9

2.4 REGIONAL CLIMATE 9

2.5 CURRENT LAND USE 10

3.0 RELEVANT LEGISLATION, POLICY AND GUIDELINES 11

3.1 LEGISLATION 11

3.1.1 Commonwealth Environment Protection and Biodiversity Conservation Act 1999 11

3.1.2 Queensland Nature Conservation Act 1992 11

3.1.3 Queensland Vegetation Management Act 1999 12

3.1.4 Queensland Land Protection (Pest and Stock Route Management) Act 2002 13

3.2 POLICIES AND GUIDELINES 13

3.2.1 Offsets under the Environmental Protection and Biodiversity Conservation Act 1999 13

3.2.2 Queensland Environmental Offsets Policy 14

3.2.3 Biodiversity and Mapping Methodology (BAMM) 15

3.2.4 Queensland Biodiversity Planning Assessments and EHP Biodiversity Status 16

3.2.5 Back on Track Species Prioritisation Framework 16

4.0 DATABASE SEARCH AND LITERATURE REVIEW 18

4.1 FLORA 18

4.1.1 Threatened Ecological Communities 18

4.1.2 Regional Ecosystems 19

4.1.3 Species of Conservation Significance 21

4.1.4 Back on Track Flora Species 21

4.2 FAUNA 22

4.2.1 Fauna Species of Conservation Significance 22

4.2.2 Back on Track Fauna Species 24

4.2.3 Migratory Fauna Species 25

4.3 ENVIRONMENTALLY SENSITIVE AREAS 27

4.4 WETLAND MAPPING 29

5.0 METHODOLOGY 31

5.1 INITIAL SITE SCOPING 31
5.2 FLORA SURVEY METHODOLOGY 31
5.2.1 Flora and Regional Ecosystem Identification 33
5.2.2 Surveys for Species of Conservation Significance 33
5.3 FAUNA SURVEY METHODOLOGY 33
5.3.1 Fauna Survey Sites 34
5.3.2 Detection Methods 36
5.3.3 Survey effort 39
6.0 RESULTS AND DISCUSSION 41
6.1 SURVEY TIMING 41
6.2 WEATHER CONDITIONS 41
6.3 FLORA SURVEY RESULTS 42
6.3.1 Community 1 – Low Open Woodland of Snappy Gum (*Eucalyptus leucophloia*) on metamorphic hills 44
6.3.1.1 Community Description 44
6.3.1.2 Conservation Value 45
6.3.1.3 Vegetation Condition and Habitat Value 46
6.3.2 Community 2 – Low Open Woodland of Cloncurry Box (*Eucalyptus leucophylla*) and Bloodwood (*Corymbia terminalis*) on Metamorphic hills 46
6.3.2.1 Community Description 46
6.3.2.2 Conservation Value 47
6.3.2.3 Vegetation Condition and Habitat Value 48
6.3.3 Community 3 – Low Open Woodland of Cloncurry Box (*E. leucophylla*) on Alluvial Flats 48
6.3.3.1 Community Description 48
6.3.3.2 Conservation Value 49
6.3.3.3 Vegetation Condition and Habitat Value 50
6.3.4 Community 4 – River Red Gum (*Eucalyptus camaldulensis*) and Northern Swamp Box (*Lophostemon grandiflorus*) Riparian Woodland 50
6.3.4.1 Community Description 50
6.3.4.2 Conservation Value 51
6.3.4.3 Vegetation Condition and Habitat Value 52
6.3.5 Community 5 – Low Open Woodland of Arid Peach (*Terminalia aridicola*) on Rocky Outcrops 52
6.3.5.1 Community Description 52
6.3.5.2 Conservation Value 53
6.3.5.3 Vegetation Condition and Habitat Value 54
6.3.6 Community 6 – Capricornia (*Corymbia Capricornia*) Ridges 54
6.3.6.1 Community Description 54
6.3.6.2 Conservation Value 55
6.3.6.3 Vegetation Condition and Habitat Value 55

6.3.7 Community 7 – Low Open Woodland of Cloncurry Box (*E. leucophylla*) and Bloodwood (*C. terminalis*) on granites ... 56
6.3.7.1 Community Description ... 56
6.3.7.2 Conservation Value ... 56
6.3.7.3 Vegetation Condition and Habitat Value ... 57
6.3.8 Flora Species of Conservation Significance ... 57
6.3.9 Weeds of Management Concern ... 57
6.4 FAUNA SURVEY RESULTS ... 58
6.4.1 Amphibians ... 58
6.4.1.1 Habitat Values ... 58
6.4.2 Observed Species ... 58
6.4.2.1 Amphibian Species of Conservation Significance ... 59
6.4.3 Reptiles ... 59
6.4.3.1 Habitat Values ... 59
6.4.3.2 Observed Species ... 60
6.4.3.3 Reptile Species of Conservation Significance ... 63
6.4.4 Birds ... 63
6.4.4.1 Habitat Values ... 63
6.4.4.2 Observed Species ... 64
6.4.4.3 Bird Species of Conservation Significance ... 64
6.4.4.4 EPBC Act Listed Migratory and Marine Species ... 64
6.4.5 Mammals ... 65
6.4.5.1 Habitat Values ... 65
6.4.5.2 Observed Species ... 66
6.4.5.3 Mammal Species of Conservation Significance ... 68
6.4.6 Pest Species ... 70
6.4.7 Regional Fauna Species of Conservation Significance ... 71
7.0 ENVIRONMENTAL VALUES, POTENTIAL IMPACTS AND MITIGATION .. 78
7.1 SUMMARY OF ENVIRONMENTAL VALUES ... 78
7.2 POTENTIAL IMPACTS ... 79
7.3 MITIGATION AND MANAGEMENT STRATEGIES ... 83
7.3.1 Flora Management ... 83
7.3.2 Fauna Management ... 83
7.3.3 Threatened Species Management ... 84
7.3.4 Weed and Pest Management ... 84
7.3.4.1 Weed Management ... 84
7.3.4.2 Pest Management ... 85
7.3.4.3 Emission Management ... 85
7.3.4.4 Training and awareness ... 86
7.4 ENVIRONMENTAL OFFSET ASSESSMENT ... 86

REFERENCES **90**

LIST OF FIGURES

Figure 1 Project Locality 6
Figure 2 Waterbodies on and Surrounding the Project Site 8
Figure 3 Mean Temperature and Rainfall Data for the Region 9
Figure 4 Regional Ecosystem Mapping over the Project Site 20
Figure 5 Environmentally Sensitive Areas on and Surrounding the Project Site 28
Figure 6 Queensland Wetland mapping over the Project Site 30
Figure 7 Flora Survey Locations on the Project Site 32
Figure 8 Terrestrial Fauna Survey Locations on the Project Site 35
Figure 9 Vegetation Communities within the Study Area 43
Figure 10 Threatened Species Records 69
Figure 11 PNRW Habitat Areas 70
Figure 12 Impacts on Vegetation Communities 80
Figure 13 Potential Impacts on Watercourses and PNRW Habitat 87

LIST OF TABLES

Table 1 Regional Ecosystems Mapped within the Project Site 19
Table 2 Flora Species of Conservation Significance within the Project Region 21
Table 3 Southern Gulf NRM Region Back on Track Priority Flora Species 21
Table 4 Fauna Species of Conservation Significance Occurring within the Project Region 22
Table 5 Back on Track Priority Fauna Species in the Southern Gulf NRM region 24
Table 6 Migratory and Marine Species within the Project Region 25
Table 7 Summary of Sampling Effort 40
Table 8 Community 1 Profile 44
Table 9 Community 2 Profile 46
Table 10 Community 3 Profile 48
Table 11 Community 4 Profile 50
Table 12 Community 5 Profile 52
Table 13 Community 6 Profile 54
Table 14 Community 7 Profile 56
Table 15 Flora of Conservation Significance known from the Region - Not Identified on the Project 57

Table 16 Threatened Fauna known from the Region Not Observed on the Project site 72
Table 17 Potential Impacts on Vegetation Communities 81
Table 18 Summary of Environmental Offset Requirements 88

LIST OF PHOTO PLATES

Photo Plate 1 Low open woodland of Snappy Gum (*E. leucophloia*) on metamorphic hills 45
Photo Plate 2 Low open woodland of Cloncurry Box and Bloodwood on metamorphic hills 47
Photo Plate 3 Low open woodland of Cloncurry Box on alluvial flats 49
Photo Plate 4 River Red Gum and Northern Swamp Box Riparian Woodland 51
Photo Plate 5 Low open woodland of Arid Peach on rocky outcrops 53
Photo Plate 6 Capricornia ridges 55
Photo Plate 7 *Litoria coplandi* recorded in a small sandstone gorge (OBSO2) 59
Photo Plate 8 Hosmer's Skink (*Egernia hosmeri*) captured in an Elliott trap at FA6 60
Photo Plate 9 Northern Spiny-tailed Gecko at FA5 61
Photo Plate 10 Northern Hooded Scaly-foot (*Pygopus steelescotti*) captured at FA1 62
Photo Plate 11 Robust Blind Snake (*Ramphotyphlops ligatus*) captured at FA5 63
Photo Plate 12 Common Planigale (*Planigale maculata)* captured at FA5 67
Photo Plate 13 Purple-necked Rock-wallaby at FA8 68
Photo Plate 14 Pitfall Line at DSFS1 ..... A
Photo Plate 15 Pitfall Line at DSFS2 ..... A
Photo Plate 16 Pitfall Line at Study Site DSFS3 ..... B
Photo Plate 17 Pitfall Line at DSFS4 ..... B
Photo Plate 18 Pitfall Line at DSFS5 C
Photo Plate 19 Pitfall Line at TR01 C
Photo Plate 20 Pitfall Line at TR02 ..... D
Photo Plate 21 Pitfall Line at TR03 ..... D
Photo Plate 22 Pitfall Line at TR04 ..... E
Photo Plate 23 Pitfall Line at TR05 ..... E
Photo Plate 24 Pitfall Line at TR06 ..... F
Photo Plate 25 Pitfall Line at TR07 ..... F
Photo Plate 26 Pitfall Line at TR08 ..... G
Photo Plate 27 Pitfall Line at FA1 ..... H
Photo Plate 28 Pitfall Line at FA2 I
Photo Plate 29 Rocky outcrop habitat at FA3 I
Photo Plate 30 Pitfall Line at FA4 ..... J
Photo Plate 31 Pitfall Line at FA5 ..... K

Photo Plate 32 Low Open Snappy Gum Woodland on Hillsides at FA6 ..... K
Photo Plate 33 Rocky outcrop habitat at FA7 L
Photo Plate 34 Harp trap in River Red Gum / Northern Swamp Box Creek at FA8 .....M

LIST OF APPENDICES

Appendix A Database Search Results ..... A
Appendix B Fauna Study Sites..... B
Appendix C Flora Species Inventory C
Appendix D Fauna Species Inventory ..... D
Appendix E Bat Call Analysis Results ..... E
Appendix F Pest Species Fact Sheets..... F

LIST OF ABBREVIATIONS

°C	-	degrees Celsius
AARC	-	AustralAsian Resource Consultants Pty Ltd
BAMM	-	Biodiversity and Mapping Methodology
BoT	-	Back on Track
BPA	-	Biodiversity Planning Assessments
CAMBA	-	China-Australia Migratory Bird Agreement
cm	-	centimetre
CopperChem	-	CopperChem Limited
DBMP	-	Direct Benefit Management Plan
DOE	-	Department of the Environment
E	-	Endangered
EHP	-	Department of Environment and Heritage Protection
EM Plan	-	Environmental Management Plan
EPBC Act	-	*Environment Protection and Biodiversity Conservation Act 1999*

EPM	-	Mineral Exploration Permit
ESA	-	Environmentally Sensitive Area
GIS	-	Geographical Information System
ha	-	hectare
JAMBA	-	Japan-Australia Migratory Bird Agreement
km	-	kilometres
km/h	-	kilometres/hour
km^2	-	square kilometres
LC	-	Least Concern
LP Act	-	*Land Protection (Pest and Stock Route Management) Act 2002*
Ma	-	Marine
Mi	-	Migratory
MLA	-	Mining Lease Application
MNES	-	Matter of National Environmental Significance
MSES	-	Matters of State Environmental Significance
mm	-	millimetres
NC Act	-	*Nature Conservation Act 1992*
NCWR	-	*Nature Conservation (Wildlife) Regulation 2006*
NL	-	Not Listed
NRM	-	Natural Resource Management
NT	-	Near Threatened
PNRW	-	Purple-necked Rock-wallaby
RAD	-	Recovery Actions Database
RE	-	Regional Ecosystem
REDD	-	Regional Ecosystem Description Database
SL	-	Special Least Concern
V	-	Vulnerable

VMA	-	*Vegetation Management Act 1999*
VMR	-	*Vegetation Management Regulation 2012*
WoNS	-	Weeds of National Significance

EXECUTIVE SUMMARY

AustralAsian Resource Consultants was commissioned by CopperChem Limited to undertake a Terrestrial Flora and Fauna Assessment of the proposed Barbara Copper Project (the Project). This assessment forms part of a series of baseline studies required for the Project's Environmental Authority application. To assess the environmental values of flora and fauna communities on the Project site, AustralAsian Resource Consultants undertook the following scope of works:

- Completion of a literature and database review to identify species, regional ecosystems and ecological communities of conservation significance within the region in which the Project is located;

- Compilation of an inventory of the ecological communities, regional ecosystems, vertebrate fauna and flora inhabiting the Project site, with a particular focus on species and communities of conservation significance; and

- Preparation of a report describing significant ecological factors, potential impacts and outlining possible management strategies, in order to reduce any foreseeable impacts associated with the proposed activities.

The Project is located approximately 50 kilometres north-east of Mount Isa and 100 kilometres west of Cloncurry in the Northwest Highlands Bioregion. The Project is a proposed copper and gold mining operation which will involve open-cut mining and associated activities on the Project site. Historically the Project site has been subject to cattle grazing and mining activities, whilst more recent activities have been limited to low intensity cattle grazing and mineral exploration activities.

Database searches revealed that no threatened ecological communities and species occur in the region in which the Project site is located. One Environmentally Sensitive Area identified as an Endangered Regional Ecosystem is mapped on the Project site.

Four site surveys were undertaken during the wet and dry season periods in 2011 and 2014. In 2011, a wet season survey was conducted between the 28th March and 3rd of April, and a dry season survey was undertaken between the 19th and 25th October. Recent surveys were conducted from 30th January to 7th February 2014 during the wet season and between the 1st and 8th August 2014 in the dry season.

To provide a comprehensive assessment of biodiversity values on the Project site, a total of thirty-six secondary flora transects and twenty-one fauna trapping sites were conducted throughout the Project site. Fauna survey techniques utilised included Elliott trapping, pitfall and funnel trapping, camera trapping, harp trapping and bat call recording, habitat searching, spotlighting and bird surveying.

A total of one-hundred and sixty-seven species of plants were recorded during the Project surveys. Seven vegetation communities were identified on the Project site, all of which are classified as remnant vegetation. The vegetation communities are representative of five different Regional Ecosystems. Vegetation communities identified on the Project site include:

- Community 1 - Low Open Woodland of Snappy Gum (*Eucalyptus leucophloia*) on Metamorphic Hills;

- Community 2 - Low Open Woodland of Cloncurry Box (*Eucalyptus leucophylla*) and Bloodwood (*Corymbia terminalis*) on Metamorphic Hills;

- Community 3 - Low Open Woodland of Cloncurry Box (*E. leucophylla*) on Alluvial Flats;
- Community 4 - River Red Gum (*Eucalyptus camaldulensis*) and Northern Swamp Box (*Lophostemon grandiflorus*) Riparian Woodland;
- Community 5 - Low Open Woodland of Arid Peach (*Terminalia aridicola*) on Rocky Outcrops;
- Community 6 - Capricornia (*Corymbia capricornia*) Ridges; and
- Community 7 - Low Open Woodland of Cloncurry Box (*Eucalyptus leucophylla*) and Bloodwood (*Corymbia terminalis*) on granites.

Community 1 occupies the vast majority of the Project site, while all other communities occur in patches throughout the site.

No threatened flora species were identified on the Project site during field surveys. Six weed species were recorded in low densities across the Project site. None of the recorded weed species are listed as declared weeds under the Queensland *Land Protection (Pest and Stock Route Management) Act 2002* or Weeds of National Significance.

A total of one-hundred and forty-four fauna species were identified on the Project site, consisting of nine amphibians, eighty birds, twenty-seven reptiles and twenty-eight mammals. One threatened bird species, the Golden-backed Honeyeater (*Melithreptus gularis laetior*) and one threatened mammal species, the Purple-necked Rock-wallaby (*Petrogale purpureicollis*) were recorded on the Project site. Under the Queensland *Nature Conservation (Wildlife) Regulation 2006,* the Golden-backed Honeyeater is classified as Near Threatened and the Purple-necked Rock-wallaby is listed as Vulnerable. One migratory bird species, the Rainbow Bee-eater was also recorded on the Project site. Site surveys recorded a suite of five pest species consisting of the Cane Toad (*Rhinella marina)*, Wild Dog/Dingo (*Canis familiaris)*, Feral Pig (*Sus scrofa*), House Mouse (*Mus domesticus*) and domestic Cow (*Bos taurus*). The Wild Dog/Dingo and Feral Pig are both classified as Class 2 declared pest animals under the *Land Protection (Pest and Stock Route Management) Act 2002*.

The following potential impacts were identified for the Project:

- Clearing of remnant vegetation will result in the loss of small areas of Regional Ecosystems, as well as the loss of habitat for flora species;
- Reduction in the availability of fauna habitat, leading to the displacement of native fauna and an increase in competition for resources in retained habitats;
- Reduction in the size and connectivity of habitat, particularly within riparian corridors and the south-east portion of the Project site;
- Removal of mature trees will lead to loss of habitat for hollow-dwelling fauna;
- Removal of potential shelter and forage habitat for threatened fauna species leading to fauna displacement and increased competition;
- Fauna injury or death may result from Project clearing activities and increased vehicle movements on-site;
- Project disturbances such as artificial lighting and noise pollution may impact on local fauna, particularly nocturnal birds and mammals;

- Soil erosion, sedimentation and vegetation smothering;
- Introduction, spread and increased abundance of weed species due to vegetation clearing, which alters micro-climate conditions and increased vehicle presence and movement across the Project site;
- Increased pest abundance where Project disturbance creates favourable conditions including increased resource availability (e.g. food and water) and enhanced site access through vegetation clearing and the creation of new tracks; and
- Increased risk of fire.

To address these potential impacts, mitigation and management strategies are recommended as summarised below.

- The vegetation clearing footprint should be restricted to approved disturbance areas;
- Disturbed areas should be rehabilitated progressively throughout the life of the mine, where possible, and at Project completion;
- Removed topsoil should be retained, stockpiled and re-used in rehabilitation works on the Project site;
- Appropriate erosion controls should be implemented;
- To prevent fauna injury and mortality, an appropriately qualified and experienced fauna spotter/catcher should be present during clearing operations and speed limits shall be implemented across the Project site;
- Potential environmental offsetting for impacts on matters of State Environmental Significance such as Purple-necked Rock-wallabies and Regional Ecosystems on watercourses;
- Emission control measures should be implemented to minimise dust and noise generation, control artificial lighting;
- Chemicals and hazardous substances should be stored in accordance with the relevant Material Safety Data Sheets;
- Waste receptacles and artificial water sources should be fenced or sealed to prevent increases in pest abundance;
- A Bushfire Management Plan should be developed to minimise the risk of uncontrolled fires;
- A Weed Management Plan should be developed and implemented;
- A Pest Management Plan should be developed and implemented; and
- All staff and contractors are to receive environmental awareness and mitigation training.

1.0 INTRODUCTION

AustralAsian Resource Consultants Pty Ltd (AARC) was commissioned by CopperChem Limited (CopperChem) to conduct a Terrestrial Flora and Fauna Assessment of the proposed Barbara Copper Project (the Project). This work constitutes one of the baseline studies required for the Project's Environmental Authority Application.

This study provides an assessment of the presence of flora and fauna species on the Project site and identifies potential impacts that the proposed mining activities (construction, operation and decommissioning) may have on the local biota.

The Barbara Copper Project is a proposed copper-gold mining operation in north-west Queensland. The Project is a joint venture between CopperChem Limited and Syndicated Metals Limited. The Project site occurs within the Mineral Exploration Permit (EPM) tenements 16112 and 15564 and encompasses Mining Lease Application (MLA) 90241. This assessment covers approximately 1945 hectares (ha) of land which is referred to herein, as the Study area. The location of the Barbara Copper Project is shown in Figure 1.

To gain an understanding of the site's ecological values under various climatic conditions, four terrestrial flora and fauna surveys have been conducted during the 2011 and 2014 wet and dry seasons. The Project area assessed during the 2011 surveys was limited to Mining Lease Application (MLA) 90241. As the Study area has since expanded, additional surveys were conducted in 2014 to encompass the entire area of interest. Flora and fauna surveys were conducted as follows:

- A preliminary wet season survey was conducted over seven day period between the 28th March 2011 and 3rd of April 2011;
- A dry season survey conducted over a period of seven days between the 19th and 25th October 2011;
- A second wet season survey was conducted over nine consecutive days from the 30th January to 7th February 2014; and
- A second dry season survey was conducted over eight consecutive days from the 1st to 8th August 2014.

1.1 SCOPE OF STUDY

To assess the ecological values of flora and fauna communities within the Project site, the following scope of works was undertaken:

- Database searches to identify species of conservation significance known from the region (provided in Appendix A). This enabled these species to be targeted during the field survey component of the study;
- Field surveys employing standard methodologies to determine the composition of terrestrial flora and fauna species inhabiting the Project site, particularly species of conservation significance; and
- The preparation of a report to CopperChem describing the ecological features identified and outlining possible management strategies to reduce any foreseeable impact associated with the proposed mining activities.

2.0 PROJECT DESCRIPTION

Sections 2.1 to 2.5 describe the relevant aspects of the Project site, including location, local geography, topography, local watercourses, regional climate and current land uses.

2.1 PROJECT LOCATION

The Barbara Copper Project is situated in the Mount Isa Inlier, of the Northwest Highlands Bioregion, approximately 50 kilometres (km) north-east of Mount Isa and 100 km west of Cloncurry. The city of Mount Isa is the closest residential area. The regional location of the Project site is shown in Figure 1.

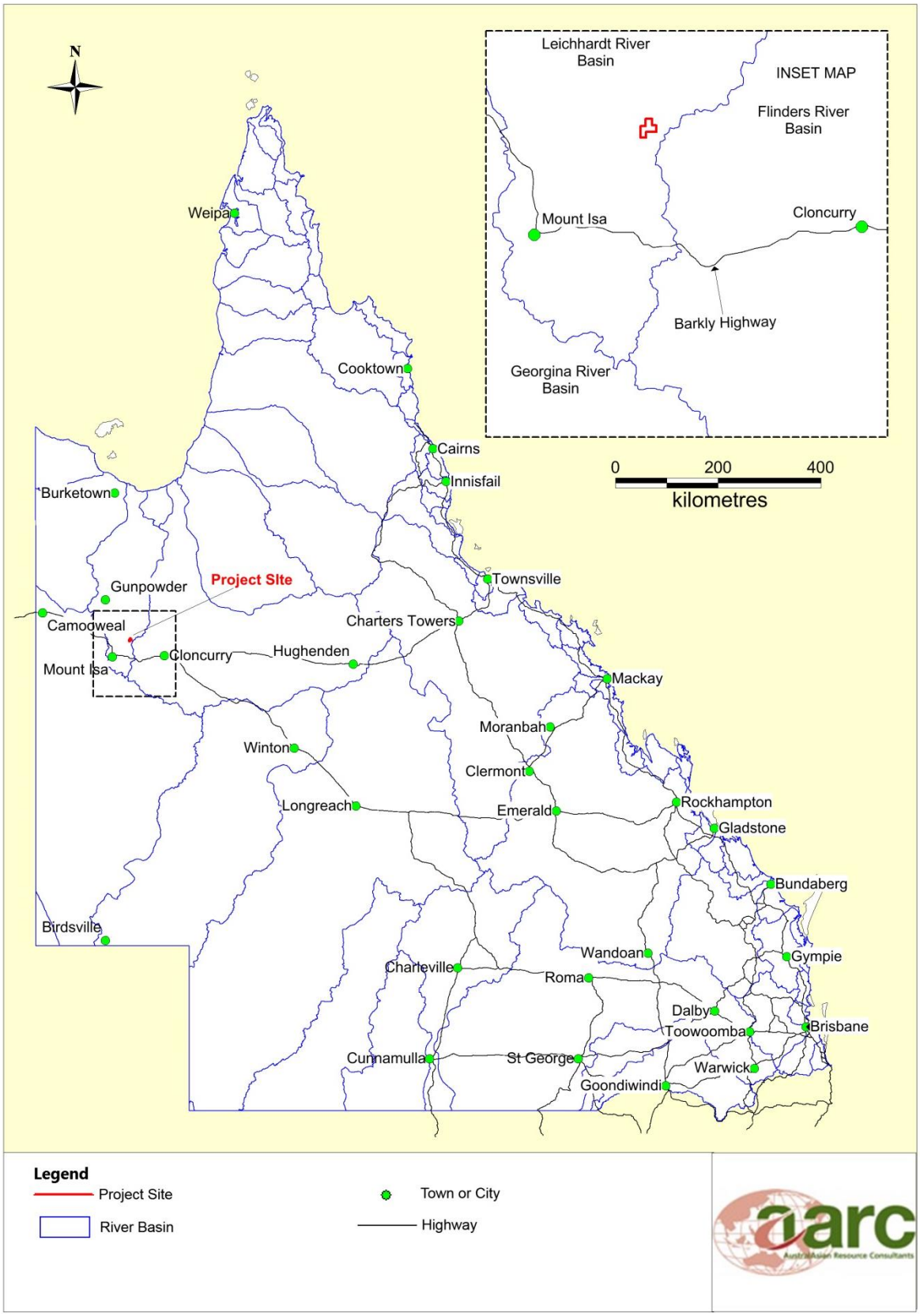

Figure 1 Project Locality

2.2 LOCAL WATERWAYS AND TOPOGRAPHY

The Project site is largely situated on rocky, undulating hills and outcropping, rocky ridgelines. The Project site lies within the Leichhardt drainage basin which spans an area of approximately 32, 878 square kilometres (km^2), originating to the south of Mount Isa and draining via the Leichhardt River into the Gulf of Carpentaria.

The Project is traversed by numerous drainage lines and ephemeral watercourses which drain into the Leichhardt River (refer to Figure 2). With the exception of one stream order 3 watercourse ('Watercourse A'), all other watercourses on the Project are classified as stream order 1 and 2. The third order watercourse passes from the east, through the south-west portion of the site, flows west, off-site and returns through the western boundary in the north before heading off-site and draining north-west into the Leichhardt River. All other drainage lines and tributaries occurring on the Project site drain into the third order watercourse. The Leichhardt River eventually drains into the Gulf of Carpentaria.

One permanent and several semi-permanent waterholes occur on watercourses throughout the Project site (refer to Figure 2). There are no wetlands or pastoral dams on the Project site.

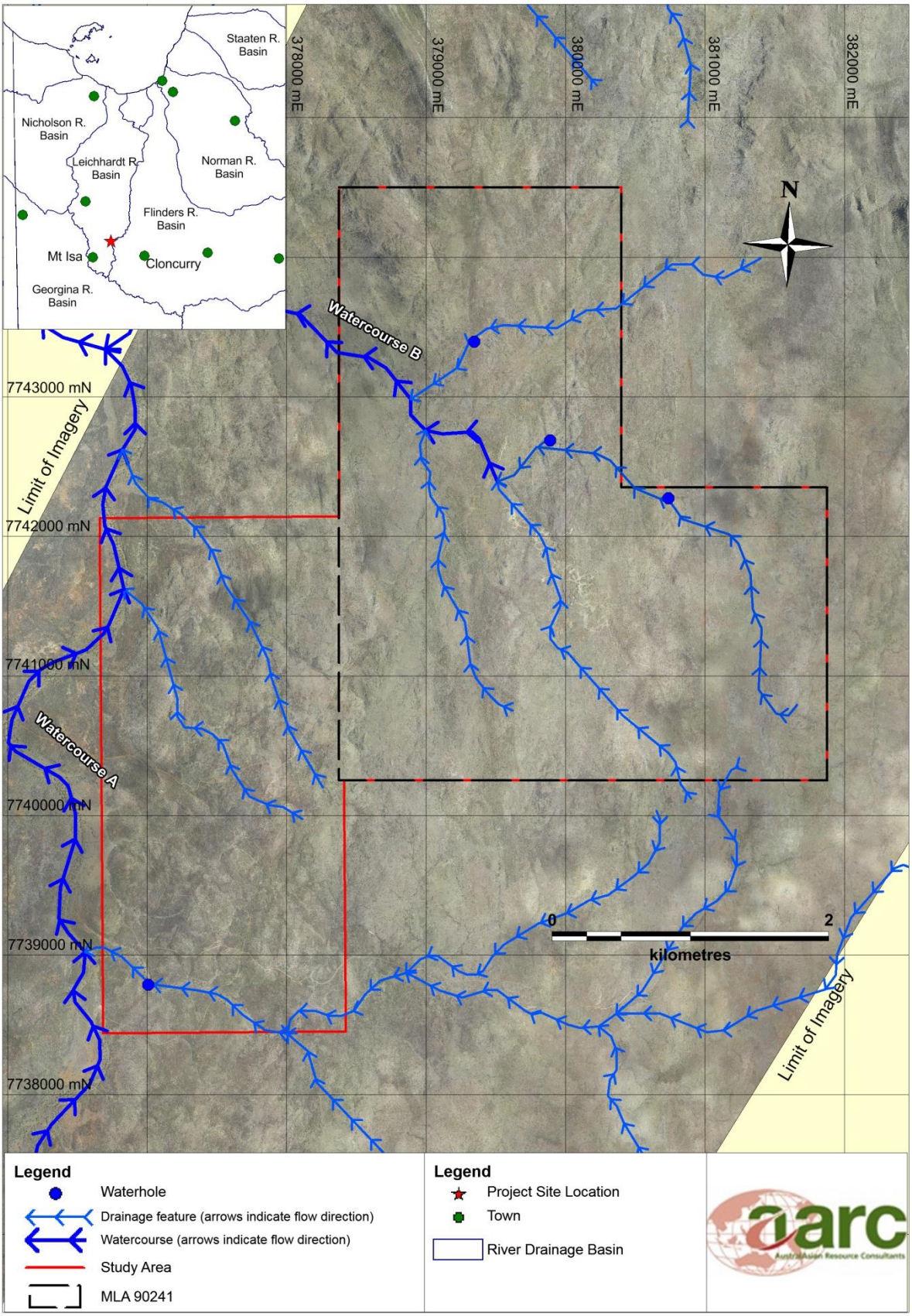

Figure 2 Waterbodies on and Surrounding the Project Site

2.3 GEOLOGY

The underlying geology on the project site is comprised predominantly of old Leichhardt Metamorphics from the Proterozoic era. Leichhardt metamorphics are made up of old metamorphic rock of volcanic origin and includes rhyolite, rhyodacite and dacite, phyllonite, acid gneiss, minor tiff, siltstone and quartzsite.

The copper sulphide starts close to surface and is up to 45 metres in thickness and consists of massive sulphide through to stringer veins within an alteration zone of biotite, tourmaline and quartz.

The near surface copper mineralisation is recoverable through open pit mining with the higher grade material below the limits of an open pit potentially recoverable by underground mining methods.

2.4 REGIONAL CLIMATE

The climate is characterised by semi-arid conditions with hot, wet summer months influenced by monsoonal activity and dry, cold winter months. The mean annual rainfall for the region (based on data from the West Leichhardt Station weather station between 1893 and 2014) is approximately 430 millimetres (mm). Mean monthly rainfall recorded from the West Leichhardt Station (station no. 29121) since 1893 is shown in Figure 3. This graph indicates the wet season occurs between December and March and dry season conditions occur between April and November.

Mean minimum and maximum temperatures for the region have been sourced from the Mount Isa Aero weather station (station no. 29127) which provides data recorded over a period of 48 years between 1966 and 2014. Monthly mean minimum and maximum temperatures for the region are shown in Figure 3. Generally, the hottest months occur between October and March and the coldest months occur between May and August. The highest mean maximum temperature occurs in December while the lowest mean minimum temperature occurs in July. The annual mean maximum temperature for the region is 31.8°C while the annual mean minimum temperature is 17.2°C.

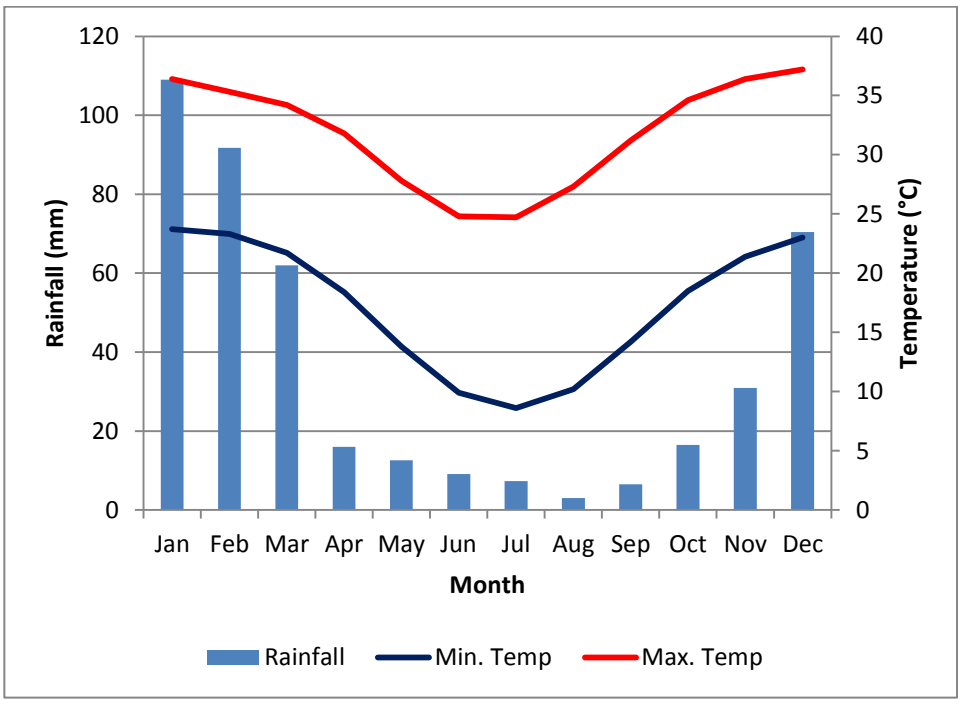

Figure 3 Mean Temperature and Rainfall Data for the Region

2.5 CURRENT LAND USE

Current land uses on the Project site include low intensity cattle grazing and mineral exploration activities. Historically, mining activities and cattle grazing have dominated the land-use, evidence of this is noted throughout the site, with fences, cattle grids and disused mine shafts obvious.

3.0 RELEVANT LEGISLATION, POLICY AND GUIDELINES

3.1 LEGISLATION

Commonwealth and State legislation relevant to the assessment of flora, fauna and biodiversity on the Project site is discussed below.

3.1.1 Commonwealth Environment Protection and Biodiversity Conservation Act 1999

Under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), an action will require approval from the Federal Environment Minister if the action has, will have, or is likely to have a significant impact on a Matter of National Environmental Significance, where a Matter of National Environmental Significance is:

- World Heritage Properties;
- National Heritage Places;
- RAMSAR wetlands of international importance;
- Listed threatened species and communities;
- Migratory species protected under international agreements;
- Nuclear actions; and
- The Commonwealth marine environment.

Of the above Matters of National Environment Significance, the following is applicable to the Project site:

- Migratory species protected under international agreements.

The Project is unlikely to affect any MNES therefore no EPBC referral has been submitted and no controlled actions are to be applied.

3.1.2 Queensland Nature Conservation Act 1992

The most relevant components of the *Nature Conservation Act 1992* (NC Act) to the Project are the sections which pertain to Wildlife and Habitat Conservation. The classes of wildlife[1] to which the NC Act applies include protected wildlife, which is defined as:

- Extinct wildlife;
- Endangered wildlife;
- Vulnerable wildlife;
- Near Threatened wildlife; and

[1]Under the NC Act, wildlife is defined to be any taxon of an animal, plant, protist, prokaryote or virus.

- Least Concern wildlife.

Species listed under the above classes are published in the associated *Nature Conservation (Wildlife) Regulation 2006* (NCWR).

The NC Act defines 'threatening processes' as any process that is capable of:

a) Threatening the survival of any protected area, area of major interest, protected wildlife, community of native wildlife or native wildlife habitat; or

b) Affecting the capacity of any protected area, area of major interest, protected wildlife, community of native wildlife or native wildlife habitat to sustain natural processes.

The NC Act is relevant to the Project site should any protected[2] flora or fauna species (as detailed in the NCWR) be found on the Project site.

3.1.3 Queensland Vegetation Management Act 1999

The *Vegetation Management Act 1999* (VM Act) is a part of a planning framework for the management of native vegetation across Queensland. The *Vegetation Management Regulation 2012* (VMR) prescribes the status of each of the REs identified within Queensland.

Although the VM Act does not apply to the clearing of vegetation on the Project site, the scientific basis for biodiversity conservation is still valid and can be used to assess the conservation significance of the vegetation communities on the Project site. This includes the conservation status categories of each RE under the VM Act, which are listed below, as is the definition of Remnant Vegetation.

Endangered Regional Ecosystems:

- <10% of pre-clearing extent remaining; and
- 10 - 30% of pre-clearing extent remaining and remnant <10,000 ha.

Of Concern Regional Ecosystems:

- 10 - 30% of pre-clearing distribution remains; and
- 30% of the pre-clearing extent remains and the remnant vegetation remaining is <10,000 ha.

Least Concern Regional Ecosystems:

- >30% of the pre-clearing distribution remains and remnant vegetation remaining is >10,000 ha.

Remnant Vegetation:

'Remnant Vegetation' for an area of Queensland for which there is no RE map or remnant vegetation map is any vegetation where the predominant canopy:

[2] Under the *Nature Conservation Act 1992*, a protected plant is any threatened, near threatened or least concern wildlife. Similarly, protected fauna is defined as being any native wildlife prescribed under the Act.

- covers more than 50% of the undisturbed predominant canopy;
- averages more than 70% of the vegetation's undisturbed height; and
- is composed of species characteristic of the vegetation's undisturbed dominant canopy.

3.1.4 Queensland Land Protection (Pest and Stock Route Management) Act 2002

The objectives of the Land Protection (Pest and Stock Route Management) Act 2002 (LP Act) are to provide for:

a) Pest Management; and

b) Stock route network management.

Chapter 2 of the LP Act relates directly to the management, control, prohibition, and regulation of the introduction, spread and keeping of certain plants and animals declared under the Act.

Classes of pests described in the LP Act include:

- Class 1 – one that is not commonly present in Queensland, and if introduced would cause an adverse economic, environmental or social impact;
- Class 2 – one that is somewhat established in Queensland and has, or could have, a substantial adverse economic, environmental or social impact; and
- Class 3 – one that is extensive in Queensland and has, or could have, an adverse economic, environmental or social impact.

Chapter 3 of the LP Act relates to the protection and management of the state stock route network.

The LP Act is relevant to the Project site in regards to the control and management of declared pest plant (weed) and animal species.

3.2 POLICIES AND GUIDELINES

Current policies and guidelines, conservation, recovery and management plans that have been produced by government or non-government organisations relevant to flora, fauna and biodiversity on the Project site are discussed below.

3.2.1 Offsets under the Environmental Protection and Biodiversity Conservation Act 1999

The purpose of the draft policy *Use of Environmental Offsets under the Environment Protection and Biodiversity Conservation Act 1999* statement is to outline the Australian Government's position on the use of environmental offsets under the EPBC Act. Environmental offsets can be used under the EPBC Act to maintain or enhance the health, diversity and productivity of the environment as it relates to matters protected by the EPBC Act.

Environmental offsets can be applied as an approval condition under the EPBC Act for developments that have undergone assessment. They may be used when a development will result in impacts on a matter protected by the EPBC Act. Environmental offsets are not applicable to all approvals under the EPBC Act. Offsets should not be applied where the impacts of a development are considered to be

minor in nature or could reasonably be mitigated. In some circumstances suitable offsets may not be available to adequately compensate for the impacts of a development and a decision on the overall acceptability of the project will need to be made.

Eight principles have been identified by the Australian Government for the use of environmental offsets under the EPBC Act. These principles are used in assessment of any proposed environmental offsets. The eight principles include:

1. Environmental offsets should be targeted to the matter protected by the EPBC Act that is being impacted.

2. A flexible approach should be taken to the design and use of environmental offsets to achieve long-term and certain conservation outcomes which are cost effective for proponents.

3. Environmental offsets should deliver a real conservation outcome.

4. Environmental offsets should be developed as a package of actions - which may include both direct and indirect offsets.

5. Environmental offsets should, as a minimum, be commensurate with the magnitude of the impacts of the development and ideally deliver outcomes that are 'like for like'.

6. Environmental offsets should be located within the same general area as the development activity.

7. Environmental offsets should be delivered in a timely manner and be long lasting.

8. Environmental offsets should be enforceable, monitored and audited.

3.2.2 Queensland Environmental Offsets Policy

The *Queensland Environmental Offsets Policy (Version 1.0)* requires offsets for a broad range of activities, including mining projects. Offsets are required when an applicant has demonstrated that despite all efforts to avoid or minimise impacts on Matters of State Environmental Significance (MSES) there is still residual impact. MSES (as outlined in Schedule 2 of the *Environmental Offsets Regulation 2014*) include:

- Regulated vegetation including:

    i. Endangered and Of Concern regional ecosystems;

    ii. Regional ecosystems that intersect areas shown as wetlands on the Vegetation Management Wetlands map;

    iii. Regional ecosystems located within a prescribed distance from the defining banks of a watercourse; or

    iv. Essential habitat;

- Areas that provide connectivity;

- Mapped wetlands and watercourse including:

i. wetland protection areas, or areas of high ecological significance as shown on the Map of referable wetlands;

ii. high ecological value waters (as defined und the Environmental Protection (Water) Policy 2009);

- High preservation areas within a Wild Rivers area;
- Protected wildlife habitat;
- Protected areas;
- Highly protected zones of State marine parks;
- Fish habitat areas;
- Waterways providing for fish passage;
- Marine plants; and
- Legally secured offsets.

Offsets can be delivered as proponent-driven offset, by financial settlement offset or a combination of both delivery options. A proponent-driven offset means that the authority holder (or proponent) is responsible for undertaking the delivery of the offset which may be delivered as a 'land-based' offset or as a Direct Benefit Management Plan (DBMP), or a combination. A DBMP is a strategy that delivers an offset through priority management actions that address threats to, and provide substantial benefits for the impacted prescribed environmental matter, including on a landscape scale. A DBMP may also be used to deliver a conservation outcome from a financial settlement offset.

The Project has the potential to have residual impacts on the following state significant environmental values:

- Protected wildlife habitat; and
- Regional ecosystems on watercourses.

No other MSES occur on the Project site.

Offsets proposed must comply with the criteria and offset rules set out in the *Queensland Environmental Offset Policy*.

3.2.3 Biodiversity and Mapping Methodology (BAMM)

The Biodiversity and Mapping Methodology was developed in 2002 and has application for identifying areas with various levels of significance for biodiversity. These include threatened ecosystems or taxa, large tracts of habitat in good condition and buffers to wetlands or other types of habitat important for the maintenance of biodiversity. Essential Habitat, RE Mapping, habitat quality and connectivity are all addressed in BAMM.

3.2.4 Queensland Biodiversity Planning Assessments and EHP Biodiversity Status

In 2002 Expert Panels were established to appraise biodiversity values in each of Queensland's bioregions. A specialised panel was established to assess biodiversity values for Fauna, Flora or Landscape. Findings from these panels were made in conjunction with Biodiversity Assessment Mapping Methodology (BAMM) and contributed to the Biodiversity Planning Assessments (BPA) for each subregion.

Biodiversity components included in the BPA consisted of threatened ecosystems or taxa, large tracts of habitat in good condition, ecosystem diversity, landscape context and connection, and buffers to wetlands or other types of habitat important for the maintenance of biodiversity or ecological processes. Assessments were all integrated into GIS maps and databases.

Biodiversity Planning Assessments are occasionally updated to address changes in status, taxonomy or mapping.

The Department of Environment and Heritage Protection (EHP) 'Biodiversity Status' is derived from the BAMM and is regulated under the Environment Protection Act. It is a conservation prioritisation system involving assigning status to particular REs to assist with biodiversity planning in Queensland. Unlike the status of REs under the VM Act, the EHP Biodiversity status is based on an assessment of criteria derived from BAMM in addition to knowledge of the pre-clearing and extent of the RE (taken from data collected under the VM Act). It takes into account other threatening processes in addition to land clearing. Such processes include:

- The reduction in biodiversity within the REs;
- Weed invasion;
- Grazing pressures;
- Inappropriate fire management;
- Fragmentation; and
- Infrastructure development.

Geographical Information System (GIS) data output displays spatial information on the significant features identified during the BPAs.

No significant BPA values have been identified on the Project site as a BPA has not yet been prepared and approved for the Northwest Highlands Bioregion.

3.2.5 Back on Track Species Prioritisation Framework

The "Back on Track" (BoT) species prioritisation framework is a Queensland government initiative developed to:

- Prioritise Queensland's native species to guide conservation management and recovery;
- Enable the strategic allocation of limited conservation resources for achieving greatest biodiversity outcomes; and

- Increase the capacity of government, Natural Resource Management (NRM) bodies and communities to make informed decisions by making information widely accessible.

The framework prioritises all fauna and flora species irrespective of their classification under the NC Act or EPBC Act. A series of criteria are used to prioritise each species or taxon. This allows relevant parties to identify species that are at risk and species which have the greatest chance of recovery with available resources.

The framework also identifies actions and threats common to a range of species encouraging a multi-species or landscape approach to conservation.

A “Back on Track Actions for Biodiversity Document” has been produced to address priority species and associated impacts and actions for each NRM region. A list of priority species/taxa has been developed for each NRM region and a ‘Back on Track’ priority ranking has been given to each. A separate priority ranking for NRM region and state wide has been given to each species. The list of Priority Species for state and NRM region can be accessed from the Back on Track Actions for Biodiversity Document or by searching the Recovery Actions Database (RAD).

Desktop research may reveal that some of the species identified as ‘priority’ taxa for the NRM region and the state of QLD may occur on the Project site or in the surrounding area. These species have been addressed in this report.

4.0 DATABASE SEARCH AND LITERATURE REVIEW

Database searches collate information on flora and fauna species, regional ecosystems and important habitat areas identified in the region from previous surveys, community records and other sources. A review of such databases facilitates the formulation of specific field survey techniques to target certain flora and fauna species known from the region.

The following database searches were completed using a 100 km buffer around a central coordinate:

- Protected Matters Search, administered by the Department of the Environment (DOE). This search was used to ascertain if any Matters of National Environmental Significance are likely to occur on the Project site; and

- EHP's Wildlife Online database. This search provides a list of all flora and fauna species recorded in the search area, including any threatened species.

EHP's RE mapping was reviewed to determine which remnant vegetation communities were mapped on the Project area. The RE mapping also shows any mapped Essential Habitat for threatened species.

EHP's Environmentally Sensitive Area (ESA) mapping was consulted to identify any ESAs on the Project site. ESAs include endangered REs, national parks, state forests, Ramsar wetlands and other protected areas.

The 'Back on Track' Species Prioritisation Framework Recovery Actions Database (RAD) for the Southern Gulf Catchment was consulted to identify the regionally significant fauna and flora species in the Project region.

Queensland Wetland Mapping Database was searched to determine if there are any wetlands mapped on the Project site.

Relevant literature and reports from previous ecological surveys conducted in the vicinity of the Project were also reviewed. The following reports were consulted to gain an understanding of the ecology of the Project area:

- Mount Remarkable Project: Interim Terrestrial Flora and Fauna Report (EcoSmart Ecology 2011); and

- Mount Remarkable Project: Terrestrial Flora and Fauna Assessment (AARC 2012).

The database searches and literature review revealed that a number of flora and fauna species of conservation significance are known from the Project site and surrounding area. Database search results are included in Appendix A and summarised below.

4.1 FLORA

4.1.1 Threatened Ecological Communities

The Protected Matters Search tool indicates that no Threatened Ecological Communities occur within 100 km of the Project site.

4.1.2 Regional Ecosystems

A review of the Regional Ecosystem mapping revealed the Project site contains five REs as listed in Table 1 below. These REs are present as either whole or mixed polygons. All five REs are listed under the VM Act as Least Concern. Under the EHP Biodiversity Status, RE 1.3.6 is listed as Of Concern and RE 1.3.7 is listed as Endangered. The RE map for the Project site is shown in Figure 4.

Table 1 Regional Ecosystems Mapped within the Project Site

Regional Ecosystem	Description	VM Act Status	EHP Biodiversity Status
1.3.6	*Corymbia aparrerinja*, *Corymbia terminalis* open woodland on sandy terraces	Least Concern	Of Concern
1.3.7	*Eucalyptus camaldulensis* woodland on channels and levees	Least Concern	Endangered
1.11.2	*Eucalyptus leucophloia* low open woodland	Least Concern	No Concern at Present
1.11.3	*Corymbia terminalis* low open woodland on basic metamorphics	Least Concern	No Concern at Present
1.12.1	*Eucalyptus leucophloia* low open woodland on granites	Least Concern	No Concern at Present

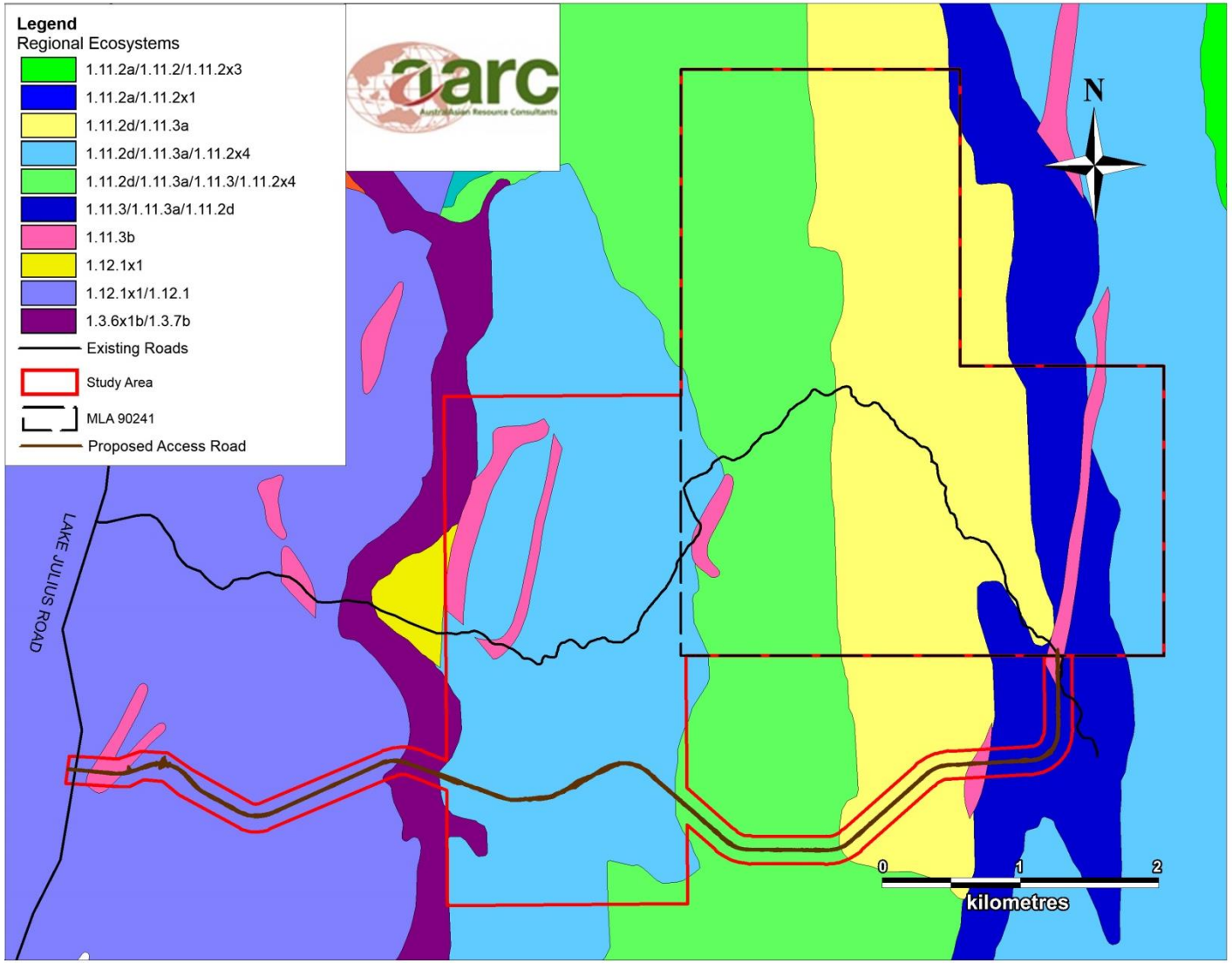

Figure 4 Regional Ecosystem Mapping over the Project Site

4.1.3 Species of Conservation Significance

A protected plants flora survey trigger map was generated using co-ordinates centred on the Project site. This search was undertaken to identify any areas at high risk of supporting protected flora species on the Project or surrounding lands. Areas shown on the map as high risk are subject to particular requirements under Queensland legislation. This search identified no high risk areas on the Project or surrounding region.

Database searches identified two flora species of conservation significance that have been recorded within the region in which the Project is located (Appendix A). These species are listed in Table 2 along with a summary of the habitat requirements and the conservation status of each.

Table 2 Flora Species of Conservation Significance within the Project Region

Scientific Name	Conservation Status		Habitat Description
	NC Act	EPBC Act	
Ptilotus maconochiei	NT	NL	*Eucalyptus leucophloia* and *Corymbia aspera* woodland, with *Triodia pungens* groundcover. On quartzite ridge tops, hillsides, slopes and shale
Ipomoea antonschmidii	NT	NL	*Eucalyptus leucophloia, Corymbia capricornia, Corymbia aparrerinja* and *Eucalyptus camaldulensis* woodlands. Grows in a variety of habitats, including rocky, sandy and red clay substrates. Occurs along the Lake Julius pipeline, Gunpowder and north of Mount Isa

Key:

NL - indicates this species is not listed under the EPBC Act.
NT - indicates this specie is listed in the schedules of the NCWR as a Near Threatened species

4.1.4 Back on Track Flora Species

The RAD search results indicate two BoT priority flora species occur in the Southern Gulf NRM region. These species are listed in Table 3. This table also details the BoT level of priority, NC Act and EPBC Act classifications for each species.

Table 3 Southern Gulf NRM Region Back on Track Priority Flora Species

Scientific Name	Common Name	NRM BoT Priority Ranking	State BoT Priority Ranking	NC Act Status	EPBC Act Status
Cycas couttsiana	-	High	Critical	NT	NL
Eriocaulon carsonii	-	Critical	High	E	E
Pandanus aquaticus	River Pandanus	High	Medium	LC	NL
Aponogeton queenslandicus		High	Medium	LC	NL

Key: NT – Near Threatened, E – Endangered, LC – Least Concern, NL – Not Listed

C. couttsiana is known only to occur in the southern Gregory Range, approximately 430 km to the north-east of the Project site. It occurs in open grassy woodlands in red sandy loams derived from basalt or dolerite, on flat to steeply sloping country (Hill 1998). Suitable habitat for this species is not likely to occur on the Project site.

E. carsonii is known to occur only in spring fed wetlands in relatively flat landscapes where permanent groundwater occurs. Suitable habitat for this species does not occur on or adjacent to the Project site.

Pandanus aquaticus occurs in tropical regions of north-western Queensland, Northern Territory and Western Australia. It grows in shallow water and along the margins of watercourses. Suitable habitat for this species is restricted to the gulf estuaries to the far north of the Project.

Aponogeton queenslandicus is a perennial aquatic plant that grows in temporary freshwater bodies, typically 30 – 60 cm in depth, in drier regions. It prefers clay substrates and occurs in gilgais, melon-holes and roadside ditches. The Project site does not provide suitable habitat for this species.

4.2 FAUNA

4.2.1 Fauna Species of Conservation Significance

Thirty-one fauna species have been identified or potentially occur in the region surrounding the Project site. These species are listed in Table 4.

No essential habitat for threatened fauna was identified on the Regional Ecosystem mapping for the Project site.

Table 4 Fauna Species of Conservation Significance Occurring within the Project Region

Scientific Name	Common Name	Status	
		EPBC Act	NC Act
Birds			
Accipiter novaehollandiae	Grey Goshawk	NL	NT
Amytornis dorotheae	Carpentarian Grasswren	NL	NT
Ephippiorhynchus asiaticus	Black-necked Stork	NL	NT
Epthianura crocea crocea	Yellow Chat (gulf)	NL	V
Erythrotriorchis radiatus	Red Goshawk	V	E
Erythrura gouldiae	Gouldian Finch	E	E
Falco hypoleucos	Grey Falcon	NL	NT
Grantiella picta	Painted Honeyeater	NL	V
Heteromunia pectoralis	Pictorella Mannikin	NL	NT
Lophoictinia isura	Square-tailed Kite	NL	NT

Scientific Name	Common Name	Status	
		EPBC Act	NC Act
Malurus coronatus	Purple-crowned Fairy-wren	NL	V
Melithreptus gularis laetior	Golden-backed Honeyeater	NL	NT
Nettapus coromandelianus	Cotton Pygmy-goose	NL	NT
Numenius madagascariensis	Eastern Curlew	Ma, Mi	NT
Pezoporus occidentalis	Night Parrot	E	E
Poephila cincta cincta	Black-throated Finch (southern)	E	E
Polytelis alexandrae	Princess Parrot	V	NL
Rostratula australis	Australian Painted Snipe	E	V
Stictonetta naevosa	Freckled Duck	NL	NT
Mammals			
Hipposideros stenotis	Northern Leaf-nosed Bat	NL	V
Macrotis lagotis	Greater Bilby	V	E
Petrogale purpureicollis	Purple-necked Rock-wallaby	NL	V
Pseudantechinus mimulus	Carpentarian Antechinus	V	NL
Sminthopsis douglasi	Julia Creek Dunnart	E	E
Tachyglossus aculeatus	Short-beaked Echidna	NL	SL
Reptiles			
Acanthophis hawkei	Plains Death Adder	V	NL
Elseya lavarackorum	Gulf Snapping Turtle	E	V
Emydura subglobosa worrelli	Diamond Head Turtle	NL	NT
Sharks			
Pristis pristis	Freshwater Sawfish	V	NL

Key:
E – indicates this species is listed as Endangered under the NC Act or the EPBC Act
V – indicates this species is listed as Vulnerable under the NC Act or the EPBC Act
NT – indicates this species is listed as Near Threatened under the NC Act or the EPBC Act
LC – indicates this species is listed as Least Concern under the NC Act or the EPBC Act
SL – indicates this species is listed as Special Least concern under the NC Act
Mi – indicates this species is classified as a Migratory species under the EPBC Act
Ma - indicates this species is classified as a Marine species under the EPBC Act
NL - indicates this species is not listed as a threatened species under either the NC Act or the EPBC Act

4.2.2 Back on Track Fauna Species

The RAD search results indicate 14 BoT priority terrestrial fauna species occur in the Southern Gulf NRM region. These species are listed in Table 5. This table details the BoT priority ranking at the state and regional level, as well as the NC Act and EPBC Act classifications for each species. It should be noted that marine animals have been excluded from these results.

Table 5 Back on Track Priority Fauna Species in the Southern Gulf NRM region

Scientific Name	Common Name	BoT Priority Ranking		NC Act Status	EBBC Act Status
		NRM Region	State		
Birds					
Amytornis ballarae	Kalkadoon Grasswren	High	High	LC	NL
Amytornis dorotheae	Carpentarian Grasswren	High	High	NT	NL
Erythrotriorchis radiatus	Red Goshawk	High	High	E	V
Esacus magnirostris	Beach Stone-curlew	High	High	V	NL
Grantiella picta	Painted Honeyeater	High	High	V	NL
Lophochroa leadbeateri	Major Mitchell's Cockatoo	High	High	V	NL
Malurus coronatus	Purple-crowned Fairy-wren	High	High	V	NL
Neochmia ruficauda clarescens	Star Finch (northern subspecies)	High	High	LC	NL
Rostratula australis	Australian Painted Snipe	High	Medium	V	E
Sternula albifrons	Little Tern	High	High	E	NL
Mammals					
Macroderma gigas	Ghost Bat	Critical	Critical	V	NL
Sminthopsis douglasi	Julia Creek Dunnart	Critical	Critical	E	E
Reptiles					
Acanthophis antarcticus	Common Death Adder	High	Medium	NT	NL
Elseya lavarackorum	Gulf Snapping Turtle	High	High	V	E

Key:
E – indicates this species is listed as Endangered under the NC Act or the EPBC Act
V – indicates this species is listed as Vulnerable under the NC Act or the EPBC Act
NT – indicates this species is listed as Near Threatened under the NC Act or the EPBC Act
LC – indicates this species is listed as Least Concern under the NC Act or the EPBC Act
NL - indicates this species is not listed as a threatened species under the NC Act or the EPBC Act

4.2.3 Migratory Fauna Species

The Protected Matter Search identified 40 listed migratory, marine and/or Special Least Concern (as classified under the NC Act) species that may inhabit the Project region. Special Least Concern (SL) species are those species which are classified as least concern under the NC Act and are subject to a special bilateral or international agreement[3]. A full list of migratory species is presented in Table 6.

Table 6 Migratory and Marine Species within the Project Region

Scientific Name	Common Name	NC Act Special Least Concern	Listed Marine Species	Listed Migratory Species		
				Marine Species	Terrestrial Species	Wetland Species
Acrocephalus australis	Australian Reed-warbler	X	-	-	-	-
Actitis hypoleucos	Common Sandpiper	X	X	-	-	-
Anseranas semipalmata	Magpie Goose	-	X	-	-	-
Apus pacificus	Fork-Tailed Swift	X	X	X	-	-
Ardea alba	Great Egret	X	X	-	-	X
Ardea ibis	Cattle Egret	X	X	-	-	X
Arenaria interpres	Ruddy Turnstone	X	X	-	-	-
Calidris acuminata	Sharp-tailed Sandpiper	X	X	-	-	X
Calidris ferruginea	Curlew Sandpiper	X	X	-	-	X
Calidris ruficollis	Red-necked Stint	X	X	-	-	X
Calidris subminuta	Long-toed Stint	X	X	-	-	-
Charadrius mongolus	Lesser Sand Plover	X	X	-	-	X
Charadrius ruficapillus	Red-capped Plover	-	X	-	-	-
Charadrius veredus	Oriental Plover	X	X	-	-	X
Chlidonias leucopterus	White-winged Black Tern	X	X	-	-	-
Cuculus optatus	Oriental cuckoo	X	X	-	-	-
Gallinago hardwickii	Latham's Snipe	X	X	-	-	-
Gallinago megala	Swinhoe's snipe	X	X	-	-	-

[3] Such agreements include Japan-Australia Migratory Bird Agreement (JAMBA), China-Australia Migratory Bird Agreement (CAMBA) & Bonn Convention.

Scientific Name	Common Name	NC Act Special Least Concern	Listed Marine Species	Listed Migratory Species		
				Marine Species	Terrestrial Species	Wetland Species
Glareola maldivarum	Oriental Pratincole	X	X	-	-	X
Haliaeetus leucogaster	White-Bellied Sea-Eagle	X	X	-	X	-
Himantopus himantopus	Black-winged Stilt	-	X	-	-	-
Hirundo rustica	Barn Swallow	X	X	-	-	-
Hydroprogne caspia	Caspian tern	X	X	-	-	-
Limosa lapponica	Bar-tailed Godwit	-	X	-	-	X
Limosa limosa	Black-tailed Godwit	X	X	-	-	X
Merops ornatus	Rainbow Bee-eater	X	X	-	X	-
Numenius minutus	Little Curlew	X	X	-	-	X
Numenius phaeopus	Whimbrel	-	X	-	-	X
Pandion cristatus	Eastern Osprey	X	-	-	-	-
Pandion haliaetus	Osprey	-	X	-	-	-
Phalaropus lobatus	red-necked phalarope	-	X	-	-	-
Plegadis falcinellus	Glossy Ibis	X	X	-	-	-
Pluvialis fulva	Pacific Golden Plover	X	X	-	-	X
Recurvirostra novaehollandiae		-	X	-	-	-
Rostratula australis	Australian Painted Snipe	-	X	-	-	X
Stiltia isabella		-	X	-	-	
Tringa glareola	Wood Sandpiper	X	X	-	-	X
Tringa nebularia	Common Greenshank	X	X	-	-	-
Tringa stagnatilis	Marsh Sandpiper	X	X	-	-	X
Xenus cinereus	Terek Sandpiper	X	X	X	-	-

4.3 ENVIRONMENTALLY SENSITIVE AREAS

A review of EHP's ESA mapping revealed a Category B ESA is mapped as occurring in the west of the Project site (refer to Figure 5). This ESA presents as a narrow strip of RE 1.3.7 - River Red Gum (*Eucalyptus camaldulensis*) woodland on channels and levees, occurring along the western boundary and adjoining lands. RE 1.3.7 is classified under EHP's Biodiversity Status as Endangered. No conservation parks, declared fish habitat areas, wilderness areas, aquatic reserves, heritage or historic areas, national estates, World Heritage listings, sites listed under international treaties or agreements or biodiversity and scientific reserves are located within or adjacent to the Project site.

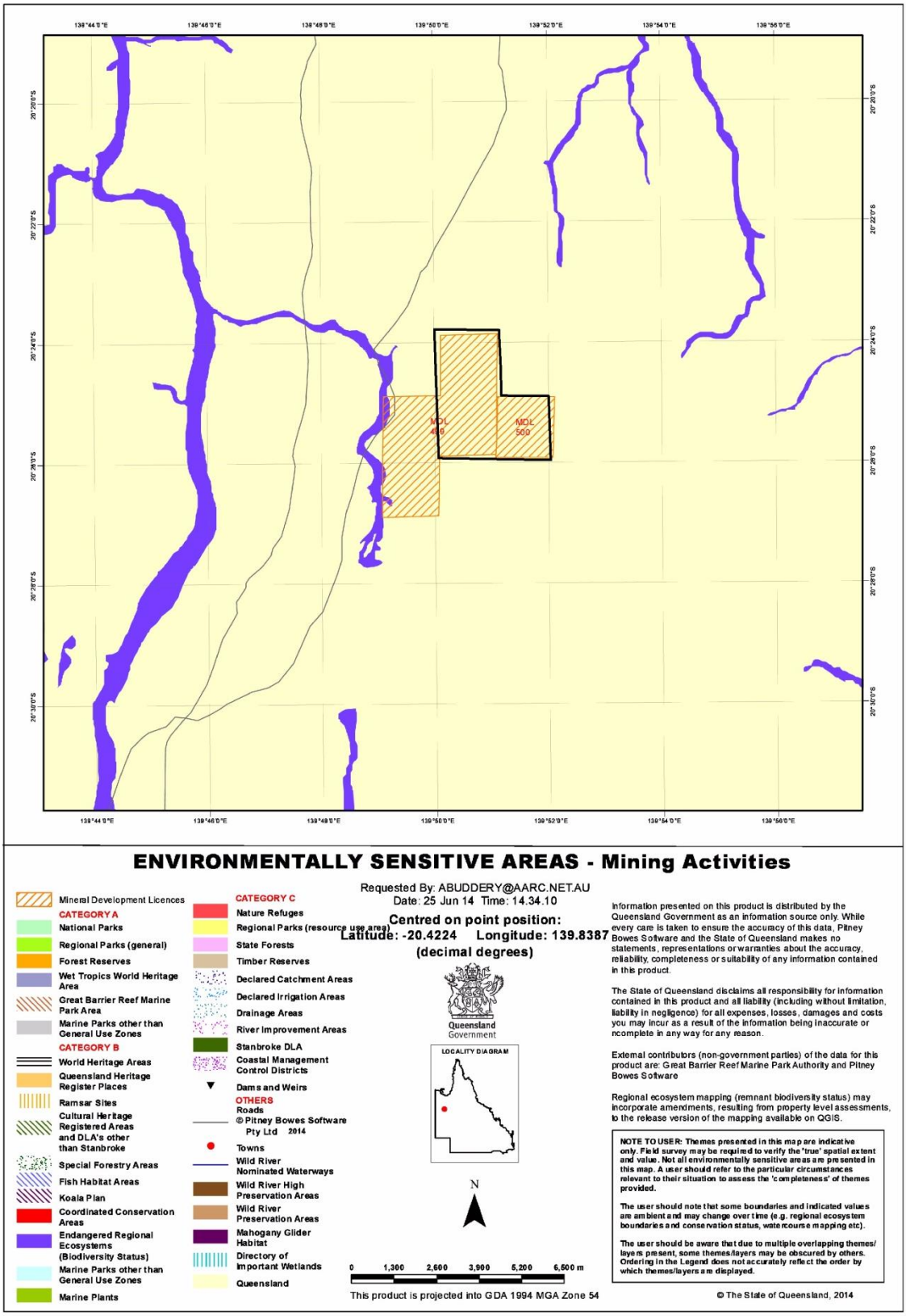

Figure 5 Environmentally Sensitive Areas on and Surrounding the Project Site

4.4 WETLAND MAPPING

The WetlandMaps database indicates that the Project site contains riverine systems (drainage lines) only (refer to Figure 6). No palustrine wetlands, lacustrine wetlands or springs are mapped within or adjacent to the Project site. The nearest wetlands are lacustrine in nature and are located approximately 2 km south-west and 7.5 km north-east (Glenroy Dam) of the Project. Neither of these wetlands occurs within the downstream receiving environment of the Project. Lake Julius occurs approximately 17 km downstream of the Project on the Leichhardt River. This wetland occurs within the downstream flow path of the Project and could be impacted by Project activities during heavy flow events.

No wetlands of international importance as nominated under the Ramsar Convention have been recorded within the Project site or surrounding region.

Wetland values are discussed in further detail in the Barbara Copper Project Aquatic Ecology Assessment (AARC, 2014).

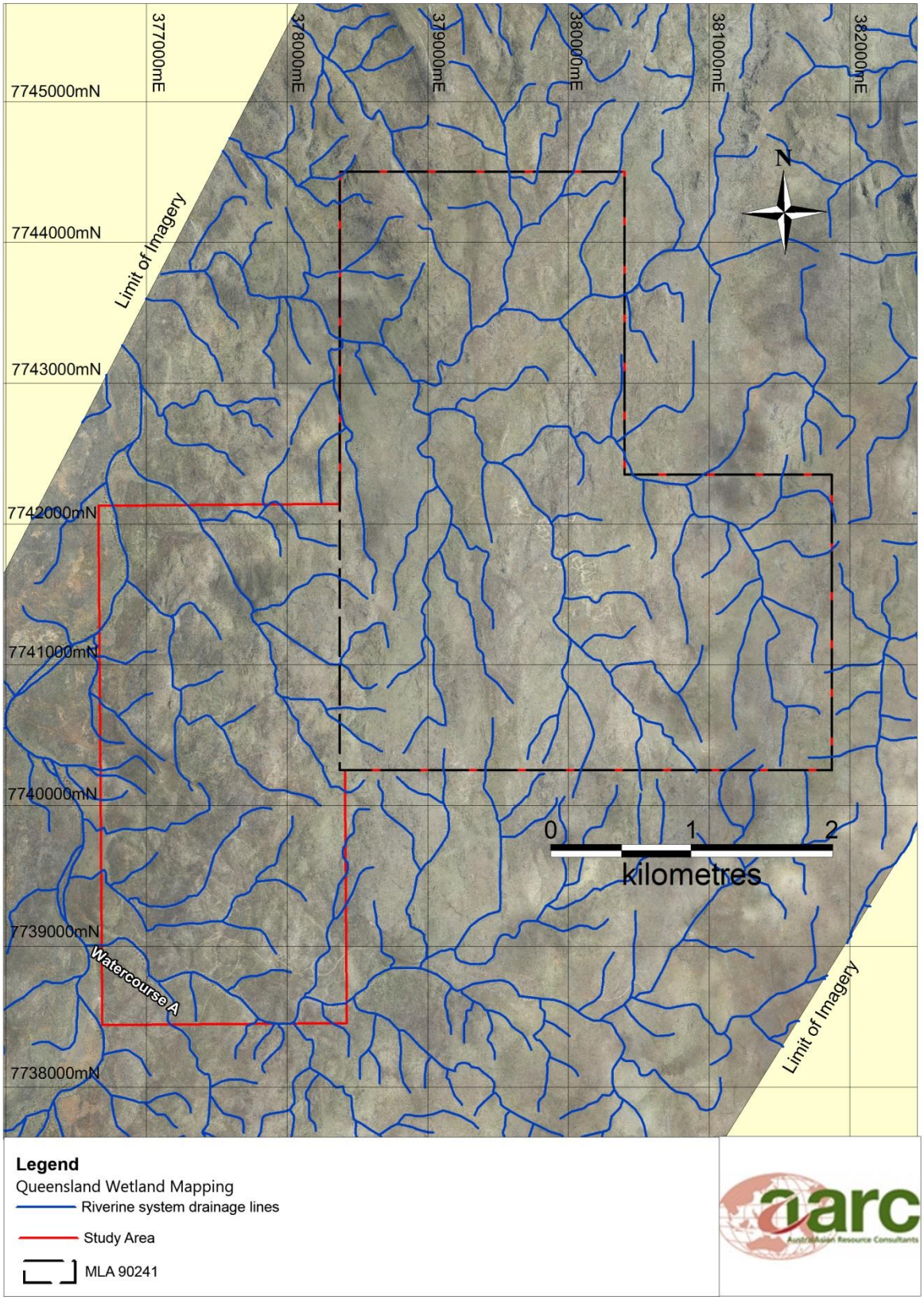

Figure 6 Queensland Wetland mapping over the Project Site

5.0 METHODOLOGY

5.1 INITIAL SITE SCOPING

Site scoping was conducted through the examination of aerial photography, satellite imagery and existing EHP RE and Essential Habitat Mapping. This enabled the ecologists to gain an overall perspective of the vegetation distribution and landscape features on the Project site. Desktop analysis also allowed the survey team to predict the location of trapping efforts according to the basic understanding of REs and landforms from government maps.

Vehicle-based reconnaissance was carried out, where possible, to assist in locating suitable survey sites, maximising the representative vegetation and fauna habitat survey coverage. This also aided in targeting habitats potentially occupied by species of conservation significance. Areas of potential sensitivity (for example, creek lines and rocky outcrops) were surveyed on foot. This allowed further ecological familiarisation and comprehensive survey coverage.

5.2 FLORA SURVEY METHODOLOGY

The flora sampling regime was designed and conducted in accordance with the *Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland* (Neldner *et al*., 2012) in order to meet the following objectives:

- Obtain a detailed floristic summary of the Project site through the compilation of a flora species list;
- Define distinct vegetation communities and compile detailed descriptions of the floristic assemblages in each community;
- Identify threatened or conservation significant flora species and ecological communities; and
- Produce a comprehensive site vegetation map at a 1:10 000 scale, using the EHP vegetation maps to plan appropriate Quaternary and Secondary sites.

Neldner *et al*. (2012) describes four levels of sampling. Two of these sampling techniques (Secondary transects and Quaternary plots) were used in the flora assessment for the Project. Each survey technique was undertaken as follows:

- *Secondary* – consist of a 20 m x 50 m transect, precisely marked using a Global Positioning System (GPS) and accurately measured with a marking tape. Data recorded at each Secondary site included a complete floral assemblage (all species observed from each vegetation layer). Species that fall outside the plot but are deemed typical of the community are also listed. Where a plant could not be positively identified to species level, a voucher specimen was collected for identification by the Queensland Herbarium. Relative abundance for individual woody species in each stratum, stem density, foliage projection cover and height of the tree and shrub layers was recorded. Percentage composition of each ground cover species was recorded in five 1 m x 1 m quadrats located at 10 m intervals along the transect line. A minimum of one representative Secondary plot was positioned in each of the REs known to exist on the Project site. A total of 26 secondary transects were sampled during the 2011 wet and dry season surveys. A further 10 Secondary flora sites were assessed during the 2014 wet and dry season surveys.

- *Quaternary* – These rapid vegetation surveys include marking the GPS location, recording the dominant species in the characteristic layers along with soil/landform and structural data. Recording soil and landform data is essential as many REs can only be differentiated by the land zone they occur on, due to their floristic assemblage descriptions being virtually identical. Quaternary plots are commonly used in the ground truthing of mapping previously completed for the local area. The plots are projected on a geographical information system and used in conjunction with local geological maps (which determine land zone) to effectively map the vegetation of the site. A total of 598 Quaternary plots were surveyed on and surrounding the Project site during the 2011 surveys. A further 137 Quaternary assessments were conducted during the 2014 survey, to ensure adequate site coverage over the revised Project area and to meet the minimum observation requirements for vegetation mapping at the 1:10 000 scale (i.e. 25 Observations/100ha).

All transect locations were first identified in conjunction with assessment of the RE Vegetation maps obtained from EHP. Flora and habitat values identified in the desktop assessment were also targeted in the site selection process. Different flora transects were sampled in the dry season and wet season to best account for both annual and perennial species assemblages.

The condition and quality of vegetation at each survey site was assessed. Attention was paid to identifying the presence of weeds, species of conservation significance or potential habitat for species of conservation significance.

The locations of the flora survey sites are shown in Figure 7.

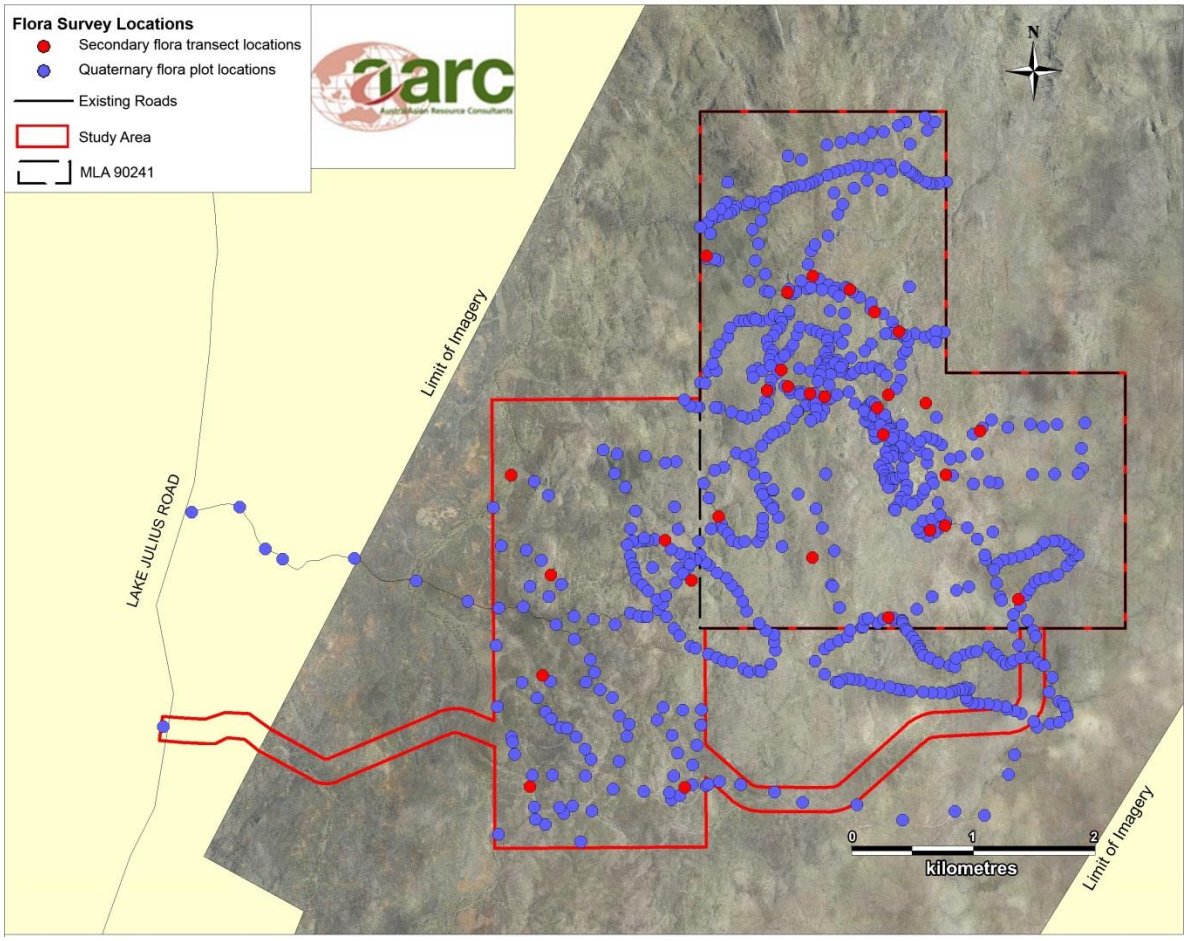

Figure 7 Flora Survey Locations on the Project Site

5.2.1 Flora and Regional Ecosystem Identification

All plants encountered during the survey were identified by experienced ecologists using a number of field guides and other reference material where necessary. All REs were described and classified according to EHP's Regional Ecosystem Descriptions Database (EHP, 2012). For any plant species that could not be identified in the field, a voucher specimen was collected and sent to the Queensland Herbarium for identification.

Vegetation (RE) maps of the Project site were produced at a minimum scale of 1:10 000 following the completion of field surveys. The maps were developed based upon survey results, satellite images, aerial photographs, and geological maps featuring the Project site. Where possible, each RE was mapped as a homogenous polygon wherever it occurs on the Project site. Occasionally vegetation patches occur that consist of more than one RE. When the least common RE in the remnant patch is smaller than the minimum mappable area defined in Neldner *et al*. (2012) or the structure of the vegetation does not allow clear delineation of each RE, all contributing REs may be mapped together as a "mixed polygon".

5.2.2 Surveys for Species of Conservation Significance

A number of flora species of conservation significance were highlighted in the desktop searches undertaken prior to the field survey. Targeted searches for species of conservation significance were undertaken upon the identification of suitable habitat in the field. Such searches involved the use of methods discussed in Neldner *et al*. (2012).

The targeted survey technique utilised in this study was the 'Random Meander' survey. This technique involves traversing areas of suitable habitat along a meandering route whilst searching for the plant species of interest. If there was any uncertainty in identification of a species, a voucher specimen was collected for identification by the Queensland Herbarium.

5.3 FAUNA SURVEY METHODOLOGY

The fauna sampling methodology employed for the Project site during the 2011 surveys was based on survey techniques provided in *Recommended Fauna Survey Methodology for Environmental Impact Assessments* (DERM 2009). Sampling of vertebrate fauna was conducted primarily along transects established in each of the major fauna habitat types and at changes in vegetation community groups. Secondary sites were established to provide important information on fauna species associated with preferred habitat, as well as increasing the chances of finding species of conservation significance. Their inclusion in the assessment provides a more robust survey methodology and greater survey coverage.

The fauna survey methodology employed for the Project during the 2014 wet and dry season surveys was based on the Terrestrial Vertebrate Fauna Survey Guidelines for Queensland (DSITIA, 2012). The survey was conducted in compliance with AARC's scientific purposes permit and animal ethics approval. All fauna trapping efforts were conducted over four consecutive nights (unless otherwise stated). Motion detector cameras and micro-bat acoustic detection devices were set at each of the survey sites. Fauna sites sampled during the wet season survey were largely positioned in the same habitat types during the dry season survey to identify seasonal variation in species diversity and abundance. Fauna survey methods undertaken during the 2014 wet and dry season surveys are described in detail in Section 5.3.2.

During all surveys, observations of species outside the specific fauna study locations were noted as incidental observations.

Many fauna species, notably frogs and reptiles, do not have widely accepted common names. Scientific names for species often change with taxonomic revisions. For the purpose of this report, all nomenclature used will follow that used in the EHP Wildlife Atlas.

5.3.1 Fauna Survey Sites

Fauna transects were positioned to maximise the potential for sampling all wildlife present by targeting the full range of habitat types present on site. During the 2011 survey periods, a total of 13 primary transects and 10 secondary transects were established for fauna sampling. Fauna survey sites were established at seven locations during the 2014 wet and dry season surveys. One fauna site located in Snappy Gum woodland habitat on metamorphic hills (FA3) was replaced during the dry season survey due to access restrictions and the need to increase sampling effort in River Red Gum Riparian habitat since ground truthing revealed a greater habitat presence than indicated by current RE mapping. All fauna survey locations, including the fauna site which was added during the dry season (FA8) are shown in Figure 8.

Descriptions and photos of each survey site are provided in Appendix B.

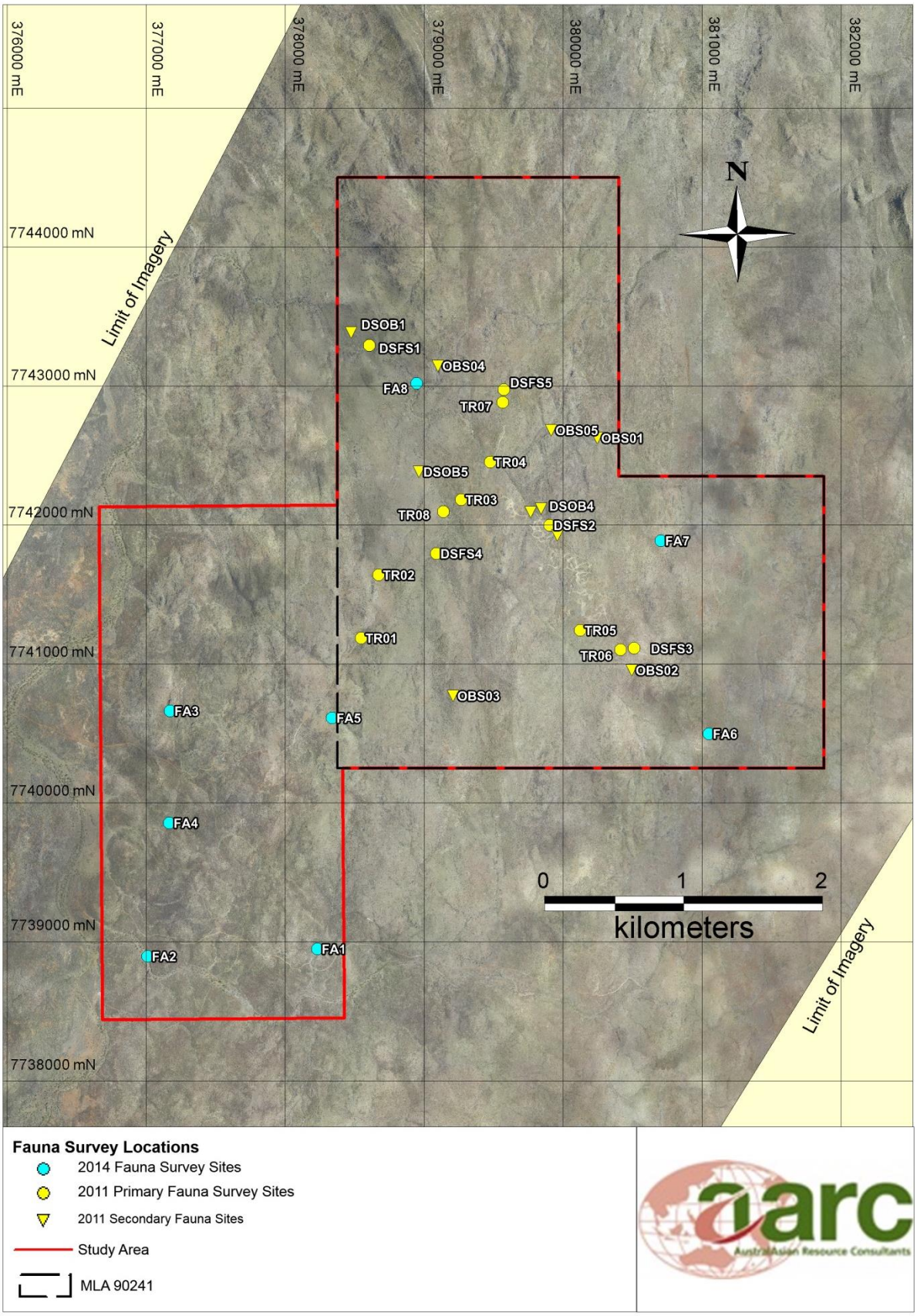

Figure 8 Terrestrial Fauna Survey Locations on the Project Site

5.3.2 Detection Methods

A description of the techniques employed to survey the fauna occurring on the Project site is provided below.

Elliott trapping

Type 'A' Elliott traps (aluminium boxes with doors triggered by a floor treadle) were used to target small ground-dwelling mammals inhabiting the Project site during the field survey period. Traps were baited with a mixture of oats, honey, peanut butter, sesame oil and vanilla essence (referred to here-in as 'marsupial bait'). At each site, 20 Elliott traps were deployed at 5-10 m intervals along a 100 m transect. The methodology was altered slightly during the 2014 survey to meet the *Terrestrial Vertebrate Fauna Survey Guidelines*, such that 20 Elliott traps were deployed at 10 m intervals along two 100 m transects within a 100x100 m plot or one 200 m transect, depending on the nature of the target habitat (i.e. linear riparian habitats typically featured a 200m trap line). Traps were strategically positioned under shrubs or beside logs to reduce exposure of trapped animals to the sun, wind and rain and maximise trap success.

Elliott trapping was conducted at 5 locations within the Project site during the 2011 wet season survey and a further 5 different locations during the 2011 dry season survey. During the 2014 wet season survey, Elliott traps were deployed across seven fauna sites, resulting in an overall survey effort of 560 trap nights. Elliott trapping was also conducted at seven fauna sites during the dry season survey providing another 560 nights of trap effort.

Automated camera trapping

Automated camera trapping is a less invasive method of surveying medium and large-sized nocturnal terrestrial species. Cameras are usually attached to a tree in a position that offers an unobstructed view over a track or clearing. A bait tube constructed of a PVC pipe and filled with 'marsupial bait' and in some cases, sardines, was pegged to the ground and positioned in clear view of the camera. Motion-sensing technology in the camera picks up movement by target fauna which then triggers an automatic photographic response. This is a highly effective survey method and is now widely used instead of cage trapping (DSITIA, 2012). Automated cameras were deployed for four nights at all seven fauna survey locations during the 2014 wet and dry season surveys. Survey effort comprised 28 camera trap nights during each survey.

Pitfall trapping

A pitfall trap line was established at most the survey sites to target small ground-dwelling fauna (reptiles, mammals and amphibians). Each line consisted of a 20 centimetre (cm) tall drift fence running along the ground and crossing the middle of four 20 litre buckets buried flush with the soil surface. Each pitfall trapping line was constructed in a T-shape design with 45 m of drift fence and buckets placed at approximately 7.5 m intervals. The bottom edge of each drift fence was buried to guide target animals towards the buckets. A small amount of soil, vegetation litter, a damp sponge and a small plastic pipe were placed in the bottom of each bucket to provide shelter and moisture for captured wildlife. Given that the Project site is dominant by rocky hills and outcrops, pitfall trapping efforts have largely been restricted to the lower alluvial areas. During the 2011 wet and dry season surveys, pitfall trapping was conducted at four fauna sites. Pitfall trapping was also conducted at an additional four survey sites during each of the 2014 wet and dry season surveys with a total of 64 trap nights in each survey.

Funnel trapping

Funnel traps are elongated box-shaped traps made of wire and fine mesh. They have two funnel shaped entrances which allow fauna to enter with ease but make exiting difficult. Six funnel traps were positioned at each fauna sites in order to catch medium and large-sized terrestrial reptiles, snakes and some species of medium-sized skinks, dragons and geckos, which are able to climb out of pitfall traps. Funnel traps were placed either at the end of each drift fence at all pitfall trapping lines or along fallen timber or rocky outcrops at all other sites. Four funnel traps were used at each fauna site during both the 2011 wet season and dry season surveys. During the each of the 2014 surveys, six funnel traps were placed in association with each pitfall trapping line. Where a pitfall line could not be established, 10 funnel traps were placed in suitable habitat within the fauna site (100x100m plot). Total funnel trap effort during each of the wet and dry season surveys was 216 trap nights.

Micro-bat surveying

Micro-bats (Microchiropterans) form an extremely diverse group of wildlife and the identification of individual species requires the use of specialised survey methods due to the superficial similarity of many species, their small size, and largely inaudible calls.

In order to navigate and hunt at night micro-bats use high frequency echolocation calls, most of which are above the frequency range audible to humans (i.e. ultrasound). These echolocation calls provide an opportunity to unobtrusively survey and identify micro-bats through the use of a specialised ultrasonic recorder such as an ANABAT or Songmeter. An ANABAT recorder was strategically positioned to detect micro-bat calls at five fauna trapping sites during the 2011 wet season survey event. Another ANABAT was strategically located at seven different fauna trapping locations during the 2011 dry season survey. A Songmeter was also deployed at each of the seven fauna trapping locations during the 2014 wet season survey. Songmeters were left at each site for 3 nights. Sound recordings were sent to an experienced bat-call analyst (Greg Ford of Balance Environmental, Toowoomba, Queensland) for analysis.

Successful harp trapping relies on the availability of flyways consisting of narrow gaps in dense vegetation, typically along roadways or watercourses. Suitable flyways are rare on the Project site due to the very open and sparse nature of the canopy vegetation. Harp trapping was conducted at one site over four nights during the 2011 wet season survey. Harp trapping was also conducted at two sites during the 2014 dry season survey. Trapping was conducted over two nights at each site, providing a total of four trap nights.

Bird surveying

A dedicated search for diurnal birds was conducted visually and aurally on mornings and afternoons in the immediate vicinity of each fauna transect during each of the 2011 and 2014 survey periods. In addition, opportunistic diurnal searches were also conducted on foot in areas considered likely to have high avian diversity (e.g. vegetated watercourses), or likely to contain cryptic or threatened bird species. During each survey period, diurnal bird searching was conducted over a period of 5 to 13 hours with a total of 30 hours spent searching for birds across the Project site.

Spotlighting

Spotlighting was carried out at night in various sections of the Project site in order to observe nocturnal wildlife (i.e. owls and arboreal mammals) unlikely to be detected by other survey methods. Two spotlighting techniques were employed:

1. Walk searches: Areas within the Project site considered likely to contain cryptic or threatened species, or high fauna diversity were investigated on foot. These areas were randomly traversed by two ecologists equipped with spotlights and binoculars, and wherever possible, bark crevices and tree hollows were examined. A slow walking speed (approximately 1 km per hour) was maintained across the length of the survey area to fully facilitate intensive listening and thorough visual searching. While this technique improves the likelihood of detecting small cryptic species, it is a time consuming activity that does not permit the coverage of large areas. A total of 20 spotlight hours were undertaken on foot within the Project site during the 2011 wet and dry season surveys. The total spotlight hours undertaken on foot within the Project site was seven person hours during the 2014 wet season survey and four person hours during the 2014 dry season survey. Cool and particularly windy conditions prevailed throughout the dry season survey, most likely hindering the potential for fauna detection.

2. Vehicle searches: Spotlighting was also conducted from a slow-moving vehicle where established roads/tracks permitted driving through areas considered likely to have high wildlife diversity or cryptic or threatened species. One 55-watt 12-volt spotlight was used to scan roadside vegetation for arboreal and ground-dwelling wildlife. An advantage of this survey technique is the efficiency with which large areas can be covered. A total of 14 hours of vehicle spotlighting were undertaken on the Project site during the 2011 dry and wet surveys. A total of one person hour of vehicle spotlighting was undertaken on the Project site during the 2014 wet season survey. Approximately three hours of vehicle spotlighting was conducted during the dry season survey.

Habitat searching

To further enhance the likelihood of detecting small cryptic species, opportunistic diurnal searches of likely micro-habitats were conducted at each fauna site and in other selected areas on the Project site. Searching techniques involved the rolling of rocks and logs, rustling through leaf litter, and peeling back of exfoliating bark from standing trees. In addition, notes were made on habitat features such as tree hollow numbers or the presence of fallen logs and bark. Observed animals were caught where possible to aid positive species identification. A total of seven person hours were spent active searching during each of the 2014 surveys.

Scat/track searching

At each survey site a search of the immediate area was conducted for evidence of the presence of wildlife through the identification of obvious tracks, scats and other signs of occupation (e.g. tree trunk scratchings).

Scats were collected and sent to a scat analysis expert (i.e. Barbara Triggs) for identification of the species responsible for the scat and/or where possible, the identification of prey species material present in predator scats.

Incidental recordings

Throughout each survey period, numerous wildlife species were observed or heard on the Project site during the course of routine activities (i.e. driving between sites, checking traps, vegetation surveys etc.). Where required, a closer inspection of detected wildlife was carried out to ensure positive species identification. All incidental observations were recorded.

5.3.3 Survey effort

Survey effort undertaken during each survey event is detailed in Table 7 below for each fauna sampling techniques.

Table 7 Summary of Sampling Effort

Sampling Technique	2011 Wet Season Survey	2011 Dry Season Survey	2014 Wet Season Survey	2014 Dry Season Survey
Elliott Trapping	5 sites x 20 traps over 4 nights = 400 trap nights	5 sites x 20 traps over 4 nights = 400 trap nights	7 sites x 20 traps over 4 nights = 560 trap nights	7 sites x 20 traps over 4 nights = 560 trap nights
Automated Camera Trapping	N/A	N/A	7 sites x 1 camera over 4 nights = 28 trap nights	7 sites x 1 camera over 4 nights = 28 trap nights
Pitfall Trapping	4 sites x 5 buckets over 4 nights = 80 trap nights	4 sites x 5 buckets over 4 nights = 80 trap nights	4 sites x 4 buckets over 4 nights = 64 trap nights	4 sites x 4 buckets over 4 nights = 64 trap nights
Funnel Trapping	8 sites x 4 funnels over 4 nights = 128 trap nights	5 sites x 4 funnels over 4 nights = 80 trap nights	4 sites x 6 funnels over 4 nights = 96 trap nights 3 sites x 10 funnels over 4 nights = 120 Total = 216 trap nights	4 sites x 6 funnels over 4 nights = 96 trap nights 3 sites x 10 funnels over 4 nights = 120 Total = 216 trap nights
Micro-bat Surveying	Bat Detector: 5 sites x 1 detector for 1 night = 5 trap nights Harp Trapping: 1 site x 1 harp trap for 4 nights = 4 trap nights	Bat Detector: 7 sites x 1 bat detector for 1 night = 7 trap nights	Bat Detector: 7 sites x 1 bat detector for 3 nights = 21 trap nights	Bat Detector: 7 sites x 1 bat detector for 3 nights = 21 trap nights Harp Trapping: 2 sites x 2 nights = 4 trap nights
Bird Surveying	13 hrs total search time across Project site	5 hrs total search time across all 5 fauna sites	7 hrs total search time across all 7 fauna sites	5 hrs total search time across all 7 fauna sites
Spotlighting	2 x 30 person minute searches at each site = 20 person hours in total		2 x 30 person minute searches at each site = 7 person hours	2 x 30 person minute searches at four sites = 4 person hours
Habitat Searching	2 x 30 person minute searches at 13 sites = 13 person hours	2 x 30 person minute searches at 5 sites = 5 person hours	2 x 30 person minute searches 7 sites = 7 person hours	2 x 30 person minute searches 7 sites = 7 person hours

6.0 RESULTS AND DISCUSSION

6.1 SURVEY TIMING

Survey timing was selected in accordance with the *Terrestrial Vertebrate Fauna Survey Guidelines for Queensland* (DSITIA, 2012). These guidelines recommend that fauna surveys within the North West Highlands bioregion should be conducted during or immediately following the wet season (i.e. December to May) and during the dry season (i.e. August to October). Surveys were conducted during the wet and dry season periods in 2011 and 2014. Wet season surveys were conducted from 28th March to 3rd of April, 2011 and 30th January to 7th February, 2014. Dry season surveys were conducted from 19th to 25th October, 2011 and 1st to 8th August, 2014.

6.2 WEATHER CONDITIONS

Seasonal surveys are imperative for a comprehensive and scientifically valid ecological assessment. Complementing wet season and dry season surveys are conducted to ensure species which are migratory, transient or responsive to particular environmental conditions are captured, in addition to identifying seasonal variation in both species diversities and abundances. Survey timing is based on conceptual seasonal months. That is, they correspond to historic rainfall data and known weather patterns. Often however, the yearly weather cycle is more than wet and dry and includes the build-up period before the wet season that brings high humidity as moisture builds up in the air and post wet season as waterholes and creeks slowly dry up and dry winds strengthen. These transitional periods in combination with localised ecological response produce an environment that is continually adapting and adjusting. It is imperative that these periods be included, in combination with consideration to changing weather pattern behaviours when determining timing of wet and dry surveys as part of any seasonal flora and fauna assessment. The window of survey often needs to be adjusted to suit local conditions.

March/April 2011

Climate data preceding the 2011 wet season survey was consistent with average temperatures for January with minimum and maximum temperatures between 23.0°C and 35.7°C, and above average rainfall with a total of 267.2 mm. February 2011 had slightly lower temperatures (22.6°C to 33.47°C) accompanied by less rainfall (195 mm). Total rainfall in March 2011 was higher than previous months with 303 mm of rain along with average temperatures of 21.6°C to 30.2°C. During April 2011, a total of 11.0 mm of rainfall was recorded with temperatures averaging in the range of 16.1°C to 29.6°C.

During the survey period (28th March and 3th April 2011), a total of 11 mm rainfall was recorded and temperatures were recorded in the range of 17.2°C to 32.2°C.

October 2011

The second survey was conducted towards the end of the 2011 dry season period (19th - 25th October 2011). Conditions were typical for the season, with a mean minimum temperature of 18.1 ºC and a mean maximum of 35.2 ºC during the month of October 2011. A small amount of rain fell during the survey period with a total of 1mm recorded. A total 30mm rainfall was recorded in the 4 months prior to the survey.

January/February 2014

A second wet season survey was conducted between 30th January and 7th February 2014 when conditions varied from hot, fine and sunny at the beginning of the survey to partly cloudy or overcast

with cooler temperatures for the remainder of the survey. Conditions on the 3rd February saw a rapid drop in maximum temperature (up to 5°C), afternoon storms and light evening rain resulting in a total of 43 mm rainfall being recorded in a 24 hour period. Maximum temperatures recorded during the survey period ranged from 30.6°C to 39.8°C. Minimum temperatures were recorded in the range of 19.4°C to 27.2°C. A total of 50.4 mm of rainfall was recorded at the West Leichhardt Station (29121) in the wet season months leading up to the survey (November 2013 – January 2014). It should be noted that no rainfall readings were recorded at this Station during the month of January 2014. The next closest weather station (Lake Julius – 29171) recorded 33.4 mm of rainfall. Therefore, the actual rainfall for the November 2013 to January 2014 period was likely closer to 84 mm.

August 2014

A second dry season survey was conducted from the 1st to the 8th of August 2014. Weather conditions during this survey typically consisted of cooler temperatures, extended periods of cloud cover clearing toward the end of the survey, a brief period of rainfall and very windy conditions. Throughout the survey, daily wind gusts recorded at the Mount Isa Aero station ranged from 33 to 52 kilometres/hour (km/h).

Climate readings from the Mount Isa Aero station (029127) revealed minimum temperatures in the range of 1.2 to 17.6 °C and maximum temperatures ranging from 22.2 to 29.1 °C. A very light and brief shower occurred on the afternoon of August 2nd but has not been recorded by any of the nearby weather stations (i.e. West Leichhardt Station, Lake Julius station or the Mount Isa Aero station). Since the previous survey, a total of 166.8 mm of rainfall has been recorded from the West Leichhardt Station with 152.8 mm recorded to the end of February and no rainfall recorded since April 2nd.

6.3 FLORA SURVEY RESULTS

A total of 167 flora species were identified on the Project site during field surveys. A full list of species observed is provided in Appendix C.

Seven vegetation communities were recorded across the Project site, all of which are classified as remnant vegetation. These communities are representative of five REs as described below.

Each vegetation community is discussed in detail below. The location and extent of each vegetation community on the Project site is presented in Figure 9.

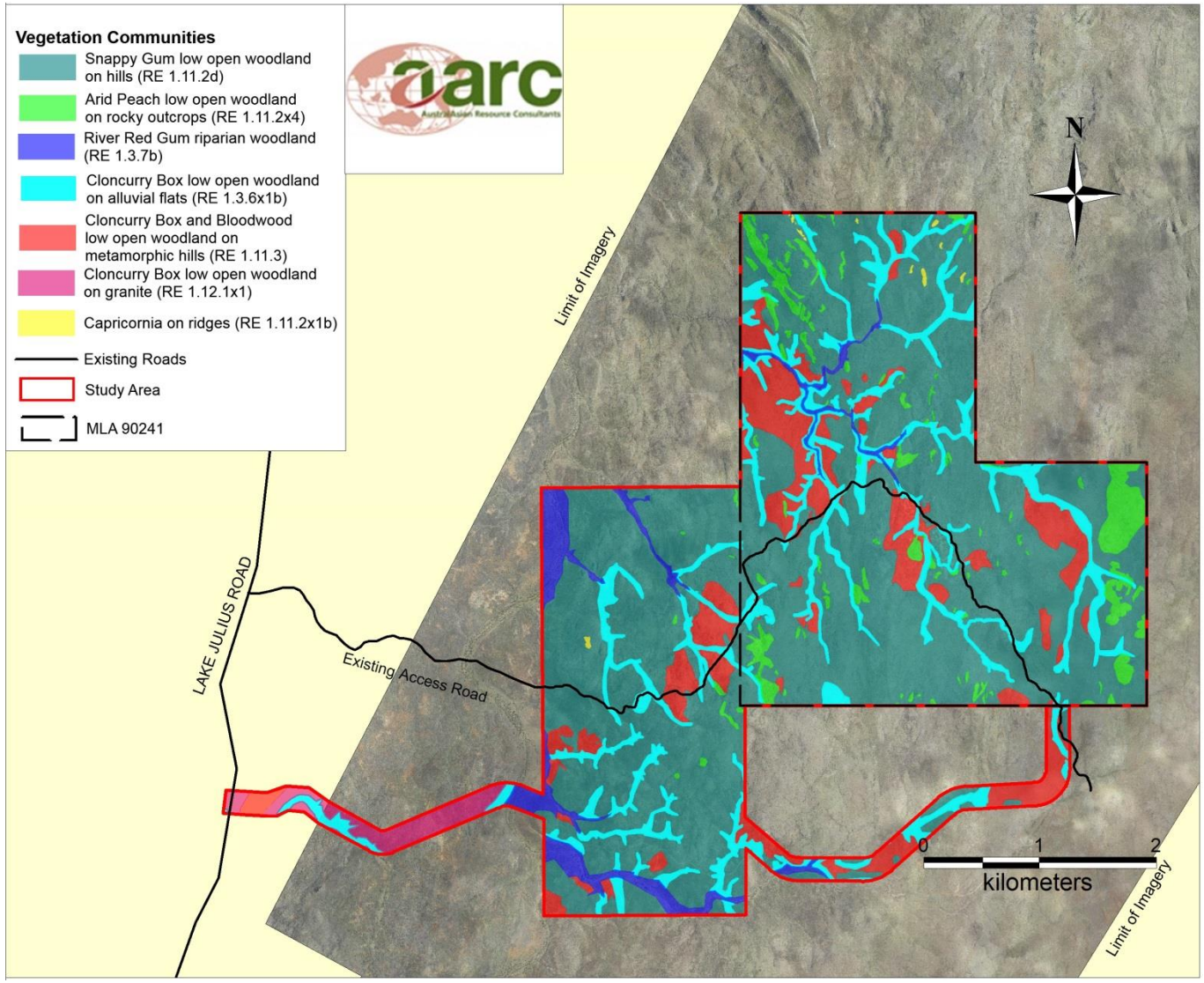

Figure 9 Vegetation Communities within the Study Area

6.3.1 Community 1 – Low Open Woodland of Snappy Gum (*Eucalyptus leucophloia*) on metamorphic hills

6.3.1.1 Community Description

Community 1 is described as low open woodland on metamorphic hills and occurs throughout the majority of the Project site. This community typically consists of a five to eight metre tall canopy that is dominated by Snappy Gum (*E. leucophloia*) and provides a canopy cover of approximately 2 to 10 %.

This community is consistent with RE 1.11.2d. Detailed information on Community 1, including the dominant species in each stratum of vegetation is presented in Table 8.

Table 8 Community 1 Profile

Regional Ecosystem	1.11.2d - Low open woodland of *Eucalyptus leucophloia* often with *E. leucophylla*, *Corymbia* spp., *Terminalia aridicola* and/or *Brachychiton collinus* on rock outcrops with a very sparse shrub layer of *Acacia* spp. and a sparse to very sparse ground layer of *Triodia pungens*. Occurs on steep rocky slopes and crests on metamorphosed igneous rocks.
Extent within Study Area	1, 348 ha
EPBC Status	Not listed
VM Act Status	Least Concern
Biodiversity Status	No concern at present
Tree Layer	*Eucalyptus leucophloia* (D), *Corymbia terminalis* (A), *Terminalia aridicola* (A), *Brachychiton collinus* (A), *Corymbia aparrerinja* (O), *Corymbia capricornia* (O), *Eucalyptus leucophylla* (O)
Shrub Layer	*Acacia phlebocarpa* (D), *Acacia chisholmii* (SD), *Acacia holosericea* (A), *Acacia monticola* (A), *Acacia melleodora* (A)
Ground Layer	*Triodia pungens* (D)
Weed Species	*Cenchrus ciliaris (O), Vachellia farnesiana (O), Aerva javanica (O)*
Canopy Height	5 to 8 m
Crown Cover	2 – 10%

Key: D = Dominant, CD = Co-dominant, SD = Sub-dominant, A = Associated, O = Occasional

This community of low open woodland on hills intergrades with other communities on hills, such as *Corymbia capricornia* ridges, with the latter usually occurring on the top most quartz-stony ridges. Western Bloodwood (*Corymbia terminalis*), Whitewood (*Atalaya hemiglauca*), Arid Peach (*Terminalia aridicola)* and Hill Kurrajong (*Brachychiton collinus*) are commonly associated with this community. Wattles such as Tabletop Wattle (*A. phlebocarpa*) and Turpentine *(A. chisholmii*) dominate the shrub layer. Other common wattles include Soap bush (*A. holosericea), A. melleodora* and *A. retivenea.* Other less common shrub species occurring in this community include *Acacia orthocarpa*, *Gossypium australe* and *Grevillea wickhamii*.

Spinifex dominates the ground layer, primarily Soft Spinifex (*Triodia pungens)*, but with Grey Spinifex (*Triodia longiceps)* common on the lower slopes and Feathertop Spinifex (*Triodia bitextura)* on a few rocky ridges. Other common grasses are Silky Oilgrass (*Cymbopogon bombycinus)*, Conetop Nineawn (*Enneapogon lindleyanus)*, Mountain Wanderrie Grass (*Eriachne mucronata)*, Silkytop Grass (*Mnesithea Formosa),* Whitegrass *(Sehima nervosum)* and Australian Dropseed (*Sporobolus australasicus)*.

The herbs are mainly annuals or short-lived perennials, including *Bulbostylis barbata*, Grey Jute (*Corchorus sericeus)*, Orange Spadeflower (*Hybanthus aurantiacus)*, Rusty Indigo (*Indigofera colutea)* and Copper Plant (*Polycarpaea spirostylis)*.

Photo Plate 1 Low open woodland of Snappy Gum (*E. leucophloia*) on metamorphic hills

6.3.1.2 Conservation Value

Species

Targeted searches for species of conservation significance were conducted. Ground-truthing identified no species of conservation significance within this community. The potential on site occurrence of threatened species identified in the database searches is described in Table 15.

Community

Low open woodland of Snappy Gum (*Eucalyptus leucophloia*) on metamorphic hills (RE 1.11.2d), is listed as 'Least Concern' under the VM Act and 'No Concern at Present' under the EHP Biodiversity Status. This ecological community is not listed under the EPBC Act. Areas in which RE 1.11.2 is under reserve include Lawn Hill (Gregory) Resources Reserve and the Boodjamulla (Lawn Hill) National Park.

Intact stands of this community are vast and abundant throughout the region and it is unlikely disturbance within the Project site will significantly impact on the regional occurrence of this community.

6.3.1.3 Vegetation Condition and Habitat Value

Evidence of low intensity cattle grazing was observed throughout this community with visible impacts limited to faecal evidence. Weed diversity and abundance is relatively low within this RE. Seed dispersal vectors likely include wind transport as well as cattle and avian dispersal. Introduced flora species Buffel Grass (*Pennesetum ciliare*) and Kapok (*Aerva javanica*) were observed to be widespread throughout the community, however present in low densities. No weeds of national significance were found within RE 1.11.2d. Overall, the condition of Snappy Gum low open woodland (RE 1.11.2d) on the Project site is healthy.

The landform and vegetation throughout this community provides habitat for macropods, small mammals, reptiles and open woodland birds.

6.3.2 Community 2 – Low Open Woodland of Cloncurry Box (*Eucalyptus leucophylla*) and Bloodwood (*Corymbia terminalis*) on Metamorphic hills

6.3.2.1 Community Description

This vegetation type tended to occur on the pediment slopes and flat open areas below the steeper metamorphic hills. This community features a variable canopy height ranging from 8 to 15 m with an equally variable crown of 5 to 25 % cover.

Community 2 is consistent with RE 1.11.3 - *Corymbia terminalis* low open woodland on basic metamorphics. The community composition is described in terms of dominant species in each stratum of vegetation as detailed in Table 9.

Table 9 Community 2 Profile

Regional Ecosystem	1.11.3 - Low open woodland of *Corymbia terminalis* usually with *Eucalyptus leucophylla* or *E. leucophloia* with *Acacia* spp. dominated shrub layer and ground layer of *Triodia* spp. and/or tussock grasses. Includes areas of *Acacia* spp. shrubland and *Triodia* spp. grassland. Occurs on metabasalts and dolerites; skeletal soils, some shallow loams.
Extent within Study Area	236.8 ha
EPBC Status	Not listed
VM Act Status	Least Concern
Biodiversity Status	No concern at present
Tree Layer	*E. leucophylla* (CD), *C. terminalis* (CD), *E. leucophloia* (A), *Terminalia aridicola* (A), *Atalaya hemiglauca* (O), *Brachychiton collinus* (O)
Shrub Layer	*A. holosericea* (CD), *A. Chisholmii* (CD), *A. phlebocarpa* (A), *A. meleodora* (A), *Gossypium australe* (A).
Ground Layer	*Triodia pungens* (D)
Weed Species	*C. ciliaris (O), V. farnesiana (O), A. javanica (O)*
Canopy Height	8 – 15 m
Crown Cover	5 – 25 %

Key: D = Dominant, CD = Co-dominant, SD = Sub-dominant, A = Associated, O = Occasional

The RE Cloncurry Box (*E. leucophylla*) and Western Bloodwood (*C. terminalis*) on metamorphic hills and lower slopes, often exhibits a sub-dominant presence of Western Bloodwood and associated Snappy gum, Arid Peach and Whitewood. Other occasional canopy species include *Corymbia*

aparrerinja and Hill Kurrajong. The shrub layer includes Soap Bush, Turpentine, *Eremophila longifolia* and *Gossypium australe*.

The ground layer is dominated by Soft Spinifex with a sub-dominant presence of Whitegrass. Other commonly occurring ground cover species include Grey Spinifex, Kangaroo grass (*Themeda triandra*) and the twining herbs *Galactia tenuiflora* and *Vigna radiata*.

A photograph of a secondary transect surveyed within this community is shown in Photo Plate 2.

Photo Plate 2 Low open woodland of Cloncurry Box and Bloodwood on metamorphic hills

6.3.2.2 Conservation Value

Species

Targeted searches for species of conservation significance were conducted throughout this community. Ground-truthing failed to identify any species of conservation significance within RE 1.11.3 at the time of the surveys. The potential for threatened species identified in database searches, to occur on site is described in Table 15.

Community

RE 1.11.3 is listed as 'Least Concern' under the VM Act and 'No Concern at Present' under the EHP Biodiversity Status. This community is not classified as a listed ecological community under the EPBC Act.

Intact stands of this community are abundant throughout the region, with greater than 10, 000 ha of the state-wide extent of this RE remaining. It is unlikely disturbance within the Project site will significantly impact on the regional occurrence or integrity of this community.

6.3.2.3 Vegetation Condition and Habitat Value

While this community was typically subject to low intensity cattle grazing, the impacts were more prominent in areas adjacent to watercourses. As a result of increased grazing pressure, these areas exhibit greater disturbance and weed abundances. Buffel Grass was occasionally observed in high densities and was recorded as co-dominant with Soft Spinifex in areas adjacent to ephemeral watercourses. Introduced flora species were otherwise found to have a sparse presence within this community. Native species tended to dominate the drier open plains and lower slopes of the surrounding hills. No weeds of national significance were recorded within this community.

This community provides good habitat variety for birds, large macropods and reptiles in particular through the provision of rocky substrates, leaf litter, fallen timber and Spinifex tussocks.

6.3.3 Community 3 – Low Open Woodland of Cloncurry Box (*E. leucophylla*) on Alluvial Flats

6.3.3.1 Community Description

This vegetation community occurs on alluvial soils adjacent to ephemeral watercourses. It is consistent with RE 1.3.6x1b which is described as *Eucalyptus leucophylla* woodland with a mid-dense ground layer dominated by tussock grasses. The characteristics of this community and the dominant species within each stratum of vegetation are detailed in Table 10.

Table 10 Community 3 Profile

Regional Ecosystem	1.3.6x1b - Floodplain (other than floodplain wetlands*). Eucalyptus leucophylla* woodland with a mid-dense ground layer dominated by tussock grasses. Occurs on narrow terraces.
Extent within Study Area	163.5 ha
EPBC Status	Not listed
VM Act Status	Least Concern
Biodiversity Status	Of Concern
Tree Layer	*E. leucophylla* (D), *Lophostemon grandiflorus* (A), *C. terminalis* (O),
Shrub Layer	*A. holosericea* (D), *Terminalia aridicola* (A), *A. Chisholmii* (A), *Melaleuca bracteata* (A), *A. phlebocarpa* (A), *Flueggea virosa subsp. melanthesoides (*O), *Gossypium australe* (O)
Ground Layer	*Triodia pungens* (D)
Weed Species	*C. ciliaris (O), V. farnesiana (O), A. javanica (O)*
Canopy Height	8 – 15 m
Crown Cover	25 %

Key: D = Dominant, CD = Co-dominant, SD = Sub-dominant, A = Associated, O = Occasional

This low open woodland community is dominated by Cloncurry box while Northern Swamp Box (*Lophostemon grandiflorus*) occurs in association and Western Bloodwood has a sparse presence. The canopy of this community varies from 8 to 15 m in height and has a cover of approximately 25 %. Common shrubs include Soap Bush, Arid Peach, Turpentine, White Currant Bush *(Flueggea virosa subsp. melanthesoides)*, River Teatree (*Melaleuca bracteata*), Tabletop Wattle and *Gossypium australe*.

Soft Spinifex dominates the ground layer and is largely accompanied by Grey Spinifex and Silky Browntop (*Eulalia aurea*) with Conetop Nineawn occurring occasionally. On average the ground cover

comprised 19.9 % native grasses, 0.8 % native forbs/shrubs, 46 % litter, 22.3 % rock and 11 % bare ground.

Photo Plate 3 Low open woodland of Cloncurry Box on alluvial flats

6.3.3.2 Conservation Value

Species

Targeted searches for species of conservation significance determined that no species of conservation significance were found to inhabit the Cloncurry Box open woodland community (RE 1.3.6x1b) at the time of surveys. The potential for threatened species identified in database searches, to occur on site is described in Table 15.

Community

RE 1.3.6x1b is listed as being 'Least Concern' under the VM Act and is not classed as a threatened ecological community under the EPBC Act. It has been given an 'Of Concern' DERM Biodiversity status due to a high grazing pressure, changed fire regimes and subjection to Buffel Grass invasion. Areas within the Northwest Highlands bioregion where RE 1.3.6 is protected include the Boodjamulla (Lawn Hill) National Park, Lawn Hill (Gregory) Resources Reserve, Camooweal Caves National Park and Lawn Hill (Gregory River Base) Resources Reserve.

Intact stands of this community are abundant within this Queensland bioregion, with the total regional mapped extent of this RE compromising of greater than 10,000 ha. The Project is not likely to impact on the regional extent or health of this community.

6.3.3.3 Vegetation Condition and Habitat Value

Overall, the condition of Cloncurry Box creek flats on the Project site is healthy, with a relatively high diversity of flora species. This is one of the most fertile habitats on the property and is susceptible to greater weed invasion. Introduced species recorded within this community include Mimosa *(V. farnesiana*), Buffel Grass and Kapok. On some drainage lines, Buffel was recorded as co-dominant with native grasses. Kapok was found to occur sporadically throughout the community.

With a ground layer that is comprised predominantly of litter and rock this community provides an abundance of habitat suited to reptiles. This community also provides habitat for birds and large macropods as well as amphibians during wet periods.

6.3.4 Community 4 – River Red Gum (*Eucalyptus camaldulensis*) and Northern Swamp Box (*Lophostemon grandiflorus*) Riparian Woodland

6.3.4.1 Community Description

The River Red Gum and Northern Swamp Box riparian woodland community occurs in association with the major creeks on the Project site. It is consistent with RE 1.3.7b which, in short, is described as fringing woodland of *Eucalyptus camaldulensis*, usually with *Lophostemon grandiflorus* and *Melaleuca bracteata* and/or *M. dissitiflora*. The characteristics of this community and the dominant species within each stratum of vegetation are detailed in Table 11.

Table 11 Community 4 Profile

Regional Ecosystem	1.3.7b - Riverine wetland or fringing riverine wetland. Fringing woodland of *Eucalyptus camaldulensis*, usually with *Lophostemon grandiflorus* and *Melaleuca bracteata* and/or *M. dissitiflora*. Occurs on recent levees and channel deposits of medium and smaller tributaries which are dry for most of the year; alluvial soils.
Extent within Study Area	75.19 ha
EPBC Status	Not listed
VM Act Status	Least Concern
Biodiversity Status	Endangered
Tree Layer	*Eucalyptus camaldulensis (*CD*), Lophostemon grandiflorus* (CD)
Shrub Layer	*Melaleuca bracteata* (CD), *Sesbania javanica* (CD), *A. holosericea* (A), *Flueggea virosa subsp. melanthesoides (*O)
Ground Layer	*Cenchrus ciliaris (*D*)*
Weed Species	*Cenchrus ciliaris (O), V. farnesiana (O)*
Canopy Height	10 – 14 m
Crown Cover	35 %

Key: D = Dominant, CD = Co-dominant, SD = Sub-dominant, A = Associated, O = Occasional

The community is dominated by River Red Gum and Northern Swamp Box (*Lophostemon grandiflorus*). River Teatree and *Sesbania javanica* have a co-dominant presence within the understorey. Other common shrub species present include Soap Bush, White Currant Bush and *Acacia hemsleyi*. Upstream areas, which dry out early in the year, lack the presence of *Eucalyptus camaldulensis*, but remain dominated by *Lophostemon grandiflorus*. Black tea-tree (*Melaleuca bracteata*) can form dense thickets in the upstream areas.

This community is typically dominated by Buffel Grass. Other grasses present include *Triodia* spp., *Paspalidium constrictum,* Elastic Grass *(Eragrostis tenuifolia*), Button Grass (*Dactyloctenium radulans*) and Whitegrass,

A variety of annual or short-lived perennial plants were recorded in association with the riparian community, including Hairy Indigo, Tar Vine (*Boerhavia schomburgkiana*), *Heliotropium cunninghamii*, Rhyncho, *Galactia tenuiflora*, *Ipomoea plebeia* and *Polymeria longifolia.*

Photo Plate 4 River Red Gum and Northern Swamp Box Riparian Woodland

6.3.4.2 Conservation Value

Species

Targeted searches for threatened flora species were conducted throughout RE 1.3.7b. At the time of the surveys no flora species of conservation significance were recorded within the community. The potential for threatened species identified in database searches, to occur on site is described in Table 15.

Community

The River Red Gum and Northern Swamp Box riparian woodland community (RE 1.3.7) is listed as Least Concern under the VM Act and is not listed under the EPBC Act as a threatened ecological community. However, this RE is classified as an Endangered community under the EHP Biodiversity Status. This listing is due to severe degradation as a result of high grazing pressure. Within

Queensland, protected areas containing RE 1.3.7 are limited to Boodjamulla (Lawn Hill) National Park. RE 1.3.7 is considered abundant with greater than > 10, 000 ha remaining within Queensland.

6.3.4.3 Vegetation Condition and Habitat Value

This riparian community provides good habitat variety for reptiles, amphibians, birds and mammals through the presence of hollow bearing trees, rocky substrates, leaf litter and fallen timber as well as temporary aquatic habitats.

This riparian community (RE 1.3.7b) is subject to invasion by introduced species that are known to occur commonly throughout the region including Buffel Grass, Red Natal Grass (*Melinis repens*) and Mimosa. No weed species, listed under the LP Act or listed as of national significance, were observed within the riparian community. This zone was dominated mostly by native vegetation with only low levels of introduced species found in the dry waterways and on stream banks.

Overall the condition of this RE on the Project site is good with only a low diversity of introduced species recorded throughout.

6.3.5 Community 5 – Low Open Woodland of Arid Peach (*Terminalia aridicola*) on Rocky Outcrops

6.3.5.1 Community Description

This community occurs on most rocky outcrops in the northern and eastern portions of the Study area. This community is consistent with RE 1.11.2x4. RE 1.11.2x4 can be described in short, as low open woodland of *Terminalia aridicola* +/- *Brachychiton collinus*, *Alphitonia* spp. and *Corymbia aspera* on rock outcrops on hills and ranges. The characteristics of this community and the dominant flora species in each stratum of vegetation are outlined in Table 12.

Table 12 Community 5 Profile

Regional Ecosystem	1.11.2x4: Low open woodland of *Terminalia aridicola*, often with *Brachychiton collinus*, *Alphitonia* spp. and *Corymbia aspera* with mid-dense shrub layer of *Acacia* spp. and ground layer of mixed tussock grasses and *Triodia* spp. Occurs on rock outcrops on hills and ranges on strongly folded siliceous sedimentary and metamorphic pre-Cambrian rocks.
Extent within Study Area	81.05 ha
EPBC Status	Not Listed
VM Act Status	Least Concern
Biodiversity Status	No concern at present
Tree Layer	*Terminalia aridicola* (D), *Brachychiton collinus* (SD), *E. leucophloia* (A)
Shrub Layer	*Trema tomentosa* (D), A. *phlebocarpa* (A), *A. chisholmii* (A)
Ground Layer	*Triodia pungens* (D), *Cymbopogon bombycinus* (A), *Sehima nervosum* (A)
Weed Species	*Cenchrus ciliaris* (O)
Canopy Height	4 – 7 m
Crown Cover	4 – 50 %

Key: D = Dominant, CD = Co-dominant, SD = Sub-dominant, A = Associated, O = Occasional

This community is dominated by Arid Peach (*Terminalia aridicola*) with associated Hill Kurrajong (*Brachychiton collinus*) and often occurs in association with Snappy Gum woodlands. The shrub layer typically contains Turpentine, Tabletop Wattle and Poison Peach (*Trema tomentosa*).

The ground layer is dominated by Soft Spinifex with associated grasses such as Silky Oilgrass and Whitegrass. Herbs recorded in this community include New Holland Rattlepod (*Crotalaria novae-hollandiae)* and Narrow-leafed Indigo (*Indigofera linifolia)*.

Photo Plate 5 Low open woodland of Arid Peach on rocky outcrops

6.3.5.2 Conservation Value

Species

Despite the completion of targeted searches for species of conservation significance, no threatened flora species were recorded within this community at the time of the Project surveys. The potential for threatened species identified in database searches, to occur on site is described in Table 15.

Community

RE 1.11.2x4 is listed as 'Least Concern' under the VM Act, 'No Concern at Present' under the DERM Biodiversity Status and is not listed under the EPBC Act.

RE 1.11.2 is not protected within the Northwest Highlands bioregion and is not under current threat from clearing or non-native species encroachment. RE 1.11.2 is considered abundant within the region, with the state-wide remnant extent greater than 10,000 ha.

6.3.5.3 Vegetation Condition and Habitat Value

Flora surveys revealed that native flora species dominated the dry rocky outcrops with only a scattered presence and low abundance of the introduced Buffel Grass recorded. No weed species listed under the LP Act or listed as Weeds of National Significance were recorded from this community.

Habitat features in this community include rocky substrates, Spinifex tussocks, leaf litter and fallen timber. This community provides plentiful habitat value for birds, reptiles and rock-dwelling mammals (e.g. Rock Rats and Purple-necked Rock-wallabies) in particular.

6.3.6 Community 6 – Capricornia (*Corymbia Capricornia*) Ridges

6.3.6.1 Community Description

Capricornia (*Corymbia capricornia*) dominates narrow rocky, typically quartz, ridges in the north east of the property. This community is consistent with RE 1.11.2x1b, which is described in short as low open woodland of *Corymbia Capricornia* on hills. The characteristics of this community and the dominant flora species in each stratum of vegetation are outlined in Table 13.

Table 13 Community 6 Profile

Regional Ecosystem	1.11.2x1b: Low open woodland of *Eucalyptus herbertiana* and/or *Corymbia capricornia*, mixed shrub layer and ground layer of *Triodia pungens* and tussock grasses. Occurs on hills on Surprise Creek Formation.
Extent within Study Area	1.92 ha
EPBC Status	Not Listed
VM Act Status	Least Concern
Biodiversity Status	No concern at present
Tree Layer	*Corymbia capricornia* (D), *Eucalyptus leucophloia* (A), *Alphitonia excelsa* (A), *Terminalia aridicola* (A)
Shrub Layer	*Acacia monticola (A), A. orthocarpa (A)*
Ground Layer	*Triodia bitextura (D), Cymbopogon bombycinus (A)*
Weed Species	N/A
Canopy Height	4.5 – 6.5 m
Crown Cover	<5 %

Key: D = Dominant, CD = Co-dominant, SD = Sub-dominant, A = Associated, O = Occasional

This community occurs on small isolated ridges that form a distinct change in ecotone as the terrain rises sharply and the geology becomes dominated by quartz rock. Associated trees include Snappy gum, *Alphitonia excelsa* and *Terminalia aridicola*. Shrubs include *Acacia monticola* and *A. orthocarpa*.

The groundlayer is often sparsely dispersed amongst the rocks. Normally an uncommon spinifex (*Triodia bitextura*) dominates this community rather than the more common *T. pungens*. Other grasses include *Cymbopogon bombycinus*, *Digitaria gibbosa* and *Mnesithea formosa*. Herbs include *Hybanthus aurantiacus* and *Spermacoce auriculata*.

Photo Plate 6 Capricornia ridges

6.3.6.2 Conservation Value

Species

Targeted searches for species of conservation significance determined that no species of conservation significance inhabit the Capricornia ridges. The potential for threatened species identified in database searches, to occur on site is described in Table 15.

Community

The community of Capricornia on ridges (RE 1.11.2x1b) is listed as 'Least Concern' under the VM Act, 'No Concern at Present' under the DERM Biodiversity Status and is not listed under the EPBC Act.

Although RE 1.11.2 is not protected within the Northwest Highlands bioregion, intact stands are abundant throughout this Queensland bioregion. RE 1.11.2x1b is not under threat from clearing and is considered abundant within the region, with the state-wide remnant extent greater than 10,000 ha. This community occurs outside the Project's proposed disturbance areas.

6.3.6.3 Vegetation Condition and Habitat Value

A low diversity and density of introduced species was recorded in association with the Capricornia ridges. Weed species recorded in low densities included including Buffel Grass and Beggar's Ticks (*Bidens bipinnata*). No weed species, listed under the LP Act or listed as of national significance, were observed within the Capricornia ridges community.

This community occupies very small areas of rocky quartz ridges, which are likely to provide limited habitat value for reptiles, birds and mammals.

6.3.7 Community 7 – Low Open Woodland of Cloncurry Box (*E. leucophylla*) and Bloodwood (*C. terminalis*) on granites

6.3.7.1 Community Description

This low open woodland community of Cloncurry Box (*E. leucophylla*) and Western Bloodwood (*C. terminalis*) occurs in association with stony hills and rises on granite to the west of the Project site.

This community closely resembles RE 1.12.1x1, which can be described in short as 'Low open woodland of *Eucalyptus leucophylla* often with *Corymbia terminalis* or *C. aparrerinja*. The defining characteristics of this community including the dominant flora species in each stratum of vegetation are outlined in Table 14.

Table 14 Community 7 Profile

Regional Ecosystem	1.12.1x1: Low open woodland of *Eucalyptus leucophylla* often with *Corymbia terminalis* or *C. aparrerinja*, shrub layer of *Acacia chisholmii* with hummock grass ground layer of *Triodia* spp. Includes areas of treeless *Triodia* spp. grasslands and *Acacia* spp. shrublands. Occurs on ranges and stony hills and rises on igneous rocks; skeletal soils and some shallow red earths.
Extent within Study Area	38.26 ha
EPBC Status	Not Listed
VM Act Status	Least Concern
Biodiversity Status	No concern at present
Tree Layer	*Eucalyptus leucophylla* (CD), *C. terminalis* (CD), *Atalaya hemiglauca* (A)
Shrub Layer	*Acacia chisholmii* (D), *Carissa lanceolata* (A)
Ground Layer	*Triodia* spp. (D)

Key: D = Dominant, CD = Co-dominant, SD = Sub-dominant, A = Associated, O = Occasional

This low open woodland community generally comprises a co-dominant canopy of Cloncurry Box (*E. leucophylla*) and Western Bloodwood (*C. terminalis*) on stony hills, rises and undulating plains. Whitewood commonly forms a low tree layer throughout the community. The shrub layer is typically dominated by Turpentine, while Conkerberry occurs commonly.

The ground layer was dominated by Triodia tussocks with occasional *Aristida* spp. and large patches of bare earth occurring sporadically.

6.3.7.2 Conservation Value

Species

Field surveys completed to date have not included targeted searches for threatened flora species within this community. Such surveys will need to be completed prior to construction of the proposed access road. The potential for threatened species identified in database searches, to occur on site is described in Table 15.

Community

RE 1.12.1 is listed as 'Least Concern' under the VM Act, 'No Concern at Present' under the DERM Biodiversity Status and is not listed under the EPBC Act.

This RE is not under current threat from clearing or non-native species encroachment. RE 1.12.1 is considered abundant within the region, with the state-wide remnant extent greater than 10,000 ha. RE 1.12.1 is protected in the Boodjamulla (Lawn Hill) National Park area in the Northwest Highlands bioregion.

6.3.7.3 Vegetation Condition and Habitat Value

This community occurs as part of a large patch of remnant vegetation. Previous disturbance within this community is limited to low intensity cattle grazing activities.

This community provides good habitat variety for birds, large macropods and reptiles in particular through the provision of rocky substrates, fallen timber and Spinifex tussocks. The small rocky hills and low rock outcrops are likely to support reptiles and small mammals. Highly mobile species such as birds and macropods are likely to utilise this community as forage habitat.

6.3.8 Flora Species of Conservation Significance

Database searches identified two threatened flora species within the region of the Project site. An assessment of the likelihood of these species occurring on the Project site is provided in Table 15.

Table 15 Flora of Conservation Significance known from the Region - Not Identified on the Project

Scientific Name	Habitat Description	Likelihood of Occurrence
Ptilotus maconochiei	*Eucalyptus leucophloia* and *Corymbia aspera* woodland, with *Triodia pungens* groundcover. On quartzite ridge tops, hillsides, slopes and shale	Potential habitat for this species occurs on the small quartzite ridgetops located on the Project site. Despite extensive field surveys, this species was not observed.
Ipomoea antonschmidii	*Eucalyptus leucophloia, Corymbia capricornia, Corymbia aparrerinja* and *Eucalyptus camaldulensis* woodlands. Grows in a variety of habitats, including rocky, sandy and red clay substrates. Occurs along the Lake Julius pipeline, Gunpowder and north of Mount Isa	This species grows on shallow, red, stony soils in a variety of habitats, some of which are represented on the Project. It is known to occur within 15 km of the Project. While this species was not observed during field surveys, there is potential for this species to occur on the Project site.

Targeted searches across the Project site failed to detect the presence of any plants of conservation significance. Given that no threatened flora species have been recorded on the Project site, it is highly unlikely that the Project will impact on any flora species of conservation significance.

6.3.9 Weeds of Management Concern

Six introduced weed species were recorded in low densities across the Project. Introduced weeds present on the project site included the following:

- Buffel Grass (*Cenchrus ciliaris*);
- Red Natal Grass (*Melinis repens*);

- Asthma Plant (*Chamaesyce hirta);*
- Beggar's Ticks (*Bidens bipinnata*);
- Kapok Bush (*Aerva javanica*); and
- Mimosa Bush (*Vachellia farnesiana*).

All weed species recorded on the Project site are known to occur commonly throughout the broader region. No weed species recorded on the Project are listed as declared weeds under the Queensland *Land Protection (Pest and Stock Route Management) Act 2002.* No Commonwealth listed Weeds of National Significance (WoNS) were identified on the Project site. Introduced plant species are classified by the Commonwealth Government as WoNS if they present a serious threat to industry, water supply, human health/safety, plant communities and/or cultural values.

6.4 FAUNA SURVEY RESULTS

A total of 144 fauna species were identified during wet and dry season surveys on the Project site. The suite of fauna species recorded included nine amphibians, twenty-seven reptiles, eighty birds and twenty-eight mammals. A complete list of fauna species recorded on the Project site is provided in Appendix D.

Each of the major vertebrate groups observed on the Project site is discussed below in Sections 6.4.1 to 6.4.5. Pest species observed on the Project site are discussed in Section 6.4.6. Fauna species of conservation significance are discussed in Section 6.4.7.

6.4.1 Amphibians

6.4.1.1 Habitat Values

Amphibian habitat on the Project site varies seasonally due to the ephemeral nature of creeks and associated drainage lines. During the dry season (May-October), sandy drainage lines offer the majority of the potential habitat for burrowing species capable of spending extensive period's underground awaiting rain. The waterholes present on the Project site function as three temporary and one permanent water source, all of which would support amphibian habitation to some extent. However, the limited availability of permanent water restricts the habitat potential for any non-burrowing amphibians to persist during the dry season. During the wet season (November-April), habitat variation and suitability increases in response to increased rainfall.

6.4.2 Observed Species

A total of 9 amphibian species were noted throughout the Project site. Two amphibian species observed during the 2011 wet season survey, Sandstone Frog (*Litoria coplandi)* and Wotjulum Frog (*Litoria wotjulumensis)* were noted to be at the limits of their distribution in the Mount Isa area. Other species noted during the Project surveys include the Green Tree Frog (*Litoria caerulea),* Northern Snapping Frog (*Cyclorana australis*), Long-footed Frog *(Cyclorana longipes),* Northern Laughing Treefrog *(Litoria rothi),* Ruddy Treefrog *(Litoria rubella),* Ornate Burrowing Frog (*Platyplectrum ornatum*) and the introduced Cane Toad *(Rhinella marina*).

The Cane Toad was first recorded on the Project site during the 2011 terrestrial flora and fauna surveys. While it was not observed during the 2014 wet or dry season field surveys, it was recorded in low numbers during the 2014 wet and dry season aquatic ecology surveys (refer to the Barbara

Copper Project Aquatic Ecology report). The Cane Toad is not listed as a declared pest species under the LP Act.

While two species were recorded outside their normal distribution (i.e. *Litoria coplandi* and *Litoria wotjulumensis*), all other amphibian species observed during the Project surveys are known to occur commonly throughout the local region. A full list of observed amphibian species is included in Appendix D of this report.

Photo Plate 7 *Litoria coplandi* recorded in a small sandstone gorge (OBSO2)

6.4.2.1 Amphibian Species of Conservation Significance

No amphibians of conservation significance have been previously recorded within the region (Appendix A). It is considered unlikely that any amphibian species of conservation significance occur on the Project site.

The presence of *Litoria coplandi* and *Litoria wotjulumensis* on the Project site indicates a potential extension to the known distribution of each species, however, neither is considered species of conservation significance.

6.4.3 Reptiles

6.4.3.1 Habitat Values

Australia's environment supports an extremely diverse assemblage of reptile species which exploit a wide array of micro-habitats (e.g. tree hollows, rock crevices, soil cracks) and food sources (e.g. succulent leaves, termites, grasshoppers, birds, and other reptiles) (Pianka 1969a; 1969b). This diversity encompasses species of widely different body sizes (skinks *v.* monitors), and life history strategies (burrowing blind snakes *v*. arboreal geckos).

The Project site provides a variety of habitat types thought to be suitable for reptile species occurring in the region. Micro-habitats such as those associated with tree hollows, vegetated watercourses, open woodlands scattered with fallen timber and rocky outcrops may suit a variety of reptile species.

6.4.3.2 Observed Species

The two wet season surveys and two dry season surveys conducted in 2011 and 2014, recorded a total of 27 reptile species on the Project site. All reptile species recorded on the Project site are listed in Appendix D.

A large variety of skinks comprising 11 species were encountered on the Project. These species include Gravelly-soil Ctenotus (*Ctenotus lateralis),* Rock Ctenotus (*Ctenotus saxatilis*)*,* Leopard Ctenotus (*Ctenotus pantherinus),* Eastern Striped Skink (*Ctenotus robustus*), Carpentarian Ctenotus (*Ctenotus striaticeps*)*,* Shaded-litter Rainbow-skink *(Carlia munda)*, Two-spined Rainbow-skink (*Carlia amax),* Agile Snake-eyed Skink (*Cryptoblepharus zoticus),* Metallic Snake-eyed Skink *(Cryptoblepharus metallicus),* Northern Soil-crevice Skink (*Proablepharus tenuis*) and Hosmer's Skink (*Egernia hosmeri)* (Photo Plate 8)*.*

Photo Plate 8 Hosmer's Skink (*Egernia hosmeri*) captured in an Elliott trap at FA6

Four gecko species were identified, predominantly whilst spotlighting in watercourses. These included Northern Spiny-tailed Gecko (*Strophurus ciliaris*) (Photo Plate 9), Robust Dtella (*Gehyra robusta),* Tree Dtella *(Gehyra variegata) and* Bynoe's Gecko *(Heteronotia binoei)*.

Photo Plate 9 Northern Spiny-tailed Gecko at FA5

The remaining reptile species observed on the Project site were Gilbert's Dragon *(Amphibolurus gilbertii*), Merten's Water Monitor (*Varanus mertensi*), Ridge-tailed Monitor (*Varanus acanthurus*), Children's Python (*Anteresia childreni*), Olive Python (*Liasis olivaceus*), Northern Hooded Scaly-foot *(Pygopus steelescotti*) (Photo Plate 10), Burton's Legless Lizard (*Lialis burtonis*), Northern Blind Snake (*Ramphotyphlops diversus*)*,* Robust Blind Snake (*Ramphotyphlops ligatus*) (Photo Plate 11), Curl Snake (*Suta suta*), Sombre Whipsnake (*Demansia quaesitor*) and Collared Whipsnake (*Demansia torquata*).

Photo Plate 10 Northern Hooded Scaly-foot (*Pygopus steelescotti*) captured at FA1

Photo Plate 11 Robust Blind Snake (*Ramphotyphlops ligatus*) captured at FA5

6.4.3.3 Reptile Species of Conservation Significance

No reptiles of conservation significance were observed on the Project site during either of the wet or dry season surveys. Database searches identified three reptile species of conservation significance within the region of the Project site. All three reptiles have specific habitat requirements. The Death Adder occurs on flat, treeless, cracking-soil riverine floodplains (Cogger 2000), while the Gulf Snapping Turtle and Diamond Head Turtle require permanent rivers and waterbodies to survive. The Project area lacks suitable habitat for reptile species of conservation significance that are known from the region.

6.4.4 Birds

6.4.4.1 Habitat Values

Avian assemblages are generally determined by factors such as food sources (e.g. fruit, nectar, seeds, and insects), as well as a mosaic of habitat structures such as grasses, thick understorey, midstorey and canopy vegetation (i.e. vertical habitat complexity). Generally, the more food sources available and the more complex the structure of the vegetation, the more diverse the avifauna will be.

Food sources on the Project site are generally restricted to seeds, nectar, insects and vertebrate prey items (or carrion). The Project Site and also the surrounding area largely lacked a permanent or abundant supply of fruit producing plant species, suggesting fructivorous species are less likely to occur.

6.4.4.2 Observed Species

A combined total of 80 bird species were recorded on the Project site during the 2011 and 2014 flora and fauna surveys, with all species considered common throughout the region. The suite of birds recorded on the Project site included one listed Marine and Migratory species, the Rainbow Bee-eater (*Merops ornatus*) and one State listed near threatened species, the Golden-backed Honeyeater (*Melithreptus gularis laetior*). These species are discussed in more detail in Section 6.4.4.3 and 6.4.4.4. All bird species recorded on the Project site are listed in Appendix D.

A large diversity of granivorous birds were recorded on Project site including the Peaceful Dove (*Geopelia striata*), Diamond Dove (*Geopelia cuneata)*, Spinifex Pigeon (*Geophaps plumiferal*), Crested Pigeon (*Ocyphaps lophotes*), Common Bronzewing (*Phaps chalcoptera*), and a variety of finches and parrots common to the region such as the Zebra Finch (*Taeniopygia guttata*), Long-tailed Finch (*Poephila acuticauda*), Double Barred Finch (*Taeniopygia bichenovii*), Red-winged Parrot (*Aprosmictus erythropterus*) and Budgerigar (*Melopsittacus undulatus*).

The site contained a large variety of honeyeaters with many species observed. The most commonly recorded honeyeater species were the Brown Honeyeater (*Lichmera indistincta*), Grey-headed Honeyeater (*Ptilotula keartlandi*) and Yellow-throated Miner (*Manorina flavigula*).

Four raptor species were observed on the Project site during the surveys, including the Wedge-tail Eagle (*Aquila audax*), Brown Falcon (*Falco berigora*), Collared Sparrowhawk (*Accipiter cirrocephalus*) and Black-shouldered Kite (*Elanus axillaris*). In addition to these species, several other birds that are known to feed on vertebrate species were detected, including the Magpie (*Cracticus tibicen*), Australian Raven (*Corvus coronoides*), Blue-winged Kookaburra (*Dacelo leachii*), Pied Butcherbird (*Cracticus nigrogularis*), Red-backed Kingfisher (*Todiramphus pyrrhopygius*) and Magpie Lark (*Grallina cyanoleuca*).

Two nocturnal birds were observed whilst spotlighting during the 2011 and 2014 surveys. Both were observed to be nocturnal predators including Spotted Nightjar (*Eurostopodus argus*), and Australian Owlet Nightjar (*Aegotheles cristatus*).

6.4.4.3 Bird Species of Conservation Significance

Golden-backed Honeyeaters (*Melithreptus gularis laetior*) were observed on the project site during the 2011 wet and dry season surveys. This species was later observed on the Project during the 2014 dry season survey. This species is listed as Near Threatened under the Nature Conservation Act 1992. The Golden-backed Honeyeater is a widely roaming species, able to cover large distances quickly. While they may exploit any habitats within the study area, they are most likely to frequent creek lines and riparian vegetation associations (RE's 1.3.6 and 1.3.7a,b) where flowering tree species such as *Lophostemon grandiflorus* and *Eucalyptus camaldulensis* are common. The locations in which the Golden-backed Honeyeater has been recorded on the Project site are shown in Figure 10. The operational works of the project are not concentrated along the watercourses and there is a large abundance of suitable habitat located throughout the surrounding region. Impacts from the Project are unlikely to influence the regional populations of this species. No other bird species of conservation significance were recorded on the Project at the time of the surveys.

6.4.4.4 EPBC Act Listed Migratory and Marine Species

One bird species observed on the Project site at the time of the surveys, the Rainbow Bee-eater (*Merops ornatus*) is listed under the EPBC Act as Marine and Migratory. The Rainbow Bee-eater inhabits all of mainland Queensland, as well as Indonesia, New Guinea and the Solomon Islands. This species is widespread and breeds throughout most of its range, with the exception of southern birds,

which move north to breed. Species which utilise the Project site are not at the extent of their known range and the population in the area does not constitute an 'ecologically significant proportion' of the total population of this species. Impacts from the Project are highly unlikely to meet the significant impact criteria for migratory species as defined in the Matters of National Environmental Significance. While the species does inhabit the site, the surrounding region provides suitable habitat that can be utilised and impacts from the project are unlikely to significantly impact the habitat or distribution of this species in the region.

6.4.5 Mammals

6.4.5.1 Habitat Values

The morphology of mammal species varies widely from small rodents to larger kangaroos and even bats. The ecology of each of these groups is equally variable and they are assessed separately in the following sections.

Small Mammals

Habitats suitable for small mammals include areas that provide a plentiful food source and suitable shelter sites. The highest density of small mammal species is usually associated with reliable rainfall which is reflected in a reliable source of food and dense ground vegetation, particularly shrubs and grasses.

The diversity of small mammals is often limited by the lack of a predictable food supply and open ground vegetation. Consequently, small mammal populations can fluctuate dramatically in response to rainfall which increases seed production and insect abundance. During less favourable periods, small mammal populations can be very low.

The Project site provided a variety of habitat types suitable for small ground-dwelling mammals, including vegetated open woodlands, vegetated water courses and rocky outcrops and escarpments.

Medium and Large Mammals

Factors affecting the occurrence of medium and large sized mammals are varied. Important factors can include land-clearing, feral animal predation and grazing pressures. Consequently, medium-sized mammals are considered to be highly populated in most of eastern Australia.

Habitats on the Project site do not include large areas of dense native vegetation. Rather, the open grassy woodland is typical of the region is likely to be reflected in the medium-sized mammal community. Rocky outcrops provide habitat for rock-wallabies to roost and forage.

Larger mammals such as kangaroos have been much less affected by predation and land clearing activities. In fact, many species have flourished in response to increased areas of grassland and open vegetation. Habitat on the Project site for this mammal group is favourable.

Arboreal Mammals

The majority of arboreal mammals that occur in Australia utilise tree hollows for nesting and shelter (Menkhorst and Knight 2004). A shortage of nest hollows is likely to limit arboreal mammal populations where the density of hollow bearing trees is less than two to eight trees per ha (Smith and Lindenmayer 1988).

Hollow-bearing trees in the broader region of the Project generally occur along creek-lines, separated by open areas that would be difficult for arboreal mammals to cross without venturing onto the ground. This vegetation structure occurs throughout the Project site, with hollow bearing trees largely restricted to the River Red Gum and Northern Swamp Box creeks (RE 1.3.7a).

Bats

The density and diversity of Australian bat species is determined primarily by the availability of suitable nesting and roosting sites. Roosting sites can include locations such as thick foliage, loose exfoliating bark, rock caves or cavities, tree hollows or even fabricated structures such as old buildings and culverts (Churchill 1998).

Consequently, areas with a large number of hollow-bearing trees that occur within remnant vegetation are of high value to many bat species. As bats have a small body size, these hollows can be much smaller in size than required by arboreal mammals. Possible roosting sites were present on the Project site and included tree hollows in the River Red Gum and Northern Swamp Box creeks (RE 1.3.7a), caves and crevices in the rocky outcrops areas and disused mining shafts. Some hollows were also noted in the *Eucalyptus leucophloia* (Snappy Gum) located throughout the more open areas of the site.

6.4.5.2 Observed Species

In total, twenty-eight mammal species were observed on the Project site, comprising 24 native species and 4 introduced species. Introduced species recorded as having a presence on the Project site include the House Mouse (*Mus domesticus*), Dingo/Wild Dog (*Canis familiaris),* Feral Pig (*Sus scrofa*) and Cow (*Bos taurus*). One introduced species, the House Mouse (*Mus domesticus*) was captured in an Elliott trap at Fauna Site 3 during the 2011 dry season survey. All other pest species were recorded either through direct observation or analysis of faecal scats.

Two of the introduced species, the Dingo/Wild Dog and Feral Pig are classified as Class 2 pest animals under the LP Act. Discussion of these introduced species is provided in Section 8.6. All mammal species recorded on the Project site are listed in Appendix D.

Twenty-four native mammal species were recorded on the Project site and include Desert Mouse (*Pseudomys desertor*), Delicate Mouse (*Pseudomys delicatulus*), Long-haired Rat (*Rattus villosissimus*), Long-tailed Planigale (*Planigale ingrami*), Common Planigale (*Planigale maculata*), Stripe-faced Dunnart (*Sminthopsis macroura*), Echidna (*Tachyglossus aculeatus*), Common Wallaroo (*Macropus robustus*), Red Kangaroo (*Macropus rufus*), Spectacled Hare-wallaby (*Lagorchestes conspicillatus*) and Purple-necked Rock-wallaby (*Petrogale purpureicollis*). A photograph of a Common Planigale captured at FA5 is provided in Photo Plate 12.

Photo Plate 12 Common Planigale (*Planigale maculata)* captured at FA5

A total of 12 micro-bat species were positively identified on the Project site, all of which are not listed under the EPBC Act or NCWR. Commonly identified species, with more than 20 positive calls recorded most nights, included Gould's Wattled Bat (*Chalinolobus gouldii*), Inland Broad-nosed Bat (*Scotorepens balstoni*), Inland Forest Bat (*Vespadelus baverstocki*) and Yellow-bellied Sheathtail Bat (*Saccolaimus flaviventris*). Additional species identified included the Beccari's Freetail Bat (*Mormopeterus beccarii*), Northern Freetail Bat (*Chaerephon jobensis*), Eastern Dusky Leaf-nosed Bat (*Hipposideros ater*), Hoary Wattled Bat (*Chalinolobus nigrogriseus*), Troughton's Sheathtail Bat (*Taphozous troughtoni*), Common Sheathtail Bat (*Taphozous georgianus*), Little Broad-nosed Bat (*Scotorepens greyii*), Finlayson's Cave Bat (*Vespadelus finlaysoni*), Little-red Flying-fox (*Pteropus scapulatus*), an unknown Long-eared Bat (*Nyctophilus* sp.) and an unknown Freetail Bat (*Mormopterus* sp.). The Long-eared Bat (*Nyctophilus* sp.) could not be identified to species level because it cannot be reliably differentiated from call data. Long-eared Bats generally produce distinctive calls. The species most likely to be present in the Project area is *N. geoffroyi*. Three other species (*N. arnhemensis*, *N. bifax* and *N. walkeri*) also occur in the far northwest of Queensland but are primarily restricted to moist habitats such as watercourses lined with pandanus and paperbark, which occur in small isolated fragments on the Project Site. The unresolved calls of the Freetail Bat (*Mormopterus* sp.) were considered to be representative of a small *Mormopterus* sp. with the calls being similar to those calls produced by *Mormopterus* sp. 3 (Balance Environmental, 2014).

The alluvial areas such as River Red Gum and Northern Swamp-box Riparian Woodland (RE 1.3.7a) held the highest abundance of microbats, although areas such as rocky outcrops on hills, Snappy Gum (*Eucalyptus leucophloia*) hollows and manmade structures such as abandoned mine shafts and the current exploration camp also provided ample roosting and feeding habitat.

Appendix E details the ANABAT analysis results.

6.4.5.3 Mammal Species of Conservation Significance

One mammal species of conservation significance, the Purple-necked Rock-wallaby (PNRW) has been recorded on the Project site. This species was observed on the Project site during both the 2011 and 2014 wet season surveys. A photo of a Purple-necked Rock-wallaby captured on a sensor camera at FA8 during the 2014 dry season survey is provided in Photo Plate 13. The Purple-necked Rock-wallaby is listed in the schedules of the NCWR as a Vulnerable species but is not listed under the EPBC Act.

Photo Plate 13 Purple-necked Rock-wallaby at FA8

This species is known in the region and occupies rock outcrops, boulder piles, cliffs, gorges, rocky slopes and gullies within dry Eucalypt and acacia woodlands where Spinifex dominates the understorey (Curtis and Dennis 2012). Large successful populations generally have access to permanent freshwater and populations may wither without it during extended droughts. However, Purple-necked Rock-wallabies are highly adapted to dry conditions and can obtain their water from dew and by extracting it from herbage (Van Dyck and Strahan 2008). Rock-wallabies exhibit strong fidelity to home ranges and their movements between roosting sites and feeding areas are highly predictable (Horsup 1994).

Rocky habitat used by Rock-wallabies provides protection from predation by species such as Dingo (*Canis lupus dingo*), Fox (*Vulpes vulpes*) and Wedge-tail Eagle (*Aquila audux*) as well as temperature extremes during the day. At night they move over larger areas to feed on plants growing in deeper soils (Law and Dickman 1988). Caves within rocky outcrops provide a micro environment that buffers temperatures and maintain higher levels of humidity than outside the rocks (Short 1982).

Purple-necked Rock-wallabies are less likely to occur widely over the study area. Rather, the species is associated with large rock outcrops and screed slopes that provide overhangs, cracks and small cavernous structures. While many individuals are sedentary, remaining at the same rock outcrop for extended periods, some individuals (particularly young males) may move several kilometres in search of new habitats.

These individuals are probably responsible for scats and other traces that can often be located in small isolated outcrops, which are unlikely to support a resident individual or family group in the long-term. Within the study area, most suitable habitat was observed on hill-tops and along two small gorges. Site coordinates were recorded where all threatened species were observed and are demonstrated in Figure 10 below.

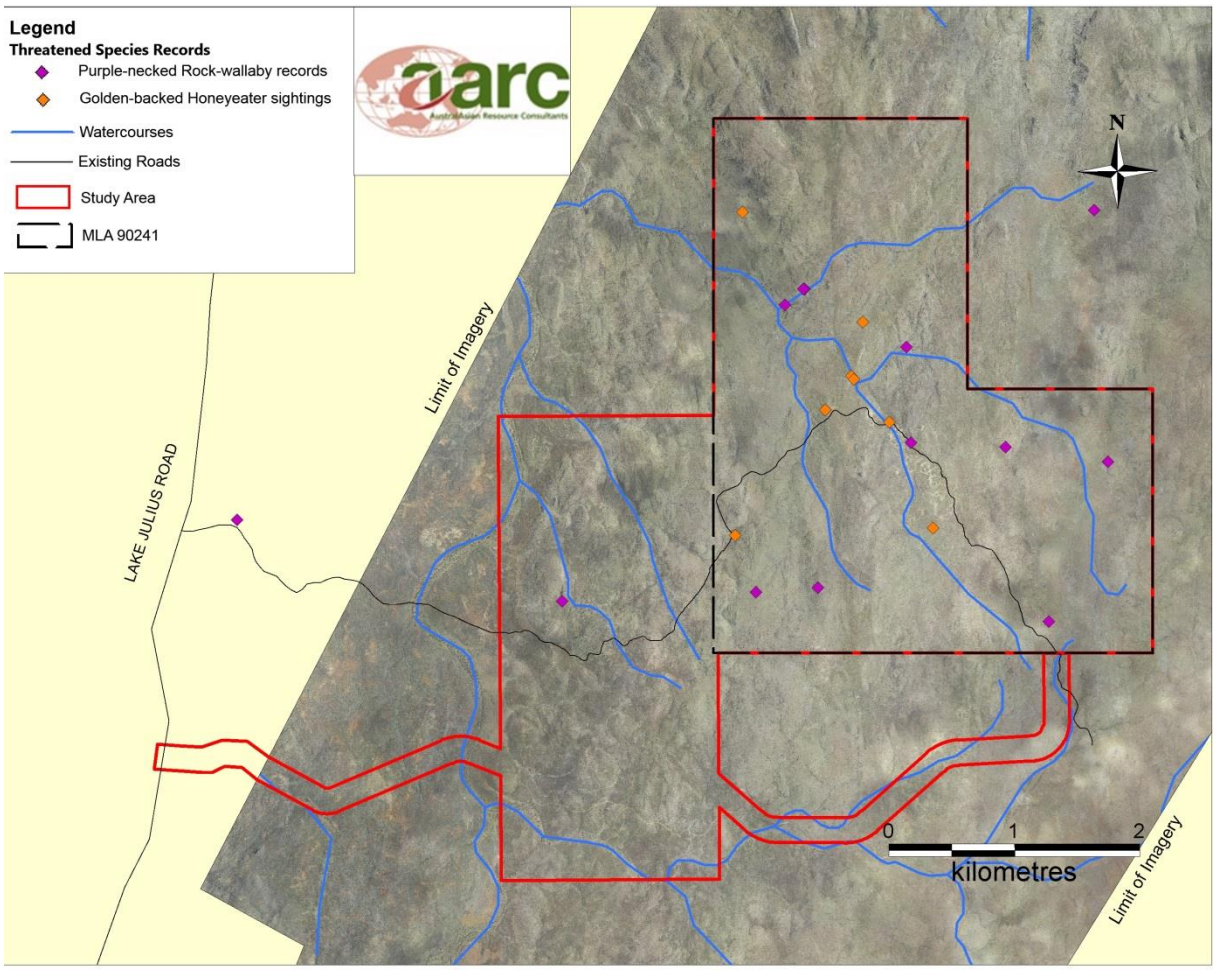

Figure 10 Threatened Species Records

During the 2011 wet season survey, a number of individuals (e.g. more than five) were located within these two gorges, along with abundant scat evidence, suggesting these locations may support semi-permanent and sizable populations. While no sightings were recorded during the 2011 dry season surveys, at least one individual was observed at three different locations across the Project (including one of the gorges) during the 2014 wet season survey. Both gorges and the bulk of outcropping hill-top habitat lie outside the main resource areas. Areas of potential PNRW habitat are shown in Figure 11. Potential Project impacts on PNRW habitat are discussed in Sections 7.2 and 7.4.

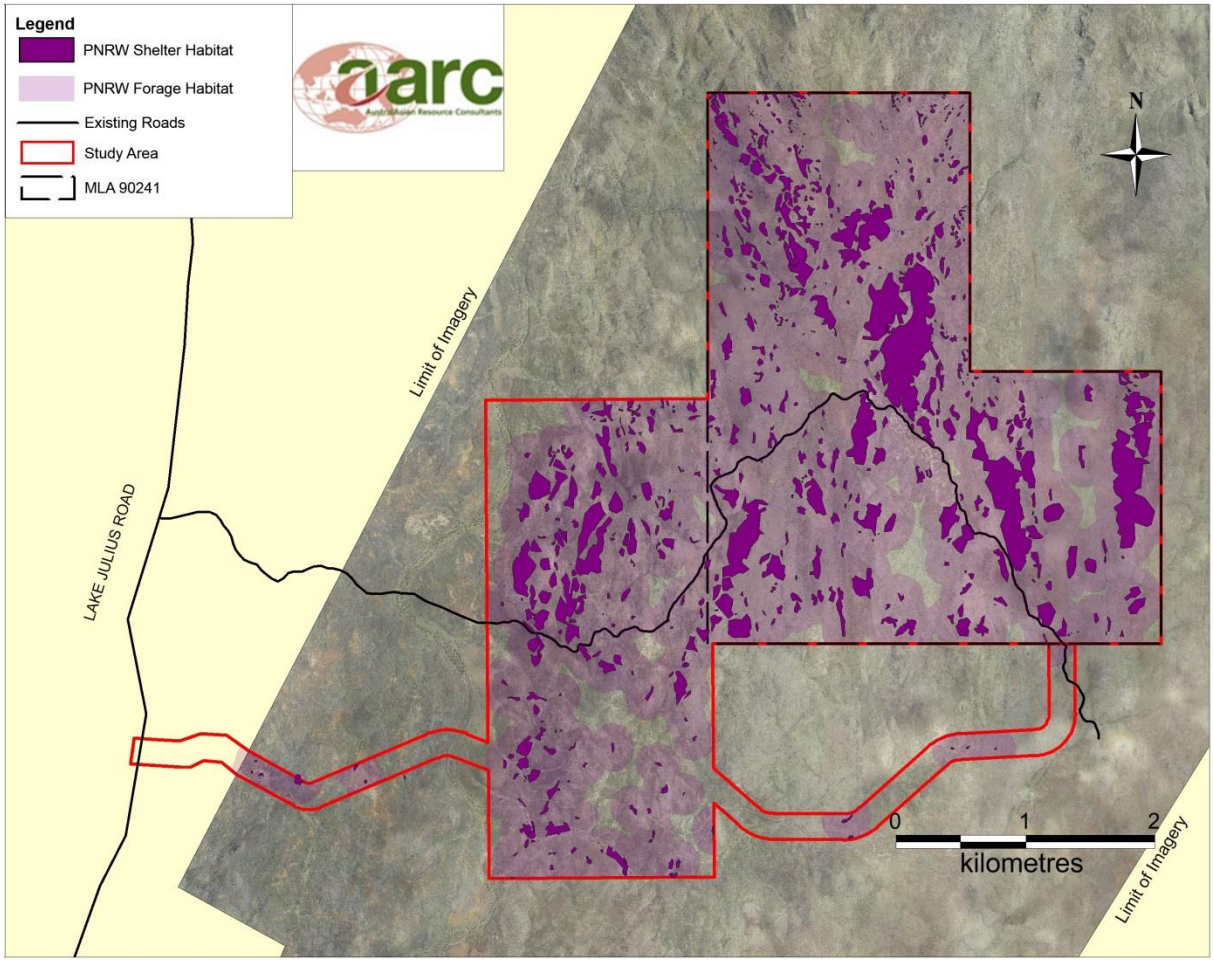

Figure 11 PNRW Habitat Areas

Species of conservation significance known from the region which were not detected during the survey are discussed in Section 6.4.7.

6.4.6 Pest Species

Field surveys positively identified five introduced fauna species as having a presence on the Project site either through direct observation or detection of species presence indicators (i.e. faecal scats, tracks, etc.). Pest species present include the Cane Toad, Wild Dog/Dingo, Feral Pig and House Mouse as well as domestic cattle. Two of the introduced species, the Wild Dog/Dingo and Feral Pig are classified as Class 2 pest animals under the LP Act. Pest species fact sheets outlining appropriate management controls for each species are provided in Appendix F.

Dingos/Wild Dogs are natural predators and present a threat to native wildlife in the area. Feral Pigs can have significant impacts on the environment including weed dispersal, degradation of waterbodies, soil erosion, predation on native species and potentially dispersal of diseases to native fauna.

While Cane Toads are not a declared species, they present a serious threat to native wildlife. The Cane Toad consumes a wide variety of native animals including frogs, small reptiles, mammals and birds and causes the death of native predators that consume their toxins.

6.4.7 Regional Fauna Species of Conservation Significance

As previously mentioned, two fauna species of conservation significance (i.e. Golden-backed Honeyeater and Purple-necked Rock-wallaby) have been identified on the Project site. Under the NCWR, the Golden-backed Honeyeater is listed as Near Threatened and the Purple-necked Rock-wallaby is listed Vulnerable. No fauna species listed as threatened under the EPBC Act were identified on the Project site. Furthermore, no Back on Track Priority fauna species identified in the region were recorded on the Project.

Table 16 below discusses species of conservation significance that are known from the broader region and have been identified from desktop searches (Appendix A), but were not observed on the Project site during surveys.

The assessment of potential for presence and impact on each species is based on the knowledge of ecologists, information obtained from field surveys on the Project site, previous surveys conducted on or near the Project site and scientific literature.

Table 16 Threatened Fauna known from the Region Not Observed on the Project site

Scientific Name **Common Name**	**Status**		**Habitat Requirements**	**Likelihood**
	EPBC Act	**NC Act**		
Birds				
Accipiter novaehollandiae Grey Goshawk	NL	NT	This species prefers rainforests, forests, forested gullies and valleys, taller woodlands, timbered watercourses and may be found in open country during autumn dispersal	**Possible.** The Project site lacks habitat preferred by this species. It is likely that any occurrence of this species on the Project site would be of a temporary nature during periods of dispersal. Given the species primarily occupies coastal and sub-coastal regions, the Project is unlikely to have an impact on this species
Amytornis dorotheae Carpentarian Grasswren	NL	NT	The Carpentarian Grasswren has a highly restricted distribution from the 'Gulf fall' escarpments in NT, south-east to Lawn Hill National Park and East to Gunpowder-Mount Isa. Preferred habitats typically incorporate areas of Spinifex, sparse shrubs and eucalypts on sandstone escarpments and gullies (Pizzey & Knight 2007).	**Unlikely.** Preferred habitat for this species does not occur on the Project site.
Ephippiorhynchus asiaticus Black-necked Stork	NL	NT	This species is a wetland indicator species occurring where wetland habitat exists throughout Queensland.	**Unlikely**. As suitable habitat does not occur on the Project site it is unlikely that this species would occur on the Project.

Scientific Name **Common Name**	**Status**		**Habitat Requirements**	**Likelihood**
	EPBC Act	**NC Act**		
Epthianura crocea crocea Yellow Chat (gulf)	NL	V	This species inhabits low vegetation around the margins of ephemeral wetlands, floodplains, swamps and bore drains, vegetated dams, salt lakes, clay pans and lagoons, sewerage ponds or reservoirs. The Gulf subspecies of Yellow Chat is distributed across the Lake Eyre and Gulf of Carpentaria drainage basins (Curtis & Dennis 2012).	**Unlikely.** Suitable habitat for this species does not occur on or adjacent to the Project site.
Erythrotriorchis radiatus Red Goshawk	V	E	This species generally prefers coastal and sub-coastal open forest and woodland that supports a mosaic of vegetation types. They tend to nest in tall emergent trees located in close proximity to permanent freshwater (Curtis & Dennis 2012).	**Unlikely**: Suitable habitat does not occur on the Project site.
Erythrura gouldiae Gouldian Finch	E	E	This species occupies open tropical woodlands with a grassy understorey dominated by annual Sorghum (*Sarga* spp.) grasses and breeds in Eucalypt open woodlands on ridges, rocky foothills or escarpment country; during the wet season it feeds in Spinifex dominant habitats and wet lowlands with diverse perennial grasses. (Curtis & Dennis 2012).	**Possible:** This species may occur on the Project site as it prefers to feed in Spinifex grasslands during the wet season and typically nests in hollow-bearing Eucalypts including *E. leucophloia* (DoE 2014, Curtis and Dennis 2012). Both habitat types occur on the Project site. While the Project may remove some habitat for this species, suitable habitat occurs in abundance throughout the surrounding region. The Project is not likely to have a significant impact on the species.
Falco hypoleucos Grey Falcon	NL	NT	This species occupies lightly treed inland plains, gibber deserts, sandridges, pastoral lands, timbered watercourses and seldom the driest deserts (Pizzey & Knight 2007).	**Unlikely.** Preferred habitat for this species does not occur on the Project.

Scientific Name **Common Name**	**Status**		**Habitat Requirements**	**Likelihood**
	EPBC Act	**NC Act**		
Grantiella picta Painted Honeyeater	NL	V	This species prefers deep, productive soils, in Acacia dominant woodlands and relies on abundant mistletoes for food (Curtis & Dennis 2012).	**Unlikely.** The Project site does not provide suitable habitat for this species.
Heteromunia pectoralis Pictorella Mannikin	NL	NT	Pictorella Mannikin is found in open country with sparse trees and a groundlayer of grass or Spinifex, tall grass in Acacia woodlands near water and on grassy flats along creeks (Pizzey & Knight 2007). The species distribution extends from the Fitzroy River Valley in central north QLD across north west QLD, NT and WA.	**Possible:** The Project site contains suitable habitat for the Pictorella Mannikin. However, suitable habitat is highly available throughout the surrounding region, signifying it is unlikely the Project provides critical habitat. Furthermore, given the extent of the species range, it is unlikely the Project will have an adverse impact on the species should it occur intermittently.
Lophoictinia isura Square-tailed Kite	NL	NT	This species is widely distributed across mainland Australia and is known to inhabit heathlands, woodlands, forests, tropical and subtropical rainforest, timbered watercourses, hills and gorges.	**Possible**: Portions of the Project site provide suitable habitat for this species including timbered watercourses, hills and gorges. Given the availability of habitat for this species throughout the region, the Project is unlikely to have an impact on the species should it occur in the area.
Malurus coronatus Purple-crowned Fairy-wren	NL	V	Primary habitat for the Purple-crowned Fairy-wren consists of river-fringing vegetation with a dense mid-storey and a high tree canopy, typically dominated by River Pandanus (*Pandanus aquaticus*) or Rivergrass (*Chionachne cyanthopoda*) beside permanent freshwater pools (Curtis & Dennis 2012).	**Unlikely.** Suitable habitat for this species is highly restricted to the well vegetated margins of permanent freshwater rivers or billabongs. The Project site lacks suitable habitat.
Nettapus coromandelianus Cotton Pygmy-goose	NL	NT	This species occupies deeper freshwater swamps, lagoons and dams with semi-emergent aquatic plants (Pizzey & Knight 2007)	**Unlikely**. The Project site lacks wetland habitats which are a strict habitat requirement for this species.

Scientific Name **Common Name**	**Status**		**Habitat Requirements**	**Likelihood**
	EPBC Act	**NC Act**		
Numenius madagascariensis Eastern Curlew	Ma, Mi	NT	This species occupies estuaries, tidal mudflats, sandpits, salt marshes, mangroves, occasionally fresh or brackish lakes or bare grassland near water (Pizzey & Knight 2007)	**Unlikely.** The Project site lacks estuarine and freshwater habitats required by this species.
Pezoporus occidentalis Night Parrot	E	E	The Night Parrot occupies Spinifex hummock grasslands on rocky ranges, breakaways or open herbaceous flats around salt lakes and occasionally Mitchell Grass (*Astrebla* spp.) downs and flats (Curtis & Dennis 2012).	**Possible.** This species, whilst rare, has been recorded using Spinifex grasslands to the south of the Project site. Little is known of this species however, due to the proximity of this site to a cluster of confirmed sightings, it is possible this species may occur on the Project site (Curtis and Dennis 2012).
Poephila cincta cincta Black-throated Finch (southern)	E	E	This species occupies grassy, open woodlands and forests that are Eucalyptus, Corymbia and Melaleuca dominant and located within a few kilometres of water (Curtis & Dennis 2012).	**Unlikely.** Whilst suitable habitat for this species occurs on the Project site, it is unlikely that this species will occur on the Project site as the site is located outside its known distribution.
Polytelis alexandrae Princess Parrot	V	NL	The Princess Parrot inhabits open savanna woodlands and shrublands on sand dunes and flats in the arid zone of western and central Australia (DoE 2014a).	**Unlikely.** It is unlikely that this species will occur on the Project site as it lacks suitable habitat and occurs outside the species known distribution.
Rostratula australis Australian Painted Snipe	E	V	This species has a scattered distribution and is typically found utilising shallow inland freshwater or brackish wetlands with low vegetation (Curtis & Dennis 2012). This species is nomadic and exists where suitable habitat occurs temporarily.	**Unlikely.** No suitable habitat for this species occurs on the Project site.

Scientific Name **Common Name**	**Status**		**Habitat Requirements**	**Likelihood**
	EPBC Act	**NC Act**		
Stictonetta naevosa Freckled Duck	NL	NT	This species prefers large, well-vegetated swamps and moves to open lakes during dry periods (Pizzey & Knight 2007).	**Unlikely.** Suitable habitat for this species does not occur on or adjacent to the Project site.
Mammals				
Hipposideros stenotis Northern Leaf-nosed Bat	NL	V	This species requires escarpments, rocky ranges or boulder piles for roost habitat. Adjacent habitats include tussock and Spinifex grasslands, open woodland vine thickets and riparian forests (Curtis & Dennis 2012).	**Possible**. Suitable habitat for this species occurs throughout the Project site and surrounding lands. The Project may impact on habitat for this species. However, given that suitable habitat is vastly available throughout the broader region, it is unlikely that the Project will impact on the species.
Macrotis lagotis Greater Bilby	V	E	The Greater Bilby inhabits primarily clay areas and some stony plains in the Channel Country in south-western QLD (Curtis & Dennis 2012).	**Unlikely**. There are no records of this species near the Project site and is unlikely to be noted. The closest records are near the Northern Territory border. There is suitable habitat of the Project site as this species inhabits Spinifex grasslands (*Triodia* sp.); however, due to the distance of the Project from existing records this species' presence is unlikely.
Pseudantechinus mimulus Carpentarian Antechinus	V	NL	The Carpentarian Antechinus occupies rocky areas, or woodlands close by. They inhabit open woodlands of *Eucalyptus leucophloia*, *E. normantonensis*, *Corymbia terminalis*, *Atalaya hemiglauca* and *Acacia* spp. over hummock grasslands, sandstone boulders, pavements and outcrops (Curtis & Dennis 2012).	**Possible.** Suitable habitat for this species occurs throughout the Project site and surrounding lands. While the Project may impact on habitat for this species, it is not likely to impact on the species itself, given that suitable habitat is abundant throughout the region and the species has not been recorded on the Project site.

Scientific Name **Common Name**	**Status**		**Habitat Requirements**	**Likelihood**
	EPBC Act	**NC Act**		
Sminthopsis douglasi Julia Creek Dunnart	E	E	This species is restricted to the Mitchell Grass Downs in north-west QLD. Primary habitat for this species consists of grass-covered cracking clay soils of ashy or stony nature (Curtis & Dennis 2012).	**Unlikely.** This species is predominantly found in Mitchell Grass regional ecosystems, which occurs north-west and south-east of the Project site. Due to the absence of suitable habitat on or near the Project site, it is unlikely that this species occurs in the vicinity of the Project.
Reptiles				
Acanthophis hawkei Plains Death Adder	V	NL	This species occurs on flat, treeless, cracking-soil riverine floodplains (Cogger 2000).	**Unlikely.** Suitable habitat for this species does not occur on the Project site.
Elseya lavarackorum Gulf Snapping Turtle	E	V	The Gulf Snapping Turtle occupies slow flowing freshwater rivers and streams of the Gulf of Carpentaria and may occur in either alluvial or rocky areas (Curtis & Dennis 2012).	**Unlikely**: The Project site lacks flowing stream habitats and is thereby unlikely support this species.
Emydura subglobosa worrelli Diamond Head Turtle	NL	NT	The Diamond Head Turtle inhabits larger rivers and permanent lakes and lagoons (Cogger 2000).	**Unlikely.** The Project site lacks permanent waterbodies that would otherwise support the Diamond Head Turtle.
Sharks				
Pristis pristis Freshwater Sawfish	V	NL	The Freshwater Sawfish occupies rivers and estuaries during the juvenile and sub-adult life stages while large mature Sawfish tend to occur in coastal and offshore waters up to 25 m deep (DoE 2014a).	**Unlikely.** There is no suitable habitat (i.e. permanent watercourses) located on or near the Project site.

7.0 ENVIRONMENTAL VALUES, POTENTIAL IMPACTS AND MITIGATION

This section provides a summary of the environmental values of the Project site. Suggested strategies to minimise Project impacts upon the local native flora and fauna, and recommendations regarding rehabilitation of the Project site are also outlined below.

7.1 SUMMARY OF ENVIRONMENTAL VALUES

The following environmental values have been identified on the Project site, which are potentially subject to Project impacts:

- The watercourses located on the Project site provide the most floristically diverse vegetation communities. Vegetation communities located on the watercourses such as Regional Ecosystem 1.3.6x1b (Cloncurry Box creek flats) and 1.3.7b (River Red Gum and Northern Swamp Box riparian woodlands) help maintain the environmental integrity of the watercourses by stabilising the banks with the root system and prevent erosion during flooding events. The fertile soils also leave these communities most vulnerable to invasion by introduced flora species such as Buffel Grass and Mimosa;

- The watercourse communities provide foraging and roosting habitat for a wide variety of birds, and bats, as well as shelter for reptile and amphibian species. These watercourses also provide breeding habitat for amphibians during wet season periods. The threatened Golden-backed Honeyeater has been observed in association with several watercourses on the Project site;

- One permanent and several semi-permanent waterholes are scattered throughout the Project site and provide important habitat and water sources for amphibians, birds and macropods during drier periods. In conjunction with the watercourses, these waterholes potentially play a vital role in supporting amphibian breeding cycles during and post wet season periods.

- The vegetation communities associated with Regional Ecosystem 1.11.2 dominate the rocky escarpments located on the Project site. Rocky escarpments provide microhabitat for a number of fauna (e.g. bats and reptiles) that utilise the shelter and protection provided by the many crevices. The rocky escarpments also provide forage and shelter habitat for the threatened Purple-necked Rock-wallaby (*Petrogale purpureicollis*) which has been observed in several locations throughout the Project site.

- Overall, the Project site contains a low diversity and abundance of introduced weed species. All weed species recorded on the Project are common and naturalised throughout the Mount Isa region. No State declared weed species or WoNS were recorded on the Project.

- A number of pest species are known to have a presence on the Project site. The suite of pest species includes two State declared Class 2 pest species, the Wild Dog/Dingo and Feral Pig. Wild Dogs and Feral Pigs both present significant predation threats to native fauna. Feral Pigs also have the potential to cause significant environmental disturbance. It is a responsibility of land owners and managers to control declared Class 2 pest animals on their land. The Cane Toad appears to have a sparse distribution and small abundance on the Project site. Due to the arid conditions in the region the Cane Toad can be managed effectively by preventing access to artificial water sources.

7.2 POTENTIAL IMPACTS

Development of the Project will create several areas of disturbance for the purposes of constructing mine infrastructure, open cut mining and associated processing areas. The Project will require the removal of remnant vegetation in designated areas causing a reduction in the total area of remnant vegetation across the Project site. For the most part, those areas of remnant vegetation that will be impacted by the Project have previously been subject to grazing and mineral exploration activities and are subsequently degraded. Previously undisturbed areas, particularly in the north of the Study area will be conserved in their natural state. The potential impacts of the Project on each vegetation community are illustrated in Figure 12 and detailed in Table 17.

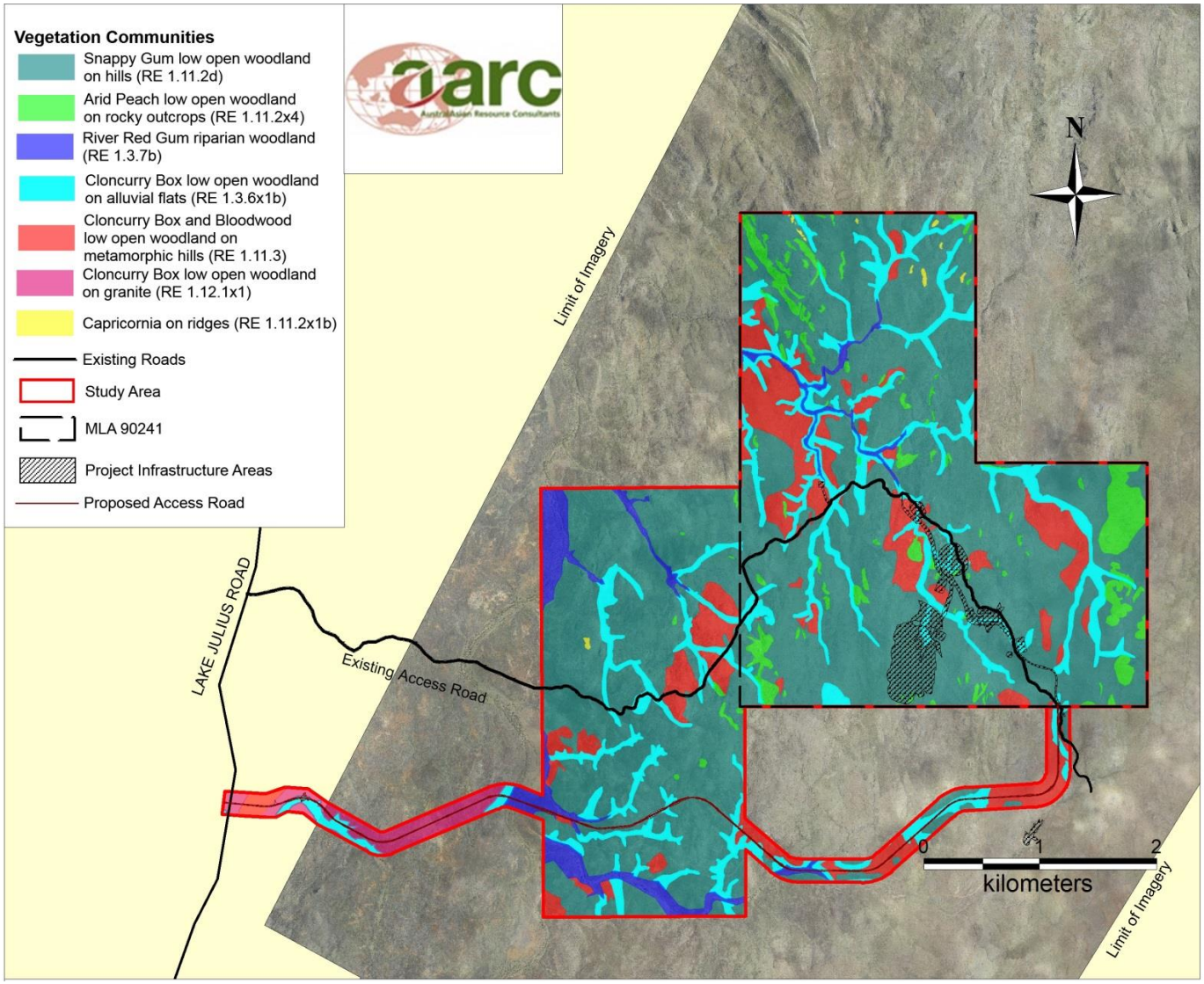

Figure 12 Impacts on Vegetation Communities

Table 17 Potential Impacts on Vegetation Communities

Vegetation Community	VM Act Status/ Biodiversity Status	Current extent on the Project site (ha)	Loss (ha)			Extent to Remain on the Project site (ha)	Current extent of RE in NW Highlands Bioregion
			Project	Proposed Access Road	Total		
Community 1 / RE 1.11.2d	LC / NC	1, 348	41.47	6.01	47.48	1, 288	1,329,179
Community 2 / RE 1.11.3	LC / NC	236.8	3.28	4.78	8.06	220.1	474,619
Community 3 / RE 1.3.6x1b	LC / OC	163.5	3.44	3.09	6.53	151.6	145,707
Community 4 / 1.3.7b	LC / E	75.19	0	1.72	1.72	72.02	72,708
Community 5 / RE 1.11.2x4	LC / NC	81.05	0.67	0	0.67	80.38	1,329,179
Community 6 / RE 1.11.2x1b	LC / NC	1.92	0	0	0	1.92	1,329,179
Community 7 / RE 1.12.1x1	LC / NC	38.26	0	2.96	2.96	30.31	242,957
TOTAL		1,944.7	48.86	18.56	67.42	1,844.3	

As shown in Table 17, the Project will have the greatest impact on Community 1 (loss of 47.48 ha of vegetation), which also has the greatest presence in Study area (1,348 ha). In total, the Project will impact on 48.15 ha or 3.36% of the current extent of RE 1.11.2 in the Study area. Of all regional ecosystems present, RE 1.11.2 is the most well represented community within both the Study area and the Northwest Highlands Bioregion where 1,329,179 ha of the RE remains. Project related impacts on RE 1.11.2 comprise less than 0.004% of the bioregional extent of the RE and are therefore not likely to constitute a significant impact. The Project will have no impact on Community 6 or RE 1.11.2x1b.

The Project will result in the loss of 8.06 ha or 3.4% of the current extent of RE 1.11.3 occurring within the Study area and just 0.0017% of the bioregional extent. The construction of the proposed access road has the potential to remove up to 2.96 ha or 7.7% of the current extent of RE 1.12.1x1 occurring within the Study area and just 0.003% of the bioregional extent.

While all REs on the Project site are listed as Least Concern under the VM Act, the Project will impact on one RE listed as Of Concern under the EHP Biodiversity Status (RE 1.3.6) and another listed as Endangered under the Biodiversity Status (RE 1.3.7). Project development has the potential to result in the loss of 6.53 ha (or approximately 3.99%) of the current extent of RE 1.3.6 occurring within the Study area (163.5 ha). The Project and access road construction will impact on 1.72 ha (or 2.29%) of the current extent of RE 1.3.7 within the Study area (75.19 ha). Overall, the Project will impact on just 0.0044% of the bioregional extent of RE 1.3.6 and 0.0024% of the bioregional extent of RE 1.3.7.

In summary, the potential impacts of the Project and access road development will not have significant impacts on any REs at the bioregional level. While the Project has the potential to disturb approximately 3.5% (67.4 ha) of the existing 1,944.7 ha of remnant vegetation, the majority of the existing remnant vegetation will be retained in its current state.

The removal of remnant vegetation will result in the direct loss of habitat for flora and fauna species. Native fauna will be displaced and left to compete for habitat in undisturbed areas. Clearing of mature trees in particular, will result in an immediate and long-term reduction in habitat availability for hollow-

dwelling fauna. The availability of forage habitat will also be reduced leading to increased competition. Lighting of Project infrastructure and roads may disturb nocturnal birds and bats and lead to avoidance behaviours in which the animal is forced to disperse to undisturbed lands.

Riparian corridors are major sources of connectivity for local faunal communities. The Project will result in the partial removal of some regional ecosystems on drainage features and one watercourse. In particular, the construction of the proposed access road will require the removal of a small area of the River Red Gum riparian woodland community adjacent to the western boundary of the Project. Clearing in the Project areas will also impact on a few drainage lines at the top of the catchment which may reduce habitat connectivity in the area. Habitat fragmentation is most likely to occur as a result of clearing in the south-east of the Project, where Project disturbance will be concentrated. For less mobile species this may have an impact on fauna dispersal and breeding activities. Given the extent of retained habitat across the site, the Project is not expected to have any detrimental impacts on habitat connectivity.

The Project has the potential to cause fauna injuries or even mortality. This risk is particularly high during the clearing operations, when smaller, less mobile species are most likely to be harmed. Construction of roads and increased vehicle movements will increase the risk of collisions with fauna. There is also potential for ground-dwelling fauna to become harmed should they attempt to access mine voids.

Development of the Project and proposed haul road will result in the removal of approximately 4.3 ha of potential shelter habitat and associated foraging habitat for the Purple-necked Rock-wallaby (refer to Figure 13). While suitable habitat will remain in abundance in the undisturbed portions of the Project site and surrounding lands, the Project may have a significant impact on the local population of PNRWs. Disturbance within riparian habitats along creeks, drainage lines and gullies will impact on the availability of habitat for the Golden-backed Honeyeater. The Project is not expected to have a significant impact on this species given that this species is highly mobile, the vast majority of suitable habitat will be retained on the Project, and suitable habitat occurs in abundance throughout the broader region.

Clearing and disturbance may result in top soil exposure and reduced slope or bank stability leading to soil erosion. Soil erosion can lead to increased sediment loads and vegetation smothering in watercourses downstream of the disturbance.

Project disturbance is likely to cause edge effects in adjoining areas of retained vegetation. Construction and operational activities may increase the risk of weed introduction and spread on the Project site. Earth moving activities and vehicle movement can spread weed seeds into and around the Project site. This has the potential to cause degradation of vegetation communities remaining on site.

The Project development phase will involve the construction of roads, tracks, water storages and waste disposal areas. Anthropogenic activities on the Project site will introduce additional food sources for fauna such as food scraps. These actions will increase the suitability of the Project site to feral animals, and may lead to an increase in their numbers. Increased pest numbers will lead to increased predation upon and competition with native fauna, which may lead to further reductions in native populations.

The Project will introduce new ignition sources and combustible materials onto the Project site. This may lead to an increased risk of fire on the Project site. This risk will be minimal due to the provision of firefighting equipment and site emergency response personnel.

The Project will require various hydrocarbons and a small number of other chemicals to be stored and used on site. Ore processing will be conducted off-site eliminating the need for bulk chemical storage on the Project site. Inappropriate use, handling and storage of such substances present the potential for contaminants to enter soil and surface water.

7.3 MITIGATION AND MANAGEMENT STRATEGIES

7.3.1 Flora Management

Project infrastructure has been located to avoid and minimise the area of vegetation clearing, particularly in the River Red Gum riparian woodland community, which has a Biodiversity Status of Endangered. To minimise the disturbance footprint all infrastructure has been positioned in the south-east corner of the Project site. The majority of the Project site will be undisturbed with the exception of existing tracks.

The removal of vegetation should be restricted to those areas required to establish the mine pit and infrastructure areas. Areas to be cleared must be clearly demarcated and clearing shall not commence until approval has been provided by the relevant supervisor. Erosion controls shall be installed prior to commencement and maintained during of vegetation clearing to minimise erosion potential. Top soil removed from site should be retained and stockpiled for used in site rehabilitation works. Top soil stockpiles should be surrounded by appropriate erosion control measures to prevent soil loss and sedimentation further downstream.

All disturbed areas shall be rehabilitated at the completion of the Project. Where possible, disturbed areas shall undergo progressive rehabilitation works. The suite of flora species used in rehabilitation works should be selected from the relevant vegetation communities present on the Project site prior to clearing (refer to Section 6.3 and Appendix C). No introduced flora species are to be used in site rehabilitation works.

7.3.2 Fauna Management

Vegetation clearing works have the potential to cause injury and mortality to fauna in the clearance zone. Clearing shall be conducted in a staged manner, to give fauna the opportunity to move away from the clearing front. An appropriately qualified and experienced fauna spotter/catcher shall be present prior to and during all vegetation clearing works to inspect for fauna and relocate animals where required. In the event that any fauna are sighted, clearing works must cease until the animal moves on or is relocated by the spotter/catcher. All tree hollows must be inspected for fauna prior to removal and hollow-bearing trees should be lowered gently to the ground with the hollows facing upward.

Vehicles on site access roads also pose a risk to local fauna. Site speed limits should be restricted to reduce the risk of wildlife-vehicle collisions. Injured and orphaned animals should be removed from site and taken to the relevant wildlife caring group or local veterinarian for treatment.

A Bushfire Management Plan should be developed to minimise the risk of uncontrolled fires on the Project site. High intensity fires are likely to have an adverse impact on both flora and fauna species. If planned burning operations are to be implemented, they should mimic the natural fire regime of the region and be limited to small areas to avoid complete removal of habitat.

7.3.3 Threatened Species Management

The Project will result in the removal of potential foraging habitat for the Golden-backed Honeyeater. The Project will also result in the removal of 4 ha of potential shelter habitat and associated foraging habitat for the Purple-necked Rock-wallaby. Impacts on threatened species should be minimised by:

- Reinstating suitable habitat by replanting feed and shelter species (i.e. spinifex, Turpentine, Cloncurry Box, Northern Swamp Box, other native grasses and forbs) at Project completion;
- Inspecting Cloncurry Box woodlands for Golden-backed Honeyeater nests prior to clearing. Active nests should not be disturbed;
- Inspecting potential PNRW shelter areas for resident rock-wallabies. Their habitat shall not be disturbed until such time as they have been relocated;
- All impacts on PNRW shelter and associated forage habitat shall be offset in accordance with the Queensland Environmental Offsets Policy;
- Preventing fires on the Project site to minimise further habitat loss or degradation;
- Implementing a Weed and Pest Management Plan to minimise predation and habitat degradation;
- Implement reduced speed limits on site, particularly in the vicinity of PNRW habitat areas; and
- Training all site personnel and contractors in the risk of wildlife-vehicle collisions and the importance of following site speed limits and slowing down for fauna.

7.3.4 Weed and Pest Management

Development and disturbance of the Project site has the potential to introduce additional weed species onto the site through increased vehicle movements across the site. Clearing of vegetation and the introduction of additional food and water sources creates favourable conditions for both weed and pest species.

7.3.4.1 Weed Management

Six introduced flora species or weeds were identified on the Project site. No weeds occurring on the Project are declared weed species or WoNS. While land managers are only required to control declared weeds, other weeds should be managed and prevented from spreading throughout the Project site and surrounding lands. A Weed Management Plan should be developed to guide the control and prevention of weeds on the Project.

The Weed Management Plan should address the following areas:

- Vehicle washdown requirements - Vehicles should be washed down prior to entering the Project site to avoid the introduction of new weed species;
- Staff training - Staff should be made aware of major weed species in the locality and required to report any weed infestations to their supervisor;
- Weed control program – Introduced grasses and herbaceous weeds should be sprayed prior to commencement of Project construction and annually in the dry season to minimise weed

prevalence and opportunity for dispersal. Woody weeds should be controlled in accordance with the methods relevant to the species as recommended by the Department of Agriculture, Fisheries and Forestry; and

- Ongoing weed monitoring by site environmental officers.

7.3.4.2 Pest Management

Of the five pest species known to occur on the Project site, two (Dingo/Wild Dog and Feral Pig) are declared under the LP Act as Class 2 pest animals. Pest control actions are required for the two declared pests, and are also recommended for the non-declared Cane Toad. Dingoes/Wild Dogs and Feral Pigs are predators and present a threat to native wildlife. Significant impacts of Feral Pig habitation also include weed dispersal, degradation of waterbodies, soil erosion and potentially dispersal of diseases.

A Pest Management Plan should be prepared and implemented as part of the Project. The implementation of pest controls will reduce predation pressure on native fauna, reduce pressures on riparian ecosystems and minimise the risk of injuries and disease spread to site personnel, native wildlife and cattle grazing in the area. 1080 (sodium monofluroacetate) baiting programs are an effective control method for Wild dog and Feral Pig control and should be undertaken across the Project site.

While not a declared pest species, the Cane toad remains one of the greatest threats to Australia's ecosystems. Mechanical collection measures can aid in reducing the local population of Cane Toads. Nocturnal Cane Toad collection programs should be implemented on a regular basis. Cane Toads are to be placed in a freezer immediately following collection. An important component of Cane Toad control is the removal of any eggs from temporary or more permanent waterbodies throughout the Project. Troughs, dams and other permanent or semi-permanent water holding structures should be regularly inspected for Cane Toads and their eggs. Artificial ponding areas provide potential breeding sites and should be eliminated.

It is recommended that potential food and water sources are appropriately managed to reduce pest abundance. Pests may be excluded from waste receptacles and artificial water sources by sealing and/or fencing these structures, where possible.

7.3.4.3 Emission Management

Construction and operation of the Project will result in increased noise, dust, vibration and lighting of the Project site. The impacts of these emissions or disturbances on flora and fauna species will vary from species to species. Appropriate control measures should be implemented to minimise emission levels across the Project and surrounding areas. Suitable emissions controls may include the following:

- Dust suppression - covering loads, installing pollution control equipment (e.g. bag filters or a cyclone) to dust generating equipment, applying suitable work practices to minimise dust generation, and spraying water on roads and tracks as required, creating or leaving wind breaks or screens to prevent the spread of dust.

- Noise suppression - providing and maintaining low noise equipment, implementing noise barriers or reduction measures in sensitive areas, limiting the hours of operation or at least timing of high impact activities (e.g. blasting) to minimise disturbance to nocturnal fauna.

- Lighting controls – provide directional lighting to minimise the area of disturbance and the impact on nocturnal fauna.

All chemicals are to be stored as directed by the Material Data Safety Sheet and applicable Australian Standards, in sealed and bunded areas to minimise the risk of soil and water contamination. Spill response equipment must be provided at chemical storage areas and any spills that enter waterways must be reported to EHP. All staff must be trained in spill response procedures.

Clean water should be diverted around disturbed areas to minimise water pollution and sedimentation.

7.3.4.4 Training and awareness

All staff and contractors will receive environmental awareness training as a component of the site induction. This training will include, but may not be limited to:

- The appearance of the threatened fauna species known to occur on the Project site:
- The appearance and impacts of pest and weed species known to occur on the Project site;
- Reporting procedures for sightings of threatened fauna, weeds and pests;
- Vegetation clearing rules;
- The importance of correct waste disposal and not feeding wildlife or pests;
- The risk of wildlife-vehicle collisions and the importance of following designated site speed limits;
- Designated strategies for weed and pest control;
- Fire management; and
- Spill response procedures.

7.4 ENVIRONMENTAL OFFSET ASSESSMENT

The terrestrial flora and fauna assessment identified two Matters of State Environmental Significance on the Project site including, protected wildlife habitat and regional ecosystems on watercourses. The Project will impact on protected wildlife habitat for one species listed Special Least Concern, the Echidna and one vulnerable species, the PNRW. Impacts on MSES are demonstrated in Figure 13. Environmental offsetting is required where there will be an unavoidable significant residual impact on a State significant environmental value. An assessment of the offset requirements for the Project is presented in Table 18.

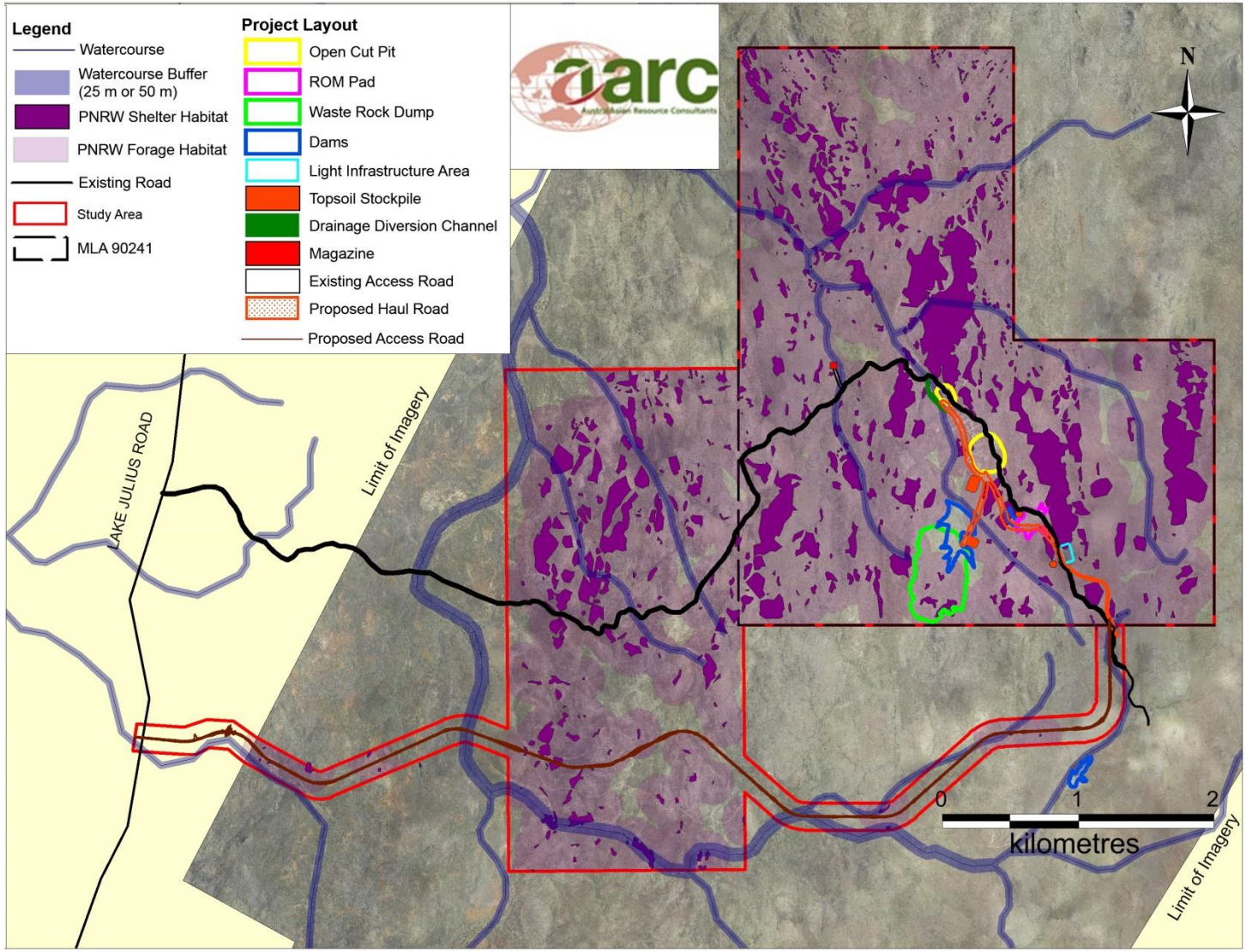

Figure 13 Potential Impacts on Watercourses and PNRW Habitat

Table 18 Summary of Environmental Offset Requirements

Matter of State Environmental Significance	Impact Assessment	Nature of Impact	Offset Requirement
Echidna (*Tachyglossus aculeatus*) The Echidna is listed as *Special Least Concern* under the *Nature Conservation (Wildlife) Regulation 2006.* This species is not listed at the Commonwealth level.	Residual impact – the Project will remove an area of suitable habitat for this species. Considering the Echidna occurs commonly throughout the region and the surrounding landscape provides vast areas of suitable habitat, the extent proposed to be removed is unlikely to have a significant impact on the local population.	Residual	Not Required.
Purple-necked Rock-wallaby (*Petrogale purpureicollis*) The Purple-necked Rock-wallaby is listed as ***Vulnerable*** under the *Nature Conservation (Wildlife) Regulation 2006.* This species is not listed at the Commonwealth level.	Significant Residual impact – the PNRW has been recorded in several locations across the Project site (Figure 10). Construction of the Project and proposed access road will impact on approximately 3.5 ha of shelter habitat within the MLA and approximately 1.3 ha of shelter habitat within the remaining study area and associated foraging areas. Project disturbance areas have been restricted to the south-east portion of the Project site where minimal PNRW habitat exists. A far greater abundance of PNRW habitat occurs in undisturbed portions of site and suitable habitat is well-represented throughout the bioregion.	Significant Residual	Offsetting Required

Matter of State Environmental Significance	Impact Assessment	Nature of Impact	Offset Requirement
Mapped Watercourses The Project site contains several watercourses that are identified on the vegetation management watercourse map and are vegetated with remnant vegetation. Clearing of remnant riparian vegetation potentially triggers offsetting requirements.	Residual impact –In total the Project and associated activities have the potential to remove 6.5 ha of remnant vegetation on watercourses. The Project and proposed access road will remove 4.7 ha of regional ecosystems within 25 m of the defining banks of mapped stream order 1 and 2 watercourses. Project disturbance is largely limited to ephemeral drainage lines in the south-east corner of the Project site leaving the majority of the existing watercourses and riparian habitats on the Project unharmed. In total, the Study Area contains approximately 75 ha of Regional Ecosystem 1.3.7b (River Red Gum riparian woodland). Of which, 1.8 ha occurring within 50 m of the defining banks of a stream order 3 watercourse may be impacted by the construction of the proposed access road and upgrading of the existing access road. Vegetation clearing in RE 1.3.7b will be limited to narrow corridors and is not expected to have a significant impact on the habitat or corridor values.	Residual	Potential offsetting required (refer to Aquatic Ecology Report)

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Appendix A Database Search Results

Australian Government

Department of the Environment

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

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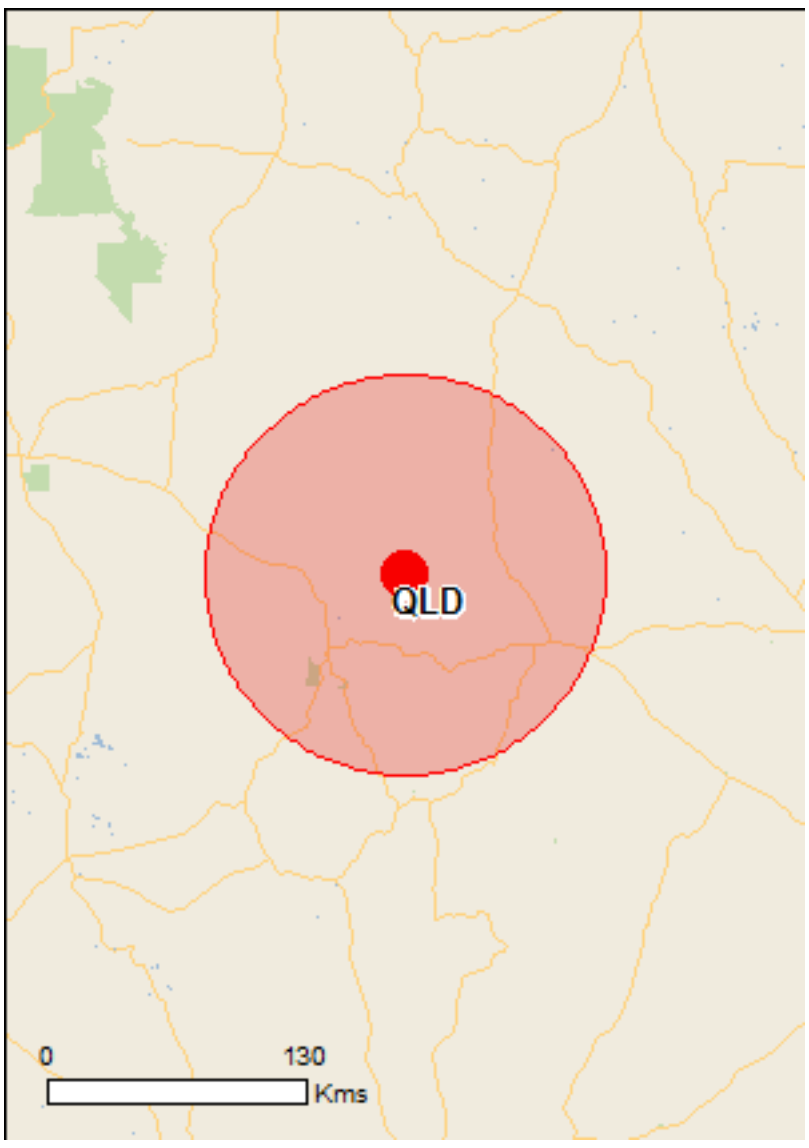
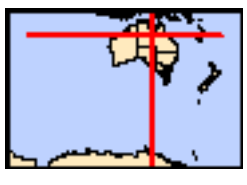
- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates

Buffer: 100.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Areas:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	10
Listed Migratory Species:	19

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place and the heritage values of a place on the Register of the National Estate.

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	1
Commonwealth Heritage Places:	None
Listed Marine Species:	26
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

Place on the RNE:	11
State and Territory Reserves:	1
Regional Forest Agreements:	None
Invasive Species:	27
Nationally Important Wetlands:	2
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Birds		
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat may occur within area
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat known to occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat likely to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Mammals		
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat likely to occur within area
Pseudantechinus mimulus Carpentarian Antechinus [59283]	Vulnerable	Species or species habitat known to occur within area
Sminthopsis douglasi Julia Creek Dunnart [305]	Endangered	Species or species habitat may occur within area
Reptiles		
Acanthophis hawkei Plains Death Adder [83821]	Vulnerable	Species or species habitat known to occur within area
Elseya lavarackorum Gulf Snapping Turtle [67197]	Endangered	Species or species habitat known to occur

Name	Status	Type of Presence within area
Sharks		
Pristis pristis Largetooth Sawfish, Freshwater Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat likely to occur within area

Listed Migratory Species

[Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Migratory Wetlands Species		
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]		Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat known to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Species or species habitat known to occur within area
Numenius phaeopus Whimbrel [849]		Species or species habitat known to occur

Name	Threatened	Type of Presence
		within area
Pluvialis fulva Pacific Golden Plover [25545]		Species or species habitat known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat likely to occur within area
Tringa glareola Wood Sandpiper [829]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Species or species habitat known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Defence - MT ISA TRAINING DEPOT

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]		Species or species habitat known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Species or species habitat known to occur

Name	Threatened	Type of Presence
		within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat known to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat known to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Himantopus himantopus Black-winged Stilt [870]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Species or species habitat known to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Species or species habitat known to occur within area
Numenius phaeopus Whimbrel [849]		Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Species or species habitat known to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Species or species habitat known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat likely to occur within area
Stiltia isabella Australian Pratincole [818]		Species or species habitat known to occur within area
Tringa glareola Wood Sandpiper [829]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Species or species habitat known to occur within area
Reptiles		
Crocodylus johnstoni Freshwater Crocodile, Johnston's Crocodile, Johnston's River Crocodile [1773]		Species or species habitat may occur within area

Extra Information

Places on the RNE [Resource Information]

Note that not all Indigenous sites may be listed.

Name	State	Status
Natural		
Fountain Range	QLD	Registered
Indigenous		
Battle Mountain	QLD	Indicative Place
Frank Creek Site	QLD	Indicative Place
Little Brumby Creek Site	QLD	Indicative Place
Bower Bird Area	QLD	Registered
Lake Moondarra Quarry 1 Area	QLD	Registered
The Granites Area	QLD	Registered
Historic		
Casa Grande	QLD	Indicative Place
Mount Isa Underground Hospital	QLD	Indicative Place
Cloncurry Courthouse	QLD	Registered
Tent House	QLD	Registered

State and Territory Reserves [Resource Information]

Name	State
Bullen Bullen	QLD

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Frogs		
Bufo marinus Cane Toad [1772]		Species or species habitat likely to occur within area
Rhinella marina Cane Toad [83218]		Species or species habitat likely to occur within area
Mammals		

Name	Status	Type of Presence
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Camelus dromedarius Dromedary, Camel [7]		Species or species habitat likely to occur within area
Equus caballus Horse [5]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Acacia nilotica subsp. indica Prickly Acacia [6196]		Species or species habitat may occur within area
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
Cryptostegia grandiflora Rubber Vine, Rubbervine, India Rubber Vine, India Rubbervine, Palay Rubbervine, Purple Allamanda [18913]		Species or species habitat likely to occur within area
Cylindropuntia spp. Prickly Pears [85131]		Species or species habitat likely to occur within area
Eichhornia crassipes Water Hyacinth, Water Orchid, Nile Lily [13466]		Species or species habitat likely to occur within area
Jatropha gossypifolia Cotton-leaved Physic-Nut, Bellyache Bush, Cotton-leaf Physic Nut, Cotton-leaf Jatropha, Black Physic Nut [7507]		Species or species habitat likely to occur within area
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Parkinsonia aculeata Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Parthenium hysterophorus Parthenium Weed, Bitter Weed, Carrot Grass, False Ragweed [19566]		Species or species habitat likely to occur

Name	Status	Type of Presence
		within area
Prosopis spp. Mesquite, Algaroba [68407]		Species or species habitat likely to occur within area
Salvinia molesta Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area
Tamarix aphylla Athel Pine, Athel Tree, Tamarisk, Athel Tamarisk, Athel Tamarix, Desert Tamarisk, Flowering Cypress, Salt Cedar [16018]		Species or species habitat likely to occur within area
Vachellia nilotica Prickly Acacia, Blackthorn, Prickly Mimosa, Black Piquant, Babul [84351]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus Asian House Gecko [1708]		Species or species habitat likely to occur within area

Nationally Important Wetlands [Resource Information]

Name	State
Lake Julius	QLD
Lake Moondarra	QLD

Coordinates

-20.4224 139.83871

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World Heritage and Register of National Estate properties, Wetlands of International Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Department of Environment, Climate Change and Water, New South Wales
-Department of Sustainability and Environment, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment and Natural Resources, South Australia
-Parks and Wildlife Service NT, NT Dept of Natural Resources, Environment and the Arts
-Environmental and Resource Management, Queensland
-Department of Environment and Conservation, Western Australia
-Department of the Environment, Climate Change, Energy and Water
-Birds Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-SA Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Atherton and Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
-State Forests of NSW
-Geoscience Australia
-CSIRO
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Queensland Government

Wildlife Online Extract

Search Criteria:	Species List for a Defined Area
	Species: All
	Type: All
	Status: All
	Records: All
	Date: All
	Latitude: 19.7941 to 20.4224
	Longitude: 140.4997 to 139.8386
	Email: hdick@aarc.net.au
	Date submitted: Tuesday 17 Jun 2014 16:13:00
	Date extracted: Tuesday 17 Jun 2014 16:20:03

The number of records retrieved = 435

Disclaimer

As the DSITIA is still in a process of collating and vetting data, it is possible the information given is not complete. The information provided should only be used for the project for which it was requested and it should be appropriately acknowledged as being derived from Wildlife Online when it is used.

The State of Queensland does not invite reliance upon, nor accept responsibility for this information. Persons should satisfy themselves through independent means as to the accuracy and completeness of this information.

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Feedback about Wildlife Online should be emailed to wildlife.online@science.dsitia.qld.gov.au

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	amphibians	Bufonidae	*Rhinella marina*	cane toad	Y			2
animals	amphibians	Hylidae	*Litoria inermis*	bumpy rocketfrog		C		3
animals	amphibians	Hylidae	*Litoria pallida*	pallid rocketfrog		C		3
animals	amphibians	Hylidae	*Litoria caerulea*	common green treefrog		C		6
animals	amphibians	Hylidae	*Cyclorana australis*	northern snapping frog		C		7
animals	amphibians	Hylidae	*Litoria rothii*	northern laughing treefrog		C		2
animals	amphibians	Hylidae	*Litoria rubella*	ruddy treefrog		C		6
animals	amphibians	Limnodynastidae	*Platyplectrum ornatum*	ornate burrowing frog		C		3
animals	birds	Acanthizidae	*Acanthiza chrysorrhoa*	yellow-rumped thornbill		C		5
animals	birds	Acanthizidae	*Gerygone fusca*	western gerygone		C		3
animals	birds	Acanthizidae	*Smicrornis brevirostris*	weebill		C		87
animals	birds	Accipitridae	*Aquila audax*	wedge-tailed eagle		C		10
animals	birds	Accipitridae	*Circus assimilis*	spotted harrier		C		3
animals	birds	Accipitridae	*Hamirostra melanosternon*	black-breasted buzzard		C		7
animals	birds	Accipitridae	*Accipiter cirrocephalus*	collared sparrowhawk		C		6
animals	birds	Accipitridae	*Milvus migrans*	black kite		C		37
animals	birds	Accipitridae	*Accipiter fasciatus*	brown goshawk		C		9
animals	birds	Accipitridae	*Haliastur sphenurus*	whistling kite		C		27
animals	birds	Accipitridae	*Haliaeetus leucogaster*	white-bellied sea-eagle		SL		4
animals	birds	Aegothelidae	*Aegotheles cristatus*	Australian owlet-nightjar		C		11
animals	birds	Alaudidae	*Mirafra javanica*	Horsfield's bushlark		C		1
animals	birds	Alcedinidae	*Ceyx azureus*	azure kingfisher		C		2
animals	birds	Anatidae	*Malacorhynchus membranaceus*	pink-eared duck		C		3
animals	birds	Anatidae	*Dendrocygna eytoni*	plumed whistling-duck		C		4
animals	birds	Anatidae	*Anas superciliosa*	Pacific black duck		C		3
animals	birds	Anatidae	*Aythya australis*	hardhead		C		3
animals	birds	Anatidae	*Anas gracilis*	grey teal		C		3
animals	birds	Anatidae	*Nettapus coromandelianus*	cotton pygmy-goose		NT		1
animals	birds	Anhingidae	*Anhinga novaehollandiae*	Australasian darter		C		14
animals	birds	Ardeidae	*Egretta novaehollandiae*	white-faced heron		C		15
animals	birds	Ardeidae	*Nycticorax caledonicus*	Nankeen night-heron		C		7
animals	birds	Ardeidae	*Ixobrychus flavicollis*	black bittern		C		5
animals	birds	Ardeidae	*Egretta garzetta*	little egret		C		2
animals	birds	Ardeidae	*Ardea intermedia*	intermediate egret		C		3
animals	birds	Ardeidae	*Ardea pacifica*	white-necked heron		C		16
animals	birds	Ardeidae	*Ardea modesta*	eastern great egret		SL		10
animals	birds	Artamidae	*Cracticus nigrogularis*	pied butcherbird		C		29
animals	birds	Artamidae	*Artamus superciliosus*	white-browed woodswallow		C		2
animals	birds	Artamidae	*Artamus leucorynchus*	white-breasted woodswallow		C		8
animals	birds	Artamidae	*Cracticus torquatus*	grey butcherbird		C		1
animals	birds	Artamidae	*Artamus personatus*	masked woodswallow		C		4
animals	birds	Artamidae	*Cracticus tibicen*	Australian magpie		C		12
animals	birds	Artamidae	*Artamus cinereus*	black-faced woodswallow		C		33
animals	birds	Artamidae	*Artamus minor*	little woodswallow		C		15
animals	birds	Burhinidae	*Burhinus grallarius*	bush stone-curlew		C		10
animals	birds	Cacatuidae	*Calyptorhynchus banksii*	red-tailed black-cockatoo		C		3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Cacatuidae	*Eolophus roseicapillus*	galah		C		24
animals	birds	Cacatuidae	*Nymphicus hollandicus*	cockatiel		C		31
animals	birds	Cacatuidae	*Cacatua galerita*	sulphur-crested cockatoo		C		25
animals	birds	Cacatuidae	*Cacatua sanguinea*	little corella		C		8
animals	birds	Campephagidae	*Coracina novaehollandiae*	black-faced cuckoo-shrike		C		23
animals	birds	Campephagidae	*Coracina papuensis*	white-bellied cuckoo-shrike		C		5
animals	birds	Campephagidae	*Lalage sueurii*	white-winged triller		C		11
animals	birds	Campephagidae	*Coracina maxima*	ground cuckoo-shrike		C		2
animals	birds	Casuariidae	*Dromaius novaehollandiae*	emu		C		2
animals	birds	Charadriidae	*Elseyornis melanops*	black-fronted dotterel		C		19
animals	birds	Charadriidae	*Vanellus miles*	masked lapwing		C		4
animals	birds	Charadriidae	*Vanellus miles miles*	masked lapwing (northern subspecies)		C		7
animals	birds	Ciconiidae	*Ephippiorhynchus asiaticus*	black-necked stork		NT		5
animals	birds	Climacteridae	*Climacteris melanura*	black-tailed treecreeper		C		16
animals	birds	Columbidae	*Geophaps plumifera*	spinifex pigeon		C		22
animals	birds	Columbidae	*Geopelia humeralis*	bar-shouldered dove		C		9
animals	birds	Columbidae	*Phaps chalcoptera*	common bronzewing		C		16
animals	birds	Columbidae	*Ocyphaps lophotes*	crested pigeon		C		20
animals	birds	Columbidae	*Geopelia striata*	peaceful dove		C		45
animals	birds	Columbidae	*Geopelia cuneata*	diamond dove		C		22
animals	birds	Coraciidae	*Eurystomus orientalis*	dollarbird		C		6
animals	birds	Corcoracidae	*Struthidea cinerea*	apostlebird		C		24
animals	birds	Corvidae	*Corvus orru*	Torresian crow		C		10
animals	birds	Corvidae	*Corvus coronoides*	Australian raven		C		34
animals	birds	Corvidae	*Corvus sp.*					12
animals	birds	Cuculidae	*Cacomantis variolosus*	brush cuckoo		C		3
animals	birds	Cuculidae	*Eudynamys orientalis*	eastern koel		C		4
animals	birds	Cuculidae	*Centropus phasianinus*	pheasant coucal		C		2
animals	birds	Cuculidae	*Scythrops novaehollandiae*	channel-billed cuckoo		C		3
animals	birds	Cuculidae	*Chalcites basalis*	Horsfield's bronze-cuckoo		C		2
animals	birds	Cuculidae	*Cacomantis pallidus*	pallid cuckoo		C		1
animals	birds	Cuculidae	*Chalcites osculans*	black-eared cuckoo		C		1
animals	birds	Estrildidae	*Poephila acuticauda*	long-tailed finch		C		16
animals	birds	Estrildidae	*Emblema pictum*	painted finch		C		2
animals	birds	Estrildidae	*Taeniopygia bichenovii*	double-barred finch		C		18
animals	birds	Estrildidae	*Taeniopygia guttata*	zebra finch		C		47
animals	birds	Estrildidae	*Heteromunia pectoralis*	pictorella mannikin		NT		2
animals	birds	Eurostopodidae	*Eurostopodus argus*	spotted nightjar		C		8/1
animals	birds	Falconidae	*Falco hypoleucos*	grey falcon		NT		1
animals	birds	Falconidae	*Falco cenchroides*	Nankeen kestrel		C		8
animals	birds	Falconidae	*Falco subniger*	black falcon		C		1
animals	birds	Falconidae	*Falco berigora*	brown falcon		C		9
animals	birds	Falconidae	*Falco longipennis*	Australian hobby		C		8
animals	birds	Gruidae	*Grus rubicunda*	brolga		C		10
animals	birds	Halcyonidae	*Dacelo leachii*	blue-winged kookaburra		C		28
animals	birds	Halcyonidae	*Todiramphus sanctus*	sacred kingfisher		C		8

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Halcyonidae	*Todiramphus pyrrhopygius*	red-backed kingfisher		C		8
animals	birds	Hirundinidae	*Petrochelidon ariel*	fairy martin		C		9
animals	birds	Laridae	*Chlidonias hybrida*	whiskered tern		C		1
animals	birds	Maluridae	*Malurus lamberti*	variegated fairy-wren		C		27/1
animals	birds	Maluridae	*Amytornis ballarae*	Kalkadoon grasswren		C		8
animals	birds	Maluridae	*Malurus coronatus*	purple-crowned fairy-wren		V		2/2
animals	birds	Maluridae	*Malurus melanocephalus*	red-backed fairy-wren		C		8/1
animals	birds	Megaluridae	*Cincloramphus mathewsi*	rufous songlark		C		6
animals	birds	Megaluridae	*Cincloramphus cruralis*	brown songlark		C		2
animals	birds	Megaluridae	*Eremiornis carteri*	spinifexbird		C		4
animals	birds	Meliphagidae	*Philemon citreogularis*	little friarbird		C		31
animals	birds	Meliphagidae	*Ptilotula penicillatus*	white-plumed honeyeater		C		42/1
animals	birds	Meliphagidae	*Conopophila rufogularis*	rufous-throated honeyeater		C		25
animals	birds	Meliphagidae	*Acanthagenys rufogularis*	spiny-cheeked honeyeater		C		3
animals	birds	Meliphagidae	*Melithreptus brevirostris*	brown-headed honeyeater		C		1
animals	birds	Meliphagidae	*Melithreptus gularis laetior*	golden-backed honeyeater		NT		1
animals	birds	Meliphagidae	*Sugomel niger*	black honeyeater		C		1
animals	birds	Meliphagidae	*Entomyzon cyanotis*	blue-faced honeyeater		C		1
animals	birds	Meliphagidae	*Manorina flavigula*	yellow-throated miner		C		35
animals	birds	Meliphagidae	*Phylidonyris niger*	white-cheeked honeyeater		C		1
animals	birds	Meliphagidae	*Ptilotula plumulus*	grey-fronted honeyeater		C		26
animals	birds	Meliphagidae	*Epthianura tricolor*	crimson chat		C		5
animals	birds	Meliphagidae	*Gavicalis virescens*	singing honeyeater		C		6
animals	birds	Meliphagidae	*Stomiopera unicolor*	white-gaped honeyeater		C		6/2
animals	birds	Meliphagidae	*Cissomela pectoralis*	banded honeyeater		C		3
animals	birds	Meliphagidae	*Lichmera indistincta*	brown honeyeater		C		32
animals	birds	Meliphagidae	*Melithreptus gularis*	black-chinned honeyeater		NT		4
animals	birds	Meliphagidae	*Philemon argenticeps*	silver-crowned friarbird		C		1
animals	birds	Meliphagidae	*Ptilotula flavescens*	yellow-tinted honeyeater		C		13
animals	birds	Meliphagidae	*Ptilotula keartlandi*	grey-headed honeyeater		C		38
animals	birds	Meropidae	*Merops ornatus*	rainbow bee-eater		SL		22
animals	birds	Monarchidae	*Myiagra inquieta*	restless flycatcher		C		14
animals	birds	Monarchidae	*Grallina cyanoleuca*	magpie-lark		C		41
animals	birds	Motacillidae	*Anthus novaeseelandiae*	Australasian pipit		C		1
animals	birds	Nectariniidae	*Dicaeum hirundinaceum*	mistletoebird		C		13
animals	birds	Neosittidae	*Daphoenositta chrysoptera*	varied sittella		C		3
animals	birds	Oriolidae	*Oriolus sagittatus*	olive-backed oriole		C		10
animals	birds	Otididae	*Ardeotis australis*	Australian bustard		C		7
animals	birds	Pachycephalidae	*Colluricincla harmonica*	grey shrike-thrush		C		28/2
animals	birds	Pachycephalidae	*Pachycephala rufiventris*	rufous whistler		C		29
animals	birds	Pachycephalidae	*Colluricincla megarhyncha*	little shrike-thrush		C		1
animals	birds	Pachycephalidae	*Oreoica gutturalis*	crested bellbird		C		8
animals	birds	Pardalotidae	*Pardalotus rubricatus*	red-browed pardalote		C		14
animals	birds	Pardalotidae	*Pardalotus striatus*	striated pardalote		C		32
animals	birds	Passeridae	*Passer domesticus*	house sparrow	Y			1
animals	birds	Pelecanidae	*Pelecanus conspicillatus*	Australian pelican		C		3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Petroicidae	*Petroica goodenovii*	red-capped robin		C		1
animals	birds	Petroicidae	*Melanodryas cucullata*	hooded robin		C		4
animals	birds	Petroicidae	*Microeca fascinans*	jacky winter		C		10
animals	birds	Phalacrocoracidae	*Phalacrocorax sulcirostris*	little black cormorant		C		4
animals	birds	Phalacrocoracidae	*Phalacrocorax carbo*	great cormorant		C		1
animals	birds	Phalacrocoracidae	*Microcarbo melanoleucos*	little pied cormorant		C		4
animals	birds	Phalacrocoracidae	*Phalacrocorax varius*	pied cormorant		C		3
animals	birds	Phasianidae	*Coturnix ypsilophora*	brown quail		C		3
animals	birds	Podargidae	*Podargus strigoides*	tawny frogmouth		C		5
animals	birds	Podicipedidae	*Poliocephalus poliocephalus*	hoary-headed grebe		C		1
animals	birds	Podicipedidae	*Tachybaptus novaehollandiae*	Australasian grebe		C		1
animals	birds	Pomatostomidae	*Pomatostomus temporalis*	grey-crowned babbler		C		33/1
animals	birds	Psittacidae	*Trichoglossus haematodus moluccanus*	rainbow lorikeet		C		1
animals	birds	Psittacidae	*Barnardius zonarius macgillivrayi*	Cloncurry parrot		C		10/1
animals	birds	Psittacidae	*Aprosmictus erythropterus*	red-winged parrot		C		26
animals	birds	Psittacidae	*Psitteuteles versicolor*	varied lorikeet		C		31
animals	birds	Psittacidae	*Melopsittacus undulatus*	budgerigar		C		36
animals	birds	Psittacidae	*Barnardius zonarius*	Australian ringneck		C		14
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus nuchalis*	great bowerbird		C		10
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus maculatus*	spotted bowerbird		C		10/1
animals	birds	Rallidae	*Porzana fluminea*	Australian spotted crake		C		1
animals	birds	Rallidae	*Tribonyx ventralis*	black-tailed native-hen		C		1
animals	birds	Rallidae	*Fulica atra*	Eurasian coot		C		2
animals	birds	Recurvirostridae	*Himantopus himantopus*	black-winged stilt		C		2
animals	birds	Recurvirostridae	*Recurvirostra novaehollandiae*	red-necked avocet		C		1
animals	birds	Rhipiduridae	*Rhipidura leucophrys*	willie wagtail		C		59
animals	birds	Rhipiduridae	*Rhipidura albiscapa*	grey fantail		C		4
animals	birds	Scolopacidae	*Calidris acuminata*	sharp-tailed sandpiper		SL		1
animals	birds	Strigidae	*Ninox connivens*	barking owl		C		3
animals	birds	Strigidae	*Ninox boobook*	southern boobook		C		7
animals	birds	Threskiornithidae	*Threskiornis molucca*	Australian white ibis		C		1
animals	birds	Threskiornithidae	*Plegadis falcinellus*	glossy ibis		SL		1
animals	birds	Threskiornithidae	*Platalea regia*	royal spoonbill		C		3
animals	birds	Threskiornithidae	*Threskiornis spinicollis*	straw-necked ibis		C		3
animals	birds	Turnicidae	*Turnix velox*	little button-quail		C		1
animals	birds	Tytonidae	*Tyto javanica*	eastern barn owl		C		2
animals	insects	Nymphalidae	*Euploea core corinna*	common crow				2
animals	insects	Nymphalidae	*Danaus chrysippus petilia*	lesser wanderer				2
animals	insects	Nymphalidae	*Hypolimnas bolina nerina*	varied eggfly				5
animals	insects	Nymphalidae	*Junonia villida calybe*	meadow argus				1
animals	insects	Papilionidae	*Papilio demoleus sthenelus*	chequered swallowtail				3
animals	insects	Pieridae	*Catopsilia pyranthe crokera*	white migrant				1
animals	insects	Pieridae	*Catopsilia pomona pomona*	lemon migrant				1
animals	insects	Pieridae	*Belenois java teutonia*	caper white				1
animals	insects	Pieridae	*Eurema smilax*	small grass-yellow				1
animals	mammals	Emballonuridae	*Taphozous sp.*					2

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	mammals	Macropodidae	*Petrogale purpureicollis*	purple-necked rock-wallaby		V		4
animals	mammals	Macropodidae	*Onychogalea unguifera*	northern nailtail wallaby		C		3
animals	mammals	Macropodidae	*Macropus rufus*	red kangaroo		C		5
animals	mammals	Macropodidae	*Macropus agilis*	agile wallaby		C		1
animals	mammals	Macropodidae	*Macropus robustus*	common wallaroo		C		3
animals	mammals	Molossidae	*Chaerephon jobensis*	northern freetail bat		C		1
animals	mammals	Molossidae	*Mormopterus beccarii*	Beccari's freetail bat		C		1
animals	mammals	Muridae	*Hydromys chrysogaster*	water rat		C		1
animals	mammals	Muridae	*Pseudomys desertor*	desert mouse		C		1
animals	mammals	Muridae	*Pseudomys johnsoni*			C		2
animals	mammals	Pteropodidae	*Pteropus scapulatus*	little red flying-fox		C		1
animals	mammals	Tachyglossidae	*Tachyglossus aculeatus*	short-beaked echidna		SL		1
animals	mammals	Vespertilionidae	*Chalinolobus nigrogriseus*	hoary wattled bat		C		1
animals	mammals	Vespertilionidae	*Vespadelus sp.*					1/1
animals	mammals	Vespertilionidae	*Scotorepens greyii*	little broad-nosed bat		C		14/2
animals	mammals	Vespertilionidae	*Chalinolobus gouldii*	Gould's wattled bat		C		3
animals	mammals	Vespertilionidae	*Scotorepens balstoni*	inland broad-nosed bat		C		4/3
animals	mammals	Vespertilionidae	*Vespadelus finlaysoni*	Finlayson's cave bat		C		1
animals	ray-finned fishes	Ambassidae	*Ambassis species*	northwest glassfish				1
animals	ray-finned fishes	Clupeidae	*Nematalosa erebi*	bony bream				2
animals	ray-finned fishes	Melanotaeniidae	*Melanotaenia splendida splendida*	eastern rainbowfish				1
animals	ray-finned fishes	Terapontidae	*Amniataba percoides*	barred grunter				1
animals	ray-finned fishes	Terapontidae	*Leiopotherapon unicolor*	spangled perch				3
animals	reptiles	Agamidae	*Ctenophorus caudicinctus*	ring-tailed dragon		C		1
animals	reptiles	Agamidae	*Amphibolurus temporalis*	swamplands lashtail		C		2
animals	reptiles	Agamidae	*Diporiphora bilineata*	two-lined dragon		C		1
animals	reptiles	Agamidae	*Chlamydosaurus kingii*	frilled lizard		C		1
animals	reptiles	Agamidae	*Amphibolurus gilberti*	Gilbert's dragon		C		7
animals	reptiles	Agamidae	*Diporiphora magna*			C		3
animals	reptiles	Agamidae	*Pogona vitticeps*			C		3/1
animals	reptiles	Boidae	*Aspidites melanocephalus*	black-headed python		C		2
animals	reptiles	Crocodylidae	*Crocodylus johnstoni*	Australian freshwater crocodile		C		1
animals	reptiles	Diplodactylidae	*Diplodactylus conspicillatus*	fat-tailed diplodactylus		C		3
animals	reptiles	Diplodactylidae	*Lucasium stenodactylum*	crowned gecko		C		4
animals	reptiles	Diplodactylidae	*Lucasium immaculatum*			C		2
animals	reptiles	Diplodactylidae	*Rhynchoedura ornata sensu lato*	beaked gecko		C		1/1
animals	reptiles	Elapidae	*Furina ornata*	orange-naped snake		C		1
animals	reptiles	Elapidae	*Suta suta*	myall snake		C		1
animals	reptiles	Elapidae	*Vermicella annulata*	bandy-bandy		C		1
animals	reptiles	Elapidae	*Pseudonaja textilis*	eastern brown snake		C		1
animals	reptiles	Gekkonidae	*Gehyra sp.*					1
animals	reptiles	Gekkonidae	*Gehyra nana*			C		1
animals	reptiles	Gekkonidae	*Gehyra dubia*			C		2
animals	reptiles	Gekkonidae	*Gehyra robusta*			C		2
animals	reptiles	Gekkonidae	*Heteronotia binoei*	Bynoe's gecko		C		4/1
animals	reptiles	Gekkonidae	*Gehyra versicolor*			C		3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	reptiles	Pygopodidae	*Delma nasuta*	sharp-snouted legless lizard		C		1
animals	reptiles	Pygopodidae	*Lialis burtonis*	Burton's legless lizard		C		1
animals	reptiles	Scincidae	*Ctenotus hebetior*			C		1
animals	reptiles	Scincidae	*Ctenotus lateralis*			C		8
animals	reptiles	Scincidae	*Ctenotus decaneurus*			C		1
animals	reptiles	Scincidae	*Ctenotus pulchellus*			C		2/2
animals	reptiles	Scincidae	*Ctenotus pantherinus*			C		6
animals	reptiles	Scincidae	*Ctenotus striaticeps*			C		2
animals	reptiles	Scincidae	*Tiliqua multifasciata*	Centralian blue-tongued lizard		C		1
animals	reptiles	Scincidae	*Cryptoblepharus zoticus*	agile snake-eyed skink		C		1
animals	reptiles	Scincidae	*Cryptoblepharus pannosus*	ragged snake-eyed skink		C		1
animals	reptiles	Scincidae	*Cryptoblepharus plagiocephalus sensu lato*			C		1
animals	reptiles	Scincidae	*Egernia hosmeri*	Hosmer's skink		C		2
animals	reptiles	Scincidae	*Carlia amax*			C		2
animals	reptiles	Scincidae	*Menetia maini*			C		1
animals	reptiles	Typhlopidae	*Ramphotyphlops diversus*			C		2
animals	reptiles	Varanidae	*Varanus acanthurus*	ridge-tailed monitor		C		3/1
animals	reptiles	Varanidae	*Varanus mertensi*	Mertens' water monitor		C		5
animals	reptiles	Varanidae	*Varanus panoptes*	yellow-spotted monitor		C		2
fungi	sac fungi	Lecideaceae	*Lecidea*			C		1/1
fungi	sac fungi	Teloschistaceae	*Caloplaca*			C		1/1
plants	ferns	Lindsaeaceae	*Lindsaea ensifolia subsp. ensifolia*			C		1/1
plants	ferns	Nephrolepidaceae	*Nephrolepis brownii*			C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus macrocephalus*	green pussytails		C		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera denticulata*	lesser joyweed		C		1/1
plants	higher dicots	Amaranthaceae	*Gomphrena breviflora*			C		1/1
plants	higher dicots	Amaranthaceae	*Gomphrena leptophylla*			C		2/2
plants	higher dicots	Amaranthaceae	*Amaranthus interruptus*			C		1/1
plants	higher dicots	Amaranthaceae	*Gomphrena lanata*			C		3/3
plants	higher dicots	Apocynaceae	*Calotropis gigantea*		Y			2/2
plants	higher dicots	Apocynaceae	*Calotropis procera*		Y			4/4
plants	higher dicots	Asteraceae	*Pluchea dentex*	bowl daisy		C		1/1
plants	higher dicots	Asteraceae	*Pluchea rubelliflora*			C		1/1
plants	higher dicots	Asteraceae	*Streptoglossa decurrens*			C		1/1
plants	higher dicots	Asteraceae	*Pterocaulon serrulatum var. velutinum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium haesum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium tanythrix*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium tenuifolium*			C		2/2
plants	higher dicots	Boraginaceae	*Heliotropium cunninghamii*			C		1/1
plants	higher dicots	Boraginaceae	*Trichodesma zeylanicum var. zeylanicum*			C		2/2
plants	higher dicots	Byttneriaceae	*Waltheria indica*			C		2/2
plants	higher dicots	Caesalpiniaceae	*Senna artemisioides subsp. oligophylla*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna notabilis*			C		2/2
plants	higher dicots	Caryophyllaceae	*Polycarpaea spirostylis subsp. spirostylis*			C		1/1
plants	higher dicots	Caryophyllaceae	*Polycarpaea corymbosa var. corymbosa*			C		1/1
plants	higher dicots	Caryophyllaceae	*Polycarpaea breviflora*			C		1/1

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plants	higher dicots	Caryophyllaceae	*Polycarpaea spirostylis subsp. glabra*			C		1/1
plants	higher dicots	Celastraceae	*Denhamia cunninghamii*			C		1/1
plants	higher dicots	Chenopodiaceae	*Maireana georgei*			C		1/1
plants	higher dicots	Cleomaceae	*Cleome gynandra*		Y			1/1
plants	higher dicots	Cleomaceae	*Cleome viscosa*	tick-weed		C		2/2
plants	higher dicots	Combretaceae	*Terminalia aridicola subsp. aridicola*			C		2/2
plants	higher dicots	Convolvulaceae	*Ipomoea plebeia*	bellvine		C		1/1
plants	higher dicots	Convolvulaceae	*Polymeria ambigua*			C		1/1
plants	higher dicots	Convolvulaceae	*Jacquemontia browniana*			C		1/1
plants	higher dicots	Convolvulaceae	*Bonamia pannosa*			C		3/3
plants	higher dicots	Cucurbitaceae	*Cucumis melo*			C		2/2
plants	higher dicots	Cucurbitaceae	*Cucumis argenteus*			C		2/2
plants	higher dicots	Euphorbiaceae	*Euphorbia australis var. subtomentosa*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia hirta*		Y			1/1
plants	higher dicots	Fabaceae	*Vigna*			C		1/1
plants	higher dicots	Fabaceae	*Cullen cinereum*			C		1/1
plants	higher dicots	Fabaceae	*Swainsona burkei*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia virens*			C		6/6
plants	higher dicots	Fabaceae	*Cullen balsamicum*			C		1/1
plants	higher dicots	Fabaceae	*Cullen leucanthum*			C		1/1
plants	higher dicots	Fabaceae	*Indigofera colutea*	sticky indigo		C		1/1
plants	higher dicots	Fabaceae	*Indigofera linnaei*	Birdsville indigo		C		1/1
plants	higher dicots	Fabaceae	*Cajanus acutifolius*			C		2/2
plants	higher dicots	Fabaceae	*Cajanus lanuginosus*			C		1/1
plants	higher dicots	Fabaceae	*Indigofera linifolia*			C		2/2
plants	higher dicots	Fabaceae	*Indigofera pratensis*			C		1/1
plants	higher dicots	Fabaceae	*Sesbania benthamiana*			C		3/3
plants	higher dicots	Fabaceae	*Tephrosia leptoclada*			C		2/2
plants	higher dicots	Fabaceae	*Crotalaria medicaginea*	trefoil rattlepod		C		1/1
plants	higher dicots	Fabaceae	*Tephrosia lasiochlaena*			C		2/2
plants	higher dicots	Fabaceae	*Indigastrum parviflorum*			C		1/1
plants	higher dicots	Fabaceae	*Macroptilium atropurpureum*	siratro	Y			1/1
plants	higher dicots	Fabaceae	*Tephrosia rosea var. rosea*			C		4/4
plants	higher dicots	Fabaceae	*Zornia prostrata var. prostrata*			C		1/1
plants	higher dicots	Fabaceae	*Sesbania cannabina var. cannabina*			C		1/1
plants	higher dicots	Fabaceae	*Zornia muriculata subsp. angustata*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia brachyodon var. longifolia*			C		3/3
plants	higher dicots	Fabaceae	*Tephrosia sp. (Mt Isa P.L.Harris 277)*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia brachyodon var. cloncurrensis*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia sp. (Magazine Hill P.Jones 365)*			C		4/4
plants	higher dicots	Fabaceae	*Crotalaria novae-hollandiae subsp. novae-hollandiae*			C		3/3
plants	higher dicots	Fabaceae	*Tephrosia phaeosperma var. (Westmoreland S.Melville 967)*			C		1/1
plants	higher dicots	Goodeniaceae	*Scaevola ovalifolia*			C		1/1
plants	higher dicots	Goodeniaceae	*Goodenia vilmoriniae*			C		4/4
plants	higher dicots	Goodeniaceae	*Goodenia fascicularis*			C		1/1

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plants	higher dicots	Goodeniaceae	*Scaevola*			C		3/3
plants	higher dicots	Lamiaceae	*Vitex benthamiana*			C		1/1
plants	higher dicots	Lamiaceae	*Mesosphaerum suaveolens*		Y			2/2
plants	higher dicots	Lamiaceae	*Ocimum caryophyllinum*			C		1/1
plants	higher dicots	Loranthaceae	*Diplatia grandibractea*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus sturtii var. grandiflorus*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon hannii*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon arenarium*			C		1/1
plants	higher dicots	Malvaceae	*Gossypium australe*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus meraukensis*	Merauke hibiscus		C		1/1
plants	higher dicots	Malvaceae	*Sida rohlenae subsp. rohlenae*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia victoriae subsp. fasciaria*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia sp. (Coolullah M.Lazarides 3988)*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia retivenea subsp. retivenea*			C		3/3
plants	higher dicots	Mimosaceae	*Vachellia farnesiana*		Y			2/2
plants	higher dicots	Mimosaceae	*Acacia holosericea*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia tenuissima*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia melleodora*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia elachantha*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia chisholmii*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia gonoclada*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia galioides*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia laccata*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia cambagei*	gidgee		C		2/2
plants	higher dicots	Mimosaceae	*Acacia acradenia*			C		5/5
plants	higher dicots	Moraceae	*Ficus racemosa var. racemosa*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus camaldulensis subsp. obtusa*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus leucophylla x E.pruinosa*			C		3/3
plants	higher dicots	Myrtaceae	*Eucalyptus leucophloia subsp. euroa*			C		3/3
plants	higher dicots	Myrtaceae	*Lophostemon grandiflorus*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus leucophylla*			C		2/2
plants	higher dicots	Myrtaceae	*Melaleuca fluviatilis*			C		1/1
plants	higher dicots	Myrtaceae	*Corymbia capricornia*			C		1/1
plants	higher dicots	Myrtaceae	*Melaleuca argentea*	silver tea-tree		C		2/2
plants	higher dicots	Myrtaceae	*Melaleuca viridiflora var. viridiflora*			C		1/1
plants	higher dicots	Myrtaceae	*Melaleuca trichostachya*			C		1/1
plants	higher dicots	Nyctaginaceae	*Boerhavia burbidgeana*			C		1/1
plants	higher dicots	Nyctaginaceae	*Boerhavia pubescens*			C		1/1
plants	higher dicots	Orobanchaceae	*Buchnera ramosissima*			C		1/1
plants	higher dicots	Plantaginaceae	*Stemodia viscosa*			C		2/2
plants	higher dicots	Polygalaceae	*Polygala barklyensis*			C		2/2
plants	higher dicots	Portulacaceae	*Sedopsis armitii*			C		1/1
plants	higher dicots	Portulacaceae	*Portulaca*			C		1/1
plants	higher dicots	Portulacaceae	*Portulaca australis*			C		1/1
plants	higher dicots	Proteaceae	*Hakea lorea subsp. lorea*			C		1/1
plants	higher dicots	Proteaceae	*Grevillea dryandri subsp. dryandri*			C		1/1

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plants	higher dicots	Rubiaceae	*Psydrax oleifolia*			C		1/1
plants	higher dicots	Rubiaceae	*Oldenlandia mitrasacmoides subsp. mitrasacmoides*			C		1/1
plants	higher dicots	Rubiaceae	*Kohautia australiensis*			C		1/1
plants	higher dicots	Rubiaceae	*Spermacoce auriculata*			C		1/1
plants	higher dicots	Sapindaceae	*Dodonaea stenophylla*			C		1/1
plants	higher dicots	Scrophulariaceae	*Eremophila latrobei subsp. latrobei*			C		1/1
plants	higher dicots	Solanaceae	*Solanum quadriloculatum*			C		5/5
plants	higher dicots	Solanaceae	*Solanum echinatum*			C		2/2
plants	higher dicots	Solanaceae	*Solanum succosum*			C		4/4
plants	higher dicots	Solanaceae	*Solanum esuriale*	quena		C		1/1
plants	higher dicots	Solanaceae	*Datura inoxia*		Y			3/3
plants	higher dicots	Sparrmanniaceae	*Corchorus sidoides subsp. vermicularis*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Corchorus sericeus subsp. densiflorus*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Triumfetta marsupiata*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Triumfetta johnstonii*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Triumfetta rupestris*			C		4/4
plants	higher dicots	Sparrmanniaceae	*Triumfetta plumigera*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Corchorus pumilio*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Corchorus tridens*			C		2/2
plants	higher dicots	Violaceae	*Hybanthus enneaspermus*			C		3/3
plants	lower dicots	Papaveraceae	*Argemone ochroleuca subsp. ochroleuca*	Mexican poppy	Y			1/1
plants	monocots	Arecaceae	*Livistona rigida*			C		2/2
plants	monocots	Cyperaceae	*Lipocarpha microcephala*			C		1/1
plants	monocots	Cyperaceae	*Bulbostylis barbata*			C		3/3
plants	monocots	Cyperaceae	*Cyperus squarrosus*	bearded flatsedge		C		1/1
plants	monocots	Cyperaceae	*Cyperus dactylotes*			C		1/1
plants	monocots	Cyperaceae	*Cyperus vaginatus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus javanicus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus carinatus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus iria*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis sp. (Thargomindah D.E.Boyland 3094)*			C		1/1
plants	monocots	Cyperaceae	*Cyperus microcephalus subsp. microcephalus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus cunninghamii subsp. cheradicus*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis corynocarya*			C		1/1
plants	monocots	Cyperaceae	*Fimbristylis microcarya*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis littoralis*			C		1/1
plants	monocots	Poaceae	*Urochloa piligera*			C		2/2
plants	monocots	Poaceae	*Aristida latifolia*	feathertop wiregrass		C		1/1
plants	monocots	Poaceae	*Echinochloa colona*	awnless barnyard grass	Y			1/1
plants	monocots	Poaceae	*Eragrostis cumingii*			C		1/1
plants	monocots	Poaceae	*Oxychloris scariosa*	winged chloris		C		1/1
plants	monocots	Poaceae	*Tragus australianus*	small burr grass		C		1/1
plants	monocots	Poaceae	*Bothriochloa pertusa*		Y			1/1
plants	monocots	Poaceae	*Dichanthium fecundum*	curly bluegrass		C		1/1
plants	monocots	Poaceae	*Enneapogon asperatus*			C		1/1
plants	monocots	Poaceae	*Aristida hygrometrica*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	monocots	Poaceae	*Dichanthium annulatum*	sheda grass	Y			1/1
plants	monocots	Poaceae	*Aristida inaequiglumis*			C		1/1
plants	monocots	Poaceae	*Brachyachne convergens*	common native couch		C		2/2
plants	monocots	Poaceae	*Enneapogon polyphyllus*	leafy nineawn		C		2/2
plants	monocots	Poaceae	*Cenchrus pennisetiformis*		Y			1/1
plants	monocots	Poaceae	*Sporobolus australasicus*			C		1/1
plants	monocots	Poaceae	*Paspalidium rarum*			C		1/1
plants	monocots	Poaceae	*Mnesithea formosa*			C		1/1
plants	monocots	Poaceae	*Chloris pectinata*	comb chloris		C		1/1
plants	monocots	Poaceae	*Aristida contorta*	bunched kerosene grass		C		1/1
plants	monocots	Poaceae	*Themeda triandra*	kangaroo grass		C		1/1
plants	monocots	Poaceae	*Eriachne ciliata*			C		1/1
plants	monocots	Poaceae	*Eragrostis minor*	smaller stinkgrass	Y			1/1
plants	monocots	Poaceae	*Sehima nervosum*			C		1/1
plants	monocots	Poaceae	*Eriachne obtusa*			C		1/1
plants	monocots	Poaceae	*Eriachne mucronata forma (Alpha C.E.Hubbard 7882)*			C		1/1
plants	monocots	Poaceae	*Eriachne sp. (Dugald River B.K.Simon+ 3007)*			C		1/1
plants	monocots	Poaceae	*Yakirra australiensis var. australiensis*			C		1/1
plants	monocots	Poaceae	*Bothriochloa bladhii subsp. bladhii*			C		1/1
plants	monocots	Poaceae	*Cynodon dactylon var. dactylon*		Y			1/1
plants	monocots	Poaceae	*Aristida holathera var. holathera*			C		2/2
plants	monocots	Poaceae	*Eriachne pulchella subsp. dominii*			C		1/1

CODES

I - Y indicates that the taxon is introduced to Queensland and has naturalised.

Q - Indicates the Queensland conservation status of each taxon under the *Nature Conservation Act 1992.* The codes are Extinct in the Wild (PE), Endangered (E), Vulnerable (V), Near Threatened (NT), Least Concern (C) or Not Protected ( ).

A - Indicates the Australian conservation status of each taxon under the *Environment Protection and Biodiversity Conservation Act 1999.* The values of EPBC are Conservation Dependent (CD), Critically Endangered (CE), Endangered (E), Extinct (EX), Extinct in the Wild (XW) and Vulnerable (V).

Records – The first number indicates the total number of records of the taxon for the record option selected (i.e. All, Confirmed or Specimens).
This number is output as 99999 if it equals or exceeds this value. The second number located after the / indicates the number of specimen records for the taxon.
This number is output as 999 if it equals or exceeds this value.

Queensland Government

Wildlife Online Extract

Search Criteria:	Species List for a Defined Area
	Species: All
	Type: All
	Status: All
	Records: All
	Date: All
	Latitude: 20.4224 to 21.0475
	Longitude: 139.8386 to 139.1728
	Email: hdick@aarc.net.au
	Date submitted: Tuesday 17 Jun 2014 16:21:01
	Date extracted: Tuesday 17 Jun 2014 16:30:03

The number of records retrieved = 993

Disclaimer

As the DSITIA is still in a process of collating and vetting data, it is possible the information given is not complete. The information provided should only be used for the project for which it was requested and it should be appropriately acknowledged as being derived from Wildlife Online when it is used.

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Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	amphibians	Bufonidae	*Rhinella marina*	cane toad	Y			14/7
animals	amphibians	Hylidae	*Litoria pallida*	pallid rocketfrog		C		1
animals	amphibians	Hylidae	*Litoria inermis*	bumpy rocketfrog		C		10/9
animals	amphibians	Hylidae	*Cyclorana novaehollandiae*	eastern snapping frog		C		3
animals	amphibians	Hylidae	*Litoria rubella*	ruddy treefrog		C		9/7
animals	amphibians	Hylidae	*Litoria caerulea*	common green treefrog		C		6/4
animals	amphibians	Hylidae	*Cyclorana australis*	northern snapping frog		C		18/18
animals	amphibians	Limnodynastidae	*Platyplectrum ornatum*	ornate burrowing frog		C		2/1
animals	birds	Acanthizidae	*Smicrornis brevirostris*	weebill		C		274
animals	birds	Acanthizidae	*Acanthiza chrysorrhoa*	yellow-rumped thornbill		C		40/1
animals	birds	Acanthizidae	*Acanthiza apicalis*	inland thornbill		C		3
animals	birds	Acanthizidae	*Gerygone fusca*	western gerygone		C		2
animals	birds	Accipitridae	*Elanus axillaris*	black-shouldered kite		C		15
animals	birds	Accipitridae	*Aquila audax*	wedge-tailed eagle		C		48
animals	birds	Accipitridae	*Erythrotriorchis radiatus*	red goshawk		E	V	1
animals	birds	Accipitridae	*Hamirostra melanosternon*	black-breasted buzzard		C		5
animals	birds	Accipitridae	*Accipiter cirrocephalus*	collared sparrowhawk		C		24
animals	birds	Accipitridae	*Hieraaetus morphnoides*	little eagle		C		15
animals	birds	Accipitridae	*Haliaeetus leucogaster*	white-bellied sea-eagle		SL		25
animals	birds	Accipitridae	*Haliastur sphenurus*	whistling kite		C		198
animals	birds	Accipitridae	*Aviceda subcristata*	Pacific baza		C		1
animals	birds	Accipitridae	*Accipiter fasciatus*	brown goshawk		C		24
animals	birds	Accipitridae	*Lophoictinia isura*	square-tailed kite		NT		1
animals	birds	Accipitridae	*Circus approximans*	swamp harrier		C		1
animals	birds	Accipitridae	*Pandion cristatus*	eastern osprey		SL		9
animals	birds	Accipitridae	*Milvus migrans*	black kite		C		281
animals	birds	Accipitridae	*Circus assimilis*	spotted harrier		C		3
animals	birds	Acrocephalidae	*Acrocephalus australis*	Australian reed-warbler		SL		129/1
animals	birds	Aegothelidae	*Aegotheles cristatus*	Australian owlet-nightjar		C		8
animals	birds	Alaudidae	*Mirafra javanica*	Horsfield's bushlark		C		2
animals	birds	Alcedinidae	*Ceyx azureus*	azure kingfisher		C		4
animals	birds	Anatidae	*Anas gracilis*	grey teal		C		155
animals	birds	Anatidae	*Anas castanea*	chestnut teal		C		1
animals	birds	Anatidae	*Anas sp.*					1
animals	birds	Anatidae	*Cygnus atratus*	black swan		C		52
animals	birds	Anatidae	*Anas superciliosa*	Pacific black duck		C		192
animals	birds	Anatidae	*Chenonetta jubata*	Australian wood duck		C		67
animals	birds	Anatidae	*Anas platyrhynchos*	northern mallard	Y			1
animals	birds	Anatidae	*Dendrocygna eytoni*	plumed whistling-duck		C		52
animals	birds	Anatidae	*Dendrocygna arcuata*	wandering whistling-duck		C		16
animals	birds	Anatidae	*Nettapus pulchellus*	green pygmy-goose		C		47
animals	birds	Anatidae	*Stictonetta naevosa*	freckled duck		NT		4
animals	birds	Anatidae	*Tadorna tadornoides*	Australian shelduck		C		1
animals	birds	Anatidae	*Nettapus coromandelianus*	cotton pygmy-goose		NT		4
animals	birds	Anatidae	*Malacorhynchus membranaceus*	pink-eared duck		C		89
animals	birds	Anatidae	*Biziura lobata*	musk duck		C		1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Anatidae	*Aythya australis*	hardhead		C		184
animals	birds	Anatidae	*Anas rhynchotis*	Australasian shoveler		C		2
animals	birds	Anhingidae	*Anhinga novaehollandiae*	Australasian darter		C		169
animals	birds	Anseranatidae	*Anseranas semipalmata*	magpie goose		C		1
animals	birds	Ardeidae	*Ardea intermedia*	intermediate egret		C		132
animals	birds	Ardeidae	*Ardea ibis*	cattle egret		SL		52
animals	birds	Ardeidae	*Ardea modesta*	eastern great egret		SL		147
animals	birds	Ardeidae	*Ardea pacifica*	white-necked heron		C		123
animals	birds	Ardeidae	*Egretta garzetta*	little egret		C		46
animals	birds	Ardeidae	*Nycticorax caledonicus*	Nankeen night-heron		C		38
animals	birds	Ardeidae	*Ixobrychus flavicollis*	black bittern		C		1
animals	birds	Ardeidae	*Egretta novaehollandiae*	white-faced heron		C		130
animals	birds	Artamidae	*Artamus superciliosus*	white-browed woodswallow		C		18
animals	birds	Artamidae	*Artamus leucorynchus*	white-breasted woodswallow		C		51
animals	birds	Artamidae	*Artamus cyanopterus*	dusky woodswallow		C		1
animals	birds	Artamidae	*Strepera graculina*	pied currawong		C		2
animals	birds	Artamidae	*Artamus minor*	little woodswallow		C		30
animals	birds	Artamidae	*Cracticus tibicen*	Australian magpie		C		128/1
animals	birds	Artamidae	*Artamus cinereus*	black-faced woodswallow		C		176
animals	birds	Artamidae	*Cracticus nigrogularis*	pied butcherbird		C		187
animals	birds	Artamidae	*Artamus personatus*	masked woodswallow		C		22
animals	birds	Burhinidae	*Burhinus grallarius*	bush stone-curlew		C		6
animals	birds	Cacatuidae	*Eolophus roseicapillus*	galah		C		130
animals	birds	Cacatuidae	*Cacatua sanguinea*	little corella		C		100/3
animals	birds	Cacatuidae	*Nymphicus hollandicus*	cockatiel		C		85
animals	birds	Cacatuidae	*Calyptorhynchus banksii*	red-tailed black-cockatoo		C		1
animals	birds	Cacatuidae	*Cacatua galerita*	sulphur-crested cockatoo		C		84
animals	birds	Campephagidae	*Coracina novaehollandiae*	black-faced cuckoo-shrike		C		195
animals	birds	Campephagidae	*Lalage sueurii*	white-winged triller		C		101/2
animals	birds	Campephagidae	*Coracina maxima*	ground cuckoo-shrike		C		7
animals	birds	Campephagidae	*Coracina papuensis*	white-bellied cuckoo-shrike		C		10
animals	birds	Casuariidae	*Dromaius novaehollandiae*	emu		C		5
animals	birds	Charadriidae	*Erythrogonys cinctus*	red-kneed dotterel		C		49
animals	birds	Charadriidae	*Charadrius australis*	inland dotterel		C		1/1
animals	birds	Charadriidae	*Elseyornis melanops*	black-fronted dotterel		C		161
animals	birds	Charadriidae	*Charadrius veredus*	oriental plover		SL		8
animals	birds	Charadriidae	*Vanellus tricolor*	banded lapwing		C		3
animals	birds	Charadriidae	*Pluvialis fulva*	Pacific golden plover		SL		4
animals	birds	Charadriidae	*Vanellus miles*	masked lapwing		C		99
animals	birds	Charadriidae	*Vanellus miles miles*	masked lapwing (northern subspecies)		C		58
animals	birds	Charadriidae	*Charadrius ruficapillus*	red-capped plover		C		66
animals	birds	Charadriidae	*Charadrius mongolus*	lesser sand plover		SL		1
animals	birds	Ciconiidae	*Ephippiorhynchus asiaticus*	black-necked stork		NT		40
animals	birds	Cisticolidae	*Cisticola exilis*	golden-headed cisticola		C		8
animals	birds	Climacteridae	*Climacteris melanura*	black-tailed treecreeper		C		76/1
animals	birds	Columbidae	*Geopelia striata*	peaceful dove		C		217/8

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Columbidae	*Geopelia cuneata*	diamond dove		C		126/24
animals	birds	Columbidae	*Geophaps plumifera*	spinifex pigeon		C		134/36
animals	birds	Columbidae	*Ocyphaps lophotes*	crested pigeon		C		211/4
animals	birds	Columbidae	*Phaps chalcoptera*	common bronzewing		C		48/5
animals	birds	Columbidae	*Phaps histrionica*	flock bronzewing		C		1/1
animals	birds	Columbidae	*Columba livia*	rock dove	Y			31
animals	birds	Columbidae	*Streptopelia chinensis*	spotted dove	Y			1
animals	birds	Coraciidae	*Eurystomus orientalis*	dollarbird		C		15
animals	birds	Corcoracidae	*Struthidea cinerea*	apostlebird		C		43
animals	birds	Corvidae	*Corvus sp.*					11
animals	birds	Corvidae	*Corvus orru*	Torresian crow		C		20
animals	birds	Corvidae	*Corvus bennetti*	little crow		C		3
animals	birds	Corvidae	*Corvus coronoides*	Australian raven		C		231/1
animals	birds	Cuculidae	*Chalcites osculans*	black-eared cuckoo		C		3/1
animals	birds	Cuculidae	*Scythrops novaehollandiae*	channel-billed cuckoo		C		10
animals	birds	Cuculidae	*Cuculus optatus*	oriental cuckoo		SL		1
animals	birds	Cuculidae	*Cacomantis pallidus*	pallid cuckoo		C		16
animals	birds	Cuculidae	*Eudynamys orientalis*	eastern koel		C		15
animals	birds	Cuculidae	*Cacomantis variolosus*	brush cuckoo		C		1
animals	birds	Cuculidae	*Centropus phasianinus*	pheasant coucal		C		25
animals	birds	Cuculidae	*Chalcites basalis*	Horsfield's bronze-cuckoo		C		16/1
animals	birds	Estrildidae	*Poephila acuticauda*	long-tailed finch		C		29
animals	birds	Estrildidae	*Emblema pictum*	painted finch		C		82/4
animals	birds	Estrildidae	*Erythrura gouldiae*	Gouldian finch		E	E	1
animals	birds	Estrildidae	*Neochmia ruficauda*	star finch		C		1
animals	birds	Estrildidae	*Lonchura castaneothorax*	chestnut-breasted mannikin		C		19
animals	birds	Estrildidae	*Taeniopygia guttata*	zebra finch		C		233
animals	birds	Estrildidae	*Heteromunia pectoralis*	pictorella mannikin		NT		37
animals	birds	Estrildidae	*Poephila cincta cincta*	black-throated finch (white-rumped subspecies)		E	E	1
animals	birds	Estrildidae	*Taeniopygia bichenovii*	double-barred finch		C		68
animals	birds	Eurostopodidae	*Eurostopodus argus*	spotted nightjar		C		16/1
animals	birds	Falconidae	*Falco berigora*	brown falcon		C		41
animals	birds	Falconidae	*Falco subniger*	black falcon		C		6
animals	birds	Falconidae	*Falco longipennis*	Australian hobby		C		25
animals	birds	Falconidae	*Falco peregrinus*	peregrine falcon		C		1
animals	birds	Falconidae	*Falco cenchroides*	Nankeen kestrel		C		29
animals	birds	Falconidae	*Falco hypoleucos*	grey falcon		NT		1
animals	birds	Glareolidae	*Stiltia isabella*	Australian pratincole		C		46
animals	birds	Glareolidae	*Glareola maldivarum*	oriental pratincole		SL		3/2
animals	birds	Gruidae	*Grus rubicunda*	brolga		C		31
animals	birds	Halcyonidae	*Todiramphus sanctus*	sacred kingfisher		C		71
animals	birds	Halcyonidae	*Dacelo leachii*	blue-winged kookaburra		C		113
animals	birds	Halcyonidae	*Todiramphus pyrrhopygius*	red-backed kingfisher		C		74
animals	birds	Hirundinidae	*Petrochelidon ariel*	fairy martin		C		84
animals	birds	Hirundinidae	*Hirundo rustica*	barn swallow		SL		3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Hirundinidae	*Hirundo neoxena*	welcome swallow		C		34
animals	birds	Hirundinidae	*Petrochelidon nigricans*	tree martin		C		33
animals	birds	Jacanidae	*Irediparra gallinacea*	comb-crested jacana		C		98
animals	birds	Laridae	*Chlidonias hybrida*	whiskered tern		C		42
animals	birds	Laridae	*Hydroprogne caspia*	Caspian tern		SL		942
animals	birds	Laridae	*Chroicocephalus novaehollandiae*	silver gull		C		75
animals	birds	Laridae	*Chlidonias leucopterus*	white-winged black tern		SL		5
animals	birds	Laridae	*Gelochelidon nilotica*	gull-billed tern		C		28
animals	birds	Maluridae	*Amytornis sp.*					2
animals	birds	Maluridae	*Malurus lamberti*	variegated fairy-wren		C		137/2
animals	birds	Maluridae	*Amytornis ballarae*	Kalkadoon grasswren		C		77/8
animals	birds	Maluridae	*Amytornis dorotheae*	Carpentarian grasswren		NT		1
animals	birds	Maluridae	*Malurus leucopterus*	white-winged fairy-wren		C		12
animals	birds	Maluridae	*Malurus melanocephalus*	red-backed fairy-wren		C		36
animals	birds	Megaluridae	*Eremiornis carteri*	spinifexbird		C		60/2
animals	birds	Megaluridae	*Megalurus gramineus*	little grassbird		C		17
animals	birds	Megaluridae	*Cincloramphus cruralis*	brown songlark		C		4
animals	birds	Megaluridae	*Cincloramphus mathewsi*	rufous songlark		C		29
animals	birds	Meliphagidae	*Epthianura crocea crocea*	yellow chat (gulf)		V		3
animals	birds	Meliphagidae	*Melithreptus albogularis*	white-throated honeyeater		C		2
animals	birds	Meliphagidae	*Melithreptus gularis laetior*	golden-backed honeyeater		NT		4
animals	birds	Meliphagidae	*Sugomel niger*	black honeyeater		C		4
animals	birds	Meliphagidae	*Grantiella picta*	painted honeyeater		V		2
animals	birds	Meliphagidae	*Myzomela obscura*	dusky honeyeater		C		1
animals	birds	Meliphagidae	*Epthianura crocea*	yellow chat		V		2
animals	birds	Meliphagidae	*Entomyzon cyanotis*	blue-faced honeyeater		C		2
animals	birds	Meliphagidae	*Manorina flavigula*	yellow-throated miner		C		300/1
animals	birds	Meliphagidae	*Ptilotula plumulus*	grey-fronted honeyeater		C		188/6
animals	birds	Meliphagidae	*Epthianura tricolor*	crimson chat		C		44
animals	birds	Meliphagidae	*Gavicalis virescens*	singing honeyeater		C		54
animals	birds	Meliphagidae	*Philemon buceroides*	helmeted friarbird		C		1
animals	birds	Meliphagidae	*Stomiopera unicolor*	white-gaped honeyeater		C		5
animals	birds	Meliphagidae	*Cissomela pectoralis*	banded honeyeater		C		7
animals	birds	Meliphagidae	*Epthianura aurifrons*	orange chat		C		15
animals	birds	Meliphagidae	*Lichmera indistincta*	brown honeyeater		C		214
animals	birds	Meliphagidae	*Melithreptus gularis*	black-chinned honeyeater		NT		45
animals	birds	Meliphagidae	*Philemon argenticeps*	silver-crowned friarbird		C		44
animals	birds	Meliphagidae	*Ptilotula flavescens*	yellow-tinted honeyeater		C		24
animals	birds	Meliphagidae	*Ptilotula keartlandi*	grey-headed honeyeater		C		127/5
animals	birds	Meliphagidae	*Certhionyx variegatus*	pied honeyeater		C		1
animals	birds	Meliphagidae	*Philemon citreogularis*	little friarbird		C		135
animals	birds	Meliphagidae	*Ptilotula penicillatus*	white-plumed honeyeater		C		318/3
animals	birds	Meliphagidae	*Conopophila rufogularis*	rufous-throated honeyeater		C		69/1
animals	birds	Meliphagidae	*Acanthagenys rufogularis*	spiny-cheeked honeyeater		C		53/1
animals	birds	Meropidae	*Merops ornatus*	rainbow bee-eater		SL		210
animals	birds	Monarchidae	*Grallina cyanoleuca*	magpie-lark		C		339

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Monarchidae	*Myiagra inquieta*	restless flycatcher		C		85
animals	birds	Motacillidae	*Anthus novaeseelandiae*	Australasian pipit		C		48
animals	birds	Nectariniidae	*Dicaeum hirundinaceum*	mistletoebird		C		179
animals	birds	Neosittidae	*Daphoenositta chrysoptera*	varied sittella		C		5
animals	birds	Oriolidae	*Oriolus sagittatus*	olive-backed oriole		C		57
animals	birds	Oriolidae	*Sphecotheres vieilloti*	Australasian figbird		C		1
animals	birds	Otididae	*Ardeotis australis*	Australian bustard		C		29
animals	birds	Pachycephalidae	*Oreoica gutturalis*	crested bellbird		C		17/1
animals	birds	Pachycephalidae	*Colluricincla harmonica*	grey shrike-thrush		C		91/1
animals	birds	Pachycephalidae	*Pachycephala rufiventris*	rufous whistler		C		105/1
animals	birds	Pardalotidae	*Pardalotus rubricatus*	red-browed pardalote		C		53
animals	birds	Pardalotidae	*Pardalotus striatus*	striated pardalote		C		120/2
animals	birds	Passeridae	*Passer domesticus*	house sparrow	Y			49
animals	birds	Pelecanidae	*Pelecanus conspicillatus*	Australian pelican		C		143
animals	birds	Petroicidae	*Petroica goodenovii*	red-capped robin		C		8
animals	birds	Petroicidae	*Melanodryas cucullata*	hooded robin		C		22/2
animals	birds	Petroicidae	*Microeca fascinans*	jacky winter		C		80/1
animals	birds	Phalacrocoracidae	*Phalacrocorax carbo*	great cormorant		C		52
animals	birds	Phalacrocoracidae	*Phalacrocorax varius*	pied cormorant		C		36
animals	birds	Phalacrocoracidae	*Microcarbo melanoleucos*	little pied cormorant		C		127
animals	birds	Phalacrocoracidae	*Phalacrocorax sulcirostris*	little black cormorant		C		164
animals	birds	Phasianidae	*Pavo cristatus*	Indian peafowl	Y			5
animals	birds	Phasianidae	*Coturnix pectoralis*	stubble quail		C		3
animals	birds	Phasianidae	*Coturnix ypsilophora*	brown quail		C		20
animals	birds	Podargidae	*Podargus strigoides*	tawny frogmouth		C		21/1
animals	birds	Podicipedidae	*Tachybaptus novaehollandiae*	Australasian grebe		C		205
animals	birds	Podicipedidae	*Poliocephalus poliocephalus*	hoary-headed grebe		C		48
animals	birds	Podicipedidae	*Podiceps cristatus*	great crested grebe		C		56
animals	birds	Pomatostomidae	*Pomatostomus temporalis*	grey-crowned babbler		C		213
animals	birds	Psittacidae	*Barnardius zonarius*	Australian ringneck		C		76
animals	birds	Psittacidae	*Trichoglossus haematodus moluccanus*	rainbow lorikeet		C		10
animals	birds	Psittacidae	*Platycercus adscitus*	pale-headed rosella		C		1
animals	birds	Psittacidae	*Barnardius zonarius macgillivrayi*	Cloncurry parrot		C		16/8
animals	birds	Psittacidae	*Trichoglossus chlorolepidotus*	scaly-breasted lorikeet		C		1
animals	birds	Psittacidae	*Melopsittacus undulatus*	budgerigar		C		248
animals	birds	Psittacidae	*Psitteuteles versicolor*	varied lorikeet		C		125/1
animals	birds	Psittacidae	*Aprosmictus erythropterus*	red-winged parrot		C		160
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus nuchalis*	great bowerbird		C		24
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus maculatus*	spotted bowerbird		C		160/4
animals	birds	Rallidae	*Porzana fluminea*	Australian spotted crake		C		6
animals	birds	Rallidae	*Porzana pusilla*	Baillon's crake		C		10
animals	birds	Rallidae	*Fulica atra*	Eurasian coot		C		110
animals	birds	Rallidae	*Porzana tabuensis*	spotless crake		C		3
animals	birds	Rallidae	*Amaurornis cinerea*	white-browed crake		C		1
animals	birds	Rallidae	*Tribonyx ventralis*	black-tailed native-hen		C		15
animals	birds	Rallidae	*Gallinula tenebrosa*	dusky moorhen		C		90

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Rallidae	*Porphyrio porphyrio*	purple swamphen		C		75
animals	birds	Rallidae	*Gallirallus philippensis*	buff-banded rail		C		9
animals	birds	Recurvirostridae	*Himantopus himantopus*	black-winged stilt		C		197
animals	birds	Recurvirostridae	*Recurvirostra novaehollandiae*	red-necked avocet		C		23
animals	birds	Rhipiduridae	*Rhipidura albiscapa*	grey fantail		C		27
animals	birds	Rhipiduridae	*Rhipidura leucophrys*	willie wagtail		C		330
animals	birds	Rostratulidae	*Rostratula australis*	Australian painted snipe		V	E	7
animals	birds	Scolopacidae	*Numenius madagascariensis*	eastern curlew		NT		1
animals	birds	Scolopacidae	*Gallinago hardwickii*	Latham's snipe		SL		6
animals	birds	Scolopacidae	*Calidris ruficollis*	red-necked stint		SL		15
animals	birds	Scolopacidae	*Calidris ferruginea*	curlew sandpiper		SL		12
animals	birds	Scolopacidae	*Tringa stagnatilis*	marsh sandpiper		SL		33
animals	birds	Scolopacidae	*Phalaropus lobatus*	red-necked phalarope		SL		1
animals	birds	Scolopacidae	*Calidris subminuta*	long-toed stint		SL		6
animals	birds	Scolopacidae	*Calidris acuminata*	sharp-tailed sandpiper		SL		251
animals	birds	Scolopacidae	*Arenaria interpres*	ruddy turnstone		SL		2
animals	birds	Scolopacidae	*Actitis hypoleucos*	common sandpiper		SL		15/1
animals	birds	Scolopacidae	*Tringa nebularia*	common greenshank		SL		18
animals	birds	Scolopacidae	*Numenius minutus*	little curlew		SL		5
animals	birds	Scolopacidae	*Heteroscelus sp.*					2
animals	birds	Scolopacidae	*Tringa glareola*	wood sandpiper		SL		16
animals	birds	Scolopacidae	*Xenus cinereus*	terek sandpiper		SL		1
animals	birds	Scolopacidae	*Limosa limosa*	black-tailed godwit		SL		8
animals	birds	Scolopacidae	*Gallinago megala*	Swinhoe's snipe		SL		10
animals	birds	Strigidae	*Ninox boobook*	southern boobook		C		19
animals	birds	Strigidae	*Ninox connivens*	barking owl		C		2
animals	birds	Threskiornithidae	*Platalea regia*	royal spoonbill		C		36
animals	birds	Threskiornithidae	*Threskiornis molucca*	Australian white ibis		C		39
animals	birds	Threskiornithidae	*Threskiornis spinicollis*	straw-necked ibis		C		119
animals	birds	Threskiornithidae	*Platalea flavipes*	yellow-billed spoonbill		C		10
animals	birds	Threskiornithidae	*Plegadis falcinellus*	glossy ibis		SL		115
animals	birds	Turnicidae	*Turnix velox*	little button-quail		C		5
animals	birds	Tytonidae	*Tyto javanica*	eastern barn owl		C		2
animals	mammals	Bovidae	*Bos sp.*	cattle	Y			1
animals	mammals	Bovidae	*Bos taurus*	European cattle	Y			1
animals	mammals	Camelidae	*Camelus dromedarius*	one-humped camel	Y			2
animals	mammals	Dasyuridae	*Pseudantechinus mimulus*	Carpentarian antechinus		C	V	3/3
animals	mammals	Emballonuridae	*Taphozous troughtoni*	Troughton's sheathtail bat		C		4/3
animals	mammals	Emballonuridae	*Saccolaimus flaviventris*	yellow-bellied sheathtail bat		C		1
animals	mammals	Emballonuridae	*Taphozous georgianus*	common sheathtail bat		C		5/5
animals	mammals	Equidae	*Equus caballus*	horse	Y			2
animals	mammals	Hipposideridae	*Hipposideros stenotis*	northern leaf-nosed bat		V		1
animals	mammals	Macropodidae	*Macropus robustus*	common wallaroo		C		7/2
animals	mammals	Macropodidae	*Macropus rufus*	red kangaroo		C		2
animals	mammals	Macropodidae	*Lagorchestes conspicillatus*	spectacled hare-wallaby		C		1
animals	mammals	Macropodidae	*Petrogale purpureicollis*	purple-necked rock-wallaby		V		4/3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	mammals	Molossidae	*Chaerephon jobensis*	northern freetail bat		C		1/1
animals	mammals	Molossidae	*Mormopterus beccarii*	Beccari's freetail bat		C		6/6
animals	mammals	Molossidae	*Mormopterus loriae ridei*	little north-eastern freetail bat		C		1/1
animals	mammals	Muridae	*Rattus sordidus*	canefield rat		C		1
animals	mammals	Muridae	*Pseudomys johnsoni*			C		5
animals	mammals	Muridae	*Zyzomys argurus*	common rock-rat		C		2/2
animals	mammals	Pteropodidae	*Pteropus scapulatus*	little red flying-fox		C		3
animals	mammals	Vespertilionidae	*Scotorepens greyii*	little broad-nosed bat		C		9/4
animals	mammals	Vespertilionidae	*Vespadelus finlaysoni*	Finlayson's cave bat		C		3/3
animals	mammals	Vespertilionidae	*Vespadelus sp.*					2/1
animals	mammals	Vespertilionidae	*Chalinolobus gouldii*	Gould's wattled bat		C		4/3
animals	mammals	Vespertilionidae	*Nyctophilus geoffroyi*	lesser long-eared bat		C		4/4
animals	mammals	Vespertilionidae	*Vespadelus baverstocki*	inland forest bat		C		1
animals	ray-finned fishes	Ambassidae	*Ambassis macleayi*	Macleay's glassfish				146
animals	ray-finned fishes	Ambassidae	*Ambassis species*	northwest glassfish				62
animals	ray-finned fishes	Ambassidae	*Ambassis sp.*					2
animals	ray-finned fishes	Ariidae	*Neoarius graeffei*	blue catfish				5
animals	ray-finned fishes	Ariidae	*Neoarius leptaspis*	boofhead catfish				1
animals	ray-finned fishes	Belonidae	*Strongylura krefftii*	freshwater longtom				105
animals	ray-finned fishes	Centropomidae	*Lates calcarifer*	barramundi				169
animals	ray-finned fishes	Clupeidae	*Nematalosa erebi*	bony bream				939
animals	ray-finned fishes	Eleotridae	*Oxyeleotris selheimi*	blackbanded gudgeon				117
animals	ray-finned fishes	Eleotridae	*Oxyeleotris lineolata*	sleepy cod				109
animals	ray-finned fishes	Gobiidae	*Awaous acritosus*	roman-nose goby				1
animals	ray-finned fishes	Gobiidae	*Glossogobius giuris*	tank goby				4
animals	ray-finned fishes	Gobiidae	*Glossogobius aureus*	golden flathead goby				3
animals	ray-finned fishes	Melanotaeniidae	*Melanotaenia splendida inornata*	checkered rainbowfish				263
animals	ray-finned fishes	Melanotaeniidae	*Melanotaenia splendida splendida*	eastern rainbowfish				2
animals	ray-finned fishes	Plotosidae	*Porochilus rendahli*	Rendahl's catfish				1
animals	ray-finned fishes	Plotosidae	*Neosilurus hyrtlii*	Hyrtl's catfish				10
animals	ray-finned fishes	Plotosidae	*Neosilurus ater*	black catfish				1
animals	ray-finned fishes	Plotosidae	*Anodontiglanis dahli*	toothless catfish				1
animals	ray-finned fishes	Terapontidae	*Leiopotherapon unicolor*	spangled perch				111
animals	ray-finned fishes	Terapontidae	*Amniataba percoides*	barred grunter				680
animals	ray-finned fishes	Terapontidae	*Hephaestus fuliginosus*	sooty grunter				82
animals	ray-finned fishes	Toxotidae	*Toxotes chatareus*	sevenspot archerfish				41
animals	reptiles	Agamidae	*Tympanocryptis cephalus*			C		1/1
animals	reptiles	Agamidae	*Ctenophorus caudicinctus*	ring-tailed dragon		C		9/6
animals	reptiles	Agamidae	*Diporiphora bilineata*	two-lined dragon		C		2/1
animals	reptiles	Agamidae	*Amphibolurus gilberti*	Gilbert's dragon		C		7/1
animals	reptiles	Agamidae	*Pogona vitticeps*			C		2
animals	reptiles	Agamidae	*Moloch horridus*	thorny devil		C		1
animals	reptiles	Agamidae	*Diporiphora sp.*					1/1
animals	reptiles	Boidae	*Aspidites melanocephalus*	black-headed python		C		3/1
animals	reptiles	Boidae	*Liasis olivaceus*	olive python		C		2
animals	reptiles	Boidae	*Antaresia childreni*	children's python		C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	reptiles	Chelidae	*Emydura subglobosa worrelli*	diamond head turtle		NT		3
animals	reptiles	Crocodylidae	*Crocodylus johnstoni*	Australian freshwater crocodile		C		3
animals	reptiles	Diplodactylidae	*Lucasium immaculatum*			C		2/2
animals	reptiles	Diplodactylidae	*Strophurus ciliaris*	spiny-tailed gecko		C		10/3
animals	reptiles	Diplodactylidae	*Strophurus taeniatus*	white-striped gecko		C		1/1
animals	reptiles	Diplodactylidae	*Oedura marmorata*	marbled velvet gecko		C		1/1
animals	reptiles	Diplodactylidae	*Amalosia rhombifer*	zig-zag gecko		C		2/2
animals	reptiles	Elapidae	*Brachyurophis incinctus*			C		1
animals	reptiles	Elapidae	*Furina ornata*	orange-naped snake		C		1
animals	reptiles	Elapidae	*Pseudonaja modesta*	ringed brown snake		C		4/4
animals	reptiles	Elapidae	*Demansia olivacea sensu lato*	marble-headed whip snake		C		1
animals	reptiles	Elapidae	*Suta punctata*	little spotted snake		C		1/1
animals	reptiles	Gekkonidae	*Gehyra robusta*			C		22/19
animals	reptiles	Gekkonidae	*Gehyra versicolor*			C		8/8
animals	reptiles	Gekkonidae	*Heteronotia binoei*	Bynoe's gecko		C		4/2
animals	reptiles	Gekkonidae	*Gehyra dubia*			C		1
animals	reptiles	Pygopodidae	*Lialis burtonis*	Burton's legless lizard		C		2
animals	reptiles	Pygopodidae	*Delma borea*			C		1/1
animals	reptiles	Scincidae	*Tiliqua multifasciata*	Centralian blue-tongued lizard		C		2/2
animals	reptiles	Scincidae	*Ctenotus striaticeps*			C		1
animals	reptiles	Scincidae	*Ctenotus pantherinus*			C		2
animals	reptiles	Scincidae	*Ctenotus pulchellus*			C		2/2
animals	reptiles	Scincidae	*Ctenotus lateralis*			C		6/4
animals	reptiles	Scincidae	*Ctenotus inornatus*			C		1
animals	reptiles	Scincidae	*Egernia hosmeri*	Hosmer's skink		C		3/2
animals	reptiles	Scincidae	*Ctenotus hebetior*			C		1
animals	reptiles	Scincidae	*Carlia amax*			C		1
animals	reptiles	Varanidae	*Varanus mertensi*	Mertens' water monitor		C		3
animals	reptiles	Varanidae	*Varanus tristis*	black-tailed monitor		C		2/1
animals	reptiles	Varanidae	*Varanus acanthurus*	ridge-tailed monitor		C		7/4
animals	reptiles	Varanidae	*Varanus glebopalma*	long-tailed rock monitor		C		1
fungi	uncertain	Fungus	*Fungus*			C		1/1
plants	ferns	Adiantaceae	*Cheilanthes brownii*			C		4/4
plants	ferns	Adiantaceae	*Cheilanthes nudiuscula*			C		2/2
plants	ferns	Adiantaceae	*Cheilanthes sieberi subsp. sieberi*			C		1/1
plants	ferns	Adiantaceae	*Cheilanthes sieberi subsp. pseudovellea*			C		1/1
plants	ferns	Marsileaceae	*Marsilea costulifera*	narrow-leaved nardoo		C		1/1
plants	ferns	Salviniaceae	*Salvinia molesta*	salvinia	Y			1/1
plants	higher dicots	Acanthaceae	*Nelsonia campestris*			C		2/2
plants	higher dicots	Acanthaceae	*Rostellularia adscendens*			C		1/1
plants	higher dicots	Acanthaceae	*Rostellularia adscendens var. clementii*			C		1/1
plants	higher dicots	Aizoaceae	*Trianthema triquetra*	red spinach		C		1/1
plants	higher dicots	Aizoaceae	*Trianthema portulacastrum*	black pigweed	Y			1/1
plants	higher dicots	Amaranthaceae	*Aerva javanica*		Y			5/5
plants	higher dicots	Amaranthaceae	*Ptilotus nobilis subsp. nobilis*			C		4/4
plants	higher dicots	Amaranthaceae	*Ptilotus sessilifolius*			C		7/7

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plants	higher dicots	Amaranthaceae	*Ptilotus macrocephalus*	green pussytails		C		1/1
plants	higher dicots	Amaranthaceae	*Amaranthus interruptus*			C		2/2
plants	higher dicots	Amaranthaceae	*Gomphrena leptophylla*			C		2/2
plants	higher dicots	Amaranthaceae	*Alternanthera pungens*	khaki weed	Y			2/2
plants	higher dicots	Amaranthaceae	*Ptilotus maconochiei*			NT		9/9
plants	higher dicots	Amaranthaceae	*Amaranthus undulatus*			C		4/4
plants	higher dicots	Amaranthaceae	*Alternanthera sp. (Mt Isa R.L.Specht+ 49)*			C		4/4
plants	higher dicots	Amaranthaceae	*Gomphrena arida*			C		3/3
plants	higher dicots	Amaranthaceae	*Gomphrena lanata*			C		3/3
plants	higher dicots	Amaranthaceae	*Ptilotus incanus*			C		4/4
plants	higher dicots	Amaranthaceae	*Ptilotus obovatus*			C		6/6
plants	higher dicots	Amaranthaceae	*Ptilotus spicatus*			C		1/1
plants	higher dicots	Amaranthaceae	*Achyranthes aspera*			C		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera nana*	hairy joyweed		C		1/1
plants	higher dicots	Amaranthaceae	*Amaranthus viridis*	green amaranth	Y			1/1
plants	higher dicots	Amaranthaceae	*Ptilotus clementii*			C		5/5
plants	higher dicots	Amaranthaceae	*Ptilotus decipiens*			C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus fusiformis*			C		4/4
plants	higher dicots	Amaranthaceae	*Ptilotus schwartzii*			C		3/3
plants	higher dicots	Apocynaceae	*Marsdenia viridiflora subsp. tropica*			C		5/5
plants	higher dicots	Apocynaceae	*Sarcostemma brevipedicellatum*			C		1/1
plants	higher dicots	Apocynaceae	*Gymnanthera cunninghamii*			C		1/1
plants	higher dicots	Apocynaceae	*Tylophora cinerascens*			C		1/1
plants	higher dicots	Apocynaceae	*Calotropis procera*		Y			1/1
plants	higher dicots	Apocynaceae	*Calotropis gigantea*		Y			1/1
plants	higher dicots	Apocynaceae	*Cascabela thevetia*	yellow oleander	Y			1/1
plants	higher dicots	Apocynaceae	*Carissa lanceolata*			C		2/2
plants	higher dicots	Apocynaceae	*Cynanchum floribundum*			C		1/1
plants	higher dicots	Asteraceae	*Blumea mollis*			C		3/3
plants	higher dicots	Asteraceae	*Blumea tenella*			C		1/1
plants	higher dicots	Asteraceae	*Pluchea dentex*	bowl daisy		C		7/7
plants	higher dicots	Asteraceae	*Soliva sessilis*		Y			1/1
plants	higher dicots	Asteraceae	*Bidens bipinnata*	bipinnate beggar's ticks	Y			3/3
plants	higher dicots	Asteraceae	*Eclipta prostrata*	white eclipta		C		2/2
plants	higher dicots	Asteraceae	*Tridax procumbens*	tridax daisy	Y			1/1
plants	higher dicots	Asteraceae	*Flaveria trinervia*		Y			1/1
plants	higher dicots	Asteraceae	*Olearia subspicata*			C		1/1
plants	higher dicots	Asteraceae	*Peripleura obovata*			C		2/2
plants	higher dicots	Asteraceae	*Peripleura virgata*			C		4/4
plants	higher dicots	Asteraceae	*Glossocardia bidens*	native cobbler's pegs		C		1/1
plants	higher dicots	Asteraceae	*Streptoglossa odora*			C		3/3
plants	higher dicots	Asteraceae	*Pluchea rubelliflora*			C		4/4
plants	higher dicots	Asteraceae	*Pterocaulon redolens*			C		1/1
plants	higher dicots	Asteraceae	*Xanthium occidentale*		Y			1/1
plants	higher dicots	Asteraceae	*Calotis xanthosioidea*			C		1/1
plants	higher dicots	Asteraceae	*Cyanthillium cinereum*			C		3/3

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plants	higher dicots	Asteraceae	*Streptoglossa bubakii*			C		1/1
plants	higher dicots	Asteraceae	*Acanthospermum hispidum*	star burr	Y			3/3
plants	higher dicots	Asteraceae	*Pterocaulon sphacelatum*	applebush		C		1/1
plants	higher dicots	Asteraceae	*Streptoglossa decurrens*			C		8/8
plants	higher dicots	Asteraceae	*Sphaeromorphaea littoralis*			C		1/1
plants	higher dicots	Asteraceae	*Chrysocephalum pterochaetum*	perennial sunray		C		1/1
plants	higher dicots	Asteraceae	*Pluchea ferdinandi-muelleri*			C		5/5
plants	higher dicots	Asteraceae	*Centipeda minima subsp. minima*			C		1/1
plants	higher dicots	Asteraceae	*Lactuca serriola forma serriola*		Y			1/1
plants	higher dicots	Asteraceae	*Peripleura hispidula var. setosa*			C		1/1
plants	higher dicots	Asteraceae	*Brachyscome ciliaris var. lanuginosa*			C		1/1
plants	higher dicots	Asteraceae	*Pterocaulon serrulatum var. velutinum*			C		3/3
plants	higher dicots	Asteraceae	*Rutidosis helichrysoides subsp. acutiglumis*			C		1/1
plants	higher dicots	Boraginaceae	*Ehretia saligna*			C		1/1
plants	higher dicots	Boraginaceae	*Coldenia procumbens*			C		1/1
plants	higher dicots	Boraginaceae	*Trichodesma zeylanicum var. latisepalum*			C		1/1
plants	higher dicots	Boraginaceae	*Trichodesma zeylanicum var. zeylanicum*			C		2/2
plants	higher dicots	Boraginaceae	*Heliotropium ballii*			C		16/16
plants	higher dicots	Boraginaceae	*Heliotropium haesum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium aequoreum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium tanythrix*			C		1/1
plants	higher dicots	Boraginaceae	*Trichodesma zeylanicum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium frohlichii*			C		2/2
plants	higher dicots	Boraginaceae	*Heliotropium ovalifolium*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium tenuifolium*			C		4/4
plants	higher dicots	Boraginaceae	*Heliotropium cunninghamii*			C		4/4
plants	higher dicots	Boraginaceae	*Heliotropium curassavicum*	smooth heliotrope	Y			2/2
plants	higher dicots	Boraginaceae	*Heliotropium fasciculatum*			C		1/1
plants	higher dicots	Brassicaceae	*Lepidium strongylophyllum*			C		3/3
plants	higher dicots	Byblidaceae	*Byblis liniflora*			C		2/2
plants	higher dicots	Byttneriaceae	*Keraudrenia nephrosperma*			C		1/1
plants	higher dicots	Cactaceae	*Cylindropuntia fulgida var. mamillata*		Y			2/2
plants	higher dicots	Caesalpiniaceae	*Senna glutinosa subsp. pruinosa*			C		3/3
plants	higher dicots	Caesalpiniaceae	*Senna glutinosa subsp. glutinosa*			C		2/2
plants	higher dicots	Caesalpiniaceae	*Senna*			C		3/3
plants	higher dicots	Caesalpiniaceae	*Senna venusta*			C		3/3
plants	higher dicots	Caesalpiniaceae	*Senna notabilis*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Lysiphyllum gilvum*	bauhinia		C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna occidentalis*	coffee senna	Y			1/1
plants	higher dicots	Caesalpiniaceae	*Senna planitiicola*			C		2/2
plants	higher dicots	Caesalpiniaceae	*Senna artemisioides*			C		2/2
plants	higher dicots	Caesalpiniaceae	*Chamaecrista deserti*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Parkinsonia aculeata*	parkinsonia	Y			1/1
plants	higher dicots	Caesalpiniaceae	*Petalostylis cassioides*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Chamaecrista exigua var. exigua*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna artemisioides subsp. oligophylla*			C		2/2

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Caesalpiniaceae	*Senna artemisioides subsp. sturtii*			C		1/1
plants	higher dicots	Campanulaceae	*Wahlenbergia gracilis*	sprawling bluebell		C		2/2
plants	higher dicots	Campanulaceae	*Wahlenbergia tumidifructa*			C		2/2
plants	higher dicots	Campanulaceae	*Wahlenbergia communis*	tufted bluebell		C		2/2
plants	higher dicots	Campanulaceae	*Isotoma petraea*	rock isotome		C		1/1
plants	higher dicots	Capparaceae	*Capparis umbonata*			C		2/2
plants	higher dicots	Capparaceae	*Capparis mitchellii*			C		1/1
plants	higher dicots	Capparaceae	*Capparis loranthifolia var. loranthifolia*			C		1/1
plants	higher dicots	Caryophyllaceae	*Polycarpaea breviflora*			C		2/2
plants	higher dicots	Caryophyllaceae	*Polycarpaea spirostylis*			C		1/1
plants	higher dicots	Caryophyllaceae	*Polycarpaea spirostylis subsp. glabra*			C		3/3
plants	higher dicots	Caryophyllaceae	*Polycarpaea corymbosa*			C		1/1
plants	higher dicots	Celastraceae	*Denhamia cunninghamii*			C		4/4
plants	higher dicots	Chenopodiaceae	*Maireana georgei*			C		6/6
plants	higher dicots	Chenopodiaceae	*Dysphania rhadinostachya subsp. rhadinostachya*			C		2/2
plants	higher dicots	Chenopodiaceae	*Maireana triptera*	three-wing bluebush		C		4/4
plants	higher dicots	Chenopodiaceae	*Salsola australis*			C		2/2
plants	higher dicots	Chenopodiaceae	*Sclerolaena glabra*			C		1/1
plants	higher dicots	Chenopodiaceae	*Sclerolaena minuta*			C		2/2
plants	higher dicots	Chenopodiaceae	*Sclerolaena cuneata*	tangled copperburr		C		2/2
plants	higher dicots	Chenopodiaceae	*Enchylaena tomentosa*			C		1/1
plants	higher dicots	Chenopodiaceae	*Maireana campanulata*			C		2/2
plants	higher dicots	Chenopodiaceae	*Sclerolaena bicornis*			C		1/1
plants	higher dicots	Chenopodiaceae	*Sclerolaena eriacantha*			C		2/2
plants	higher dicots	Chenopodiaceae	*Sclerolaena lanicuspis*			C		7/7
plants	higher dicots	Chenopodiaceae	*Sclerolaena cornishiana*			C		3/3
plants	higher dicots	Chenopodiaceae	*Einadia nutans subsp. nutans*			C		1/1
plants	higher dicots	Chenopodiaceae	*Einadia nutans subsp. eremaea*			C		1/1
plants	higher dicots	Chenopodiaceae	*Sclerolaena bicornis var. horrida*			C		1/1
plants	higher dicots	Chenopodiaceae	*Tecticornia indica subsp. leiostachya*			C		1/1
plants	higher dicots	Chenopodiaceae	*Maireana villosa*			C		6/6
plants	higher dicots	Cleomaceae	*Cleome viscosa*	tick-weed		C		3/3
plants	higher dicots	Combretaceae	*Terminalia aridicola subsp. aridicola*			C		2/2
plants	higher dicots	Combretaceae	*Terminalia aridicola*			C		1/1
plants	higher dicots	Combretaceae	*Terminalia aridicola subsp. chillagoensis*			C		1/1
plants	higher dicots	Convolvulaceae	*Ipomoea muelleri*	poison morning-glory		C		2/2
plants	higher dicots	Convolvulaceae	*Polymeria ambigua*			C		3/3
plants	higher dicots	Convolvulaceae	*Ipomoea polymorpha*			C		1/1
plants	higher dicots	Convolvulaceae	*Ipomoea racemigera*			C		1/1
plants	higher dicots	Convolvulaceae	*Xenostegia tridentata*			C		7/7
plants	higher dicots	Convolvulaceae	*Jacquemontia browniana*			C		1/1
plants	higher dicots	Convolvulaceae	*Operculina aequisepala*			C		1/1
plants	higher dicots	Convolvulaceae	*Jacquemontia paniculata*			C		2/2
plants	higher dicots	Convolvulaceae	*Bonamia media var. villosa*			C		1/1
plants	higher dicots	Convolvulaceae	*Evolvulus alsinoides var. decumbens*			C		3/3
plants	higher dicots	Convolvulaceae	*Jacquemontia paniculata var. tomentosa*			C		3/3

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plants	higher dicots	Convolvulaceae	*Ipomoea plebeia*	bellvine		C		2/2
plants	higher dicots	Convolvulaceae	*Bonamia pannosa*			C		3/3
plants	higher dicots	Convolvulaceae	*Ipomoea nil*		Y			2/2
plants	higher dicots	Convolvulaceae	*Bonamia media*			C		3/3
plants	higher dicots	Cucurbitaceae	*Citrullus colocynthis*	colocynth	Y			2/2
plants	higher dicots	Cucurbitaceae	*Cucumis melo*			C		2/2
plants	higher dicots	Cucurbitaceae	*Citrullus lanatus*		Y			1/1
plants	higher dicots	Cucurbitaceae	*Cucumis argenteus*			C		3/3
plants	higher dicots	Cucurbitaceae	*Momordica balsamina*	balsam apple	Y			1/1
plants	higher dicots	Droseraceae	*Drosera burmanni*			C		1/1
plants	higher dicots	Droseraceae	*Drosera indica*			C		2/2
plants	higher dicots	Euphorbiaceae	*Euphorbia trigonosperma*			C		10/10
plants	higher dicots	Euphorbiaceae	*Euphorbia schultzii var. comans*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia australis var. subtomentosa*			C		6/6
plants	higher dicots	Euphorbiaceae	*Euphorbia tannensis subsp. eremophila*			C		3/3
plants	higher dicots	Euphorbiaceae	*Euphorbia*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia operta*			C		4/4
plants	higher dicots	Euphorbiaceae	*Microstachys chamaelea*			C		3/3
plants	higher dicots	Euphorbiaceae	*Euphorbia accedens*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia biconvexa*			C		2/2
plants	higher dicots	Euphorbiaceae	*Euphorbia drummondii*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia heterophylla*		Y			2/2
plants	higher dicots	Euphorbiaceae	*Jatropha gossypiifolia*	bellyache bush	Y			1/1
plants	higher dicots	Euphorbiaceae	*Ricinus communis*	castor oil bush	Y			2/2
plants	higher dicots	Fabaceae	*Sesbania benthamiana*			C		3/3
plants	higher dicots	Fabaceae	*Jacksonia lateritica*			C		3/3
plants	higher dicots	Fabaceae	*Stylosanthes viscosa*		Y			1/1
plants	higher dicots	Fabaceae	*Tephrosia delestangii*			C		3/3
plants	higher dicots	Fabaceae	*Tephrosia flagellaris*			C		3/3
plants	higher dicots	Fabaceae	*Indigofera haplophylla*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia lasiochlaena*			C		4/4
plants	higher dicots	Fabaceae	*Indigofera queenslandica*			C		1/1
plants	higher dicots	Fabaceae	*Gastrolobium grandiflorum*			C		1/1
plants	higher dicots	Fabaceae	*Macroptilium atropurpureum*	siratro	Y			2/2
plants	higher dicots	Fabaceae	*Crotalaria novae-hollandiae*			C		1/1
plants	higher dicots	Fabaceae	*Galactia tenuiflora var. lucida*			C		2/2
plants	higher dicots	Fabaceae	*Vigna lanceolata var. latifolia*			C		2/2
plants	higher dicots	Fabaceae	*Rhynchosia minima var. australis*			C		1/1
plants	higher dicots	Fabaceae	*Rhynchosia minima var. tomentosa*			C		1/1
plants	higher dicots	Fabaceae	*Vigna lanceolata var. lanceolata*			C		3/3
plants	higher dicots	Fabaceae	*Galactia tenuiflora forma sericea*			C		2/2
plants	higher dicots	Fabaceae	*Sesbania cannabina var. cannabina*			C		3/3
plants	higher dicots	Fabaceae	*Zornia muriculata subsp. angustata*			C		5/5
plants	higher dicots	Fabaceae	*Crotalaria medicaginea var. neglecta*			C		2/2
plants	higher dicots	Fabaceae	*Tephrosia brachyodon var. longifolia*			C		7/7
plants	higher dicots	Fabaceae	*Tephrosia sp. (Mt Isa P.L.Harris 277)*			C		9/9

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Fabaceae	*Tephrosia brachyodon var. cloncurrensis*			C		2/2
plants	higher dicots	Fabaceae	*Tephrosia sp. (Magazine Hill P.Jones 365)*			C		6/6
plants	higher dicots	Fabaceae	*Tephrosia sp. (Pannikan Springs A.R.Bean+ 5612)*			C		1/1
plants	higher dicots	Fabaceae	*Crotalaria novae-hollandiae subsp. novae-hollandiae*			C		2/2
plants	higher dicots	Fabaceae	*Tephrosia phaeosperma var. (Westmoreland S.Melville 967)*			C		2/2
plants	higher dicots	Fabaceae	*Glycine*			C		1/1
plants	higher dicots	Fabaceae	*Galactia*			C		2/2
plants	higher dicots	Fabaceae	*Cullen pallidum*			C		1/1
plants	higher dicots	Fabaceae	*Indigofera trita*			C		4/4
plants	higher dicots	Fabaceae	*Tephrosia supina*			C		5/5
plants	higher dicots	Fabaceae	*Tephrosia virens*			C		5/5
plants	higher dicots	Fabaceae	*Clitoria ternatea*	butterfly pea	Y			1/1
plants	higher dicots	Fabaceae	*Cullen balsamicum*			C		4/4
plants	higher dicots	Fabaceae	*Rhynchosia minima*			C		1/1
plants	higher dicots	Fabaceae	*Glycine tomentella*	woolly glycine		C		1/1
plants	higher dicots	Fabaceae	*Indigofera colutea*	sticky indigo		C		2/2
plants	higher dicots	Fabaceae	*Indigofera hirsuta*	hairy indigo		C		2/2
plants	higher dicots	Fabaceae	*Indigofera linnaei*	Birdsville indigo		C		3/3
plants	higher dicots	Fabaceae	*Aeschynomene indica*	budda pea		C		2/2
plants	higher dicots	Fabaceae	*Cajanus acutifolius*			C		4/4
plants	higher dicots	Fabaceae	*Cajanus lanuginosus*			C		2/2
plants	higher dicots	Fabaceae	*Galactia tenuiflora*			C		2/2
plants	higher dicots	Fabaceae	*Medicago polymorpha*	burr medic	Y			1/1
plants	higher dicots	Fabaceae	*Stylosanthes hamata*		Y			2/2
plants	higher dicots	Fabaceae	*Templetonia hookeri*			C		2/2
plants	higher dicots	Fabaceae	*Tephrosia eriocarpa*			C		1/1
plants	higher dicots	Fabaceae	*Alysicarpus muelleri*			C		1/1
plants	higher dicots	Fabaceae	*Cullen australasicum*			C		2/2
plants	higher dicots	Fabaceae	*Indigofera linifolia*			C		3/3
plants	higher dicots	Fabaceae	*Indigofera pratensis*			C		3/3
plants	higher dicots	Fabaceae	*Indigofera scabrella*			C		1/1
plants	higher dicots	Frankeniaceae	*Frankenia serpyllifolia*			C		1/1
plants	higher dicots	Goodeniaceae	*Scaevola*			C		3/3
plants	higher dicots	Goodeniaceae	*Goodenia lunata*			C		1/1
plants	higher dicots	Goodeniaceae	*Goodenia ramelii*			C		4/4
plants	higher dicots	Goodeniaceae	*Goodenia armitiana*			C		2/2
plants	higher dicots	Goodeniaceae	*Scaevola sp. (Mt Isa P.L.Harris 699)*			C		1/1
plants	higher dicots	Goodeniaceae	*Goodenia vilmoriniae*			C		5/5
plants	higher dicots	Goodeniaceae	*Goodenia triodiophila*			C		4/4
plants	higher dicots	Goodeniaceae	*Scaevola browniana subsp. browniana*			C		1/1
plants	higher dicots	Goodeniaceae	*Goodenia grandiflora*			C		3/3
plants	higher dicots	Lamiaceae	*Mesosphaerum suaveolens*		Y			1/1
plants	higher dicots	Lamiaceae	*Clerodendrum tomentosum*			C		1/1
plants	higher dicots	Lamiaceae	*Ocimum caryophyllinum*			C		2/2
plants	higher dicots	Lamiaceae	*Anisomeles malabarica*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Lamiaceae	*Ocimum x citriodorum*			C		1/1
plants	higher dicots	Lamiaceae	*Clerodendrum floribundum*			C		3/3
plants	higher dicots	Loganiaceae	*Mitrasacme micrantha*			C		1/1
plants	higher dicots	Loganiaceae	*Mitrasacme nudicaulis var. nudicaulis*			C		1/1
plants	higher dicots	Loganiaceae	*Mitrasacme pygmaea*			C		1/1
plants	higher dicots	Loranthaceae	*Lysiana exocarpi subsp. exocarpi*			C		1/1
plants	higher dicots	Loranthaceae	*Lysiana subfalcata*			C		3/3
plants	higher dicots	Loranthaceae	*Amyema sanguinea var. sanguinea*			C		4/4
plants	higher dicots	Loranthaceae	*Lysiana spathulata subsp. spathulata*			C		6/6
plants	higher dicots	Loranthaceae	*Diplatia grandibractea*			C		1/1
plants	higher dicots	Loranthaceae	*Amyema villiflora subsp. villiflora*			C		1/1
plants	higher dicots	Loranthaceae	*Amyema quandang var. quandang*			C		2/2
plants	higher dicots	Loranthaceae	*Dendrophthoe odontocalyx*			C		1/1
plants	higher dicots	Lythraceae	*Rotala occultiflora*			C		1/1
plants	higher dicots	Lythraceae	*Ammannia multiflora*	jerry-jerry		C		2/2
plants	higher dicots	Lythraceae	*Rotala mexicana*			C		1/1
plants	higher dicots	Malvaceae	*Sida*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus*			C		3/3
plants	higher dicots	Malvaceae	*Sida sp. (Doomadgee F.W.Whitehouse AQ116275)*			C		1/1
plants	higher dicots	Malvaceae	*Sida sp. (Musselbrook M.B.Thomas+ MRS437)*			C		7/7
plants	higher dicots	Malvaceae	*Sida arenicola*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon hannii*			C		3/3
plants	higher dicots	Malvaceae	*Abutilon macrum*			C		1/1
plants	higher dicots	Malvaceae	*Sida cordifolia*		Y			2/2
plants	higher dicots	Malvaceae	*Sida fibulifera*			C		7/7
plants	higher dicots	Malvaceae	*Sida goniocarpa*			C		1/1
plants	higher dicots	Malvaceae	*Sida nematopoda*			C		2/2
plants	higher dicots	Malvaceae	*Sida platycalyx*	lifesaver burr		C		1/1
plants	higher dicots	Malvaceae	*Abutilon lepidum*			C		8/8
plants	higher dicots	Malvaceae	*Hibiscus sturtii*			C		3/3
plants	higher dicots	Malvaceae	*Malva parviflora*	small-flowered mallow	Y			1/1
plants	higher dicots	Malvaceae	*Sida cleisocalyx*			C		2/2
plants	higher dicots	Malvaceae	*Sida hackettiana*			C		4/4
plants	higher dicots	Malvaceae	*Hibiscus burtonii*			C		2/2
plants	higher dicots	Malvaceae	*Abutilon arenarium*			C		4/4
plants	higher dicots	Malvaceae	*Abutilon otocarpum*			C		2/2
plants	higher dicots	Malvaceae	*Gossypium australe*			C		9/9
plants	higher dicots	Malvaceae	*Gossypium nelsonii*			C		3/3
plants	higher dicots	Malvaceae	*Herissantia crispa*			C		1/1
plants	higher dicots	Malvaceae	*Gossypium sturtianum*			C		3/3
plants	higher dicots	Malvaceae	*Hibiscus leptocladus*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus meraukensis*	Merauke hibiscus		C		2/2
plants	higher dicots	Malvaceae	*Hibiscus verdcourtii*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon leucopetalum*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus pentaphyllus*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus brachychlaenus*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Malvaceae	*Hibiscus brachysiphonius*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus sturtii var. sturtii*			C		1/1
plants	higher dicots	Malvaceae	*Sida rohlenae subsp. rohlenae*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon fraseri subsp. fraseri*			C		3/3
plants	higher dicots	Malvaceae	*Hibiscus sturtii var. platychlamys*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus sturtii var. campylochlamys*			C		4/4
plants	higher dicots	Malvaceae	*Malvastrum americanum var. americanum*		Y			2/2
plants	higher dicots	Malvaceae	*Sida sp. (Jericho E.J.Thompson+ JER117)*			C		5/5
plants	higher dicots	Meliaceae	*Azadirachta indica*		Y			1/1
plants	higher dicots	Meliaceae	*Khaya senegalensis*		Y			1/1
plants	higher dicots	Menyanthaceae	*Nymphoides indica*	water snowflake		C		1/1
plants	higher dicots	Mimosaceae	*Acacia bivenosa*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia cowleana*			C		7/7
plants	higher dicots	Mimosaceae	*Acacia hemsleyi*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia ligulata*			C		2/2
plants	higher dicots	Mimosaceae	*Albizia lebbeck*	Indian siris		C		2/2
plants	higher dicots	Mimosaceae	*Acacia acradenia*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia adsurgens*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia galioides*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia gonoclada*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia hammondii*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia monticola*			C		9/9
plants	higher dicots	Mimosaceae	*Acacia thomsonii*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia victoriae*			C		2/2
plants	higher dicots	Mimosaceae	*Prosopis pallida*		Y			2/2
plants	higher dicots	Mimosaceae	*Acacia chisholmii*			C		6/6
plants	higher dicots	Mimosaceae	*Acacia elachantha*			C		5/5
plants	higher dicots	Mimosaceae	*Acacia hemignosta*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia lysiphloia*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia megalantha*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia melleodora*			C		7/7
plants	higher dicots	Mimosaceae	*Acacia orthocarpa*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia tenuissima*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia asperulacea*			C		6/6
plants	higher dicots	Mimosaceae	*Acacia holosericea*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia phlebocarpa*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia chippendalei*			C		12/12
plants	higher dicots	Mimosaceae	*Acacia sericophylla*			C		4/4
plants	higher dicots	Mimosaceae	*Vachellia bidwillii*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia ancistrocarpa*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia estrophiolata*			C		1/1
plants	higher dicots	Mimosaceae	*Vachellia farnesiana*		Y			2/2
plants	higher dicots	Mimosaceae	*Neptunia dimorphantha*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia aneura var. aneura*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia excelsa subsp. angusta*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia retivenea subsp. retivenea*			C		4/4

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Mimosaceae	*Acacia sp. (Coolullah M.Lazarides 3988)*			C		8/8
plants	higher dicots	Mimosaceae	*Leucaena leucocephala subsp. leucocephala*		Y			3/3
plants	higher dicots	Mimosaceae	*Acacia colei*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia laccata*			C		2/2
plants	higher dicots	Molluginaceae	*Glinus oppositifolius*			C		1/1
plants	higher dicots	Moraceae	*Ficus brachypoda*			C		1/1
plants	higher dicots	Moraceae	*Ficus opposita*			C		1/1
plants	higher dicots	Moraceae	*Ficus cerasicarpa*			C		4/4
plants	higher dicots	Myrtaceae	*Corymbia aparrerinja*			C		2/2
plants	higher dicots	Myrtaceae	*Corymbia capricornia*			C		2/2
plants	higher dicots	Myrtaceae	*Corymbia leichhardtii*	rustyjacket		C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus melanophloia x E.normantonensis*			C		1/1
plants	higher dicots	Myrtaceae	*Melaleuca leucadendra*	broad-leaved tea-tree		C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus leucophylla*			C		7/7
plants	higher dicots	Myrtaceae	*Melaleuca dissitiflora*			C		1/1
plants	higher dicots	Myrtaceae	*Lophostemon grandiflorus*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus normantonensis*	Normanton box		C		10/10
plants	higher dicots	Myrtaceae	*Eucalyptus leucophloia subsp. euroa*			C		3/3
plants	higher dicots	Myrtaceae	*Eucalyptus melanophloia subsp. nana*			C		12/12
plants	higher dicots	Myrtaceae	*Eucalyptus camaldulensis subsp. obtusa*			C		3/3
plants	higher dicots	Myrtaceae	*Melaleuca viridiflora var. viridiflora*			C		1/1
plants	higher dicots	Myrtaceae	*Lophostemon grandiflorus subsp. riparius*			C		2/2
plants	higher dicots	Myrtaceae	*Melaleuca bracteata*			C		4/4
plants	higher dicots	Myrtaceae	*Corymbia terminalis*			C		1/1
plants	higher dicots	Myrtaceae	*Calytrix brownii*			C		1/1
plants	higher dicots	Myrtaceae	*Corymbia aspera*			C		7/7
plants	higher dicots	Myrtaceae	*Eucalyptus nudicaulis*			C		9/9
plants	higher dicots	Nyctaginaceae	*Boerhavia repleta*			C		3/3
plants	higher dicots	Nyctaginaceae	*Boerhavia pubescens*			C		5/5
plants	higher dicots	Nyctaginaceae	*Boerhavia paludosa*			C		3/3
plants	higher dicots	Oleaceae	*Jasminum calcareum*			C		1/1
plants	higher dicots	Oleaceae	*Jasminum didymum subsp. lineare*			C		2/2
plants	higher dicots	Onagraceae	*Ludwigia*			C		1/1
plants	higher dicots	Onagraceae	*Ludwigia perennis*			C		1/1
plants	higher dicots	Onagraceae	*Ludwigia peploides subsp. montevidensis*			C		1/1
plants	higher dicots	Onagraceae	*Ludwigia octovalvis*	willow primrose		C		1/1
plants	higher dicots	Orobanchaceae	*Buchnera linearis*			C		3/3
plants	higher dicots	Orobanchaceae	*Striga squamigera*			C		2/2
plants	higher dicots	Passifloraceae	*Passiflora foetida*		Y			3/3
plants	higher dicots	Pentapetaceae	*Melhania ovata*			C		3/3
plants	higher dicots	Pentapetaceae	*Melhania oblongifolia*			C		1/1
plants	higher dicots	Phyllanthaceae	*Breynia oblongifolia*			C		1/1
plants	higher dicots	Phyllanthaceae	*Flueggea leucopyrus*			C		2/2
plants	higher dicots	Phyllanthaceae	*Phyllanthus hebecarpus*			C		1/1
plants	higher dicots	Phyllanthaceae	*Sauropus trachyspermus*			C		2/2
plants	higher dicots	Phyllanthaceae	*Phyllanthus exilis*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Phyllanthaceae	*Phyllanthus carpentariae*			C		1/1
plants	higher dicots	Phyllanthaceae	*Phyllanthus*			C		2/2
plants	higher dicots	Phyllanthaceae	*Sauropus*			C		1/1
plants	higher dicots	Phyllanthaceae	*Flueggea virosa subsp. melanthesoides*			C		2/2
plants	higher dicots	Phyllanthaceae	*Phyllanthus maderaspatensis*			C		3/3
plants	higher dicots	Pittosporaceae	*Pittosporum angustifolium*			C		2/2
plants	higher dicots	Plantaginaceae	*Scoparia dulcis*	Scoparia	Y			1/1
plants	higher dicots	Plantaginaceae	*Mecardonia procumbens*		Y			2/2
plants	higher dicots	Plantaginaceae	*Stemodia*			C		1/1
plants	higher dicots	Plantaginaceae	*Bacopa monnieri*			C		2/2
plants	higher dicots	Plantaginaceae	*Stemodia lythrifolia*			C		5/5
plants	higher dicots	Plantaginaceae	*Stemodia viscosa*			C		4/4
plants	higher dicots	Plantaginaceae	*Stemodia glabella*			C		1/1
plants	higher dicots	Polygonaceae	*Persicaria attenuata*			C		2/2
plants	higher dicots	Polygonaceae	*Polygonum plebeium*	small knotweed		C		1/1
plants	higher dicots	Portulacaceae	*Calandrinia ptychosperma*			C		1/1
plants	higher dicots	Portulacaceae	*Portulaca intraterranea*			C		1/1
plants	higher dicots	Portulacaceae	*Portulaca oligosperma*			C		1/1
plants	higher dicots	Portulacaceae	*Grahamia australiana*			C		1/1
plants	higher dicots	Portulacaceae	*Portulaca filifolia*			C		1/1
plants	higher dicots	Portulacaceae	*Calandrinia pumila*			C		1/1
plants	higher dicots	Portulacaceae	*Portulaca sp. (Blackall G.Le Gros AQ101965)*			C		1/1
plants	higher dicots	Proteaceae	*Grevillea striata*	beefwood		C		1/1
plants	higher dicots	Proteaceae	*Hakea arborescens*			C		1/1
plants	higher dicots	Proteaceae	*Hakea chordophylla*			C		2/2
plants	higher dicots	Proteaceae	*Grevillea mimosoides*			C		2/2
plants	higher dicots	Proteaceae	*Hakea lorea subsp. lorea*			C		3/3
plants	higher dicots	Proteaceae	*Grevillea wickhamii subsp. aprica*			C		8/8
plants	higher dicots	Proteaceae	*Grevillea dryandri subsp. dryandri*			C		2/2
plants	higher dicots	Rhamnaceae	*Alphitonia excelsa*	soap tree		C		4/4
plants	higher dicots	Rubiaceae	*Dentella repens*	dentella		C		1/1
plants	higher dicots	Rubiaceae	*Pavetta rupicola*			C		5/5
plants	higher dicots	Rubiaceae	*Psydrax oleifolia*			C		3/3
plants	higher dicots	Rubiaceae	*Oldenlandia galioides*			C		3/3
plants	higher dicots	Rubiaceae	*Spermacoce auriculata*			C		5/5
plants	higher dicots	Rubiaceae	*Kohautia australiensis*			C		2/2
plants	higher dicots	Rubiaceae	*Spermacoce brachystema*			C		5/5
plants	higher dicots	Rubiaceae	*Synaptantha tillaeacea var. tillaeacea*			C		3/3
plants	higher dicots	Rubiaceae	*Oldenlandia mitrasacmoides subsp. mitrasacmoides*			C		2/2
plants	higher dicots	Santalaceae	*Anthobolus leptomerioides*			C		2/2
plants	higher dicots	Santalaceae	*Santalum lanceolatum*			C		4/4
plants	higher dicots	Sapindaceae	*Dodonaea lanceolata var. lanceolata*			C		3/3
plants	higher dicots	Sapindaceae	*Dodonaea viscosa subsp. mucronata*			C		3/3
plants	higher dicots	Sapindaceae	*Dodonaea stenophylla*			C		3/3
plants	higher dicots	Sapindaceae	*Dodonaea barklyana*			C		2/2
plants	higher dicots	Sapindaceae	*Alectryon oleifolius subsp. elongatus*			C		2/2

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plants	higher dicots	Sapindaceae	*Dodonaea viscosa subsp. angustissima*			C		1/1
plants	higher dicots	Scrophulariaceae	*Eremophila latrobei*			C		2/2
plants	higher dicots	Scrophulariaceae	*Eremophila macgillivrayi*			C		1/1
plants	higher dicots	Scrophulariaceae	*Eremophila mitchellii*			C		3/3
plants	higher dicots	Scrophulariaceae	*Eremophila longifolia*	berrigan		C		4/4
plants	higher dicots	Solanaceae	*Nicotiana glauca*	tree tobacco	Y			1/1
plants	higher dicots	Solanaceae	*Solanum torvum*	devil's fig	Y			1/1
plants	higher dicots	Solanaceae	*Datura inoxia*		Y			4/4
plants	higher dicots	Solanaceae	*Solanum succosum*			C		5/5
plants	higher dicots	Solanaceae	*Physalis angulata*		Y			2/2
plants	higher dicots	Solanaceae	*Nicotiana megalosiphon*			C		1/1
plants	higher dicots	Solanaceae	*Nicotiana megalosiphon subsp. sessilifolia*			C		2/2
plants	higher dicots	Solanaceae	*Solanum ferocissimum*			C		3/3
plants	higher dicots	Solanaceae	*Solanum quadriloculatum*			C		7/7
plants	higher dicots	Solanaceae	*Solanum senticosum*			C		7/7
plants	higher dicots	Solanaceae	*Nicotiana benthamiana*			C		2/2
plants	higher dicots	Solanaceae	*Solanum echinatum*			C		5/5
plants	higher dicots	Sparrmanniaceae	*Triumfetta*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Corchorus pumilio*			C		5/5
plants	higher dicots	Sparrmanniaceae	*Corchorus sidoides subsp. vermicularis*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Corchorus sericeus subsp. densiflorus*			C		18/18
plants	higher dicots	Sparrmanniaceae	*Corchorus sidoides subsp. sidoides*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Corchorus sericeus subsp. sericeus*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Triumfetta marsupiata*			C		4/4
plants	higher dicots	Sparrmanniaceae	*Triumfetta johnstonii*			C		5/5
plants	higher dicots	Sparrmanniaceae	*Corchorus tridens*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Triumfetta plumigera*			C		5/5
plants	higher dicots	Sparrmanniaceae	*Triumfetta rupestris*			C		3/3
plants	higher dicots	Sparrmanniaceae	*Corchorus sericeus*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Grewia retusifolia*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Triumfetta triandra*			C		1/1
plants	higher dicots	Sterculiaceae	*Brachychiton collinus*			C		2/2
plants	higher dicots	Stylidiaceae	*Stylidium desertorum*			C		1/1
plants	higher dicots	Stylidiaceae	*Stylidium floribundum*			C		1/1
plants	higher dicots	Tamaricaceae	*Tamarix aphylla*	athel pine	Y			4/4
plants	higher dicots	Ulmaceae	*Trema tomentosa*			C		2/2
plants	higher dicots	Ulmaceae	*Trema tomentosa var. tomentosa*			C		2/2
plants	higher dicots	Verbenaceae	*Phyla nodiflora*	carpetweed		C		1/1
plants	higher dicots	Violaceae	*Hybanthus enneaspermus*			C		3/3
plants	higher dicots	Violaceae	*Hybanthus aurantiacus*			C		6/6
plants	higher dicots	Zygophyllaceae	*Tribulus cistoides*	bulls head vine		C		1/1
plants	higher dicots	Zygophyllaceae	*Tribulopis angustifolia*			C		3/3
plants	higher dicots	Zygophyllaceae	*Tribulus terrestris*	caltrop		C		3/3
plants	higher dicots	Zygophyllaceae	*Tribulopis pentandra*			C		3/3
plants	higher dicots	Zygophyllaceae	*Tribulus astrocarpus*			C		1/1
plants	higher dicots	Zygophyllaceae	*Tribulus*			C		1/1

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plants	liverworts	Liverwort	*Liverwort*			C		1/1
plants	lower dicots	Lauraceae	*Cassytha glabella forma glabella*			C		1/1
plants	lower dicots	Menispermaceae	*Tinospora smilacina*	snakevine		C		3/3
plants	monocots	Araceae	*Spirodela oligorrhiza*			C		3/3
plants	monocots	Colchicaceae	*Iphigenia indica*			C		1/1
plants	monocots	Commelinaceae	*Commelina ensifolia*	scurvy grass		C		1/1
plants	monocots	Cyperaceae	*Cyperus cunninghamii subsp. cunninghamii*			C		4/4
plants	monocots	Cyperaceae	*Cyperus microcephalus subsp. microcephalus*			C		5/5
plants	monocots	Cyperaceae	*Fimbristylis aestivalis var. aestivalis*			C		1/1
plants	monocots	Cyperaceae	*Cyperus cunninghamii subsp. cheradicus*			C		2/2
plants	monocots	Cyperaceae	*Cyperus iria*			C		6/6
plants	monocots	Cyperaceae	*Cyperus exaltatus*	tall flatsedge		C		2/2
plants	monocots	Cyperaceae	*Cyperus betchei subsp. commiscens*			C		3/3
plants	monocots	Cyperaceae	*Schoenoplectus lateriflorus*			C		1/1
plants	monocots	Cyperaceae	*Fimbristylis bisumbellata*			C		1/1
plants	monocots	Cyperaceae	*Schoenoplectus subulatus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus bifax*	western nutgrass		C		1/1
plants	monocots	Cyperaceae	*Cyperus fulvus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus conicus*			C		2/2
plants	monocots	Cyperaceae	*Fuirena ciliaris*			C		1/1
plants	monocots	Cyperaceae	*Cyperus carinatus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus difformis*	rice sedge		C		2/2
plants	monocots	Cyperaceae	*Cyperus microcephalus subsp. saxicola*			C		1/1
plants	monocots	Cyperaceae	*Cyperus vaginatus*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis nuda*			C		1/1
plants	monocots	Cyperaceae	*Cyperus dactylotes*			C		6/6
plants	monocots	Cyperaceae	*Cyperus ixiocarpus*			C		4/4
plants	monocots	Cyperaceae	*Cyperus nervulosus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus pulchellus*			C		2/2
plants	monocots	Cyperaceae	*Cyperus squarrosus*	bearded flatsedge		C		3/3
plants	monocots	Cyperaceae	*Bulbostylis barbata*			C		13/13
plants	monocots	Cyperaceae	*Fimbristylis dichotoma*	common fringe-rush		C		1/1
plants	monocots	Cyperaceae	*Eleocharis atropurpurea*			C		1/1
plants	monocots	Cyperaceae	*Fimbristylis aestivalis*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis littoralis*			C		1/1
plants	monocots	Cyperaceae	*Fimbristylis microcarya*			C		3/3
plants	monocots	Cyperaceae	*Lipocarpha microcephala*			C		4/4
plants	monocots	Cyperaceae	*Bolboschoenus caldwellii*			C		1/1
plants	monocots	Hydrocharitaceae	*Hydrilla verticillata*	hydrilla		C		1/1
plants	monocots	Hydrocharitaceae	*Vallisneria nana*			C		1/1
plants	monocots	Juncaceae	*Juncus aridicola*	tussock rush		C		1/1
plants	monocots	Juncaceae	*Juncus continuus*			C		1/1
plants	monocots	Najadaceae	*Najas marina*			C		2/2
plants	monocots	Poaceae	*Eragrostis tenuifolia*	elastic grass	Y			1/1
plants	monocots	Poaceae	*Aristida*			C		1/1
plants	monocots	Poaceae	*Perotis rara*	comet grass		C		3/3

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plants	monocots	Poaceae	*Eulalia aurea*	silky browntop		C		4/4
plants	monocots	Poaceae	*Aristida acuta*			C		2/2
plants	monocots	Poaceae	*Melinis repens*	red natal grass	Y			4/4
plants	monocots	Poaceae	*Panicum buncei*			C		2/2
plants	monocots	Poaceae	*Sarga plumosum*			C		4/4
plants	monocots	Poaceae	*Chloris inflata*	purpletop chloris	Y			3/3
plants	monocots	Poaceae	*Chloris pumilio*			C		1/1
plants	monocots	Poaceae	*Chloris virgata*	feathertop rhodes grass	Y			1/1
plants	monocots	Poaceae	*Eriachne obtusa*			C		3/3
plants	monocots	Poaceae	*Panicum effusum*			C		5/5
plants	monocots	Poaceae	*Sarga timorense*			C		1/1
plants	monocots	Poaceae	*Sehima nervosum*			C		2/2
plants	monocots	Poaceae	*Setaria surgens*			C		1/1
plants	monocots	Poaceae	*Triodia molesta*			C		5/5
plants	monocots	Poaceae	*Triodia pungens*			C		13/13
plants	monocots	Poaceae	*Eragrostis minor*	smaller stinkgrass	Y			3/3
plants	monocots	Poaceae	*Eragrostis olida*			C		2/2
plants	monocots	Poaceae	*Polytrias indica*		Y			1/1
plants	monocots	Poaceae	*Themeda triandra*	kangaroo grass		C		5/5
plants	monocots	Poaceae	*Triraphis mollis*	purple plumegrass		C		1/1
plants	monocots	Poaceae	*Acrachne racemosa*			C		2/2
plants	monocots	Poaceae	*Aristida contorta*	bunched kerosene grass		C		3/3
plants	monocots	Poaceae	*Aristida pruinosa*			C		3/3
plants	monocots	Poaceae	*Cenchrus robustus*			C		1/1
plants	monocots	Poaceae	*Chloris pectinata*	comb chloris		C		1/1
plants	monocots	Poaceae	*Digitaria brownii*			C		5/5
plants	monocots	Poaceae	*Digitaria gibbosa*			C		3/3
plants	monocots	Poaceae	*Mnesithea formosa*			C		7/7
plants	monocots	Poaceae	*Paspalidium rarum*			C		2/2
plants	monocots	Poaceae	*Setaria apiculata*			C		1/1
plants	monocots	Poaceae	*Paspalidium constrictum*			C		1/1
plants	monocots	Poaceae	*Pseudoraphis spinescens*	spiny mudgrass		C		2/2
plants	monocots	Poaceae	*Schizachyrium perplexum*			C		3/3
plants	monocots	Poaceae	*Sporobolus actinocladus*	katoora grass		C		2/2
plants	monocots	Poaceae	*Cenchrus pennisetiformis*		Y			7/7
plants	monocots	Poaceae	*Enneapogon robustissimus*			C		4/4
plants	monocots	Poaceae	*Sporobolus australasicus*			C		3/3
plants	monocots	Poaceae	*Diplachne fusca var. fusca*			C		2/2
plants	monocots	Poaceae	*Eriochloa pseudoacrotricha*			C		1/1
plants	monocots	Poaceae	*Urochloa gilesii var. gilesii*			C		3/3
plants	monocots	Poaceae	*Cynodon dactylon var. dactylon*		Y			2/2
plants	monocots	Poaceae	*Megathyrsus maximus var. maximus*		Y			1/1
plants	monocots	Poaceae	*Aristida holathera var. holathera*			C		5/5
plants	monocots	Poaceae	*Eriachne pulchella subsp. dominii*			C		4/4
plants	monocots	Poaceae	*Bothriochloa bladhii subsp. bladhii*			C		4/4
plants	monocots	Poaceae	*Eriachne pulchella subsp. pulchella*			C		2/2

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plants	monocots	Poaceae	*Megathyrsus maximus var. pubiglumis*		Y			1/1
plants	monocots	Poaceae	*Cynodon nlemfuensis var. nlemfuensis*		Y			3/3
plants	monocots	Poaceae	*Urochloa holosericea subsp. velutina*			C		1/1
plants	monocots	Poaceae	*Yakirra australiensis var. intermedia*			C		1/1
plants	monocots	Poaceae	*Panicum decompositum var. decompositum*			C		1/1
plants	monocots	Poaceae	*Yakirra australiensis var. australiensis*			C		1/1
plants	monocots	Poaceae	*Eriachne sp. (Dugald River B.K.Simon+ 3007)*			C		6/6
plants	monocots	Poaceae	*Eriachne mucronata forma (Alpha C.E.Hubbard 7882)*			C		6/6
plants	monocots	Poaceae	*Eriachne mucronata forma (Burnham R.W.Purdie 1370)*			C		8/8
plants	monocots	Poaceae	*Aristida polyclados*			C		2/2
plants	monocots	Poaceae	*Cymbopogon ambiguus*	lemon grass		C		3/3
plants	monocots	Poaceae	*Cymbopogon obtectus*			C		2/2
plants	monocots	Poaceae	*Digitaria ctenantha*			C		1/1
plants	monocots	Poaceae	*Enteropogon ramosus*			C		5/5
plants	monocots	Poaceae	*Eragrostis cumingii*			C		2/2
plants	monocots	Poaceae	*Eragrostis elongata*			C		7/7
plants	monocots	Poaceae	*Eragrostis speciosa*			C		5/5
plants	monocots	Poaceae	*Leptochloa digitata*			C		1/1
plants	monocots	Poaceae	*Oxychloris scariosa*	winged chloris		C		4/4
plants	monocots	Poaceae	*Panicum larcomianum*			C		1/1
plants	monocots	Poaceae	*Tragus australianus*	small burr grass		C		3/3
plants	monocots	Poaceae	*Triodia burbidgeana*			C		3/3
plants	monocots	Poaceae	*Aristida longicollis*			C		3/3
plants	monocots	Poaceae	*Bothriochloa pertusa*		Y			1/1
plants	monocots	Poaceae	*Brachyachne ciliaris*	hairy native couch		C		1/1
plants	monocots	Poaceae	*Dichanthium fecundum*	curly bluegrass		C		3/3
plants	monocots	Poaceae	*Enneapogon asperatus*			C		2/2
plants	monocots	Poaceae	*Enneapogon avenaceus*			C		1/1
plants	monocots	Poaceae	*Eragrostis tenellula*	delicate lovegrass		C		4/4
plants	monocots	Poaceae	*Eragrostis xerophila*			C		1/1
plants	monocots	Poaceae	*Sorghum arundinaceum*	Rhodesian Sudan grass	Y			1/1
plants	monocots	Poaceae	*Tripogon loliiformis*	five minute grass		C		1/1
plants	monocots	Poaceae	*Aristida biglandulosa*			C		3/3
plants	monocots	Poaceae	*Chrysopogon elongatus*			C		1/1
plants	monocots	Poaceae	*Cymbopogon bombycinus*	silky oilgrass		C		3/3
plants	monocots	Poaceae	*Dichanthium annulatum*	sheda grass	Y			1/1
plants	monocots	Poaceae	*Eragrostis desertorum*	woollybutt		C		3/3
plants	monocots	Poaceae	*Eragrostis lanicaulis*			C		1/1
plants	monocots	Poaceae	*Eragrostis leptocarpa*	drooping lovegrass		C		3/3
plants	monocots	Poaceae	*Sporobolus caroli*	fairy grass		C		1/1
plants	monocots	Poaceae	*Triodia basedowii*			C		1/1
plants	monocots	Poaceae	*Triodia bitextura*			C		6/6
plants	monocots	Poaceae	*Triodia brizoides*			C		10/10
plants	monocots	Poaceae	*Triodia longiceps*	giant grey spinifex		C		5/5
plants	monocots	Poaceae	*Urochloa piligera*			C		1/1
plants	monocots	Poaceae	*Xerochloa barbata*			C		4/4

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	monocots	Poaceae	*Aristida latifolia*	feathertop wiregrass		C		1/1
plants	monocots	Poaceae	*Aristida leptopoda*	white speargrass		C		1/1
plants	monocots	Poaceae	*Chrysopogon fallax*			C		1/1
plants	monocots	Poaceae	*Digitaria bicornis*			C		1/1
plants	monocots	Poaceae	*Echinochloa colona*	awnless barnyard grass	Y			1/1
plants	monocots	Poaceae	*Eriachne pulchella*			C		1/1
plants	monocots	Poaceae	*Paspalum distichum*	water couch		C		1/1
plants	monocots	Poaceae	*Setaria sphacelata*		Y			1/1
plants	monocots	Poaceae	*Triodia mitchellii*	buck spinifex		C		6/6
plants	monocots	Poaceae	*Yakirra pauciflora*			C		1/1
plants	monocots	Poaceae	*Heteropogon contortus*	black speargrass		C		2/2
plants	monocots	Poaceae	*Iseilema vaginiflorum*	red flinders grass		C		1/1
plants	monocots	Poaceae	*Schizachyrium fragile*	firegrass		C		2/2
plants	monocots	Poaceae	*Aristida inaequiglumis*			C		4/4
plants	monocots	Poaceae	*Bothriochloa ewartiana*	desert bluegrass		C		3/3
plants	monocots	Poaceae	*Enneapogon lindleyanus*			C		1/1
plants	monocots	Poaceae	*Enneapogon polyphyllus*	leafy nineawn		C		4/4
plants	monocots	Poaceae	*Eragrostis trichophora*		Y			1/1
plants	monocots	Poaceae	*Paraneurachne muelleri*			C		2/2
plants	monocots	Poaceae	*Paspalidium basicladum*			C		3/3
plants	monocots	Poaceae	*Urochloa mosambicensis*	sabi grass	Y			1/1
plants	monocots	Poaceae	*Urochloa subquadripara*		Y			1/1
plants	monocots	Poaceae	*Dactyloctenium radulans*	button grass		C		1/1
plants	monocots	Pontederiaceae	*Monochoria cyanea*			C		1/1
plants	monocots	Pontederiaceae	*Eichhornia crassipes*	water hyacinth	Y			1/1
plants	monocots	Potamogetonaceae	*Potamogeton tricarinatus*	floating pondweed		C		1/1
plants	monocots	Typhaceae	*Typha domingensis*			C		1/1
plants		Phrymaceae	*Glossostigma diandrum*			C		1/1
plants		Streptophyceae	*Chara vulgaris*			C		1/1

CODES

I - Y indicates that the taxon is introduced to Queensland and has naturalised.

Q - Indicates the Queensland conservation status of each taxon under the *Nature Conservation Act 1992.* The codes are Extinct in the Wild (PE), Endangered (E), Vulnerable (V), Near Threatened (NT), Least Concern (C) or Not Protected ( ).

A - Indicates the Australian conservation status of each taxon under the *Environment Protection and Biodiversity Conservation Act 1999.* The values of EPBC are Conservation Dependent (CD), Critically Endangered (CE), Endangered (E), Extinct (EX), Extinct in the Wild (XW) and Vulnerable (V).

Records – The first number indicates the total number of records of the taxon for the record option selected (i.e. All, Confirmed or Specimens).
This number is output as 99999 if it equals or exceeds this value. The second number located after the / indicates the number of specimen records for the taxon.
This number is output as 999 if it equals or exceeds this value.

Queensland Government

Wildlife Online Extract

Search Criteria:	Species List for a Defined Area
	Species: All
	Type: All
	Status: All
	Records: All
	Date: All
	Latitude: 20.4236 to 21.0048
	Longitude: 140.5269 to 139.8569
	Email: hdick@aarc.net.au
	Date submitted: Tuesday 17 Jun 2014 16:44:59
	Date extracted: Tuesday 17 Jun 2014 16:50:03

The number of records retrieved = 533

Disclaimer

As the DSITIA is still in a process of collating and vetting data, it is possible the information given is not complete. The information provided should only be used for the project for which it was requested and it should be appropriately acknowledged as being derived from Wildlife Online when it is used.

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Feedback about Wildlife Online should be emailed to wildlife.online@science.dsitia.qld.gov.au

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	amphibians	Bufonidae	*Rhinella marina*	cane toad	Y			2
animals	amphibians	Hylidae	*Litoria rubella*	ruddy treefrog		C		1
animals	amphibians	Hylidae	*Litoria caerulea*	common green treefrog		C		1
animals	amphibians	Hylidae	*Litoria electrica*	buzzing treefrog		C		1
animals	amphibians	Hylidae	*Cyclorana australis*	northern snapping frog		C		1
animals	amphibians	Hylidae	*Cyclorana cultripes*	grassland collared frog		C		1
animals	amphibians	Hylidae	*Litoria inermis*	bumpy rocketfrog		C		1
animals	amphibians	Hylidae	*Cyclorana brevipes*	superb collared frog		C		2/1
animals	amphibians	Myobatrachidae	*Uperoleia trachyderma*	orange shouldered gungan		C		1
animals	birds	Acanthizidae	*Smicrornis brevirostris*	weebill		C		71
animals	birds	Acanthizidae	*Gerygone fusca*	western gerygone		C		1
animals	birds	Acanthizidae	*Acanthiza chrysorrhoa*	yellow-rumped thornbill		C		23
animals	birds	Accipitridae	*Pandion cristatus*	eastern osprey		SL		1
animals	birds	Accipitridae	*Aquila audax*	wedge-tailed eagle		C		28
animals	birds	Accipitridae	*Milvus migrans*	black kite		C		113
animals	birds	Accipitridae	*Elanus axillaris*	black-shouldered kite		C		2
animals	birds	Accipitridae	*Hamirostra melanosternon*	black-breasted buzzard		C		2
animals	birds	Accipitridae	*Circus approximans*	swamp harrier		C		1
animals	birds	Accipitridae	*Accipiter fasciatus*	brown goshawk		C		12
animals	birds	Accipitridae	*Haliastur sphenurus*	whistling kite		C		95
animals	birds	Accipitridae	*Haliaeetus leucogaster*	white-bellied sea-eagle		SL		14
animals	birds	Accipitridae	*Hieraaetus morphnoides*	little eagle		C		2
animals	birds	Accipitridae	*Accipiter cirrocephalus*	collared sparrowhawk		C		7
animals	birds	Acrocephalidae	*Acrocephalus australis*	Australian reed-warbler		SL		6
animals	birds	Aegothelidae	*Aegotheles cristatus*	Australian owlet-nightjar		C		8/1
animals	birds	Alaudidae	*Mirafra javanica*	Horsfield's bushlark		C		2
animals	birds	Anatidae	*Anas rhynchotis*	Australasian shoveler		C		1
animals	birds	Anatidae	*Aythya australis*	hardhead		C		60
animals	birds	Anatidae	*Anas superciliosa*	Pacific black duck		C		64
animals	birds	Anatidae	*Dendrocygna eytoni*	plumed whistling-duck		C		4
animals	birds	Anatidae	*Nettapus pulchellus*	green pygmy-goose		C		1
animals	birds	Anatidae	*Malacorhynchus membranaceus*	pink-eared duck		C		20
animals	birds	Anatidae	*Anas gracilis*	grey teal		C		51
animals	birds	Anatidae	*Cygnus atratus*	black swan		C		1
animals	birds	Anatidae	*Chenonetta jubata*	Australian wood duck		C		6
animals	birds	Anhingidae	*Anhinga novaehollandiae*	Australasian darter		C		75
animals	birds	Apodidae	*Apus pacificus*	fork-tailed swift		SL		1
animals	birds	Ardeidae	*Ardea modesta*	eastern great egret		SL		58
animals	birds	Ardeidae	*Egretta garzetta*	little egret		C		12
animals	birds	Ardeidae	*Ixobrychus flavicollis*	black bittern		C		2
animals	birds	Ardeidae	*Nycticorax caledonicus*	Nankeen night-heron		C		21
animals	birds	Ardeidae	*Egretta novaehollandiae*	white-faced heron		C		60
animals	birds	Ardeidae	*Ardea ibis*	cattle egret		SL		3
animals	birds	Ardeidae	*Ardea pacifica*	white-necked heron		C		57
animals	birds	Ardeidae	*Ardea intermedia*	intermediate egret		C		36
animals	birds	Artamidae	*Cracticus tibicen*	Australian magpie		C		55

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Artamidae	*Artamus personatus*	masked woodswallow		C		3
animals	birds	Artamidae	*Strepera graculina*	pied currawong		C		1
animals	birds	Artamidae	*Artamus cyanopterus*	dusky woodswallow		C		1
animals	birds	Artamidae	*Artamus cinereus*	black-faced woodswallow		C		63
animals	birds	Artamidae	*Artamus leucorynchus*	white-breasted woodswallow		C		22
animals	birds	Artamidae	*Artamus superciliosus*	white-browed woodswallow		C		5
animals	birds	Artamidae	*Cracticus nigrogularis*	pied butcherbird		C		65
animals	birds	Artamidae	*Artamus minor*	little woodswallow		C		29
animals	birds	Artamidae	*Cracticus torquatus*	grey butcherbird		C		2
animals	birds	Burhinidae	*Burhinus grallarius*	bush stone-curlew		C		1
animals	birds	Cacatuidae	*Cacatua galerita*	sulphur-crested cockatoo		C		46
animals	birds	Cacatuidae	*Cacatua sanguinea*	little corella		C		36/1
animals	birds	Cacatuidae	*Nymphicus hollandicus*	cockatiel		C		44
animals	birds	Cacatuidae	*Eolophus roseicapillus*	galah		C		72
animals	birds	Campephagidae	*Lalage sueurii*	white-winged triller		C		33
animals	birds	Campephagidae	*Coracina novaehollandiae*	black-faced cuckoo-shrike		C		66
animals	birds	Campephagidae	*Coracina papuensis*	white-bellied cuckoo-shrike		C		3
animals	birds	Campephagidae	*Coracina maxima*	ground cuckoo-shrike		C		4
animals	birds	Casuariidae	*Dromaius novaehollandiae*	emu		C		7
animals	birds	Charadriidae	*Vanellus miles*	masked lapwing		C		40
animals	birds	Charadriidae	*Elseyornis melanops*	black-fronted dotterel		C		48
animals	birds	Charadriidae	*Erythrogonys cinctus*	red-kneed dotterel		C		8
animals	birds	Charadriidae	*Vanellus miles miles*	masked lapwing (northern subspecies)		C		18
animals	birds	Charadriidae	*Charadrius ruficapillus*	red-capped plover		C		1
animals	birds	Ciconiidae	*Ephippiorhynchus asiaticus*	black-necked stork		NT		13
animals	birds	Cisticolidae	*Cisticola exilis*	golden-headed cisticola		C		1
animals	birds	Climacteridae	*Climacteris melanura*	black-tailed treecreeper		C		41/2
animals	birds	Columbidae	*Geophaps plumifera*	spinifex pigeon		C		34/1
animals	birds	Columbidae	*Geopelia striata*	peaceful dove		C		96
animals	birds	Columbidae	*Phaps histrionica*	flock bronzewing		C		1/1
animals	birds	Columbidae	*Phaps chalcoptera*	common bronzewing		C		25
animals	birds	Columbidae	*Ocyphaps lophotes*	crested pigeon		C		46
animals	birds	Columbidae	*Geopelia humeralis*	bar-shouldered dove		C		2
animals	birds	Columbidae	*Geopelia cuneata*	diamond dove		C		50
animals	birds	Columbidae	*Columba livia*	rock dove	Y			5
animals	birds	Coraciidae	*Eurystomus orientalis*	dollarbird		C		3
animals	birds	Corcoracidae	*Struthidea cinerea*	apostlebird		C		18
animals	birds	Corvidae	*Corvus orru*	Torresian crow		C		18
animals	birds	Corvidae	*Corvus bennetti*	little crow		C		4
animals	birds	Corvidae	*Corvus coronoides*	Australian raven		C		83/1
animals	birds	Corvidae	*Corvus sp.*					13
animals	birds	Cuculidae	*Eudynamys orientalis*	eastern koel		C		2
animals	birds	Cuculidae	*Cacomantis variolosus*	brush cuckoo		C		1
animals	birds	Cuculidae	*Centropus phasianinus*	pheasant coucal		C		9
animals	birds	Cuculidae	*Scythrops novaehollandiae*	channel-billed cuckoo		C		1
animals	birds	Cuculidae	*Chalcites basalis*	Horsfield's bronze-cuckoo		C		4

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Cuculidae	*Chalcites osculans*	black-eared cuckoo		C		1
animals	birds	Cuculidae	*Cacomantis pallidus*	pallid cuckoo		C		3
animals	birds	Estrildidae	*Taeniopygia guttata*	zebra finch		C		78
animals	birds	Estrildidae	*Poephila acuticauda*	long-tailed finch		C		13
animals	birds	Estrildidae	*Emblema pictum*	painted finch		C		25
animals	birds	Estrildidae	*Taeniopygia bichenovii*	double-barred finch		C		53
animals	birds	Estrildidae	*Neochmia ruficauda*	star finch		C		2
animals	birds	Estrildidae	*Heteromunia pectoralis*	pictorella mannikin		NT		4
animals	birds	Estrildidae	*Lonchura castaneothorax*	chestnut-breasted mannikin		C		2
animals	birds	Estrildidae	*Erythrura gouldiae*	Gouldian finch		E	E	1
animals	birds	Eurostopodidae	*Eurostopodus argus*	spotted nightjar		C		3
animals	birds	Falconidae	*Falco subniger*	black falcon		C		2
animals	birds	Falconidae	*Falco hypoleucos*	grey falcon		NT		2
animals	birds	Falconidae	*Falco berigora*	brown falcon		C		24/1
animals	birds	Falconidae	*Falco peregrinus*	peregrine falcon		C		1
animals	birds	Falconidae	*Falco cenchroides*	Nankeen kestrel		C		14
animals	birds	Falconidae	*Falco longipennis*	Australian hobby		C		8
animals	birds	Glareolidae	*Stiltia isabella*	Australian pratincole		C		5
animals	birds	Gruidae	*Grus rubicunda*	brolga		C		28
animals	birds	Halcyonidae	*Todiramphus sanctus*	sacred kingfisher		C		24
animals	birds	Halcyonidae	*Dacelo leachii*	blue-winged kookaburra		C		35
animals	birds	Halcyonidae	*Todiramphus pyrrhopygius*	red-backed kingfisher		C		14
animals	birds	Hirundinidae	*Hirundo neoxena*	welcome swallow		C		7
animals	birds	Hirundinidae	*Hirundo sp.*					5
animals	birds	Hirundinidae	*Petrochelidon ariel*	fairy martin		C		32
animals	birds	Hirundinidae	*Petrochelidon nigricans*	tree martin		C		10
animals	birds	Hirundinidae	*Cheramoeca leucosterna*	white-backed swallow		C		2
animals	birds	Jacanidae	*Irediparra gallinacea*	comb-crested jacana		C		5
animals	birds	Laridae	*Gelochelidon nilotica*	gull-billed tern		C		2
animals	birds	Laridae	*Chlidonias hybrida*	whiskered tern		C		4
animals	birds	Laridae	*Hydroprogne caspia*	Caspian tern		SL		39
animals	birds	Laridae	*Chroicocephalus novaehollandiae*	silver gull		C		19
animals	birds	Maluridae	*Malurus melanocephalus*	red-backed fairy-wren		C		7
animals	birds	Maluridae	*Malurus leucopterus*	white-winged fairy-wren		C		2
animals	birds	Maluridae	*Amytornis ballarae*	Kalkadoon grasswren		C		13
animals	birds	Maluridae	*Malurus lamberti*	variegated fairy-wren		C		29
animals	birds	Megaluridae	*Eremiornis carteri*	spinifexbird		C		4
animals	birds	Megaluridae	*Megalurus gramineus*	little grassbird		C		1
animals	birds	Megaluridae	*Cincloramphus cruralis*	brown songlark		C		4
animals	birds	Megaluridae	*Cincloramphus mathewsi*	rufous songlark		C		10
animals	birds	Meliphagidae	*Certhionyx variegatus*	pied honeyeater		C		1
animals	birds	Meliphagidae	*Philemon citreogularis*	little friarbird		C		37
animals	birds	Meliphagidae	*Ptilotula penicillatus*	white-plumed honeyeater		C		125/1
animals	birds	Meliphagidae	*Conopophila rufogularis*	rufous-throated honeyeater		C		20
animals	birds	Meliphagidae	*Acanthagenys rufogularis*	spiny-cheeked honeyeater		C		7
animals	birds	Meliphagidae	*Melithreptus albogularis*	white-throated honeyeater		C		4

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Meliphagidae	*Melithreptus gularis laetior*	golden-backed honeyeater		NT		1
animals	birds	Meliphagidae	*Epthianura aurifrons*	orange chat		C		11
animals	birds	Meliphagidae	*Cissomela pectoralis*	banded honeyeater		C		3
animals	birds	Meliphagidae	*Gavicalis virescens*	singing honeyeater		C		19
animals	birds	Meliphagidae	*Epthianura tricolor*	crimson chat		C		20
animals	birds	Meliphagidae	*Ptilotula plumulus*	grey-fronted honeyeater		C		21
animals	birds	Meliphagidae	*Manorina flavigula*	yellow-throated miner		C		76
animals	birds	Meliphagidae	*Grantiella picta*	painted honeyeater		V		5
animals	birds	Meliphagidae	*Sugomel niger*	black honeyeater		C		4
animals	birds	Meliphagidae	*Ptilotula keartlandi*	grey-headed honeyeater		C		38
animals	birds	Meliphagidae	*Ptilotula flavescens*	yellow-tinted honeyeater		C		6
animals	birds	Meliphagidae	*Lichmera indistincta*	brown honeyeater		C		92
animals	birds	Meliphagidae	*Melithreptus gularis*	black-chinned honeyeater		NT		7
animals	birds	Meliphagidae	*Philemon argenticeps*	silver-crowned friarbird		C		10
animals	birds	Meropidae	*Merops ornatus*	rainbow bee-eater		SL		76
animals	birds	Monarchidae	*Myiagra inquieta*	restless flycatcher		C		40
animals	birds	Monarchidae	*Grallina cyanoleuca*	magpie-lark		C		139
animals	birds	Motacillidae	*Anthus novaeseelandiae*	Australasian pipit		C		14
animals	birds	Nectariniidae	*Dicaeum hirundinaceum*	mistletoebird		C		42
animals	birds	Neosittidae	*Daphoenositta chrysoptera*	varied sittella		C		3
animals	birds	Oriolidae	*Oriolus sagittatus*	olive-backed oriole		C		18
animals	birds	Otididae	*Ardeotis australis*	Australian bustard		C		7
animals	birds	Pachycephalidae	*Colluricincla harmonica*	grey shrike-thrush		C		44
animals	birds	Pachycephalidae	*Oreoica gutturalis*	crested bellbird		C		9
animals	birds	Pachycephalidae	*Pachycephala rufiventris*	rufous whistler		C		54
animals	birds	Pardalotidae	*Pardalotus rubricatus*	red-browed pardalote		C		24
animals	birds	Pardalotidae	*Pardalotus striatus*	striated pardalote		C		74
animals	birds	Passeridae	*Passer domesticus*	house sparrow	Y			14
animals	birds	Pelecanidae	*Pelecanus conspicillatus*	Australian pelican		C		54
animals	birds	Petroicidae	*Petroica goodenovii*	red-capped robin		C		6/1
animals	birds	Petroicidae	*Melanodryas cucullata*	hooded robin		C		4
animals	birds	Petroicidae	*Microeca fascinans*	jacky winter		C		42
animals	birds	Phalacrocoracidae	*Phalacrocorax sulcirostris*	little black cormorant		C		48
animals	birds	Phalacrocoracidae	*Microcarbo melanoleucos*	little pied cormorant		C		57
animals	birds	Phalacrocoracidae	*Phalacrocorax varius*	pied cormorant		C		14
animals	birds	Phalacrocoracidae	*Phalacrocorax carbo*	great cormorant		C		25
animals	birds	Phasianidae	*Coturnix ypsilophora*	brown quail		C		5
animals	birds	Podargidae	*Podargus strigoides*	tawny frogmouth		C		6
animals	birds	Podicipedidae	*Podiceps cristatus*	great crested grebe		C		42
animals	birds	Podicipedidae	*Poliocephalus poliocephalus*	hoary-headed grebe		C		6
animals	birds	Podicipedidae	*Tachybaptus novaehollandiae*	Australasian grebe		C		76
animals	birds	Pomatostomidae	*Pomatostomus temporalis*	grey-crowned babbler		C		83
animals	birds	Psittacidae	*Polytelis alexandrae*	princess parrot		C	V	1
animals	birds	Psittacidae	*Melopsittacus undulatus*	budgerigar		C		40
animals	birds	Psittacidae	*Psitteuteles versicolor*	varied lorikeet		C		67
animals	birds	Psittacidae	*Barnardius zonarius*	Australian ringneck		C		36

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Psittacidae	*Barnardius zonarius macgillivrayi*	Cloncurry parrot		C		24/14
animals	birds	Psittacidae	*Aprosmictus erythropterus*	red-winged parrot		C		59/3
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus maculatus*	spotted bowerbird		C		64
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus nuchalis*	great bowerbird		C		8
animals	birds	Rallidae	*Porphyrio porphyrio*	purple swamphen		C		2
animals	birds	Rallidae	*Tribonyx ventralis*	black-tailed native-hen		C		1
animals	birds	Rallidae	*Gallinula tenebrosa*	dusky moorhen		C		11
animals	birds	Rallidae	*Fulica atra*	Eurasian coot		C		18
animals	birds	Recurvirostridae	*Himantopus himantopus*	black-winged stilt		C		52
animals	birds	Recurvirostridae	*Recurvirostra novaehollandiae*	red-necked avocet		C		2
animals	birds	Rhipiduridae	*Rhipidura leucophrys*	willie wagtail		C		149
animals	birds	Rhipiduridae	*Rhipidura albiscapa*	grey fantail		C		4
animals	birds	Scolopacidae	*Tringa nebularia*	common greenshank		SL		1
animals	birds	Scolopacidae	*Tringa stagnatilis*	marsh sandpiper		SL		1
animals	birds	Strigidae	*Ninox boobook*	southern boobook		C		6
animals	birds	Threskiornithidae	*Platalea regia*	royal spoonbill		C		5
animals	birds	Threskiornithidae	*Threskiornis molucca*	Australian white ibis		C		15
animals	birds	Threskiornithidae	*Platalea flavipes*	yellow-billed spoonbill		C		1
animals	birds	Threskiornithidae	*Threskiornis spinicollis*	straw-necked ibis		C		33
animals	birds	Threskiornithidae	*Plegadis falcinellus*	glossy ibis		SL		6
animals	birds	Turnicidae	*Turnix velox*	little button-quail		C		2
animals	insects	Lycaenidae	*Theclinesthes miskini miskini*	wattle blue (Australian subspecies)				1
animals	insects	Nymphalidae	*Euploea core corinna*	common crow				1
animals	insects	Nymphalidae	*Junonia villida calybe*	meadow argus				1
animals	insects	Nymphalidae	*Hypolimnas bolina nerina*	varied eggfly				1
animals	insects	Papilionidae	*Papilio aegeus aegeus*	orchard swallowtail (Australian subspecies)				1
animals	insects	Papilionidae	*Papilio demoleus sthenelus*	chequered swallowtail				1
animals	malacostracans	Parastacidae	*Cherax quadricarinatus*	redclaw				1
animals	mammals	Bovidae	*Bos sp.*	cattle	Y			1
animals	mammals	Emballonuridae	*Taphozous georgianus*	common sheathtail bat		C		1
animals	mammals	Emballonuridae	*Taphozous troughtoni*	Troughton's sheathtail bat		C		1/1
animals	mammals	Macropodidae	*Lagorchestes conspicillatus*	spectacled hare-wallaby		C		2
animals	mammals	Macropodidae	*Petrogale purpureicollis*	purple-necked rock-wallaby		V		9/1
animals	mammals	Macropodidae	*Macropus robustus*	common wallaroo		C		4
animals	mammals	Macropodidae	*Macropus rufus*	red kangaroo		C		1
animals	mammals	Macropodidae	*Macropus agilis*	agile wallaby		C		2
animals	mammals	Muridae	*Pseudomys johnsoni*			C		9
animals	mammals	Muridae	*Zyzomys argurus*	common rock-rat		C		3
animals	mammals	Pteropodidae	*Pteropus scapulatus*	little red flying-fox		C		1
animals	mammals	Tachyglossidae	*Tachyglossus aculeatus*	short-beaked echidna		SL		1
animals	mammals	Vespertilionidae	*Chalinolobus gouldii*	Gould's wattled bat		C		1
animals	mammals	Vespertilionidae	*Vespadelus finlaysoni*	Finlayson's cave bat		C		1/1
animals	ray-finned fishes	Ambassidae	*Ambassis macleayi*	Macleay's glassfish				14
animals	ray-finned fishes	Ambassidae	*Ambassis species*	northwest glassfish				27
animals	ray-finned fishes	Ambassidae	*Parambassis gulliveri*	giant glassfish				5

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	ray-finned fishes	Ambassidae	*Ambassis sp.*					31
animals	ray-finned fishes	Ariidae	*Neoarius leptaspis*	boofhead catfish				2
animals	ray-finned fishes	Centropomidae	*Lates calcarifer*	barramundi				23
animals	ray-finned fishes	Clupeidae	*Nematalosa erebi*	bony bream				706
animals	ray-finned fishes	Eleotridae	*Oxyeleotris selheimi*	blackbanded gudgeon				186
animals	ray-finned fishes	Eleotridae	*Oxyeleotris lineolata*	sleepy cod				22
animals	ray-finned fishes	Gobiidae	*Glossogobius aureus*	golden flathead goby				6
animals	ray-finned fishes	Gobiidae	*Glossogobius giuris*	tank goby				1
animals	ray-finned fishes	Melanotaeniidae	*Melanotaenia splendida inornata*	checkered rainbowfish				456
animals	ray-finned fishes	Plotosidae	*Anodontiglanis dahli*	toothless catfish				1
animals	ray-finned fishes	Terapontidae	*Leiopotherapon unicolor*	spangled perch				137
animals	ray-finned fishes	Terapontidae	*Hephaestus fuliginosus*	sooty grunter				21
animals	ray-finned fishes	Terapontidae	*Amniataba percoides*	barred grunter				202
animals	ray-finned fishes	Terapontidae	*Scortum ogilbyi*	Gulf grunter				1
animals	reptiles	Agamidae	*Ctenophorus caudicinctus*	ring-tailed dragon		C		1
animals	reptiles	Agamidae	*Pogona vitticeps*			C		3/1
animals	reptiles	Agamidae	*Amphibolurus gilberti*	Gilbert's dragon		C		3/2
animals	reptiles	Agamidae	*Tympanocryptis lineata*	lined earless dragon		C		1
animals	reptiles	Boidae	*Antaresia stimsoni*	Stimson's python		C		1
animals	reptiles	Boidae	*Aspidites melanocephalus*	black-headed python		C		1
animals	reptiles	Diplodactylidae	*Strophurus ciliaris*	spiny-tailed gecko		C		1/1
animals	reptiles	Elapidae	*Suta suta*	myall snake		C		1/1
animals	reptiles	Elapidae	*Pseudonaja nuchalis sensu lato*	western brown snake		C		1
animals	reptiles	Gekkonidae	*Heteronotia binoei*	Bynoe's gecko		C		2/1
animals	reptiles	Gekkonidae	*Gehyra versicolor*			C		2/2
animals	reptiles	Gekkonidae	*Gehyra robusta*			C		1
animals	reptiles	Pygopodidae	*Lialis burtonis*	Burton's legless lizard		C		2
animals	reptiles	Pygopodidae	*Delma nasuta*	sharp-snouted legless lizard		C		2
animals	reptiles	Pygopodidae	*Delma borea*			C		1
animals	reptiles	Pygopodidae	*Pygopus steelescotti*	northern hooded scaly-foot		C		1/1
animals	reptiles	Scincidae	*Cryptoblepharus plagiocephalus sensu lato*			C		1/1
animals	reptiles	Scincidae	*Tiliqua multifasciata*	Centralian blue-tongued lizard		C		3/2
animals	reptiles	Scincidae	*Tiliqua scincoides*	eastern blue-tongued lizard		C		1/1
animals	reptiles	Scincidae	*Ctenotus lateralis*			C		1
animals	reptiles	Scincidae	*Ctenotus hebetior*			C		1/1
animals	reptiles	Scincidae	*Egernia hosmeri*	Hosmer's skink		C		3/2
animals	reptiles	Varanidae	*Varanus mertensi*	Mertens' water monitor		C		1
animals	uncertain	Indeterminate	*Indeterminate*	Unknown or Code Pending		C		1
fungi	club fungi	Basidiomycota	*Polyporus*			C		1/1
fungi	sac fungi	Physciaceae	*Dirinaria confluens*			C		1/1
plants	ferns	Adiantaceae	*Cheilanthes brownii*			C		1/1
plants	ferns	Adiantaceae	*Cheilanthes nudiuscula*			C		1/1
plants	ferns	Adiantaceae	*Cheilanthes sieberi subsp. pseudovellea*			C		1/1
plants	ferns	Salviniaceae	*Salvinia molesta*	salvinia	Y			1/1
plants	higher dicots	Aizoaceae	*Trianthema triquetra*	red spinach		C		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera denticulata*	lesser joyweed		C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Amaranthaceae	*Aerva javanica*		Y			9/9
plants	higher dicots	Amaranthaceae	*Gomphrena arida*			C		2/2
plants	higher dicots	Amaranthaceae	*Gomphrena lanata*			C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus incanus*			C		2/2
plants	higher dicots	Amaranthaceae	*Ptilotus obovatus*			C		2/2
plants	higher dicots	Amaranthaceae	*Ptilotus spicatus*			C		1/1
plants	higher dicots	Amaranthaceae	*Achyranthes aspera*			C		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera nana*	hairy joyweed		C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus leucocoma*			C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus fusiformis*			C		2/2
plants	higher dicots	Amaranthaceae	*Ptilotus schwartzii*			C		1/1
plants	higher dicots	Amaranthaceae	*Amaranthus undulatus*			C		2/2
plants	higher dicots	Amaranthaceae	*Ptilotus maconochiei*			NT		1/1
plants	higher dicots	Amaranthaceae	*Gomphrena celosioides*	gomphrena weed	Y			1/1
plants	higher dicots	Amaranthaceae	*Ptilotus sessilifolius*			C		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera angustifolia*			C		1/1
plants	higher dicots	Apocynaceae	*Cryptostegia grandiflora*	rubber vine	Y			1/1
plants	higher dicots	Apocynaceae	*Sarcostemma brevipedicellatum*			C		1/1
plants	higher dicots	Apocynaceae	*Carissa lanceolata*			C		2/2
plants	higher dicots	Apocynaceae	*Calotropis procera*		Y			3/3
plants	higher dicots	Asteraceae	*Rhodanthe microglossa*	clustered sunray		C		1/1
plants	higher dicots	Asteraceae	*Streptoglossa bubakii*			C		1/1
plants	higher dicots	Asteraceae	*Acanthospermum hispidum*	star burr	Y			1/1
plants	higher dicots	Asteraceae	*Pterocaulon sphacelatum*	applebush		C		1/1
plants	higher dicots	Asteraceae	*Streptoglossa decurrens*			C		3/3
plants	higher dicots	Asteraceae	*Apowollastonia cylindrica*			C		1/1
plants	higher dicots	Asteraceae	*Blumea tenella*			C		1/1
plants	higher dicots	Asteraceae	*Pterocaulon serrulatum var. velutinum*			C		1/1
plants	higher dicots	Asteraceae	*Pterocaulon serrulatum var. serrulatum*			C		2/2
plants	higher dicots	Asteraceae	*Rutidosis helichrysoides subsp. acutiglumis*			C		1/1
plants	higher dicots	Asteraceae	*Peripleura obovata*			C		1/1
plants	higher dicots	Asteraceae	*Eclipta prostrata*	white eclipta		C		1/1
plants	higher dicots	Asteraceae	*Glossocardia*			C		1/1
plants	higher dicots	Asteraceae	*Pseudognaphalium luteoalbum*	Jersey cudweed		C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium haesum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium conocarpum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium styotrichum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium cunninghamii*			C		4/4
plants	higher dicots	Boraginaceae	*Trichodesma zeylanicum var. zeylanicum*			C		2/2
plants	higher dicots	Boraginaceae	*Heliotropium ballii*			C		2/2
plants	higher dicots	Byttneriaceae	*Melochia pyramidata*		Y			1/1
plants	higher dicots	Cactaceae	*Cylindropuntia fulgida var. mamillata*		Y			1/1
plants	higher dicots	Caesalpiniaceae	*Lysiphyllum cunninghamii*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Petalostylis cassioides*			C		4/4
plants	higher dicots	Caesalpiniaceae	*Senna planitiicola*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna notabilis*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Caesalpiniaceae	*Senna venusta*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna glutinosa subsp. pruinosa*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna artemisioides subsp. helmsii*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna artemisioides subsp. sturtii*			C		1/1
plants	higher dicots	Campanulaceae	*Lobelia arnhemiaca*			C		1/1
plants	higher dicots	Caryophyllaceae	*Polycarpaea breviflora*			C		1/1
plants	higher dicots	Caryophyllaceae	*Polycarpaea spirostylis subsp. glabra*			C		2/2
plants	higher dicots	Chenopodiaceae	*Salsola australis*			C		1/1
plants	higher dicots	Chenopodiaceae	*Einadia nutans*			C		2/2
plants	higher dicots	Chenopodiaceae	*Dysphania rhadinostachya subsp. rhadinostachya*			C		2/2
plants	higher dicots	Cleomaceae	*Cleome viscosa*	tick-weed		C		2/2
plants	higher dicots	Combretaceae	*Terminalia aridicola subsp. aridicola*			C		1/1
plants	higher dicots	Convolvulaceae	*Ipomoea muelleri*	poison morning-glory		C		2/2
plants	higher dicots	Convolvulaceae	*Ipomoea coptica*			C		1/1
plants	higher dicots	Convolvulaceae	*Polymeria longifolia*	polymeria		C		1/1
plants	higher dicots	Convolvulaceae	*Operculina aequisepala*			C		2/2
plants	higher dicots	Convolvulaceae	*Bonamia media var. media*			C		1/1
plants	higher dicots	Convolvulaceae	*Evolvulus alsinoides var. decumbens*			C		1/1
plants	higher dicots	Convolvulaceae	*Ipomoea nil*		Y			1/1
plants	higher dicots	Convolvulaceae	*Bonamia media*			C		1/1
plants	higher dicots	Cucurbitaceae	*Momordica balsamina*	balsam apple	Y			3/3
plants	higher dicots	Ebenaceae	*Diospyros humilis*	small-leaved ebony		C		1/1
plants	higher dicots	Elatinaceae	*Bergia trimera*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia tannensis subsp. eremophila*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia biconvexa*			C		1/1
plants	higher dicots	Euphorbiaceae	*Jatropha gossypiifolia*	bellyache bush	Y			2/2
plants	higher dicots	Euphorbiaceae	*Euphorbia australis var. subtomentosa*			C		2/2
plants	higher dicots	Fabaceae	*Indigofera hirsuta*	hairy indigo		C		1/1
plants	higher dicots	Fabaceae	*Cullen pustulatum*			C		1/1
plants	higher dicots	Fabaceae	*Cullen balsamicum*			C		5/5
plants	higher dicots	Fabaceae	*Cajanus pubescens*			C		2/2
plants	higher dicots	Fabaceae	*Vigna lanceolata*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia virens*			C		1/1
plants	higher dicots	Fabaceae	*Swainsona burkei*			C		2/2
plants	higher dicots	Fabaceae	*Glycine falcata*			C		2/2
plants	higher dicots	Fabaceae	*Indigofera linnaei*	Birdsville indigo		C		2/2
plants	higher dicots	Fabaceae	*Cajanus acutifolius*			C		2/2
plants	higher dicots	Fabaceae	*Cajanus lanuginosus*			C		3/3
plants	higher dicots	Fabaceae	*Alysicarpus muelleri*			C		1/1
plants	higher dicots	Fabaceae	*Crotalaria verrucosa*			C		1/1
plants	higher dicots	Fabaceae	*Indigofera pratensis*			C		4/4
plants	higher dicots	Fabaceae	*Galactia*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia lasiochlaena*			C		1/1
plants	higher dicots	Fabaceae	*Crotalaria novae-hollandiae subsp. novae-hollandiae*			C		2/2
plants	higher dicots	Fabaceae	*Tephrosia sp. (Musselbrook M.B.Thomas+ MRS472)*			C		3/3
plants	higher dicots	Fabaceae	*Tephrosia sp. (Adels Grove A.de Lestang 359)*			C		2/2

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Fabaceae	*Tephrosia sp. (Magazine Hill P.Jones 365)*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia brachyodon var. longifolia*			C		4/4
plants	higher dicots	Fabaceae	*Crotalaria aridicola subsp. glabrata*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia rosea var. rosea*			C		1/1
plants	higher dicots	Fabaceae	*Rhynchosia minima var. australis*			C		1/1
plants	higher dicots	Fabaceae	*Vigna lanceolata var. lanceolata*			C		4/4
plants	higher dicots	Goodeniaceae	*Scaevola*			C		3/3
plants	higher dicots	Goodeniaceae	*Goodenia grandiflora*			C		1/1
plants	higher dicots	Goodeniaceae	*Goodenia fascicularis*			C		1/1
plants	higher dicots	Haloragaceae	*Myriophyllum verrucosum*	water milfoil		C		2/1
plants	higher dicots	Lamiaceae	*Clerodendrum floribundum*			C		1/1
plants	higher dicots	Lamiaceae	*Vitex benthamiana*			C		11/11
plants	higher dicots	Lamiaceae	*Mesosphaerum suaveolens*		Y			1/1
plants	higher dicots	Loranthaceae	*Lysiana subfalcata*			C		1/1
plants	higher dicots	Loranthaceae	*Decaisnina brittenii subsp. brittenii*			C		1/1
plants	higher dicots	Loranthaceae	*Lysiana spathulata subsp. spathulata*			C		3/3
plants	higher dicots	Loranthaceae	*Lysiana spathulata subsp. parvifolia*			C		1/1
plants	higher dicots	Loranthaceae	*Amyema sanguinea var. sanguinea*			C		1/1
plants	higher dicots	Lythraceae	*Ammannia multiflora*	jerry-jerry		C		2/1
plants	higher dicots	Malvaceae	*Abelmoschus ficulneus*	native rosella		C		1/1
plants	higher dicots	Malvaceae	*Hibiscus brachychlaenus*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus sturtii var. campylochlamys*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus meraukensis*	Merauke hibiscus		C		2/2
plants	higher dicots	Malvaceae	*Gossypium nelsonii*			C		1/1
plants	higher dicots	Malvaceae	*Gossypium australe*			C		2/2
plants	higher dicots	Malvaceae	*Hibiscus coatesii*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon hannii*			C		2/2
plants	higher dicots	Malvaceae	*Sida fibulifera*			C		3/3
plants	higher dicots	Malvaceae	*Sida goniocarpa*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia hemsleyi*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia tropica*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia acradenia*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia monticola*			C		2/2
plants	higher dicots	Mimosaceae	*Prosopis pallida*		Y			1/1
plants	higher dicots	Mimosaceae	*Acacia chisholmii*			C		9/9
plants	higher dicots	Mimosaceae	*Acacia melleodora*			C		5/5
plants	higher dicots	Mimosaceae	*Acacia orthocarpa*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia tenuissima*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia phlebocarpa*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia chippendalei*			C		1/1
plants	higher dicots	Mimosaceae	*Vachellia bidwillii*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia ancistrocarpa*			C		2/2
plants	higher dicots	Mimosaceae	*Neptunia dimorphantha*			C		1/1
plants	higher dicots	Mimosaceae	*Vachellia sutherlandii*			C		1/1
plants	higher dicots	Mimosaceae	*Neptunia gracilis forma gracilis*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia retivenea subsp. retivenea*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Mimosaceae	*Acacia victoriae subsp. fasciaria*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia limbata*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia salicina*	doolan		C		1/1
plants	higher dicots	Moraceae	*Ficus rubiginosa forma rubiginosa*			C		1/1
plants	higher dicots	Moraceae	*Ficus aculeata var. aculeata*			C		1/1
plants	higher dicots	Myrtaceae	*Lophostemon grandiflorus subsp. riparius*			C		2/2
plants	higher dicots	Myrtaceae	*Eucalyptus melanophloia subsp. nana*			C		2/2
plants	higher dicots	Myrtaceae	*Corymbia bella*			C		2/2
plants	higher dicots	Myrtaceae	*Corymbia aspera*			C		2/2
plants	higher dicots	Myrtaceae	*Melaleuca nervosa*			C		1/1
plants	higher dicots	Myrtaceae	*Corymbia terminalis*			C		3/3
plants	higher dicots	Myrtaceae	*Melaleuca bracteata*			C		3/2
plants	higher dicots	Myrtaceae	*Eucalyptus nudicaulis*			C		3/3
plants	higher dicots	Myrtaceae	*Melaleuca fluviatilis*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus leucophylla*			C		5/5
plants	higher dicots	Myrtaceae	*Melaleuca dissitiflora*			C		2/2
plants	higher dicots	Myrtaceae	*Melaleuca trichostachya*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus camaldulensis*			C		1
plants	higher dicots	Myrtaceae	*Lophostemon grandiflorus*			C		1
plants	higher dicots	Myrtaceae	*Eucalyptus pruinosa subsp. pruinosa*			C		1/1
plants	higher dicots	Nyctaginaceae	*Boerhavia schomburgkiana*			C		1/1
plants	higher dicots	Nyctaginaceae	*Boerhavia pubescens*			C		2/2
plants	higher dicots	Nyctaginaceae	*Boerhavia sp. (St George A.Hill AQ399299)*			C		1/1
plants	higher dicots	Pedaliaceae	*Josephinia eugeniae*	josephinia burr		C		1/1
plants	higher dicots	Pentapetaceae	*Melhania ovata*			C		1/1
plants	higher dicots	Phyllanthaceae	*Phyllanthus fuernrohrii*			C		1/1
plants	higher dicots	Phyllanthaceae	*Breynia oblongifolia*			C		1/1
plants	higher dicots	Phyllanthaceae	*Phyllanthus carpentariae*			C		1/1
plants	higher dicots	Phyllanthaceae	*Phyllanthus maderaspatensis*			C		1/1
plants	higher dicots	Plantaginaceae	*Stemodia viscosa*			C		3/3
plants	higher dicots	Polygonaceae	*Persicaria barbata*			C		2/1
plants	higher dicots	Portulacaceae	*Portulaca oligosperma*			C		1/1
plants	higher dicots	Portulacaceae	*Portulaca oleracea*	pigweed	Y			1/1
plants	higher dicots	Proteaceae	*Grevillea mimosoides*			C		1/1
plants	higher dicots	Proteaceae	*Hakea arborescens*			C		2/2
plants	higher dicots	Proteaceae	*Hakea lorea subsp. lorea*			C		4/4
plants	higher dicots	Rhamnaceae	*Alphitonia excelsa*	soap tree		C		1/1
plants	higher dicots	Rubiaceae	*Pavetta rupicola*			C		2/2
plants	higher dicots	Rubiaceae	*Kohautia australiensis*			C		1/1
plants	higher dicots	Rubiaceae	*Spermacoce auriculata*			C		1/1
plants	higher dicots	Santalaceae	*Santalum lanceolatum*			C		2/2
plants	higher dicots	Sapindaceae	*Dodonaea lanceolata var. lanceolata*			C		1/1
plants	higher dicots	Sapindaceae	*Dodonaea viscosa subsp. mucronata*			C		1/1
plants	higher dicots	Sapindaceae	*Dodonaea stenophylla*			C		1/1
plants	higher dicots	Scrophulariaceae	*Eremophila longifolia*	berrigan		C		1/1
plants	higher dicots	Scrophulariaceae	*Eremophila oppositifolia subsp. rubra*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Scrophulariaceae	*Eremophila latrobei subsp. latrobei*			C		3/3
plants	higher dicots	Solanaceae	*Solanum succosum*			C		2/2
plants	higher dicots	Solanaceae	*Solanum quadriloculatum*			C		4/4
plants	higher dicots	Solanaceae	*Solanum echinatum*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Triumfetta rupestris*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Corchorus pumilio*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Corchorus sericeus subsp. densiflorus*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Triumfetta marsupiata*			C		2/2
plants	higher dicots	Sterculiaceae	*Brachychiton collinus*			C		2/2
plants	higher dicots	Ulmaceae	*Trema tomentosa var. tomentosa*			C		1/1
plants	higher dicots	Ulmaceae	*Trema tomentosa*			C		1/1
plants	higher dicots	Verbenaceae	*Phyla nodiflora*	carpetweed		C		1/1
plants	higher dicots	Zygophyllaceae	*Tribulus cistoides*	bulls head vine		C		2/2
plants	higher dicots	Zygophyllaceae	*Tribulus terrestris*	caltrop		C		1/1
plants	higher dicots	Zygophyllaceae	*Tribulopis pentandra*			C		1/1
plants	lower dicots	Lauraceae	*Cassytha capillaris*			C		1/1
plants	monocots	Cyperaceae	*Cyperus brevifolius*	Mullumbimby couch	Y			1
plants	monocots	Cyperaceae	*Cyperus pulchellus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus vaginatus*			C		5/4
plants	monocots	Cyperaceae	*Cyperus difformis*	rice sedge		C		1/1
plants	monocots	Cyperaceae	*Cyperus rotundus*	nutgrass	Y			1/1
plants	monocots	Cyperaceae	*Cyperus iria*			C		1/1
plants	monocots	Cyperaceae	*Fimbristylis aestivalis*			C		1/1
plants	monocots	Najadaceae	*Najas tenuifolia*	water nymph		C		1/1
plants	monocots	Poaceae	*Themeda avenacea*			C		1/1
plants	monocots	Poaceae	*Themeda triandra*	kangaroo grass		C		2/2
plants	monocots	Poaceae	*Aristida pruinosa*			C		2/2
plants	monocots	Poaceae	*Digitaria brownii*			C		1/1
plants	monocots	Poaceae	*Mnesithea formosa*			C		1/1
plants	monocots	Poaceae	*Paspalidium rarum*			C		1/1
plants	monocots	Poaceae	*Triodia brizoides*			C		1/1
plants	monocots	Poaceae	*Triodia longiceps*	giant grey spinifex		C		1/1
plants	monocots	Poaceae	*Aristida latifolia*	feathertop wiregrass		C		1/1
plants	monocots	Poaceae	*Cenchrus setigerus*		Y			1/1
plants	monocots	Poaceae	*Chrysopogon fallax*			C		1/1
plants	monocots	Poaceae	*Echinochloa colona*	awnless barnyard grass	Y			2/1
plants	monocots	Poaceae	*Triodia mitchellii*	buck spinifex		C		1/1
plants	monocots	Poaceae	*Digitaria ctenantha*			C		2/2
plants	monocots	Poaceae	*Aristida longicollis*			C		2/2
plants	monocots	Poaceae	*Dichanthium fecundum*	curly bluegrass		C		4/4
plants	monocots	Poaceae	*Enneapogon asperatus*			C		3/3
plants	monocots	Poaceae	*Enneapogon nigricans*	niggerheads		C		1/1
plants	monocots	Poaceae	*Eragrostis basedowii*			C		1/1
plants	monocots	Poaceae	*Tripogon loliiformis*	five minute grass		C		1/1
plants	monocots	Poaceae	*Urochloa praetervisa*			C		1/1
plants	monocots	Poaceae	*Cymbopogon bombycinus*	silky oilgrass		C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	monocots	Poaceae	*Eragrostis leptocarpa*	drooping lovegrass		C		1/1
plants	monocots	Poaceae	*Heteropogon contortus*	black speargrass		C		2/2
plants	monocots	Poaceae	*Iseilema vaginiflorum*	red flinders grass		C		1/1
plants	monocots	Poaceae	*Bothriochloa ewartiana*	desert bluegrass		C		2/2
plants	monocots	Poaceae	*Enneapogon cylindricus*	jointed nineawn		C		1/1
plants	monocots	Poaceae	*Enneapogon eremophilus*			C		1/1
plants	monocots	Poaceae	*Enneapogon lindleyanus*			C		4/4
plants	monocots	Poaceae	*Enneapogon polyphyllus*	leafy nineawn		C		5/5
plants	monocots	Poaceae	*Paspalidium constrictum*			C		1/1
plants	monocots	Poaceae	*Pseudoraphis spinescens*	spiny mudgrass		C		1/1
plants	monocots	Poaceae	*Eriochloa pseudoacrotricha*			C		1/1
plants	monocots	Poaceae	*Urochloa gilesii var. gilesii*			C		1/1
plants	monocots	Poaceae	*Cynodon dactylon var. dactylon*		Y			1/1
plants	monocots	Poaceae	*Aristida holathera var. holathera*			C		1/1
plants	monocots	Poaceae	*Eriachne pulchella subsp. dominii*			C		1/1
plants	monocots	Poaceae	*Panicum decompositum var. tenuius*			C		1/1
plants	monocots	Poaceae	*Eriachne pulchella subsp. pulchella*			C		1/1
plants	monocots	Poaceae	*Eriachne mucronata forma (Alpha C.E.Hubbard 7882)*			C		2/2
plants	monocots	Poaceae	*Iseilema fragile*			C		1/1
plants	monocots	Poaceae	*Eragrostis olida*			C		1/1
plants	monocots	Poaceae	*Cynodon dactylon*		Y			1
plants	monocots	Poaceae	*Aristida exserta*			C		1/1
plants	monocots	Poaceae	*Triodia pungens*			C		3/3
plants	monocots	Poaceae	*Triodia molesta*			C		1/1
plants	monocots	Poaceae	*Sehima nervosum*			C		2/2
plants	monocots	Poaceae	*Eriachne obtusa*			C		1/1
plants	monocots	Poaceae	*Eulalia aurea*	silky browntop		C		2/2
plants	mosses	Bryophyte	*Bryophyte*			C		1/1

CODES

I - Y indicates that the taxon is introduced to Queensland and has naturalised.

Q - Indicates the Queensland conservation status of each taxon under the *Nature Conservation Act 1992.* The codes are Extinct in the Wild (PE), Endangered (E), Vulnerable (V), Near Threatened (NT), Least Concern (C) or Not Protected ( ).

A - Indicates the Australian conservation status of each taxon under the *Environment Protection and Biodiversity Conservation Act 1999.* The values of EPBC are Conservation Dependent (CD), Critically Endangered (CE), Endangered (E), Extinct (EX), Extinct in the Wild (XW) and Vulnerable (V).

Records – The first number indicates the total number of records of the taxon for the record option selected (i.e. All, Confirmed or Specimens).
This number is output as 99999 if it equals or exceeds this value. The second number located after the / indicates the number of specimen records for the taxon.
This number is output as 999 if it equals or exceeds this value.

Queensland Government

Wildlife Online Extract

Search Criteria:	Species List for a Defined Area
	Species: All
	Type: All
	Status: All
	Records: All
	Date: All
	Latitude: 19.7534 to 20.422
	Longitude: 139.8376 to 139.2124
	Email: hdick@aarc.net.au
	Date submitted: Tuesday 17 Jun 2014 16:59:23
	Date extracted: Tuesday 17 Jun 2014 17:00:15

The number of records retrieved = 475

Disclaimer

As the DSITIA is still in a process of collating and vetting data, it is possible the information given is not complete. The information provided should only be used for the project for which it was requested and it should be appropriately acknowledged as being derived from Wildlife Online when it is used.

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Feedback about Wildlife Online should be emailed to wildlife.online@science.dsitia.qld.gov.au

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	amphibians	Bufonidae	*Rhinella marina*	cane toad	Y			1/1
animals	amphibians	Myobatrachidae	*Uperoleia trachyderma*	orange shouldered gungan		C		1/1
animals	birds	Acanthizidae	*Smicrornis brevirostris*	weebill		C		89
animals	birds	Acanthizidae	*Acanthiza chrysorrhoa*	yellow-rumped thornbill		C		4
animals	birds	Acanthizidae	*Gerygone fusca*	western gerygone		C		1
animals	birds	Accipitridae	*Milvus migrans*	black kite		C		8
animals	birds	Accipitridae	*Accipiter cirrocephalus*	collared sparrowhawk		C		3
animals	birds	Accipitridae	*Accipiter novaehollandiae*	grey goshawk		NT		1
animals	birds	Accipitridae	*Aquila audax*	wedge-tailed eagle		C		8
animals	birds	Accipitridae	*Haliaeetus leucogaster*	white-bellied sea-eagle		SL		2
animals	birds	Accipitridae	*Accipiter fasciatus*	brown goshawk		C		2
animals	birds	Accipitridae	*Haliastur sphenurus*	whistling kite		C		20
animals	birds	Acrocephalidae	*Acrocephalus australis*	Australian reed-warbler		SL		2
animals	birds	Aegothelidae	*Aegotheles cristatus*	Australian owlet-nightjar		C		2
animals	birds	Alcedinidae	*Ceyx azureus*	azure kingfisher		C		3
animals	birds	Anatidae	*Malacorhynchus membranaceus*	pink-eared duck		C		1
animals	birds	Anatidae	*Nettapus coromandelianus*	cotton pygmy-goose		NT		1
animals	birds	Anatidae	*Nettapus pulchellus*	green pygmy-goose		C		2
animals	birds	Anatidae	*Dendrocygna arcuata*	wandering whistling-duck		C		1
animals	birds	Anatidae	*Dendrocygna eytoni*	plumed whistling-duck		C		2
animals	birds	Anatidae	*Chenonetta jubata*	Australian wood duck		C		4
animals	birds	Anatidae	*Anas superciliosa*	Pacific black duck		C		5
animals	birds	Anatidae	*Aythya australis*	hardhead		C		3
animals	birds	Anatidae	*Anas gracilis*	grey teal		C		2
animals	birds	Anatidae	*Cygnus atratus*	black swan		C		1
animals	birds	Anhingidae	*Anhinga novaehollandiae*	Australasian darter		C		13
animals	birds	Ardeidae	*Nycticorax caledonicus*	Nankeen night-heron		C		3
animals	birds	Ardeidae	*Ardea modesta*	eastern great egret		SL		4
animals	birds	Ardeidae	*Ardea pacifica*	white-necked heron		C		8
animals	birds	Ardeidae	*Ardea intermedia*	intermediate egret		C		5
animals	birds	Ardeidae	*Egretta garzetta*	little egret		C		1
animals	birds	Ardeidae	*Egretta novaehollandiae*	white-faced heron		C		4
animals	birds	Ardeidae	*Ixobrychus flavicollis*	black bittern		C		2
animals	birds	Artamidae	*Cracticus nigrogularis*	pied butcherbird		C		16
animals	birds	Artamidae	*Artamus minor*	little woodswallow		C		5
animals	birds	Artamidae	*Artamus cinereus*	black-faced woodswallow		C		33
animals	birds	Artamidae	*Cracticus tibicen*	Australian magpie		C		11
animals	birds	Artamidae	*Artamus leucorynchus*	white-breasted woodswallow		C		9
animals	birds	Cacatuidae	*Nymphicus hollandicus*	cockatiel		C		12
animals	birds	Cacatuidae	*Cacatua sanguinea*	little corella		C		5
animals	birds	Cacatuidae	*Cacatua galerita*	sulphur-crested cockatoo		C		12
animals	birds	Cacatuidae	*Eolophus roseicapillus*	galah		C		13
animals	birds	Campephagidae	*Coracina papuensis*	white-bellied cuckoo-shrike		C		4
animals	birds	Campephagidae	*Lalage sueurii*	white-winged triller		C		9
animals	birds	Campephagidae	*Coracina novaehollandiae*	black-faced cuckoo-shrike		C		16
animals	birds	Casuariidae	*Dromaius novaehollandiae*	emu		C		1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Charadriidae	*Vanellus miles miles*	masked lapwing (northern subspecies)		C		4
animals	birds	Charadriidae	*Vanellus miles*	masked lapwing		C		3
animals	birds	Charadriidae	*Elseyornis melanops*	black-fronted dotterel		C		14
animals	birds	Ciconiidae	*Ephippiorhynchus asiaticus*	black-necked stork		NT		5
animals	birds	Climacteridae	*Climacteris melanura*	black-tailed treecreeper		C		45
animals	birds	Columbidae	*Geopelia cuneata*	diamond dove		C		10
animals	birds	Columbidae	*Geophaps plumifera*	spinifex pigeon		C		7
animals	birds	Columbidae	*Geopelia humeralis*	bar-shouldered dove		C		1
animals	birds	Columbidae	*Phaps chalcoptera*	common bronzewing		C		12
animals	birds	Columbidae	*Ocyphaps lophotes*	crested pigeon		C		10
animals	birds	Columbidae	*Geopelia striata*	peaceful dove		C		32
animals	birds	Columbidae	*Columba livia*	rock dove	Y			1
animals	birds	Coraciidae	*Eurystomus orientalis*	dollarbird		C		4
animals	birds	Corcoracidae	*Struthidea cinerea*	apostlebird		C		6
animals	birds	Corvidae	*Corvus sp.*					1
animals	birds	Corvidae	*Corvus bennetti*	little crow		C		1
animals	birds	Corvidae	*Corvus coronoides*	Australian raven		C		39
animals	birds	Corvidae	*Corvus orru*	Torresian crow		C		2
animals	birds	Cuculidae	*Cacomantis pallidus*	pallid cuckoo		C		1
animals	birds	Cuculidae	*Chalcites basalis*	Horsfield's bronze-cuckoo		C		3
animals	birds	Cuculidae	*Scythrops novaehollandiae*	channel-billed cuckoo		C		1
animals	birds	Cuculidae	*Centropus phasianinus*	pheasant coucal		C		1
animals	birds	Cuculidae	*Eudynamys orientalis*	eastern koel		C		2
animals	birds	Estrildidae	*Taeniopygia guttata*	zebra finch		C		19
animals	birds	Estrildidae	*Emblema pictum*	painted finch		C		2
animals	birds	Estrildidae	*Neochmia ruficauda*	star finch		C		1
animals	birds	Estrildidae	*Poephila acuticauda*	long-tailed finch		C		10
animals	birds	Estrildidae	*Lonchura castaneothorax*	chestnut-breasted mannikin		C		1
animals	birds	Estrildidae	*Heteromunia pectoralis*	pictorella mannikin		NT		4
animals	birds	Estrildidae	*Poephila cincta cincta*	black-throated finch (white-rumped subspecies)		E	E	1
animals	birds	Estrildidae	*Taeniopygia bichenovii*	double-barred finch		C		24
animals	birds	Eurostopodidae	*Eurostopodus argus*	spotted nightjar		C		2
animals	birds	Falconidae	*Falco berigora*	brown falcon		C		4
animals	birds	Falconidae	*Falco longipennis*	Australian hobby		C		2
animals	birds	Falconidae	*Falco cenchroides*	Nankeen kestrel		C		2
animals	birds	Gruidae	*Grus rubicunda*	brolga		C		2
animals	birds	Halcyonidae	*Todiramphus pyrrhopygius*	red-backed kingfisher		C		4
animals	birds	Halcyonidae	*Todiramphus sanctus*	sacred kingfisher		C		5
animals	birds	Halcyonidae	*Dacelo leachii*	blue-winged kookaburra		C		11
animals	birds	Hirundinidae	*Petrochelidon nigricans*	tree martin		C		1
animals	birds	Hirundinidae	*Petrochelidon ariel*	fairy martin		C		5
animals	birds	Jacanidae	*Irediparra gallinacea*	comb-crested jacana		C		4
animals	birds	Laridae	*Gelochelidon nilotica*	gull-billed tern		C		1
animals	birds	Laridae	*Hydroprogne caspia*	Caspian tern		SL		1
animals	birds	Maluridae	*Malurus melanocephalus*	red-backed fairy-wren		C		8

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Maluridae	*Amytornis dorotheae*	Carpentarian grasswren		NT		2
animals	birds	Maluridae	*Malurus lamberti*	variegated fairy-wren		C		38
animals	birds	Maluridae	*Amytornis ballarae*	Kalkadoon grasswren		C		19
animals	birds	Megaluridae	*Cincloramphus mathewsi*	rufous songlark		C		4
animals	birds	Megaluridae	*Eremiornis carteri*	spinifexbird		C		7
animals	birds	Meliphagidae	*Philemon citreogularis*	little friarbird		C		17
animals	birds	Meliphagidae	*Certhionyx variegatus*	pied honeyeater		C		1
animals	birds	Meliphagidae	*Acanthagenys rufogularis*	spiny-cheeked honeyeater		C		2
animals	birds	Meliphagidae	*Ptilotula penicillatus*	white-plumed honeyeater		C		27
animals	birds	Meliphagidae	*Conopophila rufogularis*	rufous-throated honeyeater		C		10
animals	birds	Meliphagidae	*Cissomela pectoralis*	banded honeyeater		C		1
animals	birds	Meliphagidae	*Ptilotula flavescens*	yellow-tinted honeyeater		C		11
animals	birds	Meliphagidae	*Philemon argenticeps*	silver-crowned friarbird		C		9
animals	birds	Meliphagidae	*Lichmera indistincta*	brown honeyeater		C		15
animals	birds	Meliphagidae	*Melithreptus gularis*	black-chinned honeyeater		NT		5
animals	birds	Meliphagidae	*Manorina flavigula*	yellow-throated miner		C		29
animals	birds	Meliphagidae	*Ptilotula plumulus*	grey-fronted honeyeater		C		78
animals	birds	Meliphagidae	*Gavicalis virescens*	singing honeyeater		C		15
animals	birds	Meliphagidae	*Stomiopera unicolor*	white-gaped honeyeater		C		6
animals	birds	Meliphagidae	*Ptilotula keartlandi*	grey-headed honeyeater		C		21
animals	birds	Meropidae	*Merops ornatus*	rainbow bee-eater		SL		23
animals	birds	Monarchidae	*Myiagra inquieta*	restless flycatcher		C		19
animals	birds	Monarchidae	*Grallina cyanoleuca*	magpie-lark		C		37
animals	birds	Motacillidae	*Anthus novaeseelandiae*	Australasian pipit		C		2
animals	birds	Nectariniidae	*Dicaeum hirundinaceum*	mistletoebird		C		12
animals	birds	Neosittidae	*Daphoenositta chrysoptera*	varied sittella		C		3
animals	birds	Oriolidae	*Oriolus sagittatus*	olive-backed oriole		C		7
animals	birds	Otididae	*Ardeotis australis*	Australian bustard		C		1
animals	birds	Pachycephalidae	*Colluricincla harmonica*	grey shrike-thrush		C		22
animals	birds	Pachycephalidae	*Oreoica gutturalis*	crested bellbird		C		3
animals	birds	Pachycephalidae	*Pachycephala rufiventris*	rufous whistler		C		25
animals	birds	Pardalotidae	*Pardalotus rubricatus*	red-browed pardalote		C		9
animals	birds	Pardalotidae	*Pardalotus striatus*	striated pardalote		C		27
animals	birds	Passeridae	*Passer domesticus*	house sparrow	Y			2
animals	birds	Pelecanidae	*Pelecanus conspicillatus*	Australian pelican		C		6
animals	birds	Petroicidae	*Melanodryas cucullata*	hooded robin		C		2
animals	birds	Petroicidae	*Microeca fascinans*	jacky winter		C		12
animals	birds	Phalacrocoracidae	*Phalacrocorax carbo*	great cormorant		C		1
animals	birds	Phalacrocoracidae	*Phalacrocorax sulcirostris*	little black cormorant		C		7
animals	birds	Phalacrocoracidae	*Microcarbo melanoleucos*	little pied cormorant		C		7
animals	birds	Phalacrocoracidae	*Phalacrocorax varius*	pied cormorant		C		1
animals	birds	Phasianidae	*Coturnix ypsilophora*	brown quail		C		4
animals	birds	Podargidae	*Podargus strigoides*	tawny frogmouth		C		2
animals	birds	Podicipedidae	*Tachybaptus novaehollandiae*	Australasian grebe		C		4
animals	birds	Pomatostomidae	*Pomatostomus temporalis*	grey-crowned babbler		C		29
animals	birds	Psittacidae	*Melopsittacus undulatus*	budgerigar		C		8

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Psittacidae	*Barnardius zonarius*	Australian ringneck		C		8
animals	birds	Psittacidae	*Psitteuteles versicolor*	varied lorikeet		C		11
animals	birds	Psittacidae	*Trichoglossus haematodus moluccanus*	rainbow lorikeet		C		1
animals	birds	Psittacidae	*Aprosmictus erythropterus*	red-winged parrot		C		20
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus nuchalis*	great bowerbird		C		5
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus maculatus*	spotted bowerbird		C		8
animals	birds	Rallidae	*Fulica atra*	Eurasian coot		C		1
animals	birds	Rallidae	*Porzana pusilla*	Baillon's crake		C		1
animals	birds	Rallidae	*Gallinula tenebrosa*	dusky moorhen		C		1
animals	birds	Recurvirostridae	*Himantopus himantopus*	black-winged stilt		C		2
animals	birds	Rhipiduridae	*Rhipidura leucophrys*	willie wagtail		C		42
animals	birds	Rhipiduridae	*Rhipidura albiscapa*	grey fantail		C		1
animals	birds	Scolopacidae	*Tringa glareola*	wood sandpiper		SL		1
animals	birds	Strigidae	*Ninox connivens*	barking owl		C		1
animals	birds	Threskiornithidae	*Platalea regia*	royal spoonbill		C		3
animals	birds	Threskiornithidae	*Threskiornis spinicollis*	straw-necked ibis		C		4
animals	birds	Threskiornithidae	*Plegadis falcinellus*	glossy ibis		SL		1
animals	mammals	Canidae	*Canis lupus dingo*	dingo				1
animals	mammals	Macropodidae	*Macropus rufus*	red kangaroo		C		3
animals	mammals	Macropodidae	*Lagorchestes conspicillatus*	spectacled hare-wallaby		C		3
animals	mammals	Vespertilionidae	*Chalinolobus gouldii*	Gould's wattled bat		C		9/9
animals	ray-finned fishes	Ambassidae	*Ambassis species*	northwest glassfish				56
animals	ray-finned fishes	Ambassidae	*Ambassis macleayi*	Macleay's glassfish				250
animals	ray-finned fishes	Apogonidae	*Glossamia aprion*	mouth almighty				52
animals	ray-finned fishes	Ariidae	*Neoarius graeffei*	blue catfish				27
animals	ray-finned fishes	Belonidae	*Strongylura krefftii*	freshwater longtom				68
animals	ray-finned fishes	Centropomidae	*Lates calcarifer*	barramundi				8
animals	ray-finned fishes	Clupeidae	*Nematalosa erebi*	bony bream				351
animals	ray-finned fishes	Eleotridae	*Oxyeleotris selheimi*	blackbanded gudgeon				31
animals	ray-finned fishes	Eleotridae	*Oxyeleotris lineolata*	sleepy cod				97
animals	ray-finned fishes	Gobiidae	*Glossogobius aureus*	golden flathead goby				2
animals	ray-finned fishes	Melanotaeniidae	*Melanotaenia splendida inornata*	checkered rainbowfish				86
animals	ray-finned fishes	Terapontidae	*Hephaestus fuliginosus*	sooty grunter				29
animals	ray-finned fishes	Terapontidae	*Leiopotherapon unicolor*	spangled perch				10
animals	ray-finned fishes	Terapontidae	*Amniataba percoides*	barred grunter				178
animals	ray-finned fishes	Toxotidae	*Toxotes chatareus*	sevenspot archerfish				34
animals	reptiles	Agamidae	*Amphibolurus gilberti*	Gilbert's dragon		C		2/2
animals	reptiles	Agamidae	*Ctenophorus caudicinctus*	ring-tailed dragon		C		1/1
animals	reptiles	Crocodylidae	*Crocodylus johnstoni*	Australian freshwater crocodile		C		1
animals	reptiles	Elapidae	*Demansia flagellatio*			C		1
animals	reptiles	Elapidae	*Suta suta*	myall snake		C		1
animals	reptiles	Gekkonidae	*Gehyra robusta*			C		1/1
animals	reptiles	Scincidae	*Ctenotus pulchellus*			C		3/3
animals	reptiles	Scincidae	*Ctenotus striaticeps*			C		2/2
animals	reptiles	Scincidae	*Ctenotus lateralis*			C		1/1
plants	ferns	Adiantaceae	*Cheilanthes brownii*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Acanthaceae	*Nelsonia campestris*			C		2/2
plants	higher dicots	Amaranthaceae	*Ptilotus fusiformis*			C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus schwartzii*			C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus maconochiei*			NT		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera pungens*	khaki weed	Y			1/1
plants	higher dicots	Amaranthaceae	*Alternanthera sp. (Mt Isa R.L.Specht+ 49)*			C		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera angustifolia*			C		1/1
plants	higher dicots	Amaranthaceae	*Amaranthus interruptus*			C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus spicatus*			C		1/1
plants	higher dicots	Amaranthaceae	*Gomphrena lanata*			C		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera denticulata*	lesser joyweed		C		1/1
plants	higher dicots	Amaranthaceae	*Amaranthus cochleitepalus*			C		1/1
plants	higher dicots	Apocynaceae	*Marsdenia viridiflora subsp. tropica*			C		1/1
plants	higher dicots	Apocynaceae	*Sarcostemma brevipedicellatum*			C		1/1
plants	higher dicots	Apocynaceae	*Carissa lanceolata*			C		1/1
plants	higher dicots	Asteraceae	*Pterocaulon serrulatum var. velutinum*			C		2/2
plants	higher dicots	Asteraceae	*Centipeda minima subsp. minima*			C		1/1
plants	higher dicots	Asteraceae	*Streptoglossa decurrens*			C		1/1
plants	higher dicots	Asteraceae	*Pterocaulon ciliosum*			C		2/2
plants	higher dicots	Asteraceae	*Tridax procumbens*	tridax daisy	Y			1/1
plants	higher dicots	Asteraceae	*Bidens bipinnata*	bipinnate beggar's ticks	Y			2/2
plants	higher dicots	Asteraceae	*Blumea saxatilis*			C		1/1
plants	higher dicots	Boraginaceae	*Trichodesma zeylanicum var. latisepalum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium cunninghamii*			C		2/2
plants	higher dicots	Boraginaceae	*Heliotropium tenuifolium*			C		3/3
plants	higher dicots	Boraginaceae	*Heliotropium tanythrix*			C		2/2
plants	higher dicots	Boraginaceae	*Heliotropium haesum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium ballii*			C		1/1
plants	higher dicots	Byttneriaceae	*Waltheria indica*			C		1/1
plants	higher dicots	Byttneriaceae	*Melochia pyramidata*		Y			1/1
plants	higher dicots	Caesalpiniaceae	*Senna glutinosa subsp. glutinosa*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna notabilis*			C		3/3
plants	higher dicots	Caesalpiniaceae	*Senna venusta*			C		1/1
plants	higher dicots	Caryophyllaceae	*Polycarpaea corymbosa var. corymbosa*			C		2/2
plants	higher dicots	Chenopodiaceae	*Maireana villosa*			C		1/1
plants	higher dicots	Cleomaceae	*Cleome cleomoides*			C		1/1
plants	higher dicots	Cleomaceae	*Cleome viscosa*	tick-weed		C		1/1
plants	higher dicots	Combretaceae	*Terminalia canescens*			C		1/1
plants	higher dicots	Convolvulaceae	*Ipomoea polymorpha*			C		1/1
plants	higher dicots	Convolvulaceae	*Jacquemontia sp. (Fairview R.W.Johnson 4026)*			C		1/1
plants	higher dicots	Convolvulaceae	*Bonamia sp. (Musselbrook M.B.Thomas+ MRS639)*			C		1/1
plants	higher dicots	Convolvulaceae	*Jacquemontia paniculata var. tomentosa*			C		1/1
plants	higher dicots	Convolvulaceae	*Evolvulus alsinoides var. villosicalyx*			C		1/1
plants	higher dicots	Convolvulaceae	*Evolvulus alsinoides var. decumbens*			C		1/1
plants	higher dicots	Convolvulaceae	*Ipomoea antonschmidii*			NT		6/6
plants	higher dicots	Convolvulaceae	*Ipomoea lonchophylla*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Convolvulaceae	*Ipomoea muelleri*	poison morning-glory		C		2/2
plants	higher dicots	Convolvulaceae	*Ipomoea costata*			C		1/1
plants	higher dicots	Convolvulaceae	*Bonamia media*			C		3/3
plants	higher dicots	Cucurbitaceae	*Citrullus lanatus*		Y			1/1
plants	higher dicots	Cucurbitaceae	*Momordica balsamina*	balsam apple	Y			2/2
plants	higher dicots	Euphorbiaceae	*Microstachys chamaelea*			C		2/2
plants	higher dicots	Euphorbiaceae	*Euphorbia hassallii*			C		2/2
plants	higher dicots	Euphorbiaceae	*Euphorbia australis var. subtomentosa*			C		3/3
plants	higher dicots	Euphorbiaceae	*Euphorbia papillata var. papillata*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia trigonosperma*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia hirta*		Y			2/2
plants	higher dicots	Euphorbiaceae	*Euphorbia coghlanii*			C		2/2
plants	higher dicots	Euphorbiaceae	*Ricinus communis*	castor oil bush	Y			1/1
plants	higher dicots	Fabaceae	*Tephrosia sp. (Magazine Hill P.Jones 365)*			C		2/2
plants	higher dicots	Fabaceae	*Tephrosia phaeosperma var. (Westmoreland S.Melville 967)*			C		3/3
plants	higher dicots	Fabaceae	*Cullen cinereum*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia virens*			C		3/3
plants	higher dicots	Fabaceae	*Rhynchosia minima*			C		1/1
plants	higher dicots	Fabaceae	*Desmodium muelleri*			C		1/1
plants	higher dicots	Fabaceae	*Indigofera colutea*	sticky indigo		C		1/1
plants	higher dicots	Fabaceae	*Indigofera hirsuta*	hairy indigo		C		1/1
plants	higher dicots	Fabaceae	*Indigofera linnaei*	Birdsville indigo		C		1/1
plants	higher dicots	Fabaceae	*Aeschynomene indica*	budda pea		C		2/2
plants	higher dicots	Fabaceae	*Galactia tenuiflora*			C		1/1
plants	higher dicots	Fabaceae	*Alysicarpus muelleri*			C		1/1
plants	higher dicots	Fabaceae	*Crotalaria verrucosa*			C		3/3
plants	higher dicots	Fabaceae	*Indigofera brevidens*			C		1/1
plants	higher dicots	Fabaceae	*Indigofera linifolia*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia delestangii*			C		4/4
plants	higher dicots	Fabaceae	*Tephrosia remotiflora*			C		1/1
plants	higher dicots	Fabaceae	*Aphyllodium biarticulatum*			C		1/1
plants	higher dicots	Fabaceae	*Galactia tenuiflora var. lucida*			C		1/1
plants	higher dicots	Fabaceae	*Galactia tenuiflora forma sericea*			C		1/1
plants	higher dicots	Fabaceae	*Sesbania cannabina var. cannabina*			C		1/1
plants	higher dicots	Fabaceae	*Galactia tenuiflora var. macrantha*			C		1/1
plants	higher dicots	Fabaceae	*Zornia muriculata subsp. angustata*			C		3/3
plants	higher dicots	Fabaceae	*Crotalaria aridicola subsp. glabrata*			C		1/1
plants	higher dicots	Fabaceae	*Crotalaria medicaginea var. neglecta*			C		2/2
plants	higher dicots	Fabaceae	*Tephrosia brachyodon var. longifolia*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia*			C		1/1
plants	higher dicots	Fabaceae	*Indigofera*			C		1/1
plants	higher dicots	Fabaceae	*Crotalaria dissitiflora subsp. rugosa*			C		1/1
plants	higher dicots	Goodeniaceae	*Goodenia strangfordii*			C		1/1
plants	higher dicots	Goodeniaceae	*Scaevola sp. (Mt Isa P.L.Harris 699)*			C		2/2
plants	higher dicots	Goodeniaceae	*Scaevola amblyanthera*			C		1/1

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plants	higher dicots	Goodeniaceae	*Goodenia ramelii*			C		2/2
plants	higher dicots	Haloragaceae	*Myriophyllum verrucosum*	water milfoil		C		1/1
plants	higher dicots	Lamiaceae	*Mesosphaerum suaveolens*		Y			1/1
plants	higher dicots	Lamiaceae	*Ocimum caryophyllinum*			C		1/1
plants	higher dicots	Lamiaceae	*Vitex benthamiana*			C		1/1
plants	higher dicots	Loganiaceae	*Mitrasacme connata*			C		1/1
plants	higher dicots	Loranthaceae	*Amyema sanguinea var. sanguinea*			C		1/1
plants	higher dicots	Loranthaceae	*Decaisnina brittenii subsp. brittenii*			C		1/1
plants	higher dicots	Loranthaceae	*Amyema quandang var. bancroftii*	broad-leaved grey mistletoe		C		1/1
plants	higher dicots	Loranthaceae	*Lysiana spathulata subsp. spathulata*			C		2/2
plants	higher dicots	Lythraceae	*Rotala mexicana*			C		1/1
plants	higher dicots	Malvaceae	*Sida*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus*			C		4/4
plants	higher dicots	Malvaceae	*Sida spinosa*	spiny sida	Y			1/1
plants	higher dicots	Malvaceae	*Abutilon hannii*			C		3/3
plants	higher dicots	Malvaceae	*Abutilon macrum*			C		1/1
plants	higher dicots	Malvaceae	*Sida cleisocalyx*			C		1/1
plants	higher dicots	Malvaceae	*Sida hackettiana*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon arenarium*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon otocarpum*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon malvifolium*	bastard marshmallow		C		1/1
plants	higher dicots	Malvaceae	*Hibiscus meraukensis*	Merauke hibiscus		C		1/1
plants	higher dicots	Malvaceae	*Hibiscus verdcourtii*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon leucopetalum*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus pentaphyllus*			C		1/1
plants	higher dicots	Malvaceae	*Sida rohlenae subsp. rohlenae*			C		3/3
plants	higher dicots	Malvaceae	*Hibiscus sturtii var. campylochlamys*			C		2/2
plants	higher dicots	Malvaceae	*Sida sp. (Aramac E.J.Thompson+ JER192)*			C		1/1
plants	higher dicots	Malvaceae	*Sida sp. (Jericho E.J.Thompson+ JER117)*			C		1/1
plants	higher dicots	Malvaceae	*Sida sp. (Musselbrook M.B.Thomas+ MRS437)*			C		7/7
plants	higher dicots	Mimosaceae	*Acacia limbata*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia bivenosa*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia cambagei*	gidgee		C		1/1
plants	higher dicots	Mimosaceae	*Acacia shirleyi*	lancewood		C		2/2
plants	higher dicots	Mimosaceae	*Acacia acradenia*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia calligera*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia galioides*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia gonoclada*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia monticola*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia umbellata*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia chisholmii*			C		5/5
plants	higher dicots	Mimosaceae	*Acacia elachantha*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia hemignosta*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia lysiphloia*			C		8/8
plants	higher dicots	Mimosaceae	*Acacia megalantha*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia orthocarpa*			C		3/3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Mimosaceae	*Acacia tenuissima*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia asperulacea*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia holosericea*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia phlebocarpa*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia stenophylla*	belalie		C		1/1
plants	higher dicots	Mimosaceae	*Acacia chippendalei*			C		1/1
plants	higher dicots	Mimosaceae	*Dichrostachys spicata*			C		1/1
plants	higher dicots	Mimosaceae	*Neptunia dimorphantha*			C		1/1
plants	higher dicots	Mimosaceae	*Vachellia sutherlandii*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia monticola x A.phlebocarpa*			C		3/3
plants	higher dicots	Mimosaceae	*Neptunia gracilis forma gracilis*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia victoriae subsp. fasciaria*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia sp. (Urandangi L.Pedley 2025)*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia drepanocarpa subsp. drepanocarpa*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia sp. (Coolullah M.Lazarides 3988)*			C		6/6
plants	higher dicots	Moraceae	*Ficus aculeata var. aculeata*			C		1/1
plants	higher dicots	Myrtaceae	*Melaleuca argentea*	silver tea-tree		C		2/2
plants	higher dicots	Myrtaceae	*Corymbia terminalis*			C		3/3
plants	higher dicots	Myrtaceae	*Corymbia capricornia*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus herbertiana*	kalumburu gum		C		3/3
plants	higher dicots	Myrtaceae	*Melaleuca trichostachya*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus normantonensis*	Normanton box		C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus leucophylla x E.pruinosa*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus pruinosa subsp. pruinosa*			C		2/2
plants	higher dicots	Myrtaceae	*Eucalyptus camaldulensis subsp. obtusa*			C		1/1
plants	higher dicots	Myrtaceae	*Corymbia grandifolia subsp. grandifolia*			C		1/1
plants	higher dicots	Myrtaceae	*Lophostemon grandiflorus subsp. riparius*			C		2/2
plants	higher dicots	Myrtaceae	*Corymbia*			C		1/1
plants	higher dicots	Myrtaceae	*Corymbia aspera*			C		1/1
plants	higher dicots	Myrtaceae	*Calytrix brownii*			C		2/2
plants	higher dicots	Myrtaceae	*Corymbia polycarpa*	long-fruited bloodwood		C		1/1
plants	higher dicots	Onagraceae	*Ludwigia perennis*			C		1/1
plants	higher dicots	Pentapetaceae	*Melhania ovata*			C		1/1
plants	higher dicots	Phyllanthaceae	*Phyllanthus maderaspatensis*			C		2/2
plants	higher dicots	Phyllanthaceae	*Phyllanthus lacunarius*			C		1/1
plants	higher dicots	Phyllanthaceae	*Breynia oblongifolia*			C		1/1
plants	higher dicots	Picrodendraceae	*Petalostigma quadriloculare*			C		1/1
plants	higher dicots	Plantaginaceae	*Stemodia glabella*			C		2/2
plants	higher dicots	Plantaginaceae	*Stemodia lythrifolia*			C		1/1
plants	higher dicots	Plumbaginaceae	*Plumbago zeylanica*	native plumbago		C		2/2
plants	higher dicots	Polygalaceae	*Polygala pterocarpa*			C		1/1
plants	higher dicots	Polygalaceae	*Polygala*			C		1/1
plants	higher dicots	Proteaceae	*Grevillea dryandri subsp. dryandri*			C		1/1
plants	higher dicots	Proteaceae	*Grevillea wickhamii subsp. aprica*			C		4/4
plants	higher dicots	Proteaceae	*Hakea chordophylla*			C		1/1
plants	higher dicots	Proteaceae	*Hakea arborescens*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Proteaceae	*Grevillea heliosperma*			C		2/2
plants	higher dicots	Rubiaceae	*Oldenlandia mitrasacmoides subsp. mitrasacmoides*			C		1/1
plants	higher dicots	Rubiaceae	*Oldenlandia argillacea*			C		1/1
plants	higher dicots	Rubiaceae	*Spermacoce auriculata*			C		2/2
plants	higher dicots	Rubiaceae	*Oldenlandia galioides*			C		1/1
plants	higher dicots	Rubiaceae	*Spermacoce argillacea*			C		1/1
plants	higher dicots	Sapindaceae	*Dodonaea lanceolata var. lanceolata*			C		1/1
plants	higher dicots	Scrophulariaceae	*Eremophila acrida*			C		1/1
plants	higher dicots	Solanaceae	*Solanum quadriloculatum*			C		2/2
plants	higher dicots	Solanaceae	*Solanum echinatum*			C		2/2
plants	higher dicots	Solanaceae	*Solanum succosum*			C		6/6
plants	higher dicots	Sparrmanniaceae	*Corchorus sericeus subsp. densiflorus*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Triumfetta marsupiata*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Triumfetta rupestris*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Triumfetta plumigera*			C		3/3
plants	higher dicots	Sparrmanniaceae	*Corchorus olitorius*	jute		C		1/1
plants	higher dicots	Sterculiaceae	*Brachychiton collinus*			C		1/1
plants	higher dicots	Violaceae	*Hybanthus enneaspermus*			C		2/2
plants	higher dicots	Violaceae	*Hybanthus aurantiacus*			C		1/1
plants	higher dicots	Zygophyllaceae	*Tribulopis pentandra*			C		2/2
plants	higher dicots	Zygophyllaceae	*Tribulopis solandri*			C		2/2
plants	lower dicots	Lauraceae	*Cassytha filiformis*	dodder laurel		C		1/1
plants	lower dicots	Papaveraceae	*Argemone ochroleuca subsp. ochroleuca*	Mexican poppy	Y			1/1
plants	monocots	Arecaceae	*Livistona rigida*			C		2/2
plants	monocots	Commelinaceae	*Commelina ensifolia*	scurvy grass		C		2/2
plants	monocots	Cyperaceae	*Cyperus bifax*	western nutgrass		C		2/2
plants	monocots	Cyperaceae	*Cyperus fulvus*			C		5/5
plants	monocots	Cyperaceae	*Scleria brownii*			C		2/2
plants	monocots	Cyperaceae	*Cyperus carinatus*			C		7/7
plants	monocots	Cyperaceae	*Cyperus difformis*	rice sedge		C		1/1
plants	monocots	Cyperaceae	*Cyperus vaginatus*			C		3/3
plants	monocots	Cyperaceae	*Cyperus nervulosus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus pulchellus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus squarrosus*	bearded flatsedge		C		1/1
plants	monocots	Cyperaceae	*Fimbristylis elegans*			C		1/1
plants	monocots	Cyperaceae	*Fimbristylis macrantha*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis littoralis*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis microcarya*			C		1/1
plants	monocots	Cyperaceae	*Lipocarpha microcephala*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis depauperata*			C		1/1
plants	monocots	Cyperaceae	*Cyperus conicus var. conicus*			C		3/3
plants	monocots	Cyperaceae	*Cyperus betchei subsp. betchei*			C		1/1
plants	monocots	Cyperaceae	*Cyperus betchei subsp. commiscens*			C		4/4
plants	monocots	Cyperaceae	*Cyperus cunninghamii subsp. cheradicus*			C		3/3
plants	monocots	Cyperaceae	*Cyperus microcephalus subsp. microcephalus*			C		2/2
plants	monocots	Cyperaceae	*Cyperus iria*			C		2/2

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	monocots	Poaceae	*Aristida*			C		1/1
plants	monocots	Poaceae	*Eriachne mucronata forma (Burnham R.W.Purdie 1370)*			C		2/2
plants	monocots	Poaceae	*Eulalia aurea*	silky browntop		C		1/1
plants	monocots	Poaceae	*Sarga plumosum*			C		2/2
plants	monocots	Poaceae	*Eriachne obtusa*			C		1/1
plants	monocots	Poaceae	*Panicum effusum*			C		2/2
plants	monocots	Poaceae	*Sarga timorense*			C		1/1
plants	monocots	Poaceae	*Setaria surgens*			C		1/1
plants	monocots	Poaceae	*Triodia molesta*			C		1/1
plants	monocots	Poaceae	*Triodia pungens*			C		1/1
plants	monocots	Poaceae	*Aristida exserta*			C		3/3
plants	monocots	Poaceae	*Aristida ingrata*			C		1/1
plants	monocots	Poaceae	*Digitaria minima*			C		1/1
plants	monocots	Poaceae	*Eragrostis minor*	smaller stinkgrass	Y			1/1
plants	monocots	Poaceae	*Eriachne ciliata*			C		1/1
plants	monocots	Poaceae	*Iseilema fragile*			C		1/1
plants	monocots	Poaceae	*Aristida nitidula*			C		1/1
plants	monocots	Poaceae	*Aristida pruinosa*			C		1/1
plants	monocots	Poaceae	*Digitaria brownii*			C		2/2
plants	monocots	Poaceae	*Eragrostis fallax*			C		1/1
plants	monocots	Poaceae	*Mnesithea formosa*			C		1/1
plants	monocots	Poaceae	*Paspalidium rarum*			C		2/2
plants	monocots	Poaceae	*Triodia bitextura*			C		3/3
plants	monocots	Poaceae	*Triodia brizoides*			C		2/2
plants	monocots	Poaceae	*Urochloa piligera*			C		1/1
plants	monocots	Poaceae	*Arundinella setosa*			C		3/3
plants	monocots	Poaceae	*Digitaria ciliaris*	summer grass	Y			2/2
plants	monocots	Poaceae	*Echinochloa colona*	awnless barnyard grass	Y			2/2
plants	monocots	Poaceae	*Eriachne mucronata*			C		2/2
plants	monocots	Poaceae	*Eriachne pulchella*			C		1/1
plants	monocots	Poaceae	*Triodia mitchellii*	buck spinifex		C		1/1
plants	monocots	Poaceae	*Eragrostis cumingii*			C		2/2
plants	monocots	Poaceae	*Eragrostis speciosa*			C		1/1
plants	monocots	Poaceae	*Tragus australianus*	small burr grass		C		1/1
plants	monocots	Poaceae	*Bothriochloa pertusa*		Y			1/1
plants	monocots	Poaceae	*Dichanthium fecundum*	curly bluegrass		C		2/2
plants	monocots	Poaceae	*Enneapogon asperatus*			C		1/1
plants	monocots	Poaceae	*Enneapogon nigricans*	niggerheads		C		1/1
plants	monocots	Poaceae	*Eragrostis basedowii*			C		1/1
plants	monocots	Poaceae	*Eragrostis laniflora*			C		1/1
plants	monocots	Poaceae	*Eragrostis stagnalis*			C		1/1
plants	monocots	Poaceae	*Eragrostis tenellula*	delicate lovegrass		C		1/1
plants	monocots	Poaceae	*Iseilema macratherum*			C		1/1
plants	monocots	Poaceae	*Tripogon loliiformis*	five minute grass		C		1/1
plants	monocots	Poaceae	*Cymbopogon bombycinus*	silky oilgrass		C		2/2
plants	monocots	Poaceae	*Eragrostis desertorum*	woollybutt		C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	monocots	Poaceae	*Paspalidium clementii*			C		1/1
plants	monocots	Poaceae	*Schizachyrium fragile*	firegrass		C		1/1
plants	monocots	Poaceae	*Aristida inaequiglumis*			C		1/1
plants	monocots	Poaceae	*Bothriochloa ewartiana*	desert bluegrass		C		1/1
plants	monocots	Poaceae	*Enneapogon lindleyanus*			C		2/2
plants	monocots	Poaceae	*Enneapogon polyphyllus*	leafy nineawn		C		2/2
plants	monocots	Poaceae	*Dactyloctenium radulans*	button grass		C		1/1
plants	monocots	Poaceae	*Digitaria nematostachya*			C		1/1
plants	monocots	Poaceae	*Pseudoraphis spinescens*	spiny mudgrass		C		1/1
plants	monocots	Poaceae	*Sporobolus actinocladus*	katoora grass		C		1/1
plants	monocots	Poaceae	*Sporobolus australasicus*			C		1/1
plants	monocots	Poaceae	*Eriachne pulchella subsp. dominii*			C		1/1
plants	monocots	Poaceae	*Eriachne pulchella subsp. pulchella*			C		1/1
plants	monocots	Poaceae	*Dichanthium sericeum subsp. sericeum*			C		1/1
plants	monocots	Poaceae	*Eriachne sp. (Dugald River B.K.Simon+ 3007)*			C		1/1
plants	monocots	Poaceae	*Eriachne mucronata forma (Alpha C.E.Hubbard 7882)*			C		1/1
plants	monocots	Potamogetonaceae	*Potamogeton crispus*	curly pondweed		C		1/1

CODES

I - Y indicates that the taxon is introduced to Queensland and has naturalised.

Q - Indicates the Queensland conservation status of each taxon under the *Nature Conservation Act 1992.* The codes are Extinct in the Wild (PE), Endangered (E), Vulnerable (V), Near Threatened (NT), Least Concern (C) or Not Protected ( ).

A - Indicates the Australian conservation status of each taxon under the *Environment Protection and Biodiversity Conservation Act 1999.* The values of EPBC are Conservation Dependent (CD), Critically Endangered (CE), Endangered (E), Extinct (EX), Extinct in the Wild (XW) and Vulnerable (V).

Records – The first number indicates the total number of records of the taxon for the record option selected (i.e. All, Confirmed or Specimens).
This number is output as 99999 if it equals or exceeds this value. The second number located after the / indicates the number of specimen records for the taxon.
This number is output as 999 if it equals or exceeds this value.

Recovery Actions Database

Title: Species list for 'Back on Track' priority species in Southern Gulf

Extracted: 18/06/2014 10:34:48

Search Criteria: [Back on Track Rank (NRM Back on Track Rank), NRM Region (Southern Gulf)]

NRM Region of Occurrence	Kingdom	Plant/Animal Type	Species Scientific Name	Species Common Name	NRM BoT Rank	State BoT Rank	NCA Status	EPBC Status
Southern Gulf	*Animals*	*Arachnids*	*Selenocosmia crassipes*		High	Critical	Least concern	
Southern Gulf	*Animals*	*Arachnids*	*Selenotypus plumipes*		High	Critical	Least concern	
Southern Gulf	*Animals*	*Birds*	*Amytornis ballarae*	Kalkadoon grasswren	High	High	Least concern	
Southern Gulf	*Animals*	*Birds*	*Amytornis dorotheae*	Carpentarian grasswren	High	High	Near threatened	
Southern Gulf	*Animals*	*Birds*	*Erythrotriorchis radiatus*	red goshawk	High	High	Endangered	Vulnerable
Southern Gulf	*Animals*	*Birds*	*Esacus magnirostris*	beach stone-curlew	High	High	Vulnerable	
Southern Gulf	*Animals*	*Birds*	*Grantiella picta*	painted honeyeater	High	High	Vulnerable	
Southern Gulf	*Animals*	*Birds*	*Lophochroa leadbeateri*	Major Mitchell's cockatoo	High	High	Vulnerable	
Southern Gulf	*Animals*	*Birds*	*Malurus coronatus*	purple-crowned fairy-wren	High	High	Vulnerable	
Southern Gulf	*Animals*	*Birds*	*Neochmia ruficauda clarescens*	star finch (northern subspecies)	High	High	Least concern	
Southern Gulf	*Animals*	*Birds*	*Rostratula australis*	Australian painted snipe	High	Medium	Vulnerable	Endangered
Southern Gulf	*Animals*	*Birds*	*Sternula albifrons*	little tern	High	High	Endangered	
Southern Gulf	*Animals*	*Fish*	*Dasyatis fluviorum*	estuary stingray	High	High	Not Protected	
Southern Gulf	*Animals*	*Fish*	*Glyphis glyphis*	Bizant River shark	Critical	Critical	Not Protected	Critically Endangered
Southern Gulf	*Animals*	*Fish*	*Pristis clavata*	dwarf sawfish	High	High	Not Protected	Vulnerable
Southern Gulf	*Animals*	*Fish*	*Pristis pristis*	freshwater sawfish	High	High	Not Protected	Vulnerable
Southern Gulf	*Animals*	*Fish*	*Pristis zijsron*	green sawfish	High	High	Not Protected	Vulnerable
Southern Gulf	*Animals*	*Mammals*	*Dugong dugon*	dugong	Critical	Critical	Vulnerable	
Southern Gulf	*Animals*	*Mammals*	*Macroderma gigas*	ghost bat	Critical	Critical	Vulnerable	
Southern Gulf	*Animals*	*Mammals*	*Orcaella heinsohni*	Australian snubfin dolphin	Critical	Critical	Near threatened	
Southern Gulf	*Animals*	*Mammals*	*Sminthopsis douglasi*	Julia Creek dunnart	Critical	Critical	Endangered	Endangered
Southern Gulf	*Animals*	*Mammals*	*Sousa chinensis*	Indo-Pacific humpback dolphin	Critical	Critical	Near threatened	
Southern Gulf	*Animals*	*Reptiles*	*Acanthophis antarcticus*	common death adder	High	Medium	Near threatened	
Southern Gulf	*Animals*	*Reptiles*	*Caretta caretta*	loggerhead turtle	Critical	Critical	Endangered	Endangered

Southern Gulf	*Animals*	*Reptiles*	*Chelonia mydas*	green turtle	Critical	Critical	Vulnerable	Vulnerable
Southern Gulf	*Animals*	*Reptiles*	*Elseya lavarackorum*	Gulf snapping turtle	High	High	Vulnerable	Endangered
Southern Gulf	*Animals*	*Reptiles*	*Eretmochelys imbricata*	hawksbill turtle	Critical	Critical	Vulnerable	Vulnerable
Southern Gulf	*Animals*	*Reptiles*	*Lepidochelys olivacea*	olive ridley turtle	Critical	Critical	Endangered	Endangered
Southern Gulf	*Animals*	*Reptiles*	*Natator depressus*	flatback turtle	High	Critical	Vulnerable	Vulnerable
Southern Gulf	*Plants*	*Cycads*	*Cycas couttsiana*		High	Critical	Near threatened	
Southern Gulf	*Plants*	*Herbs*	*Eriocaulon carsonii*		Critical	High	Endangered	Endangered
Southern Gulf	*Plants*	*Trees*	*Pandanus aquaticus*		High	Medium	Least concern	
Southern Gulf	*Plants*	*Water plants*	*Aponogeton queenslandicus*		High	Medium	Least concern	

Appendix B Fauna Study Sites

2011 Study Sites

Terrestrial fauna study sites sampled during the 2011 surveys are described and illustrated below.

DSFS1 was located in a dry watercourse in the north-west corner of the Project site. Photo Plate 14 provides graphic representation of the study site centred around the pitfall trapping line.

Photo Plate 14 Pitfall Line at DSFS1

DSFS2 was positioned in a dry waterway, adjacent to steep rocky hills in the centre of the site. Photographic representation of the pitfall trapping line and typical habitat at DSFS2 is shown in Photo Plate 15.

Photo Plate 15 Pitfall Line at DSFS2

DSFS3 was located in on the pediment slope of a Snappy Gum dominated hillside. A photograph of the fauna site and the associated pitfall trapping line is shown in Photo Plate 16.

Photo Plate 16 Pitfall Line at Study Site DSFS3

DSFS4 was located in a dry watercourse dominated by *Melaleuca bracteata*. A photograph of the pitfall trapping line at DSFS4 is shown in Photo Plate 17.

Photo Plate 17 Pitfall Line at DSFS4

DSFS5 was located on top of a stony hillside dominated by *Acacia phlebocarpa.* The pitfall trapping line at DSFS5 is shown in Photo Plate 18.

Photo Plate 18 Pitfall Line at DSFS5

TR01 was located in the south-western corner of the Project site among Cloncurry Box hills. Photo Plate 19 provides graphic representation of the study site centred around the pitfall trapping line.

Photo Plate 19 Pitfall Line at TR01

TR02 was located in the east of the Project site on undulating Snappy Gum hills. The fauna site and pitfall trapping line in particular are shown in Photo Plate 20.

Photo Plate 20 Pitfall Line at TR02

TR03 was located in the centre of the Project site among Snappy Gum hills. Photo Plate 21 provides graphic representation of the study site centred around the pitfall trapping line.

Photo Plate 21 Pitfall Line at TR03

TR04 was located on the creek flats of a mapped watercourse in the centre of the Project site. The pitfall trapping line established within fauna site TR04 is shown in Photo Plate 22.

Photo Plate 22 Pitfall Line at TR04

TR05 was located on the lower slopes of a hillside dominated by Snappy Gum. The pitfall line and typical habitat at fauna site TR05 is shown in Photo Plate 23.

Photo Plate 23 Pitfall Line at TR05

TR06 was located on a stony hillside in the south-east of the Project site. Fauna site TR06 is shown in Photo Plate 24 along with the pitfall trapping line established at the time of the survey.

Photo Plate 24 Pitfall Line at TR06

TR07 was positioned in close proximity to the DSFS5 on an undulating hill dominated by Snappy Gum and Bloodwoods. The pitfall line established at TR07 is shown in Photo Plate 25 which also provides graphical presentation of the study site.

Photo Plate 25 Pitfall Line at TR07

TR08 was located toward the centre of the Project site on the creek flats of a mapped watercourse. The fauna site and pitfall trapping line as established at the time of the survey are shown in Photo Plate 26.

Photo Plate 26 Pitfall Line at TR08

2014 Fauna Study Sites

FA1 was positioned in a Cloncurry Box drainage line in the south-west portion of the Project site. The low vegetation canopy was dominated by Cloncurry Box and associated with a dense understorey of *Melaleuca bracteata* and a sparse ground layer on sandy clay soils. The ground layer was dominated by Buffel and cattle tracks were prominent throughout the habitat area. The shallow creek channels were dry at the time of the survey with minor erosion in some areas. Photo Plate 27 provides graphic representation of the study site centred around the pitfall trapping line.

Photo Plate 27 Pitfall Line at FA1

FA2 was located in River Red Gum Riparian woodland on the major creek that passes through the south-west corner of the site. The vegetation canopy is dominated by River Red Gum while the understorey is dominated by Arid Peach and Turpentine. The ground layer is sparse due to grazing cattle movements on the creek embankments and the rocky nature of the high bank. The habitat area contains moderate cover of leaf litter, a few logs and many hollows within the River Red Gum trees. The fauna site runs along a major creek which was dry at the time of the survey. A photograph of the fauna site, centred around the pitfall trapping line is shown in Photo Plate 28.

Photo Plate 28 Pitfall Line at FA2

FA3 was located in the mid-western portion of the Project site on an outcropping rocky hilltop. This outcropping hill occurs as part of a series of rocky ranges that form the dominant landform in this area of the Project. The vegetation community consists of low open woodland of Snappy Gum with the occasional Hill Kurrajong, an understorey of Arid Peach and Turpentine and a Soft Spinifex (*Triodia pungens*) dominant ground layer. The rocky outcrop landform provides an abundance of habitat for reptiles and rock-wallabies. A few hollow-bearing trees occur at the rear of the outcrop. The rocky outcrop that forms the focus of the FA3 is shown in Photo Plate 29.

Photo Plate 29 Rocky outcrop habitat at FA3

FA4 was centred around low open woodlands of Cloncurry Box on an ephemeral drainage line and valley flat located in the west of the Project site. Either side of the valley flat features low relief rocky hills that are dominated by Snappy Gum and Turpentine. This fauna site featured good habitat variety with plenty of leaf litter, grassy tussocks, fallen timber and cracking bark. Combined these features were found to support an abundance of retiles. A photograph of the fauna site and the pitfall trapping line, in particular, is shown in Photo Plate 30.

Photo Plate 30 Pitfall Line at FA4

FA5 was located in Cloncurry Box woodlands on a small dry drainage line in the central-western portion of the site. The Cloncurry Box dominant canopy is accompanied by the occasional Northern Swamp Box, while the understorey contains a mix of Turpentine, Arid Peach, Conkerberry and Whitewood. Buffel and Soft Spinifex co-dominate the ground layer. The fauna site was surrounded by Snappy Gum dominant hills. Habitat features include small hollows, rocks, leaf litter and grassy tussocks. A photograph of the pitfall trapping line at FA5 is shown in Photo Plate 31.

Photo Plate 31 Pitfall Line at FA5

FA6 was located in low open Snappy Gum woodlands on a rocky hill in the south-east of the Project site. The Snappy Gum dominant vegetation community consists of the occasional bloodwood in the canopy, Arid Peach and Tabletop Wattle in the understorey and a ground layer of Kangaroo Grass, Soft Spinifex and Mountain Wanderrie Grass. The site featured good habitat variety with many grass tussocks, low shrubs, outcropping rock habitat, some leaf litter and fallen timber. A broad landscape photographic view of FA6 is shown in Photo Plate 32.

Photo Plate 32 Low Open Snappy Gum Woodland on Hillsides at FA6

FA7 was located in low open Snappy Gum woodland on a rocky outcrop and hillslope in the east of the Project site. The vegetation canopy was dominated by Snappy Gum with associated Arid Peach and a shrub layer of Tabletop Wattle, Soap Bush and Turpentine. The ground layer was dominated by Soft Spinifex, Common Fringe-sedge and *Paspalidium distans*. The site contained moderate habitat variety with plenty of outcropping rocks, crevices and grass tussocks but little leaf litter, fallen timber or tree hollows. A portion of the hilltop rocky outcrop at FA7 is shown in Photo Plate 33.

Photo Plate 33 Rocky outcrop habitat at FA7

FA8 was located along a River Red Gum creek in the north of the Project site. The riparian canopy was typically dominated by River Red Gum while Northern Swamp Box forms a dense understorey in the upstream reach of the fauna transect. The creek consisted of a sandy to rocky, cobble bed with boulder outcrops occurring sporadically. There was a good cover of leaf litter and an abundance of tree hollows. The upstream section of the creek at FA8 is shown in Photo Plate 34.

Photo Plate 34 Harp trap in River Red Gum / Northern Swamp Box Creek at FA8

Appendix C Flora Species Inventory

Scientific Name	Common Name	Conservation Status		2011 Records	Flora Survey Transect										
		NC Act/LP Act	EPBC Act		FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8	FT9	FT10	OPPS
Abildgaardia vaginata		LC	NL	X											
Abutilon hannii		LC	NL	X											
Acacia chisholmii	Turpentine	LC	NL	X	X			X	X	X					
Acacia coriacea		LC	NL	X											
Acacia gonoclada		LC	NL	X											
Acacia hemsleyi		LC	NL			X	X								
Acacia hemignosta		LC	NL	X											X
Acacia holosericea	Soapbush	LC	NL	X			X		X			X	X	X	
Acacia melleodora		LC	NL	X								X	X		X
Acacia monticola	Red Wattle	LC	NL								X			X	
Acacia orthocarpa		LC	NL	X											X
Acacia phlebocarpa	Tabletop Wattle	LC	NL	X							X	X	X	X	
Acacia retivenea	Net-vein Wattle	LC	NL	X											X
Achyranthes aspera		LC	NL	X											
Aerva javanica		I	NL	X											
Alphitonia excelsa	Red Ash	LC	NL	X											
Anisomeles malabarica		LC	NL	X											
Aristida holathera		LC	NL	X											
Aristida latifolia		LC	NL	X											
Aristida longicollis		LC	NL		X	X		X							
Aristida pruinosa		LC	NL			X	X								X
Aristida sp.		LC	NL									X			

Scientific Name	Common Name	Conservation Status		2011 Records	Flora Survey Transect										
		NC Act/LP Act	EPBC Act		FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8	FT9	FT10	OPPS
Atalaya hemiglauca	Whitewood	LC	NL	X	X	X		X	X	X					X
Bidens bipinnata	Bipinnate Beggar's Ticks	I	NL	X											
Bonamia media		LC	NL	X										X	
Boerhavia sp.		LC	NL			X	X	X	X		X		X		
Bothriochloa ewartiana	Forest Bluegrass	LC	NL	X									X		
Brachyachne convergens		LC	NL	X											X
Brachychiton collinus	Hill Kurrajong	LC	NL	X											X
Bulbostylis barbata		LC	NL	X											X
Cajanus sp.		LC	NL			X									
Carissa lanceolata	Conkerberry	LC	NL	X					X			X	X		X
Cenchrus ciliaris	Buffel Grass	I	NL	X	X	X	X	X		X					
Chamaecrista absus		LC	NL	X											
Chamaecrista concinna		LC	NL	X											
Chamaesyce hirta	Asthma Plant	I	NL												X
Cheilanthes brownii	Woolly Cloak Fern	LC	NL					X		X	X	X			
Cheilanthes sieberi		LC	NL	X											
Chloris pectinata	Comb Chloris	LC	NL	X											
Chrysopogon elongatus		LC	NL	X											
Chrysopogon fallax		LC	NL	X											
Cleome viscosa	Tickweed	LC	NL	X		X	X	X	X	X	X				X

Scientific Name	Common Name	Conservation Status		2011 Records	Flora Survey Transect										
		NC Act/LP Act	EPBC Act		FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8	FT9	FT10	OPPS
Corchorus aestuans		LC	NL	X											
Corchorus sericeus	Grey Jute	LC	NL	X					X		X	X		X	
Corchorus sidoides	Flannel Jute	LC	NL		X			X							
Corymbia aparrerinja	Ghost Gum	LC	NL	X						X			X		X
Corymbia capricornia		LC	NL	X										X	
Corymbia polycarpa	Long-fruited Bloodwood	LC	NL	X											
Corymbia terminalis	Northern Bloodwood	LC	NL	X	X					X			X	X	X
Crotalaria novae-hollandiae subsp. novae-hollandiae	New Holland Rattlepod	LC	NL	X											X
Cryptandra propinqua		LC	NL	X											
Cucumis maderaspatanus		LC	NL	X											
Cucumis melo		LC	NL	X										X	
Cymbopogon bombycinus	Lemon-scented Grass	LC	NL	X				X	X	X	X	X	X		
Cyperus cunninghamii		LC	NL				X								
Cyperus microcephalus subsp. microcephalus		LC	NL			X									
Dactyloctenium radulans	Button Grass	LC	NL	X											X

Scientific Name	Common Name	Conservation Status		2011 Records	Flora Survey Transect										
		NC Act/LP Act	EPBC Act		FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8	FT9	FT10	OPPS
Digitaria gibbosa		LC	NL	X											
Dodonaea lanceolata var. lanceolata		LC	NL	X											
Enneapogon avenaceus	Common Bottlewashers	LC	NL				X	X	X	X	X				
Enneapogon lindleyanus		LC	NL		X					X		X		X	X
Enneapogon polyphyllus	Leafy Nineawn	LC	NL	X									X		X
Enteropogon ramosus	Twirly Windmill Grass	LC	NL						X						X
Eragrostis sp.		LC	NL			X									
Eragrostis tenellula	Delicate Lovegrass	LC	NL	X											X
Eremophila latrobei		LC	NL											X	X
Eremophila longifolia	Berrigan	LC	NL	X	X			X	X						
Eriachne ciliata		LC	NL	X											
Eriachne mucronata	Mountain Wanderrie Grass	LC	NL	X								X	X	X	
Eriachne mucronata forma (Alpha C.E. Hubbard 7882)		LC	NL						X		X				
Eucalyptus camaldulensis	River Red Gum	LC	NL	X		X	X								X

Scientific Name	Common Name	Conservation Status		2011 Records	Flora Survey Transect										
		NC Act/LP Act	EPBC Act		FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8	FT9	FT10	OPPS
Eucalyptus leucophloia	Snappy Gum	LC	NL					X			X	X	X	X	X
Eucalyptus leucophylla	Cloncurry Box	LC	NL	X	X			X	X	X			X		X
Eulalia aurea	Silky Browntop	LC	NL	X				X						X	X
Euphorbia biconvexa		LC	NL		X				X	X			X		
Euphorbia drummondii		LC	NL	X											
Euphorbia tannensis subsp. tannensis		LC	NL								X	X			
Evolvulus alsinoides	Tropical Speedwell	LC	NL	X								X			X
Fimbristylis dichotoma	Common Fringe-sedge	LC	NL	X	X			X			X	X	X		X
Flueggea leucopyrus	Bushweed	LC	NL												X
Flueggea virosa subsp. melanthesoides	White Currant Bush	LC	NL	X	X	X	X		X						X
Galactia tenuiflora	Galactia	LC	NL	X		X	X	X	X						X
Glycine sp.		LC	NL						X						
Goodenia ramelii		LC	NL												X
Goodenia vilmoriniae		LC	NL												X
Gomphrena canescens subsp. canescens		LC	NL	X											
Gossypium australe	Native Cotton	LC	NL	X	X			X	X	X				X	
Grevillea mimosoides	Caustic Bush	LC	NL	X											X
Grevillea wickhamii	Holly-leaved Grevillea	LC	NL	X											X

Scientific Name	Common Name	Conservation Status		2011 Records	Flora Survey Transect										
		NC Act/LP Act	EPBC Act		FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8	FT9	FT10	OPPS
Hakea arborescens		LC	NL	X											
Hakea chordophylla	Bootlace Oak	LC	NL		X					X			X		X
Hakea lorea		LC	NL	X											
Heliotropium ballii		LC	NL											X	X
Heliotropium conocarpum		LC	NL	X											
Heliotropium cunninghamii		LC	NL				X	X	X		X	X	X		
Heteropogon contortus	Black Speargrass	LC	NL	X					X	X					X
Hibiscus meraukensis	Merauke hibiscus	LC	NL	X											
Hibiscus sturtii		LC	NL	X										X	X
Hybanthus aurantiacus		LC	NL	X											
Hybanthus enneaspermus		LC	NL	X										X	
Hyptis suaveolens	Hyptis	LC	NL			X									
Indigofera colutea	Sticky Indigo	LC	NL	X											X
Indigofera hirsuta	Hairy Indigo	LC	NL	X											X
Indigofera linifolia		LC	NL	X										X	X
Indigofera linnaei	Birdsville Indigo	LC	NL	X											
Indigofera pratensis	Forest Indigo	LC	NL	X								X			X
Indigofera sp.		LC	NL						X				X		
Indigofera trita		LC	NL	X											

Scientific Name	Common Name	Conservation Status		2011 Records	Flora Survey Transect										
		NC Act/LP Act	EPBC Act		FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8	FT9	FT10	OPPS
Lophostemon grandiflorus	Northern Swamp Mahogany	LC	NL	X		X	X		X						X
Ludwigia octovalvis	Willow Primrose	LC	NL	X											
Lysiphyllum cunninghamii		LC	NL	X											X
Maytenus cunninghamii	Yellow Berry Bush	LC	NL	X					X						X
Melaleuca bracteata	Black Tea-tree	LC	NL	X	X										X
Melhania oblongifolia	Velvet Hibiscus	LC	NL	X										X	X
Melinis repens	Red Natal Grass	I	NL	X											
Mnesithea formosa	Silkytop Grass	LC	NL	X							X				X
Neptunia dimorphantha	Sensitive Plant	LC	NL										X		
Neptunia gracilis		LC	NL	X											
Ocimum tenuiflorum		LC	NL	X											
Panicum decompositum		LC	NL	X											
Paspalidium constrictum		LC	NL										X	X	X
Paspalidium distans		LC	NL				X								
Paspalidium rarum	Rare Paspalidium	LC	NL								X	X			X
Peripleura hispidula var. hispidula	Fuzzweed	LC	NL												X
Perotis rara	Comet Grass	LC	NL	X											

Scientific Name	Common Name	Conservation Status		2011 Records	Flora Survey Transect										
		NC Act/LP Act	EPBC Act		FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8	FT9	FT10	OPPS
Phyllanthus maderaspatensis		LC	NL						X					X	X
Ptilotus obovatus		LC	NL												X
Santalum lanceolatum	Sandalwood	LC	NL												X
Sarcostemma brevipedicellatum	Caustic Bush	LC	NL												X
Senna artemisioides subsp. helmsii	Crinkle Leaf Cassia	LC	NL											X	X
Senna planitiicola		LC	NL												X
Senna venusta	Graceful Cassia	LC	NL												X
Sida fibulifera	Pin Sida	LC	NL									X	X		X
Sida sp.		LC	NL							X					
Sida subspicata	Spiked Sida	LC	NL											X	X
Solanum ellipticum	Potato Bush	LC	NL		X									X	X
Solanum esuriale	Quena	LC	NL												X
Solanum quadriloculatum		LC	NL							X					X
Spermacoce auriculata		LC	NL	X											
Sporobolus actinocladus	Katoora Grass	LC	NL	X											X
Sporobolus australasicus	Australian Dropseed	LC	NL	X											X
Stackhousia viminea	Slender	LC	NL	X											

Scientific Name	Common Name	Conservation Status		2011 Records	Flora Survey Transect										
		NC Act/LP Act	EPBC Act		FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8	FT9	FT10	OPPS
	Stackhousia														
Streptoglossa bubakii		LC	NL	X											
Streptoglossa decurrens		LC	NL	X											
Swainsona burkei	Hairy Darling Pea	LC	NL								X				
Tephrosia brachyodon var longifolia	Narrow-leaved Tephrosia	LC	NL			X						X			X
Tephrosia rosea		LC	NL	X										X	X
Tephrosia sp.		LC	NL					X							
Tephrosia virens		LC	NL	X											
Terminalia aridicola	Arid Peach	LC	NL	X				X	X			X	X	X	X
Themeda triandra	Kangaroo Grass	LC	NL	X					X	X	X	X	X	X	X
Tinospora smilacina	Snake Vine	LC	NL	X	X					X					X
Trema tomentosa		LC	NL	X											
Trianthema triquetra	Red Spinach	LC	NL				X								
Tribulopsis pentandra		LC	NL					X	X	X	X	X	X		
Trichodesma zeylanicum	Camel Bush	LC	NL	X							X	X			X
Triodia bitextura		LC	NL	X											X
Triodia pungens	Soft Spinifex	LC	NL	X	X		X	X		X	X	X	X	X	X
Triodia longiceps	Giant Grey Spinifex	LC	NL	X											X
Triumfetta plumigera		LC	NL	X											
Triumfetta microcantha		LC	NL								X				X

Scientific Name	Common Name	Conservation Status		2011 Records	Flora Survey Transect										
		NC Act/LP Act	EPBC Act		FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8	FT9	FT10	OPPS
Urochloa sp.		LC	NL								X				
Vachellia bidwillii	Corkwood Wattle	LC	NL	X											X
Vachellia farnesiana	Mimosa Bush	I	NL			X	X								X
Vigna radiata		I	NL	X											
Waltheria indica		LC	NL	X											
Zornia muriculata		LC	NL	X											

Key:

LC – This species is classified as Least Concern under the NC Act

I – Introduced species

NL – This species is not listed under the EPBC Act as a species of conservation significance

Appendix D Fauna Species Inventory

Family	Scientific Name	Common Name	Conservation Status		Wet season Survey								Dry Season Survey							
			NC Act / LP Act	EPBC Act	OPPS	FA1	FA2	FA3	FA4	FA5	FA6	FA7	OPPS	FA1	FA2	FA4	FA5	FA6	FA7	FA8
Reptiles																				
Agamidae	*Amphibolurus gilberti*	Gilberts Dragon	LC	NL										X	X					
Boidae	*Antaresia childreni*	Children's Python	LC	NL							X									
Boidae	*Liasis olivaceus*	Olive Python	LC	NL			X				X									
Elapidae	*Suta suta*	Curl Snake	LC	NL														X		
Gekkonidae	*Strophurus ciliaris*	Northern Spiny-tailed Gecko	LC	NL						X										
Gekkonidae	*Gehyra robusta*	Robust Dtella	LC	NL		X		X			X	X			X	X				X
Gekkonidae	*Gehyra variegata*	Tree Dtella	LC	NL					X					X						
Gekkonidae	*Heteronotia binoei*	Bynoe's Gecko	LC	NL											X					
Pygopodidae	*Lialis burtonis*	Burton's Legless Lizard	LC	NL									X							
Pygopodidae	*Pygopus steelescotti*	Northern Hooded Scaly-foot	LC	NL		X														
Scincidae	*Carlia amax*	Two-spined Rainbow-skink	LC	NL			X					X								
Scincidae	*Carlia munda*	Shaded-litter Rainbow-skink	LC	NL									X						X	X
Scincidae	*Cryptoblepharus metallicus*	Metallic Snake-eyed Skink	LC	NL					X											
Scincidae	*Cryptoblepharus zoticus*	Agile Snake-eyed Skink	LC	NL								X								
Scincidae	*Ctenotus lateralis*	Gravelly-soil Ctenotus	LC	NL					X						X					
Scincidae	*Ctenotus saxatilis*	Rock Ctenotus	LC	NL			X		X											
Scincidae	*Ctenotus striaticeps*	Carpentarian Ctenotus	LC	NL					X											
Scincidae	*Egernia hosmeri*	Hosmer's Skink	LC	NL							X							X		
Scincidae	*Proablepharus tenuis*	Northern Soil-crevice Skink	LC	NL							X									
Typhlopidae	*Ramphotyphlops diversus*	Northern Blind Snake	LC	NL		X	X		X	X										
Typhlopidae	*Ramphotyphlops ligatus*	Robust Blind Snake	LC	NL					X	X										
Varanidae	*Varanus acanthurus*	Ridge-tailed Monitor	LC	NL		X														
Amphibians																				
Hylidae	*Cyclorana longipes*	Long-footed Frog	LC	NL					X											
Hylidae	*Litoria caerulea*	Common Green Treefrog	LC	NL	X	X	X		X			X								
Hylidae	*Litoria rubella*	Ruddy Treefrog	LC	NL	X		X					X								
Birds																				
Acanthizidae	*Smicrornis brevirostris*	Weebill	LC	NL	X	X	X		X	X		X	X		X				X	X
Accipitridae	*Accipiter cirrocephalus*	Collared Sparrowhawk	LC	NL							X		X							
Accipitridae	*Aquila audax*	Wedge-tailed Eagle	LC	NL									X							
Accipitridae	*Elanus axillaris*	Black-shouldered Kite	LC	NL	X				X											
Accipitridae	*Haliastur sphenurus*	Whistling Kite	LC	NL									X	X						
Aegothelidae	*Aegotheles cristatus*	Australian Owlet-nightjar	LC	NL				X												
Artamidae	*Artamus cinereus melanops*	Black-faced Woodswallow	LC	NL	X			X			X	X	X							
Artamidae	*Artamus personatus*	Masked Woodswallow	LC	NL	X								X							
Artamidae	*Cracticus nigrogularis*	Pied Butcherbird	LC	NL	X			X	X	X										
Artamidae	*Cracticus tibicen*	Australian Magpie	LC	NL	X								X							
Cacatuidae	*Nymphicus hollandicus*	Cockatiel	LC	NL															X	
Campephagidae	*Coracina novaehollandiae*	Black-faced Cuckoo-shrike	LC	NL	X	X	X	X					X						X	
Campephagidae	*Lalage sueurii*	White-winged Triller	LC	NL	X						X	X								
Climacteridae	*Climacteris melanura*	Black-tailed Treecreeper	LC	NL									X							
Columbidae	*Geopelia cuneata*	Diamond Dove	LC	NL	X			X					X		X	X				X
Columbidae	*Geopelia striata*	Peaceful Dove	LC	NL	X	X	X			X	X		X		X					X
Columbidae	*Geophaps plumifera*	Spinifex Pigeon	LC	NL	X															
Columbidae	*Ocyphaps lophotes*	Crested Pigeon	LC	NL										X						
Columbidae	*Phaps chalcoptera*	Common Bronzewing	LC	NL	X			X		X	X		X					X		X
Corcoracidae	*Eurystomus orientalis*	Dollarbird	LC	NL	X															
Corcoracidae	*Struthidea cinerea*	Apostlebird	LC	NL	X				X											
Corvidae	*Corvus coronoides*	Australian Raven	LC	NL											X					
Corvidae	*Corvus orru*	Torresian Crow	LC	NL		X	X							X	X					
Cuculidae	*Cacomantis variolosus*	Brush Cuckoo	LC	NL							X	X								

Family	Scientific Name	Common Name	Conservation Status		Wet season Survey								Dry Season Survey							
			NC Act / LP Act	EPBC Act	OPPS	FA1	FA2	FA3	FA4	FA5	FA6	FA7	OPPS	FA1	FA2	FA4	FA5	FA6	FA7	FA8
Cuculidae	*Eudynamys orientalis*	Eastern Koel	LC	NL	X						X									
Estrildidae	*Taeniopygia bichenovii*	Double-barred Finch	LC	NL	X	X	X		X		X	X	X		X					X
Estrildidae	*Taeniopygia guttata*	Zebra Finch	LC	NL	X			X		X	X		X	X	X					
Eurostopodidae	*Eurostopodus argus*	Spotted Nightjar	LC	NL	X															
Falconidae	*Falco berigora*	Brown Falcon	LC	NL	X								X							
Halcyonidae	*Dacelo leachii*	Blue-winged Kookaburra	LC	NL	X		X													X
Halcyonidae	*Todiramphus pyrrhopygius*	Red-backed Kingfisher	LC	NL	X															
Halcyonidae	*Todiramphus sanctus*	Sacred Kingfisher	LC	NL	X		X													
Maluridae	*Malurus lamberti*	Variegated Fairy-wren	LC	NL	X	X		X		X			X			X				X
Maluridae	*Malurus leucopterus*	White-winged Fairy-wren	LC	NL	X				X	X										
Maluridae	*Malurus melanocephalus*	Red-backed Fairy-wren	LC	NL	X								X							
Megaluridae	*Cincloramphus mathewsi*	Rufous Songlark	LC	NL	X						X									
Meliphagidae	*Lichmera indistincta*	Brown Honeyeater	LC	NL	X														X	
Meliphagidae	*Ptilotula keartlandi*	Grey-headed Honeyeater	LC	NL						X			X	X						
Meliphagidae	*Philemon citreogularis*	Little Friarbird	LC	NL		X		X		X	X	X								
Meliphagidae	*Melithreptus gularis laetior*	Golden-backed Honeyeater	NT	NL									X						X	
Meropidae	*Merops ornatus*	Rainbow Bee-eater	LC	Mi	X		X				X	X	X							
Monarchidae	*Grallina cyanoleuca*	Magpie-lark	LC	NL	X		X		X				X				X			
Monarchidae	*Myiagra inquieta*	Restless Flycatcher	LC	NL	X	X	X			X		X		X	X	X				X
Otididae	*Ardeotis australis*	Australian Bustard	LC	NL	X															
Pachycephalidae	*Colluricincla harmonica*	Grey Shrike-thrush	LC	NL	X					X			X							
Pachycephalidae	*Pachycephala rufiventris*	Rufous Whistler	LC	NL	X	X	X			X		X	X	X	X				X	X
Pardalotidae	*Pardalotus striatus*	Striated Pardalote	LC	NL									X		x					X
Petroicidae	*Microeca fascinans*	Jacky Winter	LC	NL	X															
Phasianidae	*Coturnix pectoralis*	Stubble Quail	LC	NL	X															
Pomatostomidae	*Pomatostomus temporalis rubeculus*	Grey-crowned Babbler (north-western)	LC	NL	X	X	X	X	X					X			X			
Psittacidae	*Aprosmictus erythropterus*	Red-winged Parrot	LC	NL						X										
Psittacidae	*Melopsittacus undulatus*	Budgerigar	LC	NL									X	X	X			X	X	X
Psittacidae	*Psitteuteles versicolor*	Varied Lorikeet	LC	NL		X	X													
Ptilonorhynchidae	*Ptilonorhynchus maculatus*	Spotted Bowerbird	LC	NL									X							
Rhipiduridae	*Rhipidura leucophrys*	Willie Wagtail	LC	NL	X				X				X	X						
Mammals																				
Bovidae	*Bos taurus*	Cow	I	NL		X	X		X	X										
Canidae	*Canis familiaris*	Wild Dog	C2	NL									*							
Dasyuridae	*Planigale maculata*	Common Planigale	LC	NL													X			
Dasyuridae	*Sminthopsis macroura*	Stripe-faced Dunnart	LC	NL							#									
Macropodidae	*Lagorchestes conspicillatus*	Spectacled Hare-wallaby	LC	NL				X		X										
Macropodidae	*Macropus robustus*	Common Wallaroo	LC	NL	X						X		X						X	
Macropodidae	*Petrogale purpureicollis*	Purple-necked Rock-wallaby	V	NL	X			X										*	X	X
Hipposideridae	*Hipposideros ater*	Eastern Dusky Leaf-nosed Bat	LC	NL		X	X													
Suidae	*Sus scrofa*	Pig	C2	NL											X	*	*			
Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat	LC	NL		X	X	X	X	X	X			^	^				^	^
Vespertilionidae	*Chalinolobus nigrogriseus*	Hoary Wattled Bat	LC	NL		X	X	X	X		X								^	^
Vespertilionidae	*Nyctophilus sp.*					X	X		X											
Vespertilionidae	*Scotorepens balstoni*	Inland Broad-nosed Bat	LC	NL		X	X	X	X	X				^	^				^	^
Vespertilionidae	*Scotorepens greyii*	Little Broad-nosed Bat	LC	NL		X	X	X	X	X	X								^	^
Vespertilionidae	*Vespadelus baverstocki*	Inland Forest Bat	LC	NL															^	^
Vespertilionidae	*Vespadelus finlaysoni*	Finlayson's Cave Bat	LC	NL																^
Molossidae	*Chaerephon jobensis*	Northern Freetail Bat	LC	NL		X	X	X	X	X	X								X	X
Molossidae	*Mormopterus beccarii*	Beccari's Freetail Bat	LC	NL		X	X	*	X		X									
Molossidae	*Mormopterus sp.*					X	*	*	*											
Emballonuridae	*Saccolaimus flaviventris*	Yellow-bellied Sheathtail Bat	LC	NL		X	X	X	X		X									

Family	*Scientific Name*	Common Name	Conservation Status		Wet season Survey								Dry Season Survey							
			NC Act / LP Act	EPBC Act	OPPS	FA1	FA2	FA3	FA4	FA5	FA6	FA7	OPPS	FA1	FA2	FA4	FA5	FA6	FA7	FA8
Emballonuridae	*Taphozous georgianus*	Common Sheathtail Bat	LC	NL		X	X	X	X		X				X					
Emballonuridae	*Taphozous troughtoni*	Troughton's Sheathtail Bat	LC	NL		X	X		X		X									

Key:

LC – This species is classified as Least Concern under the NC Act

V – This species is classified as Vulnerable under either the EPBC Act and/or NC Act

I – Introduced species

C2 – Declared Class 2 pest species as classified under the LP Act

NL – This species is not listed under the EPBC Act as a species of conservation significance

- Probable identification of species from hair samples

* - Species identified from tracks, scats or other traces

^ - Probable species identification from bat calls

Appendix E Bat Call Analysis Results

Anabat echolocation data interpretation summary

Client: AARC (Mark Sanders via Paul Jackson) **Balance Job no.:** AARC1103

Project name/location: Mt Remarkable, NW of Cloncurry (March 2011)

Data summary tables

Numbers in columns indicate number of calls attributed to species/group for given night

Date:	28-Mar	29-Mar	30-Mar	31-Mar	1-Apr	Total Calls
No. sequence files recorded:	286	884	48	2	3	
Species positively identified (i.e. species definitely present)						
Chalinolobus gouldii	8	12	1			21
Nyctophilus species	18					18
Scotorepens balstoni	19	27	10			56
Vespadelus baverstocki	48	9	1			58
Vespadelus caurinus / V. finlaysoni	14	1				15
Mormopterus beccarii	2	1	1			4
Saccolaimus flaviventris	35	54	20			109
Taphozous georgianus	1					1
Total calls positively identified	145	104	33	0	0	282
Calls NOT positively identified *						
Chalinolobus gouldii / Scotorepens balstoni	1	56	7			64
C. gouldii / S. balstoni / Mormopterus species	32	22	1			55
Scotorepens greyii / Vespadelus baverstocki	32	11				43
Scotorepens greyii / Chalinolobus nigrogriseus	40	115				155
Chaerephon jobensis / Saccolaimus flaviventris	3	1				4
Mormopterus beccarii / Saccolaimus flaviventris		1	1			2
Mormopterus beccarii / Taphozous troughtoni	1					1
Unknown bat - linear w. 45° knee Fc42-45kHz	43	5				48
Unidentified bat calls	9	58				67
Total calls not positively identified	161	269	9	0	0	439
Total calls for site/night	**306**	**373**	**42**	**0**	**0**	**721**

* A species listed in the bottom section of the table that is not also listed in the top section should be considered as possibly present. Likelihood of occurrence and call identification issues for these species are discussed in the 'Reliability of species ID' section on the following pages.

Species nomenclature:

Species names used in this summary follow Churchill (2008), except for the free-tailed bats (Molossidae), which follow van Dyck & Strahan (2008) and Adams *et al.* (1988).

Call identification & reporting standard:

No bat call identification guide or key exists for the region from which these data were collected.

Call identification was based on published call descriptions (Milne 2001; Reinhold *et al* 2001; and Pennay *et al.* 2004); and on reference calls collected from various locations in Queensland, New South Wales & the Northern Territory.

Determination of species' identification was further refined by considering probability of occurrence based on distributional information presented in Churchill (2008) and van Dyck & Strahan (2008).

The format and content of this report complies with nationally accepted standards for the interpretation and reporting of Anabat data (Reardon 2003); latest version available from the Australasian Bat Society on-line at http://www.ausbats.org.au/.

Anabat echolocation data interpretation summary

Client: AARC (Mark Sanders via Paul Jackson) **Balance Job no.:** AARC1103

Project name/location: Mt Remarkable, NW of Cloncurry (March 2011)

Reliability of species ID

***Nyctophilus* species**

Nyctophilus bats generally produce distinctive calls, but the species cannot be reliably differentiated from call data. The species most likey to be present in the study area is *N. geoffroyi* . Three other species (*N. arnhemensis* , *N. daedelus* and *N. walkeri*) also occur in the far north-west of Queensland but are primarily restricted to moist habitats such as watercourses lined with pandanus and paperbark.

Vespadelus caurinus / V. finlaysoni

These species produce distinctive calls with hooked pulses at higher frequency (>50kHz) than any other species (with similar pulse shape) that would occur in the area. Most calls attributed to this species pair were in the range 57-58kHz, with a couple of sequences having slightly lower frequency (*ca.* 55kHz). The higher frequency is most likely to represent *V. caurinus* and the lower frequency *V. finlaysoni* ; however, the full range of both species is poorly known, so all calls were attributed to the pair rather than attempting an unreliable species split.

***Chalinolobus gouldii / Scotorepens balstoni / Mormopterus* species**

C. gouldii (28-34kHz) has steep and curved pulses that usually alternate in frequency by 2-3kHz. *S. balstoni* (30-36kHz) pulses are also steep and curved but do not alternate in frequency. *Mormopterus* sp (30-34kHz) pulses are generally much flatter; however, pulses sometimes steepen when flying close to vegetation and brief calls may be confused with calls from the other two spp. Similarly, *C. gouldii* and *S. balstoni* pulses sometimes lack steep initial broad-band frequency sweeps when flying in open space and these calls can appear similar to those of *Mormopterus* .

A number of steep-pulsed calls at 30-34kHz were listed as either *C. gouldii* or *S. balstoni* because they were brief and/or weak and/or showed inconclusive evidence of frequency alternation and could not be reliably distinguished. *C* alls with similarly low quality but obviously less steep pulses could have been from any of these three species. If from *Mormopterus* sp., these calls probably represent one of the un-named species in the *M. 'loriae'* complex, presumably *M.* 'species 5' (Adams et al. 1988).

Scotorepens greyii / Chalinolobus nigrogriseus

Signficant frequency overlap occurs in the range 36-39kHz, but pulse shape is sometimes diagnostic. Some *C. nigrogriseus* have flatter body of longer duration (2/3 of total pulse duration) compared with cup-shaped body of shorter duration in *S. greyii* . Most calls (and all from this survey), however, exhibit pulses with intermediate features or a mixture of pulse types and cannot be reliably differentiated.

Scotorepens greyii / Vespadelus baverstocki

S. greyii (35-40kHz) calls overlap in frequency with and have very similar pulse shapes to *V. baverstocki* (39-46kHz). A number of calls within the frequency overlap zone (39-40kHz) could have been from either of these species.

Cherephon jobensis / Saccolaimus flaviventris / Taphozous georgianus / T. troughtoni / Mormopterus beccarii

Frequency overlap occurs between these spp across a range of about 12kHz: *C. jobensis* (15-21kHz); *S. flaviventris* (17-22kHz); *T. georgianus* (21-23kHz); *T. troughtoni* (23-25kHz); *M. beccarii* (21-27kHz). Where good quality signals are recorded (i.e. long duration call sequence with numerous clearly defined pulses) species identity is usually discernible due to the shape and uniformity of pulses within the sequence. Most of the calls from this survey were of sufficient quality to be reliably attributed to one or other of these species. A few calls in this frequency range, however, were too brief and/or weak and/or noisy to be reliably identified.

Unknown bat - linear w. 45° knee Fc42-45kHz

A number of calls recorded in this survey exhibit distinctive pulse shape and frequency characteristics that cannot be readily attributed to any known species that would occur in the study area. The broad initial frequency sweep is steep with a distinct "knee" in the lower third and a straight, downward-sloping body at about 45° to the initial slope. The body lies between about 42-47kHz, with characteristic frequency (Fc) ranging from 42-44kHz.

The calls are superficially similar to those of *Miniopterus orianae oceanensis* , which is not known to occur west of Cape York. Given the frequency range of these calls and the presence of call sequences attributed to *Vespadelus baverstocki* during the same periods as these unknown calls were recorded, it is probable that they represent an unusual variant of that species, rather than another unknown species.

Unidentified bat calls

Many calls were too brief and/or weak and/or contained too much interference to enable reliable identification to species. All such calls were within frequency ranges of one or more species otherwise identified from the data and do not represent additional species.

Anabat echolocation data interpretation summary

Client: AARC (Mark Sanders via Paul Jackson) **Balance Job no.:** AARC1103

Project name/location: Mt Remarkable, NW of Cloncurry (March 2011)

References:

Adams, M., Reardon, T., Baverstock, P.R. and Watts, C.H.S. (1988). Electrophoretic resolution of species boundaries in Australian Microchiroptera. IV. The Molossidae (Chiroptera). *Australian Journal of Biological Sciences* **41**, 315-326.

Churchill, S. (2008). *Australian Bats* . Jacana Books, Allen & Unwin; Sydney.

Milne, D.J. (2002). *Key to the Bat Calls of the Top End of the Northern Territory.* Technical Report No. 71, Parks and Wildlife Commission of the Northern Territory, Darwin.

Pennay, M., Law, B. and Reinhold, L. (2004). *Bat Calls of New South Wales.* Department of Environment and Conservation, Hurstville.

Reardon, T. (2003). Standards in bat detector based surveys. *Australasian Bat Society Newsletter* **20**, 41-43.

Reinhold, L., Law, B., Ford, G. and Pennay, M. (2001). *Key to the bat calls of south-east Queensland and north-east New South Wales.* Department of Natural Resources and Mines, Brisbane.

van Dyck, S. and Strahan, R. (ed.) (2008). *The Mammals of Australia* (Third Edition); New Holland; Sydney.

Anabat Data Analysis Summary

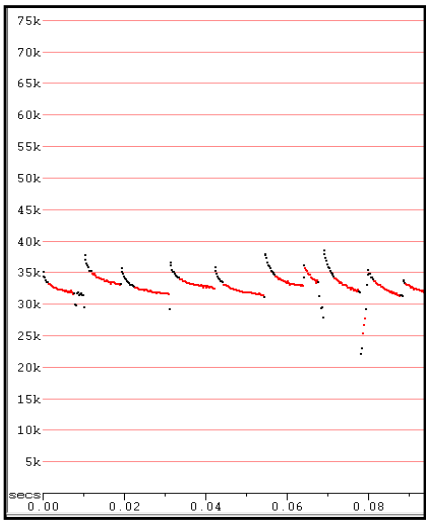
Client: AARC (Mark Sanders via Paul Jackson) **Balance Job no.:** AARC1103

Project name/location: Mt Remarkable, NW of Cloncurry (March 2011)

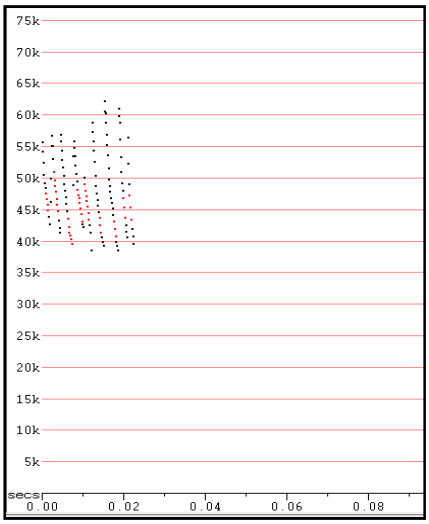
Sample calls extracted from the survey data.

Scale: 10 msec per tick; time between pulses removed (AnalookW F7 compressed mode)

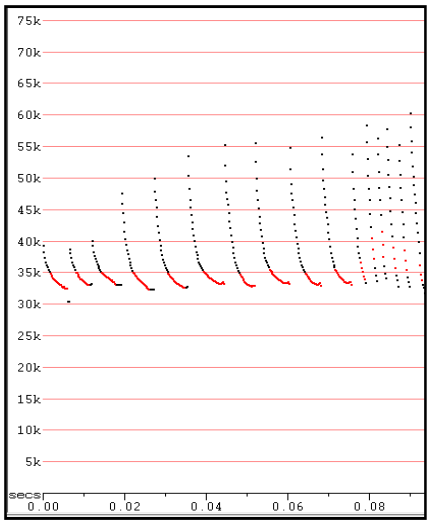
Species positively identified



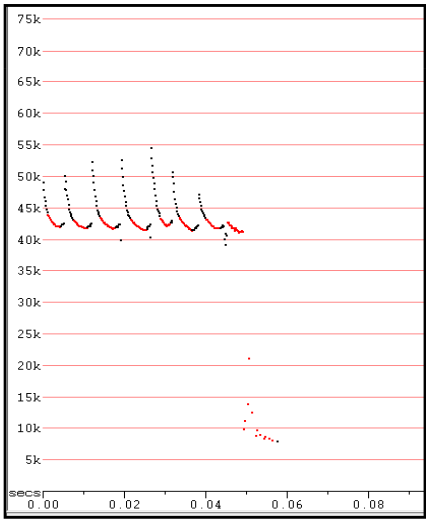
Chalinolobus gouldii



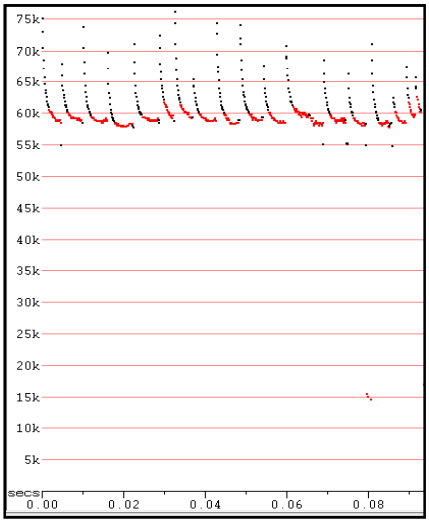
Nyctophilus species



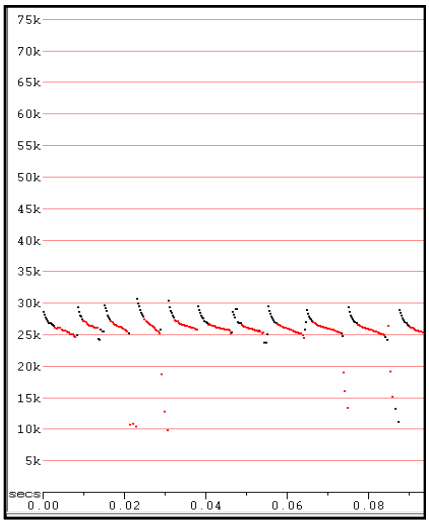
Scotorepens balstoni



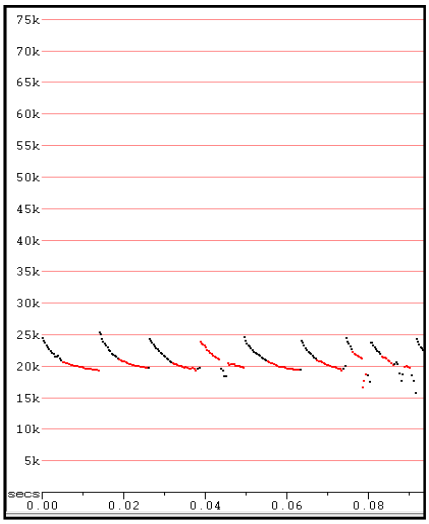
Vespadelus baverstocki



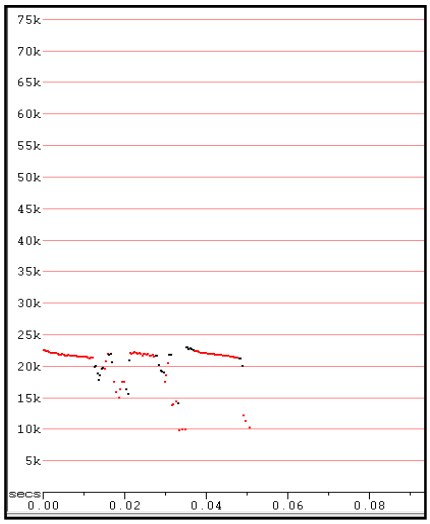
Vespadelus caurinus / V. finlaysoni



Mormopterus beccarii



Saccolaimus flaviventris



Taphozous georgianus

Anabat Data Analysis Summary

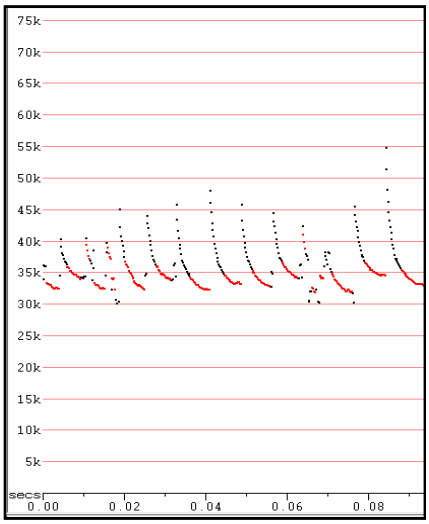
Client: AARC (Mark Sanders via Paul Jackson) **Balance Job no.:** AARC1103

Project name/location: Mt Remarkable, NW of Cloncurry (March 2011)

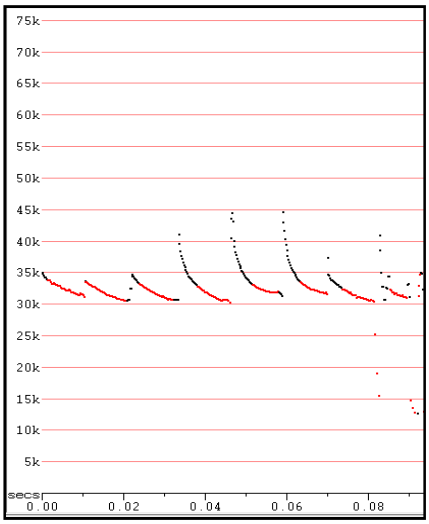
Sample calls extracted from the survey data.

Scale: 10 msec per tick; time between pulses removed (AnalookW F7 compressed mode)

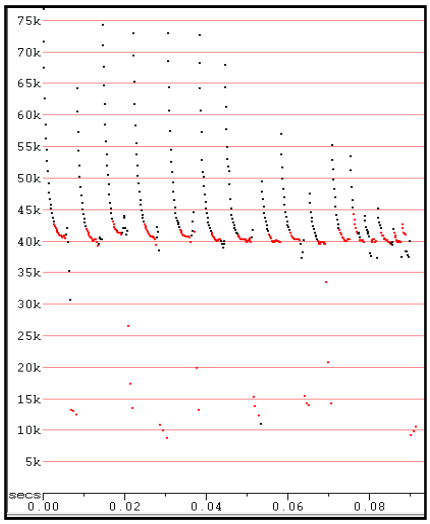
Calls NOT positively identified



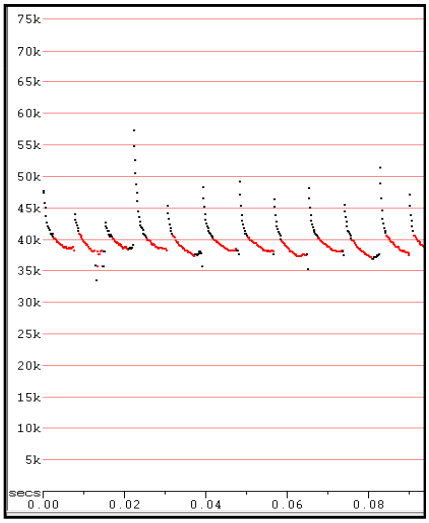
C. gouldii / S. balstoni



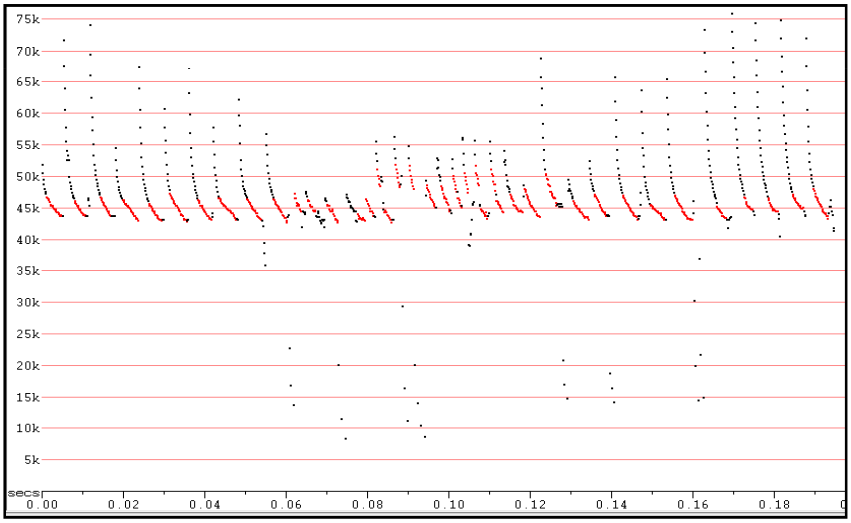
C. gouldii / S. balstoni / Mormopterus sp



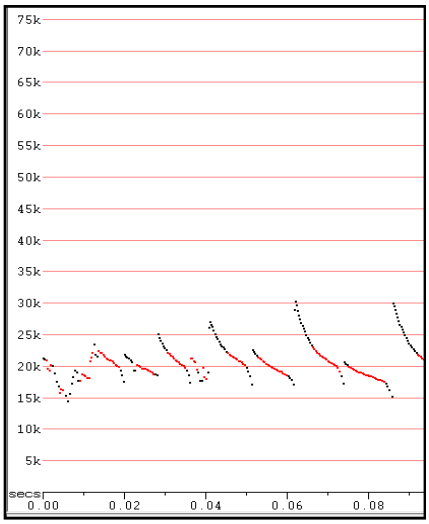
S. greyii / V. baverstocki



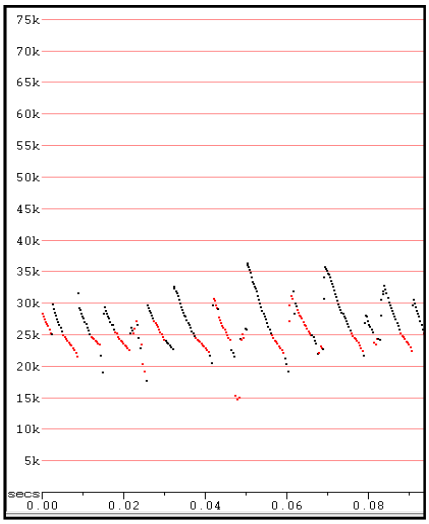
S. greyii / C. nigrogriseus



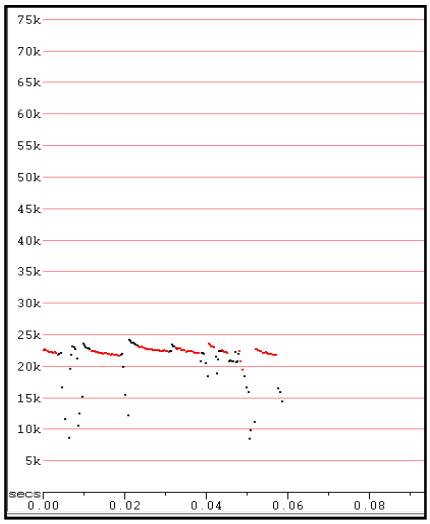
Unknown bat - linear w. 45° knee Fc42-45kHz



C. jobensis / S. flaviventris



M. beccarii / S. flaviventris



M. beccarii / T. troughtoni

Anabat echolocation data interpretation summary

Client: AARC (Mitch Gregory) **Balance Job no.:** AARC1113

Project name/location: East of Mount Isa, 10-26 October 2011

Data summary table

Numbers in columns refer to number of calls attributed to a species for a given night/site. Please note that these ***numbers do not imply relative abundance*** of the various species recorded. They may, however, be construed to represent relative differences in activity levels between the species.

Date:	**10-Oct**	**11-Oct**	**12-Oct**	**13-Oct**	**23-Oct**	**24-Oct**	**25-Oct**
No. sequence files recorded:	**43**	**11**	**182**	**27**	**169**	**422**	**139**
Species positively identified (i.e. species definitely present)							
Chalinolobus gouldii	1		44	2	6	258	3
Scotorepens balstoni			2	1	1	3	
Scotorepens greyii	1		6	4	6	5	2
Vespadelus baverstocki	1		34		1	2	
Vespadelus finlaysoni		3	4			14	
Chaerephon jobensis	2					1	
Mormopterus beccarii					1	3	1
Saccolaimus flaviventris			6		18	3	
Total calls positively identified	5	3	96	7	33	289	6
Calls NOT positively identified *							
Chalinolobus gouldii or Scotorepens balstoni		1			2	3	
S. greyii or *Chalinolobus nigrogriseus*	2	1	3	2	3	13	
Nyctophilus species							1
Mormopterus species or *C. gouldii*	1			1	9	13	61
C. jobensis or *S. flaviventris*	2		1		1	1	5
S. flaviventris or *Mormopterus beccarii*						8	3
M. beccarii or *Taphozous georgianus*	1				2		
Unidentified bat calls			11		1	75	13
Total calls NOT positively identified	6	2	15	3	18	113	83
Total calls for site/night	**11**	**5**	**111**	**10**	**51**	**402**	**89**

* A species listed in the bottom section of the table that is not also listed in the top section should be considered as possibly present. Likelihood of occurrence and call identification issues for these species are discussed in the 'Reliability of species ID' section on the following pages.

Species nomenclature:

Species names used in this summary follow Churchill (2008).

Call identification & reporting standard:

Call identification was based on published call descriptions for Qld (Reinhold *et al* 2001), NSW (Pennay *et al.* 2004) and the Northern Territory (Milne 2001); and on reference calls collected from various localities in Queensland.

Determination of species' identification was further refined by considering probability of occurrence based on distributional information presented in Churchill (2008) and van Dyck & Strahan (2008).

The format and content of this report complies with nationally accepted standards for the interpretation and reporting of Anabat data (Reardon 2003); latest version available from the Australasian Bat Society on-line at http://www.ausbats.org.au/.

Anabat echolocation data interpretation summary

Client: AARC (Mitch Gregory) **Balance Job no.:** AARC1113

Project name/location: East of Mount Isa, 10-26 October 2011

Reliability of species ID:

Chalinolobus gouldii* or *Scotorepens balstoni

C. gouldii (Fc=28-34kHz) has steep and curved pulses that usually alternate in frequency by 2-3kHz. *S. balstoni* produces pulses of similar shape that overlap in frequency (Fc=30-35kHz), but which lack frequency alternation. Numerous calls were positively attributable to both species based on these criteria; however, a few brief or poor quality calls in the range could have been from either species.

S. greyii or Chalinolobus nigrogriseus

These species' calls overlap in frequency and often have similar pulse shapes; however, they can sometimes be differentiated on subtle differences in pulse shape (*S. greyii* pulses are more curved and have upward-sloping tail *cf.* no tail or down-sloping tail in *C. nigrogriseus*). A number of calls were reliably attributable to *S. greyii* based on this characteristics, but some calls had intermediate pulse shape features and could have been from either of these species.

Mormopterus eleryi (=*Mormopterus* 'species 6') is also known to produce calls similar to those of *S. greyii* (Reardon *et al* 2008) and may hae been responsible for some of these calls.

***Nyctophilus* species**

Nyctophilus bats generally produce distinctive calls, but the species within the genus cannot be reliably differentiated from call data. Just one call was attributed to this group - it had the typical linear pulse shape of the genus, but the sequence was weak and very noisy. The species most likely to be present in the study area is *N. geoffroyi* although it is possible that both *N. daedelus* and *N. arnhemsis* also occur at this locality.

Mormopterus* species or *C. gouldii

Several *Mormopterus* species produce calls around 30-34kHz, which overlap in frequency with those of *C. gouldii* ; however, differentiation is often possible due to the flatter pulse shape in *Mormopterus* and lack of frequency alternation that is common in *C. gouldii* . Most calls in the frequency range were reliably attributable to *C. gouldii* ; however, a number of calls appeared to have consistently flat pulses andcould havebeen from *Mormopterus* sp.

The distribution and taxonomy of the *Mormopterus* species that use this call type is somewhat confusing; and it is difficult to know which species may occur in the study area. Potential candidates for this call type include: inland free-tailed bat (*M.* 'species 3') and little northern free-tailed bat (*M.* 'species 5'/*M. loriae*). The hairy-nosed free-tailed bat (*M. eleryi* /*M.* 'species 6') also occurs in this region, but has calls more like those of *S. greyii* (see above).

C. jobensis or S. flaviventris

C. jobensis (15-21kHz) calls generally have uneven or erratic pulse shapes and frequency within a given call sequence, compared with mostly uniform pulse shape and regular frequency in *S. flaviventris* (17-22kHz). Most of the calls within the relevant frequency range were reliably attributed to one or other of these species; however, a few calls were too brief and/or weak and/or noisy to be reliably attributed to either species.

S. flaviventris or Mormopterus beccarii

These species are generally distinguishable on frequency differential (*S. flaviventris* <22kHz; *M. beccarii* >23kHz) and pulse shape (steeper curves in *M. beccarii*). Numerous calls were attributed to *S. flaviventris* on this basis, and a few also to *M. beccarii* . Several brief calls, however, had intermediate pulse shapes with frequency around 22-23kHz and could have been from either species.

M. beccarii or Taphozous georgianus

T. georgianus calls (23-25kHz) overlap completely in frequency with those of *M. beccarii* (21-27kHz). Where good quality signals are recorded (i.e. long duration call sequence with numerous clearly defined pulses) *T. georgianus* calls generally have more consistent pulse shape and frequency within the sequence. Several calls were attributed to *M. beccarrii* based on the steeper and somewhat more erratic pulse shape; however, a few calls had flatter, more even pulses and could have been from either species.

Unidentified bat calls

Many calls were brief and/or weak and/or lacked conclusive evidence of identifiable characteristics, thus precluding reliable identification to species level. All such calls were within frequency ranges of one or more species otherwise identified from the data and do not represent additional species.

Anabat echolocation data interpretation summary

Client: AARC (Mitch Gregory) **Balance Job no.:** AARC1113

Project name/location: East of Mount Isa, 10-26 October 2011

References:

Churchill, S. (2008). *Australian Bats* . Jacana Books, Allen & Unwin; Sydney.

Milne, D.J. (2002). *Key to the Bat Calls of the Top End of the Northern Territory.* Technical Report No. 71, Parks and Wildlife Commission of the Northern Territory, Darwin.

Pennay, M., Law, B. and Reinhold, L. (2004). *Bat Calls of New South Wales.* Department of Environment and Conservation, Hurstville.

Reardon, T. (2003). Standards in bat detector based surveys. *Australasian Bat Society Newsletter* **20**, 41-43.

Reardon, T., Adams, M., McKenzie, N. and Jenkins, P. (2008). A new species of Australian freetail bat *Mormopterus eleryi* sp. nov. (Chiroptera: Molossidae) and a taxonomic reappraisal of *M. norfolkensis* (Gray). *Zootaxa* **1875:** 1-31.

Reinhold, L., Law, B., Ford, G. and Pennay, M. (2001). *Key to the bat calls of south-east Queensland and north-east New South Wales.* Department of Natural Resources and Mines, Brisbane.

van Dyck, S. and Strahan, R. (ed.) (2008). *The Mammals of Australia* (Third Edition); New Holland; Sydney.

Anabat Data Analysis Summary

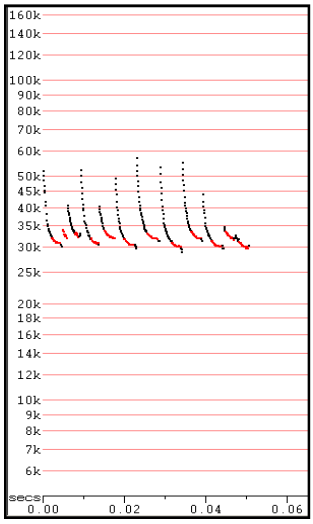
Client: AARC (Mitch Gregory) **Balance Job no.:** AARC1113

Project name/location: East of Mount Isa, 10-26 October 2011

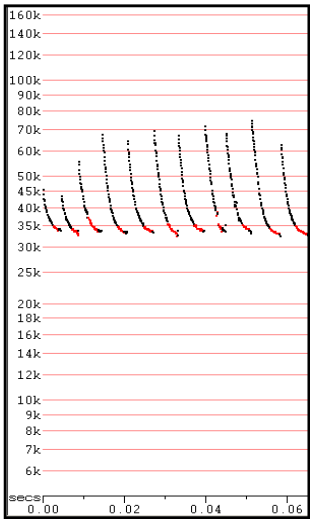
Sample calls extracted from the survey data.

Scale: 10 msec per tick; time between pulses removed (AnalookW F7 compressed mode)

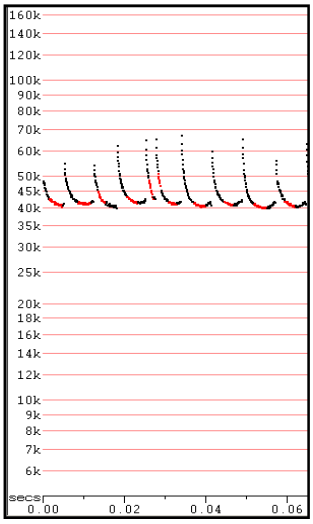
Species positively identified



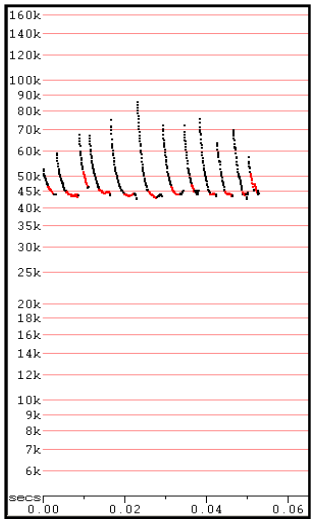
Chalinolobus gouldii



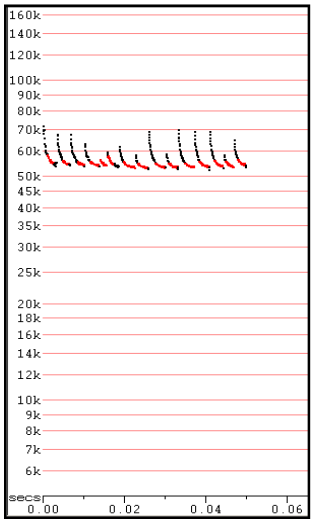
Scotorepens balstoni



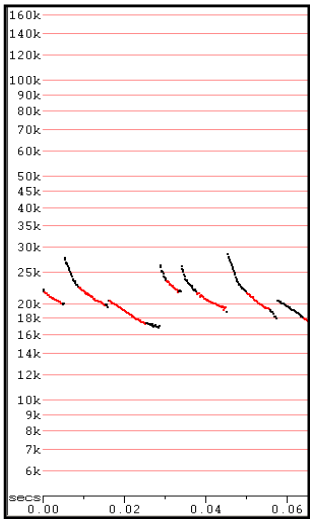
Scotorepens greyii



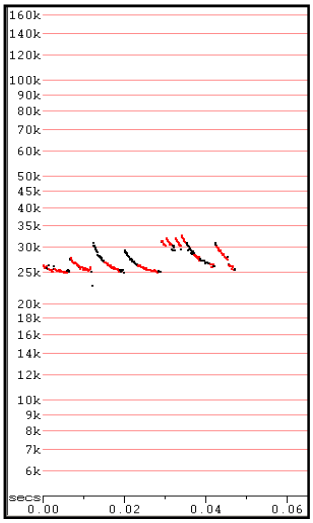
Vespadelus baverstocki



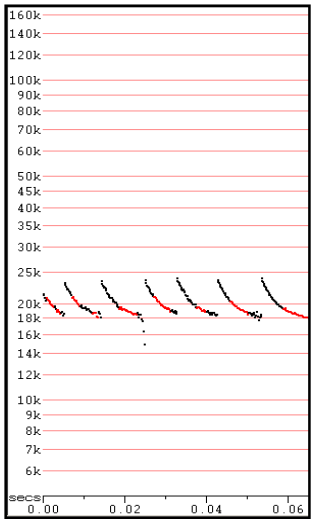
Vespadelus finlaysoni



Chaerephon jobensis



Mormopterus beccarii



Saccolaimus flaviventris

Anabat Data Analysis Summary

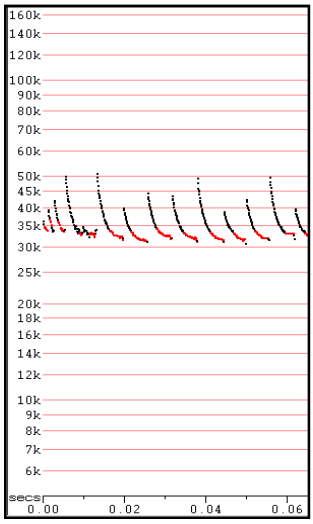
Client: AARC (Mitch Gregory) **Balance Job no.:** AARC1113

Project name/location: East of Mount Isa, 10-26 October 2011

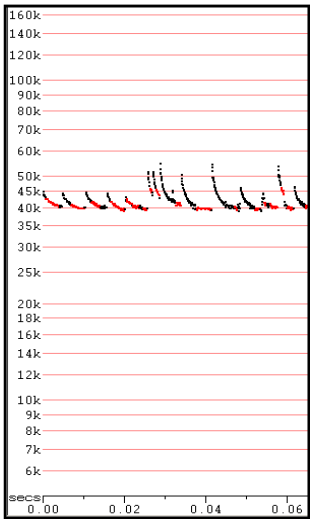
Sample calls extracted from the survey data.

Scale: 10 msec per tick; time between pulses removed (AnalookW F7 compressed mode)

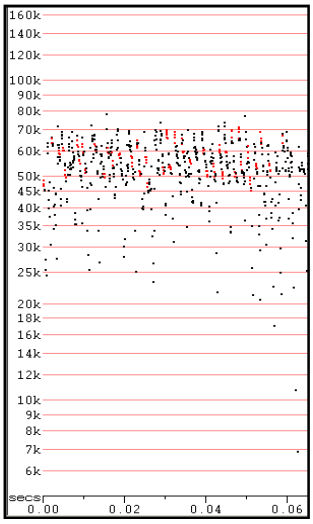
Calls NOT positively identified



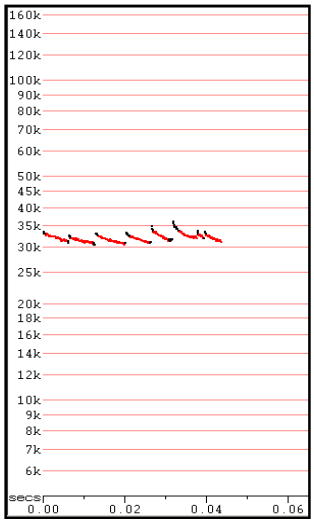
C. gouldii or S. balstoni



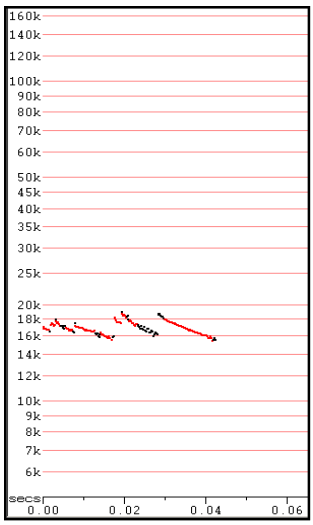
S. greyii or *C. nigrogriseus*



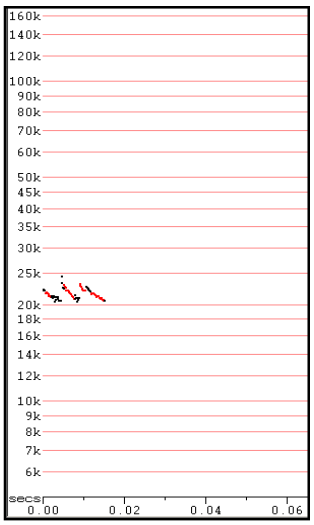
Nyctophilus species



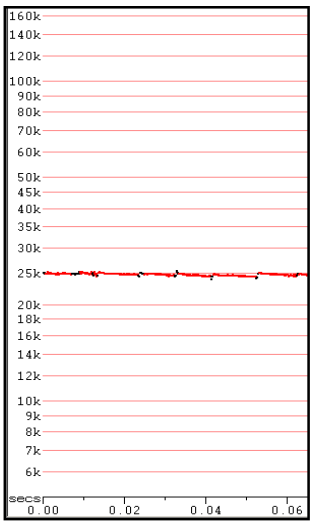
Mormopterus sp. or *C. gouldii*



C. jobensis or *S. flaviventris*



S. flaviventris or *M. beccarii*



M. beccarii or *T. georgianus*

Microbat Call Identification Report

Prepared for ("Client"):	AustralAsian Resource Consultants
Survey location/project name:	Barbara (Mt Isa)
Survey dates:	January-February 2014
Client project reference:	
Job no.:	AARC1402
Report date:	26 May 2014

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Methods

Data receipt and processing

Bat call data were recorded using Anabat (Titley Scientific, Brisbane) and Song Meter SM2 detectors (Wildlife Acoustics, USA), with the Anabat recordings saved in Anabat raw data format and the SM2 recordings saved as compressed audio files (WAC format).

Two data sets were received for analysis, with the accompanying field data sheets indicating the following expected contents:

Data set	Detector name	Recording dates	Site
1	Anabat	Nights of 4/2/14 - 6/2/14	FA6
	Song Meter 2	Nights of 30/1/14 - 1/2/14	FA1
		Nights of 2/2/14 - 4/2/14	FA4
		Nights of 5/2/14 - 6/2/14	FA5
	Song Meter 6	Nights of 30/1/14 - 1/2/14	FA2
		Nights of 2/2/14 - 4/2/14	FA3
		Nights of 5/2/14 - 6/2/14	FA7
2	Song Meter 8	Nights of 25/2/14 - 26/2/14	AQ1
		Nights of 27/2/14 - 28/2/14	AQ4

All received data files were converted to Anabat sequence file format (zero-crossing analysis, or ZCA files) prior to call analysis. The Anabat data file from Data Set 1 was converted with the *CFCread* program (Corben 2012), yielding 180 sequence files recorded over the three nights. Wildlife Acoustics' *Kaleidoscope* software was used to convert the SM2 WAC files. This process yielded some 1800 files for the two SM2 detectors submitted in Data Set 1; however, no bat call data could be extracted from the WAC files received in Data Set 2.

Relatively few sequence files were recorded from Site FA5 compared with the other sites where SM2 was deployed; and no data were recorded by SM6 at Site FA7. This lack of data from the final two nights of survey by each detector suggests that the batteries may have failed rather than reflecting a true absence of bat activity at those sites.

Bat call identification

All sequence files were analysed using *AnalookW* (Corben 2013) and a subset of 623 files containing representative samples of all call types recorded at each site were selected for identification. Species identification was achieved manually by comparing the *AnalookW* call sonograms with those of regionally-relevant reference calls and with published call descriptions (e.g. Reinhold *et al.* 2001; Milne 2002; Pennay *et al*. 2004).

Species' identification was also guided by considering their probability of occurrence based on general distribution information (Churchill 2008; van Dyck *et al.* 2013) and/or database records obtained from Wildlife Online (http://www.ehp.qld.gov.au/wildlife/wildlife-online/index.html) and/or the Atlas of Living Australia (http://www.ala.org.au).

Reporting standard

The format and content of this report follows Australasian Bat Society standards for the interpretation and reporting of bat call data (Reardon 2003), available on-line at http://www.ausbats.org.au/.

Species nomenclature follows van Dyck *et al.* (2013).

Results & Discussion

Some 800 individual bat calls were selected for identification.

Ten call types were identified positively to individual species, with two others attributable to genus level but not further differentiated. These unresolved calls included:

- near-vertical, linear FM pulses with characteristic frequency (Fc) of 40-50 kHz, from a *Nyctophilus* species bat (*N. arnhemensis, N. bifax* and *N. geoffroyi* all potentially occur in the study area); and
- relatively flat FM-qCF pulses with Fc=30-32 kHz, probably representative of a small *Mormopterus* species (similar to calls produced by *M.* 'species 3').

Table 1 Insectivorous bats recorded during the Barbara (Mt Isa) surveys, January-February 2014.

♦ denotes species positively identified from call data.
□ denotes species possibly present, but not reliably identified.

Site:	FA1	FA2	FA3	FA4	FA5	FA6	FA7
Hipposideros ater	♦	♦					
Chalinolobus gouldii	♦	♦	♦	♦	♦	♦	
Chalinolobus nigrogriseus	♦	♦	♦	♦		♦	
Nyctophilus species	♦	♦		♦			
Scotorepens balstoni	♦	♦	♦	♦	♦		
Scotorepens greyii	♦	♦	♦	♦	♦	♦	
Chaerephon jobensis	♦	♦	♦	♦	♦	♦	
Mormopterus beccarii	♦	♦	□	♦		♦	
Mormopterus species	♦	□	□	□			
Saccolaimus flaviventris	♦	♦	♦	♦		♦	
Taphozous georgianus	♦	♦	♦	♦		♦	
Taphozous troughtoni	♦	♦		♦		♦	

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Reinhold, L., Law, B., Ford, G. and Pennay, M. (2001). *Key to the bat calls of south-east Queensland and north-east New South Wales*. Department of Natural Resources and Mines, Brisbane.

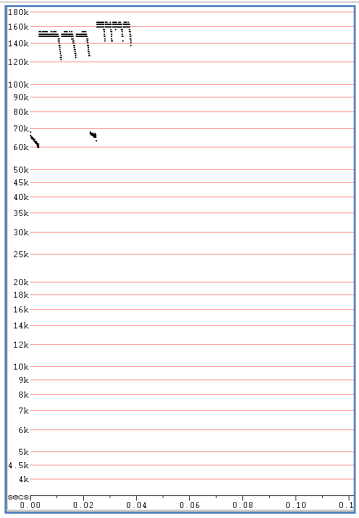
van Dyck, S., Gynther, I. and Baker, A. (eds.) (2013). *Field Companion to The Mammals of Australia*. New Holland; Sydney.

Glossary

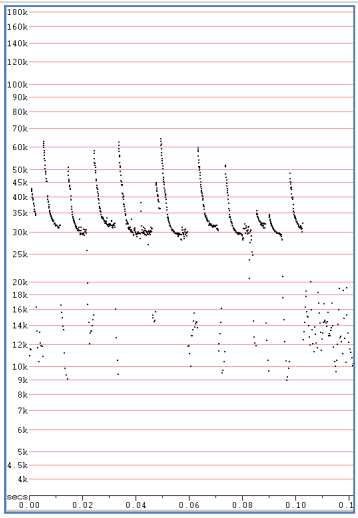
Technical terms used in this report are described in the following table.

Approach phase	The part of a bat *call* emitted as the bat starts to home in on a detected prey item; a transitional series of *pulses* between the *search phase* and *feeding buzz*, that become progressively steeper and shorter in duration.
Call	Refers to a single bat call, made up of a series of individual sound *pulses* in one or more *phases* (*search, approach, feeding buzz*).
CF (=Constant Frequency)	A type of *pulse* in which the dominant component consists of a more-or-less 'pure tone' of sound at a Constant Frequency; with *shape* appearing flat on the sonogram. Often also contains a brief *FM* component at the beginning and/or end of the CF component (*viz.* FM-CF-FM).
Characteristic frequency (Fc)	The frequency of the flattest part of a *pulse*; usually the lowest frequency reached in the *qCF* component of a pulse. This is often the primary diagnostic feature for species identification.
Duration	The time period from the beginning of a *pulse* to the end of the pulse.
Feeding buzz	The terminal part of a *call*, following the *approach phase*, emitted as the bat catches a prey item; a distinctive, rapid series of very steep, very short-duration pulses.
FM (=Frequency Modulated)	A type of *pulse* in which there is substantial change in frequency from beginning to end; *shape* ranges from almost vertical and linear through varying degrees of curvature.
FC range	Refers to the range of frequencies occupied by the *characteristic frequency* section of *pulses* within a call or set of calls.
Frequency sweep or "band-width"	The range of frequencies through which a *pulse* sweeps from beginning to end; Maximum frequency (Fmax) – minimum frequency (Fmin).
Knee	The transitional part of a *pulse* between the initial (usually steeper) frequency sweep and the *characteristic frequency* section (usually flatter); time to knee (Tk) and frequency of knee (Fk) can be diagnostic for some species.
Pulse	An individual pulse of sound within a bat *call*; the *shape*, *duration* and *characteristic frequency* of a pulse are the key diagnostic features used to differentiate species.
Pulse body	The part of the *pulse* between the *knee* and *tail* and containing the *characteristic frequency* section.
Pulse shape	The general appearance of a *pulse* on the sonogram, described using relative terms related to features such as slope and degree of curvature. See also *CF, qCF* and *FM*.
qCF (=quasi Constant Frequency)	A type of *pulse* in which there is very little change in frequency from beginning to end; *shape* appears to be almost flat. Some pulses also contain an *FM* component at the beginning and/or end of the qCF component (*viz.* FM-qCF).
Search phase	The part of a bat *call* generally required for reliable species diagnosis. A consistent series of *pulses* emitted by a bat that is searching for prey or and/or navigating through its habitat. Search phase pulses generally have longer duration, flatter slope and more consistent shape than *approach phase* and *feeding buzz* pulses.
Sequence	Literally, a sequence of *pulses* that may be from one or more bats; but generally refers to a *call* or part (e.g. *phase*) of a call.
Tail	The final component of a *pulse*, following the *characteristic frequency* section; may consist of a short or long sweep of frequencies either upward or downward from the Fc; or may be absent.

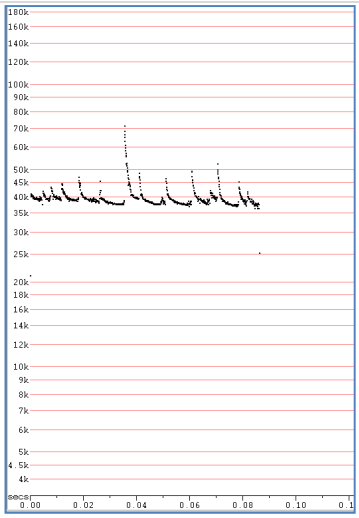
Appendix 1 Representative call sequences recorded at 'Barbara', January-February 2014. x-axis:10msec per tick; time between pulses removed. y-axis: $\log_{10}$ frequency (kHz)



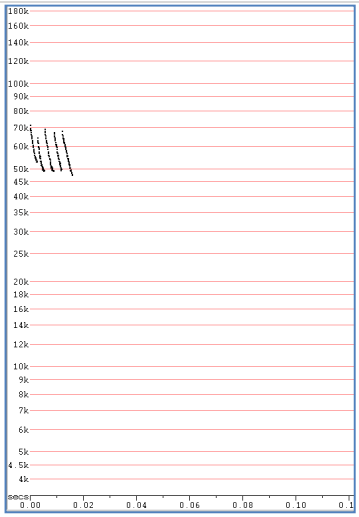
Hipposideros ater



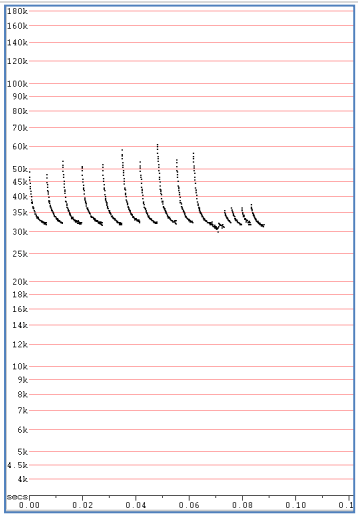
Chalinolobus gouldii



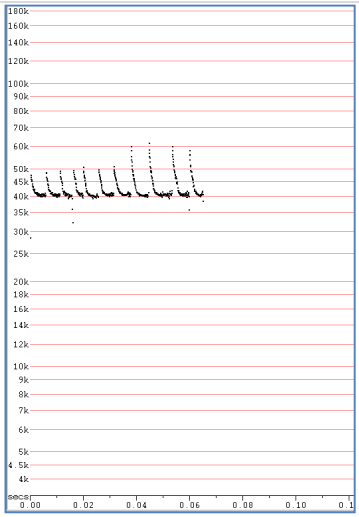
Chalinolobus nigrogriseus



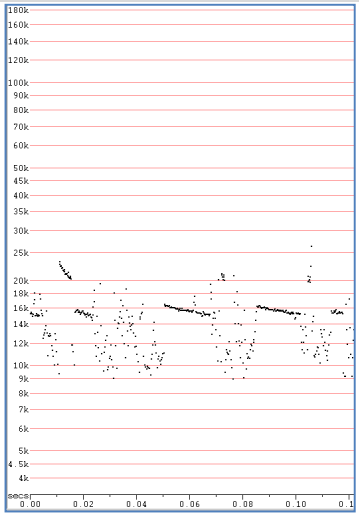
Nyctophilus species



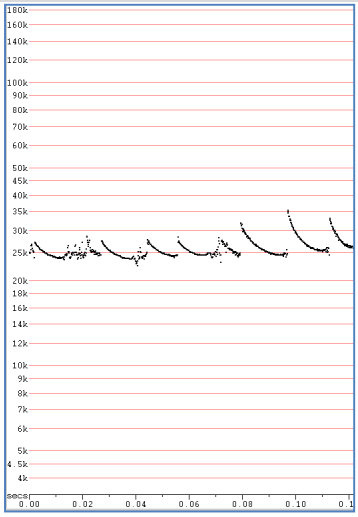
Scotorepens balstoni



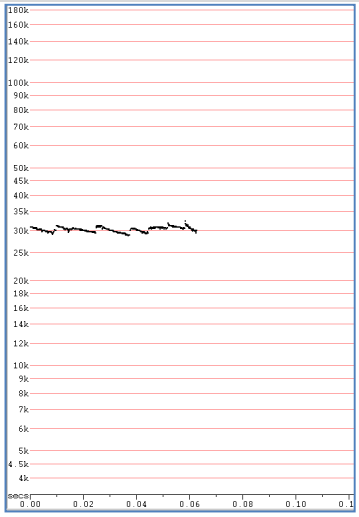
Scotorepens greyii



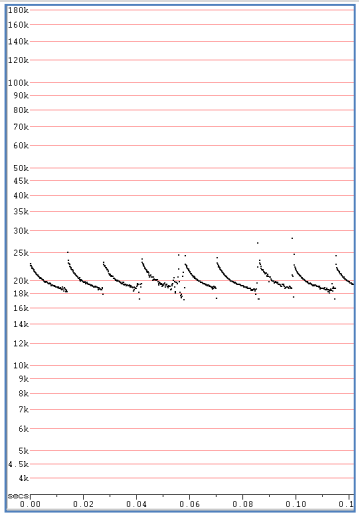
Chaerephon jobensis



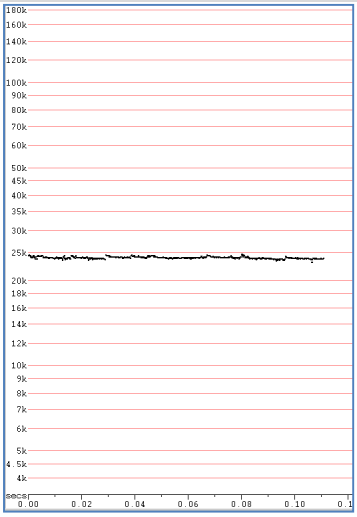
Mormopterus beccarii



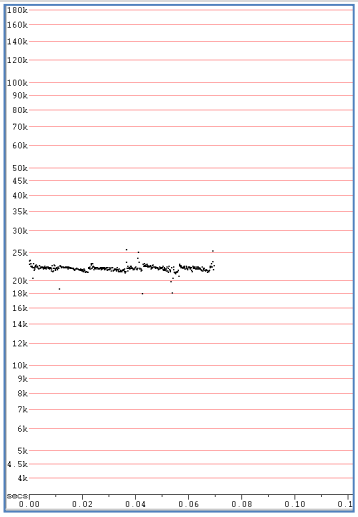
Mormopterus sp 3/sp5



Saccolaimus flaviventris



Taphozous georgianus



Taphozous troughtoni

Microbat Call Identification Report

Prepared for ("Client"):	AustralAsian Resource Consultants
Survey location/project name:	Barbara Terrestrial Fauna Survey
Survey dates:	Dry Season, August 2014
Client project reference:	
Job no.:	AARC1405
Report date:	18 August 2014

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Methods

Data receipt and post-processing

Bat call data were recorded at six sites (three nights per site) using three Song Meter SM2BAT detectors (Wildlife Acoustics, USA), with an Anabat detector (Titley Scientific, Brisbane) recording over four nights at one additional site.

Data received for analysis included the following:

Detector name	Recording dates	Site	Files received
Anabat	Nights of 4/8/14 to 7/8/14	FA6	2079 Anabat zero-crossing analysis files
Song Meter 6	Nights of 2/8/14, 3/8/14 & 4/8/14 Nights of 5/8/14, 6/8/14 & 7/8/14	FA4 FA5	25 WAV files 254 WAV files
Song Meter 8	Nights of 2/8/14, 3/8/14 & 4/8/14 Nights of 5/8/14, 6/8/14 & 7/8/14	FA2 FA8	55 WAV files 60 WAV files
Song Meter 10	Nights of 2/8/14, 3/8/14 & 4/8/14 Nights of 5/8/14, 6/8/14 & 7/8/14	FA1 FA7	20 WAV files 55 WAV files

All Song Meter WAV files were post-processed with Wildlife Acoustics' *Kaliedoscope Version 2.0.3* to generate call sequence files in Anabat zero-crossing analysis (ZCA) format.

Bat call identification

All ZCA sequence files were analysed using *AnalookW* (Corben 2014), with species identification achieved manually by comparing the *AnalookW* call sonograms with those of regionally-relevant reference calls and with published call descriptions (e.g. Reinhold *et al.* 2001; Milne 2002; Pennay *et al*. 2004).

Species' identification was also guided by considering their probability of occurrence based on general distribution information (Churchill 2008; van Dyck *et al.* 2013) and/or database records obtained from Wildlife Online (http://www.ehp.qld.gov.au/wildlife/wildlife-online/index.html) and/or the Atlas of Living Australia (http://www.ala.org.au).

Reporting standard

The format and content of this report follows Australasian Bat Society standards for the interpretation and reporting of bat call data (Reardon 2003), available on-line at http://www.ausbats.org.au/.

Species nomenclature follows van Dyck *et al.* (2013).

Results & Discussion

The Anabat unit failed to record any bat calls over the four-night deployment at Site FA6. All sequence files contained just background noise generated by insects and/or wind and/or other environmental disturbance.

Similarly, Song Meter 6 recorded only insect calls and other non-bat noise; consequently, there are no bat species records from this dry season survey for Sites FA4 or FA5.

The *Kaleidoscope* conversion process generated 185 ZCA sequence files for the other two Song Meter detectors; however, only 109 of those files contained recognisable bat calls.

The number of calls recorded at each site was very low (see Table 1), which possibly reflects reduced bat activity due to cool overnight temperatures and windy conditions. Furthermore, call quality was also quite low, with most calls having weak and fragmented pulse structures, which significantly reduced the reliability of species identification.

Only two species were positively identified form this data set: *Chaerephon jobensis*, recorded at FA7 and FA8; and *Taphozous georgianus*, recorded at FA2.

Up to seven other species may also have been present, with four additional call types recognised, each potentially representing two species. Poor recording quality and similarities in the call characteristics of some species that probably occur in the study area prevented reliable identification of these calls. The unidentified call types represented the following species groups:

- *Chalinolobus gouldii* and *Scotorepens balstoni*
    - FM-qCF pulses with characteristic frequency (Fc) around 30-33 kHz, but all calls with highly variable pulse shape and frequency characteristics
    - no clear inter-pulse frequency alternation that would readily differentiate *C. gouldii*
    - no calls with clearly uniform pulses that would be attributable to *S. balstoni*
    - both species probably responsible for some of the calls
- *Scotorepens greyii* and *Chalinolobus nigrogriseus*
    - FM-qCF pulses with Fc around 37-40 kHz
    - mostly quite short duration pulses so considered most likely from *S. greyii* but pulse shapes and frequencies inconsistent so cannot discount *C. nigrogriseus*
- *S. greyii* and *Vespadelus baverstocki*
    - FM-qCF pulses with Fc around 41-43 kHz
    - considered more likely to be from *V. baverstocki*, but only a few very brief and weak calls so possibly just *S. greyii* at upper limit of frequency range
- *Vespadelus caurinus* and *V. finlaysoni*
    - FM-qCF pulses with Fc=55-57 kHz
    - most likely from *V. finlaysoni* but all calls very messy and poor quality
    - nearest records for *V. caurinus* are in the Boodjamulla National Park area, so these calls more likely from *V. finlaysoni.*

Technical terms used in the above call descriptions are explained in the Glossary.

Table 1 Insectivorous bats recorded during the Barbara Terrestrial Fauna surveys, 2-8 August 2014.

Site:	FA1	FA7	FA2	FA8
No. of sequence files:	18	54	53	60
No. of calls identified:	1	47	26	35
Species positively identified				
Chaerephon jobensis		✓		✓
Taphozous georgianus			✓	
Species not positively identified				
Chalinolobus gouldii or *Scotorepens balstoni*	✓	✓	✓	✓
Scotorepens greyii or *Chalinolobus nigrogriseus*		✓		✓
Scotorepens greyii or *Vespadelus baverstocki*		✓		✓
Vespadelus finlaysoni or *Vespadelus caurinus*				✓

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Reinhold, L., Law, B., Ford, G. and Pennay, M. (2001). *Key to the bat calls of south-east Queensland and north-east New South Wales*. Department of Natural Resources and Mines, Brisbane.

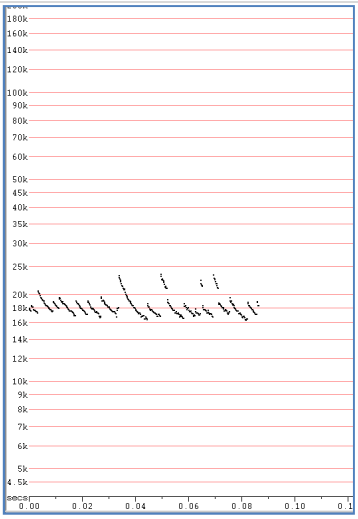
van Dyck, S., Gynther, I. and Baker, A. (eds.) (2013). *Field Companion to The Mammals of Australia*. New Holland; Sydney.

Glossary

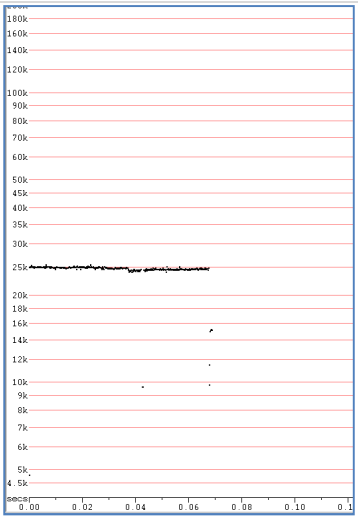
Technical terms used in this report are described in the following table.

Approach phase	The part of a bat *call* emitted as the bat starts to home in on a detected prey item; a transitional series of *pulses* between the *search phase* and *feeding buzz*, that become progressively steeper and shorter in duration.
Call	Refers to a single bat call, made up of a series of individual sound *pulses* in one or more *phases* (*search, approach, feeding buzz*).
CF (=Constant Frequency)	A type of *pulse* in which the dominant component consists of a more-or-less 'pure tone' of sound at a Constant Frequency; with *shape* appearing flat on the sonogram. Often also contains a brief *FM* component at the beginning and/or end of the CF component (*viz.* FM-CF-FM).
Characteristic frequency (Fc)	The frequency of the flattest part of a *pulse*; usually the lowest frequency reached in the *qCF* component of a pulse. This is often the primary diagnostic feature for species identification.
Duration	The time period from the beginning of a *pulse* to the end of the pulse.
Feeding buzz	The terminal part of a *call*, following the *approach phase*, emitted as the bat catches a prey item; a distinctive, rapid series of very steep, very short-duration pulses.
FM (=Frequency Modulated)	A type of *pulse* in which there is substantial change in frequency from beginning to end; *shape* ranges from almost vertical and linear through varying degrees of curvature.
FC range	Refers to the range of frequencies occupied by the *characteristic frequency* section of *pulses* within a call or set of calls.
Frequency sweep or "band-width"	The range of frequencies through which a *pulse* sweeps from beginning to end; Maximum frequency (Fmax) – minimum frequency (Fmin).
Knee	The transitional part of a *pulse* between the initial (usually steeper) frequency sweep and the *characteristic frequency* section (usually flatter); time to knee (Tk) and frequency of knee (Fk) can be diagnostic for some species.
Pulse	An individual pulse of sound within a bat *call*; the *shape*, *duration* and *characteristic frequency* of a pulse are the key diagnostic features used to differentiate species.
Pulse body	The part of the *pulse* between the *knee* and *tail* and containing the *characteristic frequency* section.
Pulse shape	The general appearance of a *pulse* on the sonogram, described using relative terms related to features such as slope and degree of curvature. See also *CF, qCF* and *FM*.
qCF (=quasi Constant Frequency)	A type of *pulse* in which there is very little change in frequency from beginning to end; *shape* appears to be almost flat. Some pulses also contain an *FM* component at the beginning and/or end of the qCF component (*viz.* FM-qCF).
Search phase	The part of a bat *call* generally required for reliable species diagnosis. A consistent series of *pulses* emitted by a bat that is searching for prey or and/or navigating through its habitat. Search phase pulses generally have longer duration, flatter slope and more consistent shape than *approach phase* and *feeding buzz* pulses.
Sequence	Literally, a sequence of *pulses* that may be from one or more bats; but generally refers to a *call* or part (e.g. *phase*) of a call.
Tail	The final component of a *pulse*, following the *characteristic frequency* section; may consist of a short or long sweep of frequencies either upward or downward from the Fc; or may be absent.

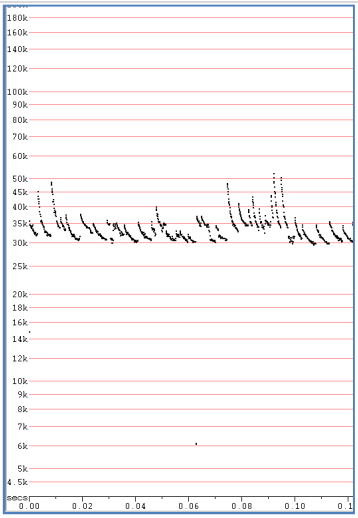
Appendix 1 Representative call sequences recorded at 'Barbara', 2-8 August 2014.
x-axis:10msec per tick; time between pulses removed. y-axis: $\log_{10}$ frequency (kHz)



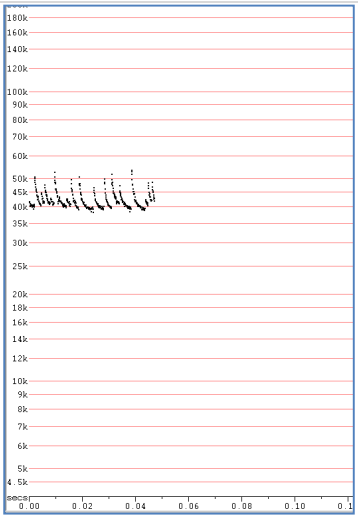
Chaerephon jobensis



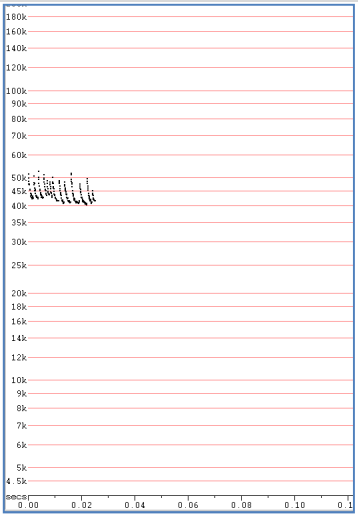
Taphozous georgianus



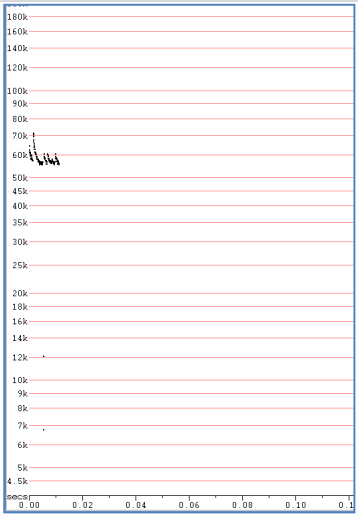
C. gouldii or *S. balstoni*



S. greyii or *C. nigrogriseus*



S. greyii or *V. baverstocki*



V. finlaysoni or *V. caurinus*

Appendix F Pest Species Fact Sheets

FERAL PIGS

Feral pigs (*Sus scrofa*) in Queensland

PEST STATUS REVIEW SERIES - LAND PROTECTION

by

C. C. McGaw

J. Mitchell

Queensland Government

Natural Resources and Mines

Acknowledgements
This assessment has drawn heavily from information contained within the Bureau of Resource Sciences publication "Managing Vertebrate Pests - Feral Pigs" (Choquenot, McIlroy and Korn 1996). Additional information and data have been included to provide the assessment with a Queensland emphasis.

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Contents

1.0 Summary 1

2.0 History 2

3.0 Current and Predicted Distribution 3

4.0 Estimates of Current and Potential Impact 5

4.1 Impact on Primary Production 5
4.2 Impact on the Environment 6
4.3 Disease 7
4.4 The Pig as a Resource 8
4.5 Cost:Benefit Relationship 9

5.0 Biology and Ecology 10

5.1 Habitat Requirements 10
5.2 Diet 10
5.3 Social Structure and Behaviour 10
5.4 Reproduction and Population Dynamics 11

6.0 Efficacy of Current Control Methods 12

6.1 Exclusion and Habitat Modification 12
6.2 Poisoning 12
6.3 Recreational Hunting 13
6.4 Trapping 14
6.5 Biological Control 15
6.6 Fertility Control 16
6.7 Shooting (helicopter and ground shooting) 17
6.8 Control During Exotic Disease Outbreaks 17

7.0 Animal Welfare Considerations 18

8.0 Management and Control Practices 19

8.1 Legislative Status in Queensland 19
8.2 Management Strategies in Queensland 20
8.2.1 Pastoral Zone 20
8.2.2 Wet Tropics 20
8.2.3 Agricultural Zone 20
8.2.4 Near Urban Situations 21
8.3 Property Management Strategies 21

9.0 Acknowledgments 22

10. References 23

1.0 Summary

Feral pigs are one of the most widespread and damaging pest animals in Queensland and they are difficult to control in some situations. Feral pigs are widely distributed and inflict damage on the environment, lower agricultural production and the general amenity of Queensland.

Feral pigs also pose a disease risk to humans and the native and domestic animals of the State. They are found across most of the State and are susceptible to many exotic and endemic diseases.

Benefits also accrue from feral pigs as they provide income to many professional and amateur hunters, and the revenue gained from the export of 'wild boar' products increase export income and injects money into many small rural communities.

There are few control methods available: baiting, trapping, shooting, hunting and exclusion. The control method used varies with the habitat, safety of people and animals, and the size and location of the area to be treated.

2.0 History

Feral pigs have been part of the Queensland landscape since about 1865. The theory that feral pigs, sometimes known as 'Captain Cookers' were derived from deliberate releases or escapes from Cook's time at Cooktown in north Queensland has been discounted. The only pigs landed by Cook were killed by a fire deliberately lit by Aborigines (Pullar 1953). There has also been some speculation that pigs were introduced from New Guinea by travellers to Cape York. This too has been shown to only be the case for the later part of last century (Pullar 1953), as there are no words in the local Aboriginal language for 'pig' before this time (Pullar 1950; Pavlov *et al.* 1992).

Feral pigs were derived from stock that were let loose or wandered away from where they were being kept, often under semi-feral conditions as settlement progressed across the State. To this day, pigs are still being introduced, both accidentally (escapes from piggeries or truck accidents) and deliberately (usually by recreational hunters), to many parts of the State.

These pigs were probably descendants of Berkshire and Tamworth pigs that were introduced to Australia, including pigs transported as part of the First Fleet (Choquenot *et al.* 1996). These pigs probably then crossed with various breeds from Europe and Asia that were brought into Australia by early settlers from these regions.

3.0 Current and Predicted Distribution

Feral pigs are distributed across much of the State (Fig.1). The distribution of feral pigs is related to their strict requirements of daily water and dense foliage for protection from weather extremes, particularly heat to which they have a poor tolerance. Even so, pigs have become established within a wide variety of habitat types from the Arid Zone to the Wet Tropics. In the more arid areas, the distribution of pigs is quite seasonal and their distribution is restricted to watercourses, associated floodplains and man-made water supplies.

Fig. 1. Relative distribution of feral pigs in Australia.
Commonwealth of Australia copyright reproduced by permission from *Managing Vertebrate Pest - Feral Pigs* Choquenot *et al* 1996 after Wilson *et al* 1992

Because feral pigs usually have quite definite home ranges, and only disperse during times of major disturbance or limitations on food resources, they have been slow dispersers across much of Queensland. Because of this, feral pigs are still colonising new areas. Some coastal areas and areas around Cunnamulla and within the Wet Tropics World Heritage Area, have only been colonised by feral pigs within the last 30 years. Many cases of feral pigs establishing in new areas are because of deliberate introduction by recreational hunters, particularly in State Forests and on other State lands.

It is estimated that there are some 4 to 6 million feral pigs in Queensland (Mitchell, *pers. comm*.). No detailed survey has been conducted to accurately estimate the size of the population, however some research has been conducted on densities in different habitat types. About 75% of the estimated population is thought to inhabit tropical north Queensland (J. Mitchell, pers comm).

There is great difficulty in accurately estimating the numbers of feral pigs because of their secretive behaviour and the dense vegetation that forms their preferred habitat. Pig numbers also vary quite considerably from season to season, and from habitat to habitat. Table 1 illustrates some of the different densities of feral pigs for a variety of habitats.

Table 1. Reported densities of feral pigs for various districts and habitats.

DISTRICT	HABITAT	DENSITY	REFERENCE
Goondiwindi	pasture woodland, forests and wheat crops	0.1-3.9 pigs/sq km	Wilson *et al* 1987
Aurukun	floodplain, swamp and woodland	1>20 pigs/sq km	Dexter 1990
Aurukun	floodplain, swamp and woodland	1-40 pigs/sq km	J.Mitchell, pers comm.
Lilyvale	floodplain, swamp and woodland	4.2 pigs/sq km	J.Mitchell, pers comm.
Lakefield National Park	floodplain, swamp and woodland	4 pigs/sq km	Mitchell 1998

4.0 Estimates of Current and Potential Impact

4.1 Impact on Primary Production

The impact of feral pigs on agriculture takes three forms (Choquenot *et al* 1996):

- value of the direct losses to agricultural production;
- value of the continuing expenditure on pig control; and
- value of lost opportunities to take profit from alternative investment of this expenditure.

It is difficult to accurately provide a dollar figure to the economic damage caused by pigs as some localities will suffer less damage because of naturally low pig numbers or adequate control methods that reduce their impacts. Despite these problems, some estimates have been made of the magnitude of costs of feral pigs.

The national loss to agriculture by feral pigs has been estimated to be in the order of $100 million, but this may be a conservative estimate (Choquenot *et al* 1996).

Pigs are responsible for damage to a variety of industries. They reduce the yields of grain crops (Benson 1980, Caley 1993), damage and consume pastures (Hone 1980), reduce yields of sugar cane and some tropical fruits such as bananas, mangoes, pawpaw and lychees (McIlroy 1993), damage netting fences, damage and pollute water sources (Tisdell 1982; O'Brien 1987) and prey upon newborn lambs (Plant *et al* 1978; Pavlov *et al* 1981; Hone 1983; Choquenot 1993).

Lamb predation by feral pigs is estimated to range from 18.7% to 32% for the semi arid rangelands (Pavlov *et al* 1981; Plant *et al* 1978). Estimates for losses to grain crops in Queensland are shown in Table 2.

Table 2. Estimated value of lost crop production for Queensland 1996

CROP	% REDUCTION IN YIELD*	VALUE#
Wheat	3	$ 1.9m
Sorghum	5	$ 9.1m
Barley	1	$ 0.3m
Maize	3	$ 0.6m
Total		$ 11.9m

* Based on Tisdell 1982
# This figure is for the end of a severe drought and the winter crop figures are significantly lower than average, with the sorghum crop being inflated due to a breaking of the drought allowing large areas to be planted to summer crops.

In 1991 it was estimated that the cost of feral pig damage to sugar cane crops was in the vicinity of $628 000, which equated to a reduction in yield of 25510 tonnes of sugar cane (McIlroy 1993). The value of other crop losses has not been accurately assessed, but pigs are known to cause severe, but often

localised, damage to crops such as potatoes, melons, mandarins, strawberries, pumpkins and tropical fruits (bananas, mangoes, lychees, pawpaws and pineapples). One farmer in the Tully area reported losses of up to 140 bunches of bananas per month (valued at between $4,200 and $12,600) for a twenty hectare plantation, but average losses in the area are about 20 bunches ($600 - $1800) per month (Noble 1996).

The damage caused to pasture and competition with domestic stock is difficult to estimate, as there is considerable variation across pasture types and their biomass. It has been shown that pig activity reduces pasture availability and can lead to the establishment of less desirable pasture species, including weeds (Hone 1980). Most work to date on the impacts of pigs on grazing industries has been concentrated on the predation of lambs and the effects on the sheep grazing lands of semi-arid New South Wales, which is similar in some respects to the southern sheep grazing areas of Queensland.

It has been estimated that Queensland spent approximately $1.1 million in 1984 on feral pig control, which equates to about $2.2 million in today's dollar values (Choquenot *et al* 1996). This amount includes both government and private expenditure on control by various means. It does not include amounts spent by recreational hunters who also contribute to control. This estimate of expenditure is based upon estimates of landholder and government expenditure on control, and so should only be used as a guide to current control costs.

4.2 Impact on the Environment

The impacts of feral pigs on the environment takes one of two forms: damage to habitats or direct damage to animal species.

Degradation of habitats is probably the most obvious form of environmental damage caused by pigs. This damage can be because of rooting, trampling, tusking or rubbing trees and consumption of plants and soil organisms.

The rooting behaviour of pigs has been linked to areas of high soil moisture such as drainage lines and swampy areas (Hone 1988, 1995; Mitchell 1993). This rooting behaviour can severely disrupt the composition of the soil's microorganisms, and subsequently nutrient cycling. Rooting can also disrupt the regeneration of plants, change the composition of the plant community, and allow water erosion to occur in drainage areas where the soil has been severely disturbed.

Pigs can physically destroy vegetation by trampling it along their paths or in the areas where they wallow. Pigs will often have a favourite rubbing tree, but this has not been linked to territory marking. This behaviour is to remove parasites and to relieve irritations. They also tusk trees as part of their normal behaviour. Undermining and rooting during feeding can lead to trees being uprooted.

Although pigs are known to feed on most parts of a wide variety of native and exotic plants, they usually prefer the softer higher energy parts, tubers and fruits. Their negative impact on plant communities is partially balanced by the positive impact of their aiding in the spread of some plants by passing their seeds in dung. This spread of plants also includes weed species.

The feral pig has also been implicated in the transmission of plant diseases such as rootrot fungus (*Phytophthora cinnamomi*) and other plant pathogens. Introduction is usually via contaminated mud and soil carried by pigs and by the physical damage to plants that allows diseases to enter through the wounds.

Feral pigs are known to consume numerous native animals including earthworms, amphipods, centipedes, beetles and other arthropods, snails, frogs, lizards, snakes, the eggs of freshwater crocodiles (C*rocodylus johnstoni*), turtles and their eggs and small ground nesting birds and their eggs (Pullar 1950; Tisdell 1984; McIlroy 1990; Mitchell 1993; Roberts *et al* 1996).

Without definitive information on the prey eaten, rates of predation, density and status of prey and whether predation is density dependent (Choquenot *et al* 1996) it is impossible to accurately determine what effect pigs have on native fauna, apart from the observable damage to individual animals.

Competition with other animal species has not been proven, but there is some evidence that pigs may compete directly with some specialist feeders such as the Cassowary (C*asuarius casuarius*) (Choquenot *et al* 1996) and other species such as the brolga (*Grus rubicundus*) and magpie geese (*Anseranas semipalmata*) (Tisdell 1984).

4.3 Disease

The feral pig poses a serious threat to Queensland's livestock industries and human health through being a potential carrier, or amplifier, of many endemic and exotic diseases. The diseases that pose the greatest threat are listed in Table 3.

Table 3. List of endemic and exotic diseases carried by feral pigs.

ENDEMIC	**EXOTIC**
Brucellosis (*Brucella suis)*	Foot and Mouth Disease (FMD)
Tuberculosis (*Mycobacterium spp*.)	Classical Swine Fever
Porcine Parvovirus	Aujeszky's Disease
Leptospirosis (*Leptospira spp*)	Japanese Encephalitis
Melioidosis (*Pseudomonas pseudomallei*)	Swine Vesicular Disease
Sparganosis (*Spirometra erinacei*)	African Swine Fever
Murray Valley Encephalitis	Trichinosis
	Rabies
	Screw-worm Fly infestations

Of the exotic diseases, Foot and Mouth Disease (FMD) poses the greatest threat to Queensland's economy. It has been estimated that a FMD outbreak would cost more than $3 billion nationally and if it were to persist in the order of $0.3 - 4 billion annually (Wilson and Choquenot 1996). FMD could have devastating effects on the livestock industries of Queensland, particularly if it were introduced through Cape York, where early detection and eradication

would be difficult. The Department of Primary Industries and the Commonwealth have formulated a national approach to exotic disease management, the Australian Veterinary Emergency Plan (AUSVETPLAN).

4.4 The Pig as a Resource

Many people are of the opinion that the feral pig should be managed as a resource rather than eradicated as a pest. Control programs are usually conducted that do not utilise the feral pig as a resource. These control programs are conducted because of the economic and environmental damage caused by feral pigs and the legislative requirement in all mainland States except the ACT and South Australia.

The feral pig marketed as 'Wild Boar', has been harvested for export since 1980. The main markets for Australian wild boar meat are European Union countries (particularly Germany, France, Italy, Belgium/Luxembourg) and Japan and Sweden. The EU countries have traditionally consumed wild boar meat, and with high human populations and decreasing boar populations in those countries, they have increasingly become dependant on imports for much of their wild boar meats.

Australia now supplies some 20-30 percent of the wild boar consumed, and is now close to overtaking Poland as the worlds largest supplier of wild boar (Ramsay 1994). This market is very volatile, with sales and prices fluctuating from year to year. The market seems to be dependent on the length and severity of the northern winter, which effects the supply of local wild boar.

The Australian Game Meat Producers Association has prepared a Code Of Practice for Humane Shooting, Harvesting and Hygienic Handling of Game Animals. This code of practice provides guidelines to shooters and pig 'chasers' on how to harvest and handle the product so that it is suitable for the export market.

The value of wild boar exports has varied between $10 and $20 million over the last few years because of Australia's drought conditions and the variability of European supply and demand (Ramsay 1994). The number of carcasses processed in Australia is shown in Table 4.

Table 4. Number of wild boar carcasses processed in Australia 1989-1992.

YEAR	CARCASSES
1989	203 837
1990	96 962
1991	101 006
1992	271 133

It has been estimated that there are about 3000 Queensland Meat and Livestock accredited shooters in Queensland and 1200 licensed professional kangaroo shooters who take pigs opportunistically (Dee, pers. comm.). There are also numerous other shooters and hunters who do not sell carcasses. Recreational feral pig hunters across Australia make a significant impact on pig numbers, as well as injecting funds into local economies where they hunt (Tisdell 1982).

In Queensland in 1996 there were about 70 seasonal chiller boxes operating that received approximately 65 000 carcasses, which was about 60% of the national total. Based on this percentage of the national trade, Queensland harvests between $6 and 12 million worth of feral pigs per year (Ramsay 1994). These boxes are located as far north as Lakeland and Doomadgee, but the grain growing areas provided the greatest and most constant supplies of 'wild boar'. The average price paid to 'hunters' in 1996 was 90 cents/kg, but by mid 1997 averaged about 70-75 cents/kg. Preferred carcasses are between 30 and 60 kg with anything below 26 kg being rejected and carcasses over 90 kg being difficult to chill and process. In 1997 there were four export licensed processing works in Queensland, located in Longreach, Roma and two at Eagle Farm in Brisbane. The game meat processing industry in Queensland employs up to 80 people during times of peak production/harvest (Dee, pers. comm.).

4.5 Cost:Benefit Relationship

Whilst the game meat industry and recreational hunters play an important role in controlling feral pigs in some localities, there is an overall net cost to the broader community from feral pigs. The damage done to crops, pastures, fences, water facilities and livestock can be quantified ($100M), and are in excess of the value of the 'wild boar' market ($20M) even without including the costs to the environment and the potential costs from exotic disease.

5.0 Biology and Ecology

5.1 Habitat Requirements

Feral pigs are found in a wide variety of habitats, ranging from dry arid areas, to high mountainous forests and grasslands, to dense tropical rainforest. The two requirements that feral pigs have that restricts their distribution in these habitats are daily water and suitable cover.

5.2 Diet

The feral pig is considered to be an opportunistic omnivore (Choquenot *et al* 1996), and it has been known to consume the following groups of foods:

fruits and seeds: grains, fruits, rainforest fruits;
foliage and stems: grasses, sugar cane, banana trees;
rhizomes, bulbs and tubers: including tuberous crops such as potatoes;
fungi; and
animal material: carrion, earthworms, lambs, arthropods.

The foods consumed vary from region to region and the potential food sources are limited by availability rather than preference for any one food type.

Pigs have a relatively high-energy requirement, particularly during lactation, and growth of young pigs (Choquenot *et al* 1996). Sows require about 15% of their diet to be crude protein in order to successfully suckle their young. This protein requirement can be met from plant material, but is met more commonly from animal matter such as earthworms, carrion, arthropods, frogs and reptiles. Animal matter rarely exceeds 5-18% of a pigs diet (Giles 1980; Pavlov 1980).

Feral pigs will relocate in response to food availability, particularly seasonal requirements for higher protein and energy associated with reproduction and growth.

5.3 Social Structure and Behaviour

The most common groupings of feral pigs is either a few sows and their young, bachelor groups (individuals less than 18 months of age), or individual boars (usually older than 18 months). After weaning pigs will remain with their mother until the next litter, or in the case of sows, until they mate (Masters 1979; Giles 1980; Pavlov 1980).

Group size varies with age, sex, food and water availability and disturbances (such as hunting or other control measures). Group size can range from solitary boars to groups of 100 or more sharing a locally scarce resource such as a single waterhole during droughts.
Feral pigs habitually make use of trails, shelter areas, feeding and watering areas (subject to availability), rubbing and tusking trees and wallows. Even though they are habitual in their use of such areas, there is no evidence that feral pigs, of either sex, actively defend territories.

The size of a feral pig's home range depends on a number of variables, sex (males have larger home ranges than females) and resources. Food availability and quality is thought to be the main determining factor influencing home range size. Home range size varies from as little as 0.16 sq km for furrowing sows, to greater than 40 sq km for individual boars in the semi arid rangelands (Saunders 1988; Giles 1980).

Feral pigs are most active at night or during times of cooler temperatures (late afternoon, early morning, cooler weather, rainy or overcast conditions. They may become active during periods of disturbance from hunting or other human activities such as stock mustering (Pullar 1950; Giles 1980; Saunders and Kay 1991).

5.4 Reproduction and Population Dynamics

The feral pig is polyoestrus; adult sows have a 21-day oestrus cycle and a gestation period of 112-114 days. Their breeding is limited by food availability and quality (particularly the dietary requirement for about 15% protein). If food quantity and quality is available then feral pigs have the ability to produce two litters every 12-15 months (Giles 1980; Pavlov 1983; Ridpath 1991).

Sexual maturity in feral pig sows is dependent on weight (25-30 kg) rather than age, similar to domestic pigs (Masters 1979; Giles 1980; Pavlov 1980). The litter size of feral pigs generally averages between 4.9 and 6.3 piglets, but may be as high as 10 under favourable conditions (Choquenot *et al* 1996).

Juvenile mortality ranges from 10-15% under favourable conditions to 90 or 100% during periods of drought (Masters 1979; Giles 1980; Saunders 1988). Adult mortality ranges from 15 to 50% depending upon food availability and quality, predators (including hunting pressure) and disease.

The potential for pig populations to grow is estimated by their exponential rate of increase (r). The corresponding (e^r) value provides the approximate multiplication rate. Table 5 gives an indication of the potential rates of increase of a feral pig population starting at 100 (female) pigs without external influences such as harvesting, control, immigrations or emigrations.

Table 5. Potential rates of population increase for a base population of 100 feral breeding sows.

HABITAT	REFERENCE	e^r	After 1 year	After 2 years
Semi-arid rangelands	Choquenot 1994	0.97	197	388
"	Giles 1980	1.82-2.0	282-300	795-900
Tablelands	Saunders et al 1990	1.28	228	519
Wet/Dry Tropics	Caley 1993	0.78 (max)	178	316

6.0 Efficacy of Current Control Methods

6.1 Exclusion and Habitat Modification

Fencing is effective for feral pig control for small high value areas such as cropping and lambing paddocks. Fencing has not been adopted as a large scale control method for several reasons: initial high expense, high maintenance costs, low cost effectiveness for large areas and relocation of the problem rather than overcoming it.

Several trials have been conducted to determine the most effective fence design (Hone and Atkinson 1983; Plant 1980; Tilley 1973). Electrification significantly increases the effectiveness of fencing to exclude or reduce the movements of feral pigs. The most effective fence design features 8/80/15 hinge joint, steel posts at 5m intervals, two top barb wires, and an electrified outrigger wire 25 cm above ground level (Hone and Atkinson 1983). This electrified fence design costs near $2500/km to construct.

Habitat modification, e.g. clearing remnant vegetation or closing water points, is rarely used as a control technique, as it results in the destruction of habitats for native species, is poor soil conservation practice and usually only moves the problem to another location.

Changes in management practices sometimes occur when pigs are a serious economic problem. The change in management usually revolves around altering the duration of lambing, but this was shown to be ineffective by Hone (1987). A more effective change in management involves lambing in paddocks away from areas of known pig activity, or changing from sheep breeding and wool growing to wool growing alone, or even cattle production in extreme cases of pig predation. The shift in enterprise may involve potential lost income to the landholder.

6.2 Poisoning

Poisoning is the most cost effective and efficient control method currently available for feral pig control (Korn 1986). The use of poisons is restricted, with baits containing 1080 only being able to be prepared by registered operators.

1080 (Sodium monofluroacetate) poison is the one of only two products registered for use in Queensland to control feral pigs, the other being CSSP (see below). 1080 poison has many attributes that make it suitable for general usage; it is found in many native plant species, therefore native animals have a certain inbuilt tolerance to it, and it degrades readily in soil. There are several disadvantages in using 1080; it is highly toxic to dogs, it has no antidote and secondary poisoning, via animals consuming carcasses, can occur.

1080 has been widely used for feral pig control across Queensland and can be used with meat (in western and northern grazing areas), grain, pellets or vegetables, as the bait material. Prefeeding is usually conducted for a period of 2 or 3 days before poisoning to attract as many pigs as possible to the bait station.

Not all pigs within an area will take baits (depending on alternative food availability, density of baits and pigs). The success rates of baiting vary considerably, with population reductions ranging from 58% to 99.4% (Hone and Pederson 1980; Bryant and Hone 1984). The success of baiting also varies with operator experience and incidence of vomiting. Pigs are known to vomit following 1080 ingestion, and males are known to vomit more than females independent of amount of poison ingested (Hone 1987). This vomiting behaviour by feral pigs will reduce the effectiveness of current baiting campaigns and may lead to bait shyness for future campaigns. Anti-emetic compounds have not been shown to reduce the amount of vomiting by feral pigs (O'Brien *et al.* 1986).

Warfarin, an anticoagulant, is another poison that has been trialed for use in feral pig control. It has not however been registered for use by the National Registration Authority for broad scale use. It has several benefits over other poisons, it has an antidote (Vitamin K), can require several doses before causing death, secondary poisoning does not occur, it does not cause vomiting and is cheaper than 1080. It does however have some disadvantages: it is not specific, requires several doses before becoming effective and can take several days before mortality occurs.

Phosphorus based poisons (Sayers Alport Phosphorus-SAP and CSSP) have been used in the past by landholders. They cause a long and painful death, and consequently are not used or recommended by the Department of Natural Resources and Mines. Because they could previously be purchased by landholders without restriction, they have been widely used and stored by landholders. The exact amount of these poisons used in pig control is unknown. These poisons also have serious impacts on non-target species as dose rates vary and there is no control over the use of stocks held by landholders.

6.3 Recreational Hunting

It has been estimated that recreational hunters kill 15-20% of the feral pig population in accessible areas annually (Tisdell 1982). The use of recreational hunters to control pig numbers is seldom effective as recreational hunters only kill a small percentage of the population, disperse pigs through regular disturbance and hunt on relatively small, easily accessible areas.

However the value of recreational hunters to the broader community must not be overlooked, recreational hunting can provide significant revenue to small communities.

Hunters have been known to introduce pigs to 'clean' areas to provide themselves with hunting opportunities in the future. Hunters have also been known not to take small pigs or sows or to castrate males or to cut the ears off pigs to make them more difficult to catch with dogs, thus insuring 'sport' in future seasons. These actions are in direct opposition to effective pig control.

The use of dogs to hunt pigs, either to flush them out of shelter, or to chase and catch them has been criticized by animal welfare groups, but is currently legal throughout Queensland. A review of the animal protection legislation by the Department of Primary Industries may alter this situation. The success of dogs capturing pigs has been studied and results show that solitary pigs are caught on 90% of the occasions when chased (Caley 1993), when groups of

pigs are encountered only one is usually caught and only about 70% of those chased are caught (Oliver *et al.* 1992). Another risk associated with using dogs is them becoming lost and their subsequently becoming 'feral', preying on stock and native animals.

6.4 Trapping

Trapping of feral pigs has gained increasing acceptance as trap designs improve, feeding behaviour is better understood and the restrictions on the use of poisoned baits increases. Trapping is relatively expensive and labour intensive and so not practical for large scale control. Trapping is environmentally friendly, relatively humane and some costs can be defrayed against the sale of pig carcasses. However, the success of trapping has been found to vary from 28% of the population (Saunders *et al* 1993), to 81% (Choquenot 1993).

Some of the other advantages of trapping over other control methods are that (Lukins 1989):

- trapping does not interfere with normal pig behaviour (unlike shooting or dogging);
- the number of pigs is known exactly, and carcasses can be removed safely;
- it is a flexible technique and can be fitted into routine property activities, making it economical in terms of labour, materials and number of operators; and
- properly designed traps can be moved or re-used as necessary. Good trapping makes use of opportunities as they arise.

Hone *et al* (1980) outlined the points that landholders and managers need to consider when trapping:

- type of trap to use;
- number of traps to use;
- where to put traps;
- number of nights each trap is used;
- type and amount of bait to use; and
- amount and duration of pre-feeding.

Several trap types are successful. The relative success and design of trap to use depends on the local environment, materials, number of pigs to be trapped and presence of non-target species such as cassowaries (Figure 2.).

Some of the other factors that may influence the decision to trap include: it is time consuming and expensive to initially build and maintain traps.

The Department of Natural Resources and Mines advises landholders to consider trapping when poisoning is impractical, or as a follow up to poisoning. The Department also advises landholders to reduce disturbance to pigs from shooting or dogs before and during the trapping period.

Hone (1984) has described the important steps in trapping:

- feeding sites should be placed where feral pigs are active, for example, water points and pop-holes in fences;
- initially, feed the pigs with bait such as grain and pellets (fermented material is often attractive), vegetables or fruit, meat or carrion;
- build the trap where feed is being taken, and leave it open and baited, but not set, for one or two nights;
- then set the trap each night;
- if the feed is being taken, continue to trap until no more pigs are caught;
- leave the trap unset and feed a different bait from that used initially;
- if feral pigs start taking the bait, set the trap for several nights; and
- once no bait is taken, start feeding elsewhere before moving the trap.

6.5 Biological Control

Pathogens and immunocontraception via a vector have been suggested as possible biological control methods for feral pigs.

These methods have not been pursued, as it would be difficult if not impossible to stop the spread of any disease or disease borne immunocontraception to domestic pigs. The feral pig industry, and the associated export and flow on revenue would also be significantly affected by any such disease.

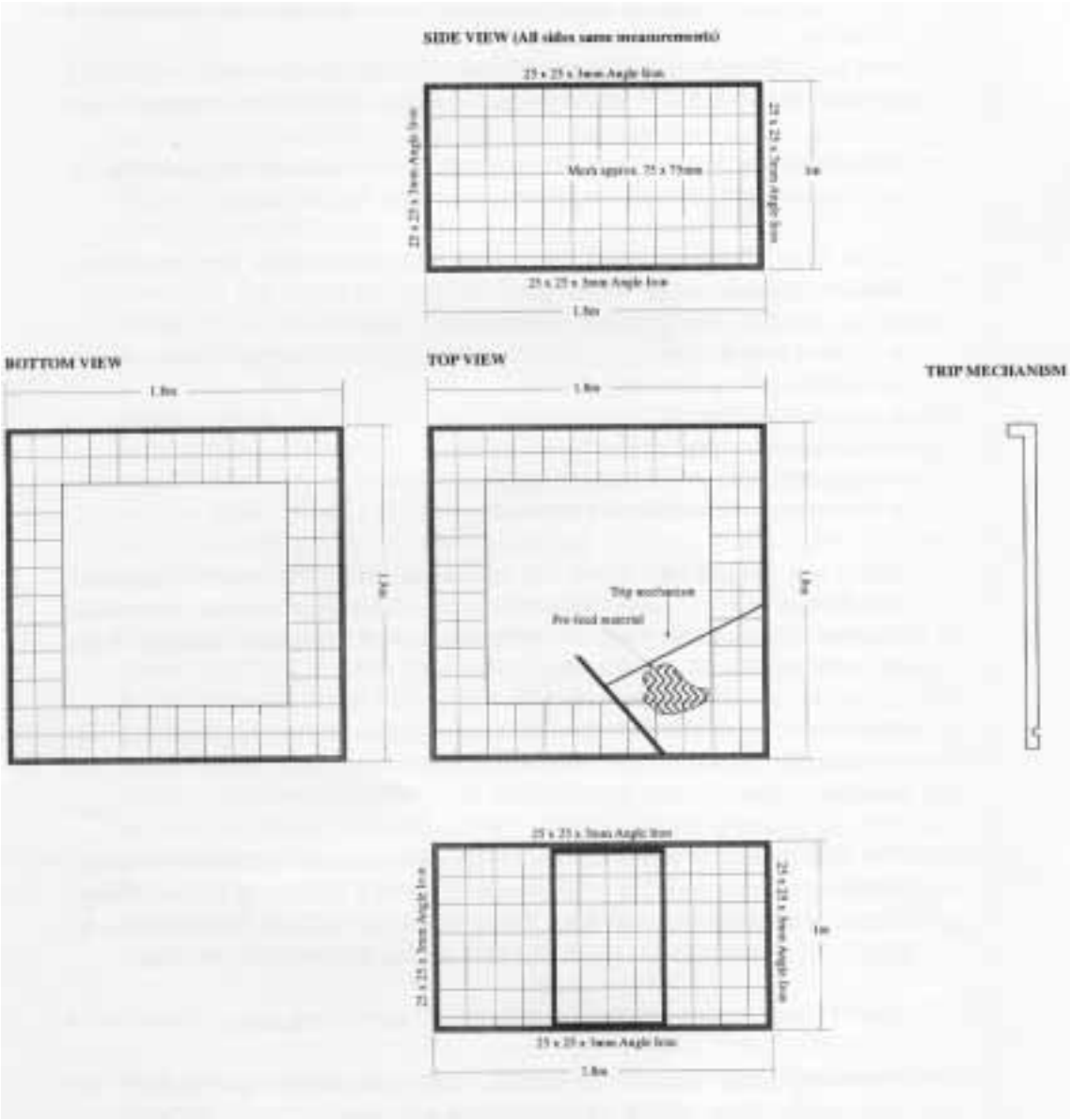

Fig.2 Cassowary Safe Feral Pig - Box Trap (Mitchell and Dorrington)

6.6 Fertility Control

Currently there is no work being carried out on producing an immunocontraceptive bait for feral pigs. There is research being conducted on finding an immunocontraceptive for control of rabbits, foxes and rodents. As with these other species, there are problems involved in possibly developing such a control method (Bomford 1990):

- lack of long-acting contraceptive compounds (making repeat dosing necessary);
- high costs of delivery by baits (particularly when repeat dosing is needed);
- less effect on population size than when an equivalent number of pigs are killed, due to repeat dosing requirements; and
- potential effects on non-target species.

Because delivery methods are the same it would be far more efficient to provide a poisoned bait than an immunocontraceptive bait.

6.7 Shooting (helicopter and ground shooting)

Shooting has been used as a control method ever since feral pigs first became a problem in Queensland. Shooting, particularly from the ground is a very labour and resource intensive method, and cannot be used to control pigs over large areas, particularly when pigs are at low densities. Shooting, both ground and air, can cause pigs to disperse and requires a great deal of skill for it to be cost effective.

The use of helicopters in recent times has made shooting a more economic option, particularly in inaccessible areas. Helicopter shooting still has some shortcomings. Some habitat types can conceal pigs from the air making them difficult to shoot and shooting cannot be used as a stand alone control measure, as it will only reduce the population by a limited amount.

It has been proposed to use ‘Judas’ pigs in a similar way as ‘Judas’ goats are used in feral goat control. This method involves the use of a radio collared individual to locate other animals after it is released and rejoins a group. Because pigs are not as gregarious as goats, this method has limited application and is seldom used.

6.8 Control During Exotic Disease Outbreaks

In the event of an exotic disease outbreak, financial and legal control constraints take on less importance and the amount of control required is increased. The procedure for an exotic disease outbreak, as set out in the AUSVETPLAN, requires that containment of the disease within a geographic area occurs first, and secondly that vector population reduction is carried out as quickly as possible. Monitoring of the adjoining vector population for disease incidence must also be carried out to assess the rate of spread of the disease.

To successfully plan an eradication campaign for containment of an outbreak of exotic disease within a feral pig population several factors, including the delay in first detecting infected animals, the prevalence of infection and the size and location of the area to be decontaminated must be determined (Pech and McIlroy 1990). In order to eradicate an exotic disease, it is necessary to reduce the vector population to the threshold at which the disease will not spread. This varies for different areas but has been estimated to be in the order of 95%. However, in simulated exercises reductions in the order of 40-80% have been achieved. This result indicates that current planning and control measures for pigs will need to be modified to achieve successful reduction of populations to required levels.

7.0 Animal Welfare Considerations

In Queensland the *Animals Protection Act* 1925, gives no protection to any feral animal but does provide, in broad terms, that procedures to destroy declared animals must not constitute 'unreasonable, unnecessary or unjustifiable ill-treatment'. Ill-treat is defined as : ill-treat, wound, mutilate, overdrive, override, overwork, abuse, worry, torment, torture and cause any animal unnecessary pain or suffering; also overload or overdrive when loaded, and overcrowd, and unreasonably beat or kick.

This legislation is currently being reviewed. Once the legislation review is complete, a new Act is expected to be tabled in 1998. This new legislation will be prepared by the Department of Primary Industries in consultation with animal welfare groups, the pet industry, environmental groups, primary producers and the Department of Natural Resources and Mines and will have broad community input.

As mentioned above, the use of dogs in chasing and capturing pigs has been condemned by animal welfare groups, but remains legal in Queensland. There have been suggestions that the practice has been withdrawn from the recommended methods list in NSW, and penalties of up to $10 000 being applicable for using this method of pest control.

8.0 Management and Control Practices

8.1 Legislative Status in Queensland

The feral pig is a declared animal under Section 69 of the *Rural Lands Protection Act* 1985. It is categorized as an A1, A2 and A6 animal for the whole State, which means that:

A1 in respect of an area if the introduction of those animals into that area should, in the opinion of the Governor in Council be prohibited;

A2 in respect of an area if those animals-
(i) are not vertebrate animals native to that area; and
(ii) should, in the opinion of the Governor in Council, be destroyed in that area;

A6 in respect of an area if the keeping and selling of those animals in that area should, in the opinion of the Governor in Council, be subject to prescribed conditions and restrictions.

Penalties applicable to landholders for noncompliance with the provisions of the Act, are shown in Table 6.

Table 6. Offences and penalties applicable to feral pigs in Queensland.

OFFENCE	MAX. FIRST OFFENCE	MAX. SECOND OFFENCE
Failure to control	$375	$1,500
Failure to comply with direction	$1,500	$3,750
Introduction of Category A1 animals	$7,500	
Restrictions on keeping and selling A6 animals	$3,750	
Liberating declared animals	$7,500	

Section 80 of the *Rural Lands Protection Act 1985* places the responsibility for control of declared animals with the landholder, and there is a penalty of $375 for failure to control. As can be seen from the list of penalties, people releasing feral pigs into areas for hunting purposes are liable to a $7,500 fine, and persons who keep feral pigs are liable to fines up to $3,750.

The Department of Natural Resources and Mines policy is to 'reduce the impact of feral pigs through coordinated and sustained control programs in strategic areas of Queensland where feral pigs constitute a high risk to agricultural production and/or the environment.'

The policy states that A2 animals shall be subject to 'sustained control in strategic areas in concert with commercial utilisation where appropriate for established pests.' This has been further explained by defining:

Sustained control as ' the implementation of control on a regular basis to keep population at or below a threshold density at which the benefit of control is equal to or greater than the cost of control. Sustained control requires the development of pest animal management plans that include regular and integrated control options. (Integrated control is the use and combination of multiple control techniques).'

Commercial utilisation (harvesting and hunting) as ' utilising animal pests as a resource is particularly appropriate for some species such as the feral horse, feral pig, feral goat and rabbit. Commercial utilisation can be integrated with other control methods to regulate pest animal numbers and should be incorporated in management plans.'

8.2 Management Strategies in Queensland

8.2.1 Pastoral Zone

In the pastoral zone, the main management strategy is baiting, including aerial bait dispersal. This strategy is used because any program needs to cover large areas, but should be concentrated around areas where pig activity is greatest such as around, but not too close to, drainage lines and watering points. The actual impact of feral pigs in these extensive grazing areas, particularly the cattle grazing areas, is limited. Commercial utilisation by professional and recreational hunters also forms part of the overall control strategy, as it is control at a low cost to the landholder. Because this zone takes in arid and semi arid regions, feral pig numbers are subject to wide variations due to climatic extremes that lead to food and water shortages, but also occasional large numbers.

8.2.2 Wet Tropics

The Wet Tropics presents unique problems due to the inaccessible nature of the terrain, high conservation value, plentiful food and water, and proximity to urban settlement. Control is mainly by using traps (cassowary and wallaby safe) with limited baiting in some areas. Trapping is conducted at accessible sites that border or are in close proximity to agricultural enterprises and urban settlement. Broadscale baiting is not possible because of the presence of endangered fauna and tourists. A project to determine the impacts of feral pigs on the natural environment in this region, and a successful community based trapping program has been running in this area for several years. Shooting and 'dogging' are considered to be ineffective control methods because of the thick vegetation and the potential for dogs to escape or become lost, and become problems themselves.

8.2.3 Agricultural Zone

Feral pigs cause a great deal of damage to agricultural crops, particularly grain crops (as shown in Table 2) and considerable resources are allocated to control in this zone. The main means of control is capturing either with dogs or in traps, or hunting. The feral pig or 'wild boar' industry provides a significant input into local economies, and also controls a significant number of pigs. Baiting is carried out to a lesser extent depending on landholder

perceptions of hunting, the extent of the problem, proximity to chiller boxes, prices paid for carcasses and availability of alternate food sources.

8.2.4 Near Urban Situations

Feral pigs are reasonably common in these situations, and are sometimes found in surprising numbers: approximately 100 feral pigs were found along a creek line in the Redland Bay area, south of Brisbane in 1996. Feral pigs in these situations cause damage to parklands, for example Mt Glorious National Park, and to gardens and hobby farms. Control options in these situations are limited. Baiting can only be used in areas where it is considered to be safe by the local Land Protection Officer. Trapping is considered to be the safest and most effective control option. Hunting is of limited value because of firearms restrictions and the problems of using dogs. Exclusion fencing is practiced and is effective for high value areas.

8.3 Property Management Strategies

The Bureau of Resource Sciences (BRS) (Choquenot *et al.* 1996) has outlined four stages of a strategic management program at both the local and regional level:

Problem definition - The problem, if it is real or perceived, needs to be defined. This process will compare the dollar or conservation value of the damage caused by feral pigs, with the benefits received from controlling them. The estimation of environmental costs and benefits is difficult and requires the costing of intangible factors.

Developing a management plan - The main components of developing a management plan is to establish: a set of objectives (interim and long-term goals), a time frame to achieve goals, and indicators for measuring performance. There are several options for the level of control, these range from local eradication, strategic management, commercial management, crisis management or no management, depending on the particular situation. Strategic management offers the most flexible option, as it allows for changes in economic, environmental and pest circumstances. Control techniques need to be included in the preparation of the plan.

Implementing the plan - In order to effectively implement the plan, it is essential to gain broad support for the plan. Stakeholders should be identified and their involvement and 'ownership' of the plan should be encouraged.

Monitoring and evaluating progress - Monitoring of both the operational (cost effectiveness) and performance (effectiveness of the management plan) components of the plan is essential if changes are to be made, and mistakes rectified.

This approach to preparing an effective management plan will allow for the preparation of a dynamic plan that can be adapted for a variety of situations and changing circumstances.

9.0 Acknowledgments

This assessment has drawn heavily from information contained within the Bureau of Resource Sciences publication “Managing Vertebrate Pests - Feral Pigs” (Choquenot, McIlroy and Korn 1996). Additional information and data has been include so as to give the assessment a Queensland emphasis.

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House mouse (*Mus domesticus*) in Queensland

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Contents

1.0 Summary **1**
2.0 History **2**
3.0 Current and Predicted Distribution **3**
3.1 Monitoring Methods 4
3.1.1 Trap Lines 4
3.1.2 Bait Cards 4
3.1.3 Visible Sightings 4
3.1.4 Rate of Bait Removal 5
3.1.5 Crop Damage 5
4.0 Estimates of Current and Potential Impact **6**
4.1 Impact on Primary Production 6
4.1.1 Impact on grain growers 6
4.1.2 Impact on sheep and cattle graziers 7
4.1.3 Impact on horticulturalists 8
4.1.4 Impact on intensive livestock producers 8
4.1.5 Off-farm impact 8
4.2 Impact on the Environment 10
5.0 Biology and Ecology **12**
5.1 Diet 12
5.2 Gnawing behaviour 12
5.3 Reproductive Capacity and Population Dynamics 12
5.4 Other Behavioural Characteristics 13
5.4.1 Feeding behaviour 14
5.4.2 Sensory capabilities 14
6.0 Efficacy of Current Control Methods **15**
6.1 Poisoning 15
6.1.1 In crops 15
Value of baiting during mouse plagues 15
6.1.2 Around buildings 16
6.2 Trapping 16
6.3 Exclusion 17
6.4 Habitat Modification 17
6.5 Other Control Measures 17
6.5.1 Use of raptor perches 17
6.5.2 Chemical repellents 17
6.5.3 Ultrasonic devices 17
6.5.4 Biological Control 17
7.0 Human and Animal Welfare Considerations **19**
7.1 Disease 19
7.2 Other health risks 19
7.2.1 Risk of poisoning 19
7.2.2 Risk of fire 19
7.3 Animal Welfare Issues 20
7.3.1 Impact of mice on livestock 20
7.3.2 Humane control of mice 20
8.0 Legislation and Policy **21**
8.1 Legislative Status of Mice in Queensland 21
8.2 Queensland Department of Natural Resources and Mines' Policy on Mice 21
9.0 Recommended Management and Control Practices **22**
9.1 Managing Mice around Buildings 22
9.2 Managing Mice on Farms 22
10. References **24**

Appendix 1. A Summary of the Biology and Ecology of the House Mouse **27**
Appendix 2: Rodenticides that are registered for use in Qld **28**

1.0 Summary

Mice cause serious damage to Queensland grain crops during mouse plagues. The problem is most severe on the Darling Downs where plagues are more frequent but major crop damage has also occurred in recent years in the Dawson and Callide catchments and around Goondiwindi. Mice are a problem in other crops as well, especially vegetable crops, and on pig and poultry farms within these regions.

Mice are also a serious nuisance in homes and buildings during a plague. They contaminate foodstuffs, destroy paper and cloth goods, and gnaw on electrical equipment and other possessions. Because they can transmit *Salmonella* (which causes food poisoning), they constitute a potential health hazard if they are in food preparation areas.

Control of mice is usually achieved by trapping and poisoning. Trapping is effective in buildings that can largely be made 'mouse-proof' by blocking all holes and placing sealing strips on doors. The few mice that enter are easily removed by trapping. Where buildings cannot be rodent-proofed (e.g. sheds), a number of rodenticides are available for use.

No rodenticide is currently registered for broadacre use, although zinc phosphide bait is presently under consideration by the National Registration Authority for Agricultural and Veterinary Chemicals (NRA). If it receives registration, strategic baiting will then be an option available to farmers. At present, their management options are restricted to habitat manipulation, except during major plagues, when the NRA provides temporary registration of a rodenticide for in-crop control.

Plagues vary in timing and location within a district according to the degree to which on-farm environmental factors are conducive to a build up in mouse numbers. For this reason each farmer needs to monitor mouse numbers on their farm at regular intervals so they can take appropriate management actions to control mice when their numbers are building up and thus restrict the amount of crop damage. Tracking mouse numbers through time can provide an advance warning of a plague.

Regular broadscale monitoring is undertaken on the Darling Downs each year (in June, September, October and November) by the Department of Natural Resources and Mines. A one per cent trap success or greater (that is, 9 or more mice caught in 940 traps) in spring is considered the commencement of the increase phase. Conversely, a plague is not expected if the September trap return is lower than one per cent.

Mice are not a declared pest under the *Rural Lands Protection Act 1985* so there is no legal requirement that they be controlled. The Queensland Department of Natural Resources and Mines' policy on mice includes provision for the department to monitor rodent populations on the Central Darling Downs and provide short and long term predictions on the potential for plague development.

2.0 History

House mice (*Mus domesticus*) are introduced pests probably arriving in Australia at the time of European settlement (Singleton and Redhead 1989). They are now distributed throughout the continent and are ubiquitous in agricultural areas where they are usually found in areas of long grass (e.g. along fencelines), within crops and stubble, and around sheds and houses. At most times, their numbers are low but when seasonal conditions are favourable, their numbers can increase to such a level that they become a serious pest, causing damage to crops, stored products and equipment. These events are called mouse plagues.

The earliest reported plague of mice in Queensland was in 1917 on the Darling Downs. From then until 1980, plagues occurred on average once every 10 years, but since 1980 the incidence of plagues has increased (Singleton and Brown 1998). Between 1980 and 1995, a plague has occurred on the Darling Downs on average every three years. This increase in frequency of plagues has been attributed to the progressive adoption in recent years of conservation farming practices such as stubble retention that provides undisturbed habitat for mice for long periods of the year (Singleton and Brown 1998).

The trigger for a mouse plague is considered to be above-average autumn rainfall—particularly if the rain follows one or two years of drought. Saunders and Giles (1977) suggested that this relationship arises because populations of mice and their natural predators, pathogens and parasites decline during a drought, and then when conditions again become favourable, mouse populations reach plague proportions before these normal agents of mortality are re-established. However Redhead *et al.* (1985) proposed that drought-breaking rain, rather than drought *per se,* was the important factor, as it ensured a good growth of grasses in the following spring when the breeding season of mice begins. If conditions continue to be favourable, breeding continues through summer and, by autumn, mice can be in plague proportions (Redhead and Singleton 1988; Singleton 1989).

3.0 Current and Predicted Distribution

Although mice are found throughout Queensland, plagues of mice occur primarily in the grain-growing areas (Fig. 1). It appears from a questionnaire sent to members of the Queensland Grain Growers Association in 1997 that the frequency of plagues varies between grain-growing areas. For example, the questionnaire returns indicated that four plagues had occurred on the Darling Downs between 1992 and 1997. In contrast only one plague occurred in Goondiwindi and South West Queensland (in 1995), and one in the Dawson and Callide Valley regions (in 1997). Very few problems were experienced with mice in the Lockyer, Burnett and Emerald regions over the five years.

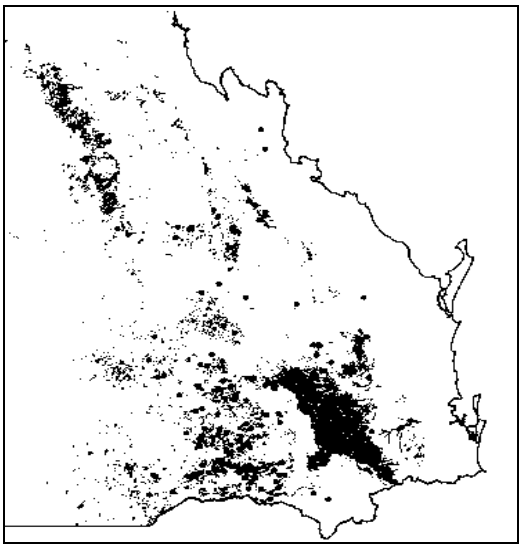

Figure 1. Map of grain-growing areas in Queensland The extent and frequency of plagues also varied between farms within each region. Although the Darling Downs had experienced four plagues between 1992 and 1997, the majority of farmers experienced only one plague within this time interval (Table 1).

Table 1. Number of plagues experienced between 1992 and 1997 by Darling Downs respondents (*n*=204) to a questionnaire (from Donkin and Caughley 1998).

No. of plagues experienced	% of respondents
0	22
1	53
2	23
3	2

These results show how spatially and temporally variable plagues can be. A farmer will experience a mouse plague according to the degree to which on-farm environmental factors are conducive to a build up in mouse numbers. For this reason farmers need to monitor mouse numbers on their farms at regular intervals to detect the onset of a plague. They will then be able to take appropriate management actions to control mice at that time and thus restrict the amount of crop damage.

Regular broadscale monitoring can track mouse numbers through time to provide an advance warning of a plague. Such monitoring is undertaken by the Department of

Natural Resources and Mines on the Darling Downs and the data collected are entered into a model that predicts the probability of a plague at least six months in advance.

3.1 Monitoring Methods

3.1.1 Trap Lines

The monitoring on the central Darling Downs by the Department of Natural Resources and Mines is undertaken each year in June, September, October and November. Forty-seven trap lines with 20 break-back traps in each (total of 940 traps) are set for one night. The number of mice caught is entered into a model developed by the Queensland University of Technology that predicts the probability of plague the following autumn. For example, a one per cent trap success or greater (that is, 9 or more mice caught in 940 traps) in September is considered the commencement of an increase phase that will lead to a plague the following autumn. Conversely, a plague is not expected if the September trap return is lower than one per cent.

Lines of break-back traps in different habitats could also be used by farmers for on-farm monitoring. The method gives a good indication of abundance and provides a cheap, simple and effective means of keeping track of mouse numbers over time.

3.1.2 Bait Cards

Bait cards have been introduced recently as a technique for estimating the likely effectiveness of crop baiting. Bait cards are 10cm x 10cm square pieces of white paper that are soaked in canola oil and pegged out overnight in a crop or other habitat. To obtain a reasonable estimate, at least five cards should be placed 5-10 metres apart at each site.

The bait card technique is a less reliable indicator of mouse numbers. The amount of a card eaten is largely a reflection of the numbers of mice and the availability of food for the mice rather than the numbers of mice present *per se*. When food is plentiful, the cards may be largely untouched even when mouse numbers are high. However, if bait card take is greater than 10%, it indicates (i) that mouse numbers are high and (ii) the mice will readily take the bait and cost-effective control will be achieved.

3.1.3 Visible Sightings

There are a number of visual sighting techniques available to farmers. The presence of burrows or of worn paths between cracks on the cracking clay soils of the Darling Downs are good indicators that mice are present. The number of burrow entrances counted per unit area in crops, contour banks and along grass verges and fencelines gives an indication of mouse activity. Freshly dug soil at the entrance to a burrow indicates that the burrow is active.

Counting numbers of mice seen on a road regularly travelled at night can provide an indicator of mouse abundance. Another visual method can be the number of mice seen in a one minute period after switching on a light in a shed.

3.1.4 Rate of Bait Removal

The rate of removal of baits placed in sheds and around grain stores is a good indicator of whether mouse numbers are increasing or decreasing.

3.1.5 Crop Damage

Crop damage from mice is not a good indicator of mouse numbers as it is often unnoticed until it is severe. Signs of high mouse activity include chewed stems or damage to seed heads. Debris such as seed husks at the base of plants suggests the damage to seed heads has been caused by mice rather than insects or birds.

4.0 Estimates of Current and Potential Impact

The impact of mice on various primary industries and on rural communities has been quantified for other states. Few hard data exist for the Queensland situation but some of the data from other states can be used to gain an appreciation of the scale of the impact mice have on all of these areas.

4.1 Impact on Primary Production

Mice can have a serious economic impact on a range of farming enterprises. The principal enterprise affected is grain growing, but vegetable growers, orchardists, graziers and intensive livestock producers can also suffer significant losses during a plague. In addition to production losses, farmers incur damage to machinery and vehicles, insulation in ceilings and walls of buildings, electrical equipment and fittings, and to household items and personal possessions.

The impact varies considerably between enterprises and between years. In most years mouse numbers are low and the damage they cause is unnoticeable, but when their numbers irrupt to plague densities in grain-growing areas, the damage on farms in the affected areas and in adjacent rural townships is measured in millions of dollars (Caughley *et al.* 1994).

4.1.1 Impact on grain growers

Mice can damage grain crops at all stages of growth (Redhead and Singleton 1988). Generally, plagues irrupt in autumn at the end of a protracted breeding season and thus in Queensland the potential for damage is greatest to maturing summer crops. Mouse numbers usually decline over winter but the timing of the decline varies. If survival is high early in winter, mice can also cause severe damage to winter crops through attacking the embryonic seed heads within the tillers.

Following the 1997 Central Queensland mouse plague and baiting program a questionnaire was sent to graingrowers involved in the baiting program Caughley *et al* (1998b). For the landholders who responded, the winter crop losses prior to baiting were between 0-$100,000+; they estimated that baiting prevented further crop losses of between $1,000-$100,000+. If the estimates of the landholders who responded were typical for all landholders who baited, the total crop losses prior to baiting would have been in the order of $2.8 million, and baiting would have prevented a further $4.8 million of damage.[1] The average cost of baiting per landholder was $2,800, which provides an average cost benefit ratio of 12:1 (range 2:1 to 48:1).

In 1995, a major mouse plague was experienced on the Darling Downs and around Goondiwindi. As in 1997, a questionnaire was sent to farmers at the end of the plague. From the responses, the estimated damage to crops prior to the baiting campaign (in this case the poison used was strychnine) was in the order of $18 million; the damage prevented was estimated to be in the order of $45 million (Miller 1996). The average loss per respondent was $27,000 (range $0–$400,000), and the damage prevented $65,000 (range $0–$1,125,000). The average cost of baiting to the farmer was $1,750. No estimates of other on-farm losses and costs were made in either 1995 or 1997.

[1] The total figures are estimates for all landholders who baited, and do not include other landholders who may have suffered damage but did not bait.

The economic impact of a plague in Victoria in 1993 was evaluated by Caughley *et al.* (1994) from data gathered from 257 farmers who responded to a phone-in. In this plague, the average crop loss of the respondents was $51,100 (Table 2). Other economic losses were experienced from damage to machinery, stores, and household goods but these were small by comparison with the loss in crop production (Table 2).

Table 2. Average amount lost per grain-grower, based on information provided by those who responded to the phone-in during the 1993 mouse plague in Victoria (from Caughley *et al.* 1994).

Estimated losses in crop production	$51,000
Resowing costs	$ 2,900
Baiting costs	$ 760
Damage to sheds, machinery, household goods	$ 1,360
Total	**$56,120**

The total loss reported by the respondents was $14.4 million. The response came from 7% of the farmers in the affected shires in Victoria, but how many more farmers experienced damage in the region is unknown. In South Australia, damage from mice was also widespread in 1993. The Department of Primary Industries, South Australia estimated the losses to grain-growers in that State was in the vicinity of $46 million (Caughley *et al.* 1994).

Various estimates of crop losses have been made in other plagues. Saunders (1987) reported that a plague in 1969–70 cost grain growers in southern New South Wales, Victoria and South Australia in the order of $14 million (NPV $117 million). In 1979–80, losses in Victoria were in the order of $15–20 million (NPV $46–61 million) (Redhead 1988). In 1984, surveys conducted by Government agencies in South Australia, Victoria and New South Wales placed losses in excess of $13 million (NPV $22 million).

Damage is recorded in localised areas in years between major plagues. For example, a plague in the Murrumbidgee Irrigation Area in 1994 caused an estimated $8 million of damage (Croft and Caughley 1995). Over the past 30 years, the average *annual* impact of mice on the Australian grain-growing industry was conservatively placed at $8 million by Caughley *et al*. (1994). Not surprisingly, the increasing incidence of mouse plagues (Singleton and Brown 1998) is deemed a matter of considerable concern both in Queensland and nationally.

4.1.2 Impact on sheep and cattle graziers

No value has been placed on losses experienced by graziers during mouse plagues. In Victoria in 1993, farmers reported severe depletion of medic pastures and a resultant loss in stock condition, especially in ewes and lambs (Caughley *et al.* 1994). Other losses experienced by graziers were damage to stored hay and wool bales. As with all other farmers in affected regions, graziers would have also suffered losses from damage to sheds, equipment and household goods, to which needs to be added the cost of bait to control the numbers of mice.

4.1.3 Impact on horticulturalists

Mice cause damage to a range of horticultural crops during plagues. Vegetable growers report losses in broccoli, tomatoes, capsicum, chilli, garlic, pumpkins and melons. Grapes, apples and other soft fruit are also damaged and serious losses can occur in almond and pistachio orchards. In the 1984 plague, losses to vegetable growers were placed at $100,000 (NPV $162,000) in Victoria (Redhead 1988). No estimates are available for other areas or plagues but losses are likely to be significant.

4.1.4 Impact on intensive livestock producers

Pig and poultry farmers in plague-affected areas can sustain major losses in livestock production, arising from stress (pigs in particular are highly stress-labile) and from direct physical attacks by mice upon the animals themselves (Table 3). Feed costs also increase. During the 1993 plague in Victoria, producers reported feed costs rose by up to 50%. Mice also block feed lines, gnaw on electrical wiring in air conditioners and waste disposal units, and cause damage to sheds (particularly the insulation in the walls). The losses experienced by intensive livestock producers during the 1993 plague were in the order of $530,000 in the worst affected area in north-western Victoria (Caughley *et al.* 1994).

Table 3. Losses experienced by pig and poultry producers in Victoria during the 1993 plague (from Caughley *et al.* 1994).

Pigs		Poultry	
Sows		**Layers**	
Conception rate		Weight	Down 30-50%
Litter size	Down 20-50%	Mortality	Up 15%
Litter mortality	Down 20-30%		
Baconers	Up	**Eggs**	
Growth rate		Number	Down 20%
Mortality	Down 20%	Size and quality	Down
Carcase quality	Up		
	Down 10%		

4.1.5 Off-farm impact

During plagues, mice often cause damage in rural townships. The types of off-farm impacts on rural businesses include:

- Damage to plant and equipment (particularly electrical appliances);
- Spoiling and consumption of perishables intended for sale;
- Lost business opportunity from not stocking, and therefore not selling, products considered at risk (e.g. packet foods); and
- Cost of redirected time and effort spent trapping and cleaning to protect goods and maintain health and hygiene standards.

Businesses where there are few food resources for mice (e.g. banks, machinery sales or fuel distributors) are not affected to the same extent as those that stock perishable goods. However, in all businesses, electrical and electronic equipment is at risk.

Only one detailed assessment of the off-farm economic cost of a mouse plague to townspeople has been conducted. During the 1993 plague, rural townspeople were interviewed across a broad spectrum of retail businesses and community services in South Australia[2] (Caughley *et al.* 1994). Everyone interviewed indicated that their most significant cost was the time required to mouse-proof, bait, trap, clean, and search for and dispose of carcasses; in many instances, these costs were incurred every day for the duration of the plague (in this case, for four months). For the purposes of their assessment, Caughley *et al.* (1994) costed all such time at $10 per hour.

Apart from time, the losses incurred were principally from damage to goods and electrical equipment. Three factors determined the extent of damage experienced: type of business, its location and type of construction. Retail outlets with large quantities of feed or foodstuffs, such as rural suppliers, grocers, supermarkets and bakeries, suffered more than other businesses. Secondly, those situated on the edges of town had more problems than similar businesses located centrally. Thirdly, the age and construction of the business premises determined how easy it was to exclude mice. Rural suppliers recorded the highest losses (Table 4). Their businesses were usually located on the edges of towns, their stock included large amounts of produce palatable to mice (e.g. grain and seed supplies, organic fertilisers and pet foods), and their premises were often open sheds that were impossible to mouse-proof. Food retailers, hotels and motels also experienced high costs. Goods and equipment were damaged and high labour costs were incurred in cleaning premises to the standard required by council health regulations. Schools and hospitals incurred similar costs in maintaining standards of hygiene.

Table 4. Average costs to retailers, community services and residents interviewed in plague-affected regions of South Australia, 1993, and some extrapolated estimates for the region (data from Caughley *et al.* 1994).

Service or business	No. sampled	Average cost	No. in plague area	Estimated total (South Aust.)
Retailers				
Rural suppliers	9	$7,451	45	$335,295
Food retailers	33	$2,304	100	$230,400
Hotels and motels	13	$2,496	82	$204,672
Other (e.g. finance)	72	$ 778		
Community services				
Schools	9	$2,734	24	$65,616
Hospitals	7	$2,107	36	$75,852
Councils, postal and emergency services	14	$ 814		
Households*	48	$ 280		

* Household costs do not include a costed labour component.

Telephone communications can be vulnerable to damage during mouse plagues. Not surprisingly, automatic exchanges in plague-prone areas are constructed to be mouse-proof and they are regularly checked by technicians who lay rodenticide baits as an extra precaution. Despite this state of preparedness, mice gained access to

[2]Note: the estimates were of costs incurred up to the time of the survey. No flow-on costs beyond the duration of the plague nor costs incurred prior to the plague (for example, construction costs in making buildings mouse-proof) were included. Some of the costs identified by a business or individual would have come from the sale of goods or services by another, but no method was available to balance the ledger.

one exchange in South Australia during the 1993 plague. It cost $30,000 to replace the damaged equipment; after parts were replaced, mouse-proofing the building cost a further $600.

Another enterprise that is highly vulnerable during mouse plagues is grain handling. Losses to grain stored in vertical silos are small since the structures are essentially mouse-proof. However, some grain is still stored in horizontal sheds on the Eyre Peninsula in South Australia and during the 1993 plague, mice caused considerable, though uncosted, losses in these sheds. In Victoria, in addition to silos, grain is stored in horizontal sheds and covered bunkers. With the onset of the plague in 1993, the Victorian grain-handling authorities instituted specific measures to limit losses; these included increased vigilance (bunker covers were checked weekly for holes or other signs of mouse infestation); the removal of grain from districts where the plague was severe; and the increased use of rodenticides around horizontal storage sheds. Between April and October, $12,000 was spent on bait. South Australian grain handling authorities spent $25,000 on bait over the same period. No estimates of losses to stored grain have been made in Queensland where grain is stored in similar ways to other states.

Many other off-farm costs of mouse plagues are intangible. For example, redirection of State Government staff to managing mouse plagues is usually uncosted. The one exception is for the 1995 plague on the Darling Downs where Fisher (1996) estimated that the cost to Queensland Government Departments of the strychnine baiting campaign was $311,000.

4.2 Impact on the Environment

The impact of mice on the environment has not been researched. Potential impacts could be:

- Competition with native fauna for food resources;
- Depletion of seed banks in pastures and native vegetation;
- Increased risk of soil erosion through the consequent reduction of ground cover;
- Increased predator pressure on native species at the end of a plague if predator numbers have increased in response to availability of mice during the plague; and
- Transmission of disease to other fauna.

Another important potential environmental impact is non-target mortalities arising from poisons used to control mice. Several rodenticides may legally be used around sheds and buildings, the most commonly used products being the anticoagulants brodifacoum (Talon™) and bromadiolone (Bromakil™). These baits take several days to kill and, as a consequence, can indirectly kill predators that feed on mice that have consumed poisoned bait. Carcasses of Australian kestrels (*Falco cenchroides*) are not infrequently seen around grain handling facilities.

Non-target mortality also occurs during broadacre baiting campaigns. Monitoring during the strychnine baiting campaign in Queensland in 1995 found approximately 120 birds that were considered to have died from strychnine poisoning (Lundie-Jenkins and Brown, 1996). After the same baiting campaign, landholders reported over 300 bird carcasses of a variety of species found after the baiting campaign, but the cause of death could not be confidently attributed to the strychnine baiting (Miller 1996). Strychnine was detected in carcasses of the following species: apostle bird, cockatiel, crested pigeon, feral pigeon, galah, sulphur crested cockatoo, Australian kestrel, black-shouldered kite, letter-wing kite, crow, emu, magpie and magpie lark. The greatest proportion of the bird deaths came from a single site where the bait had

been distributed 10 m beyond a fenceline into bordering woodland. By comparison, the effect of the baiting campaign on populations of non-target species had been minimal when bait had been distributed according to the established protocols.

Monitoring during the strychnine baiting campaign in 1993 in South Australia found 665 birds believed to have been killed by strychnine (Bird 1995). Most were granivores (67% of species and 98% of individuals found) and the commonest species killed were crested pigeons and feral pigeons.

In contrast, non-target mortalities recorded during the zinc phosphide baiting campaign in Central Queensland in 1997 were very few (Caughley *et al*.1998). The only species whose carcasses were found and tested positive for phosphine were Torresian crow (*n=4*) and Australian magpie (*n=1*). Similar low non-target mortality has been reported with zinc phosphide baits in the United States (Ramey and Sterner 1995; Parker and Hannan-Jones 1996). However, native rodents may have been poisoned if they were present in the areas baited. None were found dead during monitoring but they are known to occur at very low densities in crops and grassy habitats in Central Queensland.

The environmental fate of poisons not consumed has received some attention. Strychnine is gradually adsorbed onto soil particles where, in soils with high clay content, it breaks down within 45 days (Kookana *et al.* 1997). No evidence of crop uptake or of movement into water bodies has been recorded. Studies in the United States have also shown that zinc phosphide breaks down rapidly and its use does not lead to contamination of soils or water bodies (Parker and Hannan-Jones 1996).

5.0 Biology and Ecology

Three salient aspects of the biology of mice explain their pest status. The first is their diet, the second their propensity for gnawing, and the third is their reproductive capacity.

5.1 Diet

Mice are highly opportunistic feeders. They predominantly feed on grass seeds but also eat invertebrates and other plant material. They are cannibalistic during plagues.

In the laboratory, a mouse consumes 3–4 grams of food per day. Saunders (1987) calculated that during a plague in a sunflower crop mice were eating around 12 kg of sunflower seeds per hectare per day. If numbers remained high up to harvest, more than half a tonne would have been consumed per hectare, reducing the yield by some 29%. However, mice often eat only part of a seed so calculations such as these can underestimate the true level of damage.

5.2 Gnawing behaviour

The upper and lower incisors of all rodents grow continuously and are constantly ground down by grinding or by gnawing. Mice frequently gnaw on any hard surface. They are notorious for the damage they cause by gnawing on plastic. Telephone cables and electrical wiring are particularly susceptible. In addition to the direct damage, the gnawing on wiring can cause fires, set off alarms and disrupt telecommunications.

5.3 Reproductive Capacity and Population Dynamics

Mice living in buildings may breed throughout the year but in the field breeding is mostly in spring and early summer. The start of breeding is usually triggered by the increase in seed and insect availability in spring (Bomford 1987; Tann *et al.* 1991). The proportion of females breeding at any time is a function of the quality of the food as well as the quantity (Bomford and Redhead 1987), both of which are largely determined by rainfall. If the summer is hot and dry, reproduction ceases, but if conditions are favourable, mice will continue to breed through into autumn.

Mice are highly fecund (Table 5). The young grow rapidly and reach sexual maturity early. They are also good dispersers and quickly colonise new areas when conditions are favourable. Conversely, mortality is often high and the life span short.

Table 5. Reproductive potential of the house mouse (*Mus domesticus*) (from Caughley *et al*. 1998b).

Breeding season	From spring to autumn, depending on seasonal conditions (can breed throughout the year)
Mean litter size	6 (range 1-10; nipples 10)
Post partum oestrus	Yes
Gestation	19-20 days (although delayed implantation of up to two weeks has been reported)
Weaned at	18-21 days
Age at 1st breeding	5 weeks

Female mice can produce a litter each month during the breeding season. If the breeding season extends well into summer and the number of females participating remains high, then the doubling time for a population can be as short as three to four weeks and a plague may develop. In Fig. 2, the solid line shows the growth of a mouse population leading to a plague. Plotted on the same graph is population growth (the dotted line) that does not result in a plague. The principal differences between the two curves are: (i) starting density (i.e. number of mice at the start of the breeding season and (ii) the length of the breeding season. Quite small differences in population dynamics can produce large differences in abundance.

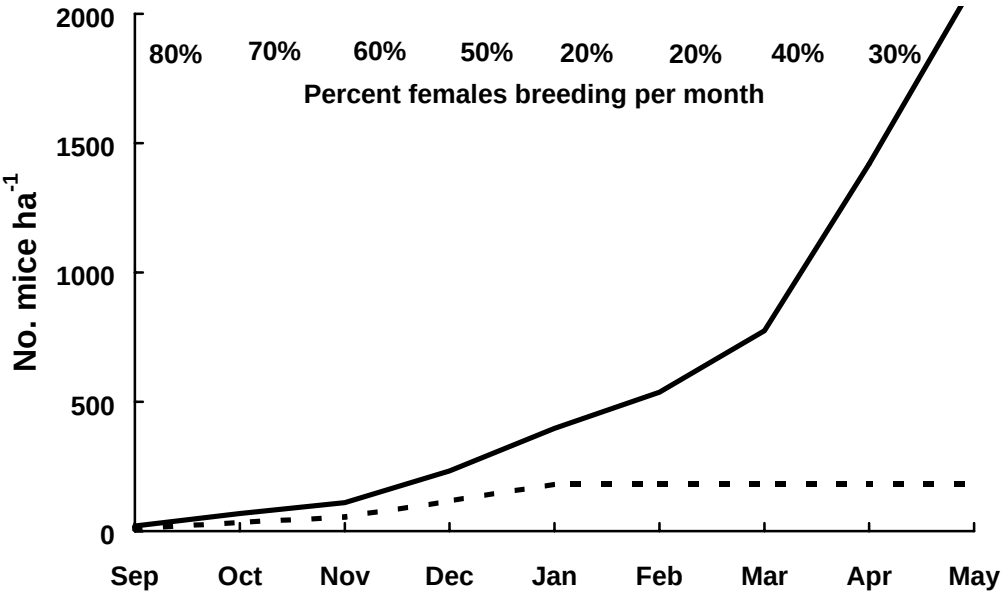

Figure 2. **Mouse Population Trends** The solid line represents the growth of a hypothetical mouse population where the starting density is 20 mice per hectare and breeding extends over eight months of the year, the proportion of females breeding each month between September and April as shown. The dotted line presents for comparison the trend in numbers of a population where the starting density is 10 mice per hectare, the breeding season is only four months long (September to December), and 80%, 70%, 60% and 40% of females participate in breeding in each of these months respectively.
Note: In both curves, litter size is set at six young per female, the sex ratio at birth at 1:1 and the age at first breeding in females at 2 months. No mortality is factored in.

This graph clearly indicates the potential for mouse populations to increase from very low numbers to large numbers in a relatively short period ie 8-9 months. The graph also shows (dotted line) that if only half the original population is present and if the breeding season is reduced then the population will not increase as dramatically.

5.4 Other Behavioural Characteristics

Mice are primarily nocturnal although they are often seen during the day when numbers are high. Mostly they spend the day in nests they have created in natural cavities or in shallow burrows e.g. in cracked soils. They tend to live in small colonies that are probably groups of related individuals. Burrows used by each group are clumped and distinct runways may be visible between their entrances. When populations are high, these runways become more obvious from their frequent use.

5.4.1 Feeding behaviour

Laboratory studies show that mice may feed from up to 20-30 different sites each night, eating only a little at each location. Consequently, the optimal baiting strategy recommended for mice is to offer a small amount of bait at a large number of sites (MacDonald and Fenn 1994).

5.4.2 Sensory capabilities

Mice have poor sight but very acute senses of smell, hearing, touch and taste. Odours are produced by specific glands and are present in urine and faeces (MacDonald and Fenn 1994). All mice mark extensively with urine, creating a network of odours on every object in their environment. They recognise other members of the group and negotiate in total darkness by these odours.

Because mice have an acute sense of smell, a number of chemical repellents have been tested as a means for excluding mice. None of the repellents has been successful for more than a short time (Smith 1994). Ultrasonic devices similarly repel for little more than a day or two (Kaukeinen 1994).

6.0 Efficacy of Current Control Methods

Management of mouse plagues at the farm level has largely been directed towards reducing mouse numbers after farmers notice damage to their crops. The reduction is usually attempted by the use of poisons.

6.1 Poisoning

6.1.1 In crops

In the past, a multitude of chemicals has been used in and around the perimeter of crops during mouse plagues. For example, during the 1970 plague in New South Wales, the chemicals[3] used included strychnine, arsenic, phosphorus, 1080, the organochlorines DDT, Dieldrin and Endrin, the organophosphates Parathion, Phosdrin and Lucijet, the fungicide Thiram and the anticoagulants Ratsak and Racumin (Ryan and Jones 1972).

Because of its effectiveness, strychnine has been the most widely used chemical but its availability has been progressively restricted since the 1980's because of its toxicity. Nonetheless, during the 1993–94 plague, it was given temporary registration by the National Registration Authority for Agricultural and Veterinary Chemicals (NRA) for broadacre distribution in South Australia and Victoria, and again during the mouse plague in southern Queensland and northern New South Wales in 1995.

However, the use of strychnine as an in-crop rodenticide was finally banned in 1997, not because of its dangers but because of Australia's need to meet international residue standards for exported products. No maximum permissible residue level (MRL) has been assigned for strychnine by the International Codex Committees on Pesticide Residues and Residues of Veterinary Drugs in Food. When no MRL is assigned, it is by default set at zero. It is impossible to prove zero residues because all assay techniques have a lower limit of detection.

Consequently, when mouse plagues irrupted in several areas of Australia in 1997, temporary registration was given by NRA to a bait formulation containing zinc phosphide. Zinc phosphide baits are widely used overseas as in-crop rodenticides and an MRL exists for the bait's breakdown product, phosphine. Good results were achieved with the bait, and the Victorian manufacturing company has applied to the NRA for registration of its product. In the interim, a minor off label permit has been issued by the NRA to allow use of the bait where and when necessary, which is valid until 30 June 1999.

Value of baiting during mouse plagues

Several studies have attempted to estimate the cost/benefits of baiting mice in crops. The first study was during a plague in the Murrumbidgee Irrigation Area in 1979–80 when Saunders (1986) baited a sunflower crop with strychnine and achieved a 90% reduction in mouse numbers. He calculated that, had the mice not been killed, they would have eaten 3.4g per mouse per day over the seven weeks remaining to harvest, equivalent to 29% of the yield. The cost of baiting (excluding labour) was $8/ha; the value of the crop was $640/ha. Baiting may thus have prevented a loss of $130/ha, giving a benefit/cost ratio of 16:1. The calculation presumes neither re-

[3] Most of these chemicals are now banned or are not registered for use on rodents.

invasion of the baited crop by mice from unbaited areas nearby, nor the possibility of a natural decline in mouse numbers over the time between baiting and harvest.

A study by Singleton *et al.* (1991) evaluated the cost/benefit of baiting with bromadiolone in summer soybean crops in the Namoi Valley using responses to a questionnaire sent to farmers. At baiting costs[4] of $45/ha and a crop value $400/ha, they estimated that the break-even point would have been when crop damage was around 11%. The extent of crop damage varied considerably between farms and between areas but on average, the damage exceeded 11%. Therefore, for more than half the respondents, the benefit of baiting would have exceeded the cost.

Mutze (1993) conducted an economic assessment of strychnine baiting in a wheat crop at the time of flowering in 1987. The baiting reduced mouse numbers by 46%. Although by the time of harvest two months later, densities were similar to pre-baiting levels, Mutze found baiting had reduced the level of damage to the grain heads by 81%. Mouse numbers were only around 50 per ha at the time of the study so the actual tonnage lost was small, approximating a 2% reduction in yield. Mutze concluded that even at those relatively low densities the cost of baiting was close to the gain in yield.

No studies have been conducted on the effectiveness of perimeter baiting but Kay *et al.* (1994a) evaluated the effect of baiting refuge habitats around irrigated soybeans with bromadiolone. They found that baiting significantly reduced the number of mice inhabiting the refuge habitat and reduced the rate at which mice invaded and colonised the adjacent crops. No significant reductions in crop damage were detected because mouse numbers overall were low.

6.1.2 Around buildings

Poisons are also widely used to control mice around buildings. Several rodenticides are registered for use in and around buildings (see Appendix B).

6.2 Trapping

Break-back traps are commonly used around houses and sheds. Trapping is preferable to baiting in these areas since:

- There is no danger of accidental poisoning of children and pets; and
- Mice do not die (and smell) in wall cavities and other inaccessible nooks and crannies.

During plagues, farmers also often use water traps where a greased bottle with a food attractant in the neck is balanced over a bucket of water. Mice fall into the water when trying to reach the food. There are numerous variations on trap designs used by farmers. If a record of the number of mice caught is kept, all of these trapping methods can provide an index of mouse numbers and allow a farmer to judge the size of the mouse problem at any given time.

Trapping is also used for monitoring mouse numbers over time in fields. For example, multiple catch traps are used in broccoli crops by the landholder on 'Wando' on the Darling Downs, and break-back traps are used by the Queensland

[4]Comprising cost of bait and grain ($4.20); cost of bait stations ($20) (which could be re-used) and cost of labour ($21) (1989$ values) (Singleton *et al.* 1991).

Department of Natural Resources and Mines personnel to follow trends in mouse numbers over transects in grain-growing areas.

6.3 Exclusion

Exclusion is a highly successful way of reducing the damage caused by mice in buildings. Houses and storages are made rodent-proof by sealing all holes, keeping doors closed, fitting traps to drains, screening all vents, etc. Barrier fencing in doorways is successfully used to exclude mice in some businesses in Queensland (e.g. seed merchants, peanut processors). Two major types of barriers are used: electric pads and counter-levered fences made of steel that allow access of machinery but prevent the entry of mice.

6.4 Habitat Modification

Undisturbed areas such as roadside verges and fencelines can act as refuge habitat for mice (Mutze 1991; Chambers *et al.* 1996). Other refuge habitats are areas where weeds or rubbish is allowed to accumulate (Singleton 1989). Reducing mice by habitat modification involves removing weeds and debris around crops, buildings and storages and controlling growth of grasses and weeds along fencelines and roads by ploughing, burning, grazing or applying herbicides. These methods are used variously by farmers throughout plague-prone areas. Other forms of habitat modification widely used are slashing and working stubble. Some of these methods may however conflict with soil conservation principles and practices, and so need to be carefully considered as part of a holistic approach to on-farm management.

6.5 Other Control Measures

6.5.1 Use of raptor perches

An option that has been researched both in Australia and overseas is the placement of raptor perches in or at the margins of crops to increase the level of predation (Howard *et al*. 1985; Kay *et al*. 1994b). While it is recognised that birds of prey cannot eat enough mice to prevent a plague (Sinclair *et al*. 1990), they can slow the rate of plague formation by several weeks.

6.5.2 Chemical repellents

Because mice have an acute sense of smell, chemical repellents have been tested as a means of control. However, as noted earlier, research has shown that the repellent effect tends to be short-lived.

6.5.3 Ultrasonic devices

Similarly, studies have shown that ultrasonic devices are unsuccessful as a practical means of rodent control (Meehan 1984; Howard and Marsh 1985). Although the animals initially withdraw from a loud new ultrasonic noise, they start to ignore it within a few days. As Smith (1994) commented, ‘behavioural modification is only effective if the animal can choose a more attractive alternative. If food or harbourage is short, or population density is high, methods that do not exclude absolutely may be overcome because the animal perceives that the alternatives are worse’.

6.5.4 Biological Control

The potential for a parasitic nematode, *Capillaria hepatica*, to control mouse populations was investigated in Australia by Singleton and his co-workers (Singleton and McCallum 1990). If mice infected with the parasite have less frequent litters,

population growth rate would be slowed and plagues would be prevented. Field trials on the Darling Downs and in the Mallee in Victoria, however, failed to demonstrate any decline in breeding by mouse populations that were experimentally infected with *C. hepatica* (Singleton *et al*. 1995; Singleton and Chambers 1996) and the research has been discontinued.

Singleton and his co-workers at the Cooperative Research Centre for Biological Control have now directed their research towards immunocontraception using a mouse-specific virus[5] that is present in nearly all Australian mouse populations (Chambers *et al*. 1997). Laboratory trials to date have shown that the virus will carry foreign material and that the modified virus will replicate in mice. The next step in the research is to identify an appropriate fertility blocking protein to attach to the virus and to study the behaviour and epidemiology of this modified virus.

[5] Murine Cytomegalovirus (MCMV)

7.0 Human and Animal Welfare Considerations

7.1 Disease

Rodents are vectors of a number of diseases that affect humans and livestock. In Australia, most of these pathogens are absent or rare but there are a few that cause problems. Perhaps the commonest are *Salmonella* bacteria that can be spread by a range of animal species (including humans). The bacteria are usually transmitted to people through food contaminated with infected urine or droppings, and can cause acute gastroenteritis (Stevenson and Hughes 1988).

Another known pathogen in mice in Australia is *Streptobacillus moniliformis* that causes rat bite fever in people and other animals (Taylor *et al.* 1994). During plagues, mice are caught occasionally with polyarthritis or abscesses ('lumpy tail') that are caused by the pathogen. Although no transmission to humans from infected mice has been recorded, one person in Australia has died from the pathogen following a bite from a wild rat (Taylor *et al*. 1994).

The best means of limiting the risk to humans from these pathogens is to exclude mice from foodstuffs and to maintain high standards of cleanliness in food preparation and eating areas. Protection of feed storages and good shed hygiene are likewise important in intensive livestock operations.

For livestock, the most serious disease that mice may transmit is swine encephalo-myocarditis that led to substantial pig mortalities on some properties in New South Wales during the mouse plagues of 1970 and 1984 (Acland and Littlejohns 1975; Seaman *et al.* 1986). Intensive livestock farmers also reported an increase in the incidence of other infectious diseases during mouse plagues. Scouring is a frequent problem in pig herds during plagues with mice aiding the transfer of bacteria between pens. During the 1984 NSW and 1993 SA plagues, infection with *Erysipelas* was reported in some herds.

7.2 Other health risks

7.2.1 Risk of poisoning

During a mouse outbreak, people take risks with poisons, using them in ways that they would not normally countenance. No poisoning of humans has been attributed to rodent baits during mouse plagues in Australia but accidental poisoning of domestic pets occurs quite frequently. During the 1993 mouse plague in South Australia, one veterinarian treated 40 dogs that according to their owners had eaten rodent bait (Caughley *et al.* 1994).

As a part of any education program prior to mouse plagues, town residents must be alerted to the dangers to pets of accidental poisoning and offered advice on how to prepare baits in bait stations or to lay them in places inaccessible to dogs.

7.2.2 Risk of fire

Mice gnawing on electrical wiring can cause fires in homes and other buildings. For intensive livestock farmers, the risk is magnified if their sheds are lined with

polyurtheane insulation since it gives off cyanide gases when it burns which is lethal to both livestock and firefighters.

7.3 Animal Welfare Issues

7.3.1 Impact of mice on livestock

During the 1993 SA plague, mice caused considerable damage to penned animals (Caughley *et al.* 1994). Poultry had their feet gnawed and, as a direct result of stress and stress-related injuries, the birds lost condition, egg production declined and mortality increased. In piggeries, breeding sows and piglets were the most seriously affected and badly gnawed animals had to be destroyed to end their suffering.

Destocking is one option available to intensive livestock producers during a mouse plague but the costs of destocking and restocking are high. Farmers usually choose to persist with baiting and the constant care of their animals.

7.3.2 Humane control of mice

With regard to mice, the primary animal welfare issue is that the control methods selected are those that cause the minimal pain, distress and discomfort to the animals being controlled. Measurements of the humaneness of rodenticides are largely subjective, but in animal welfare terms, a poison, which acts quickly to kill or leave an animal unconscious, is better than one that takes a considerable time to act.

8.0 Legislation and Policy

8.1 Legislative Status of Mice in Queensland

Mice are not a declared pest under the *Rural Lands Protection Act 1985* so there is no legal requirement that they be controlled. As the house mouse is not a native species there are no laws governing their control other than the *Animals Protection Act 1925* and *via* health regulations[6].

The use of chemical poisons is constrained by Government regulations in Queensland. A number of rodenticide poisons are registered (see Appendix B) and may be used in and around buildings, animals sheds and storage facilities. No rodenticide is registered for use in grain crops although temporary registration has been given for the broadacre distribution of strychnine and zinc phosphide during the 1995 and 1997 mouse plagues respectively.

8.2 Queensland Department of Natural Resources and Mines' Policy on Mice

The Queensland Department of Natural Resources and Mines' does not have any legislative responsibility to control or enforce the control of the house mouse but has assumed a coordination role for non-urban situations. The departments' exact role is outlined in the policy on rodents that states.

"The Department of Natural Resources and Mines will:

(a) Monitor rodent populations on the Central Darling Downs and provide short and long term predictions on the potential for plague development;
(b) Provide graingrowers with technical advice on available mouse control strategies;
(c) Undertake research to support the registration of a rodenticide suitable for incrop baiting of mice;
(d) Undertake research into integrated long term management strategies for the control of mice in farming areas;
(e) Accept responsibility for coordinating large scale emergency mouse control operations;
(f) Collaborate with industry (eg GrainGrowers Association), State Departments (Primary Industries, Environment and Health), interstate counterparts and research and development organisations, including CSIRO, as necessary to satisfy Queensland's requirements for mouse control consistent with national standards;
(g) Cooperate with industry and other organisations in the development of control options for other rodent species, subject to availability of funding.

The Department of Natural Resources and Mines will not:

(a) Declare any rodent species."

[6] An authorised health officer may give 'reasonable directions' to the owner or occupier of premises to destroy any rats and mice on those premises or to rectify conditions that are conducive to their breeding.

9.0 Recommended Management and Control Practices

The Queensland Department of Natural Resources and Mines and Mines advocates the following management and control practices.

9.1 Managing Mice around Buildings

Controlling mice in and around buildings is important for all people living in plague-prone areas. In homes, trapping is recommended, rather than the use of poisons, to avoid accidental poisoning of children or pets and to prevent the unpleasant smell of decaying mice if they die in wall cavities and inaccessible areas.

Good hygiene is very important. Because mice can carry a number of diseases, washing hands with soap and water after handling dead mice, and washing food preparation surfaces, plates, utensils, etc. before use, are strongly recommended.

If possible, houses should be made ‘mouse-proof’ by locating the routes mice are using to enter the house, blocking holes with steel wool, and placing sealing strips on doors. Foodstuffs and precious items should be stored in mouse-proof containers.

In sheds, a combination of trapping, baiting and storing goods in rodent-proof containers or on rodent-proof stands is recommended measures. Baits should be used according to directions on the manufacturer’s label. Bait blocks and pellets should be laid in bait stations to prevent mice from scattering the bait and to guard against the accidental poisoning of children and pets. The simplest design is a small plastic container with a lid, with small holes cut in the sides to give mice access to the bait.

Grassy areas around sheds and homes should be kept mown, building materials stored upright and piles of rubble or other material removed.

9.2 Managing Mice on Farms

A number of agronomic practices are available to broadacre farmers to limit the impact of mice. The best forms of defence are methods that reduce the amount of shelter and food available to mice. General farm hygiene is important - that is, cleaning up piles of rubbish and any spilt grain, and keeping grass down by slashing or spraying along roads and around verges, haystacks, etc. Minimising grain spill at harvest is also very important.

Slashing, working or burning stubble reduces both the availability of food and shelter for mice, but stubble retention is an important method for controlling soil erosion and retaining soil moisture. Controlling mice by stubble management needs to be balanced against the benefits of its retention. To optimise stubble management practices, farmers should assess the number of mice in the stubble and make their decision accordingly.

Monitoring

Regular monitoring of mouse numbers enables farmers to undertake management actions to control mice before they begin to damage crops. In order to prevent mouse damage to crops, the most important times to check mouse numbers are prior to flowering for each winter and summer crop, checking both within crops and within adjacent stubble on each occasion.

There are two principal means of monitoring. The first is break-back traps which can be set out overnight in crops, stubbles and other habitats in a line of 20 or so traps. These traps are a cheap, simple and effective means of keeping track of mouse numbers over time.

The second method is to use bait cards that are 10cm x 10cm square pieces of white paper that are soaked in canola oil and pegged out overnight in crops and in other habitats. The amount of card eaten serves as an index of mouse numbers. To obtain a reasonable estimate, at least five cards should be placed 5-10 metres apart in each habitat.

The bait card technique is a less reliable indicator of mouse numbers than break-back traps, since the amount of a card eaten is largely a reflection of the paucity of food available for the mice rather than the numbers of mice present. When food is plentiful, the cards may be relatively untouched even when mouse numbers are high. However, if bait card take is greater than 10%, it indicates (i) that mouse numbers are high and (ii) the mice will readily take the bait and cost-effective control will be achieved.

Baiting

At present, no rodenticide is registered for in-crop mouse control although an application for the registration of zinc phosphide bait is currently before the National Registration Authority for Agricultural and Veterinary Chemicals. If it receives approval, baiting crop and stubble areas will be an option available to farmers. Research has shown that the best results will be achieved by baiting when alternative food is scarce (for example, in crops before flowering commences and in stubble about one month after harvest). Recommended strategies for use of bait will be published by the Department when the product receives registration.

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Appendix 1. A Summary of the Biology and Ecology of the House Mouse

Scientific name: *Mus domesticus*
Common name: House mouse (*also* Field mouse)

Size

- Head/body length 55-100 mm
- Tail length 75-100 mm
- Weight 10-25 g

Description

- Brown, grey or black above; white, pale yellow or grey below. Fur soft, short. Distinguished from similar species by notched upper incisors and musty smell.

Reproductive characteristics

Breeding season	Mostly between spring and autumn, but can breed throughout the year
Mean litter size	6 (range 1-10; nipples 10)
Post partum oestrus	Yes
Gestation	19-20 days (although delayed implantation of up to two weeks has been reported)
Weaned at	18-21 days
Age at 1st breeding	5 weeks

Diet

- Principally seeds but omnivorous and highly opportunistic.

Behaviour

- Predominantly nocturnal except when population density is high.
- Social, living in small groups of related individuals, usually with in a home range that appears to be defended at certain times or at certain population densities. Most young disperse on reaching adulthood.
- Burrows are often complex with interconnecting tunnels. Usually shallow (less than 20 cm below the surface) but in light soils can be 100 cm or more deep. Stores of seed can sometimes be found in burrows. Also nests in natural cavities, e.g. in wood piles, back of stoves, between walls.

Appendix 2: Rodenticides that are registered for use in Qld

Department of Natural Resources and Mines

RODENTICIDES REGISTERED FOR USE IN QUEENSLAND			
Product Name	**Active Ingredient**	**Pack Sizes**	**Registered Usage Area**
Ditrac All Weather Blox Rodenticide	Brodifacoum	1.8 kg, 4 kg, 8 kg, 10 kg	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings
Ditrac Rodenticide	Brodifacoum	2 kg, 5 kg, 10 kg	Unspecified Perimeter baiting adjacent to crops
Farmoz Rodex B Rat Blocks	Brodifacoum	2 kg, 5 kg	Commercial/Industrial Buildings Domestic Buildings Public Services
Farmoz Rodex B Rodenticide Pellets	Brodifacoum	300 g, 5 kg	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings Public Services Perimeter baiting adjacent to crops
Hortico Ratsack 1 Shot Rat and Mouse Bait	Brodifacoum	150 g (2 x 75g)	Unspecified
Klerat Rodenticide Wax Blocks	Brodifacoum	10 kg	Sugarcane
Mortein Rat Kill, Rat & Mouse Killer	Brodifacoum	150 g (4 x 37.5g), 450 g (12 x 37.5g)	Unspecified
Oztec Ratal Rodenticide Pellets	Brodifacoum	200 g, 1 kg, 10 kg, 140 kg	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings Public Services Perimeter baiting adjacent to crops
Talon Rodenticide All Weather Rodenticide Wax Blocks	Brodifacoum	75 g, 1 kg, 2.4 kg, 10 kg	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings Public Services
Talon Rodenticide Pellets	Brodifacoum	50 g, 200 g, 1 kg, 10 kg	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings Public Services Perimeter baiting adjacent to crops
Bromakil Super Rat Bait	Bromadiolone	500 g, 2 kg, 5 kg, 15 kg	Commercial/Industrial Buildings Domestic Buildings Public Services Perimeter baiting adjacent to crops
Bromakil Super Rat Blocks	Bromadiolone	1.4 kg	Commercial/Industrial Buildings Domestic Buildings Public Services
Bromakil Super Rat Drink Concentrate	Bromadiolone	500 mL	Commercial/Industrial Buildings Domestic Buildings Public Services
Contrac Blox	Bromadiolone	1.8 kg, 8 kg, 9 kg	Commercial/Industrial Buildings Domestic Buildings Public Services
Contrac Rat and Mouse Bait	Bromadiolone	5 kg (100 x	Commercial/Industrial Buildings

		50g), 10 kg	Domestic Buildings Public Services Perimeter baiting adjacent to crops
Contrac Rodenticide	Bromadiolone	5 kg, 10 kg	Commercial/Industrial Buildings Domestic Buildings Public Services Perimeter baiting adjacent to crops
Country Di-O-Lone Super Rat Grain Bait	Bromadiolone	500 g, 1 kg, 2 kg, 5 kg, 10 kg, 20 kg	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings Perimeter baiting adjacent to crops
Rattex Bromablock	Bromadiolone	5 kg	Buildings Sewers/Drains
Rattex Grain Bait	Bromadiolone	5 kg	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings Perimeter baiting adjacent to crops
Rentokil Bromakil Bait for Rats and Mice	Bromadiolone	200 g	Domestic Buildings
Rentokil Bromakil Mouse Mix	Bromadiolone	750 g, 3 kg, 10 kg	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings Public Services Perimeter baiting adjacent to crops
Rentokil Bromakil Rodenticide Concentrate	Bromadiolone	1 L, 5 L, 20 L	Commercial/Industrial Buildings Domestic Buildings Public Services
Rentokil Bromakil Super Rat Bait Sachets	Bromadiolone	2.5 kg (100 x 25 g)	Domestic Buildings
Rentokil Bromakil Super Rat Blocks	Bromadiolone	500 g, 2 kg, 5 kg, 10 kg	Commercial/Industrial Buildings Domestic Buildings Public Services
Rentokil Bromakil Super Rat Drink	Bromadiolone	500 mL	Commercial/Industrial Buildings Domestic Buildings Public Services
Rentokil Bromakil Super Rat Grain Bait	Bromadiolone	2 kg, 4 kg, 15 kg	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings Perimeter baiting adjacent to crops
Rentokil Bromakil Super Rodent Blocks Rodenticide	Bromadiolone	140 g	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings
Rentokil Bromakil-P Rodenticide Pellets	Bromadiolone	200 g, 1 kg, 10 kg	Commercial/Industrial Buildings Domestic Buildings Perimeter baiting adjacent to crops
Tomcat All-Weather Blox	Bromadiolone	112 g, 224 g, 784 g, 900 g, 1.8 kg, 4 kg, 8 kg, 9 kg	Commercial/Industrial Buildings Domestic Buildings Public Services
Tomcat Rat and Mouse Bait	Bromadiolone	50 g, 200 g, 300 g, 500 g, 1.75 kg, 2.5 kg, 3.5 kg, 5 kg, 10 kg	Commercial/Industrial Buildings Domestic Buildings Public Services Perimeter baiting adjacent to crops
Yates Mouser One Shot Mouse Bait	Bromadiolone	33 g	Domestic Buildings
Yates Rat Attack One Shot Rodenticide	Bromadiolone	200 g (4 x 50 g)	Commercial/Industrial Buildings Domestic Buildings
* Rampage Rat and Mouse Bait	Cholecalciferol	1 kg, 1.5 kg	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings
Barmac Racupak Ready to use Rodenticide	Coumatetralyl	100 g	Industrial Sites/Factories
Racumin 8 Bayer Rat and	Coumatetralyl	1 kg, 10 kg	Commercial/Industrial Buildings

Mouse Rodenticide Bait Concentrate and Tracking Powder			Domestic Buildings Farm/Agricultural Buildings Meatworks (non-product areas) Wharves
Racumin Domestic Mouse and Rat Bait	Coumatetralyl	150 g	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings Meatworks (non-product areas) Wharves
Racumin Mouse and Rat Blocks Ready to use Bait Blocks	Coumatetralyl	1440 g	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings Meatworks (non-product areas) Wharves
Racumin Mouse and Rat Bait Pelleted Bait - ready to use	Coumatetralyl	1.5 kg, 15 kg	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings Meatworks (non-product areas) Wharves
Ratex Mouse and Rat Bait	Coumatetralyl	1 kg, 5 kg, 15 kg	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings Meatworks (non-product areas) Wharves
Hortico Double Strength Ratsak Ready to use Rat Bait	Warfarin	250 g, 350 g, 1 kg, 2.5 kg	Unspecified
* Rattex Gel	Warfarin	500 g	Commercial/Industrial Buildings
* Rattex Tracking Powder	Warfarin	5 kg	Commercial/Industrial Buildings Domestic Buildings
RCI Ratblitz Bait	Warfarin	3 kg, 13 kg	Unspecified
Terminator Mouse and Rat Bait	Warfarin	300 g, 1.5 kg, 8 kg	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings
Storm Wax Block Rodenticide	Flocoumafen	500 g, 3 kg, 10 kg	Commercial/Industrial Buildings Domestic Buildings Farm/Agricultural Buildings

* Supply/use restricted to licensed Pest Control Operators

Prepared by Officers of - Land Protection
Department of Natural Resources and Mines and Mines

Chemical Services
Department of Primary Industries

4 June 1998

Pest Status Reviews

Others in the series:

Prickly acacia in Queensland

Rubber vine in Queensland

Mesquite in Queensland

Cabomba in Queensland

Sicklepod in Queensland

Veterbrate Pests of Built-up areas

Hymenachne in Queensland

Bellyache bush in Queensland

Feral pigs in Queensland

Feral Goat in Queensland

For further information contact:

C.S. Walton,
Land Protection,
Natural Resources and Mines.
Phone: (07) 3406 2879.

Department of Agriculture, Fisheries and Forestry
Biosecurity Queensland

Fact sheet
PEST ANIMAL
PA21 December 2013

Cane toad

Bufo marinus

The cane toad is not a declared pest in Queensland, so there is no legal requirement to control them.

Their original introduction in 1935 was to control agricultural pests, but they proved ineffective.

For the past 60 years, cane toads have been expanding their territory in Australia, and are capable of colonising at least four of the mainland Australian states.

As the toad's geographical range continues to expand, concern has increased about their detrimental environmental effects, particularly on the wetlands of the Northern Territory.

Studies into the feasibility of biological control have commenced.

History of introduction and spread

The cane toad or giant toad is an amphibian, native to Central and South America. Cane toads have been introduced throughout the world as a biological control for insect pests of agriculture, most notably sugarcane.

A consignment of cane toads from Hawaii was released into Queensland cane fields in 1935. The introduction was surrounded by controversy as to the potential costs and benefits to Australia.

It was hoped that the toad would control Frenchi and greyback beetles—pests of economic importance to the sugarcane industry.

By 1941, however, it had become evident that the cane toad was exerting only limited control over its intended prey. There were two main reasons for this:

- Greyback beetles are only rarely in contact with the ground and Frenchi beetles invade cane fields at a time when the toads are absent due to a lack of protective cover.
- The cane toad has a wide-ranging and indiscriminate diet, and it was not solely dependant upon its intended prey.

The unlimited food source, suitable environment and low rates of predation allowed dynamic reproduction and spread. Toads were recorded in Brisbane only 10 years after release. The toad continues to thrive and has now invaded the Northern Territory and New South Wales (see Map 1).

Map 1. Distribution of the cane toad in Australia

The cane toad's advance is only limited by environmental factors, such as the availability of water for breeding, tolerable temperatures, suitable shelter and availability of food.

Toads at the frontier of their range of expansion may be larger than those in established populations. This is most probably due to greater food supply, combined with a lower incidence of disease.

Description and general information

In comparison with native frog and toad species, adult cane toads have a distinctive head and face, and are large and heavily built creatures (adults may grow to 20 cm).

Following their aquatic larval stages (eggs and tadpoles), cane toads are generally encountered at night near any source of light. Cane toads are ground-dwelling—they are poor climbers and unable to jump very high.

A definite visor or awning extends over each eye and a high angular bony ridge extends from the eyes to the nose.

The parotid glands (see Figure 1) are perhaps the most characteristic feature of the adult cane toad. These glands are large, protuberant, and are situated on the head behind each ear. These glands carry a toxin.

Map 2. Distribution of the cane toad in Queensland

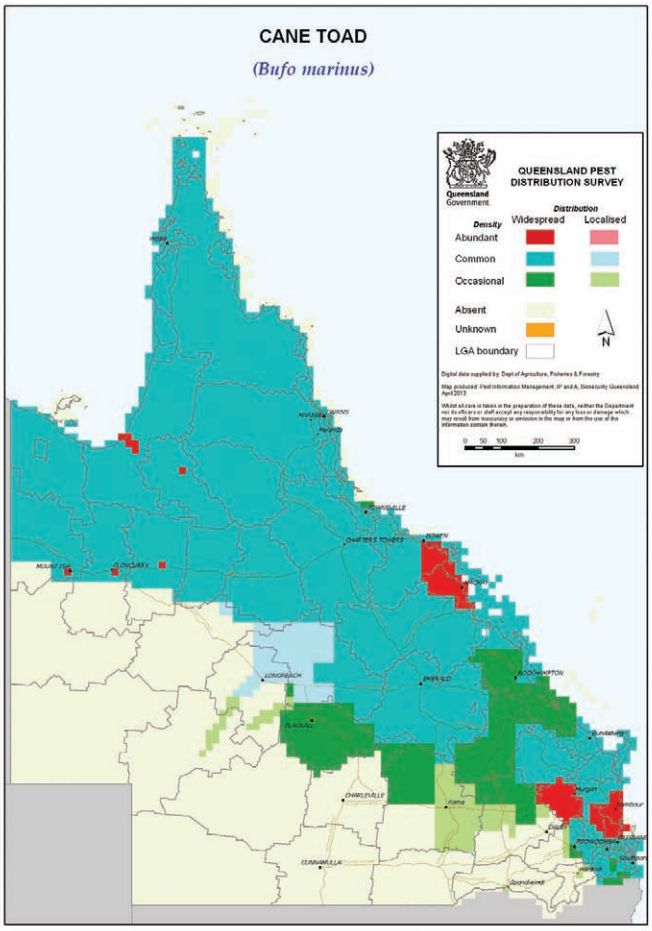
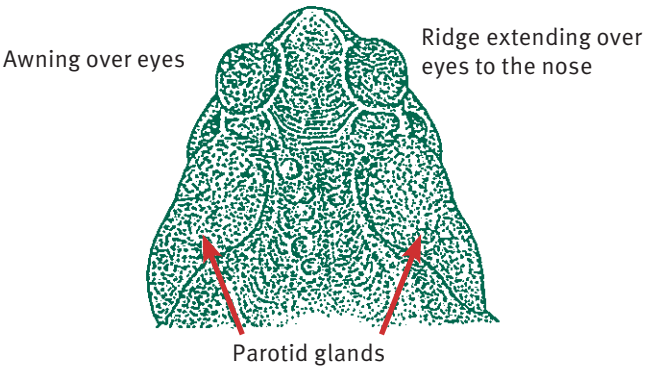


Figure 1. Distinguishing features of the cane toad



The cane toad's hands and feet are relatively small and lack discs at the tips of the digits. Webbing is absent between the fingers but is distinct and leathery between the toes.

Colouring on the dorsal (upper) surface may be brown, olive-brown or reddish-brown. The ventral (under) surface varies from white to yellow and is usually mottled with brown.

Warts are present on all cane toads; however, males possess more than females. Warts are dark brown at the caps.

Mating

Mating can occur at any time of the year and depends only on available food and permanent water. The mating call is a continuous purring trill that sounds like a running motor.

In situations where females are scarce or absent, male cane toads may have the ability to undergo a sex change to become fertile females; however, this has not been proved.

Eggs

Both cane toads and native frogs spawn in slow-moving or still water, but their eggs can be easily distinguished.

Cane toad eggs are laid in long, gelatinous 'strings' with the developing tadpoles appearing as a row of small black dots along the length. The strings are unique to cane toads, generally appearing as blobs of jelly attached to water plants or debris. Native frogs generally produce egg clusters as mounds of foam floating on the water surface.

Compared with native species, cane toad egg production is dynamic and a single clutch can contain up to 35 000 eggs. Remove any cane toad eggs found in the water and allow to dry out.

Figure 2. Drawing of toad spawn from *Wildlife of greater Brisbane*

Tadpoles

The cane toad is the only species in Australia that has a pure black tadpole. Native frogs have lighter-coloured undersides with a great range of colours and markings—cane toad tadpoles may turn paler colours to almost transparent at night.

Cane toad tadpoles are small and usually congregate in vast, slow-moving shoals. This 'shoaling' behaviour is uncharacteristic of most native species.

Unlike cane toad tadpoles, native species develop lungs at an early stage and periodically rise to the surface in order to exchange their lung gasses. Large groupings of tadpoles that do not break the water surface for air indicate cane toads.

Young toads

Following emergence from the water, the young toadlets usually congregate around the moist perimeter of the water body for about a week before they eventually disperse.

Young toads are very difficult to distinguish from the native *Uperoleiea* species, which also have parotid glands, but all *Uperolelea* species have bright red patches in the groin area.

Under ideal conditions toadlets may reach adult size within a year.

Toxicity

Bufo marinus produce venom in glands occurring in most of the skin on their upper surface. The venom is concentrated in the parotid glands as a creamy-white solution, which is released when the animal experiences extreme provocation or direct localised pressure (e.g. grasped by the mouth of a predator).

The parotid solution is highly toxic and when ingested it produces drastic acceleration of the heartbeat, shortness of breath, salivation and prostration. It is extremely painful if accidentally rubbed into the eye.

Ingestion of toads by domestic and most native animals can result in death. In some recorded cases, death has occurred within 15 minutes.

Field observations suggest that some predatory Australian species have learned how to feed safely on cane toads.

Birds have been observed flipping toads over to avoid the parotid glands. Predatory reptiles may have more trouble adapting, being unable to remove a toad from the mouth once they start feeding.

Effects on wildlife

The cane toad is poisonous at all stages of its life cycle and most native frog larvae and many aquatic invertebrates are dramatically affected by their presence.

Cane toads are voracious feeders that consume a wide variety of insects, frogs, small reptiles, mammals and even birds. Perhaps the only limiting factor to the prey taken is the width of the cane toad's mouth.

It has been suggested that cane toad competition for food and breeding grounds has been responsible for reducing the populations of some native frogs. However, many native frogs are arboreal (tree-dwelling) and occupy different niches. Cane toads don't have the native frogs' ability to 'shut down' during dry seasons when resources are limited.

Pressure from cane toads may displace native animals (frogs and other species) where they are already suffering due to manipulation of their habitat by humans and grazing animals. Animals that use waterholes as retreat sites during the dry season are especially vulnerable—toads will congregate here in large numbers.

Public health

Cane toads readily eat animal and human faecal material and, in areas of poor hygiene, they have been known to transmit disease such as salmonella.

Control

Control of cane toads is not enforced as there is currently no available effective broad scale control. Individuals and community groups have carried out removal campaigns to decrease numbers and slow the invasion front.

Fencing is recommended to keep toads out of ponds intended for native fish and frogs; a height of 50 cm is sufficient. Bird wire with 1 cm holes may keep toads out of an area.

Research indicates that spread can be delayed in semi-arid areas by blocking access to water holes.

Individual toads may be killed relatively humanely using a commercial spray available from hardware stores or may be stunned and decapitated (only by experienced operators). The removal of eggs from small water bodies such as frog ponds can be effective

Researchers have successfully mitigated impacts in recently colonised areas by 'training' predators however, large scale application of this technique is difficult.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland (call 13 25 23 or visit our website at www.biosecurity.qld.gov.au).

This fact sheet is developed with funding support from the Land Protection Fund.

Fact sheets are available from Department of Agriculture, Fisheries and Forestry (DAFF) service centres and our Customer Service Centre (telephone 13 25 23). Check our website at www.biosecurity.qld.gov.au to ensure you have the latest version of this fact sheet. The control methods referred to in this fact sheet should be used in accordance with the restrictions (federal and state legislation, and local government laws) directly or indirectly related to each control method. These restrictions may prevent the use of one or more of the methods referred to, depending on individual circumstances. While every care is taken to ensure the accuracy of this information, DAFF does not invite reliance upon it, nor accept responsibility for any loss or damage caused by actions based on it.

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Department of Agriculture, Fisheries and Forestry
Biosecurity Queensland

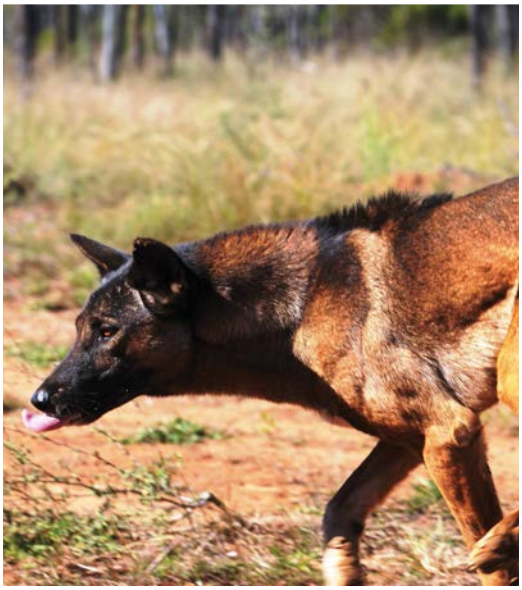
Fact sheet

DECLARED CLASS 2 PEST ANIMAL

July 2014

Wild dog control

Canis familiaris



The term wild dog refers collectively to purebred dingoes, dingo hybrids and domestic dogs that have escaped or been deliberately released.

Wild dog control methods include baiting, trapping, shooting, fencing, and the use of guardian animals to protect stock. A planned strategy using a combination of these methods that also considers wild dog behavior will enable effective management.

Declaration details

Wild dogs are a declared Class 2 pest animal under Queensland legislation. As such, all landholders in Queensland are required to reduce the number of wild dogs on their properties.

Management strategies

To increase wild dog control effectiveness, it is essential that control programs are coordinated among adjoining properties.

Queensland research has shown that in some situations wild dogs can quickly re-colonise baited areas due to a number of factors including inconsistent bait programs which do not provide comprehensive wild dog control across the landscape. Such programs may alter the dynamics of wild dog populations in the area. To prevent livestock attacks and enhance wild dog management, it is important for producers to work together using a variety of control methods.

Wild dog ecology and seasonal variations can also influence the likelihood of wild dogs coming into contact with a control tool. The timing of control should consider seasonal variations and the availability of water (where water is restricted) and then target watering points. Many land owners bait using 1080 twice a year to target wild dogs during peaks in activity associated with breeding (March/May) and then again in September/November to target pups and juveniles. However, baiting and trapping is recommended at all times when wild dogs are active.

Control

Baiting

Poison baits are the most economic, efficient and effective method of controlling wild dogs, especially in inaccessible or extensive areas. Baits can be laid quickly by hand, from vehicles and from aircraft.

Currently there are two poisons legally available for wild dog control. These are 1080 (sodium fluoroacetate) and strychnine.

Subject to restrictions, 1080 baits, either manufactured or prepared from fresh meat can be obtained through people approved under the Health (Drugs & Poisons) Regulation 1996. A permit from the Queensland Department of Health is required for land owners to purchase strychnine. Strychnine can be used both in baits and on traps. The use of both 1080 and strychnine require adherence to the associated conditions of supply.

The use of poison baits will control some but not all wild dogs. Baits should be used in conjunction with all other control tools and not be relied on as a total control method.

Meat baits are attractive both to wild dogs and a range of non-target species. When using meat baits, they can be strategically positioned as wild dogs' keen sense of smell enables them to find baits intentionally buried in sand or otherwise hidden under bushes or in hollow logs. Meat baits may also be tied to prevent their loss to non-target species.

These meat bait placement techniques help to:

- reduce the risk of poisoning non-target species
- increase wild dog contact, hence receiving a lethal dose
- minimise bait removal by non-target scavengers
- deter ants (ant-covered baits are believed to be less attractive to wild dogs).

Heavy rain within two weeks of baiting can leach 1080 from baits, but baits may still remain toxic for a considerable time.

Trapping

A key success to trapping wild dogs (using foot-hold traps) depends on the skill of the operator. Visit www.feral.org.au to watch a PestSmart video on best practice techniques for wild dog trapping.

For humane reasons and to prevent escape, poisoning traps with strychnine is recommended to quickly kill captured wild dogs. A properly poisoned trap becomes a lethal device rather than a holding device.

A mixture of dog faeces and urine is a popular lure used by trappers. Attractiveness of lures varies with seasons and locations. No single lure has yet been found that is consistently attractive to all wild dogs and repeated use of one lure can lead to aversion amongst remaining dogs.

Traps are best placed in areas of high wild dog activity (known as leads). Here the wild dog is most likely to find and investigate the decoy/odour.

A wild dog scent post (an area where urine or faeces have been deposited) can be found by walking with a domestic dog on a lead along a known pad. Trap placement in relation to the scent post can be optimised by observing the domestic dog's behaviour as it approaches. Factors to consider are:

- where on the bush it smells
- placement of feet while urinating/defecating/sniffing
- how it approaches and where it scratches in relation to the pad and scent post.

Padded, laminated or offset foot-hold traps, in a well tuned and functioning state are recommended.

Shooting

Shooting is an opportunistic method, mostly used for control of small populations or individual problem animals.

Fencing

Property fencing suitable to exclude wild dogs is expensive to build and requires continual maintenance to repair damage caused by fallen timber, fire, floods, feral and domestic animals, as well as vegetation regrowth. However, a properly maintained fence can restrict movement into an area where wild dogs have been controlled.

Electric fences suitable for wild dogs have been developed. Electrifying a fence creates a fear of the fence itself and deters wild dogs from approaching.

For property fencing to be successful, the fence must be maintained in good order and ongoing wild dog control conducted within the protected area to limit livestock impacts.

Fencing is the most effective method of protecting livestock and pets from wild dog attack on small acreage blocks.

A fence can also be a good area to place baits and traps when wild dogs are active.

Livestock guardian animals

Livestock guardian animals have been used to protect livestock from predators in Europe, Asia and America. Some producers in Queensland have decreased predation on sheep and goats using this method. The use of trapping and poisoning in conjunction with guardian animals must be well planned and managed to ensure guardian animal safety.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland (call 13 25 23 or visit our website at www.biosecurity.qld.gov.au).

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Barbara Copper Project

Aquatic Ecology Report

Prepared for:

CopperChem Ltd and Syndicated Metals Ltd

November 2014

AustralAsian Resource Consultants

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TABLE OF CONTENTS

EXECUTIVE SUMMARY 7

1.0 INTRODUCTION 11

1.1 SCOPE OF STUDY 11

2.0 PROJECT AND SITE DESCRIPTION 12

2.1 PROJECT LOCATION 12

2.2 PROJECT DESCRIPTION 12

2.3 CURRENT LAND USE 12

2.4 REGIONAL CLIMATE 14

2.5 SURFACE WATERS AND DRAINAGE 14

3.0 DATABASE SEARCHES 16

3.1 THREATENED SPECIES 16

3.1.1 Threatened Ecological Communities 16

3.1.2 Flora 16

3.1.3 Fauna 18

3.2 REGIONAL PRIORITY SPECIES 21

3.3 WETLAND HABITATS 22

3.4 ENVIRONMENTALLY SENSITIVE AREAS 24

4.0 METHODOLOGY 26

4.1 MONITORING SITES 26

4.2 STREAM MORPHOLOGY 28

4.3 STREAM SEDIMENT SAMPLING 29

4.4 SURFACE WATER QUALITY SAMPLING 30

4.5 MACROINVERTEBRATE SAMPLING 33

4.6 AQUATIC FAUNA SAMPLING 34

4.7 AQUATIC FLORA SAMPLING 36

5.0 RESULTS AND DISCUSSION 37

5.1 WEATHER CONDITIONS AT THE TIME OF SURVEY 37

5.2 HABITAT ASSESSMENT 37

5.2.1 AQ1 37

5.2.2 AQ2 38

5.2.3 AQ3 39

5.2.4 AQ4 40

5.2.5 AQ5 41

5.2.6 AQ6 42

5.2.7 AQ7 43
5.2.8 AQ8 44
5.2.9 AQ9 45
5.2.10 AQ10 46
5.2.11 AQ11 47
5.2.12 AQ12 48
5.2.13 SITE SCORES 49
5.3 STREAM SEDIMENT 50
5.3.1 Particle Size 50
5.3.2 Metal Concentrations 52
5.4 WATER QUALITY 58
5.5 MACROINVERTEBRATES 69
5.6 AQUATIC FLORA 70
5.6.1 Communities of Conservation Significance 70
5.6.2 Plants of Conservation Significance 71
5.6.3 Weed Species 72
5.7 AQUATIC AND RIPARIAN FAUNA 72
5.7.1 Mammals 72
5.7.2 Birds 73
5.7.3 Amphibians 75
5.7.4 Reptiles 76
5.7.5 Fish 77
5.7.6 Crustaceans 78
5.7.7 Fauna of Conservation Significance 79
5.7.8 Declared Pests 93
6.0 CONCLUSIONS, IMPACTS AND RECOMMENDATIONS 94
6.1 POTENTIAL IMPACTS 95
6.2 RECOMMENDED MITIGATION AND MANAGEMENT MEASURES 96
6.3 ENVIRONMENTAL MONITORING 97
6.4 ENVIRONMENTAL OFFSET REQUIREMENTS 97
7.0 REFERENCES 98

LIST OF FIGURES

Figure 1 Regional Location of the Project 13
Figure 2 Mean Monthly Rainfall and Temperature Data for the Mount Isa Region 14
Figure 3 Waterways of the Investigation Area 15

Figure 4 Wetlands of the Investigation Area 23
Figure 5 ESA Mapping for the Investigation Area and Project Site 25
Figure 6 Monitoring Site Locations 27
Figure 7 Bi-plot Interpretation....34
Figure 8 Bat Survey Locations....35
Figure 9 Particle Size Distribution – Wet Season 52
Figure 10 Particle Size Distribution – Dry Season 52
Figure 11 SIGNAL Biplot....70
Figure 12 RE 1.3.7b and the Project Disturbance Footprint 71

LIST OF TABLES

Table 1 Aquatic WoNS and Significant Weed Species of the Project Region....17
Table 2 Threatened Fauna Species of the Project Region....18
Table 3 Migratory and Marine Species of the Project Region 19
Table 4 Key to AUSRIVAS Habitat Assessment Scores (possible given score meanings) 28
Table 5 ANZECC (2000) Stream Sediment Trigger Values 29
Table 6 ANZECC Water Quality Guidelines 30
Table 7 AUSRIVAS Habitat Assessment Results....50
Table 8 Particle Size Distribution Results....50
Table 9 Metal Concentrations in Stream Sediment – Wet Season 54
Table 10 Metal Concentrations in Stream Sediment – Dry Season 56
Table 11 Wet Season Surface Water Monitoring Results 59
Table 12 Dry Season Surface Water Monitoring Results 64
Table 13 Threatened Species of the Project Region (identified by database search) 80

LIST OF PHOTO PLATES

Photo Plate 1 Site AQ1 (wet season)....38
Photo Plate 2 Site AQ2 (wet season)....39
Photo Plate 3 Site AQ3 (wet season)....40
Photo Plate 4 Site AQ4 (wet season)....41
Photo Plate 5 Site AQ5 (dry season) 42
Photo Plate 6 Site AQ6 (wet season)....43
Photo Plate 7 Site AQ7 (wet season)....44

Photo Plate 8 Site AQ8 (wet season) 45
Photo Plate 9 Site AQ9 (wet season) 46
Photo Plate 10 Site AQ10 (dry season) 47
Photo Plate 11 Site AQ11 (dry season) 48
Photo Plate 12 Site AQ12 (dry season) 49
Photo Plate 13 Purple-necked Rock-wallaby (*Petrogale purpureicollis*) at AQ6 73
Photo Plate 14 Zebra Finches (*Taeniopygia guttata*) drinking and bathing at site AQ8 75
Photo Plate 15 Northern Snapping Frog (*Cyclorana australis*) 76
Photo Plate 16 Olive Python (*Liasis olivaceus*) at site AQ8 77
Photo Plate 17 Spangled Perch (Leiopotherapon unicolor) 78
Photo Plate 18 Inland Freshwater Crab (*Austrothelphusa transversa*) captured on the Project site 79

LIST OF APPENDICES

Appendix A Database Search Results ....A
Appendix B Water and Stream Sediment Laboratory Analysis ....B
Appendix C Macroinvertebrate Analysis Results C
Appendix D Flora Species List ....D
Appendix E Fauna Species List ....E
Appendix F Bat Call Analysis Report ....F
Appendix G Pest Fact Sheets ....G

LIST OF ABBREVIATIONS

%	-	percent
ºC	-	degrees Celsius
AARC	-	AustralAsian Resource Consultants Pty Ltd
ANZECC	-	Australia and New Zealand Environment and Conservation Council
AUSRIVAS	-	Australian River Assessment System
BOM	-	Bureau of Meteorology
cm	-	centimetre
DAFF	-	Department of Agriculture, Fisheries and Forestry
DO	-	Dissolved oxygen

DoE	-	Commonwealth Department of the Environment
EC	-	Electrical conductivity
EHP	-	Queensland Department of Environment and Heritage Protection
EPBC Act	-	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
ESA	-	Environmentally Sensitive Area
ha	-	hectare
Investigation Area	-	Area studied for this report, consisting of the western section of Mineral Development Licence 499 and Mining Lease Application 90241
ISQG	-	Interim Sediment Quality Guidelines
JV	-	Joint venture
km	-	kilometre(s)
LOR	-	Limit of Reporting
LP Act	-	*Land Protection (Pest and Stock Route Management) Act 2002* (Queensland)
m	-	metre(s)
MDL	-	Mineral Development Licence
mg/kg	-	milligrams per kilogram
mg/L	-	milligrams per Litre
MLA	-	Mineral Licence Application
mm	-	millimetre(s)
MSES	-	Matter(s) of State Environmental Significance
µS	-	microSiemens
n/a	-	not applicable
NATA	-	National Association of Testing Authorities
NC Act	-	*Nature Conservation Act 1992* (Queensland)
NTU	-	Nephelometric turbidity units
PET	-	Plecoptera, Ephemoptera and Trichoptera (stoneflies, mayflies and caddis flies)

Project	-	Barbara Copper Project
Project Area	-	Mining Lease Application 90241
RE	-	Regional Ecosystem
REMP	-	Receiving Environment Monitoring Program
SIGNAL	-	Stream Invertebrate Grade Number – Average Level
TDS	-	Total dissolved solids
WoNS	-	Weed of National Significance

EXECUTIVE SUMMARY

AustralAsian Resource Consultants was commissioned by the CopperChem Ltd and Syndicated Metals Ltd Joint Venture to perform an Aquatic Ecology Assessment for the Barbara Copper Project. The aim of this Aquatic Ecology Assessment report is to describe and assess the environmental values of the waterways in the Investigation Area and recommend strategies to minimise potential impacts on aquatic ecosystems.

The Barbara Copper Project is located approximately 60 kilometres north-east of Mount Isa in north-west Queensland. The Project involves the development of an open cut copper mine. Mining will use conventional drill and blast, load and haul techniques. Copper ore will be transported by road train to an offsite processing plant. The Investigation Area is currently used for cattle grazing and mineral exploration.

Several small, unnamed drainage lines flow across the Investigation Area. These waterways are ephemeral and flow only after heavy rainfall. Site waterways drain into the Leichhardt River, which flows into the Gulf of Carpentaria. There are no wetlands within the Investigation Area boundary. Lake Julius, a large lacustrine wetland listed on the Directory of Important Wetlands in Australia, is located approximately 17 kilometres downstream of the Investigation Area.

A combination of desk-based and field-based investigations was undertaken to investigate the aquatic ecology of the Investigation Area. Database searches identified 20 species of threatened fauna and 40 species of Marine and/or Migratory animals (mostly birds) within the local region. No threatened ecological communities or threatened aquatic flora species were identified in the database searches. Category B Environmentally Sensitive Areas are mapped in the west of the Investigation Area as Endangered Regional Ecosystem 1.3.7: River Red Gum (*Eucalyptus camaldulensis*) woodland on channels and levees. No Category A or C Environmentally Sensitive Areas are mapped in the Investigation Area.

Two field surveys were undertaken to further investigate the aquatic ecology of the Investigation Area. Surveys were scheduled to fall within the wet season (February 2014) and the dry season (July 2014). A total of 12 sites were assessed for the following parameters:

- Stream morphology/habitat quality;
- Sediment particle size and metal concentration;
- Surface water quality;
- Macroinvertebrate diversity and abundance;
- Aquatic fauna diversity and abundance; and
- Riparian flora diversity and abundance.

Stream morphology was assessed using a modified version of the Australian River Assessment System protocols developed by the Department of Natural Resources and Mines. The broad habitat type, channel pattern, water level and flow, substrate character and cover, bed and bank stability, and riparian cover at each site were described. Each site was given a score out of 135, with higher numbers indicating favourable habitats.

Stream sediment monitoring was undertaken both upstream and downstream of Project activities. Samples of the stream-bed substrate were taken at regular intervals along a 50 metre stretch of the creek bed at each site. The sub-samples were mixed to obtain a composite sample, sealed in sterilised glass jars and sent to a National Association of Testing Authorities accredited laboratory for analysis.

Water quality sampling was undertaken at all sites that held water at the time of sampling. Field readings of pH, electrical conductivity, temperature and dissolved oxygen were recorded and surface water samples were collected. Samples were sent to a National Association of Testing Authorities accredited laboratory for analysis.

Macroinvertebrate samples were taken at all survey sites that contained water at the time of sampling. Macroinvertebrates were collected using a D-frame pond net and employing a kick-sampling method. Macroinvertebrates were preserved in ethanol and sent to a third party laboratory for identification.

Sampling of aquatic fauna using box and opera style traps was undertaken at sites where sufficient water was present. Spotlighting was carried out in riparian areas at night to detect nocturnal wildlife. Specialised electronic bat call recorders called Songmeters were set up in riparian areas. Recordings were sent to an experienced bat call analyst for species identification.

Riparian flora species composition was investigated using secondary transects, which are 20 x 50 metre plots. Species, abundance, density and projected foliage cover and height for the tree and shrub layers were recorded.

The Australian River Assessment System analysis results for the survey sites fell within the moderate to good habitat range. Scores were limited by erosion and impacts from cattle.

Stream sediments were found to be extremely coarse. High levels of gravel, cobbles and sand were detected in the sediment samples. Metals levels in sediments were typically low, and fell below the applicable guidelines at all sites, with the exception of copper levels at sites AQ4, AQ7 and AQ1 and nickel levels at site AQ5.

Water quality at the survey sites was impacted by the stagnant and ephemeral nature of site waterways. pH values outside the applicable guideline range were recorded at several sites (AQ1 in the wet season, AQ4, AQ7, AQ8, AQ11). Conductivity levels were high in the dry season, with all sites exceeding the applicable guideline. Site AQ4 recorded conductivity levels in excess of the guideline in the wet season. Dissolved oxygen levels were below the guideline range at most sites (AQ1 in the dry season, AQ2, AQ4, AQ6, AQ7, AQ11, AQ12). Total nitrogen and total phosphorus exceeded the guidelines at all sites in both surveys.

Metals levels in water were generally below the guideline limits, with a few exceptions. In the wet season, total and dissolved silver (at AQ4, AQ6 and AQ7), total and dissolved copper (at all sites), total zinc (AQ8), total and dissolved aluminium (at AQ4, AQ7 and AQ8) and dissolved aluminium at AQ1 were above applicable guidelines. In the dry season, total and dissolved copper (at AQ1, AQ8 and AQ11), total copper (AQ12), total and dissolved manganese (AQ12), total aluminium (AQ11 and AQ12) and total zinc (AQ11 and AQ12) exceeded the guidelines. Elevated metals levels are likely to be the result of mineralisation in the Project region.

Macroinvertebrate abundance, diversity and Stream Invertebrate Grade Number – Average Level scores for the Investigation Area were fairly low. These results are likely attributable to poor water quality and habitat availability in the ephemeral streams sampled. Stream Invertebrate Grade Number – Average Level scores fell within Quadrant 3 of a biplot, with the exception of AQ1, which fell within

Quadrant 1. Scores in Quadrant 3 indicate the impact of the harsh physical conditions associated with ephemeral waterways. Scores in Quadrant 1 indicate favourable habitat and chemically dilute waters.

A total of 153 species of plants were identified in the riparian areas of the Investigation Area. Regional Ecosystem 1.3.7b – River Red Gum (*Eucalyptus camaldulensis*) woodland on channels and levees occurs on parts of the watercourses of the Investigation Area. This Regional Ecosystem occurs mostly outside the Project disturbance footprint. No flora species of conservation significance were found in the Investigation Area. Thirteen weed species were recorded in riparian areas during the surveys.

A total of 67 species of fauna were recorded in the riparian areas of the Investigation Area, consisting of 14 mammals, 40 birds, five amphibians, six reptiles, one fish and one crustacean species. Two species of conservation significance, the Near Threatened Golden-backed Honeyeater (*Melithreptus gularis laetior*) and the Vulnerable Purple-necked Rock-wallaby (*Petrogale purpureicollis*) were recorded in riparian areas outside the Project disturbance footprint. Four introduced species, including two declared pests (Feral Pig, *Sus scrofa* and Wild Dog, *Canis familiaris*) under the *Land Protection (Pest and Stock Route Management) Act 2002* were detected during the surveys.

A number of potential impacts of Project development on aquatic and riparian areas were identified:

- Vegetation clearing, leading to erosion and siltation;
- Removal of small areas of potential habitat for a near threatened species (Golden-backed Honeyeater);
- Removal of approximately 1.8 hectares of Regional Ecosystem 1.3.7b, which has a Biodiversity Status of Endangered, to enable construction of the new site access road;
- Clearing of approximately 6.5 hectares of riparian vegetation and fauna habitat;
- Diversion of a minor drainage feature in the vicinity of the north pit;
- Construction of creek crossings;
- Release of hazardous substances, overflow of contaminated stormwater or wastewater to waterways; and
- Increases in pest and weed species and abundance.

The following mitigation strategies are recommended to address these potential impacts:

- Minimising clearing in riparian areas;
- Conducting clearing in a staged manner;
- Preserving tree hollows;
- Use of a spotter-catcher as required during clearing works;
- Rehabilitation of cleared riparian areas at site closure;
- Utilisation of sediment and erosion control structures during construction and operation;
- Vehicle washdowns;

- Implementation of Pest and Weed Management Plans and control programs;
- Regular water and sediment monitoring;
- Implementation of a Receiving Environment Monitoring Program;
- Diversion of clean water and treatment of contaminated water;
- Planting up of diversion channel area with local native riparian flora;
- Correct storage, handling and use of hazardous substances;
- Appropriate design of creek crossings and diversions;
- Staff training and awareness; and
- Potential offsetting of clearing of riparian vegetation.

1.0 INTRODUCTION

AustralAsian Resource Consultants (AARC) was commissioned by the CopperChem Ltd and Syndicated Metals Ltd Joint Venture (JV) to perform an Aquatic Ecology Assessment for the Barbara Copper Project (the Project).

1.1 SCOPE OF STUDY

This report describes and assesses the ecological features of the Project site and outlines recommended strategies to minimise the potential impacts of the Project on aquatic fauna and flora.

The scope of this study is to assess the environmental values of the surface waterways (e.g. rivers, creeks, streams and other waterbodies, including drainage lines and wetlands) which occur within and immediately upstream/downstream of the Project in terms of:

- Values identified in the *Environmental Protection (Water) Policy 2009*;
- Watercourse descriptions, including both quality and quantity;
- Morphology of watercourses, including riparian zone vegetation and watercourse form;
- Downstream water resource uses, including their significance to the local community and/or environment;
- The diversity, abundance and conservation significance of aquatic and riparian biota.

This scope was addressed through a combination of desktop and field-based investigations of the Project site and surrounding area.

2.0 PROJECT AND SITE DESCRIPTION

2.1 PROJECT LOCATION

The Project is located approximately 60 kilometres (km) north-east of Mount Isa in north-west Queensland. The Project can be accessed from the Barkly Highway and Lake Julius Road.

The regional location of the Project is illustrated in Figure 1.

2.2 PROJECT DESCRIPTION

The Project involves the development of an open cut copper mining operation. The area studied for this report (the Investigation Area) is made up of the western section of Mineral Development Licence (MDL) 499 and Mining Lease Application (MLA) 90241. Mining operations will be confined to MLA 90241 (referred to in this report as the Project Area). The Project access road will pass through MDL 499.

The proposed mine plan will include open cut mining of the copper resource, with ore to be trucked to a nearby, established third party processing plant via a new access road. Mining of the copper ore will involve conventional drill and blast, load and haul techniques. The ore will be loaded into road trains on site and transported offsite for processing.

A first order drainage feature near the north pit will be partially diverted to enable development of the pit.

2.3 CURRENT LAND USE

The current land use of the Investigation Area is low intensity cattle grazing and exploration. The Project Area has a long history of exploration and small scale mining activities.

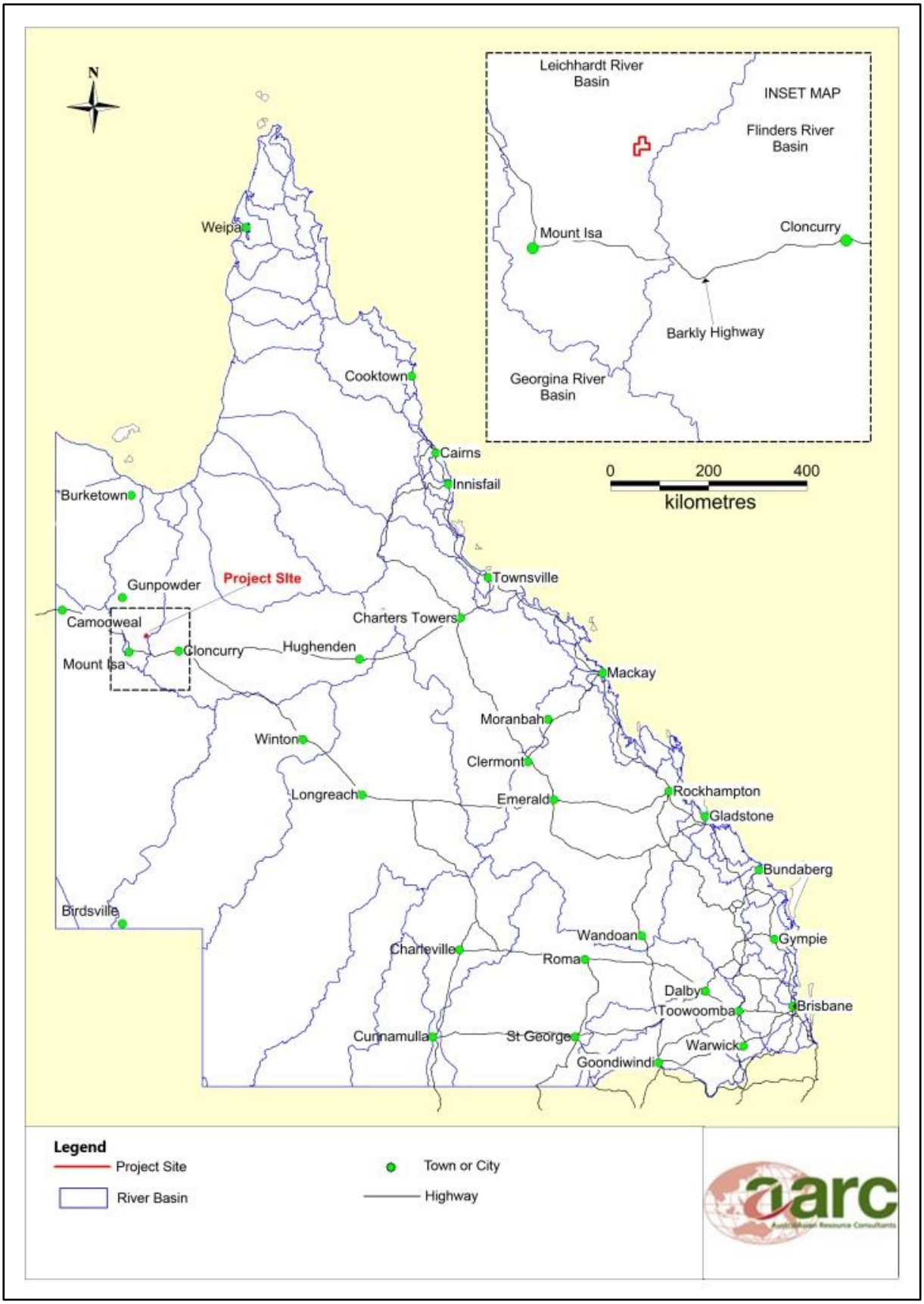

Figure 1 Regional Location of the Project

2.4 REGIONAL CLIMATE

Climate data for the Project region was sourced from the Australian Bureau of Meteorology (BOM). Rainfall data was sourced from the nearest BOM rainfall monitoring station, located at West Leichardt Station. Temperature data was sourced from the Mount Isa Aero Station. Mean monthly temperature data for the period 1967 to 2014 and mean monthly rainfall from 1894 to 2014 are presented in Figure 2. Figure 2 shows that there is significant seasonal variation in rainfall and temperature in the Project region. Rainfall is highest during the months of November to March. Average annual rainfall for the region is 430.4 millimetres (mm).

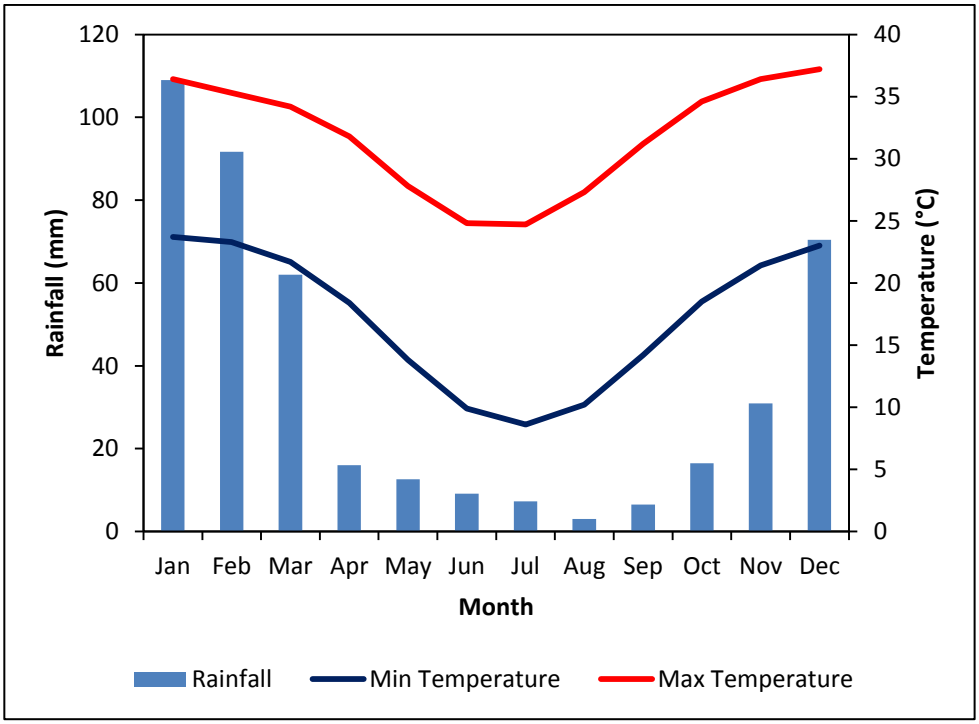

Figure 2 Mean Monthly Rainfall and Temperature Data for the Mount Isa Region

2.5 SURFACE WATERS AND DRAINAGE

The Investigation Area is crossed by numerous small, unnamed first and second order drainage lines. One larger, third order watercourse flows through the south-western and north-western areas of the Investigation Area. These waterways drain north-west to form an unnamed third order creek which flows into the Leichhardt River. The Leichhardt River flows north into the Gulf of Carpentaria. Waterways on and around the Investigation Area are shown in Figure 3.

There are no major watercourses or permanent water sources in the Investigation Area. Drainage lines in the Investigation Area are typically dry and only flow after heavy wet season rainfall.

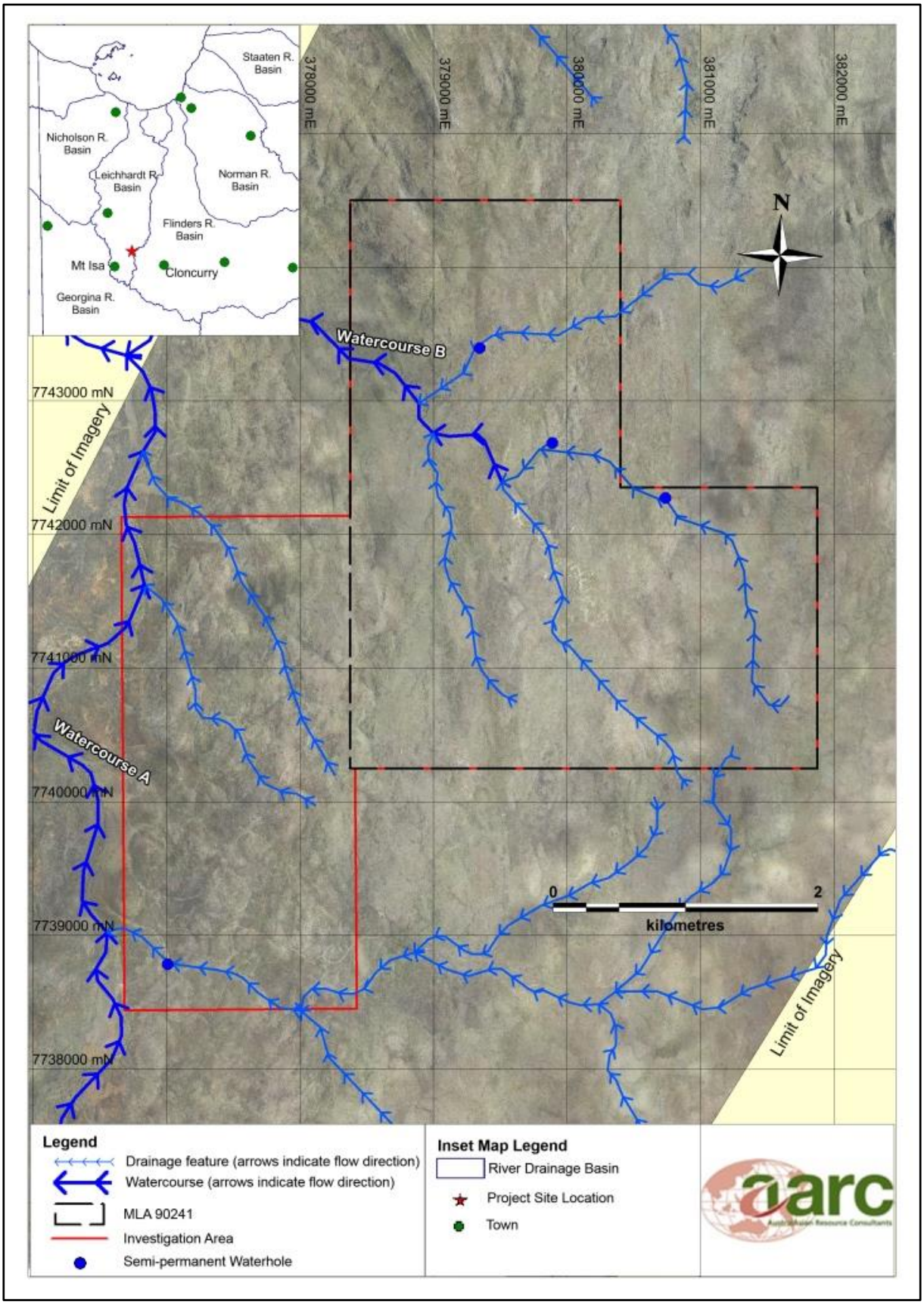

Figure 3 Waterways of the Investigation Area

3.0 DATABASE SEARCHES

Databases collate information on flora and fauna species identified from previous surveys, community records and other sources. Searches of the following relevant databases were conducted to identify aquatic flora and fauna species that may inhabit the Investigation Area:

- Protected Matters Search Tool: This is the Commonwealth Department of Environment's (DoE) database, which provides information on matters of National Environmental Significance and other matters protected by the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for a nominated area;

- Wildlife Online Database: This is the Queensland Department of Environment and Heritage Protection's (EHP) database of flora and fauna sighting records; and

- Recovery Actions Database: This database contains a list of fauna and flora species of high conservation significance (termed 'priority species') for each of the Queensland Natural Resource Management Regions.

These databases provide information on the threatened and significant species that may occur in the search area.

A search of the Queensland WetlandMaps database was also conducted, in order to identify any wetland areas known to be present in the Investigation Area.

A 100 km search radius based upon on the Investigation Area centroid was employed for the Wildlife Online and Protected Matters searches. The results of the database searches revealed that several fauna species of conservation significance that have habitat requirements intrinsically linked to aquatic systems are known from the region, as discussed below.

Database search results are included in Appendix A.

3.1 THREATENED SPECIES

3.1.1 Threatened Ecological Communities

The database searches did not identify any Endangered Ecological Communities within the search area.

3.1.2 Flora

No aquatic flora species of conservation significance were identified by the desktop searches.

Weeds of national significance (WoNS) and other introduced plants considered by the Commonwealth Government to pose a significant threat to biodiversity are included in the Protected Matters Search results. Riparian and aquatic WoNS identified from the Protected Matters Search are summarised in Table 1 below.

The WoNS program coordinates the national effort against 32 of Australia's worst invasive plants. A national strategy for each WoNS nominated weed specifies actions to better manage each weed.

The Queensland legislation applicable to weed species management is the *Land Protection (Pest and Stock Route Management) Act 2002* (LP Act), which lists declared weed species and categorises them into three classes:

- Class 1 – can cause adverse economic, environmental and social impacts. Once established in Queensland, Class 1 pests are subject to eradication from the state.

- Class 2 – established in Queensland and have, or could have, an adverse economic, environmental or social impact.

- Class 3 – established in Queensland and have, or could have, an adverse economic, environmental or social impact. The primary objective of Class 3 listing is to prevent sale, therefore preventing the spread of these pests into new areas.

Declaration under the LP Act imposes a legal responsibility for control by all landowners on land under their management.

Table 1 Aquatic WoNS and Significant Weed Species of the Project Region

Scientific Name	Common Name	Preferred Habitat	Conservation Status	
			Commonwealth	State
Cryptostegia grandiflora	Rubber Vine	Initially invades waterways, expanding outward to hillsides and pastures. Rubber Vine is established throughout most of Queensland, including north-west Queensland	WoNS	Class 2
Eichhornia crassipes	Water Hyacinth	Grows in ponds and slow moving waterways, such as rivers, dams, lakes and wetlands. It forms dense floating mats. Widespread across tropical and subtropical regions of eastern Australia	WoNS	Class 2
Jatropha gossypifolia	Bellyache Bush	Common along roadsides and riverbanks. Also found in grasslands and open woodlands. Established in northern Queensland, with smaller outbreaks across the state	WoNS	Class 2
Parkinsonia aculeata	Parkinsonia	Adapted to a wide range of soil types, found along watercourses in sub-humid and semi-arid areas of Queensland	WoNS	Class 2
Prosopis spp.	Mesquite	Can inhabit a range of climatic zones. Infestations often begin at waterways. Can form dense populations in a range of conditions and soil types. In Queensland this weed is mainly found in arid western areas	WoNS	Class 2

Scientific Name	Common Name	Preferred Habitat	Conservation Status	
			Commonwealth	State
Salvinia molesta	Salvinia	Salvinia is an aquatic weed which favours still or slow-flowing waterbodies. It has the ability to grow rapidly over the water surface forming a thick mat of vegetation	WoNS	Class 2
Tamarix aphylla	Athel Pine	Athel Pine flourishes in or near sandy watercourses, where it can form dense stands. It is well suited to arid and semi-arid areas. It is found throughout the Australian mainland, with the exception of Victoria	WoNS	Class 3

3.1.3 Fauna

The database searches identified 20 threatened fauna species in the Project region that inhabit aquatic and/or riparian habitats. These species are presented in Table 2. The likelihood of these species occurring in the Investigation Area is discussed in Section 5.7.7.

Table 2 Threatened Fauna Species of the Project Region

Scientific Name	Common Name	Conservation Status	
		EPBC Act	NC Act
Birds			
Accipiter novaehollandiae	Grey Goshawk	NL	NT
Erythrotriorchis radiatus	Red Goshawk	V	E
Ephippiorhynchus asiaticus	Black-necked Stork	NL	NT
Heteromunia pectoralis	Pictorella Mannikin	NL	NT
Epthianura crocea crocea	Yellow Chat (Gulf)	NL	V
Erythrura gouldiae	Gouldian Finch	E	E
Falco hypoleucos	Grey Falcon	NL	NT
Lophoictinia isura	Square-tailed Kite	NL	NT
Malurus coronatus	Purple-crowned Fairy-wren	NL	V
Melithreptus gularis laetior	Golden-backed Honeyeater	NL	NT

Scientific Name	Common Name	Conservation Status	
		EPBC Act	NC Act
Nettapus coromandelianus	Cotton Pygmy-goose	NL	NT
Numenius madagascariensis	Eastern Curlew	Ma, Mi	NT
Grantiella picta	Painted Honeyeater	NL	V
Pezoporus occidentalis	Night Parrot	E	E
Poephila cincta cincta	Black-throated Finch (southern)	E	E
Stictonetta naevosa	Freckled Duck	NL	NT
Rostratula australis	Australian Painted Snipe	E, Ma, Mi	V
Reptiles			
Elseya lavarackorum	Gulf Snapping Turtle	E	V
Emydura subglobosa worrelli	Diamond Head Turtle	NL	NT
Fish			
Pristis pristis	Freshwater Sawfish	V	NL

NC Act – *Nature Conservation Act 1992*
E – Endangered
V – Vulnerable
NT – Near Threatened
NL – Not listed
Ma – Marine species
Mi – Migratory species

The Protected Matters Search also identified 40 migratory and/or marine species listed under international treaties for the Project region. Migratory bird species listed under international conventions are listed as Special Least Concern wildlife under the *Nature Conservation Act 1992* (NC Act). Migratory and marine species for the Project region are listed in Table 3.

Table 3 Migratory and Marine Species of the Project Region

Scientific Name	Common Name	NC Act Special Least Concern	Listed Marine Species	Listed Migratory Species		
				Marine Species	Terrestrial Species	Wetland Species
Acrocephalus australis	Australian Reed-warbler	X	X			X
Actitis hypoleucos	Common Sandpiper	X	X			X

Scientific Name	Common Name	NC Act Special Least Concern	Listed Marine Species	Listed Migratory Species		
				Marine Species	Terrestrial Species	Wetland Species
Anseranas semipalmata	Magpie Goose		X			
Apus pacificus	Fork-Tailed Swift	X	X	X		
Ardea alba	Great Egret	X	X			X
Ardea ibis	Cattle Egret	X	X			X
Arenaria interpres	Ruddy Turnstone	X	X			X
Calidris acuminata	Sharp-tailed Sandpiper	X	X			X
Calidris ferruginea	Curlew Sandpiper	X	X			X
Calidris ruficollis	Red-necked Stint	X	X			X
Calidris subminuta	Long-toed Stint	X	X			X
Charadrius mongolus	Lesser Sand Plover	X	X			X
Charadrius ruficapillus	Red-capped Plover		X			
Charadrius veredus	Oriental Plover	X	X			X
Chlidonias leucopterus	White-winged Black Tern	X	X			
Cuculus optatus	Oriental Cuckoo	X	X			
Gallinago hardwickii	Latham's Snipe	X	X			X
Gallinago megala	Swinhoe's Snipe	X	X			
Glareola maldivarum	Oriental Pratincole	X	X			X
Haliaeetus leucogaster	White-Bellied Sea-Eagle	X	X		X	
Himantopus himantopus	Black-winged Stilt		X			
Hirundo rustica	Barn Swallow	X	X		X	
Hydroprogne caspia	Caspian Tern	X	X			
Limosa lapponica	Bar-tailed Godwit	X	X			X
Limosa limosa	Black-tailed Godwit	X	X			X
Merops ornatus	Rainbow Bee-eater	X	X		X	

Scientific Name	Common Name	NC Act Special Least Concern	Listed Marine Species	Listed Migratory Species		
				Marine Species	Terrestrial Species	Wetland Species
Numenius minutus	Little Curlew	X	X			X
Numenius phaeopus	Whimbrel	X	X			X
Pandion cristatus	Eastern Osprey	X	X			
Phalaropus lobatus	Red-necked Phalarope	X	X			
Plegadis falcinellus	Glossy Ibis	X	X			
Pluvialis fulva	Pacific Golden Plover	X	X			X
Recurvirostra novaehollandiae	Red-necked Avocet		X			
Rostratula australis	Australian Painted Snipe		X			X
Stiltia isabella	Australian Pratincole		X			
Tringa glareola	Wood Sandpiper	X	X			X
Tringa nebularia	Common Greenshank	X	X			
Tringa stagnatilis	Marsh Sandpiper	X	X			X
Xenus cinereus	Terek Sandpiper	X	X			X
Crocodylus johnstoni	Freshwater Crocodile		X			

3.2 REGIONAL PRIORITY SPECIES

The Back on Track species framework was designed to identify fauna and flora species of high conservation significance (termed 'priority species') for the Natural Resource Management regions of Queensland. The Back on Track priority species lists include species that are not listed as threatened under State or Federal legislation.

The Project is situated in the Southern Gulf National Resource Management Region. There are 33 priority species identified in this region; 25 of which have habitat requirements linked to aquatic systems. The aquatic priority species are:

- Eight bird species;
- Five fish species;
- Three mammal species;

- Six reptile species; and
- Three plant species.

The majority of these species are marine species and tropical species, which do not occur in the Investigation Area.

3.3 WETLAND HABITATS

A review of the EHP interactive WetlandMaps database and the Map of Referrable Wetlands showed that there are no mapped wetlands (including referable wetlands) within the Investigation Area. Riverine waterbodies have been identified passing through the Investigation Area (Figure 4). No wetlands of national or international importance have been recorded in the Investigation Area, including those nominated under the Ramsar Convention.

Lake Julius, a major lacustrine wetland listed on the Directory of Important Wetlands in Australia, is located approximately 17 km downstream of the Investigation Area. Lake Julius is mapped as a General Ecological Significance Wetland on the map of referrable wetlands.

The Map of Referrable Wetlands and Queensland Wetland Map for the Investigation Area are presented in Appendix A.

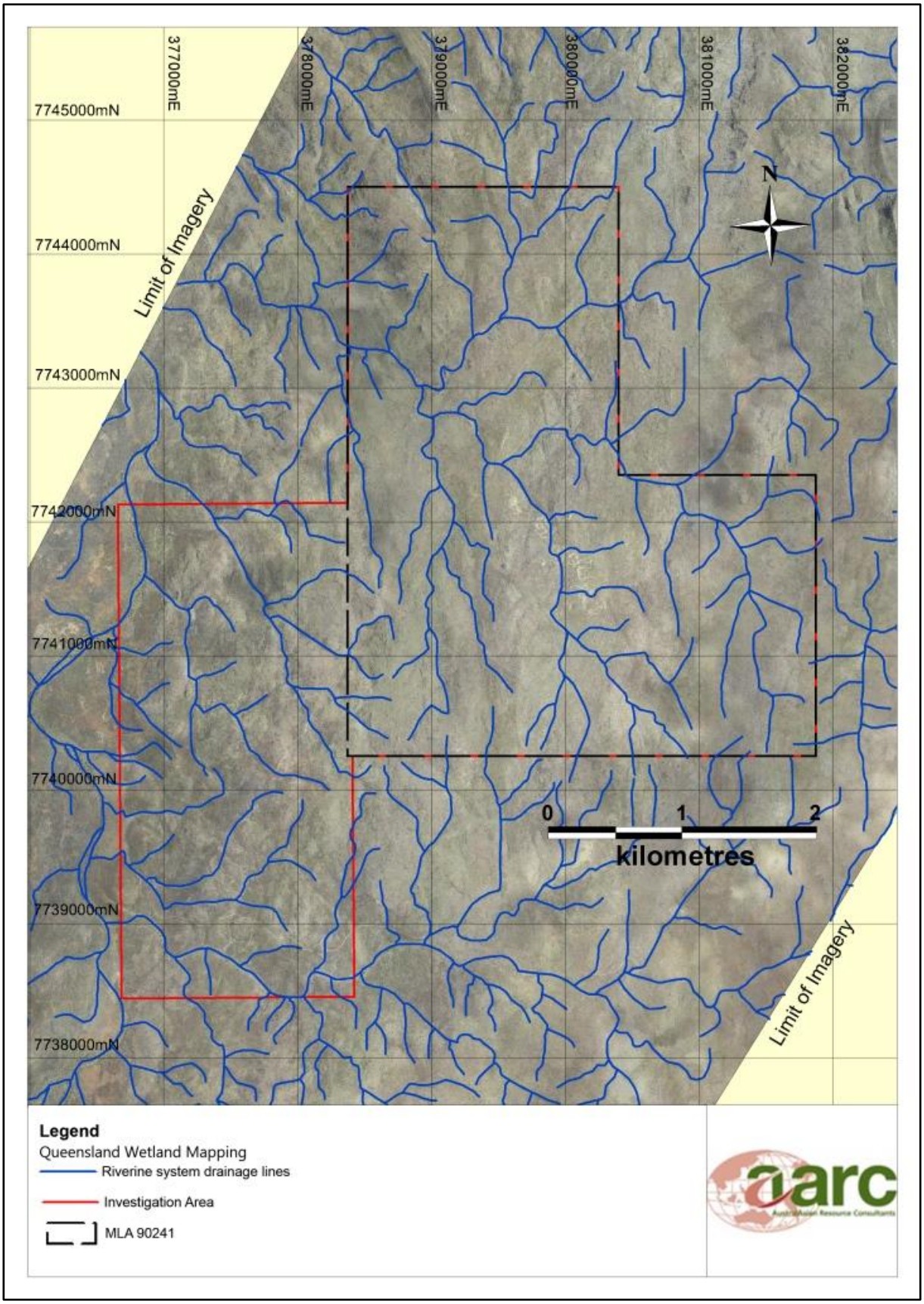

Figure 4 Wetlands of the Investigation Area

3.4 ENVIRONMENTALLY SENSITIVE AREAS

Environmentally Sensitive Areas (ESA) mapping presents Category A, B, and C areas of conservation significance, including those under international agreements (e.g. Ramsar sites), fish habitat areas, declared catchment areas, Wild River nominated waterways and areas listed under the Directory of Important Wetlands. A search of the EHP database for ESAs shows that there are areas of Category B ESA in the west of the Investigation Area, as illustrated in Figure 5 below. The Category B ESAs are a Regional Ecosystem (RE) with a Biodiversity Status of Endangered: RE 1.3.7b River Red Gum (*Eucalyptus camaldulensis*) woodland on channels and levees.

No Category A or C ESAs are present within or adjacent to the Investigation Area. No areas defined as World Heritage Areas, Ramsar sites, forestry areas, Wild River nominated waterways or essential fauna habitat are present within or adjacent to the Investigation Area.

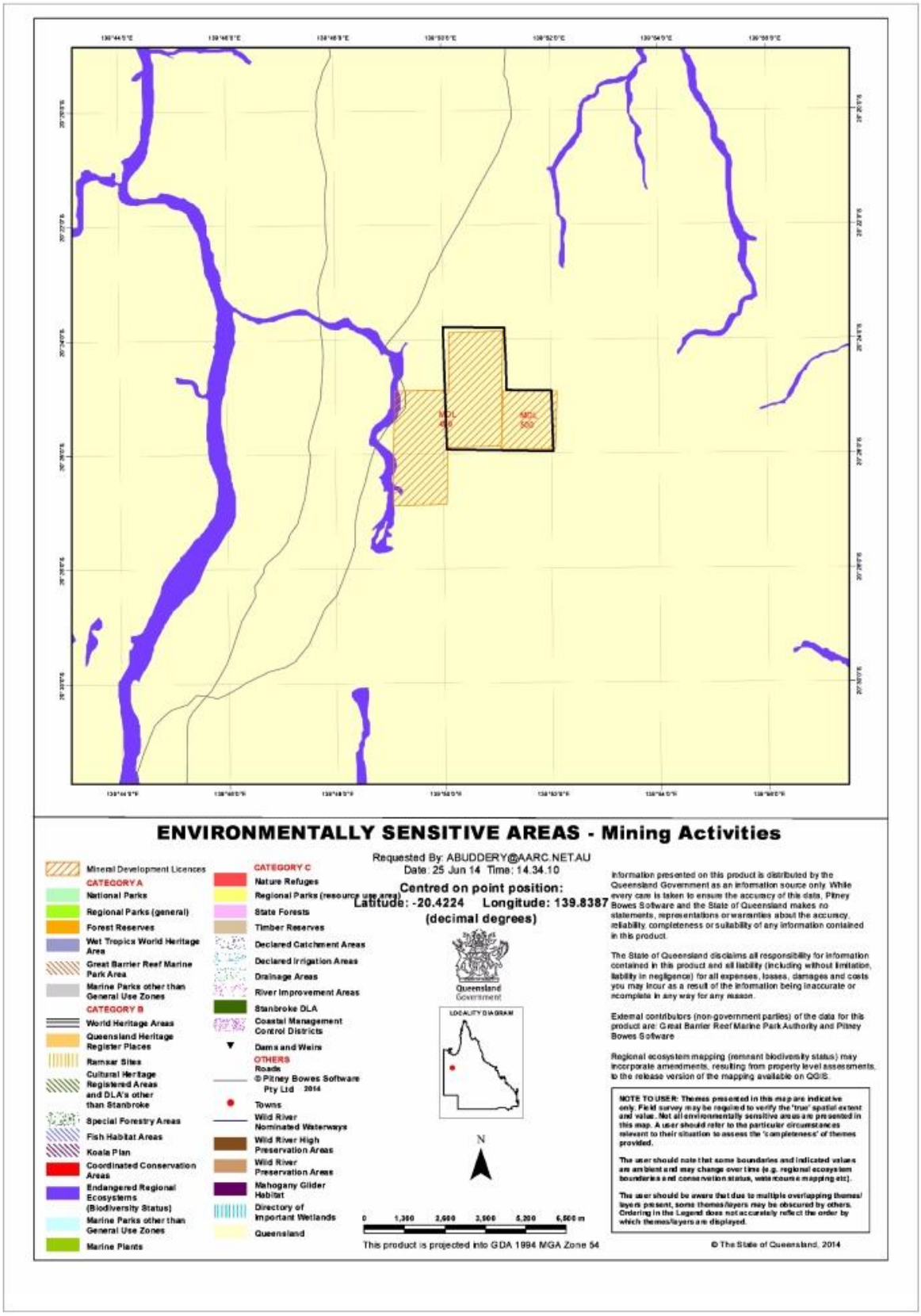

Figure 5 ESA Mapping for the Investigation Area and Project Site

4.0 METHODOLOGY

4.1 MONITORING SITES

Monitoring site locations were selected upstream and downstream of planned infrastructure to enable future monitoring of any impacts on aquatic ecosystems. Monitoring site locations are shown in Figure 6.

A total of 12 sites were assessed for the following parameters:

- Stream morphology/habitat quality;
- Sediment particle size and metal concentration;
- Aquatic fauna diversity and abundance;
- Riparian flora diversity and abundance;
- Surface water quality; and
- Macroinvertebrate diversity and abundance.

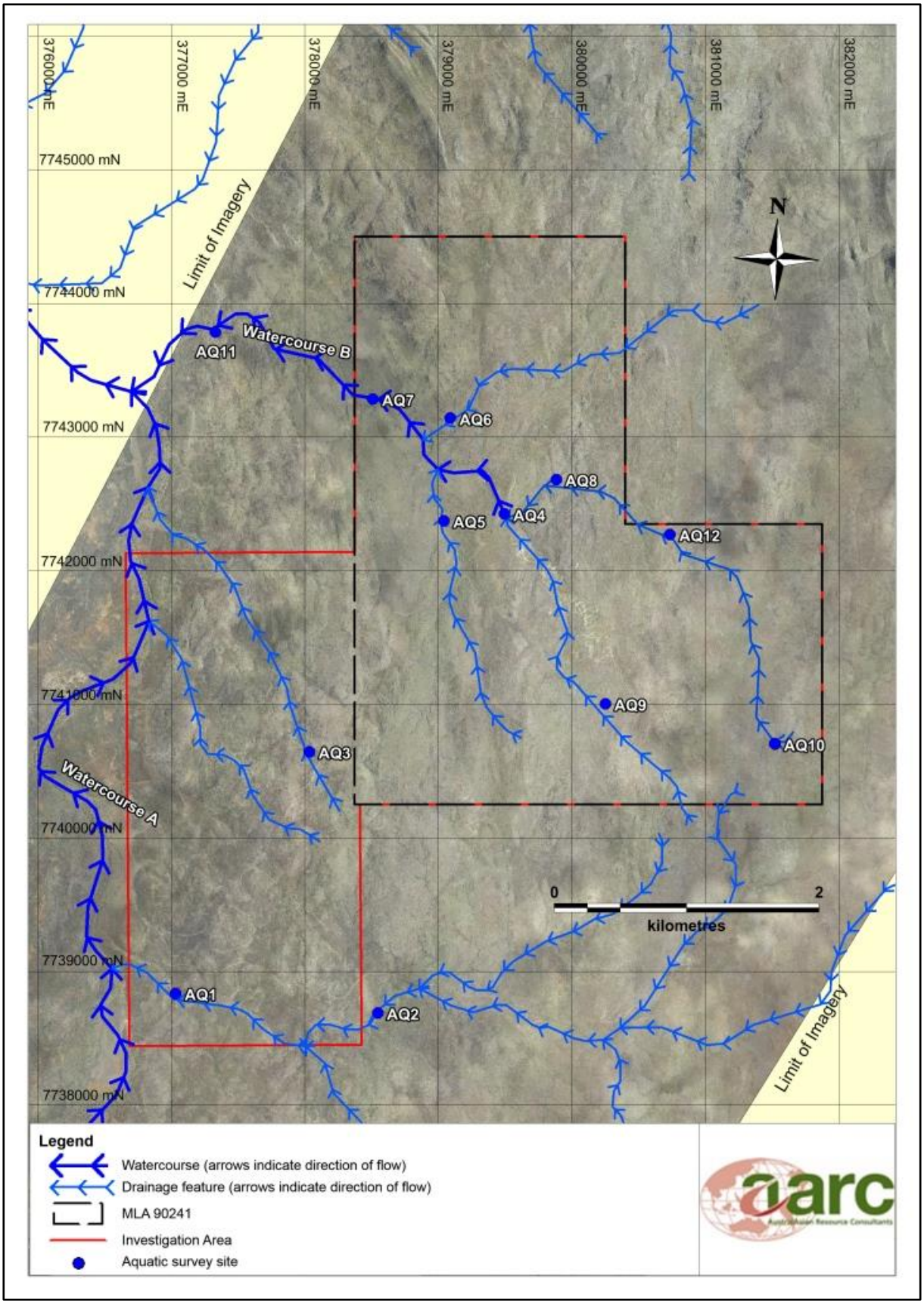

Figure 6 Monitoring Site Locations

4.2 STREAM MORPHOLOGY

A habitat assessment was performed at all sites using a modified version of the Australian River Assessment System (AUSRIVAS) protocols developed by the Department of Natural Resources and Mines. AUSRIVAS is a nationally standardised method for giving an assessment of the biological health of inland rivers within Australia. The broad habitat type, channel pattern, water level and flow, substrate character and cover, bed and bank stability, and riparian cover at each site were described in accordance with the AUSRIVAS datasheets. Certain sections in these datasheets relating to water flow information were unable to be completed due to absence of flowing water at the time of the survey. Each surveyed site was given a score out of 135, with higher numbers indicating favourable habitats normally associated with healthy waterways. Table 4 below provides a framework for interpreting habitat assessment scores.

Stream morphology sampling sites are illustrated in Figure 6.

Table 4 Key to AUSRIVAS Habitat Assessment Scores (possible given score meanings)

Habitat Assessment Score	Interpretation
0 – 35	Habitat is poor. There is limited habitat availability for in-stream fauna. There is little variation in velocity and depth of water, and the creek bed consists of a single sediment type. The water body typically consists of a small, shallow pool. Streamside vegetation, if present, consists of grasses and sedges. There is moderate to significant erosion on the banks.
36 – 70	Habitat variety is moderate. This could be due to leaf litter and other vegetation or detritus in the water, or the presence of boulders and rocks. The streamside vegetation consists mainly of grasses and sedges. There is moderate evidence of bank erosion, and the percentage of vegetative cover on the banks is less than 50%.
71 – 100	Habitat is relatively good. The bank is stable, there is variety in depth and velocity within the water body and substrate type is variable and tending towards boulders and rocks. Streamside vegetation is of trees and shrubs, adding to the bank stability. The percentage of streamside cover by vegetation is relatively high.
101 – 135	Indicates a pristine and favourable habitat. There is no bank erosion and the dominant vegetation is trees. There is great variety in depth and velocity, and the habitat is quite complex, offering many types of protection for fauna. This is usually afforded by logs and branches, leaf litter, variety in substrate type, variety in water depth, and presence of vegetation living within the water body.

4.3 STREAM SEDIMENT SAMPLING

Background stream sediment monitoring was undertaken in watercourses potentially affected by the Project, both upstream and downstream of Project activities. Sediment samples were obtained from all survey sites (refer to Figure 6). Five sub-samples of the stream-bed substrate were taken at regular intervals along a 50 metre (m) stretch of the creek bed at each site. The sub-samples were then mixed to obtain a composite sample, sealed in sterilised glass jars and sent to a National Association of Testing Authorities (NATA) accredited laboratory for analysis of the parameters outlined in Table 5. Results were compared to the Australia and New Zealand Environment and Conservation Council (ANZECC) (2000) Interim Sediment Quality Guidelines (ISQG) presented below in Table 5.

Table 5 ANZECC (2000) Stream Sediment Trigger Values

Parameter	Units	Low ISQG	High ISQG
Arsenic (As)	mg/kg	20	70
Silver (Ag)	mg/kg	1.0	3.7
Barium (Ba)	mg/kg	n/a	n/a
Beryllium (Be)	mg/kg	n/a	n/a
Cadmium (Cd)	mg/kg	1.5	10
Cobalt (Co)	mg/kg	n/a	n/a
Chromium (Cr)	mg/kg	80	370
Copper (Cu)	mg/kg	65	270
Mercury (Hg)	mg/kg	0.15	1.0
Manganese (Mn)	mg/kg	n/a	n/a
Molybdenum (Mo)	mg/kg	n/a	n/a
Nickel (Ni)	mg/kg	21	52
Lead (Pb)	mg/kg	50	220
Antimony (Sb)	mg/kg	2.0	25
Vanadium (V)	mg/kg	n/a	n/a
Zinc (Zn)	mg/kg	200	410
Selenium (Se)	mg/kg	n/a	n/a
Aluminium (Al)	mg/kg	n/a	n/a

Parameter	Units	Low ISQG	High ISQG
Iron (Fe)	mg/kg	n/a	n/a
Boron (B)	mg/kg	n/a	n/a

4.4 SURFACE WATER QUALITY SAMPLING

Water quality sampling was undertaken at all sites that held water at the time of sampling (refer to Figure 6) to determine water quality at the time of survey, in order to aid in the interpretation of biological data. Field readings of pH, electrical conductivity (EC), temperature and dissolved oxygen (DO) and surface water samples were collected. Samples were immediately refrigerated and sent to a NATA accredited laboratory for analysis. The results were compared to the ANZECC (2000) Guidelines for both Aquatic Ecosystems (slightly-moderately disturbed systems) and Livestock Drinking Water. The applicable trigger limits from these guidelines are presented below in Table 6.

Table 6 ANZECC Water Quality Guidelines

Parameter	Units	ANZECC (2000) Livestock Drinking Water	ANZECC (2000) Aquatic Ecosystems
pH	pH units	n/a	6.0 - 7.5
Conductivity (EC)	µs/cm	n/a	20 - 250
Dissolved oxygen (DO)	%	n/a	90 - 120
Total dissolved solids (TDS)	mg/L	4000	n/a
Suspended solids	mg/L	n/a	n/a
Turbidity	Nephelometric turbidity units (NTU)	n/a	2 - 15
Total alkalinity ($CaCO_3$)	mg/L	n/a	n/a
Dissolved sulphate (SO_4^{2-})	mg/L	1000	n/a
Total chloride	mg/L	n/a	n/a
Total nitrogen	mg/L	n/a	0.15

Parameter	Units	ANZECC (2000) Livestock Drinking Water	ANZECC (2000) Aquatic Ecosystems
Total phosphorus	mg/L	n/a	0.01
Dissolved Metals			
Aluminium	mg/L	n/a	0.055
Antimony	mg/L	n/a	n/a
Arsenic	mg/L	n/a	0.024
Beryllium	mg/L	n/a	n/a
Barium	mg/L	n/a	n/a
Boron	mg/L	n/a	0.37
Cadmium	mg/L	n/a	0.0002
Chromium	mg/L	n/a	0.001
Cobalt	mg/L	n/a	n/a
Copper	mg/L	n/a	0.0014
Iron	mg/L	n/a	n/a
Lead	mg/L	n/a	0.0034
Manganese	mg/L	n/a	1.9
Mercury	mg/L	n/a	0.0006
Molybdenum	mg/L	n/a	n/a
Nickel	mg/L	n/a	0.011
Selenium	mg/L	n/a	0.011
Silver	mg/L	n/a	0.00005

Parameter	Units	ANZECC (2000) Livestock Drinking Water	ANZECC (2000) Aquatic Ecosystems
Vanadium	mg/L	n/a	n/a
Zinc	mg/L	n/a	0.008
Total Metals			
Aluminium	mg/L	5	0.055
Antimony	mg/L	n/a	n/a
Arsenic	mg/L	0.5	0.024
Beryllium	mg/L	n/a	n/a
Barium	mg/L	n/a	n/a
Boron	mg/L	5	0.37
Cadmium	mg/L	0.01	0.0002
Chromium	mg/L	1.0	0.001
Cobalt	mg/L	1.0	n/a
Copper	mg/L	1.0	0.0014
Iron	mg/L	n/a	n/a
Lead	mg/L	0.1	0.0034
Manganese	mg/L	n/a	1.9
Mercury	mg/L	0.002	0.0006
Molybdenum	mg/L	n/a	n/a
Nickel	mg/L	1.0	0.011
Selenium	mg/L	0.02	0.011

Parameter	Units	ANZECC (2000) Livestock Drinking Water	ANZECC (2000) Aquatic Ecosystems
Silver	mg/L	n/a	0.00005
Vanadium	mg/L	n/a	n/a
Zinc	mg/L	20	0.008

4.5 MACROINVERTEBRATE SAMPLING

Macroinvertebrates are invertebrates that can be seen with the naked eye. The types and numbers of macroinvertebrates found in a waterway can be used as biological indicators (bio-indicators) of the health of aquatic environments for the following reasons:

1) They are generally sensitive to the cumulative impacts of a wide range of disturbances and pollutants;

2) They are abundant in freshwater systems;

3) They are relatively easy to identify; and

4) They are easy to collect (Chessman, 2003).

Macroinvertebrate sampling was undertaken at all survey sites where water was present (refer to Figure 6).

Macroinvertebrates were collected using a D-frame pond net (350 mm x 250 mm with 250 micrometer (µm) mesh) and employing a kick-sampling method (the substrate in the waterbody was disturbed and the net passed through the resulting plume to obtain benthos- and water column-dwelling macroinvertebrates). Separate samples of edge habitat and bed habitat were undertaken where possible. Only edge samples could be obtained for small water bodies.

Macroinvertebrates were placed in a white sorting tub and 'live-picked' using a pipette and tweezers for a period of 30 minutes. Macroinvertebrates were placed in a vial containing 70% ethanol and sent to a NATA accredited laboratory for identification to family or sub-family level. This data was then plotted on a Stream Invertebrate Grade Number – Average Level (SIGNAL) bi-plot for interpretation of the health of the waterbody.

The SIGNAL Index was developed by the National River Health Program as a tool for the bioassessment of water pollution and considers the taxonomic composition of the invertebrate assemblage to determine river health. Each macroinvertebrate is given a grade number between one and ten based on their sensitivity to various pollutants (Chessman, 2003), with a lower number indicating a higher tolerance to a range of conditions. The SIGNAL Index value is calculated by averaging the pollution sensitivity grade numbers of the families present at each site. Refer to Chessman (2003) for families excluded from SIGNAL scoring results.

Once plotted on a bi-plot, the SIGNAL Index and the number of invertebrate families found in a stream used together can provide an indication of the types of pollution and other physical and chemical factors that affect macroinvertebrate communities (Chessman, 2003), depending on their position within the graph (refer to Figure 7).

Quadrant 3 Often indicating toxic pollution or harsh physical environments	**Quadrant 1** Indicates favourable habitat or chemically dilute water
Quadrant 4 Usually indicating urban, industrial, or agricultural pollution	**Quadrant 2** Often indicating high salinity or nutrient levels (may be natural)

Figure 7 Bi-plot Interpretation

4.6 AQUATIC FAUNA SAMPLING

Sampling of aquatic fauna (fish and crustaceans) was undertaken at sites where sufficient water was present. Box traps and opera traps baited with dog biscuits were deployed in sections of the waterbody likely to contain aquatic fauna. All fauna captured during the survey were identified, their abundances recorded, and released back to the water.

Spotlighting was carried out at night in aquatic habitat, in an attempt to observe nocturnal wildlife that are not likely to be detected by other survey methods, such as frogs, nocturnal birds and certain reptiles. The creek banks were randomly traversed by two ecologists wearing headlamps, at a slow walking speed (approximately 1 km/hour) to facilitate intensive listening and thorough visual searching. While this technique improves the likelihood of detecting small cryptic species, it is a time consuming activity that does not permit the coverage of large areas. A total of four spotlight hours were undertaken in riparian areas.

Specialised electronic bat call recorders called Songmeters were set up in riparian areas adjacent to waterholes in the wet and dry seasons. Bat call recorders were used to record micro-bat calls at specific sites believed to provide potential bat habitat. Recordings were made at four sites in the dry season, shown in Figure 8. Recordings were sent to an experienced bat call analyst (Mr Greg Ford – Balance! Environmental Pty Ltd) for positive species identification.

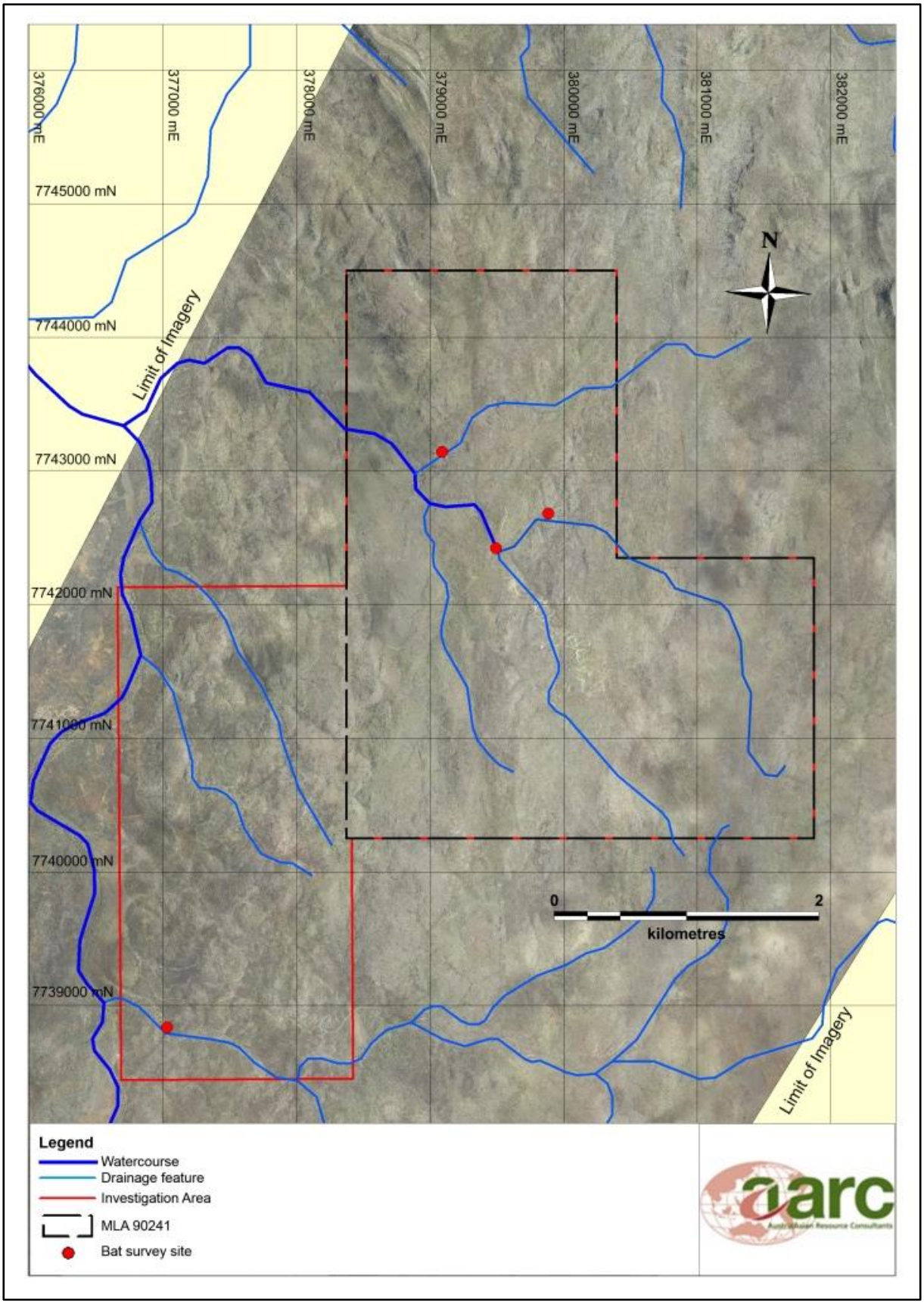

Figure 8 Bat Survey Locations

4.7 AQUATIC FLORA SAMPLING

Riparian flora species composition was investigated at ten secondary transects along riparian areas in the wet season and 12 secondary transects in the dry season. Secondary transects are 20 x 50 m plots. Data recorded in these plots includes a list of all species observed from all the major layers of vegetation. Species that fall outside the plot but are typical of the community are also listed. In addition, abundance for individual species in each strata is recorded, including density and projected foliage cover and height for the tree and shrub layers. This sampling method is in accordance with the *Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland* (Neldner et al. 2012).

5.0 RESULTS AND DISCUSSION

Surveys of the Investigation Area were undertaken from 24 February to 1 March 2014 (wet season survey) and 1 to 7 July 2014 (dry season survey). A total of ten sites were assessed in the wet season. An additional two sites containing surface water were located and added to the survey in the dry season. A total of 12 sites were assessed in the dry season survey (refer to Figure 6).

5.1 WEATHER CONDITIONS AT THE TIME OF SURVEY

Weather conditions in the first survey (24 February to 1 March) were typical of the wet season, with storms and rain showers experienced on most days of the survey. A total of 58.6 mm of rainfall was recorded during the survey. Water levels in the creeks surveyed fluctuated dramatically over the course of the survey. The weather conditions during the second survey (1 to 7 July 2014) were dry, sunny and cool. Only 1.4 mm of rainfall was recorded in the two months preceding the second survey.

5.2 HABITAT ASSESSMENT

5.2.1 AQ1

Site AQ1 is located in the third order drainage feature that passes through the western edge of the Investigation Area. This reference site lies outside the Project Area and outside the catchment in which the Project disturbance footprint is located. The drainage feature was observed to be flowing for several days during the wet season survey. By the time of the dry season survey, only a small waterhole (7 m x 4 m) in a rocky backwater remained. Large numbers of birds were observed drinking from this waterhole.

The channel at AQ1 is approximately 10 m wide, with banks from 1 m to 3 m high. The bed consists mainly of sand, with small areas of bedrock and boulders. Riparian vegetation is dominated by mature River Red Gums (*Eucalyptus camaldulensis*), *Acacia hemsleyi* and Couch (*Brachyachne convergens*). Cattle grazing adjacent to the pool have created large bare areas and grassy areas. The banks were assessed as being moderately unstable, with grasses dominating the bank cover.

Photo Plate 1 Site AQ1 (wet season)

5.2.2 AQ2

Site AQ2 is located upstream of the Investigation Area, just outside the south-eastern boundary of MDL 499. AQ2 is located upstream of site AQ1, on a tributary of the drainage feature that runs through the south-western portion of the Investigation Area. This reference site lies outside the Project Area and outside the catchment in which the Project disturbance footprint is located. A large, shallow pool was present at AQ2 in the wet season, which dried out completely by the time of the dry season survey.

The channel at AQ2 is approximately 8 m wide, with convex banks from 0.5 to 2 m in height. The substrate is dominated by gravel, with some small areas of bedrock and boulders. Riparian vegetation is sparse, and dominated by mature River Red Gums, Northern Swamp Mahogany (*Lophostemon grandiflorus*), *Acacia hemsleyi*, Couch and Twirly Windmill Grass (*Enteropogon ramosus*). The banks showed signs of erosion and cattle grazing, and were assessed as moderately unstable. There were large bare patches on the banks in the dry season.

Photo Plate 2 Site AQ2 (wet season)

5.2.3 AQ3

Site AQ3 is located on a first order drainage feature in the west of the Investigation Area. This minor drainage feature was dry in both surveys. AQ3 is located outside the Project Area and the catchment in which the Project disturbance footprint is located, downstream of the existing access road.

The channel at site AQ3 is narrow (0.5 – 2.5 m) and shallow, with banks to 0.5 m. The bed consists of sand and gravel with a cobble armour. Riparian vegetation is dominated by Cloncurry Box (*Eucalyptus leucophylla*), Turpentine (*Acacia chisholmii*) and Golden Beard Grass (*Chrysopogon fallax*). The banks are moderately stable, with little erosion present. Shrubs are the prevalent streamside cover.

Photo Plate 3 Site AQ3 (wet season)

5.2.4 AQ4

Site AQ4 is located in the central portion of the Project Area, at the junction of two small drainage features and the source of Watercourse B. A large, shallow pool of water was present at this site in the wet season survey. AQ4 was completely dry at the time of the dry season survey. AQ4 is located immediately upstream of a vehicle track through the creek. AQ4 is situated downstream of the Project disturbance footprint.

The creek channel at AQ4 is approximately 8 m wide. The creek banks are approximately 1 m high. The bed of the creek at AQ4 consists primarily of sand and gravel. The riparian vegetation at AQ4 is dominated by River Red Gums, Northern Swamp Mahogany, Soapbush (*Acacia holosericea*), Mimosa Bush (*Vachellia farnesiana*), Golden Beard Grass and Twirly Windmill Grass. The ground layer had been grazed by cattle. The banks were assessed as moderately unstable and covered mostly with grasses.

Photo Plate 4 Site AQ4 (wet season)

5.2.5 AQ5

Site AQ5 is located on a first order drainage feature in the north of the Project Area. No water was observed at AQ5 in either of the surveys. AQ5 is located downstream of the Project disturbance footprint.

The channel at AQ5 is 4 – 7 m wide, with banks to 3 m in height. The bed consists of cobbles, pebbles and sand. Riparian vegetation is dominated by Northern Swamp Mahogany, River Red Gum, Black Tea-tree (*Melaleuca bracteata*) and Silky Browntop (*Eulalia aurea*). Banks were assessed as stable, with trees forming the main component of streamside cover.

Photo Plate 5 Site AQ5 (dry season)

5.2.6 AQ6

Site AQ6 is located in a small first order drainage feature in the north of the Project Area. AQ6 is located outside the catchment in which the Project disturbance footprint is located, and can therefore be considered a reference site. A series of pools were present at this site in the wet season. All pools had dried up by the time that the dry season survey was conducted.

The channel at AQ6 is steep and rocky, with steep rock outcrops on either side of the creek. The channel is approximately 4 m wide, with the banks consisting of rock outcrops to 15 m in height. The bed is formed from large boulders and slabs of bedrock. Riparian vegetation is very sparse due to the low amount of topsoil present at this site. Northern Swamp Mahogany (*Lophostemon grandiflorus*) dominated the tree and shrub layers in the channel. Lemon-scented Grass (*Cymbopogon bombycinus*) dominated the sparse ground layer. The banks were assessed as stable, with no erosion present. Bank cover consists primarily of rocks.

Photo Plate 6 Site AQ6 (wet season)

5.2.7 AQ7

AQ7 is located on a second order watercourse (Watercourse B) in the north of the Project Area, downstream of the Project disturbance footprint and sites AQ6, AQ4, AQ5, AQ8, AQ9 and AQ10. A large pool of water was present at AQ7 in the wet season. This pool was dry during the dry season survey.

The creek at AQ7 is approximately 8 m wide, with convex banks to 2.5 m in height. The bed of the pool consists mainly of gravel, with large sections of bedrock and boulders. Riparian vegetation is dominated by River Red Gums, Northern Swamp Mahogany, Soapbush, Soft Spinifex (*Triodia pungens*) and Twirly Windmill Grass. Banks were assessed as moderately stable. Bank cover consisted mainly of trees.

Photo Plate 7 Site AQ7 (wet season)

5.2.8 AQ8

Site AQ8 is located in a first order drainage feature in the north-east of the Project Area, downstream of AQ10 and upstream of AQ4. AQ8 is located outside the catchment in which the Project disturbance footprint is located, and can therefore be considered a reference site. A large, deep waterhole is present at this site. This waterhole is thought to be permanent, due to its large size and depth. High numbers of birds were observed drinking at this site in the dry season.

The channel at AQ8 is extremely rocky, with a small dry waterfall immediately upstream of the pool. The pool exceeds 1 m in depth in places. The channel is approximately 12 m wide and banks are roughly 1.5 m high. The bed consists of a combination of bedrock, boulders and gravel. Riparian vegetation cover around the pool is sparse, and dominated by Northern Swamp Mahogany and Tall Sesbania Pea (*Sesbania javanica*). The banks were assessed as stable, with no erosion observed. Bank cover consists mainly of rock.

Photo Plate 8 Site AQ8 (wet season)

5.2.9 AQ9

Site AQ9 is located in the upper reaches of a small first order drainage feature in the east of the Project Area. AQ9 is located within the Project disturbance footprint. No water was observed at this site in either of the two surveys.

The channel at AQ9 varies in width, with an average width of 6 m. The gently sloping banks are 0.5 – 0.75 m in height. The channel bed is composed mainly of cobbles, with areas of gravel and small sections of outcropping bedrock and boulders. The riparian zone is confined to the creek channel, and is dominated by Northern Swamp Mahogany, Black Tea-tree and Northern Wanderrie Grass (*Eriachne obtusa*). The trees form dense thickets in parts of the channel. The banks were assessed as moderately stable, and were covered mainly with grasses.

Photo Plate 9 Site AQ9 (wet season)

5.2.10 AQ10

Site AQ10 is located at the source of a small first order drainage feature in the far east of the Project Area. AQ10 is located outside the catchment in which the Project disturbance footprint is located, and can therefore be considered a reference site. This site was surveyed during heavy rain in the wet season. Only a very small flow was observed in the channel. AQ10 was completely dry during the dry season survey.

The channel at AQ10 is very narrow (maximum 1 m) and shallow (approximately 0.3 m), with a bed of cobbles and gravel. The riparian vegetation consists mainly of Cloncurry Box, Soapbush and Golden-beard Grass. The banks were assessed as moderately stable, and were covered mainly by shrubs.

Photo Plate 10 Site AQ10 (dry season)

5.2.11 AQ11

Site AQ11 is located in a second order watercourse (Watercourse B) downstream of the Project Area and the Project disturbance footprint, approximately 1 km west of the north-western boundary. This site was not located until the dry season survey. One small pool and two larger pools were present at AQ11 in the dry season survey.

The channel at AQ11 is wide (15 m) and surrounded by steep rocky outcrops. The pools were approximately 0.5 m in depth at the time of survey. The right bank (looking downstream) is a gentle convex slope of approximately 1.5 m in height, while the left bank is composed of vertical bedrock to 1 m in height. The bed is composed mainly of bedrock, with areas of gravel, sand and silt. The bed had been trampled by cows, causing high turbidity in the water at the time of the survey. Algae were also observed in the water.

The riparian zone at AQ11 is confined to the channel, and dominated by River Red Gum, Northern Swamp Mahogany and *Acacia hemsleyi*. The ground layer has been stripped by grazing cattle. The creek banks were stable and covered mainly by rock.

Photo Plate 11 Site AQ11 (dry season)

5.2.12 AQ12

Site AQ12 is located in a first order drainage feature slightly to the south of the north-eastern boundary of the Project Area. AQ12 is located outside the catchment in which the Project disturbance footprint is located, and can therefore be considered a reference site. This site was not located until the dry season survey. A very small pool of water was present at this site in the dry season. AQ12 is likely to form a much larger pool during the wet season, as the channel is quite deep at this point.

The channel width varies at AQ12, ranging from a maximum of 20 m wide at the pool to 10 m wide immediately downstream. The pool is located at the foot of a large, vertical section of bedrock. The pool was very small (2 m x 2 m) at the time of survey and less than 0.3 m in depth. The water was very turbid, contained algae and had a high solids load. The pool has a sandy bottom, while the channel downstream is composed mainly of pebbles and gravel. Deposition of fine sediment was noted at the pool. The banks of the pool are gentle and convex, to approximately 4 m in height.

Riparian vegetation is not present at the pool itself, possibly because of trampling and grazing by livestock. Immediately downstream of the pool the riparian vegetation consists mainly of Northern Swamp Mahogany and Northern Wanderrie Grass. The banks were assessed as moderately stable, although vegetation cover was fairly low and bank cover was dominated by bare ground.

Photo Plate 12 Site AQ12 (dry season)

5.2.13 SITE SCORES

Each of the survey sites was assessed using the AUSRIVAS habitat assessment methodology. Sites were assessed in both the dry season survey and the wet season survey, with the exception of AQ11 and AQ12, which were only assessed in the dry season. Site scores are provided in Table 7. All sites fell with the 'moderate' to 'good' habitat range. Scores in the wet and dry season were similar. The habitat assessment results reflect the ephemeral nature of the survey sites and the impacts of grazing and erosion.

Table 7 AUSRIVAS Habitat Assessment Results

Site	Habitat Assessment Score / 135	
	Wet Season	Dry Season
AQ1	78	86
AQ2	75	79
AQ3	73	78
AQ4	55	65
AQ5	72	79
AQ6	95	94
AQ7	91	81
AQ8	80	86
AQ9	76	79
AQ10	83	82
AQ11	-	85
AQ12	-	83

5.3 STREAM SEDIMENT

5.3.1 Particle Size

Stream sediments were typically very coarse, with a high component of gravel, cobbles and sand. The particle size distribution results are presented in Table 8, Figure 9 (wet season) and Figure 10 (dry season).

Table 8 Particle Size Distribution Results

Site	Fraction (%)			
	Clay	Silt	Sand	Gravel
Wet season				
AQ1	5	7	80	8

Site	Fraction (%)			
	Clay	Silt	Sand	Gravel
AQ2	6	8	79	7
AQ3	3	6	58	33
AQ4	5	5	81	9
AQ5	4	3	59	34
AQ6	1	1	38	60
AQ7	2	1	88	9
AQ8	3	4	42	51
AQ9	4	3	62	31
AQ10	3	3	42	52
Dry season				
AQ1	9	26	35	30
AQ2	5	6	78	11
AQ3	5	11	58	26
AQ4	1	2	68	29
AQ5	2	7	83	8
AQ6	3	4	78	15
AQ7	2	3	80	15
AQ8	2	3	53	42
AQ9	3	4	55	38
AQ10	4	6	60	30
AQ11	7	12	62	19
AQ12	9	13	56	22

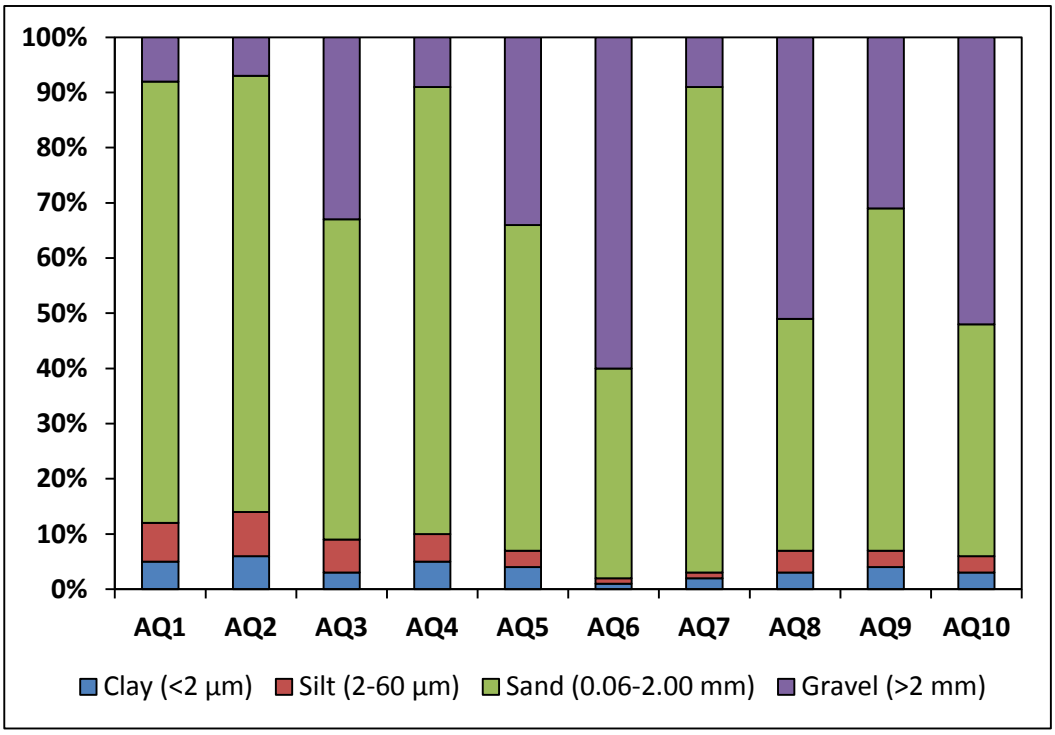

Figure 9 Particle Size Distribution – Wet Season

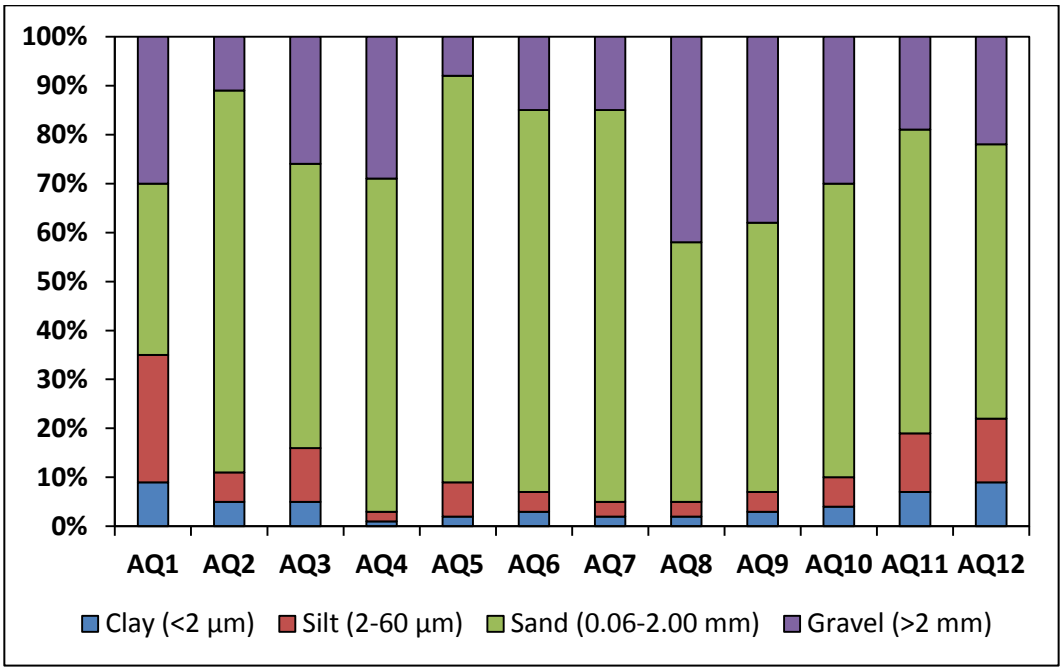

Figure 10 Particle Size Distribution – Dry Season

5.3.2 Metal Concentrations

Sediment samples were taken at each survey site in both surveys and tested for a suite of metals. Metal concentrations in sediment are shown in Table 9 (wet season) and Table 10 (dry season). Metals levels at most sites were below both the low and high ISQG. A small number of exceedences of the ANZECC low ISQG were recorded, and are highlighted in the tables in orange. No exceedences of the high ISQG were recorded. The full laboratory analysis results are presented in Appendix B.

In the wet season, copper levels above the low ISQG were recorded at AQ4 and AQ7. Copper levels above the low ISQG were also recorded at AQ1 and AQ4 in the dry season. Nickel levels at AQ5 were above the ISQG in both the wet season and dry season.

Antimony and silver levels were below the LOR at all sites. The LOR for these parameters is higher than the low ISQG, so it is not possible to ascertain if the results comply with the applicable guideline limits.

Table 9 Metal Concentrations in Stream Sediment – Wet Season

Metal	Units	Low ISQG	High ISQG	AQ1	AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10
Al	mg/kg	n/a	n/a	7940	7970	9970	7710	16500	8500	8090	8800	9420	8540
As	mg/kg	20	70	<5	<5	<5	<5	<5	<5	<5	<5	6	<5
Ag	mg/kg	1.0	3.7	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ba	mg/kg	n/a	n/a	40	60	90	40	90	60	40	70	40	40
Be	mg/kg	n/a	n/a	<1	<1	<1	<1	1	<1	<1	<1	<1	<1
B	mg/kg	n/a	n/a	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Cd	mg/kg	1.5	10	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Co	mg/kg	n/a	n/a	16	12	14	15	26	18	16	14	24	14
Cr	mg/kg	80	370	13	14	11	17	26	16	11	17	20	17
Cu	mg/kg	65	270	24	17	24	**75**	22	10	**90**	21	23	12
Fe	mg/kg	n/a	n/a	24700	26900	35600	28800	53800	24800	27400	37000	26500	28800
Hg	mg/kg	0.15	1.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Mn	mg/kg	n/a	n/a	83	83	284	130	232	403	132	436	138	98
Mo	mg/kg	n/a	n/a	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

Metal	Units	Low ISQG	High ISQG	AQ1	AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10
Ni	mg/kg	21	52	12	8	8	12	**22**	11	15	9	12	10
Pb	mg/kg	50	220	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sb	mg/kg	2.0	25	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Se	mg/kg	n/a	n/a	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
V	mg/kg	n/a	n/a	44	49	55	67	97	48	48	71	68	50
Zn	mg/kg	200	410	9	10	23	17	13	11	12	16	11	12

-**Orange font** indicates an exceedance of the low ISQG

Table 10 Metal Concentrations in Stream Sediment – Dry Season

Metal	Units	Low ISQG	High ISQG	AQ1	AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10	AQ11	AQ12
Al	mg/kg	n/a	n/a	19800	8350	12900	9510	15700	9330	9210	7230	10800	12200	15300	13300
As	mg/kg	20	70	<5	<5	<5	<5	<5	10	<5	<5	7	<5	<5	<5
Ag	mg/kg	1.0	3.7	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ba	mg/kg	n/a	n/a	200	40	110	40	90	60	40	40	40	140	80	80
Be	mg/kg	n/a	n/a	1	<1	<1	<1	1	<1	<1	<1	<1	1	1	1
B	mg/kg	n/a	n/a	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Cd	mg/kg	1.5	10	<1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1
Co	mg/kg	n/a	n/a	22	12	18	23	32	26	26	10	26	14	18	21
Cr	mg/kg	80	370	24	12	14	18	33	17	17	11	20	22	16	19
Cu	mg/kg	65	270	**73**	13	28	**119**	30	28	35	15	19	26	63	31
Fe	mg/kg	n/a	n/a	52100	27600	43500	34600	82300	38800	36400	27300	29700	42900	50200	42300
Hg	mg/kg	0.15	1.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Mn	mg/kg	n/a	n/a	459	85	350	185	211	200	146	206	142	398	265	402
Mo	mg/kg	n/a	n/a	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

Metal	Units	Low ISQG	High ISQG	AQ1	AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10	AQ11	AQ12
Ni	mg/kg	21	52	18	8	11	15	**25**	12	13	8	12	17	16	15
Pb	mg/kg	50	220	7	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sb	mg/kg	2.0	25	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Se	mg/kg	n/a	n/a	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
V	mg/kg	n/a	n/a	70	41	73	77	150	71	68	63	74	73	82	90
Zn	mg/kg	200	410	30	10	30	20	14	22	13	14	13	17	21	32

-**Orange font** indicates an exceedance of the low ISQG

5.4 WATER QUALITY

Water quality results for the wet season survey are presented in Table 11. Dry season water quality results are presented in Table 12. Exceedences of the ANZECC guidelines are presented in bold, orange font in the tables.

Physicochemical water quality in the Investigation Area was moderately poor. pH values tended to be slightly alkaline, and were above the ANZECC aquatic ecosystems guideline range at several sites (AQ1 in the wet season, AQ4, AQ7, AQ8, AQ11). Conductivity levels were high in the dry season, with all sites exceeding the ANZECC guideline. Site AQ4 recorded conductivity levels in excess of the ANZECC guideline in the wet season. Dissolved oxygen levels tended to be low, and were below the ANZECC guideline range at most sites (AQ1 in the dry season, AQ2, AQ4, AQ6, AQ7, AQ11, AQ12). The high pH and conductivity values and the low DO levels recorded are typical of stagnant, ephemeral waterbodies.

Nutrient levels (i.e. total nitrogen and total phosphorus) exceeded the ANZECC guidelines at all sites in both surveys. These high results are likely to be attributable to natural factors, as no artificial nutrient sources (such as fertilisers and sewage) are present in the Investigation Area. Nitrogen sources include decaying organic matter and animal waste. Phosphorus is found in rocks and soil, and is released to water through weathering and erosion. Animal and plant wastes are also a source of phosphorus. Nutrient levels tend to be high in ephemeral waterbodies, due to concentration from evaporation.

Metals levels in water were generally below the ANZECC guideline limits, with a few exceptions. In the wet season, total and dissolved silver (at AQ4, AQ6 and AQ7), total and dissolved copper (at all sites), total zinc (AQ8), total and dissolved aluminium (at AQ4, AQ7 and AQ8) and dissolved aluminium at AQ1 were above ANZECC aquatic ecosystems guidelines. Metal results were similar in the dry season, with total and dissolved copper (at AQ1, AQ8 and AQ11), total copper (AQ12), total and dissolved manganese (AQ12), total aluminium (AQ11 and AQ12) and total zinc (AQ11 and AQ12) exceeding the ANZECC guidelines. Copper, zinc and aluminium are naturally abundant elements and their elevated levels are likely to be the result of mineralisation in the Project region. High silver levels are also likely to be attributable to the local geology. High manganese levels were detected only at site AQ12. Manganese is an abundant metal in soil, and it is possible that trampling of the soft, sandy bed at AQ12 by cattle increased manganese levels at this site. No breaches of the Livestock Drinking Water guidelines were detected.

It should be noted that the ANZECC aquatic ecosystems guideline for silver is lower than the LOR for silver. This prevents a valid comparison of silver results below the LOR with the guideline limit.

The full water quality results are presented in Appendix B.

Table 11 Wet Season Surface Water Monitoring Results

Parameter	Units	ANZECC (2000) Livestock Drinking Water	ANZECC (2000) Aquatic Ecosystems	AQ1	AQ2	AQ4	AQ6	AQ7	AQ8
pH	pH units	n/a	6.0 - 7.5	7.64	7.45	7.72	7.24	7.66	8.06
Conductivity (EC)	µs/cm	n/a	20 - 250	169	184	262	226	199	137
Dissolved oxygen (DO)	%	n/a	90 - 120	114	72	79	64	44	109
Total dissolved solids	mg/L	4000	n/a	126	129	174	140	137	96
Suspended solids	mg/L	n/a	n/a	<5	10	11	<5	7	6
Turbidity	NTU	n/a	2 - 15	8.9	10.9	16.9	3.9	12.8	5.3
Total alkalinity ($CaCO_3$)	mg/L	n/a	n/a	83	90	106	91	81	46
Dissolved sulphate (SO_4^{2-})	mg/L	1000	n/a	<1	<1	7	9	6	6
Total chloride	mg/L	n/a	n/a	4	4	13	10	9	10
Total nitrogen	mg/L	n/a	0.15	1	1.1	0.7	0.5	0.5	0.5

Parameter	Units	ANZECC (2000) Livestock Drinking Water	ANZECC (2000) Aquatic Ecosystems	AQ1	AQ2	AQ4	AQ6	AQ7	AQ8
Total phosphorus	mg/L	n/a	0.01	**0.33**	**0.18**	**0.08**	**0.05**	**0.07**	**0.04**
Dissolved metals									
Aluminium	mg/L	n/a	0.055	**0.06**	0.05	**0.43**	0.04	**0.56**	**0.37**
Antimony	mg/L	n/a	n/a	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	mg/L	n/a	0.024	0.002	0.002	0.001	<0.001	<0.001	<0.001
Beryllium	mg/L	n/a	n/a	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	mg/L	n/a	n/a	0.034	0.045	0.051	0.032	0.026	0.023
Boron	mg/L	n/a	0.37	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cadmium	mg/L	n/a	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	n/a	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/L	n/a	n/a	<0.001	0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	n/a	0.0014	**0.003**	**0.002**	**0.025**	**0.003**	**0.009**	**0.003**

Parameter	Units	ANZECC (2000) Livestock Drinking Water	ANZECC (2000) Aquatic Ecosystems	AQ1	AQ2	AQ4	AQ6	AQ7	AQ8
Iron	mg/L	n/a	n/a	3.23	1.3	0.6	0.36	0.59	0.37
Lead	mg/L	n/a	0.0034	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	n/a	1.9	0.04	0.187	0.053	0.09	0.031	0.031
Mercury	mg/L	n/a	0.0006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	mg/L	n/a	n/a	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	mg/L	n/a	0.011	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	mg/L	n/a	0.011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	mg/L	n/a	0.00005	<0.0001	<0.0001	**0.0004**	**0.0002**	**0.0001**	<0.0001
Vanadium	mg/L	n/a	n/a	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	n/a	0.008	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total metals									
Aluminium	mg/L	5	0.055	<0.01	<0.01	**0.5**	<0.01	**0.64**	**0.31**

Parameter	Units	ANZECC (2000) Livestock Drinking Water	ANZECC (2000) Aquatic Ecosystems	AQ1	AQ2	AQ4	AQ6	AQ7	AQ8
Antimony	mg/L	n/a	n/a	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	mg/L	0.5	0.024	0.002	0.002	0.002	<0.001	<0.001	<0.001
Beryllium	mg/L	n/a	n/a	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	mg/L	5	0.37	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Barium	mg/L	n/a	n/a	0.039	0.048	0.053	0.033	0.028	0.023
Cadmium	mg/L	0.01	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	1.0	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/L	1.0	n/a	0.002	0.002	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	1.0	0.0014	**0.003**	**0.002**	**0.032**	**0.002**	**0.012**	**0.003**
Iron	mg/L	n/a	n/a	3.83	2.01	1.12	0.54	1.08	0.57
Lead	mg/L	0.1	0.0034	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	n/a	1.9	0.161	0.222	0.077	0.121	0.039	0.051

Parameter	Units	ANZECC (2000) Livestock Drinking Water	ANZECC (2000) Aquatic Ecosystems	AQ1	AQ2	AQ4	AQ6	AQ7	AQ8
Mercury	mg/L	0.002	0.0006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	mg/L	n/a	n/a	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	mg/L	1.0	0.011	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	mg/L	0.02	0.011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	mg/L	n/a	0.00005	<0.0001	<0.0001	**0.0003**	**0.0002**	**0.0001**	<0.0001
Vanadium	mg/L	n/a	n/a	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	20	0.008	<0.005	<0.005	0.007	<0.005	<0.005	**0.015**

Orange font indicates an exceedence of the ANZECC guidelines for aquatic ecosystems.

Table 12 Dry Season Surface Water Monitoring Results

Parameter	Units	ANZECC (2000) Livestock Drinking Water	ANZECC (2000) Aquatic Ecosystems	AQ1	AQ8	AQ11	AQ12
pH	pH units	n/a	6.0 - 7.5	6.9	**7.76**	**7.92**	7.14
Conductivity (EC)	µs/cm	n/a	20 - 250	**492.1**	**328.7**	**960**	**1455**
Dissolved oxygen (DO)	%	n/a	90 - 120	**65.3**	108.7	**70.7**	**35**
Total dissolved solids	mg/L	4000	n/a	320.45	214.5	624	949
Suspended solids	mg/L	n/a	n/a	44	<5	136	136
Total alkalinity ($CaCO_3$)	mg/L	n/a	n/a	166	122	371	550
Dissolved sulphate (SO_4^{2-})	mg/L	1000	n/a	26	4	4	7
Total chloride	mg/L	n/a	n/a	25	21	48	124
Total nitrogen	mg/L	n/a	0.15	**7.6**	**0.9**	**14.7**	**19.0**
Total phosphorus	mg/L	n/a	0.01	**0.59**	**0.09**	**0.97**	**1.23**

Parameter	Units	ANZECC (2000) Livestock Drinking Water	ANZECC (2000) Aquatic Ecosystems	AQ1	AQ8	AQ11	AQ12
Dissolved metals							
Aluminium	mg/L	n/a	0.055	<0.01	<0.01	0.02	<0.01
Antimony	mg/L	n/a	n/a	<0.001	<0.001	<0.001	<0.001
Arsenic	mg/L	n/a	0.024	0.001	<0.001	0.003	0.004
Beryllium	mg/L	n/a	n/a	<0.001	<0.001	<0.001	<0.001
Barium	mg/L	n/a	n/a	0.058	0.039	0.170	0.078
Boron	mg/L	n/a	0.37	0.07	0.06	0.15	0.13
Cadmium	mg/L	n/a	0.0002	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	n/a	0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/L	n/a	n/a	0.002	<0.001	0.003	0.008
Copper	mg/L	n/a	0.0014	**0.002**	**0.002**	**0.003**	<0.001
Iron	mg/L	n/a	n/a	0.65	0.07	1.08	0.64

Parameter	Units	ANZECC (2000) Livestock Drinking Water	ANZECC (2000) Aquatic Ecosystems	AQ1	AQ8	AQ11	AQ12
Lead	mg/L	n/a	0.0034	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	n/a	1.9	0.081	0.006	0.307	**6.49**
Mercury	mg/L	n/a	0.0006	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	mg/L	n/a	n/a	<0.001	<0.001	0.002	0.003
Nickel	mg/L	n/a	0.011	0.002	<0.001	0.002	0.002
Selenium	mg/L	n/a	0.011	0.0003	0.0003	0.0005	0.0008
Silver	mg/L	n/a	0.00005	<0.001	<0.001	<0.001	<0.001
Vanadium	mg/L	n/a	n/a	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	n/a	0.008	<0.005	<0.005	<0.005	<0.005
Total metals							
Aluminium	mg/L	5	0.055	0.03	0.02	**0.25**	**0.36**
Antimony	mg/L	n/a	n/a	<0.001	<0.001	<0.001	<0.001

Parameter	Units	ANZECC (2000) Livestock Drinking Water	ANZECC (2000) Aquatic Ecosystems	AQ1	AQ8	AQ11	AQ12
Arsenic	mg/L	0.5	0.024	0.001	<0.001	0.005	0.006
Beryllium	mg/L	n/a	n/a	<0.001	<0.001	<0.001	<0.001
Boron	mg/L	5	0.37	<0.05	<0.05	0.07	0.06
Barium	mg/L	n/a	n/a	0.068	0.039	0.205	0.516
Cadmium	mg/L	0.01	0.0002	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	1.0	0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/L	1.0	n/a	0.003	<0.001	0.004	0.012
Copper	mg/L	1.0	0.0014	**0.003**	**0.002**	**0.009**	**0.004**
Iron	mg/L	n/a	n/a	2.09	0.16	5.27	30.0
Lead	mg/L	0.1	0.0034	<0.001	<0.001	<0.001	0.002
Manganese	mg/L	n/a	1.9	0.110	0.046	0.529	**7.69**
Mercury	mg/L	0.002	0.0006	<0.0001	<0.0001	<0.0001	<0.0001

Parameter	Units	ANZECC (2000) Livestock Drinking Water	ANZECC (2000) Aquatic Ecosystems	AQ1	AQ8	AQ11	AQ12
Molybdenum	mg/L	n/a	n/a	<0.001	<0.001	0.002	0.003
Nickel	mg/L	1.0	0.011	0.002	<0.001	0.002	0.003
Selenium	mg/L	0.02	0.011	0.0004	0.0003	0.0004	0.0009
Silver	mg/L	n/a	0.00005	<0.001	<0.001	<0.001	<0.001
Vanadium	mg/L	n/a	n/a	<0.01	<0.01	0.01	0.02
Zinc	mg/L	20	0.008	<0.005	<0.005	**0.009**	**0.010**

Orange font indicates an exceedence of the ANZECC guidelines for aquatic ecosystems.

5.5 MACROINVERTEBRATES

Macroinvertebrate samples were taken from all sites where surface water was present. In larger pools where bed and edge habitats were present, separate samples from the edge and bed were taken. Where pools were very small or only one habitat type was present a single sample was taken. Sites AQ1, AQ2, AQ4, AQ6, AQ7 and AQ8 were sampled in the wet season. AQ1, AQ8, AQ11 and AQ12 were sampled in the dry season.

Macroinvertebrate diversity was fairly low, ranging from five taxa (at AQ12 and AQ1 bed habitat in the dry season) to 13 taxa (at AQ8 in the dry season). Total abundance was also relatively low, ranging from 40 individuals (in bed habitat at AQ1 in the dry season) to 136 individuals (at bed habitat at AQ8 in the wet season).

The Plecoptera (stoneflies), Ephemoptera (mayflies) and Trichoptera (caddis flies) (PET) are three orders of macroinvertebrates that are widely regarded as particularly sensitive to water pollution. Few PET taxa were recorded in the samples taken from the Investigation Area. No stoneflies were recorded in either survey. A single caddis fly was recorded at AQ4 in the wet season. Two individual caddis flies were recorded at sites AQ8 and AQ11 in the dry season. Higher numbers of mayflies (up to 18 individuals) were recorded. One mayfly taxon was recorded at most sites in the wet season, with two taxa at AQ7. A single mayfly taxon was recorded at both AQ8 and AQ11 in the dry season. These low numbers of PET taxa are indicative of poor water quality and/or low habitat quality.

SIGNAL scores were generally low (<4), which is reflective of the ephemeral nature of the waterways sampled. SIGNAL scores were similar between sites and across seasons, ranging from 2.53 (at AQ12 and AQ1 edge habitat in the wet season) to 3.43 (at AQ1 bed habitat in the dry season). These low scores are attributable to the poor water quality and lack of habitat availability in the small, ephemeral waterbodies sampled.

The SIGNAL scores were plotted on a biplot to assist in interpretation of the results. The SIGNAL biplot is shown in Figure 11. All sites fell within Quadrant 3 of the biplot, with the exception of AQ8 (dry season), which fell into Quadrant 1. Scores within Quadrant 3 can be indicative of either pollution or harsh physical conditions. The ephemeral nature of the waterways in the Investigation Area, drought and wet season flooding create harsh physical conditions for macroinvertebrates. Scores in Quadrant 1 indicate favourable habitat and chemically dilute waters. It is likely that AQ8 fell into Quadrant 1 because it is the only permanent water source in the Investigation Area, and provides a variety of habitat types in a large, deep pool.

The laboratory results for the macroinvertebrate samples are shown in Appendix C.

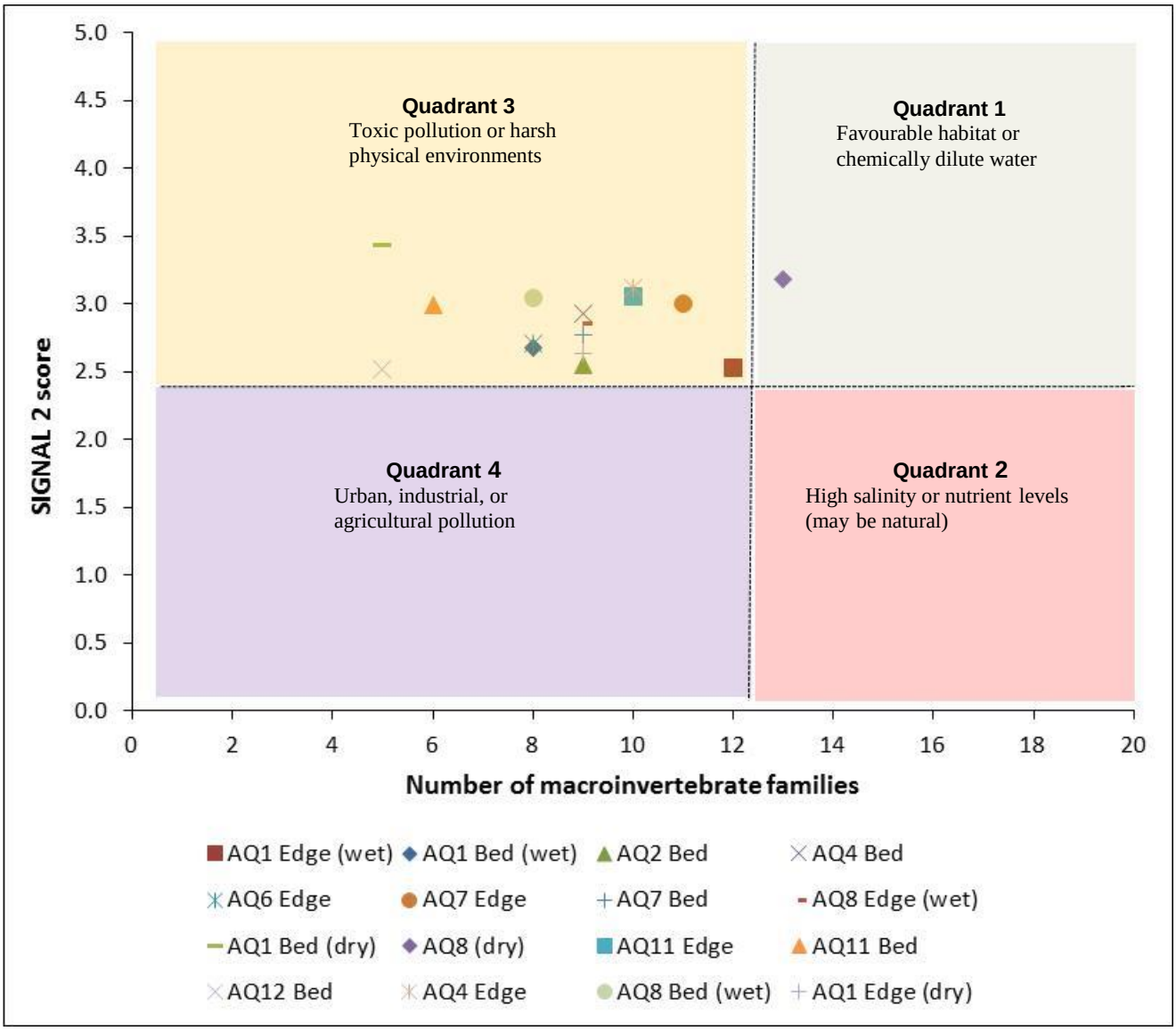

Figure 11 SIGNAL Biplot

5.6 AQUATIC FLORA

A total of 153 species of plant were identified in the riparian areas of the Investigation Area. A full list of these species is presented in Appendix D.

5.6.1 Communities of Conservation Significance

RE 1.3.7 – River Red Gum (*Eucalyptus camaldulensis*) woodland on channels and levees occurs on sections of the larger watercourses and drainage features of the Investigation Area. Approximately 75 ha of this community are found in the Investigation Area. This RE is listed as Least Concern under the *Vegetation Management Act 1999*, but has an EHP Biodiversity Status of Endangered. RE 1.3.7 is described as 'Fringing woodland of *Eucalyptus camaldulensis*, with *Melaleuca bracteata* on levees of smaller channels and *M. argentea* on those of larger ones. *Lophostemon grandiflorus* usually present, occasional *Terminalia aridicola*. *Eucalyptus microtheca* or *E. leucophylla* on finer textured soils. *Melaleuca leucadendra* may dominate creek lines where water is available for extended periods each year. Occurs on recent levees and channel deposits of larger tributaries; alluvial soils.' The vegetation observed on site is consistent with the sub-community RE 1.3.7b 'Riverine wetland or fringing riverine

wetland. Fringing woodland of *Eucalyptus camaldulensis*, usually with *Lophostemon grandiflorus* and *Melaleuca bracteata* and/or *M. dissitiflora*. Occurs on recent levees and channel deposits of medium and smaller tributaries which are dry for most of the year; alluvial soils.'

The areas of RE 1.3.7b in the Investigation Area contain a large number of mature, hollow-bearing trees which provide excellent habitat for a range of bird, bat and arboreal species. The ground layer of this community has been heavily modified by the introduction of Buffel Grass and by cattle grazing in the Investigation Area. At the regional scale, RE 1.3.7 has been severely degraded by high total grazing pressure. The extent of RE 1.3.7 in reserves is low (EHP, 2014).

The extent of RE 1.3.7b in the Investigation Area and the Project disturbance footprint are shown in Figure 12. Only 1.8 ha of the 75 ha of RE 1.3.7b on site will be directly impacted by Project activities.

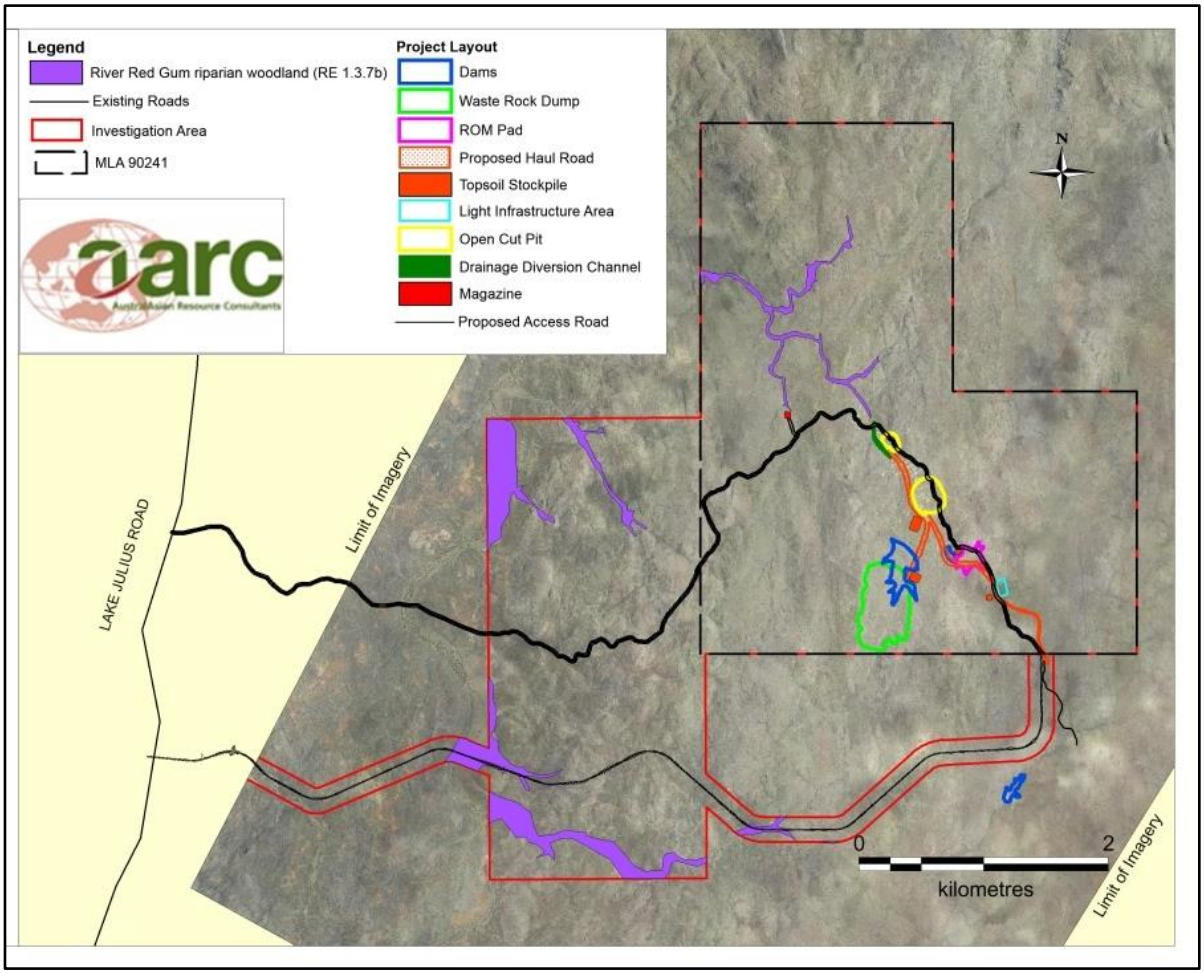

Figure 12 RE 1.3.7b and the Project Disturbance Footprint

5.6.2 Plants of Conservation Significance

No flora species of conservation significance were found in the Investigation Area. No aquatic plants of conservation significance are known from the local area; therefore it is unlikely that any threatened aquatic plants occur on site.

5.6.3 Weed Species

The introduced species Mimosa Bush (*Vachellia farnesiana*), Buffel Grass (*Cenchrus ciliaris*), Elastic Grass (*Eragrostis tenuifolia*) and Asthma Plant (*Chamaesyce hirta*) were commonly observed growing in riparian areas. Rubber Vine (*Cryptostegia grandiflora*), which is a WoNS and a Class 2 declared weed, was recorded at site AQ5. Other weeds recorded in low numbers in riparian areas were Spinyhead Sida (*Sida acuta*), Flannel Weed (*Sida cordifolia*), Paddy's Lucerne (*Sida rhombifolia*), Star Burr (*Acanthospermum hispidum*), Feathertop Rhodes Grass (*Chloris virgata*), Southern Crabgrass (*Digitaria ciliaris*), Awnless Barnyard Grass (*Echinochloa colona*) and Malvastrum (*Malvastrum americanum*). No aquatic weeds were recorded at the survey sites.

5.7 AQUATIC AND RIPARIAN FAUNA

A total of 67 species of fauna were recorded in the riparian areas of the Investigation Area, including two threatened species and four introduced species. A full list of the fauna species recorded in the riparian sections of the Investigation Area is presented in Appendix E.

5.7.1 Mammals

The waterholes on the Project site are water sources for large mammal species, such as macropods. Riparian areas also provide habitat and drinking water for smaller mammal species, such as bats.

Twelve mammal species were positively identified in riparian habitat in the Investigation Area. A further two species of bat were identified as possibly present in the Investigation Area. No aquatic mammals were observed during the surveys. Common Wallaroos (*Macropus robustus*) were occasionally observed in riparian areas and were sighted drinking at waterholes in the dry season. A Purple-necked Rock-wallaby (*Petrogale purpureicollis*) was observed on boulders adjacent to site AQ6 in the wet season (Photo Plate 13). The corpse of a Purple-necked Rock-wallaby was observed at AQ6 in the dry season survey. The Purple-necked Rock-wallaby is listed as Vulnerable under the NC Act. Site AQ6 will not be disturbed by Project activities. Detailed information on the Purple-necked Rock-wallaby is provided in the Barbara Copper Project Terrestrial Flora and Fauna Assessment (AARC, 2014).

Seven species of bats were recorded in the riparian areas of the Investigation Area. A further two species may also be present, but they could not be reliably identified from the bat call data recorded. Commonly recorded species included Gould's Wattled Bat (*Chalinolobus gouldii*), Hoary Wattled Bat (*Chalinolobus nigrogriseus*), Little Broad-nosed Bat (*Scotorepens greyii*) and Finlayson's Cave Bat (*Vespadelus finlaysoni*). A full list of the bat species recorded during the survey is presented in Appendix F.

Photo Plate 13 Purple-necked Rock-wallaby (*Petrogale purpureicollis*) at AQ6

Two exotic mammal species, European Cattle (*Bos taurus*) and Feral Pigs (*Sus scrofa*), were also recorded in riparian areas. Both these species utilise waterholes heavily for drinking water. Damage to riparian vegetation and habitat was observed as a result of these large animals accessing waterholes. Wild Dog (*Canis familiaris*) tracks were also noted at several waterholes in the Investigation Area. Wild Dogs are likely to utilise waterholes for drinking water and also to prey upon drinking fauna.

5.7.2 Birds

The waterholes of the Investigation Area provide birds with drinking and bathing water. Dense riparian vegetation provides habitat for small bird species, such as finches and fairy-wrens. Stands of River Red Gum provide nesting and foraging habitat for a range of species. The high densities of birds at waterholes provide an important food source for predators, such as snakes and raptors. Waterhole habitat will not be disturbed by Project activities.

Large numbers of birds were recorded in the riparian areas of the Investigation Area. A total of 40 bird species were recorded in the two surveys. During the dry season, several bird species were observed bathing and drinking at the remaining waterholes. Large flocks of Diamond Doves (*Geopelia cuneata*), Zebra Finches (*Taeniopygia guttata*) (shown in Photo Plate 14), Budgerigars (*Melopsittacus undulatus*) and Double-barred Finches (*Taeniopygia bichenovii*) were encountered at all waterholes in the dry season. Collared Sparrowhawks (*Accipiter cirrocephalus*) were observed preying on these birds at AQ8 and AQ11.

No aquatic bird species were recorded in the Investigation Area. One wetland species, the Black-fronted Dotterel (*Elseyornis melanops*) was observed in low numbers at AQ1 during the wet season.

One species of conservation significance, the Golden-backed Honeyeater (*Melithreptus gularis laetior*) was observed in riparian habitat in the Investigation Area. Three Golden-backed Honeyeaters were observed in the trees at AQ4. The Golden-backed Honeyeater is listed as Near Threatened under the NC Act. Site AQ4 is located outside the Project disturbance footprint. Detailed information on the Golden-backed Honeyeater is provided in the Terrestrial Flora and Fauna Assessment (AARC, 2014).

Four bird species listed as Marine species and one species listed as both Migratory and Marine were recorded in the Investigation Area. Listed Marine species recorded were:

- Black-faced Cuckoo-shrike (*Coracina novaehollandiae*);
- Dollarbird (*Eurystomus orientalis*);
- Sacred Kingfisher (*Todiramphus sanctus*);
- Magpie-lark (*Grallina cyanoleuca*); and
- Rainbow Bee-eater (*Merops ornatus*).

The Rainbow Bee-eater is also a listed Migratory species.

These five species are all widespread, common and mobile species. Suitable habitat for these Marine species will remain in the undisturbed portions of the Investigation Area and throughout the local area. No significant impact on any of these species is expected to occur as a result of project development.

Photo Plate 14 Zebra Finches (*Taeniopygia guttata*) drinking and bathing at site AQ8

5.7.3 Amphibians

Amphibian habitat in the Investigation Area is limited by the ephemeral and rocky nature of the site waterways. The waterholes of the Investigation Area (particularly AQ1 and AQ8) provide habitat and breeding areas for amphibians. This habitat will not be disturbed by Project activities.

A total of five amphibian species were recorded in the Investigation Area. Most species observed were tree frogs and burrowing frogs, which are well adapted to the arid conditions of the Investigation Area. High numbers of Green Treefrogs (*Litoria caerulea*) and Desert Treefrogs (*Litoria rubella*) were observed and heard calling at waterholes. During the wet season, high numbers of tadpoles (mainly *Cyclorana australis*, see Photo Plate 15) and juvenile frogs were observed. A single Ornate Burrowing Frog (*Platypectrum ornatum*) was observed at AQ1 in the wet season. The introduced Cane Toad (*Rhinella marina*) was heard calling in several areas of the site during the wet season and sited in low numbers at AQ1 in the dry season.

No amphibians of conservation significance were recorded during the surveys.

Photo Plate 15 Northern Snapping Frog (*Cyclorana australis*)

5.7.4 Reptiles

Six reptile species were observed in the riparian habitat of the Investigation Area. No aquatic reptiles were observed. Gilbert's Dragons (*Amphibolurus gilberti*) were observed drinking from small waterholes in the dry season survey. A large Olive Python (*Liasis olivaceus*) was observed swimming in the large waterhole at AQ8 (shown in Photo Plate 16). Waterholes such as AQ8 are excellent food sources for snakes, and will not be disturbed by Project activities. Four skink species were also recorded in riparian habitat.

Photo Plate 16 Olive Python (*Liasis olivaceus*) at site AQ8

No reptiles of conservation significance were recorded in the Investigation Area.

5.7.5 Fish

The only species of fish captured in the Investigation Area was the Spangled Perch (*Leiopotherapon unicolor*), shown in Photo Plate 17. Small numbers of juvenile Spangled Perch were captured at AQ1 in both surveys. No fish were captured at any other survey site. Large numbers of deceased and dying juvenile Spangled Perch were observed in a very small waterhole in the south-west of the Investigation Area in the dry season. The fish were severely affected by low oxygen availability in the drying waterhole.

The Spangled Perch is widespread, occurring in a broad range of habitat types such as streams, lakes, bores, dams and billabongs. It occurs in abundance in most coastal drainage systems in northern and eastern Australia; north of the Greenough River in Western Australia and as far south as the Murray-Darling River system in New South Wales (Allen et al. 2003). The Spangled Perch is common throughout the region in which the Project is located. It is known to be tolerant of varying and harsh conditions (Pusey et al. 2004).

Photo Plate 17 Spangled Perch (Leiopotherapon unicolor)

Desert Rainbowfish (*Melanotaenia splendida tatei*) were observed in waterholes across the Investigation Area at the end of the wet season. The Desert Rainbowfish occurs in central desert areas in Queensland and the Northern Territory in a broad range of habitats, including rivers, creeks, lakes, reservoirs, and swamp areas. They tend to inhabit areas with low water flow (Allen et al. 2003). The Desert Rainbowfish is common throughout the region in which the Project is located. Rainbowfish are known to be tolerant of varying and harsh environmental conditions (Pusey et al. 2004).

Fish abundance and diversity at the Investigation Area were low. This is likely due to the fact that the waterways that run through the Investigation Area originate within or very close to the site. These low-order waterways are highly ephemeral and do not provide permanent fish habitat. It is thought that the fish observed in the Investigation Area are likely to have swum upstream onto the site in the wet season. Most fish are likely to die out during the dry season, as the only permanent water source observed within the Investigation Area is the waterhole at AQ8. AQ8 is located outside the Project disturbance footprint. No fish were observed or captured at AQ8.

5.7.6 Crustaceans

Several Inland Freshwater Crabs (*Austrothelphusa transversa*) were captured in the waterways of the Investigation Area during the wet season (Photo Plate 18). Both living and deceased crabs were observed in the dry season survey. No other crustacean species were observed in the Investigation Area.

Photo Plate 18 Inland Freshwater Crab (*Austrothelphusa transversa*) captured on the Project site

5.7.7 Fauna of Conservation Significance

Aquatic and riparian species of conservation significance that are known from the broad region but were not observed in the Investigation Area by AARC during the aquatic ecology surveys are further detailed below. These species have been identified from wildlife database searches and scientific literature searches. Table 13 provides an assessment of the likelihood of these species utilising the Investigation Area.

Table 13 Threatened Species of the Project Region (identified by database search)

Scientific Name	Common Name	Conservation Status		Habitat	Notes/Likelihood of Presence on Site
		EPBC Act	NC Act		
Threatened Species					
Accipiter novaehollandiae	Grey Goshawk	NL	NT	This species prefers rainforests, forests, forested gullies and valleys, taller woodlands, timbered watercourses and may be found in open country during autumn dispersal (Pizzey and Knight, 2007).	Unlikely to occur on site as there is little suitable habitat available.
Ephippiorhynchus asiaticus	Black-necked Stork	NL	NT	Prefers open freshwater environments, including the margins of swamps, creeks and shallow floodwaters over grasslands (Pizzey and Knight, 2007).	Suitable habitat may exist temporally along the creeks of the site during flow events. Given the ephemeral nature of the creeks, they are unlikely to form important habitat for the species, and any impacts on the species are expected to be minimal.
Erythrotriorchis radiatus	Red Goshawk	V	E	Found over wooded and forested land with a mosaic of vegetation types in tropical and warm temperate climates in coastal and subcoastal areas (Marchant and Higgins, 1993).	Unlikely to occur on the site due to lack of suitable mosaic of habitat types. The site is also located outside the typical range of this species.
Erythrura gouldiae	Gouldian Finch	E	E	In Queensland the species occurs sparsely along the Gulf Coast and in the southern Cape York Peninsula. Grassy flats, trees near water, scrublands with spinifex. Breeds in savannah woodland on stony hills with Eucalypts over dense, tall native grasses (Pizzey and Knight, 2007).	Suitable habitat for this species exists on the site. Suitable habitat also occurs widely throughout the region in which the Project is located. The site is located outside the typical range of this species. It is unlikely that the Project will impact this species.

Scientific Name	Common Name	Conservation Status		Habitat	Notes/Likelihood of Presence on Site
		EPBC Act	NC Act		
Epthianura crocea crocea	Yellow Chat	NL	V	Occurs in the Lake Eyre and Gulf of Carpentaria drainage basins in inland Queensland. Inhabits low vegetation around the margins of ephemeral wetlands, floodplains, swamps, dams, salt lakes, clay pans, lagoons, sewage ponds and bore drains (Curtis et al., 2012).	Unlikely to occur on the site due to lack of suitable wetland habitat.
Falco hypoleucos	Grey Falcon	NL	NT	Inhabits plains, gibber deserts, sandridges, pastoral lands and timbered watercourses in inland Australia (Pizzey and Knight, 2007).	Suitable habitat for this species exists on site. It was not observed during the surveys. Given the mobility of this species it is unlikely to be impacted by Project development.
Grantiella picta	Painted Honeyeater	NL	V	Inhabits mistletoes in Acacia woodland, Eucalypt forests and woodlands, Black Box on watercourses, trees on farmland and gardens in eastern Australia (Pizzey and Knight, 2007).	A small amount of potentially suitable habitat for this species occurs on the waterways of the site. It was not observed during the surveys. Suitable habitat for this species will continue to exist on waterways in the undisturbed portions of the site and in the local area. No significant impact is expected.
Heteromunia pectoralis	Pictorella Mannikin	NL	NT	Tall grass in Acacia woodlands near water; grassy flats, spinifex, crops and sparsely wooded areas. Widely distributed in far north Australia and common in that area (Pizzey and Knight, 2007).	Suitable habitat for this species exists throughout the site and wider region. No individuals were observed during the surveys. It is possible that Pictorella Mannikins inhabit the site. No significant impact is expected on the species, as they are locally common and will continue to inhabit undisturbed portions of the site and the local area.

Scientific Name	Common Name	Conservation Status		Habitat	Notes/Likelihood of Presence on Site
		EPBC Act	NC Act		
Lophoictinia isura	Square-tailed Kite	NL	NT	Occurs mainly in open forests and woodlands, usually in coastal and subcoastal areas (Marchant and Higgins, 1993).	This species is widely distributed across mainland Australia and is known to inhabit timbered watercourses. There is some potentially suitable habitat for this species on the waterways of the site. Much of the suitable habitat for this species will be retained, and as it is a highly mobile species it is unlikely to be impacted by Project development.
Malurus coronatus	Purple-crowned Fairy-wren	NL	V	Primary habitat for the Purple-crowned Fairy-wren consists of river-fringing vegetation with a dense mid-storey and a high tree canopy, typically dominated by River Pandanus (*Pandanus aquaticus*) or Rivergrass (*Chionachne cyanthopoda*) beside permanent freshwater pools (Curtis et al., 2012).	The only potentially suitable habitat for this species is found at the waterhole at AQ8. However, AQ8 lacks the vegetation structure preferred by the Purple-crowned Fairy-wren. It is considered unlikely to occur in the Investigation Area.
Nettapus coromandelianus	Cotton Pygmy-goose	NL	NT	Occurs in eastern coastal Queensland, with some records from the Mount Isa region. This species occupies deeper freshwater swamps, lagoons and dams with semi-emergent aquatic plants (Pizzey and Knight, 2007).	Unlikely to occur on site due to the lack of suitable aquatic habitat.
Numenius madagascariensis	Eastern Curlew	Ma, Mi	NT	This species occupies estuaries, tidal mudflats, sandpits, salt marshes, mangroves, occasionally fresh or brackish lakes or bare grassland near water (Pizzey and Knight, 2007).	Unlikely to occur on site due to lack of suitable habitat.

Scientific Name	Common Name	Conservation Status		Habitat	Notes/Likelihood of Presence on Site
		EPBC Act	NC Act		
Pezoporus occidentalis	Night Parrot	E	E	Occurs in inland Austalia. Inhabits spinifex hummock grasslands on rocky ranges, breakaways or open herbaceous flats around salt lakes and occasionally Mitchell Grass (*Astrebla* spp.) downs and flats (Curtis et al., 2012). The Night Parrot drinks regularly at waterholes.	Suitable habitat exists on site and throughout the local region. This species could potentially occur on site. However, this species is extremely rare and the probability of its occurrence on site is low.
Poephila cincta cincta	Black-throated Finch (southern)	E	E	The southern subspecies inhabits open woodland, scrubby plains and Pandanus flats with deep cover of grasses. Its habitat is never far from water. It is known to occur south of Townsville, particularly around Townsville and Charters Towers (DoE, 2014).	The Black-throated Finch is not known from the local area. It is therefore unlikely to occur on site.
Pristis pristis	Freshwater Sawfish	V	NL	Juveniles and sub-adult Freshwater Sawfish predominantly occur in rivers and estuaries, while large mature animals tend to occur more often in coastal and offshore waters up to 25 m depth. In northern Australia, this species appears to be confined to freshwater drainages and the upper reaches of estuaries (DoE, 2014).	Highly unlikely to occur on site as there are no large permanent waterbodies present.
Elseya lavarackorum	Gulf Snapping Turtle	E	V	Currently known only from rivers and creeks draining into the Gulf of Carpentaria. Inhabits slow-flowing freshwater rivers and streams (Curtis et al., 2012).	Highly unlikely to occur on site as there are no permanent rivers or creeks present.

Scientific Name	Common Name	Conservation Status		Habitat	Notes/Likelihood of Presence on Site
		EPBC Act	NC Act		
Emydura subglobosa worrelli	Diamond Head Turtle	NL	NT	The Diamond Head Turtle inhabits larger rivers and permanent lakes and lagoons in the Gulf and Cape York regions (Cogger, 2000).	Highly unlikely to occur on site due to the absence of rivers and permanent lakes.
Stictonetta naevosa	Freckled Duck	NL	NT	In Queensland, this species is found in the south-east and south-west of the state. Occasional visitor to northern Queensland. Inhabits large, well-vegetated swamps (Pizzey and Knight, 2007).	Unlikely to occur on site due to lack of suitable habitat.
Rostratula australis	Australian Painted Snipe	E Mi Ma	V	This species inhabits shallow inland wetlands, either permanent or temporary, including palustrine wetlands (gilgais), billabongs and man-made dams throughout eastern and northern Australia (DoE, 2014).	Unlikely to occur on site due to lack of suitable wetland habitat.
Migratory Species					
Acrocephalus australis	Australian Reed-warbler	Ma, Mi	SL	Widespread throughout eastern Australia and coastal parts of western Australia. Inhabits aquatic vegetation over water, crops, bamboo, gardens and willows (Pizzey and Knight, 2007).	Unlikely to occur on site due to lack of suitable habitat.
Actitis hypoleucos	Common Sandpiper	Ma, Mi	SL	Edges of rivers and streams, dams, lakes, mangroves, mudflats, beaches and urban areas. Found from coastal to inland areas (Pizzey and Knight, 2007).	Unlikely to occur on site due to lack of suitable habitat.

Scientific Name	Common Name	Conservation Status		Habitat	Notes/Likelihood of Presence on Site
		EPBC Act	NC Act		
Anseranas semipalmata	Magpie Goose	Ma	NL	Inhabits northern Australia, including eastern Queensland and the northern ends of Western Australia and the Northern Territory. It occurs in rush and sedge-dominated swamps, as well as floodplains and rice crops (Simpson and Day, 2010).	Unlikely to occur on site due to lack of suitable habitat.
Apus pacificus	Fork-tailed Swift	Ma, Mi	SL	A migratory species that inhabits Australia in the summer months. Known to appear and forage for aerial insects over any habitat (Pizzey and Knight, 2007).	Species is strictly aerial when visiting Australia. May potentially occur over site. Development on site is unlikely to affect this species as it is strictly aerial remaining high above ground. Rarely if ever comes into contact with vegetation or land.
Ardea alba	Great Egret	Ma, Mi	SL	Common throughout Australia except in most arid areas. Known to prefer shallow water, particularly when flowing, but may be seen in any wetland area, including inundated grasslands (Pizzey and Knight, 2007).	Unlikely to occur on site due to lack of suitable habitat.
Ardea ibis	Cattle Egret	Ma, Mi	SL	Common throughout Australia except in the most arid areas. Prefers damp grasslands, particularly where cattle are abundant, but may be seen in any wetland area (Pizzey and Knight, 2007).	Unlikely to occur on site due to lack of suitable habitat.
Arenaria interpres	Ruddy Turnstone	Ma, Mi	SL	Occurs mostly in coastal areas. Prefers rocky shores or beaches (DoE, 2014).	Unlikely to occur on site, as it is a coastal species.

Scientific Name	Common Name	Conservation Status		Habitat	Notes/Likelihood of Presence on Site
		EPBC Act	NC Act		
Calidris acuminata	Sharp-tailed Sandpiper	Ma, Mi	SL	Lagoons, swamps, lakes and pools near the coast, and dams, waterholes, soaks, bore drains and bore swamps, saltpans and hypersaline saltlakes inland (DoE, 2014).	A very small amount of potentially suitable habitat for this species occurs in the waterholes of the site. Suitable habitat for this highly mobile species will remain in undisturbed areas of the site and in the local area. No significant impact is expected.
Calidris ferruginea	Curlew Sandpiper	Ma, Mi	SL	In Queensland, this species occurs mainly in coastal areas, with scattered inland records. Mainly occurs on intertidal mudflats in sheltered coastal areas, and also around non-tidal swamps, lakes and lagoons near the coast, saltworks and sewage farms. Inland they occur around ephemeral and permanent lakes, dams, waterholes and bore drains (DoE, 2014).	A very small amount of potentially suitable habitat for this species occurs in the waterholes of the site. Suitable habitat for this highly mobile species will remain in undisturbed areas of the site and in the local area. No significant impact is expected.
Calidris ruficollis	Red-necked Stint	Ma, Mi	SL	Recorded in all coastal regions, and found inland when conditions are suitable. Also inhabit saltworks and sewage farms, saltmarsh, and ephemeral or permanent shallow wetlands (including lagoons, lakes, swamps, riverbanks, waterholes, bore drains, dams, soaks and pools in saltflats) (DoE, 2014).	A very small amount of potentially suitable habitat for this species occurs in the creeks and waterholes of the site. Suitable habitat for this highly mobile species will remain in undisturbed areas of the site and in the local area. No significant impact is expected.
Calidris subminuta	Long-toed Stint	Ma, Mi	SL	Inhabits shallow freshwater or brackish wetlands including lakes, swamps, river floodplains, streams, lagoons and sewage ponds. The species is also found in areas of muddy shoreline and reservoirs (DoE, 2014).	Unlikely to occur on site due to lack of suitable habitat.

Scientific Name	Common Name	Conservation Status		Habitat	Notes/Likelihood of Presence on Site
		EPBC Act	NC Act		
Charadrius mongolus	Lesser Sand Plover	Ma, Mi	SL	Occurs mainly in coastal areas. Seldom recorded away from the coast, at margins of lakes, soaks and swamps associated with artesian bores (DoE, 2014).	Unlikely to occur on site due to lack of suitable habitat.
Charadrius ruficapillus	Red-capped Plover	Ma	NL	Occurs throughout Australia on beaches, saline wetlands and lakes, saltmarsh, mudflats, and occasionally in shallow freshwater wetlands (Pizzey and Knight, 2007).	Unlikely to occur on site due to lack of suitable habitat.
Charadrius veredus	Oriental Plover	Ma, Mi	SL	Migratory species that spends a few weeks in coastal areas before moving further inland. They usually inhabit flat, open, semi-arid or arid grasslands, where the grass is short and sparse, and interspersed with hard, bare ground, such as claypans, dry paddocks, playing fields, lawns and cattle camps, or open areas that have been recently burnt. At the onset of the wet season, some may move into lightly wooded grasslands (DoE, 2014).	There is little suitable habitat on site for this species. It is unlikely to occur on site.
Chlidonias leucopterus	White-winged Black Tern	Ma, Mi	SL	Non-breeding migrant to Australia, where it is widespread and common along south-western, northern and central-eastern coasts. Inhabits tidal wetlands, such as harbours, bays, estuaries and lagoons, and their associated tidal sandflats and mudflats. Also inhabits terrestrial wetlands, including swamps, lakes, billabongs, rivers, floodplains, reservoirs, saltworks, sewage ponds and outfalls (DoE, 2014).	Unlikely to occur on site due to lack of suitable habitat and its preference for coastal areas.

Scientific Name	Common Name	Conservation Status		Habitat	Notes/Likelihood of Presence on Site
		EPBC Act	NC Act		
Cuculus optatus	Oriental Cuckoo	Ma	SL	An uncommon regular migrant to coastal northern and eastern Australia. Inhabits monsoon forest, rainforest, river flats, roadsides, mangroves and islands (Pizzey and Knight, 2007).	Unlikely to occur on site due to lack of suitable habitat and its preference for coastal areas.
Gallinago hardwickii	Latham's Snipe	Ma, Mi	SL	A non-breeding visitor to south-eastern Australia, travelling through northern Australia to reach non-breeding areas located further south. They usually inhabit open, freshwater wetlands with low, dense vegetation (e.g. swamps, flooded grasslands or heathlands around bogs and other water bodies), as well as habitats with saline or brackish water, in modified or artificial habitats, and in habitats located close to humans or human activity (DoE, 2014).	Unlikely to occur on site due to lack of suitable habitat.
Gallinago megala	Swinhoe's Snipe	Ma, Mi	SL	There are few records of this species in Australia. Found in swamps, billabongs, river pools, small streams and sewage ponds (DoE, 2014).	A very small amount of potentially suitable habitat for this species occurs in the creeks and waterholes of the site. Suitable habitat for this highly mobile species will remain in undisturbed areas of the site and in the local area. No significant impact is expected.

Scientific Name	Common Name	Conservation Status		Habitat	Notes/Likelihood of Presence on Site
		EPBC Act	NC Act		
Glareola maldivarum	Oriental Pratincole	Ma, Mi	SL	Inhabits open plains, floodplains or short grassland (including farmland or airstrips), often with extensive bare areas. They often occur near terrestrial wetlands, such as billabongs, lakes or creeks, and artificial wetlands such as reservoirs, saltworks and sewage farms, especially around the margins. The species also occurs along the coast (DoE, 2014).	There is very little suitable habitat available on site for this species. It is unlikely to occur on site.
Haliaeetus leucogaster	White-bellied Sea-eagle	Ma, Mi	SL	Common throughout Australia except in the most arid areas. Prefers areas of permanent, deep or flowing water, where prey (fish and birds) is abundant (DoE, 2014).	Unlikely to occur on site due to lack of suitable habitat.
Himantopus himantopus	Black-winged Stilt	Ma	NL	Large inland waterbodies and estuarine or coastal habitats such as river deltas, coastal lagoons and shallow freshwater or brackish pools with extensive areas of mudflats, salt meadows, saltpans, coastal marshes and swamps (BirdLife International, 2012).	Unlikely to occur on site due to lack of suitable habitat.
Hirundo rustica	Barn Swallow	Ma, Mi	SL	Widespread in the northern hemisphere and winters in the southern hemisphere. Inhabits open country in coastal lowlands, often near water, towns and cities. Also in or over freshwater wetlands, paperbark Melaleuca woodland, mesophyll shrub thickets and tussock grassland (DoE, 2014).	Unlikely to occur on site due to lack of suitable habitat and its primarily coastal distribution.

Scientific Name	Common Name	Conservation Status		Habitat	Notes/Likelihood of Presence on Site
		EPBC Act	NC Act		
Hydroprogne caspia	Caspian Tern	Ma, Mi	SL	Widespread in coastal and inland habitat. Inhabits sheltered coastal embayments (harbours, lagoons, inlets, bays, estuaries and river deltas), near-coastal or inland terrestrial wetlands, especially lakes, waterholes, reservoirs, rivers and creeks. They also use artificial wetlands, including reservoirs, sewage ponds and saltworks (DoE, 2014).	A very small amount of potentially suitable habitat for this species occurs in the creeks and waterholes of the site. Suitable habitat for this highly mobile species will remain in undisturbed areas of the site and in the local area. No significant impact is expected.
Limosa lapponica	Bar-tailed Godwit	Ma, Mi	SL	Widespread in coastal areas, with regular inland movements. Inhabits intertidal sandflats, banks, mudflats, estuaries, inlets, harbours, coastal lagoons and bays, sewage farms, saltworks, saltlakes and brackish wetlands near coasts, sandy ocean beaches, rock platforms and coral reef-flats. Occasionally inhabits inland wetlands or areas of short grass, such as farmland, paddocks and airstrips (DoE, 2014).	Unlikely to occur on site due to lack of suitable habitat.
Limosa limosa	Black-tailed Godwit	Ma, Mi	SL	Found in coastal areas throughout Australia. There are a few inland records, from shallow lakes, swamps, dams and bore-overflows (DoE, 2014).	Unlikely to occur on site due to lack of suitable habitat.
Numenius minutus	Little Curlew	Ma, Mi	SL	Widespread in coastal regions of northern Australia. Found in grasslands, floodplains, mudflats, fields and sewage ponds (Pizzey and Knight, 2007).	Unlikely to occur on site, as it is a coastal species and little suitable habitat occurs on the site.

Scientific Name	Common Name	Conservation Status		Habitat	Notes/Likelihood of Presence on Site
		EPBC Act	NC Act		
Numenius phaeopus	Whimbrel	Ma, Mi	SL	Found mainly in coastal regions throughout Australia. It is often found on the intertidal mudflats of sheltered coasts. There are a small number of inland records from saline lakes and canegrass swamps (DoE, 2014).	Unlikely to occur on site due to lack of suitable habitat.
Pandion cristatus	Eastern Osprey	Ma, Mi	SL	This cosmopolitan species is found in coastal areas. It inhabits a range of coastal habitats and larger river systems (DoE, 2014).	Unlikely to occur on site, as it is a coastal species and there is no suitable habitat on the site.
Phalaropus lobatus	Red-necked Phalarope	Ma, Mi	SL	Irregular summer migrant to Australia. Inhabits shallow pools, saltfields, mudflats, beaches, saltmarsh and wetlands (Pizzey and Knight, 2007).	Unlikely to occur on site due to lack of suitable habitat.
Plegadis falcinellus	Glossy Ibis	Ma, Mi	SL	Widespread throughout northern and eastern Australia. Inhabits fresh water marshes at the edges of lakes and rivers, lagoons, floodplains, wet meadows, swamps, reservoirs, sewage ponds, rice-fields and cultivated areas under irrigation. Occasionally found in coastal locations such as estuaries, deltas, saltmarshes and coastal lagoons (DoE, 2014).	Unlikely to occur on site due to lack of suitable habitat.
Pluvialis fulva	Pacific Golden Plover	Ma, Mi	SL	Widespread in coastal areas of Australia. Inland it is known from major river systems and wetlands (DoE, 2014).	Unlikely to occur on site due to lack of suitable habitat.
Recurvirostra novaehollandiae	Red-necked Avocet	Ma	NL	Occurs in estuaries, mudflats, swamps, lakes, claypans and sewage ponds across much of Australia (Pizzey and Knight, 2007).	Unlikely to occur on site due to lack of suitable habitat.

Scientific Name	Common Name	Conservation Status		Habitat	Notes/Likelihood of Presence on Site
		EPBC Act	NC Act		
Stiltia isabella	Australian Pratincole	Ma	NL	Inhabits northern and inland Australia. Found near water on plains, claypans, swamp margins and sparse stony shrubland (Pizzey and Knight, 2007).	Unlikely to occur on site due to lack of suitable habitat.
Tringa glareola	Wood Sandpiper	Ma, Mi	SL	Found mainly in north-western Australia, with scattered records elsewhere. Inhabits swamps, billabongs, lakes, pools and waterholes (DoE, 2014).	A very small amount of potentially suitable habitat for this species occurs in the waterholes of the site. Suitable habitat for this highly mobile species will remain in undisturbed areas of the site and in the local area. No significant impact is expected.
Tringa nebularia	Common Greenshank	Ma, Mi	SL	Found in a range of coastal and inland wetland habitat throughout Australia (DoE, 2014).	Unlikely to occur on site due to lack of suitable wetland habitat.
Tringa stagnatilis	Marsh Sandpiper	Ma, Mi	SL	Inhabits coastal and inland wetlands throughout Australia (DoE, 2014).	Unlikely to occur on site due to lack of suitable wetland habitat.
Xenus cinereus	Terek Sandpiper	Ma, Mi	SL	Found in coastal areas throughout Australia. Inhabits mudflats, estuaries, islands and coastal swamps (Pizzey and Knight, 2007).	Unlikely to occur on site, as it is a coastal species.
Crocodylus johnstoni	Freshwater Crocodile	Ma	NL	Freshwater rivers, creeks and billabongs in northern Australia (Wilson, 2005).	Unlikely to occur on site due to lack of permanent rivers, creeks and billabongs.

E – Endangered
V – Vulnerable
NL – Not listed
NT – Near Threatened
Mi – Migratory
Ma – Marine
SL – Special Least Concern

5.7.8 Declared Pests

No declared pest species were observed in the aquatic areas of the Investigation Area during the surveys. The scats and tracks of the Feral Pig (*Sus scrofa*) and Wild Dog (*Canis familiaris*), both Class 2 declared pest species under the LP Act, were noted at several of the survey sites. Landholders are responsible for the control of Class 2 pests on their land.

Feral Pigs are omnivores, which feed on a range of native flora and fauna. Their feeding and bathing behaviour promotes erosion, bed degradation and weed spread in riparian areas. Feral Pigs can also pose a risk to human health, as they carry a range of diseases.

Wild Dogs prey on native fauna and livestock and compete with native predators such as quolls and raptors. Wild Dogs pose a risk to human health and safety.

The non-declared Cane Toad (*Rhinella marina*) was heard calling in several areas of the Project site and observed at AQ1 in the dry season. Canes Toads are highly toxic aquatic pests that feed on a variety of small native wildlife and may also compete with native frog species.

Control measures for these three pest species are outlined in Section 6.2.

6.0 CONCLUSIONS, IMPACTS AND RECOMMENDATIONS

The aquatic ecology surveys identified a range of environmental values for the waterways of the Investigation Area:

- Habitat for a range of flora and fauna species, including two threatened species;
- Areas of RE 1.3.7b, which has a Biodiversity Status of Endangered and is a Category B ESA;
- Semi-permanent and permanent waterholes;
- Drinking water for a range of terrestrial animals;
- Dry season refugia for a range of terrestrial animals;
- Nesting and roosting habitat for bird and bat species;
- Breeding habitat for a small number of amphibian species; and
- Habitat for macroinvertebrates and a small number of fish and crustacean species.

Many of these values are located primarily in areas outside the Project disturbance footprint. The Project will impact on only a small portion of the riparian habitat located in the Investigation Area.

The waterhole at AQ8 is the most significant aquatic habitat in the Investigation Area. It is the largest and deepest waterhole and is likely to be permanent. It is an important dry season and drought refuge for the fauna of the Investigation Area. AQ8 is located outside the Project disturbance footprint and outside the catchment in which Project activities will be conducted. It is therefore unlikely that the Project will impact on the environmental values of this site.

The AUSRIVAS habitat assessment found that all survey sites provided moderate to good aquatic habitat. Some areas of erosion and impacts from cattle grazing were observed at the survey sites.

Stream sediments were found to contain a high proportion of coarse particles (i.e. gravel and sand). Metal concentrations in stream sediment were generally low. Copper and nickel levels above the low ISQG were recorded at a small number of sites. All results fell below the high ISQG.

Water quality at the survey sites was generally poor. Results for pH, conductivity, DO, total nitrogen, total phosphorus, copper and aluminium exceeded the applicable guideline levels at many sites. These results are reflective of the stagnant, ephemeral nature of the waterbodies sampled and natural mineralisation in the area.

Macroinvertebrate diversity, abundance and PET richness were generally low. SIGNAL scores were correspondingly low, but were consistent with the expected results for ephemeral streams. The majority of sites fell within Quadrant 3 of the SIGNAL biplot, indicating poor habitat and water quality for macroinvertebrates in the ephemeral creeks of the Investigation Area.

The riparian areas of the Investigation Area were found to provide habitat for 153 species of plants and 67 species of animals. Two threatened fauna species, one Migratory species, five Marine species, 13 weed species and four introduced fauna species were recorded. Areas of RE 1.3.7b (River Red Gum woodland on channels and levees) were recorded along many of the waterways in the Investigation Area.

Aquatic fauna diversity and abundance were found to be low. This is thought to be due to the Project's location in the upper reaches of the catchment and the highly ephemeral nature of the Project waterways.

6.1 POTENTIAL IMPACTS

A total of approximately 6.5 ha of riparian vegetation will be removed as part of Project development. Clearing of riparian vegetation may lead to injury or mortality of resident fauna. Clearing of riparian vegetation will also remove a small portion of potential habitat for the Golden-backed Honeyeater. Impacts on the Golden-backed Honeyeater are discussed in detail in the Barbara Copper Project Terrestrial Flora and Fauna Assessment (AARC, 2014).

A small portion (approximately 1.8 ha) of the riparian vegetation to be removed to construct the new access road is classified as RE 1.3.7b (River Red Gum Riparian Woodland), which has a Biodiversity Status of Endangered. Clearing of this vegetation will lead to a small reduction in the extent and connectivity of this vegetation community. Currently there is approximately 75 ha of this vegetation community within the Investigation Area.

The removal of vegetation from the Project Area will expose large areas of topsoil, which if improperly managed may be eroded and washed into surface waters, causing increased turbidity and suspended solids levels as well as siltation of creek channels. Changes in water quality may impact aquatic biota.

Development of the north pit will require the diversion of a small first-order drainage feature around the western edge of the pit. Construction of the diversion will alter stream morphology and hydrology, and could potentially result in accelerated erosion and decreased water quality in the waterway. These potential impacts are unlikely to be significant, as this minor drainage feature does not hold water, and flows only after prolonged heavy rainfall, which occurs infrequently in the Project Area.

Construction of the Project haul roads and access road will require the establishment of creek crossings in both first-order drainage features and the larger third-order drainage feature in the southern part of the Investigation Area. Construction and usage of creek crossings may lead to impacts such as vegetation clearing and fragmentation, erosion and siltation, with associated impacts on aquatic biota.

The Project will generate stormwater runoff and site waste water. This contaminated water could potentially enter site waterways if not managed effectively, with potential to cause harm to aquatic fauna and flora.

The Project Area is located approximately 17 km upstream of Lake Julius. Lake Julius is a lacustrine wetland and water source for the city of Mount Isa. There is the potential for sediment, stormwater runoff, sewage, waterborne pollutants (such as hydrocarbons) and mine affected water (which is acidic, saline and contains sulphides and metals) from the Project Area to enter Lake Julius in extreme climatic conditions if not effectively managed, particularly in the wet season. It should be noted that any discharges made due to extreme weather will be diluted by the large amounts of uncontaminated rainwater runoff present in the catchment.

Construction and operation activities will require the storage, handling and use of minimal hazardous substances (i.e. diesel, oil, grease), which have potential to be released into waterways by spill or overflow, with adverse impacts on the health of aquatic fauna and flora.

The development of the Project will increase the amount of open area, tracks, water sources and waste on the Project Area. This may improve the suitability of the Project Area for weed and pest species, which are known to thrive in these conditions. Increased vehicle movement in the Project

Area also poses a risk of spreading weeds and introducing new weed species into the Project Area. This could result in an increase in weed abundance in riparian areas, with a consequent reduction in the integrity of riparian communities.

Measures to manage and mitigate these potential impacts are discussed below.

6.2 RECOMMENDED MITIGATION AND MANAGEMENT MEASURES

The Project layout has been designed to avoid riparian areas and areas of RE 1.3.7b where allowable by topographical constraints. The layout minimises clearing of riparian vegetation to the smallest practical extent.

At the end of project life, cleared areas should be revegetated and rehabilitated. In order to restore the existing regional ecosystems, rehabilitation works should utilise those species found in the relevant communities (refer to Appendix D). Native grass species are recommended for use in rehabilitation. Topsoil from disturbed areas should be stockpiled for use in the rehabilitation works.

Clearing of riparian vegetation should be conducted in a staged manner, to allow fauna to migrate to adjacent habitat areas, with minimal fragmentation of existing habitat and the preservation of existing vegetation corridors where possible. All large trees should be inspected for fauna prior to removal (particularly hollows). If animals are detected then clearing must cease until they move on or are relocated by an experienced spotter-catcher. Trees with hollows should be lowered gently to the ground with the hollows facing up to minimise risk of fauna injury. Hollow bearing trees or tree sections with hollows should be placed outside the disturbance area and adjacent to creeks. Any Golden-backed Honeyeater nests encountered during site clearing works should not be disturbed. Detailed mitigation measures for Project impacts on the Golden-backed Honeyeater are provided in the Barbara Copper Project Terrestrial Flora and Fauna Assessment (AARC, 2014).

A vehicle washdown bay should be installed on site and used by all vehicles that have come into contact with weeds. A Weed Management Plan should be developed to limit the spread of weed species on the Project Area. Staff should be informed of the species of weed likely to be encountered on the Project Area, the location of known weed infestations, and how to report the presence of new infestations as part of the site induction. The Weed Management Plan should include a weed control program. Weed control should focus on Mimosa Bush, Rubber Vine and any new weed species that are detected in riparian areas.

Two Class 2 pests, the Feral Pig and Wild Dog, are known to be present in the Project Area. Landowners are expected to take reasonable steps to keep land free from Class 2 pests. It is recommended that a Pest Management Plan be developed to reduce pig and dog numbers in the Project Area and prevent the introduction of other Class 2 pests into the Project Area. Control strategies outlined in the Pest Management Plan should be in-line with the local shire council pest control strategies, and the strategies suggested within the Pest Fact Sheets in Appendix G. Recommended pest control strategies are outlined briefly below.

The Queensland Government recommends 1080 (sodium monofluroacetate) baiting as the most economic and effective method for controlling feral predator species (DAFF, 2012; State of Queensland, 2013). Baits should be buried to prevent consumption by non-target species. Ideally the baiting program should be conducted in the dry season and target watering points. Poisoned grain is the recommended bait for Feral Pigs. Pigs should be pre-fed with unpoisoned bait before commencement of baiting. Fresh meat baits should be used to target dogs. Any pest animals that survive the baiting program can then be targeted by a trapping and/or shooting program (State of Queensland, 2013). Detailed information on pest management is provided in Appendix G.

Once construction of the Project commences, erosion and sediment controls (such as hessian fences, ground-cover mats or blankets and sand-bags) should be installed to prevent sediment deposition in waterways and associated water and sediment quality impacts. Clean water should be diverted around disturbed areas to prevent pollution and maintain natural flows.

Chemicals and hazardous substances used during construction and operation should be stored in sealed, bunded areas in accordance with the Material Safety Data Sheet and applicable Australian Standards. A Spill Emergency Response Procedure should be developed to outline the response to any chemical spills. Spills must be promptly contained and cleaned up as they have the potential to contaminate surface water, leading to adverse impacts on aquatic flora and fauna. EHP must be informed of any spills into waterways.

Waterway crossings should be designed to minimise erosion potential and avoid the impediment of natural flows. The materials used in construction of the crossings should be resistant to erosion, to prevent materials being washed away and deposited downstream. Disturbance of the bed and banks of watercourses should be avoided wherever possible.

The creek diversion should be designed to mimic the hydrology of the existing channel. Diversion works should be conducted in the dry season to minimise impacts on water quality. The diversion will be designed to allow natural flows back into the creek at a downstream location of the watercourse. The banks of the engineered diversion channel should be planted with native flora species from the Project region. Planting of trees should ensure that the integrity of the engineered channel is not compromised.

A segment of the Staff Induction Program should be allocated to informing staff of the Spill Emergency Response Procedure, vegetation clearing requirements, correct chemical handling and storage procedures and Pest and Weed Management Plans. Staff should also be trained in the appearance and basic ecology of the Purple-necked Rock-wallaby and Golden-backed Honeyeater and reporting requirements for sightings of these species.

6.3 ENVIRONMENTAL MONITORING

It is recommended that water and sediment quality monitoring should be continued at the survey sites to gather additional baseline data, capture natural variability and confirm the findings of the initial monitoring. It is recommended that site-specific guidelines be developed for those parameters that consistently failed to comply with the applicable guidelines (i.e. pH, conductivity, DO, copper, aluminium, nutrients).

A Receiving Environment Monitoring Program (REMP) should be developed and implemented for the Project. The REMP should include monitoring of upstream and downstream sites for water quality, sediment quality, macroinvertebrates, erosion and vegetation diversity and condition. Monitoring of the receiving environment will allow the detection of any impacts on waterways downstream of the Project Area.

6.4 ENVIRONMENTAL OFFSET REQUIREMENTS

The Queensland Environmental Offsets Policy requires environmental offsets to be delivered where a prescribed activity will create significant residual impacts on particular matters of National, State or Local environmental significance (referred to as prescribed environmental matters). The prescribed environmental matters relevant to the Project are threatened species habitat (discussed in the AARC Terrestrial Flora and Fauna Assessment, 2014) and remnant regional ecosystems intersecting waterways shown on the Vegetation Management Watercourse Map. The potential for offsetting remnant regional ecosystems intersecting waterways is currently being investigated further.

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Appendix A Database Search Results

Australian Government

Department of the Environment

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

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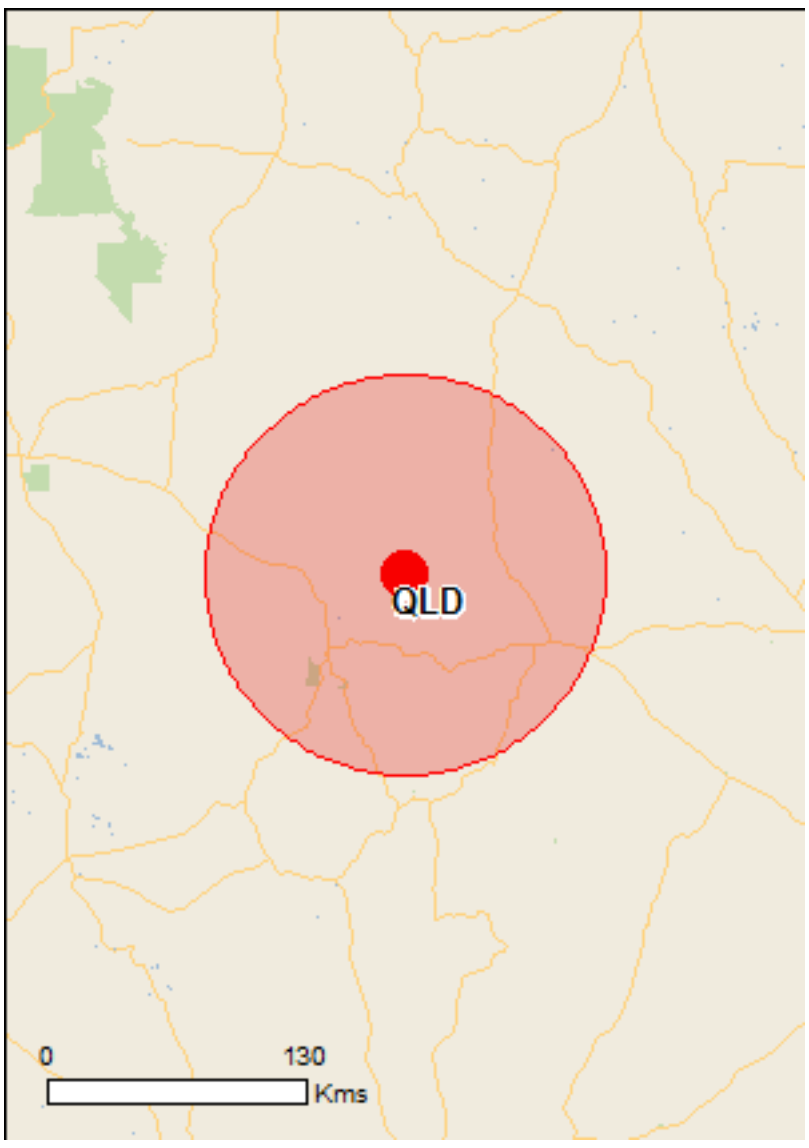
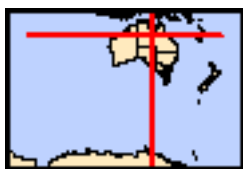
- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates

Buffer: 100.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Areas:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	10
Listed Migratory Species:	19

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place and the heritage values of a place on the Register of the National Estate.

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	1
Commonwealth Heritage Places:	None
Listed Marine Species:	26
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

Place on the RNE:	11
State and Territory Reserves:	1
Regional Forest Agreements:	None
Invasive Species:	27
Nationally Important Wetlands:	2
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Birds		
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat may occur within area
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat known to occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat likely to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Mammals		
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat likely to occur within area
Pseudantechinus mimulus Carpentarian Antechinus [59283]	Vulnerable	Species or species habitat known to occur within area
Sminthopsis douglasi Julia Creek Dunnart [305]	Endangered	Species or species habitat may occur within area
Reptiles		
Acanthophis hawkei Plains Death Adder [83821]	Vulnerable	Species or species habitat known to occur within area
Elseya lavarackorum Gulf Snapping Turtle [67197]	Endangered	Species or species habitat known to occur

Name	Status	Type of Presence within area
Sharks		
Pristis pristis Largetooth Sawfish, Freshwater Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat likely to occur within area

Listed Migratory Species

[Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Migratory Wetlands Species		
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]		Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat known to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Species or species habitat known to occur within area
Numenius phaeopus Whimbrel [849]		Species or species habitat known to occur

Name	Threatened	Type of Presence
		within area
Pluvialis fulva Pacific Golden Plover [25545]		Species or species habitat known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat likely to occur within area
Tringa glareola Wood Sandpiper [829]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Species or species habitat known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Defence - MT ISA TRAINING DEPOT

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]		Species or species habitat known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Species or species habitat known to occur

Name	Threatened	Type of Presence
		within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat known to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat known to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Himantopus himantopus Black-winged Stilt [870]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Species or species habitat known to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Species or species habitat known to occur within area
Numenius phaeopus Whimbrel [849]		Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Species or species habitat known to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Species or species habitat known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat likely to occur within area
Stiltia isabella Australian Pratincole [818]		Species or species habitat known to occur within area
Tringa glareola Wood Sandpiper [829]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Species or species habitat known to occur within area
Reptiles		
Crocodylus johnstoni Freshwater Crocodile, Johnston's Crocodile, Johnston's River Crocodile [1773]		Species or species habitat may occur within area

Extra Information

Places on the RNE [Resource Information]

Note that not all Indigenous sites may be listed.

Name	State	Status
Natural		
Fountain Range	QLD	Registered
Indigenous		
Battle Mountain	QLD	Indicative Place
Frank Creek Site	QLD	Indicative Place
Little Brumby Creek Site	QLD	Indicative Place
Bower Bird Area	QLD	Registered
Lake Moondarra Quarry 1 Area	QLD	Registered
The Granites Area	QLD	Registered
Historic		
Casa Grande	QLD	Indicative Place
Mount Isa Underground Hospital	QLD	Indicative Place
Cloncurry Courthouse	QLD	Registered
Tent House	QLD	Registered

State and Territory Reserves [Resource Information]

Name	State
Bullen Bullen	QLD

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Frogs		
Bufo marinus Cane Toad [1772]		Species or species habitat likely to occur within area
Rhinella marina Cane Toad [83218]		Species or species habitat likely to occur within area
Mammals		

Name	Status	Type of Presence
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Camelus dromedarius Dromedary, Camel [7]		Species or species habitat likely to occur within area
Equus caballus Horse [5]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Acacia nilotica subsp. indica Prickly Acacia [6196]		Species or species habitat may occur within area
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
Cryptostegia grandiflora Rubber Vine, Rubbervine, India Rubber Vine, India Rubbervine, Palay Rubbervine, Purple Allamanda [18913]		Species or species habitat likely to occur within area
Cylindropuntia spp. Prickly Pears [85131]		Species or species habitat likely to occur within area
Eichhornia crassipes Water Hyacinth, Water Orchid, Nile Lily [13466]		Species or species habitat likely to occur within area
Jatropha gossypifolia Cotton-leaved Physic-Nut, Bellyache Bush, Cotton-leaf Physic Nut, Cotton-leaf Jatropha, Black Physic Nut [7507]		Species or species habitat likely to occur within area
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Parkinsonia aculeata Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Parthenium hysterophorus Parthenium Weed, Bitter Weed, Carrot Grass, False Ragweed [19566]		Species or species habitat likely to occur

Name	Status	Type of Presence
		within area
Prosopis spp. Mesquite, Algaroba [68407]		Species or species habitat likely to occur within area
Salvinia molesta Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area
Tamarix aphylla Athel Pine, Athel Tree, Tamarisk, Athel Tamarisk, Athel Tamarix, Desert Tamarisk, Flowering Cypress, Salt Cedar [16018]		Species or species habitat likely to occur within area
Vachellia nilotica Prickly Acacia, Blackthorn, Prickly Mimosa, Black Piquant, Babul [84351]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus Asian House Gecko [1708]		Species or species habitat likely to occur within area

Nationally Important Wetlands [Resource Information]

Name	State
Lake Julius	QLD
Lake Moondarra	QLD

Coordinates

-20.4224 139.83871

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World Heritage and Register of National Estate properties, Wetlands of International Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Department of Environment, Climate Change and Water, New South Wales
-Department of Sustainability and Environment, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment and Natural Resources, South Australia
-Parks and Wildlife Service NT, NT Dept of Natural Resources, Environment and the Arts
-Environmental and Resource Management, Queensland
-Department of Environment and Conservation, Western Australia
-Department of the Environment, Climate Change, Energy and Water
-Birds Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-SA Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Atherton and Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
-State Forests of NSW
-Geoscience Australia
-CSIRO
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Queensland Government

Wildlife Online Extract

Search Criteria:	Species List for a Defined Area
	Species: All
	Type: All
	Status: All
	Records: All
	Date: All
	Latitude: 19.7941 to 20.4224
	Longitude: 140.4997 to 139.8386
	Email: hdick@aarc.net.au
	Date submitted: Tuesday 17 Jun 2014 16:13:00
	Date extracted: Tuesday 17 Jun 2014 16:20:03

The number of records retrieved = 435

Disclaimer

As the DSITIA is still in a process of collating and vetting data, it is possible the information given is not complete. The information provided should only be used for the project for which it was requested and it should be appropriately acknowledged as being derived from Wildlife Online when it is used.

The State of Queensland does not invite reliance upon, nor accept responsibility for this information. Persons should satisfy themselves through independent means as to the accuracy and completeness of this information.

No statements, representations or warranties are made about the accuracy or completeness of this information. The State of Queensland disclaims all responsibility for this information and all liability (including without limitation, liability in negligence) for all expenses, losses, damages and costs you may incur as a result of the information being inaccurate or incomplete in any way for any reason.

Feedback about Wildlife Online should be emailed to wildlife.online@science.dsitia.qld.gov.au

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	amphibians	Bufonidae	*Rhinella marina*	cane toad	Y			2
animals	amphibians	Hylidae	*Litoria inermis*	bumpy rocketfrog		C		3
animals	amphibians	Hylidae	*Litoria pallida*	pallid rocketfrog		C		3
animals	amphibians	Hylidae	*Litoria caerulea*	common green treefrog		C		6
animals	amphibians	Hylidae	*Cyclorana australis*	northern snapping frog		C		7
animals	amphibians	Hylidae	*Litoria rothii*	northern laughing treefrog		C		2
animals	amphibians	Hylidae	*Litoria rubella*	ruddy treefrog		C		6
animals	amphibians	Limnodynastidae	*Platyplectrum ornatum*	ornate burrowing frog		C		3
animals	birds	Acanthizidae	*Acanthiza chrysorrhoa*	yellow-rumped thornbill		C		5
animals	birds	Acanthizidae	*Gerygone fusca*	western gerygone		C		3
animals	birds	Acanthizidae	*Smicrornis brevirostris*	weebill		C		87
animals	birds	Accipitridae	*Aquila audax*	wedge-tailed eagle		C		10
animals	birds	Accipitridae	*Circus assimilis*	spotted harrier		C		3
animals	birds	Accipitridae	*Hamirostra melanosternon*	black-breasted buzzard		C		7
animals	birds	Accipitridae	*Accipiter cirrocephalus*	collared sparrowhawk		C		6
animals	birds	Accipitridae	*Milvus migrans*	black kite		C		37
animals	birds	Accipitridae	*Accipiter fasciatus*	brown goshawk		C		9
animals	birds	Accipitridae	*Haliastur sphenurus*	whistling kite		C		27
animals	birds	Accipitridae	*Haliaeetus leucogaster*	white-bellied sea-eagle		SL		4
animals	birds	Aegothelidae	*Aegotheles cristatus*	Australian owlet-nightjar		C		11
animals	birds	Alaudidae	*Mirafra javanica*	Horsfield's bushlark		C		1
animals	birds	Alcedinidae	*Ceyx azureus*	azure kingfisher		C		2
animals	birds	Anatidae	*Malacorhynchus membranaceus*	pink-eared duck		C		3
animals	birds	Anatidae	*Dendrocygna eytoni*	plumed whistling-duck		C		4
animals	birds	Anatidae	*Anas superciliosa*	Pacific black duck		C		3
animals	birds	Anatidae	*Aythya australis*	hardhead		C		3
animals	birds	Anatidae	*Anas gracilis*	grey teal		C		3
animals	birds	Anatidae	*Nettapus coromandelianus*	cotton pygmy-goose		NT		1
animals	birds	Anhingidae	*Anhinga novaehollandiae*	Australasian darter		C		14
animals	birds	Ardeidae	*Egretta novaehollandiae*	white-faced heron		C		15
animals	birds	Ardeidae	*Nycticorax caledonicus*	Nankeen night-heron		C		7
animals	birds	Ardeidae	*Ixobrychus flavicollis*	black bittern		C		5
animals	birds	Ardeidae	*Egretta garzetta*	little egret		C		2
animals	birds	Ardeidae	*Ardea intermedia*	intermediate egret		C		3
animals	birds	Ardeidae	*Ardea pacifica*	white-necked heron		C		16
animals	birds	Ardeidae	*Ardea modesta*	eastern great egret		SL		10
animals	birds	Artamidae	*Cracticus nigrogularis*	pied butcherbird		C		29
animals	birds	Artamidae	*Artamus superciliosus*	white-browed woodswallow		C		2
animals	birds	Artamidae	*Artamus leucorynchus*	white-breasted woodswallow		C		8
animals	birds	Artamidae	*Cracticus torquatus*	grey butcherbird		C		1
animals	birds	Artamidae	*Artamus personatus*	masked woodswallow		C		4
animals	birds	Artamidae	*Cracticus tibicen*	Australian magpie		C		12
animals	birds	Artamidae	*Artamus cinereus*	black-faced woodswallow		C		33
animals	birds	Artamidae	*Artamus minor*	little woodswallow		C		15
animals	birds	Burhinidae	*Burhinus grallarius*	bush stone-curlew		C		10
animals	birds	Cacatuidae	*Calyptorhynchus banksii*	red-tailed black-cockatoo		C		3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Cacatuidae	*Eolophus roseicapillus*	galah		C		24
animals	birds	Cacatuidae	*Nymphicus hollandicus*	cockatiel		C		31
animals	birds	Cacatuidae	*Cacatua galerita*	sulphur-crested cockatoo		C		25
animals	birds	Cacatuidae	*Cacatua sanguinea*	little corella		C		8
animals	birds	Campephagidae	*Coracina novaehollandiae*	black-faced cuckoo-shrike		C		23
animals	birds	Campephagidae	*Coracina papuensis*	white-bellied cuckoo-shrike		C		5
animals	birds	Campephagidae	*Lalage sueurii*	white-winged triller		C		11
animals	birds	Campephagidae	*Coracina maxima*	ground cuckoo-shrike		C		2
animals	birds	Casuariidae	*Dromaius novaehollandiae*	emu		C		2
animals	birds	Charadriidae	*Elseyornis melanops*	black-fronted dotterel		C		19
animals	birds	Charadriidae	*Vanellus miles*	masked lapwing		C		4
animals	birds	Charadriidae	*Vanellus miles miles*	masked lapwing (northern subspecies)		C		7
animals	birds	Ciconiidae	*Ephippiorhynchus asiaticus*	black-necked stork		NT		5
animals	birds	Climacteridae	*Climacteris melanura*	black-tailed treecreeper		C		16
animals	birds	Columbidae	*Geophaps plumifera*	spinifex pigeon		C		22
animals	birds	Columbidae	*Geopelia humeralis*	bar-shouldered dove		C		9
animals	birds	Columbidae	*Phaps chalcoptera*	common bronzewing		C		16
animals	birds	Columbidae	*Ocyphaps lophotes*	crested pigeon		C		20
animals	birds	Columbidae	*Geopelia striata*	peaceful dove		C		45
animals	birds	Columbidae	*Geopelia cuneata*	diamond dove		C		22
animals	birds	Coraciidae	*Eurystomus orientalis*	dollarbird		C		6
animals	birds	Corcoracidae	*Struthidea cinerea*	apostlebird		C		24
animals	birds	Corvidae	*Corvus orru*	Torresian crow		C		10
animals	birds	Corvidae	*Corvus coronoides*	Australian raven		C		34
animals	birds	Corvidae	*Corvus sp.*					12
animals	birds	Cuculidae	*Cacomantis variolosus*	brush cuckoo		C		3
animals	birds	Cuculidae	*Eudynamys orientalis*	eastern koel		C		4
animals	birds	Cuculidae	*Centropus phasianinus*	pheasant coucal		C		2
animals	birds	Cuculidae	*Scythrops novaehollandiae*	channel-billed cuckoo		C		3
animals	birds	Cuculidae	*Chalcites basalis*	Horsfield's bronze-cuckoo		C		2
animals	birds	Cuculidae	*Cacomantis pallidus*	pallid cuckoo		C		1
animals	birds	Cuculidae	*Chalcites osculans*	black-eared cuckoo		C		1
animals	birds	Estrildidae	*Poephila acuticauda*	long-tailed finch		C		16
animals	birds	Estrildidae	*Emblema pictum*	painted finch		C		2
animals	birds	Estrildidae	*Taeniopygia bichenovii*	double-barred finch		C		18
animals	birds	Estrildidae	*Taeniopygia guttata*	zebra finch		C		47
animals	birds	Estrildidae	*Heteromunia pectoralis*	pictorella mannikin		NT		2
animals	birds	Eurostopodidae	*Eurostopodus argus*	spotted nightjar		C		8/1
animals	birds	Falconidae	*Falco hypoleucos*	grey falcon		NT		1
animals	birds	Falconidae	*Falco cenchroides*	Nankeen kestrel		C		8
animals	birds	Falconidae	*Falco subniger*	black falcon		C		1
animals	birds	Falconidae	*Falco berigora*	brown falcon		C		9
animals	birds	Falconidae	*Falco longipennis*	Australian hobby		C		8
animals	birds	Gruidae	*Grus rubicunda*	brolga		C		10
animals	birds	Halcyonidae	*Dacelo leachii*	blue-winged kookaburra		C		28
animals	birds	Halcyonidae	*Todiramphus sanctus*	sacred kingfisher		C		8

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Halcyonidae	*Todiramphus pyrrhopygius*	red-backed kingfisher		C		8
animals	birds	Hirundinidae	*Petrochelidon ariel*	fairy martin		C		9
animals	birds	Laridae	*Chlidonias hybrida*	whiskered tern		C		1
animals	birds	Maluridae	*Malurus lamberti*	variegated fairy-wren		C		27/1
animals	birds	Maluridae	*Amytornis ballarae*	Kalkadoon grasswren		C		8
animals	birds	Maluridae	*Malurus coronatus*	purple-crowned fairy-wren		V		2/2
animals	birds	Maluridae	*Malurus melanocephalus*	red-backed fairy-wren		C		8/1
animals	birds	Megaluridae	*Cincloramphus mathewsi*	rufous songlark		C		6
animals	birds	Megaluridae	*Cincloramphus cruralis*	brown songlark		C		2
animals	birds	Megaluridae	*Eremiornis carteri*	spinifexbird		C		4
animals	birds	Meliphagidae	*Philemon citreogularis*	little friarbird		C		31
animals	birds	Meliphagidae	*Ptilotula penicillatus*	white-plumed honeyeater		C		42/1
animals	birds	Meliphagidae	*Conopophila rufogularis*	rufous-throated honeyeater		C		25
animals	birds	Meliphagidae	*Acanthagenys rufogularis*	spiny-cheeked honeyeater		C		3
animals	birds	Meliphagidae	*Melithreptus brevirostris*	brown-headed honeyeater		C		1
animals	birds	Meliphagidae	*Melithreptus gularis laetior*	golden-backed honeyeater		NT		1
animals	birds	Meliphagidae	*Sugomel niger*	black honeyeater		C		1
animals	birds	Meliphagidae	*Entomyzon cyanotis*	blue-faced honeyeater		C		1
animals	birds	Meliphagidae	*Manorina flavigula*	yellow-throated miner		C		35
animals	birds	Meliphagidae	*Phylidonyris niger*	white-cheeked honeyeater		C		1
animals	birds	Meliphagidae	*Ptilotula plumulus*	grey-fronted honeyeater		C		26
animals	birds	Meliphagidae	*Epthianura tricolor*	crimson chat		C		5
animals	birds	Meliphagidae	*Gavicalis virescens*	singing honeyeater		C		6
animals	birds	Meliphagidae	*Stomiopera unicolor*	white-gaped honeyeater		C		6/2
animals	birds	Meliphagidae	*Cissomela pectoralis*	banded honeyeater		C		3
animals	birds	Meliphagidae	*Lichmera indistincta*	brown honeyeater		C		32
animals	birds	Meliphagidae	*Melithreptus gularis*	black-chinned honeyeater		NT		4
animals	birds	Meliphagidae	*Philemon argenticeps*	silver-crowned friarbird		C		1
animals	birds	Meliphagidae	*Ptilotula flavescens*	yellow-tinted honeyeater		C		13
animals	birds	Meliphagidae	*Ptilotula keartlandi*	grey-headed honeyeater		C		38
animals	birds	Meropidae	*Merops ornatus*	rainbow bee-eater		SL		22
animals	birds	Monarchidae	*Myiagra inquieta*	restless flycatcher		C		14
animals	birds	Monarchidae	*Grallina cyanoleuca*	magpie-lark		C		41
animals	birds	Motacillidae	*Anthus novaeseelandiae*	Australasian pipit		C		1
animals	birds	Nectariniidae	*Dicaeum hirundinaceum*	mistletoebird		C		13
animals	birds	Neosittidae	*Daphoenositta chrysoptera*	varied sittella		C		3
animals	birds	Oriolidae	*Oriolus sagittatus*	olive-backed oriole		C		10
animals	birds	Otididae	*Ardeotis australis*	Australian bustard		C		7
animals	birds	Pachycephalidae	*Colluricincla harmonica*	grey shrike-thrush		C		28/2
animals	birds	Pachycephalidae	*Pachycephala rufiventris*	rufous whistler		C		29
animals	birds	Pachycephalidae	*Colluricincla megarhyncha*	little shrike-thrush		C		1
animals	birds	Pachycephalidae	*Oreoica gutturalis*	crested bellbird		C		8
animals	birds	Pardalotidae	*Pardalotus rubricatus*	red-browed pardalote		C		14
animals	birds	Pardalotidae	*Pardalotus striatus*	striated pardalote		C		32
animals	birds	Passeridae	*Passer domesticus*	house sparrow	Y			1
animals	birds	Pelecanidae	*Pelecanus conspicillatus*	Australian pelican		C		3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Petroicidae	*Petroica goodenovii*	red-capped robin		C		1
animals	birds	Petroicidae	*Melanodryas cucullata*	hooded robin		C		4
animals	birds	Petroicidae	*Microeca fascinans*	jacky winter		C		10
animals	birds	Phalacrocoracidae	*Phalacrocorax sulcirostris*	little black cormorant		C		4
animals	birds	Phalacrocoracidae	*Phalacrocorax carbo*	great cormorant		C		1
animals	birds	Phalacrocoracidae	*Microcarbo melanoleucos*	little pied cormorant		C		4
animals	birds	Phalacrocoracidae	*Phalacrocorax varius*	pied cormorant		C		3
animals	birds	Phasianidae	*Coturnix ypsilophora*	brown quail		C		3
animals	birds	Podargidae	*Podargus strigoides*	tawny frogmouth		C		5
animals	birds	Podicipedidae	*Poliocephalus poliocephalus*	hoary-headed grebe		C		1
animals	birds	Podicipedidae	*Tachybaptus novaehollandiae*	Australasian grebe		C		1
animals	birds	Pomatostomidae	*Pomatostomus temporalis*	grey-crowned babbler		C		33/1
animals	birds	Psittacidae	*Trichoglossus haematodus moluccanus*	rainbow lorikeet		C		1
animals	birds	Psittacidae	*Barnardius zonarius macgillivrayi*	Cloncurry parrot		C		10/1
animals	birds	Psittacidae	*Aprosmictus erythropterus*	red-winged parrot		C		26
animals	birds	Psittacidae	*Psitteuteles versicolor*	varied lorikeet		C		31
animals	birds	Psittacidae	*Melopsittacus undulatus*	budgerigar		C		36
animals	birds	Psittacidae	*Barnardius zonarius*	Australian ringneck		C		14
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus nuchalis*	great bowerbird		C		10
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus maculatus*	spotted bowerbird		C		10/1
animals	birds	Rallidae	*Porzana fluminea*	Australian spotted crake		C		1
animals	birds	Rallidae	*Tribonyx ventralis*	black-tailed native-hen		C		1
animals	birds	Rallidae	*Fulica atra*	Eurasian coot		C		2
animals	birds	Recurvirostridae	*Himantopus himantopus*	black-winged stilt		C		2
animals	birds	Recurvirostridae	*Recurvirostra novaehollandiae*	red-necked avocet		C		1
animals	birds	Rhipiduridae	*Rhipidura leucophrys*	willie wagtail		C		59
animals	birds	Rhipiduridae	*Rhipidura albiscapa*	grey fantail		C		4
animals	birds	Scolopacidae	*Calidris acuminata*	sharp-tailed sandpiper		SL		1
animals	birds	Strigidae	*Ninox connivens*	barking owl		C		3
animals	birds	Strigidae	*Ninox boobook*	southern boobook		C		7
animals	birds	Threskiornithidae	*Threskiornis molucca*	Australian white ibis		C		1
animals	birds	Threskiornithidae	*Plegadis falcinellus*	glossy ibis		SL		1
animals	birds	Threskiornithidae	*Platalea regia*	royal spoonbill		C		3
animals	birds	Threskiornithidae	*Threskiornis spinicollis*	straw-necked ibis		C		3
animals	birds	Turnicidae	*Turnix velox*	little button-quail		C		1
animals	birds	Tytonidae	*Tyto javanica*	eastern barn owl		C		2
animals	insects	Nymphalidae	*Euploea core corinna*	common crow				2
animals	insects	Nymphalidae	*Danaus chrysippus petilia*	lesser wanderer				2
animals	insects	Nymphalidae	*Hypolimnas bolina nerina*	varied eggfly				5
animals	insects	Nymphalidae	*Junonia villida calybe*	meadow argus				1
animals	insects	Papilionidae	*Papilio demoleus sthenelus*	chequered swallowtail				3
animals	insects	Pieridae	*Catopsilia pyranthe crokera*	white migrant				1
animals	insects	Pieridae	*Catopsilia pomona pomona*	lemon migrant				1
animals	insects	Pieridae	*Belenois java teutonia*	caper white				1
animals	insects	Pieridae	*Eurema smilax*	small grass-yellow				1
animals	mammals	Emballonuridae	*Taphozous sp.*					2

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	mammals	Macropodidae	*Petrogale purpureicollis*	purple-necked rock-wallaby		V		4
animals	mammals	Macropodidae	*Onychogalea unguifera*	northern nailtail wallaby		C		3
animals	mammals	Macropodidae	*Macropus rufus*	red kangaroo		C		5
animals	mammals	Macropodidae	*Macropus agilis*	agile wallaby		C		1
animals	mammals	Macropodidae	*Macropus robustus*	common wallaroo		C		3
animals	mammals	Molossidae	*Chaerephon jobensis*	northern freetail bat		C		1
animals	mammals	Molossidae	*Mormopterus beccarii*	Beccari's freetail bat		C		1
animals	mammals	Muridae	*Hydromys chrysogaster*	water rat		C		1
animals	mammals	Muridae	*Pseudomys desertor*	desert mouse		C		1
animals	mammals	Muridae	*Pseudomys johnsoni*			C		2
animals	mammals	Pteropodidae	*Pteropus scapulatus*	little red flying-fox		C		1
animals	mammals	Tachyglossidae	*Tachyglossus aculeatus*	short-beaked echidna		SL		1
animals	mammals	Vespertilionidae	*Chalinolobus nigrogriseus*	hoary wattled bat		C		1
animals	mammals	Vespertilionidae	*Vespadelus sp.*					1/1
animals	mammals	Vespertilionidae	*Scotorepens greyii*	little broad-nosed bat		C		14/2
animals	mammals	Vespertilionidae	*Chalinolobus gouldii*	Gould's wattled bat		C		3
animals	mammals	Vespertilionidae	*Scotorepens balstoni*	inland broad-nosed bat		C		4/3
animals	mammals	Vespertilionidae	*Vespadelus finlaysoni*	Finlayson's cave bat		C		1
animals	ray-finned fishes	Ambassidae	*Ambassis species*	northwest glassfish				1
animals	ray-finned fishes	Clupeidae	*Nematalosa erebi*	bony bream				2
animals	ray-finned fishes	Melanotaeniidae	*Melanotaenia splendida splendida*	eastern rainbowfish				1
animals	ray-finned fishes	Terapontidae	*Amniataba percoides*	barred grunter				1
animals	ray-finned fishes	Terapontidae	*Leiopotherapon unicolor*	spangled perch				3
animals	reptiles	Agamidae	*Ctenophorus caudicinctus*	ring-tailed dragon		C		1
animals	reptiles	Agamidae	*Amphibolurus temporalis*	swamplands lashtail		C		2
animals	reptiles	Agamidae	*Diporiphora bilineata*	two-lined dragon		C		1
animals	reptiles	Agamidae	*Chlamydosaurus kingii*	frilled lizard		C		1
animals	reptiles	Agamidae	*Amphibolurus gilberti*	Gilbert's dragon		C		7
animals	reptiles	Agamidae	*Diporiphora magna*			C		3
animals	reptiles	Agamidae	*Pogona vitticeps*			C		3/1
animals	reptiles	Boidae	*Aspidites melanocephalus*	black-headed python		C		2
animals	reptiles	Crocodylidae	*Crocodylus johnstoni*	Australian freshwater crocodile		C		1
animals	reptiles	Diplodactylidae	*Diplodactylus conspicillatus*	fat-tailed diplodactylus		C		3
animals	reptiles	Diplodactylidae	*Lucasium stenodactylum*	crowned gecko		C		4
animals	reptiles	Diplodactylidae	*Lucasium immaculatum*			C		2
animals	reptiles	Diplodactylidae	*Rhynchoedura ornata sensu lato*	beaked gecko		C		1/1
animals	reptiles	Elapidae	*Furina ornata*	orange-naped snake		C		1
animals	reptiles	Elapidae	*Suta suta*	myall snake		C		1
animals	reptiles	Elapidae	*Vermicella annulata*	bandy-bandy		C		1
animals	reptiles	Elapidae	*Pseudonaja textilis*	eastern brown snake		C		1
animals	reptiles	Gekkonidae	*Gehyra sp.*					1
animals	reptiles	Gekkonidae	*Gehyra nana*			C		1
animals	reptiles	Gekkonidae	*Gehyra dubia*			C		2
animals	reptiles	Gekkonidae	*Gehyra robusta*			C		2
animals	reptiles	Gekkonidae	*Heteronotia binoei*	Bynoe's gecko		C		4/1
animals	reptiles	Gekkonidae	*Gehyra versicolor*			C		3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	reptiles	Pygopodidae	*Delma nasuta*	sharp-snouted legless lizard		C		1
animals	reptiles	Pygopodidae	*Lialis burtonis*	Burton's legless lizard		C		1
animals	reptiles	Scincidae	*Ctenotus hebetior*			C		1
animals	reptiles	Scincidae	*Ctenotus lateralis*			C		8
animals	reptiles	Scincidae	*Ctenotus decaneurus*			C		1
animals	reptiles	Scincidae	*Ctenotus pulchellus*			C		2/2
animals	reptiles	Scincidae	*Ctenotus pantherinus*			C		6
animals	reptiles	Scincidae	*Ctenotus striaticeps*			C		2
animals	reptiles	Scincidae	*Tiliqua multifasciata*	Centralian blue-tongued lizard		C		1
animals	reptiles	Scincidae	*Cryptoblepharus zoticus*	agile snake-eyed skink		C		1
animals	reptiles	Scincidae	*Cryptoblepharus pannosus*	ragged snake-eyed skink		C		1
animals	reptiles	Scincidae	*Cryptoblepharus plagiocephalus sensu lato*			C		1
animals	reptiles	Scincidae	*Egernia hosmeri*	Hosmer's skink		C		2
animals	reptiles	Scincidae	*Carlia amax*			C		2
animals	reptiles	Scincidae	*Menetia maini*			C		1
animals	reptiles	Typhlopidae	*Ramphotyphlops diversus*			C		2
animals	reptiles	Varanidae	*Varanus acanthurus*	ridge-tailed monitor		C		3/1
animals	reptiles	Varanidae	*Varanus mertensi*	Mertens' water monitor		C		5
animals	reptiles	Varanidae	*Varanus panoptes*	yellow-spotted monitor		C		2
fungi	sac fungi	Lecideaceae	*Lecidea*			C		1/1
fungi	sac fungi	Teloschistaceae	*Caloplaca*			C		1/1
plants	ferns	Lindsaeaceae	*Lindsaea ensifolia subsp. ensifolia*			C		1/1
plants	ferns	Nephrolepidaceae	*Nephrolepis brownii*			C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus macrocephalus*	green pussytails		C		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera denticulata*	lesser joyweed		C		1/1
plants	higher dicots	Amaranthaceae	*Gomphrena breviflora*			C		1/1
plants	higher dicots	Amaranthaceae	*Gomphrena leptophylla*			C		2/2
plants	higher dicots	Amaranthaceae	*Amaranthus interruptus*			C		1/1
plants	higher dicots	Amaranthaceae	*Gomphrena lanata*			C		3/3
plants	higher dicots	Apocynaceae	*Calotropis gigantea*		Y			2/2
plants	higher dicots	Apocynaceae	*Calotropis procera*		Y			4/4
plants	higher dicots	Asteraceae	*Pluchea dentex*	bowl daisy		C		1/1
plants	higher dicots	Asteraceae	*Pluchea rubelliflora*			C		1/1
plants	higher dicots	Asteraceae	*Streptoglossa decurrens*			C		1/1
plants	higher dicots	Asteraceae	*Pterocaulon serrulatum var. velutinum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium haesum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium tanythrix*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium tenuifolium*			C		2/2
plants	higher dicots	Boraginaceae	*Heliotropium cunninghamii*			C		1/1
plants	higher dicots	Boraginaceae	*Trichodesma zeylanicum var. zeylanicum*			C		2/2
plants	higher dicots	Byttneriaceae	*Waltheria indica*			C		2/2
plants	higher dicots	Caesalpiniaceae	*Senna artemisioides subsp. oligophylla*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna notabilis*			C		2/2
plants	higher dicots	Caryophyllaceae	*Polycarpaea spirostylis subsp. spirostylis*			C		1/1
plants	higher dicots	Caryophyllaceae	*Polycarpaea corymbosa var. corymbosa*			C		1/1
plants	higher dicots	Caryophyllaceae	*Polycarpaea breviflora*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Caryophyllaceae	*Polycarpaea spirostylis subsp. glabra*			C		1/1
plants	higher dicots	Celastraceae	*Denhamia cunninghamii*			C		1/1
plants	higher dicots	Chenopodiaceae	*Maireana georgei*			C		1/1
plants	higher dicots	Cleomaceae	*Cleome gynandra*		Y			1/1
plants	higher dicots	Cleomaceae	*Cleome viscosa*	tick-weed		C		2/2
plants	higher dicots	Combretaceae	*Terminalia aridicola subsp. aridicola*			C		2/2
plants	higher dicots	Convolvulaceae	*Ipomoea plebeia*	bellvine		C		1/1
plants	higher dicots	Convolvulaceae	*Polymeria ambigua*			C		1/1
plants	higher dicots	Convolvulaceae	*Jacquemontia browniana*			C		1/1
plants	higher dicots	Convolvulaceae	*Bonamia pannosa*			C		3/3
plants	higher dicots	Cucurbitaceae	*Cucumis melo*			C		2/2
plants	higher dicots	Cucurbitaceae	*Cucumis argenteus*			C		2/2
plants	higher dicots	Euphorbiaceae	*Euphorbia australis var. subtomentosa*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia hirta*		Y			1/1
plants	higher dicots	Fabaceae	*Vigna*			C		1/1
plants	higher dicots	Fabaceae	*Cullen cinereum*			C		1/1
plants	higher dicots	Fabaceae	*Swainsona burkei*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia virens*			C		6/6
plants	higher dicots	Fabaceae	*Cullen balsamicum*			C		1/1
plants	higher dicots	Fabaceae	*Cullen leucanthum*			C		1/1
plants	higher dicots	Fabaceae	*Indigofera colutea*	sticky indigo		C		1/1
plants	higher dicots	Fabaceae	*Indigofera linnaei*	Birdsville indigo		C		1/1
plants	higher dicots	Fabaceae	*Cajanus acutifolius*			C		2/2
plants	higher dicots	Fabaceae	*Cajanus lanuginosus*			C		1/1
plants	higher dicots	Fabaceae	*Indigofera linifolia*			C		2/2
plants	higher dicots	Fabaceae	*Indigofera pratensis*			C		1/1
plants	higher dicots	Fabaceae	*Sesbania benthamiana*			C		3/3
plants	higher dicots	Fabaceae	*Tephrosia leptoclada*			C		2/2
plants	higher dicots	Fabaceae	*Crotalaria medicaginea*	trefoil rattlepod		C		1/1
plants	higher dicots	Fabaceae	*Tephrosia lasiochlaena*			C		2/2
plants	higher dicots	Fabaceae	*Indigastrum parviflorum*			C		1/1
plants	higher dicots	Fabaceae	*Macroptilium atropurpureum*	siratro	Y			1/1
plants	higher dicots	Fabaceae	*Tephrosia rosea var. rosea*			C		4/4
plants	higher dicots	Fabaceae	*Zornia prostrata var. prostrata*			C		1/1
plants	higher dicots	Fabaceae	*Sesbania cannabina var. cannabina*			C		1/1
plants	higher dicots	Fabaceae	*Zornia muriculata subsp. angustata*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia brachyodon var. longifolia*			C		3/3
plants	higher dicots	Fabaceae	*Tephrosia sp. (Mt Isa P.L.Harris 277)*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia brachyodon var. cloncurrensis*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia sp. (Magazine Hill P.Jones 365)*			C		4/4
plants	higher dicots	Fabaceae	*Crotalaria novae-hollandiae subsp. novae-hollandiae*			C		3/3
plants	higher dicots	Fabaceae	*Tephrosia phaeosperma var. (Westmoreland S.Melville 967)*			C		1/1
plants	higher dicots	Goodeniaceae	*Scaevola ovalifolia*			C		1/1
plants	higher dicots	Goodeniaceae	*Goodenia vilmoriniae*			C		4/4
plants	higher dicots	Goodeniaceae	*Goodenia fascicularis*			C		1/1

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plants	higher dicots	Goodeniaceae	*Scaevola*			C		3/3
plants	higher dicots	Lamiaceae	*Vitex benthamiana*			C		1/1
plants	higher dicots	Lamiaceae	*Mesosphaerum suaveolens*		Y			2/2
plants	higher dicots	Lamiaceae	*Ocimum caryophyllinum*			C		1/1
plants	higher dicots	Loranthaceae	*Diplatia grandibractea*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus sturtii var. grandiflorus*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon hannii*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon arenarium*			C		1/1
plants	higher dicots	Malvaceae	*Gossypium australe*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus meraukensis*	Merauke hibiscus		C		1/1
plants	higher dicots	Malvaceae	*Sida rohlenae subsp. rohlenae*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia victoriae subsp. fasciaria*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia sp. (Coolullah M.Lazarides 3988)*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia retivenea subsp. retivenea*			C		3/3
plants	higher dicots	Mimosaceae	*Vachellia farnesiana*		Y			2/2
plants	higher dicots	Mimosaceae	*Acacia holosericea*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia tenuissima*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia melleodora*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia elachantha*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia chisholmii*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia gonoclada*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia galioides*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia laccata*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia cambagei*	gidgee		C		2/2
plants	higher dicots	Mimosaceae	*Acacia acradenia*			C		5/5
plants	higher dicots	Moraceae	*Ficus racemosa var. racemosa*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus camaldulensis subsp. obtusa*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus leucophylla x E.pruinosa*			C		3/3
plants	higher dicots	Myrtaceae	*Eucalyptus leucophloia subsp. euroa*			C		3/3
plants	higher dicots	Myrtaceae	*Lophostemon grandiflorus*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus leucophylla*			C		2/2
plants	higher dicots	Myrtaceae	*Melaleuca fluviatilis*			C		1/1
plants	higher dicots	Myrtaceae	*Corymbia capricornia*			C		1/1
plants	higher dicots	Myrtaceae	*Melaleuca argentea*	silver tea-tree		C		2/2
plants	higher dicots	Myrtaceae	*Melaleuca viridiflora var. viridiflora*			C		1/1
plants	higher dicots	Myrtaceae	*Melaleuca trichostachya*			C		1/1
plants	higher dicots	Nyctaginaceae	*Boerhavia burbidgeana*			C		1/1
plants	higher dicots	Nyctaginaceae	*Boerhavia pubescens*			C		1/1
plants	higher dicots	Orobanchaceae	*Buchnera ramosissima*			C		1/1
plants	higher dicots	Plantaginaceae	*Stemodia viscosa*			C		2/2
plants	higher dicots	Polygalaceae	*Polygala barklyensis*			C		2/2
plants	higher dicots	Portulacaceae	*Sedopsis armitii*			C		1/1
plants	higher dicots	Portulacaceae	*Portulaca*			C		1/1
plants	higher dicots	Portulacaceae	*Portulaca australis*			C		1/1
plants	higher dicots	Proteaceae	*Hakea lorea subsp. lorea*			C		1/1
plants	higher dicots	Proteaceae	*Grevillea dryandri subsp. dryandri*			C		1/1

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plants	higher dicots	Rubiaceae	*Psydrax oleifolia*			C		1/1
plants	higher dicots	Rubiaceae	*Oldenlandia mitrasacmoides subsp. mitrasacmoides*			C		1/1
plants	higher dicots	Rubiaceae	*Kohautia australiensis*			C		1/1
plants	higher dicots	Rubiaceae	*Spermacoce auriculata*			C		1/1
plants	higher dicots	Sapindaceae	*Dodonaea stenophylla*			C		1/1
plants	higher dicots	Scrophulariaceae	*Eremophila latrobei subsp. latrobei*			C		1/1
plants	higher dicots	Solanaceae	*Solanum quadriloculatum*			C		5/5
plants	higher dicots	Solanaceae	*Solanum echinatum*			C		2/2
plants	higher dicots	Solanaceae	*Solanum succosum*			C		4/4
plants	higher dicots	Solanaceae	*Solanum esuriale*	quena		C		1/1
plants	higher dicots	Solanaceae	*Datura inoxia*		Y			3/3
plants	higher dicots	Sparrmanniaceae	*Corchorus sidoides subsp. vermicularis*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Corchorus sericeus subsp. densiflorus*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Triumfetta marsupiata*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Triumfetta johnstonii*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Triumfetta rupestris*			C		4/4
plants	higher dicots	Sparrmanniaceae	*Triumfetta plumigera*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Corchorus pumilio*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Corchorus tridens*			C		2/2
plants	higher dicots	Violaceae	*Hybanthus enneaspermus*			C		3/3
plants	lower dicots	Papaveraceae	*Argemone ochroleuca subsp. ochroleuca*	Mexican poppy	Y			1/1
plants	monocots	Arecaceae	*Livistona rigida*			C		2/2
plants	monocots	Cyperaceae	*Lipocarpha microcephala*			C		1/1
plants	monocots	Cyperaceae	*Bulbostylis barbata*			C		3/3
plants	monocots	Cyperaceae	*Cyperus squarrosus*	bearded flatsedge		C		1/1
plants	monocots	Cyperaceae	*Cyperus dactylotes*			C		1/1
plants	monocots	Cyperaceae	*Cyperus vaginatus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus javanicus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus carinatus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus iria*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis sp. (Thargomindah D.E.Boyland 3094)*			C		1/1
plants	monocots	Cyperaceae	*Cyperus microcephalus subsp. microcephalus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus cunninghamii subsp. cheradicus*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis corynocarya*			C		1/1
plants	monocots	Cyperaceae	*Fimbristylis microcarya*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis littoralis*			C		1/1
plants	monocots	Poaceae	*Urochloa piligera*			C		2/2
plants	monocots	Poaceae	*Aristida latifolia*	feathertop wiregrass		C		1/1
plants	monocots	Poaceae	*Echinochloa colona*	awnless barnyard grass	Y			1/1
plants	monocots	Poaceae	*Eragrostis cumingii*			C		1/1
plants	monocots	Poaceae	*Oxychloris scariosa*	winged chloris		C		1/1
plants	monocots	Poaceae	*Tragus australianus*	small burr grass		C		1/1
plants	monocots	Poaceae	*Bothriochloa pertusa*		Y			1/1
plants	monocots	Poaceae	*Dichanthium fecundum*	curly bluegrass		C		1/1
plants	monocots	Poaceae	*Enneapogon asperatus*			C		1/1
plants	monocots	Poaceae	*Aristida hygrometrica*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	monocots	Poaceae	*Dichanthium annulatum*	sheda grass	Y			1/1
plants	monocots	Poaceae	*Aristida inaequiglumis*			C		1/1
plants	monocots	Poaceae	*Brachyachne convergens*	common native couch		C		2/2
plants	monocots	Poaceae	*Enneapogon polyphyllus*	leafy nineawn		C		2/2
plants	monocots	Poaceae	*Cenchrus pennisetiformis*		Y			1/1
plants	monocots	Poaceae	*Sporobolus australasicus*			C		1/1
plants	monocots	Poaceae	*Paspalidium rarum*			C		1/1
plants	monocots	Poaceae	*Mnesithea formosa*			C		1/1
plants	monocots	Poaceae	*Chloris pectinata*	comb chloris		C		1/1
plants	monocots	Poaceae	*Aristida contorta*	bunched kerosene grass		C		1/1
plants	monocots	Poaceae	*Themeda triandra*	kangaroo grass		C		1/1
plants	monocots	Poaceae	*Eriachne ciliata*			C		1/1
plants	monocots	Poaceae	*Eragrostis minor*	smaller stinkgrass	Y			1/1
plants	monocots	Poaceae	*Sehima nervosum*			C		1/1
plants	monocots	Poaceae	*Eriachne obtusa*			C		1/1
plants	monocots	Poaceae	*Eriachne mucronata forma (Alpha C.E.Hubbard 7882)*			C		1/1
plants	monocots	Poaceae	*Eriachne sp. (Dugald River B.K.Simon+ 3007)*			C		1/1
plants	monocots	Poaceae	*Yakirra australiensis var. australiensis*			C		1/1
plants	monocots	Poaceae	*Bothriochloa bladhii subsp. bladhii*			C		1/1
plants	monocots	Poaceae	*Cynodon dactylon var. dactylon*		Y			1/1
plants	monocots	Poaceae	*Aristida holathera var. holathera*			C		2/2
plants	monocots	Poaceae	*Eriachne pulchella subsp. dominii*			C		1/1

CODES

I - Y indicates that the taxon is introduced to Queensland and has naturalised.

Q - Indicates the Queensland conservation status of each taxon under the *Nature Conservation Act 1992.* The codes are Extinct in the Wild (PE), Endangered (E), Vulnerable (V), Near Threatened (NT), Least Concern (C) or Not Protected ( ).

A - Indicates the Australian conservation status of each taxon under the *Environment Protection and Biodiversity Conservation Act 1999.* The values of EPBC are Conservation Dependent (CD), Critically Endangered (CE), Endangered (E), Extinct (EX), Extinct in the Wild (XW) and Vulnerable (V).

Records – The first number indicates the total number of records of the taxon for the record option selected (i.e. All, Confirmed or Specimens).
This number is output as 99999 if it equals or exceeds this value. The second number located after the / indicates the number of specimen records for the taxon.
This number is output as 999 if it equals or exceeds this value.

Queensland Government

Wildlife Online Extract

Search Criteria:	Species List for a Defined Area
	Species: All
	Type: All
	Status: All
	Records: All
	Date: All
	Latitude: 20.4224 to 21.0475
	Longitude: 139.8386 to 139.1728
	Email: hdick@aarc.net.au
	Date submitted: Tuesday 17 Jun 2014 16:21:01
	Date extracted: Tuesday 17 Jun 2014 16:30:03

The number of records retrieved = 993

Disclaimer

As the DSITIA is still in a process of collating and vetting data, it is possible the information given is not complete. The information provided should only be used for the project for which it was requested and it should be appropriately acknowledged as being derived from Wildlife Online when it is used.

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Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	amphibians	Bufonidae	*Rhinella marina*	cane toad	Y			14/7
animals	amphibians	Hylidae	*Litoria pallida*	pallid rocketfrog		C		1
animals	amphibians	Hylidae	*Litoria inermis*	bumpy rocketfrog		C		10/9
animals	amphibians	Hylidae	*Cyclorana novaehollandiae*	eastern snapping frog		C		3
animals	amphibians	Hylidae	*Litoria rubella*	ruddy treefrog		C		9/7
animals	amphibians	Hylidae	*Litoria caerulea*	common green treefrog		C		6/4
animals	amphibians	Hylidae	*Cyclorana australis*	northern snapping frog		C		18/18
animals	amphibians	Limnodynastidae	*Platyplectrum ornatum*	ornate burrowing frog		C		2/1
animals	birds	Acanthizidae	*Smicrornis brevirostris*	weebill		C		274
animals	birds	Acanthizidae	*Acanthiza chrysorrhoa*	yellow-rumped thornbill		C		40/1
animals	birds	Acanthizidae	*Acanthiza apicalis*	inland thornbill		C		3
animals	birds	Acanthizidae	*Gerygone fusca*	western gerygone		C		2
animals	birds	Accipitridae	*Elanus axillaris*	black-shouldered kite		C		15
animals	birds	Accipitridae	*Aquila audax*	wedge-tailed eagle		C		48
animals	birds	Accipitridae	*Erythrotriorchis radiatus*	red goshawk		E	V	1
animals	birds	Accipitridae	*Hamirostra melanosternon*	black-breasted buzzard		C		5
animals	birds	Accipitridae	*Accipiter cirrocephalus*	collared sparrowhawk		C		24
animals	birds	Accipitridae	*Hieraaetus morphnoides*	little eagle		C		15
animals	birds	Accipitridae	*Haliaeetus leucogaster*	white-bellied sea-eagle		SL		25
animals	birds	Accipitridae	*Haliastur sphenurus*	whistling kite		C		198
animals	birds	Accipitridae	*Aviceda subcristata*	Pacific baza		C		1
animals	birds	Accipitridae	*Accipiter fasciatus*	brown goshawk		C		24
animals	birds	Accipitridae	*Lophoictinia isura*	square-tailed kite		NT		1
animals	birds	Accipitridae	*Circus approximans*	swamp harrier		C		1
animals	birds	Accipitridae	*Pandion cristatus*	eastern osprey		SL		9
animals	birds	Accipitridae	*Milvus migrans*	black kite		C		281
animals	birds	Accipitridae	*Circus assimilis*	spotted harrier		C		3
animals	birds	Acrocephalidae	*Acrocephalus australis*	Australian reed-warbler		SL		129/1
animals	birds	Aegothelidae	*Aegotheles cristatus*	Australian owlet-nightjar		C		8
animals	birds	Alaudidae	*Mirafra javanica*	Horsfield's bushlark		C		2
animals	birds	Alcedinidae	*Ceyx azureus*	azure kingfisher		C		4
animals	birds	Anatidae	*Anas gracilis*	grey teal		C		155
animals	birds	Anatidae	*Anas castanea*	chestnut teal		C		1
animals	birds	Anatidae	*Anas sp.*					1
animals	birds	Anatidae	*Cygnus atratus*	black swan		C		52
animals	birds	Anatidae	*Anas superciliosa*	Pacific black duck		C		192
animals	birds	Anatidae	*Chenonetta jubata*	Australian wood duck		C		67
animals	birds	Anatidae	*Anas platyrhynchos*	northern mallard	Y			1
animals	birds	Anatidae	*Dendrocygna eytoni*	plumed whistling-duck		C		52
animals	birds	Anatidae	*Dendrocygna arcuata*	wandering whistling-duck		C		16
animals	birds	Anatidae	*Nettapus pulchellus*	green pygmy-goose		C		47
animals	birds	Anatidae	*Stictonetta naevosa*	freckled duck		NT		4
animals	birds	Anatidae	*Tadorna tadornoides*	Australian shelduck		C		1
animals	birds	Anatidae	*Nettapus coromandelianus*	cotton pygmy-goose		NT		4
animals	birds	Anatidae	*Malacorhynchus membranaceus*	pink-eared duck		C		89
animals	birds	Anatidae	*Biziura lobata*	musk duck		C		1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Anatidae	*Aythya australis*	hardhead		C		184
animals	birds	Anatidae	*Anas rhynchotis*	Australasian shoveler		C		2
animals	birds	Anhingidae	*Anhinga novaehollandiae*	Australasian darter		C		169
animals	birds	Anseranatidae	*Anseranas semipalmata*	magpie goose		C		1
animals	birds	Ardeidae	*Ardea intermedia*	intermediate egret		C		132
animals	birds	Ardeidae	*Ardea ibis*	cattle egret		SL		52
animals	birds	Ardeidae	*Ardea modesta*	eastern great egret		SL		147
animals	birds	Ardeidae	*Ardea pacifica*	white-necked heron		C		123
animals	birds	Ardeidae	*Egretta garzetta*	little egret		C		46
animals	birds	Ardeidae	*Nycticorax caledonicus*	Nankeen night-heron		C		38
animals	birds	Ardeidae	*Ixobrychus flavicollis*	black bittern		C		1
animals	birds	Ardeidae	*Egretta novaehollandiae*	white-faced heron		C		130
animals	birds	Artamidae	*Artamus superciliosus*	white-browed woodswallow		C		18
animals	birds	Artamidae	*Artamus leucorynchus*	white-breasted woodswallow		C		51
animals	birds	Artamidae	*Artamus cyanopterus*	dusky woodswallow		C		1
animals	birds	Artamidae	*Strepera graculina*	pied currawong		C		2
animals	birds	Artamidae	*Artamus minor*	little woodswallow		C		30
animals	birds	Artamidae	*Cracticus tibicen*	Australian magpie		C		128/1
animals	birds	Artamidae	*Artamus cinereus*	black-faced woodswallow		C		176
animals	birds	Artamidae	*Cracticus nigrogularis*	pied butcherbird		C		187
animals	birds	Artamidae	*Artamus personatus*	masked woodswallow		C		22
animals	birds	Burhinidae	*Burhinus grallarius*	bush stone-curlew		C		6
animals	birds	Cacatuidae	*Eolophus roseicapillus*	galah		C		130
animals	birds	Cacatuidae	*Cacatua sanguinea*	little corella		C		100/3
animals	birds	Cacatuidae	*Nymphicus hollandicus*	cockatiel		C		85
animals	birds	Cacatuidae	*Calyptorhynchus banksii*	red-tailed black-cockatoo		C		1
animals	birds	Cacatuidae	*Cacatua galerita*	sulphur-crested cockatoo		C		84
animals	birds	Campephagidae	*Coracina novaehollandiae*	black-faced cuckoo-shrike		C		195
animals	birds	Campephagidae	*Lalage sueurii*	white-winged triller		C		101/2
animals	birds	Campephagidae	*Coracina maxima*	ground cuckoo-shrike		C		7
animals	birds	Campephagidae	*Coracina papuensis*	white-bellied cuckoo-shrike		C		10
animals	birds	Casuariidae	*Dromaius novaehollandiae*	emu		C		5
animals	birds	Charadriidae	*Erythrogonys cinctus*	red-kneed dotterel		C		49
animals	birds	Charadriidae	*Charadrius australis*	inland dotterel		C		1/1
animals	birds	Charadriidae	*Elseyornis melanops*	black-fronted dotterel		C		161
animals	birds	Charadriidae	*Charadrius veredus*	oriental plover		SL		8
animals	birds	Charadriidae	*Vanellus tricolor*	banded lapwing		C		3
animals	birds	Charadriidae	*Pluvialis fulva*	Pacific golden plover		SL		4
animals	birds	Charadriidae	*Vanellus miles*	masked lapwing		C		99
animals	birds	Charadriidae	*Vanellus miles miles*	masked lapwing (northern subspecies)		C		58
animals	birds	Charadriidae	*Charadrius ruficapillus*	red-capped plover		C		66
animals	birds	Charadriidae	*Charadrius mongolus*	lesser sand plover		SL		1
animals	birds	Ciconiidae	*Ephippiorhynchus asiaticus*	black-necked stork		NT		40
animals	birds	Cisticolidae	*Cisticola exilis*	golden-headed cisticola		C		8
animals	birds	Climacteridae	*Climacteris melanura*	black-tailed treecreeper		C		76/1
animals	birds	Columbidae	*Geopelia striata*	peaceful dove		C		217/8

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Columbidae	*Geopelia cuneata*	diamond dove		C		126/24
animals	birds	Columbidae	*Geophaps plumifera*	spinifex pigeon		C		134/36
animals	birds	Columbidae	*Ocyphaps lophotes*	crested pigeon		C		211/4
animals	birds	Columbidae	*Phaps chalcoptera*	common bronzewing		C		48/5
animals	birds	Columbidae	*Phaps histrionica*	flock bronzewing		C		1/1
animals	birds	Columbidae	*Columba livia*	rock dove	Y			31
animals	birds	Columbidae	*Streptopelia chinensis*	spotted dove	Y			1
animals	birds	Coraciidae	*Eurystomus orientalis*	dollarbird		C		15
animals	birds	Corcoracidae	*Struthidea cinerea*	apostlebird		C		43
animals	birds	Corvidae	*Corvus sp.*					11
animals	birds	Corvidae	*Corvus orru*	Torresian crow		C		20
animals	birds	Corvidae	*Corvus bennetti*	little crow		C		3
animals	birds	Corvidae	*Corvus coronoides*	Australian raven		C		231/1
animals	birds	Cuculidae	*Chalcites osculans*	black-eared cuckoo		C		3/1
animals	birds	Cuculidae	*Scythrops novaehollandiae*	channel-billed cuckoo		C		10
animals	birds	Cuculidae	*Cuculus optatus*	oriental cuckoo		SL		1
animals	birds	Cuculidae	*Cacomantis pallidus*	pallid cuckoo		C		16
animals	birds	Cuculidae	*Eudynamys orientalis*	eastern koel		C		15
animals	birds	Cuculidae	*Cacomantis variolosus*	brush cuckoo		C		1
animals	birds	Cuculidae	*Centropus phasianinus*	pheasant coucal		C		25
animals	birds	Cuculidae	*Chalcites basalis*	Horsfield's bronze-cuckoo		C		16/1
animals	birds	Estrildidae	*Poephila acuticauda*	long-tailed finch		C		29
animals	birds	Estrildidae	*Emblema pictum*	painted finch		C		82/4
animals	birds	Estrildidae	*Erythrura gouldiae*	Gouldian finch		E	E	1
animals	birds	Estrildidae	*Neochmia ruficauda*	star finch		C		1
animals	birds	Estrildidae	*Lonchura castaneothorax*	chestnut-breasted mannikin		C		19
animals	birds	Estrildidae	*Taeniopygia guttata*	zebra finch		C		233
animals	birds	Estrildidae	*Heteromunia pectoralis*	pictorella mannikin		NT		37
animals	birds	Estrildidae	*Poephila cincta cincta*	black-throated finch (white-rumped subspecies)		E	E	1
animals	birds	Estrildidae	*Taeniopygia bichenovii*	double-barred finch		C		68
animals	birds	Eurostopodidae	*Eurostopodus argus*	spotted nightjar		C		16/1
animals	birds	Falconidae	*Falco berigora*	brown falcon		C		41
animals	birds	Falconidae	*Falco subniger*	black falcon		C		6
animals	birds	Falconidae	*Falco longipennis*	Australian hobby		C		25
animals	birds	Falconidae	*Falco peregrinus*	peregrine falcon		C		1
animals	birds	Falconidae	*Falco cenchroides*	Nankeen kestrel		C		29
animals	birds	Falconidae	*Falco hypoleucos*	grey falcon		NT		1
animals	birds	Glareolidae	*Stiltia isabella*	Australian pratincole		C		46
animals	birds	Glareolidae	*Glareola maldivarum*	oriental pratincole		SL		3/2
animals	birds	Gruidae	*Grus rubicunda*	brolga		C		31
animals	birds	Halcyonidae	*Todiramphus sanctus*	sacred kingfisher		C		71
animals	birds	Halcyonidae	*Dacelo leachii*	blue-winged kookaburra		C		113
animals	birds	Halcyonidae	*Todiramphus pyrrhopygius*	red-backed kingfisher		C		74
animals	birds	Hirundinidae	*Petrochelidon ariel*	fairy martin		C		84
animals	birds	Hirundinidae	*Hirundo rustica*	barn swallow		SL		3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Hirundinidae	*Hirundo neoxena*	welcome swallow		C		34
animals	birds	Hirundinidae	*Petrochelidon nigricans*	tree martin		C		33
animals	birds	Jacanidae	*Irediparra gallinacea*	comb-crested jacana		C		98
animals	birds	Laridae	*Chlidonias hybrida*	whiskered tern		C		42
animals	birds	Laridae	*Hydroprogne caspia*	Caspian tern		SL		942
animals	birds	Laridae	*Chroicocephalus novaehollandiae*	silver gull		C		75
animals	birds	Laridae	*Chlidonias leucopterus*	white-winged black tern		SL		5
animals	birds	Laridae	*Gelochelidon nilotica*	gull-billed tern		C		28
animals	birds	Maluridae	*Amytornis sp.*					2
animals	birds	Maluridae	*Malurus lamberti*	variegated fairy-wren		C		137/2
animals	birds	Maluridae	*Amytornis ballarae*	Kalkadoon grasswren		C		77/8
animals	birds	Maluridae	*Amytornis dorotheae*	Carpentarian grasswren		NT		1
animals	birds	Maluridae	*Malurus leucopterus*	white-winged fairy-wren		C		12
animals	birds	Maluridae	*Malurus melanocephalus*	red-backed fairy-wren		C		36
animals	birds	Megaluridae	*Eremiornis carteri*	spinifexbird		C		60/2
animals	birds	Megaluridae	*Megalurus gramineus*	little grassbird		C		17
animals	birds	Megaluridae	*Cincloramphus cruralis*	brown songlark		C		4
animals	birds	Megaluridae	*Cincloramphus mathewsi*	rufous songlark		C		29
animals	birds	Meliphagidae	*Epthianura crocea crocea*	yellow chat (gulf)		V		3
animals	birds	Meliphagidae	*Melithreptus albogularis*	white-throated honeyeater		C		2
animals	birds	Meliphagidae	*Melithreptus gularis laetior*	golden-backed honeyeater		NT		4
animals	birds	Meliphagidae	*Sugomel niger*	black honeyeater		C		4
animals	birds	Meliphagidae	*Grantiella picta*	painted honeyeater		V		2
animals	birds	Meliphagidae	*Myzomela obscura*	dusky honeyeater		C		1
animals	birds	Meliphagidae	*Epthianura crocea*	yellow chat		V		2
animals	birds	Meliphagidae	*Entomyzon cyanotis*	blue-faced honeyeater		C		2
animals	birds	Meliphagidae	*Manorina flavigula*	yellow-throated miner		C		300/1
animals	birds	Meliphagidae	*Ptilotula plumulus*	grey-fronted honeyeater		C		188/6
animals	birds	Meliphagidae	*Epthianura tricolor*	crimson chat		C		44
animals	birds	Meliphagidae	*Gavicalis virescens*	singing honeyeater		C		54
animals	birds	Meliphagidae	*Philemon buceroides*	helmeted friarbird		C		1
animals	birds	Meliphagidae	*Stomiopera unicolor*	white-gaped honeyeater		C		5
animals	birds	Meliphagidae	*Cissomela pectoralis*	banded honeyeater		C		7
animals	birds	Meliphagidae	*Epthianura aurifrons*	orange chat		C		15
animals	birds	Meliphagidae	*Lichmera indistincta*	brown honeyeater		C		214
animals	birds	Meliphagidae	*Melithreptus gularis*	black-chinned honeyeater		NT		45
animals	birds	Meliphagidae	*Philemon argenticeps*	silver-crowned friarbird		C		44
animals	birds	Meliphagidae	*Ptilotula flavescens*	yellow-tinted honeyeater		C		24
animals	birds	Meliphagidae	*Ptilotula keartlandi*	grey-headed honeyeater		C		127/5
animals	birds	Meliphagidae	*Certhionyx variegatus*	pied honeyeater		C		1
animals	birds	Meliphagidae	*Philemon citreogularis*	little friarbird		C		135
animals	birds	Meliphagidae	*Ptilotula penicillatus*	white-plumed honeyeater		C		318/3
animals	birds	Meliphagidae	*Conopophila rufogularis*	rufous-throated honeyeater		C		69/1
animals	birds	Meliphagidae	*Acanthagenys rufogularis*	spiny-cheeked honeyeater		C		53/1
animals	birds	Meropidae	*Merops ornatus*	rainbow bee-eater		SL		210
animals	birds	Monarchidae	*Grallina cyanoleuca*	magpie-lark		C		339

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Monarchidae	*Myiagra inquieta*	restless flycatcher		C		85
animals	birds	Motacillidae	*Anthus novaeseelandiae*	Australasian pipit		C		48
animals	birds	Nectariniidae	*Dicaeum hirundinaceum*	mistletoebird		C		179
animals	birds	Neosittidae	*Daphoenositta chrysoptera*	varied sittella		C		5
animals	birds	Oriolidae	*Oriolus sagittatus*	olive-backed oriole		C		57
animals	birds	Oriolidae	*Sphecotheres vieilloti*	Australasian figbird		C		1
animals	birds	Otididae	*Ardeotis australis*	Australian bustard		C		29
animals	birds	Pachycephalidae	*Oreoica gutturalis*	crested bellbird		C		17/1
animals	birds	Pachycephalidae	*Colluricincla harmonica*	grey shrike-thrush		C		91/1
animals	birds	Pachycephalidae	*Pachycephala rufiventris*	rufous whistler		C		105/1
animals	birds	Pardalotidae	*Pardalotus rubricatus*	red-browed pardalote		C		53
animals	birds	Pardalotidae	*Pardalotus striatus*	striated pardalote		C		120/2
animals	birds	Passeridae	*Passer domesticus*	house sparrow	Y			49
animals	birds	Pelecanidae	*Pelecanus conspicillatus*	Australian pelican		C		143
animals	birds	Petroicidae	*Petroica goodenovii*	red-capped robin		C		8
animals	birds	Petroicidae	*Melanodryas cucullata*	hooded robin		C		22/2
animals	birds	Petroicidae	*Microeca fascinans*	jacky winter		C		80/1
animals	birds	Phalacrocoracidae	*Phalacrocorax carbo*	great cormorant		C		52
animals	birds	Phalacrocoracidae	*Phalacrocorax varius*	pied cormorant		C		36
animals	birds	Phalacrocoracidae	*Microcarbo melanoleucos*	little pied cormorant		C		127
animals	birds	Phalacrocoracidae	*Phalacrocorax sulcirostris*	little black cormorant		C		164
animals	birds	Phasianidae	*Pavo cristatus*	Indian peafowl	Y			5
animals	birds	Phasianidae	*Coturnix pectoralis*	stubble quail		C		3
animals	birds	Phasianidae	*Coturnix ypsilophora*	brown quail		C		20
animals	birds	Podargidae	*Podargus strigoides*	tawny frogmouth		C		21/1
animals	birds	Podicipedidae	*Tachybaptus novaehollandiae*	Australasian grebe		C		205
animals	birds	Podicipedidae	*Poliocephalus poliocephalus*	hoary-headed grebe		C		48
animals	birds	Podicipedidae	*Podiceps cristatus*	great crested grebe		C		56
animals	birds	Pomatostomidae	*Pomatostomus temporalis*	grey-crowned babbler		C		213
animals	birds	Psittacidae	*Barnardius zonarius*	Australian ringneck		C		76
animals	birds	Psittacidae	*Trichoglossus haematodus moluccanus*	rainbow lorikeet		C		10
animals	birds	Psittacidae	*Platycercus adscitus*	pale-headed rosella		C		1
animals	birds	Psittacidae	*Barnardius zonarius macgillivrayi*	Cloncurry parrot		C		16/8
animals	birds	Psittacidae	*Trichoglossus chlorolepidotus*	scaly-breasted lorikeet		C		1
animals	birds	Psittacidae	*Melopsittacus undulatus*	budgerigar		C		248
animals	birds	Psittacidae	*Psitteuteles versicolor*	varied lorikeet		C		125/1
animals	birds	Psittacidae	*Aprosmictus erythropterus*	red-winged parrot		C		160
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus nuchalis*	great bowerbird		C		24
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus maculatus*	spotted bowerbird		C		160/4
animals	birds	Rallidae	*Porzana fluminea*	Australian spotted crake		C		6
animals	birds	Rallidae	*Porzana pusilla*	Baillon's crake		C		10
animals	birds	Rallidae	*Fulica atra*	Eurasian coot		C		110
animals	birds	Rallidae	*Porzana tabuensis*	spotless crake		C		3
animals	birds	Rallidae	*Amaurornis cinerea*	white-browed crake		C		1
animals	birds	Rallidae	*Tribonyx ventralis*	black-tailed native-hen		C		15
animals	birds	Rallidae	*Gallinula tenebrosa*	dusky moorhen		C		90

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Rallidae	*Porphyrio porphyrio*	purple swamphen		C		75
animals	birds	Rallidae	*Gallirallus philippensis*	buff-banded rail		C		9
animals	birds	Recurvirostridae	*Himantopus himantopus*	black-winged stilt		C		197
animals	birds	Recurvirostridae	*Recurvirostra novaehollandiae*	red-necked avocet		C		23
animals	birds	Rhipiduridae	*Rhipidura albiscapa*	grey fantail		C		27
animals	birds	Rhipiduridae	*Rhipidura leucophrys*	willie wagtail		C		330
animals	birds	Rostratulidae	*Rostratula australis*	Australian painted snipe		V	E	7
animals	birds	Scolopacidae	*Numenius madagascariensis*	eastern curlew		NT		1
animals	birds	Scolopacidae	*Gallinago hardwickii*	Latham's snipe		SL		6
animals	birds	Scolopacidae	*Calidris ruficollis*	red-necked stint		SL		15
animals	birds	Scolopacidae	*Calidris ferruginea*	curlew sandpiper		SL		12
animals	birds	Scolopacidae	*Tringa stagnatilis*	marsh sandpiper		SL		33
animals	birds	Scolopacidae	*Phalaropus lobatus*	red-necked phalarope		SL		1
animals	birds	Scolopacidae	*Calidris subminuta*	long-toed stint		SL		6
animals	birds	Scolopacidae	*Calidris acuminata*	sharp-tailed sandpiper		SL		251
animals	birds	Scolopacidae	*Arenaria interpres*	ruddy turnstone		SL		2
animals	birds	Scolopacidae	*Actitis hypoleucos*	common sandpiper		SL		15/1
animals	birds	Scolopacidae	*Tringa nebularia*	common greenshank		SL		18
animals	birds	Scolopacidae	*Numenius minutus*	little curlew		SL		5
animals	birds	Scolopacidae	*Heteroscelus sp.*					2
animals	birds	Scolopacidae	*Tringa glareola*	wood sandpiper		SL		16
animals	birds	Scolopacidae	*Xenus cinereus*	terek sandpiper		SL		1
animals	birds	Scolopacidae	*Limosa limosa*	black-tailed godwit		SL		8
animals	birds	Scolopacidae	*Gallinago megala*	Swinhoe's snipe		SL		10
animals	birds	Strigidae	*Ninox boobook*	southern boobook		C		19
animals	birds	Strigidae	*Ninox connivens*	barking owl		C		2
animals	birds	Threskiornithidae	*Platalea regia*	royal spoonbill		C		36
animals	birds	Threskiornithidae	*Threskiornis molucca*	Australian white ibis		C		39
animals	birds	Threskiornithidae	*Threskiornis spinicollis*	straw-necked ibis		C		119
animals	birds	Threskiornithidae	*Platalea flavipes*	yellow-billed spoonbill		C		10
animals	birds	Threskiornithidae	*Plegadis falcinellus*	glossy ibis		SL		115
animals	birds	Turnicidae	*Turnix velox*	little button-quail		C		5
animals	birds	Tytonidae	*Tyto javanica*	eastern barn owl		C		2
animals	mammals	Bovidae	*Bos sp.*	cattle	Y			1
animals	mammals	Bovidae	*Bos taurus*	European cattle	Y			1
animals	mammals	Camelidae	*Camelus dromedarius*	one-humped camel	Y			2
animals	mammals	Dasyuridae	*Pseudantechinus mimulus*	Carpentarian antechinus		C	V	3/3
animals	mammals	Emballonuridae	*Taphozous troughtoni*	Troughton's sheathtail bat		C		4/3
animals	mammals	Emballonuridae	*Saccolaimus flaviventris*	yellow-bellied sheathtail bat		C		1
animals	mammals	Emballonuridae	*Taphozous georgianus*	common sheathtail bat		C		5/5
animals	mammals	Equidae	*Equus caballus*	horse	Y			2
animals	mammals	Hipposideridae	*Hipposideros stenotis*	northern leaf-nosed bat		V		1
animals	mammals	Macropodidae	*Macropus robustus*	common wallaroo		C		7/2
animals	mammals	Macropodidae	*Macropus rufus*	red kangaroo		C		2
animals	mammals	Macropodidae	*Lagorchestes conspicillatus*	spectacled hare-wallaby		C		1
animals	mammals	Macropodidae	*Petrogale purpureicollis*	purple-necked rock-wallaby		V		4/3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	mammals	Molossidae	*Chaerephon jobensis*	northern freetail bat		C		1/1
animals	mammals	Molossidae	*Mormopterus beccarii*	Beccari's freetail bat		C		6/6
animals	mammals	Molossidae	*Mormopterus loriae ridei*	little north-eastern freetail bat		C		1/1
animals	mammals	Muridae	*Rattus sordidus*	canefield rat		C		1
animals	mammals	Muridae	*Pseudomys johnsoni*			C		5
animals	mammals	Muridae	*Zyzomys argurus*	common rock-rat		C		2/2
animals	mammals	Pteropodidae	*Pteropus scapulatus*	little red flying-fox		C		3
animals	mammals	Vespertilionidae	*Scotorepens greyii*	little broad-nosed bat		C		9/4
animals	mammals	Vespertilionidae	*Vespadelus finlaysoni*	Finlayson's cave bat		C		3/3
animals	mammals	Vespertilionidae	*Vespadelus sp.*					2/1
animals	mammals	Vespertilionidae	*Chalinolobus gouldii*	Gould's wattled bat		C		4/3
animals	mammals	Vespertilionidae	*Nyctophilus geoffroyi*	lesser long-eared bat		C		4/4
animals	mammals	Vespertilionidae	*Vespadelus baverstocki*	inland forest bat		C		1
animals	ray-finned fishes	Ambassidae	*Ambassis macleayi*	Macleay's glassfish				146
animals	ray-finned fishes	Ambassidae	*Ambassis species*	northwest glassfish				62
animals	ray-finned fishes	Ambassidae	*Ambassis sp.*					2
animals	ray-finned fishes	Ariidae	*Neoarius graeffei*	blue catfish				5
animals	ray-finned fishes	Ariidae	*Neoarius leptaspis*	boofhead catfish				1
animals	ray-finned fishes	Belonidae	*Strongylura krefftii*	freshwater longtom				105
animals	ray-finned fishes	Centropomidae	*Lates calcarifer*	barramundi				169
animals	ray-finned fishes	Clupeidae	*Nematalosa erebi*	bony bream				939
animals	ray-finned fishes	Eleotridae	*Oxyeleotris selheimi*	blackbanded gudgeon				117
animals	ray-finned fishes	Eleotridae	*Oxyeleotris lineolata*	sleepy cod				109
animals	ray-finned fishes	Gobiidae	*Awaous acritosus*	roman-nose goby				1
animals	ray-finned fishes	Gobiidae	*Glossogobius giuris*	tank goby				4
animals	ray-finned fishes	Gobiidae	*Glossogobius aureus*	golden flathead goby				3
animals	ray-finned fishes	Melanotaeniidae	*Melanotaenia splendida inornata*	checkered rainbowfish				263
animals	ray-finned fishes	Melanotaeniidae	*Melanotaenia splendida splendida*	eastern rainbowfish				2
animals	ray-finned fishes	Plotosidae	*Porochilus rendahli*	Rendahl's catfish				1
animals	ray-finned fishes	Plotosidae	*Neosilurus hyrtlii*	Hyrtl's catfish				10
animals	ray-finned fishes	Plotosidae	*Neosilurus ater*	black catfish				1
animals	ray-finned fishes	Plotosidae	*Anodontiglanis dahli*	toothless catfish				1
animals	ray-finned fishes	Terapontidae	*Leiopotherapon unicolor*	spangled perch				111
animals	ray-finned fishes	Terapontidae	*Amniataba percoides*	barred grunter				680
animals	ray-finned fishes	Terapontidae	*Hephaestus fuliginosus*	sooty grunter				82
animals	ray-finned fishes	Toxotidae	*Toxotes chatareus*	sevenspot archerfish				41
animals	reptiles	Agamidae	*Tympanocryptis cephalus*			C		1/1
animals	reptiles	Agamidae	*Ctenophorus caudicinctus*	ring-tailed dragon		C		9/6
animals	reptiles	Agamidae	*Diporiphora bilineata*	two-lined dragon		C		2/1
animals	reptiles	Agamidae	*Amphibolurus gilberti*	Gilbert's dragon		C		7/1
animals	reptiles	Agamidae	*Pogona vitticeps*			C		2
animals	reptiles	Agamidae	*Moloch horridus*	thorny devil		C		1
animals	reptiles	Agamidae	*Diporiphora sp.*					1/1
animals	reptiles	Boidae	*Aspidites melanocephalus*	black-headed python		C		3/1
animals	reptiles	Boidae	*Liasis olivaceus*	olive python		C		2
animals	reptiles	Boidae	*Antaresia childreni*	children's python		C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	reptiles	Chelidae	*Emydura subglobosa worrelli*	diamond head turtle		NT		3
animals	reptiles	Crocodylidae	*Crocodylus johnstoni*	Australian freshwater crocodile		C		3
animals	reptiles	Diplodactylidae	*Lucasium immaculatum*			C		2/2
animals	reptiles	Diplodactylidae	*Strophurus ciliaris*	spiny-tailed gecko		C		10/3
animals	reptiles	Diplodactylidae	*Strophurus taeniatus*	white-striped gecko		C		1/1
animals	reptiles	Diplodactylidae	*Oedura marmorata*	marbled velvet gecko		C		1/1
animals	reptiles	Diplodactylidae	*Amalosia rhombifer*	zig-zag gecko		C		2/2
animals	reptiles	Elapidae	*Brachyurophis incinctus*			C		1
animals	reptiles	Elapidae	*Furina ornata*	orange-naped snake		C		1
animals	reptiles	Elapidae	*Pseudonaja modesta*	ringed brown snake		C		4/4
animals	reptiles	Elapidae	*Demansia olivacea sensu lato*	marble-headed whip snake		C		1
animals	reptiles	Elapidae	*Suta punctata*	little spotted snake		C		1/1
animals	reptiles	Gekkonidae	*Gehyra robusta*			C		22/19
animals	reptiles	Gekkonidae	*Gehyra versicolor*			C		8/8
animals	reptiles	Gekkonidae	*Heteronotia binoei*	Bynoe's gecko		C		4/2
animals	reptiles	Gekkonidae	*Gehyra dubia*			C		1
animals	reptiles	Pygopodidae	*Lialis burtonis*	Burton's legless lizard		C		2
animals	reptiles	Pygopodidae	*Delma borea*			C		1/1
animals	reptiles	Scincidae	*Tiliqua multifasciata*	Centralian blue-tongued lizard		C		2/2
animals	reptiles	Scincidae	*Ctenotus striaticeps*			C		1
animals	reptiles	Scincidae	*Ctenotus pantherinus*			C		2
animals	reptiles	Scincidae	*Ctenotus pulchellus*			C		2/2
animals	reptiles	Scincidae	*Ctenotus lateralis*			C		6/4
animals	reptiles	Scincidae	*Ctenotus inornatus*			C		1
animals	reptiles	Scincidae	*Egernia hosmeri*	Hosmer's skink		C		3/2
animals	reptiles	Scincidae	*Ctenotus hebetior*			C		1
animals	reptiles	Scincidae	*Carlia amax*			C		1
animals	reptiles	Varanidae	*Varanus mertensi*	Mertens' water monitor		C		3
animals	reptiles	Varanidae	*Varanus tristis*	black-tailed monitor		C		2/1
animals	reptiles	Varanidae	*Varanus acanthurus*	ridge-tailed monitor		C		7/4
animals	reptiles	Varanidae	*Varanus glebopalma*	long-tailed rock monitor		C		1
fungi	uncertain	Fungus	*Fungus*			C		1/1
plants	ferns	Adiantaceae	*Cheilanthes brownii*			C		4/4
plants	ferns	Adiantaceae	*Cheilanthes nudiuscula*			C		2/2
plants	ferns	Adiantaceae	*Cheilanthes sieberi subsp. sieberi*			C		1/1
plants	ferns	Adiantaceae	*Cheilanthes sieberi subsp. pseudovellea*			C		1/1
plants	ferns	Marsileaceae	*Marsilea costulifera*	narrow-leaved nardoo		C		1/1
plants	ferns	Salviniaceae	*Salvinia molesta*	salvinia	Y			1/1
plants	higher dicots	Acanthaceae	*Nelsonia campestris*			C		2/2
plants	higher dicots	Acanthaceae	*Rostellularia adscendens*			C		1/1
plants	higher dicots	Acanthaceae	*Rostellularia adscendens var. clementii*			C		1/1
plants	higher dicots	Aizoaceae	*Trianthema triquetra*	red spinach		C		1/1
plants	higher dicots	Aizoaceae	*Trianthema portulacastrum*	black pigweed	Y			1/1
plants	higher dicots	Amaranthaceae	*Aerva javanica*		Y			5/5
plants	higher dicots	Amaranthaceae	*Ptilotus nobilis subsp. nobilis*			C		4/4
plants	higher dicots	Amaranthaceae	*Ptilotus sessilifolius*			C		7/7

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Amaranthaceae	*Ptilotus macrocephalus*	green pussytails		C		1/1
plants	higher dicots	Amaranthaceae	*Amaranthus interruptus*			C		2/2
plants	higher dicots	Amaranthaceae	*Gomphrena leptophylla*			C		2/2
plants	higher dicots	Amaranthaceae	*Alternanthera pungens*	khaki weed	Y			2/2
plants	higher dicots	Amaranthaceae	*Ptilotus maconochiei*			NT		9/9
plants	higher dicots	Amaranthaceae	*Amaranthus undulatus*			C		4/4
plants	higher dicots	Amaranthaceae	*Alternanthera sp. (Mt Isa R.L.Specht+ 49)*			C		4/4
plants	higher dicots	Amaranthaceae	*Gomphrena arida*			C		3/3
plants	higher dicots	Amaranthaceae	*Gomphrena lanata*			C		3/3
plants	higher dicots	Amaranthaceae	*Ptilotus incanus*			C		4/4
plants	higher dicots	Amaranthaceae	*Ptilotus obovatus*			C		6/6
plants	higher dicots	Amaranthaceae	*Ptilotus spicatus*			C		1/1
plants	higher dicots	Amaranthaceae	*Achyranthes aspera*			C		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera nana*	hairy joyweed		C		1/1
plants	higher dicots	Amaranthaceae	*Amaranthus viridis*	green amaranth	Y			1/1
plants	higher dicots	Amaranthaceae	*Ptilotus clementii*			C		5/5
plants	higher dicots	Amaranthaceae	*Ptilotus decipiens*			C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus fusiformis*			C		4/4
plants	higher dicots	Amaranthaceae	*Ptilotus schwartzii*			C		3/3
plants	higher dicots	Apocynaceae	*Marsdenia viridiflora subsp. tropica*			C		5/5
plants	higher dicots	Apocynaceae	*Sarcostemma brevipedicellatum*			C		1/1
plants	higher dicots	Apocynaceae	*Gymnanthera cunninghamii*			C		1/1
plants	higher dicots	Apocynaceae	*Tylophora cinerascens*			C		1/1
plants	higher dicots	Apocynaceae	*Calotropis procera*		Y			1/1
plants	higher dicots	Apocynaceae	*Calotropis gigantea*		Y			1/1
plants	higher dicots	Apocynaceae	*Cascabela thevetia*	yellow oleander	Y			1/1
plants	higher dicots	Apocynaceae	*Carissa lanceolata*			C		2/2
plants	higher dicots	Apocynaceae	*Cynanchum floribundum*			C		1/1
plants	higher dicots	Asteraceae	*Blumea mollis*			C		3/3
plants	higher dicots	Asteraceae	*Blumea tenella*			C		1/1
plants	higher dicots	Asteraceae	*Pluchea dentex*	bowl daisy		C		7/7
plants	higher dicots	Asteraceae	*Soliva sessilis*		Y			1/1
plants	higher dicots	Asteraceae	*Bidens bipinnata*	bipinnate beggar's ticks	Y			3/3
plants	higher dicots	Asteraceae	*Eclipta prostrata*	white eclipta		C		2/2
plants	higher dicots	Asteraceae	*Tridax procumbens*	tridax daisy	Y			1/1
plants	higher dicots	Asteraceae	*Flaveria trinervia*		Y			1/1
plants	higher dicots	Asteraceae	*Olearia subspicata*			C		1/1
plants	higher dicots	Asteraceae	*Peripleura obovata*			C		2/2
plants	higher dicots	Asteraceae	*Peripleura virgata*			C		4/4
plants	higher dicots	Asteraceae	*Glossocardia bidens*	native cobbler's pegs		C		1/1
plants	higher dicots	Asteraceae	*Streptoglossa odora*			C		3/3
plants	higher dicots	Asteraceae	*Pluchea rubelliflora*			C		4/4
plants	higher dicots	Asteraceae	*Pterocaulon redolens*			C		1/1
plants	higher dicots	Asteraceae	*Xanthium occidentale*		Y			1/1
plants	higher dicots	Asteraceae	*Calotis xanthosioidea*			C		1/1
plants	higher dicots	Asteraceae	*Cyanthillium cinereum*			C		3/3

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plants	higher dicots	Asteraceae	*Streptoglossa bubakii*			C		1/1
plants	higher dicots	Asteraceae	*Acanthospermum hispidum*	star burr	Y			3/3
plants	higher dicots	Asteraceae	*Pterocaulon sphacelatum*	applebush		C		1/1
plants	higher dicots	Asteraceae	*Streptoglossa decurrens*			C		8/8
plants	higher dicots	Asteraceae	*Sphaeromorphaea littoralis*			C		1/1
plants	higher dicots	Asteraceae	*Chrysocephalum pterochaetum*	perennial sunray		C		1/1
plants	higher dicots	Asteraceae	*Pluchea ferdinandi-muelleri*			C		5/5
plants	higher dicots	Asteraceae	*Centipeda minima subsp. minima*			C		1/1
plants	higher dicots	Asteraceae	*Lactuca serriola forma serriola*		Y			1/1
plants	higher dicots	Asteraceae	*Peripleura hispidula var. setosa*			C		1/1
plants	higher dicots	Asteraceae	*Brachyscome ciliaris var. lanuginosa*			C		1/1
plants	higher dicots	Asteraceae	*Pterocaulon serrulatum var. velutinum*			C		3/3
plants	higher dicots	Asteraceae	*Rutidosis helichrysoides subsp. acutiglumis*			C		1/1
plants	higher dicots	Boraginaceae	*Ehretia saligna*			C		1/1
plants	higher dicots	Boraginaceae	*Coldenia procumbens*			C		1/1
plants	higher dicots	Boraginaceae	*Trichodesma zeylanicum var. latisepalum*			C		1/1
plants	higher dicots	Boraginaceae	*Trichodesma zeylanicum var. zeylanicum*			C		2/2
plants	higher dicots	Boraginaceae	*Heliotropium ballii*			C		16/16
plants	higher dicots	Boraginaceae	*Heliotropium haesum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium aequoreum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium tanythrix*			C		1/1
plants	higher dicots	Boraginaceae	*Trichodesma zeylanicum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium frohlichii*			C		2/2
plants	higher dicots	Boraginaceae	*Heliotropium ovalifolium*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium tenuifolium*			C		4/4
plants	higher dicots	Boraginaceae	*Heliotropium cunninghamii*			C		4/4
plants	higher dicots	Boraginaceae	*Heliotropium curassavicum*	smooth heliotrope	Y			2/2
plants	higher dicots	Boraginaceae	*Heliotropium fasciculatum*			C		1/1
plants	higher dicots	Brassicaceae	*Lepidium strongylophyllum*			C		3/3
plants	higher dicots	Byblidaceae	*Byblis liniflora*			C		2/2
plants	higher dicots	Byttneriaceae	*Keraudrenia nephrosperma*			C		1/1
plants	higher dicots	Cactaceae	*Cylindropuntia fulgida var. mamillata*		Y			2/2
plants	higher dicots	Caesalpiniaceae	*Senna glutinosa subsp. pruinosa*			C		3/3
plants	higher dicots	Caesalpiniaceae	*Senna glutinosa subsp. glutinosa*			C		2/2
plants	higher dicots	Caesalpiniaceae	*Senna*			C		3/3
plants	higher dicots	Caesalpiniaceae	*Senna venusta*			C		3/3
plants	higher dicots	Caesalpiniaceae	*Senna notabilis*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Lysiphyllum gilvum*	bauhinia		C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna occidentalis*	coffee senna	Y			1/1
plants	higher dicots	Caesalpiniaceae	*Senna planitiicola*			C		2/2
plants	higher dicots	Caesalpiniaceae	*Senna artemisioides*			C		2/2
plants	higher dicots	Caesalpiniaceae	*Chamaecrista deserti*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Parkinsonia aculeata*	parkinsonia	Y			1/1
plants	higher dicots	Caesalpiniaceae	*Petalostylis cassioides*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Chamaecrista exigua var. exigua*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna artemisioides subsp. oligophylla*			C		2/2

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Caesalpiniaceae	*Senna artemisioides subsp. sturtii*			C		1/1
plants	higher dicots	Campanulaceae	*Wahlenbergia gracilis*	sprawling bluebell		C		2/2
plants	higher dicots	Campanulaceae	*Wahlenbergia tumidifructa*			C		2/2
plants	higher dicots	Campanulaceae	*Wahlenbergia communis*	tufted bluebell		C		2/2
plants	higher dicots	Campanulaceae	*Isotoma petraea*	rock isotome		C		1/1
plants	higher dicots	Capparaceae	*Capparis umbonata*			C		2/2
plants	higher dicots	Capparaceae	*Capparis mitchellii*			C		1/1
plants	higher dicots	Capparaceae	*Capparis loranthifolia var. loranthifolia*			C		1/1
plants	higher dicots	Caryophyllaceae	*Polycarpaea breviflora*			C		2/2
plants	higher dicots	Caryophyllaceae	*Polycarpaea spirostylis*			C		1/1
plants	higher dicots	Caryophyllaceae	*Polycarpaea spirostylis subsp. glabra*			C		3/3
plants	higher dicots	Caryophyllaceae	*Polycarpaea corymbosa*			C		1/1
plants	higher dicots	Celastraceae	*Denhamia cunninghamii*			C		4/4
plants	higher dicots	Chenopodiaceae	*Maireana georgei*			C		6/6
plants	higher dicots	Chenopodiaceae	*Dysphania rhadinostachya subsp. rhadinostachya*			C		2/2
plants	higher dicots	Chenopodiaceae	*Maireana triptera*	three-wing bluebush		C		4/4
plants	higher dicots	Chenopodiaceae	*Salsola australis*			C		2/2
plants	higher dicots	Chenopodiaceae	*Sclerolaena glabra*			C		1/1
plants	higher dicots	Chenopodiaceae	*Sclerolaena minuta*			C		2/2
plants	higher dicots	Chenopodiaceae	*Sclerolaena cuneata*	tangled copperburr		C		2/2
plants	higher dicots	Chenopodiaceae	*Enchylaena tomentosa*			C		1/1
plants	higher dicots	Chenopodiaceae	*Maireana campanulata*			C		2/2
plants	higher dicots	Chenopodiaceae	*Sclerolaena bicornis*			C		1/1
plants	higher dicots	Chenopodiaceae	*Sclerolaena eriacantha*			C		2/2
plants	higher dicots	Chenopodiaceae	*Sclerolaena lanicuspis*			C		7/7
plants	higher dicots	Chenopodiaceae	*Sclerolaena cornishiana*			C		3/3
plants	higher dicots	Chenopodiaceae	*Einadia nutans subsp. nutans*			C		1/1
plants	higher dicots	Chenopodiaceae	*Einadia nutans subsp. eremaea*			C		1/1
plants	higher dicots	Chenopodiaceae	*Sclerolaena bicornis var. horrida*			C		1/1
plants	higher dicots	Chenopodiaceae	*Tecticornia indica subsp. leiostachya*			C		1/1
plants	higher dicots	Chenopodiaceae	*Maireana villosa*			C		6/6
plants	higher dicots	Cleomaceae	*Cleome viscosa*	tick-weed		C		3/3
plants	higher dicots	Combretaceae	*Terminalia aridicola subsp. aridicola*			C		2/2
plants	higher dicots	Combretaceae	*Terminalia aridicola*			C		1/1
plants	higher dicots	Combretaceae	*Terminalia aridicola subsp. chillagoensis*			C		1/1
plants	higher dicots	Convolvulaceae	*Ipomoea muelleri*	poison morning-glory		C		2/2
plants	higher dicots	Convolvulaceae	*Polymeria ambigua*			C		3/3
plants	higher dicots	Convolvulaceae	*Ipomoea polymorpha*			C		1/1
plants	higher dicots	Convolvulaceae	*Ipomoea racemigera*			C		1/1
plants	higher dicots	Convolvulaceae	*Xenostegia tridentata*			C		7/7
plants	higher dicots	Convolvulaceae	*Jacquemontia browniana*			C		1/1
plants	higher dicots	Convolvulaceae	*Operculina aequisepala*			C		1/1
plants	higher dicots	Convolvulaceae	*Jacquemontia paniculata*			C		2/2
plants	higher dicots	Convolvulaceae	*Bonamia media var. villosa*			C		1/1
plants	higher dicots	Convolvulaceae	*Evolvulus alsinoides var. decumbens*			C		3/3
plants	higher dicots	Convolvulaceae	*Jacquemontia paniculata var. tomentosa*			C		3/3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Convolvulaceae	*Ipomoea plebeia*	bellvine		C		2/2
plants	higher dicots	Convolvulaceae	*Bonamia pannosa*			C		3/3
plants	higher dicots	Convolvulaceae	*Ipomoea nil*		Y			2/2
plants	higher dicots	Convolvulaceae	*Bonamia media*			C		3/3
plants	higher dicots	Cucurbitaceae	*Citrullus colocynthis*	colocynth	Y			2/2
plants	higher dicots	Cucurbitaceae	*Cucumis melo*			C		2/2
plants	higher dicots	Cucurbitaceae	*Citrullus lanatus*		Y			1/1
plants	higher dicots	Cucurbitaceae	*Cucumis argenteus*			C		3/3
plants	higher dicots	Cucurbitaceae	*Momordica balsamina*	balsam apple	Y			1/1
plants	higher dicots	Droseraceae	*Drosera burmanni*			C		1/1
plants	higher dicots	Droseraceae	*Drosera indica*			C		2/2
plants	higher dicots	Euphorbiaceae	*Euphorbia trigonosperma*			C		10/10
plants	higher dicots	Euphorbiaceae	*Euphorbia schultzii var. comans*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia australis var. subtomentosa*			C		6/6
plants	higher dicots	Euphorbiaceae	*Euphorbia tannensis subsp. eremophila*			C		3/3
plants	higher dicots	Euphorbiaceae	*Euphorbia*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia operta*			C		4/4
plants	higher dicots	Euphorbiaceae	*Microstachys chamaelea*			C		3/3
plants	higher dicots	Euphorbiaceae	*Euphorbia accedens*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia biconvexa*			C		2/2
plants	higher dicots	Euphorbiaceae	*Euphorbia drummondii*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia heterophylla*		Y			2/2
plants	higher dicots	Euphorbiaceae	*Jatropha gossypiifolia*	bellyache bush	Y			1/1
plants	higher dicots	Euphorbiaceae	*Ricinus communis*	castor oil bush	Y			2/2
plants	higher dicots	Fabaceae	*Sesbania benthamiana*			C		3/3
plants	higher dicots	Fabaceae	*Jacksonia lateritica*			C		3/3
plants	higher dicots	Fabaceae	*Stylosanthes viscosa*		Y			1/1
plants	higher dicots	Fabaceae	*Tephrosia delestangii*			C		3/3
plants	higher dicots	Fabaceae	*Tephrosia flagellaris*			C		3/3
plants	higher dicots	Fabaceae	*Indigofera haplophylla*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia lasiochlaena*			C		4/4
plants	higher dicots	Fabaceae	*Indigofera queenslandica*			C		1/1
plants	higher dicots	Fabaceae	*Gastrolobium grandiflorum*			C		1/1
plants	higher dicots	Fabaceae	*Macroptilium atropurpureum*	siratro	Y			2/2
plants	higher dicots	Fabaceae	*Crotalaria novae-hollandiae*			C		1/1
plants	higher dicots	Fabaceae	*Galactia tenuiflora var. lucida*			C		2/2
plants	higher dicots	Fabaceae	*Vigna lanceolata var. latifolia*			C		2/2
plants	higher dicots	Fabaceae	*Rhynchosia minima var. australis*			C		1/1
plants	higher dicots	Fabaceae	*Rhynchosia minima var. tomentosa*			C		1/1
plants	higher dicots	Fabaceae	*Vigna lanceolata var. lanceolata*			C		3/3
plants	higher dicots	Fabaceae	*Galactia tenuiflora forma sericea*			C		2/2
plants	higher dicots	Fabaceae	*Sesbania cannabina var. cannabina*			C		3/3
plants	higher dicots	Fabaceae	*Zornia muriculata subsp. angustata*			C		5/5
plants	higher dicots	Fabaceae	*Crotalaria medicaginea var. neglecta*			C		2/2
plants	higher dicots	Fabaceae	*Tephrosia brachyodon var. longifolia*			C		7/7
plants	higher dicots	Fabaceae	*Tephrosia sp. (Mt Isa P.L.Harris 277)*			C		9/9

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Fabaceae	*Tephrosia brachyodon var. cloncurrensis*			C		2/2
plants	higher dicots	Fabaceae	*Tephrosia sp. (Magazine Hill P.Jones 365)*			C		6/6
plants	higher dicots	Fabaceae	*Tephrosia sp. (Pannikan Springs A.R.Bean+ 5612)*			C		1/1
plants	higher dicots	Fabaceae	*Crotalaria novae-hollandiae subsp. novae-hollandiae*			C		2/2
plants	higher dicots	Fabaceae	*Tephrosia phaeosperma var. (Westmoreland S.Melville 967)*			C		2/2
plants	higher dicots	Fabaceae	*Glycine*			C		1/1
plants	higher dicots	Fabaceae	*Galactia*			C		2/2
plants	higher dicots	Fabaceae	*Cullen pallidum*			C		1/1
plants	higher dicots	Fabaceae	*Indigofera trita*			C		4/4
plants	higher dicots	Fabaceae	*Tephrosia supina*			C		5/5
plants	higher dicots	Fabaceae	*Tephrosia virens*			C		5/5
plants	higher dicots	Fabaceae	*Clitoria ternatea*	butterfly pea	Y			1/1
plants	higher dicots	Fabaceae	*Cullen balsamicum*			C		4/4
plants	higher dicots	Fabaceae	*Rhynchosia minima*			C		1/1
plants	higher dicots	Fabaceae	*Glycine tomentella*	woolly glycine		C		1/1
plants	higher dicots	Fabaceae	*Indigofera colutea*	sticky indigo		C		2/2
plants	higher dicots	Fabaceae	*Indigofera hirsuta*	hairy indigo		C		2/2
plants	higher dicots	Fabaceae	*Indigofera linnaei*	Birdsville indigo		C		3/3
plants	higher dicots	Fabaceae	*Aeschynomene indica*	budda pea		C		2/2
plants	higher dicots	Fabaceae	*Cajanus acutifolius*			C		4/4
plants	higher dicots	Fabaceae	*Cajanus lanuginosus*			C		2/2
plants	higher dicots	Fabaceae	*Galactia tenuiflora*			C		2/2
plants	higher dicots	Fabaceae	*Medicago polymorpha*	burr medic	Y			1/1
plants	higher dicots	Fabaceae	*Stylosanthes hamata*		Y			2/2
plants	higher dicots	Fabaceae	*Templetonia hookeri*			C		2/2
plants	higher dicots	Fabaceae	*Tephrosia eriocarpa*			C		1/1
plants	higher dicots	Fabaceae	*Alysicarpus muelleri*			C		1/1
plants	higher dicots	Fabaceae	*Cullen australasicum*			C		2/2
plants	higher dicots	Fabaceae	*Indigofera linifolia*			C		3/3
plants	higher dicots	Fabaceae	*Indigofera pratensis*			C		3/3
plants	higher dicots	Fabaceae	*Indigofera scabrella*			C		1/1
plants	higher dicots	Frankeniaceae	*Frankenia serpyllifolia*			C		1/1
plants	higher dicots	Goodeniaceae	*Scaevola*			C		3/3
plants	higher dicots	Goodeniaceae	*Goodenia lunata*			C		1/1
plants	higher dicots	Goodeniaceae	*Goodenia ramelii*			C		4/4
plants	higher dicots	Goodeniaceae	*Goodenia armitiana*			C		2/2
plants	higher dicots	Goodeniaceae	*Scaevola sp. (Mt Isa P.L.Harris 699)*			C		1/1
plants	higher dicots	Goodeniaceae	*Goodenia vilmoriniae*			C		5/5
plants	higher dicots	Goodeniaceae	*Goodenia triodiophila*			C		4/4
plants	higher dicots	Goodeniaceae	*Scaevola browniana subsp. browniana*			C		1/1
plants	higher dicots	Goodeniaceae	*Goodenia grandiflora*			C		3/3
plants	higher dicots	Lamiaceae	*Mesosphaerum suaveolens*		Y			1/1
plants	higher dicots	Lamiaceae	*Clerodendrum tomentosum*			C		1/1
plants	higher dicots	Lamiaceae	*Ocimum caryophyllinum*			C		2/2
plants	higher dicots	Lamiaceae	*Anisomeles malabarica*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Lamiaceae	*Ocimum x citriodorum*			C		1/1
plants	higher dicots	Lamiaceae	*Clerodendrum floribundum*			C		3/3
plants	higher dicots	Loganiaceae	*Mitrasacme micrantha*			C		1/1
plants	higher dicots	Loganiaceae	*Mitrasacme nudicaulis var. nudicaulis*			C		1/1
plants	higher dicots	Loganiaceae	*Mitrasacme pygmaea*			C		1/1
plants	higher dicots	Loranthaceae	*Lysiana exocarpi subsp. exocarpi*			C		1/1
plants	higher dicots	Loranthaceae	*Lysiana subfalcata*			C		3/3
plants	higher dicots	Loranthaceae	*Amyema sanguinea var. sanguinea*			C		4/4
plants	higher dicots	Loranthaceae	*Lysiana spathulata subsp. spathulata*			C		6/6
plants	higher dicots	Loranthaceae	*Diplatia grandibractea*			C		1/1
plants	higher dicots	Loranthaceae	*Amyema villiflora subsp. villiflora*			C		1/1
plants	higher dicots	Loranthaceae	*Amyema quandang var. quandang*			C		2/2
plants	higher dicots	Loranthaceae	*Dendrophthoe odontocalyx*			C		1/1
plants	higher dicots	Lythraceae	*Rotala occultiflora*			C		1/1
plants	higher dicots	Lythraceae	*Ammannia multiflora*	jerry-jerry		C		2/2
plants	higher dicots	Lythraceae	*Rotala mexicana*			C		1/1
plants	higher dicots	Malvaceae	*Sida*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus*			C		3/3
plants	higher dicots	Malvaceae	*Sida sp. (Doomadgee F.W.Whitehouse AQ116275)*			C		1/1
plants	higher dicots	Malvaceae	*Sida sp. (Musselbrook M.B.Thomas+ MRS437)*			C		7/7
plants	higher dicots	Malvaceae	*Sida arenicola*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon hannii*			C		3/3
plants	higher dicots	Malvaceae	*Abutilon macrum*			C		1/1
plants	higher dicots	Malvaceae	*Sida cordifolia*		Y			2/2
plants	higher dicots	Malvaceae	*Sida fibulifera*			C		7/7
plants	higher dicots	Malvaceae	*Sida goniocarpa*			C		1/1
plants	higher dicots	Malvaceae	*Sida nematopoda*			C		2/2
plants	higher dicots	Malvaceae	*Sida platycalyx*	lifesaver burr		C		1/1
plants	higher dicots	Malvaceae	*Abutilon lepidum*			C		8/8
plants	higher dicots	Malvaceae	*Hibiscus sturtii*			C		3/3
plants	higher dicots	Malvaceae	*Malva parviflora*	small-flowered mallow	Y			1/1
plants	higher dicots	Malvaceae	*Sida cleisocalyx*			C		2/2
plants	higher dicots	Malvaceae	*Sida hackettiana*			C		4/4
plants	higher dicots	Malvaceae	*Hibiscus burtonii*			C		2/2
plants	higher dicots	Malvaceae	*Abutilon arenarium*			C		4/4
plants	higher dicots	Malvaceae	*Abutilon otocarpum*			C		2/2
plants	higher dicots	Malvaceae	*Gossypium australe*			C		9/9
plants	higher dicots	Malvaceae	*Gossypium nelsonii*			C		3/3
plants	higher dicots	Malvaceae	*Herissantia crispa*			C		1/1
plants	higher dicots	Malvaceae	*Gossypium sturtianum*			C		3/3
plants	higher dicots	Malvaceae	*Hibiscus leptocladus*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus meraukensis*	Merauke hibiscus		C		2/2
plants	higher dicots	Malvaceae	*Hibiscus verdcourtii*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon leucopetalum*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus pentaphyllus*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus brachychlaenus*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Malvaceae	*Hibiscus brachysiphonius*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus sturtii var. sturtii*			C		1/1
plants	higher dicots	Malvaceae	*Sida rohlenae subsp. rohlenae*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon fraseri subsp. fraseri*			C		3/3
plants	higher dicots	Malvaceae	*Hibiscus sturtii var. platychlamys*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus sturtii var. campylochlamys*			C		4/4
plants	higher dicots	Malvaceae	*Malvastrum americanum var. americanum*		Y			2/2
plants	higher dicots	Malvaceae	*Sida sp. (Jericho E.J.Thompson+ JER117)*			C		5/5
plants	higher dicots	Meliaceae	*Azadirachta indica*		Y			1/1
plants	higher dicots	Meliaceae	*Khaya senegalensis*		Y			1/1
plants	higher dicots	Menyanthaceae	*Nymphoides indica*	water snowflake		C		1/1
plants	higher dicots	Mimosaceae	*Acacia bivenosa*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia cowleana*			C		7/7
plants	higher dicots	Mimosaceae	*Acacia hemsleyi*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia ligulata*			C		2/2
plants	higher dicots	Mimosaceae	*Albizia lebbeck*	Indian siris		C		2/2
plants	higher dicots	Mimosaceae	*Acacia acradenia*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia adsurgens*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia galioides*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia gonoclada*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia hammondii*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia monticola*			C		9/9
plants	higher dicots	Mimosaceae	*Acacia thomsonii*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia victoriae*			C		2/2
plants	higher dicots	Mimosaceae	*Prosopis pallida*		Y			2/2
plants	higher dicots	Mimosaceae	*Acacia chisholmii*			C		6/6
plants	higher dicots	Mimosaceae	*Acacia elachantha*			C		5/5
plants	higher dicots	Mimosaceae	*Acacia hemignosta*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia lysiphloia*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia megalantha*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia melleodora*			C		7/7
plants	higher dicots	Mimosaceae	*Acacia orthocarpa*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia tenuissima*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia asperulacea*			C		6/6
plants	higher dicots	Mimosaceae	*Acacia holosericea*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia phlebocarpa*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia chippendalei*			C		12/12
plants	higher dicots	Mimosaceae	*Acacia sericophylla*			C		4/4
plants	higher dicots	Mimosaceae	*Vachellia bidwillii*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia ancistrocarpa*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia estrophiolata*			C		1/1
plants	higher dicots	Mimosaceae	*Vachellia farnesiana*		Y			2/2
plants	higher dicots	Mimosaceae	*Neptunia dimorphantha*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia aneura var. aneura*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia excelsa subsp. angusta*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia retivenea subsp. retivenea*			C		4/4

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Mimosaceae	*Acacia sp. (Coolullah M.Lazarides 3988)*			C		8/8
plants	higher dicots	Mimosaceae	*Leucaena leucocephala subsp. leucocephala*		Y			3/3
plants	higher dicots	Mimosaceae	*Acacia colei*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia laccata*			C		2/2
plants	higher dicots	Molluginaceae	*Glinus oppositifolius*			C		1/1
plants	higher dicots	Moraceae	*Ficus brachypoda*			C		1/1
plants	higher dicots	Moraceae	*Ficus opposita*			C		1/1
plants	higher dicots	Moraceae	*Ficus cerasicarpa*			C		4/4
plants	higher dicots	Myrtaceae	*Corymbia aparrerinja*			C		2/2
plants	higher dicots	Myrtaceae	*Corymbia capricornia*			C		2/2
plants	higher dicots	Myrtaceae	*Corymbia leichhardtii*	rustyjacket		C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus melanophloia x E.normantonensis*			C		1/1
plants	higher dicots	Myrtaceae	*Melaleuca leucadendra*	broad-leaved tea-tree		C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus leucophylla*			C		7/7
plants	higher dicots	Myrtaceae	*Melaleuca dissitiflora*			C		1/1
plants	higher dicots	Myrtaceae	*Lophostemon grandiflorus*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus normantonensis*	Normanton box		C		10/10
plants	higher dicots	Myrtaceae	*Eucalyptus leucophloia subsp. euroa*			C		3/3
plants	higher dicots	Myrtaceae	*Eucalyptus melanophloia subsp. nana*			C		12/12
plants	higher dicots	Myrtaceae	*Eucalyptus camaldulensis subsp. obtusa*			C		3/3
plants	higher dicots	Myrtaceae	*Melaleuca viridiflora var. viridiflora*			C		1/1
plants	higher dicots	Myrtaceae	*Lophostemon grandiflorus subsp. riparius*			C		2/2
plants	higher dicots	Myrtaceae	*Melaleuca bracteata*			C		4/4
plants	higher dicots	Myrtaceae	*Corymbia terminalis*			C		1/1
plants	higher dicots	Myrtaceae	*Calytrix brownii*			C		1/1
plants	higher dicots	Myrtaceae	*Corymbia aspera*			C		7/7
plants	higher dicots	Myrtaceae	*Eucalyptus nudicaulis*			C		9/9
plants	higher dicots	Nyctaginaceae	*Boerhavia repleta*			C		3/3
plants	higher dicots	Nyctaginaceae	*Boerhavia pubescens*			C		5/5
plants	higher dicots	Nyctaginaceae	*Boerhavia paludosa*			C		3/3
plants	higher dicots	Oleaceae	*Jasminum calcareum*			C		1/1
plants	higher dicots	Oleaceae	*Jasminum didymum subsp. lineare*			C		2/2
plants	higher dicots	Onagraceae	*Ludwigia*			C		1/1
plants	higher dicots	Onagraceae	*Ludwigia perennis*			C		1/1
plants	higher dicots	Onagraceae	*Ludwigia peploides subsp. montevidensis*			C		1/1
plants	higher dicots	Onagraceae	*Ludwigia octovalvis*	willow primrose		C		1/1
plants	higher dicots	Orobanchaceae	*Buchnera linearis*			C		3/3
plants	higher dicots	Orobanchaceae	*Striga squamigera*			C		2/2
plants	higher dicots	Passifloraceae	*Passiflora foetida*		Y			3/3
plants	higher dicots	Pentapetaceae	*Melhania ovata*			C		3/3
plants	higher dicots	Pentapetaceae	*Melhania oblongifolia*			C		1/1
plants	higher dicots	Phyllanthaceae	*Breynia oblongifolia*			C		1/1
plants	higher dicots	Phyllanthaceae	*Flueggea leucopyrus*			C		2/2
plants	higher dicots	Phyllanthaceae	*Phyllanthus hebecarpus*			C		1/1
plants	higher dicots	Phyllanthaceae	*Sauropus trachyspermus*			C		2/2
plants	higher dicots	Phyllanthaceae	*Phyllanthus exilis*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Phyllanthaceae	*Phyllanthus carpentariae*			C		1/1
plants	higher dicots	Phyllanthaceae	*Phyllanthus*			C		2/2
plants	higher dicots	Phyllanthaceae	*Sauropus*			C		1/1
plants	higher dicots	Phyllanthaceae	*Flueggea virosa subsp. melanthesoides*			C		2/2
plants	higher dicots	Phyllanthaceae	*Phyllanthus maderaspatensis*			C		3/3
plants	higher dicots	Pittosporaceae	*Pittosporum angustifolium*			C		2/2
plants	higher dicots	Plantaginaceae	*Scoparia dulcis*	Scoparia	Y			1/1
plants	higher dicots	Plantaginaceae	*Mecardonia procumbens*		Y			2/2
plants	higher dicots	Plantaginaceae	*Stemodia*			C		1/1
plants	higher dicots	Plantaginaceae	*Bacopa monnieri*			C		2/2
plants	higher dicots	Plantaginaceae	*Stemodia lythrifolia*			C		5/5
plants	higher dicots	Plantaginaceae	*Stemodia viscosa*			C		4/4
plants	higher dicots	Plantaginaceae	*Stemodia glabella*			C		1/1
plants	higher dicots	Polygonaceae	*Persicaria attenuata*			C		2/2
plants	higher dicots	Polygonaceae	*Polygonum plebeium*	small knotweed		C		1/1
plants	higher dicots	Portulacaceae	*Calandrinia ptychosperma*			C		1/1
plants	higher dicots	Portulacaceae	*Portulaca intraterranea*			C		1/1
plants	higher dicots	Portulacaceae	*Portulaca oligosperma*			C		1/1
plants	higher dicots	Portulacaceae	*Grahamia australiana*			C		1/1
plants	higher dicots	Portulacaceae	*Portulaca filifolia*			C		1/1
plants	higher dicots	Portulacaceae	*Calandrinia pumila*			C		1/1
plants	higher dicots	Portulacaceae	*Portulaca sp. (Blackall G.Le Gros AQ101965)*			C		1/1
plants	higher dicots	Proteaceae	*Grevillea striata*	beefwood		C		1/1
plants	higher dicots	Proteaceae	*Hakea arborescens*			C		1/1
plants	higher dicots	Proteaceae	*Hakea chordophylla*			C		2/2
plants	higher dicots	Proteaceae	*Grevillea mimosoides*			C		2/2
plants	higher dicots	Proteaceae	*Hakea lorea subsp. lorea*			C		3/3
plants	higher dicots	Proteaceae	*Grevillea wickhamii subsp. aprica*			C		8/8
plants	higher dicots	Proteaceae	*Grevillea dryandri subsp. dryandri*			C		2/2
plants	higher dicots	Rhamnaceae	*Alphitonia excelsa*	soap tree		C		4/4
plants	higher dicots	Rubiaceae	*Dentella repens*	dentella		C		1/1
plants	higher dicots	Rubiaceae	*Pavetta rupicola*			C		5/5
plants	higher dicots	Rubiaceae	*Psydrax oleifolia*			C		3/3
plants	higher dicots	Rubiaceae	*Oldenlandia galioides*			C		3/3
plants	higher dicots	Rubiaceae	*Spermacoce auriculata*			C		5/5
plants	higher dicots	Rubiaceae	*Kohautia australiensis*			C		2/2
plants	higher dicots	Rubiaceae	*Spermacoce brachystema*			C		5/5
plants	higher dicots	Rubiaceae	*Synaptantha tillaeacea var. tillaeacea*			C		3/3
plants	higher dicots	Rubiaceae	*Oldenlandia mitrasacmoides subsp. mitrasacmoides*			C		2/2
plants	higher dicots	Santalaceae	*Anthobolus leptomerioides*			C		2/2
plants	higher dicots	Santalaceae	*Santalum lanceolatum*			C		4/4
plants	higher dicots	Sapindaceae	*Dodonaea lanceolata var. lanceolata*			C		3/3
plants	higher dicots	Sapindaceae	*Dodonaea viscosa subsp. mucronata*			C		3/3
plants	higher dicots	Sapindaceae	*Dodonaea stenophylla*			C		3/3
plants	higher dicots	Sapindaceae	*Dodonaea barklyana*			C		2/2
plants	higher dicots	Sapindaceae	*Alectryon oleifolius subsp. elongatus*			C		2/2

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Sapindaceae	*Dodonaea viscosa subsp. angustissima*			C		1/1
plants	higher dicots	Scrophulariaceae	*Eremophila latrobei*			C		2/2
plants	higher dicots	Scrophulariaceae	*Eremophila macgillivrayi*			C		1/1
plants	higher dicots	Scrophulariaceae	*Eremophila mitchellii*			C		3/3
plants	higher dicots	Scrophulariaceae	*Eremophila longifolia*	berrigan		C		4/4
plants	higher dicots	Solanaceae	*Nicotiana glauca*	tree tobacco	Y			1/1
plants	higher dicots	Solanaceae	*Solanum torvum*	devil's fig	Y			1/1
plants	higher dicots	Solanaceae	*Datura inoxia*		Y			4/4
plants	higher dicots	Solanaceae	*Solanum succosum*			C		5/5
plants	higher dicots	Solanaceae	*Physalis angulata*		Y			2/2
plants	higher dicots	Solanaceae	*Nicotiana megalosiphon*			C		1/1
plants	higher dicots	Solanaceae	*Nicotiana megalosiphon subsp. sessilifolia*			C		2/2
plants	higher dicots	Solanaceae	*Solanum ferocissimum*			C		3/3
plants	higher dicots	Solanaceae	*Solanum quadriloculatum*			C		7/7
plants	higher dicots	Solanaceae	*Solanum senticosum*			C		7/7
plants	higher dicots	Solanaceae	*Nicotiana benthamiana*			C		2/2
plants	higher dicots	Solanaceae	*Solanum echinatum*			C		5/5
plants	higher dicots	Sparrmanniaceae	*Triumfetta*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Corchorus pumilio*			C		5/5
plants	higher dicots	Sparrmanniaceae	*Corchorus sidoides subsp. vermicularis*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Corchorus sericeus subsp. densiflorus*			C		18/18
plants	higher dicots	Sparrmanniaceae	*Corchorus sidoides subsp. sidoides*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Corchorus sericeus subsp. sericeus*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Triumfetta marsupiata*			C		4/4
plants	higher dicots	Sparrmanniaceae	*Triumfetta johnstonii*			C		5/5
plants	higher dicots	Sparrmanniaceae	*Corchorus tridens*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Triumfetta plumigera*			C		5/5
plants	higher dicots	Sparrmanniaceae	*Triumfetta rupestris*			C		3/3
plants	higher dicots	Sparrmanniaceae	*Corchorus sericeus*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Grewia retusifolia*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Triumfetta triandra*			C		1/1
plants	higher dicots	Sterculiaceae	*Brachychiton collinus*			C		2/2
plants	higher dicots	Stylidiaceae	*Stylidium desertorum*			C		1/1
plants	higher dicots	Stylidiaceae	*Stylidium floribundum*			C		1/1
plants	higher dicots	Tamaricaceae	*Tamarix aphylla*	athel pine	Y			4/4
plants	higher dicots	Ulmaceae	*Trema tomentosa*			C		2/2
plants	higher dicots	Ulmaceae	*Trema tomentosa var. tomentosa*			C		2/2
plants	higher dicots	Verbenaceae	*Phyla nodiflora*	carpetweed		C		1/1
plants	higher dicots	Violaceae	*Hybanthus enneaspermus*			C		3/3
plants	higher dicots	Violaceae	*Hybanthus aurantiacus*			C		6/6
plants	higher dicots	Zygophyllaceae	*Tribulus cistoides*	bulls head vine		C		1/1
plants	higher dicots	Zygophyllaceae	*Tribulopis angustifolia*			C		3/3
plants	higher dicots	Zygophyllaceae	*Tribulus terrestris*	caltrop		C		3/3
plants	higher dicots	Zygophyllaceae	*Tribulopis pentandra*			C		3/3
plants	higher dicots	Zygophyllaceae	*Tribulus astrocarpus*			C		1/1
plants	higher dicots	Zygophyllaceae	*Tribulus*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	liverworts	Liverwort	*Liverwort*			C		1/1
plants	lower dicots	Lauraceae	*Cassytha glabella forma glabella*			C		1/1
plants	lower dicots	Menispermaceae	*Tinospora smilacina*	snakevine		C		3/3
plants	monocots	Araceae	*Spirodela oligorrhiza*			C		3/3
plants	monocots	Colchicaceae	*Iphigenia indica*			C		1/1
plants	monocots	Commelinaceae	*Commelina ensifolia*	scurvy grass		C		1/1
plants	monocots	Cyperaceae	*Cyperus cunninghamii subsp. cunninghamii*			C		4/4
plants	monocots	Cyperaceae	*Cyperus microcephalus subsp. microcephalus*			C		5/5
plants	monocots	Cyperaceae	*Fimbristylis aestivalis var. aestivalis*			C		1/1
plants	monocots	Cyperaceae	*Cyperus cunninghamii subsp. cheradicus*			C		2/2
plants	monocots	Cyperaceae	*Cyperus iria*			C		6/6
plants	monocots	Cyperaceae	*Cyperus exaltatus*	tall flatsedge		C		2/2
plants	monocots	Cyperaceae	*Cyperus betchei subsp. commiscens*			C		3/3
plants	monocots	Cyperaceae	*Schoenoplectus lateriflorus*			C		1/1
plants	monocots	Cyperaceae	*Fimbristylis bisumbellata*			C		1/1
plants	monocots	Cyperaceae	*Schoenoplectus subulatus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus bifax*	western nutgrass		C		1/1
plants	monocots	Cyperaceae	*Cyperus fulvus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus conicus*			C		2/2
plants	monocots	Cyperaceae	*Fuirena ciliaris*			C		1/1
plants	monocots	Cyperaceae	*Cyperus carinatus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus difformis*	rice sedge		C		2/2
plants	monocots	Cyperaceae	*Cyperus microcephalus subsp. saxicola*			C		1/1
plants	monocots	Cyperaceae	*Cyperus vaginatus*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis nuda*			C		1/1
plants	monocots	Cyperaceae	*Cyperus dactylotes*			C		6/6
plants	monocots	Cyperaceae	*Cyperus ixiocarpus*			C		4/4
plants	monocots	Cyperaceae	*Cyperus nervulosus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus pulchellus*			C		2/2
plants	monocots	Cyperaceae	*Cyperus squarrosus*	bearded flatsedge		C		3/3
plants	monocots	Cyperaceae	*Bulbostylis barbata*			C		13/13
plants	monocots	Cyperaceae	*Fimbristylis dichotoma*	common fringe-rush		C		1/1
plants	monocots	Cyperaceae	*Eleocharis atropurpurea*			C		1/1
plants	monocots	Cyperaceae	*Fimbristylis aestivalis*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis littoralis*			C		1/1
plants	monocots	Cyperaceae	*Fimbristylis microcarya*			C		3/3
plants	monocots	Cyperaceae	*Lipocarpha microcephala*			C		4/4
plants	monocots	Cyperaceae	*Bolboschoenus caldwellii*			C		1/1
plants	monocots	Hydrocharitaceae	*Hydrilla verticillata*	hydrilla		C		1/1
plants	monocots	Hydrocharitaceae	*Vallisneria nana*			C		1/1
plants	monocots	Juncaceae	*Juncus aridicola*	tussock rush		C		1/1
plants	monocots	Juncaceae	*Juncus continuus*			C		1/1
plants	monocots	Najadaceae	*Najas marina*			C		2/2
plants	monocots	Poaceae	*Eragrostis tenuifolia*	elastic grass	Y			1/1
plants	monocots	Poaceae	*Aristida*			C		1/1
plants	monocots	Poaceae	*Perotis rara*	comet grass		C		3/3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	monocots	Poaceae	*Eulalia aurea*	silky browntop		C		4/4
plants	monocots	Poaceae	*Aristida acuta*			C		2/2
plants	monocots	Poaceae	*Melinis repens*	red natal grass	Y			4/4
plants	monocots	Poaceae	*Panicum buncei*			C		2/2
plants	monocots	Poaceae	*Sarga plumosum*			C		4/4
plants	monocots	Poaceae	*Chloris inflata*	purpletop chloris	Y			3/3
plants	monocots	Poaceae	*Chloris pumilio*			C		1/1
plants	monocots	Poaceae	*Chloris virgata*	feathertop rhodes grass	Y			1/1
plants	monocots	Poaceae	*Eriachne obtusa*			C		3/3
plants	monocots	Poaceae	*Panicum effusum*			C		5/5
plants	monocots	Poaceae	*Sarga timorense*			C		1/1
plants	monocots	Poaceae	*Sehima nervosum*			C		2/2
plants	monocots	Poaceae	*Setaria surgens*			C		1/1
plants	monocots	Poaceae	*Triodia molesta*			C		5/5
plants	monocots	Poaceae	*Triodia pungens*			C		13/13
plants	monocots	Poaceae	*Eragrostis minor*	smaller stinkgrass	Y			3/3
plants	monocots	Poaceae	*Eragrostis olida*			C		2/2
plants	monocots	Poaceae	*Polytrias indica*		Y			1/1
plants	monocots	Poaceae	*Themeda triandra*	kangaroo grass		C		5/5
plants	monocots	Poaceae	*Triraphis mollis*	purple plumegrass		C		1/1
plants	monocots	Poaceae	*Acrachne racemosa*			C		2/2
plants	monocots	Poaceae	*Aristida contorta*	bunched kerosene grass		C		3/3
plants	monocots	Poaceae	*Aristida pruinosa*			C		3/3
plants	monocots	Poaceae	*Cenchrus robustus*			C		1/1
plants	monocots	Poaceae	*Chloris pectinata*	comb chloris		C		1/1
plants	monocots	Poaceae	*Digitaria brownii*			C		5/5
plants	monocots	Poaceae	*Digitaria gibbosa*			C		3/3
plants	monocots	Poaceae	*Mnesithea formosa*			C		7/7
plants	monocots	Poaceae	*Paspalidium rarum*			C		2/2
plants	monocots	Poaceae	*Setaria apiculata*			C		1/1
plants	monocots	Poaceae	*Paspalidium constrictum*			C		1/1
plants	monocots	Poaceae	*Pseudoraphis spinescens*	spiny mudgrass		C		2/2
plants	monocots	Poaceae	*Schizachyrium perplexum*			C		3/3
plants	monocots	Poaceae	*Sporobolus actinocladus*	katoora grass		C		2/2
plants	monocots	Poaceae	*Cenchrus pennisetiformis*		Y			7/7
plants	monocots	Poaceae	*Enneapogon robustissimus*			C		4/4
plants	monocots	Poaceae	*Sporobolus australasicus*			C		3/3
plants	monocots	Poaceae	*Diplachne fusca var. fusca*			C		2/2
plants	monocots	Poaceae	*Eriochloa pseudoacrotricha*			C		1/1
plants	monocots	Poaceae	*Urochloa gilesii var. gilesii*			C		3/3
plants	monocots	Poaceae	*Cynodon dactylon var. dactylon*		Y			2/2
plants	monocots	Poaceae	*Megathyrsus maximus var. maximus*		Y			1/1
plants	monocots	Poaceae	*Aristida holathera var. holathera*			C		5/5
plants	monocots	Poaceae	*Eriachne pulchella subsp. dominii*			C		4/4
plants	monocots	Poaceae	*Bothriochloa bladhii subsp. bladhii*			C		4/4
plants	monocots	Poaceae	*Eriachne pulchella subsp. pulchella*			C		2/2

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	monocots	Poaceae	*Megathyrsus maximus var. pubiglumis*		Y			1/1
plants	monocots	Poaceae	*Cynodon nlemfuensis var. nlemfuensis*		Y			3/3
plants	monocots	Poaceae	*Urochloa holosericea subsp. velutina*			C		1/1
plants	monocots	Poaceae	*Yakirra australiensis var. intermedia*			C		1/1
plants	monocots	Poaceae	*Panicum decompositum var. decompositum*			C		1/1
plants	monocots	Poaceae	*Yakirra australiensis var. australiensis*			C		1/1
plants	monocots	Poaceae	*Eriachne sp. (Dugald River B.K.Simon+ 3007)*			C		6/6
plants	monocots	Poaceae	*Eriachne mucronata forma (Alpha C.E.Hubbard 7882)*			C		6/6
plants	monocots	Poaceae	*Eriachne mucronata forma (Burnham R.W.Purdie 1370)*			C		8/8
plants	monocots	Poaceae	*Aristida polyclados*			C		2/2
plants	monocots	Poaceae	*Cymbopogon ambiguus*	lemon grass		C		3/3
plants	monocots	Poaceae	*Cymbopogon obtectus*			C		2/2
plants	monocots	Poaceae	*Digitaria ctenantha*			C		1/1
plants	monocots	Poaceae	*Enteropogon ramosus*			C		5/5
plants	monocots	Poaceae	*Eragrostis cumingii*			C		2/2
plants	monocots	Poaceae	*Eragrostis elongata*			C		7/7
plants	monocots	Poaceae	*Eragrostis speciosa*			C		5/5
plants	monocots	Poaceae	*Leptochloa digitata*			C		1/1
plants	monocots	Poaceae	*Oxychloris scariosa*	winged chloris		C		4/4
plants	monocots	Poaceae	*Panicum larcomianum*			C		1/1
plants	monocots	Poaceae	*Tragus australianus*	small burr grass		C		3/3
plants	monocots	Poaceae	*Triodia burbidgeana*			C		3/3
plants	monocots	Poaceae	*Aristida longicollis*			C		3/3
plants	monocots	Poaceae	*Bothriochloa pertusa*		Y			1/1
plants	monocots	Poaceae	*Brachyachne ciliaris*	hairy native couch		C		1/1
plants	monocots	Poaceae	*Dichanthium fecundum*	curly bluegrass		C		3/3
plants	monocots	Poaceae	*Enneapogon asperatus*			C		2/2
plants	monocots	Poaceae	*Enneapogon avenaceus*			C		1/1
plants	monocots	Poaceae	*Eragrostis tenellula*	delicate lovegrass		C		4/4
plants	monocots	Poaceae	*Eragrostis xerophila*			C		1/1
plants	monocots	Poaceae	*Sorghum arundinaceum*	Rhodesian Sudan grass	Y			1/1
plants	monocots	Poaceae	*Tripogon loliiformis*	five minute grass		C		1/1
plants	monocots	Poaceae	*Aristida biglandulosa*			C		3/3
plants	monocots	Poaceae	*Chrysopogon elongatus*			C		1/1
plants	monocots	Poaceae	*Cymbopogon bombycinus*	silky oilgrass		C		3/3
plants	monocots	Poaceae	*Dichanthium annulatum*	sheda grass	Y			1/1
plants	monocots	Poaceae	*Eragrostis desertorum*	woollybutt		C		3/3
plants	monocots	Poaceae	*Eragrostis lanicaulis*			C		1/1
plants	monocots	Poaceae	*Eragrostis leptocarpa*	drooping lovegrass		C		3/3
plants	monocots	Poaceae	*Sporobolus caroli*	fairy grass		C		1/1
plants	monocots	Poaceae	*Triodia basedowii*			C		1/1
plants	monocots	Poaceae	*Triodia bitextura*			C		6/6
plants	monocots	Poaceae	*Triodia brizoides*			C		10/10
plants	monocots	Poaceae	*Triodia longiceps*	giant grey spinifex		C		5/5
plants	monocots	Poaceae	*Urochloa piligera*			C		1/1
plants	monocots	Poaceae	*Xerochloa barbata*			C		4/4

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	monocots	Poaceae	*Aristida latifolia*	feathertop wiregrass		C		1/1
plants	monocots	Poaceae	*Aristida leptopoda*	white speargrass		C		1/1
plants	monocots	Poaceae	*Chrysopogon fallax*			C		1/1
plants	monocots	Poaceae	*Digitaria bicornis*			C		1/1
plants	monocots	Poaceae	*Echinochloa colona*	awnless barnyard grass	Y			1/1
plants	monocots	Poaceae	*Eriachne pulchella*			C		1/1
plants	monocots	Poaceae	*Paspalum distichum*	water couch		C		1/1
plants	monocots	Poaceae	*Setaria sphacelata*		Y			1/1
plants	monocots	Poaceae	*Triodia mitchellii*	buck spinifex		C		6/6
plants	monocots	Poaceae	*Yakirra pauciflora*			C		1/1
plants	monocots	Poaceae	*Heteropogon contortus*	black speargrass		C		2/2
plants	monocots	Poaceae	*Iseilema vaginiflorum*	red flinders grass		C		1/1
plants	monocots	Poaceae	*Schizachyrium fragile*	firegrass		C		2/2
plants	monocots	Poaceae	*Aristida inaequiglumis*			C		4/4
plants	monocots	Poaceae	*Bothriochloa ewartiana*	desert bluegrass		C		3/3
plants	monocots	Poaceae	*Enneapogon lindleyanus*			C		1/1
plants	monocots	Poaceae	*Enneapogon polyphyllus*	leafy nineawn		C		4/4
plants	monocots	Poaceae	*Eragrostis trichophora*		Y			1/1
plants	monocots	Poaceae	*Paraneurachne muelleri*			C		2/2
plants	monocots	Poaceae	*Paspalidium basicladum*			C		3/3
plants	monocots	Poaceae	*Urochloa mosambicensis*	sabi grass	Y			1/1
plants	monocots	Poaceae	*Urochloa subquadripara*		Y			1/1
plants	monocots	Poaceae	*Dactyloctenium radulans*	button grass		C		1/1
plants	monocots	Pontederiaceae	*Monochoria cyanea*			C		1/1
plants	monocots	Pontederiaceae	*Eichhornia crassipes*	water hyacinth	Y			1/1
plants	monocots	Potamogetonaceae	*Potamogeton tricarinatus*	floating pondweed		C		1/1
plants	monocots	Typhaceae	*Typha domingensis*			C		1/1
plants		Phrymaceae	*Glossostigma diandrum*			C		1/1
plants		Streptophyceae	*Chara vulgaris*			C		1/1

CODES

I - Y indicates that the taxon is introduced to Queensland and has naturalised.

Q - Indicates the Queensland conservation status of each taxon under the *Nature Conservation Act 1992.* The codes are Extinct in the Wild (PE), Endangered (E), Vulnerable (V), Near Threatened (NT), Least Concern (C) or Not Protected ( ).

A - Indicates the Australian conservation status of each taxon under the *Environment Protection and Biodiversity Conservation Act 1999.* The values of EPBC are Conservation Dependent (CD), Critically Endangered (CE), Endangered (E), Extinct (EX), Extinct in the Wild (XW) and Vulnerable (V).

Records – The first number indicates the total number of records of the taxon for the record option selected (i.e. All, Confirmed or Specimens).
This number is output as 99999 if it equals or exceeds this value. The second number located after the / indicates the number of specimen records for the taxon.
This number is output as 999 if it equals or exceeds this value.

Queensland Government

Wildlife Online Extract

Search Criteria:	Species List for a Defined Area
	Species: All
	Type: All
	Status: All
	Records: All
	Date: All
	Latitude: 20.4236 to 21.0048
	Longitude: 140.5269 to 139.8569
	Email: hdick@aarc.net.au
	Date submitted: Tuesday 17 Jun 2014 16:44:59
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Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	amphibians	Bufonidae	*Rhinella marina*	cane toad	Y			2
animals	amphibians	Hylidae	*Litoria rubella*	ruddy treefrog		C		1
animals	amphibians	Hylidae	*Litoria caerulea*	common green treefrog		C		1
animals	amphibians	Hylidae	*Litoria electrica*	buzzing treefrog		C		1
animals	amphibians	Hylidae	*Cyclorana australis*	northern snapping frog		C		1
animals	amphibians	Hylidae	*Cyclorana cultripes*	grassland collared frog		C		1
animals	amphibians	Hylidae	*Litoria inermis*	bumpy rocketfrog		C		1
animals	amphibians	Hylidae	*Cyclorana brevipes*	superb collared frog		C		2/1
animals	amphibians	Myobatrachidae	*Uperoleia trachyderma*	orange shouldered gungan		C		1
animals	birds	Acanthizidae	*Smicrornis brevirostris*	weebill		C		71
animals	birds	Acanthizidae	*Gerygone fusca*	western gerygone		C		1
animals	birds	Acanthizidae	*Acanthiza chrysorrhoa*	yellow-rumped thornbill		C		23
animals	birds	Accipitridae	*Pandion cristatus*	eastern osprey		SL		1
animals	birds	Accipitridae	*Aquila audax*	wedge-tailed eagle		C		28
animals	birds	Accipitridae	*Milvus migrans*	black kite		C		113
animals	birds	Accipitridae	*Elanus axillaris*	black-shouldered kite		C		2
animals	birds	Accipitridae	*Hamirostra melanosternon*	black-breasted buzzard		C		2
animals	birds	Accipitridae	*Circus approximans*	swamp harrier		C		1
animals	birds	Accipitridae	*Accipiter fasciatus*	brown goshawk		C		12
animals	birds	Accipitridae	*Haliastur sphenurus*	whistling kite		C		95
animals	birds	Accipitridae	*Haliaeetus leucogaster*	white-bellied sea-eagle		SL		14
animals	birds	Accipitridae	*Hieraaetus morphnoides*	little eagle		C		2
animals	birds	Accipitridae	*Accipiter cirrocephalus*	collared sparrowhawk		C		7
animals	birds	Acrocephalidae	*Acrocephalus australis*	Australian reed-warbler		SL		6
animals	birds	Aegothelidae	*Aegotheles cristatus*	Australian owlet-nightjar		C		8/1
animals	birds	Alaudidae	*Mirafra javanica*	Horsfield's bushlark		C		2
animals	birds	Anatidae	*Anas rhynchotis*	Australasian shoveler		C		1
animals	birds	Anatidae	*Aythya australis*	hardhead		C		60
animals	birds	Anatidae	*Anas superciliosa*	Pacific black duck		C		64
animals	birds	Anatidae	*Dendrocygna eytoni*	plumed whistling-duck		C		4
animals	birds	Anatidae	*Nettapus pulchellus*	green pygmy-goose		C		1
animals	birds	Anatidae	*Malacorhynchus membranaceus*	pink-eared duck		C		20
animals	birds	Anatidae	*Anas gracilis*	grey teal		C		51
animals	birds	Anatidae	*Cygnus atratus*	black swan		C		1
animals	birds	Anatidae	*Chenonetta jubata*	Australian wood duck		C		6
animals	birds	Anhingidae	*Anhinga novaehollandiae*	Australasian darter		C		75
animals	birds	Apodidae	*Apus pacificus*	fork-tailed swift		SL		1
animals	birds	Ardeidae	*Ardea modesta*	eastern great egret		SL		58
animals	birds	Ardeidae	*Egretta garzetta*	little egret		C		12
animals	birds	Ardeidae	*Ixobrychus flavicollis*	black bittern		C		2
animals	birds	Ardeidae	*Nycticorax caledonicus*	Nankeen night-heron		C		21
animals	birds	Ardeidae	*Egretta novaehollandiae*	white-faced heron		C		60
animals	birds	Ardeidae	*Ardea ibis*	cattle egret		SL		3
animals	birds	Ardeidae	*Ardea pacifica*	white-necked heron		C		57
animals	birds	Ardeidae	*Ardea intermedia*	intermediate egret		C		36
animals	birds	Artamidae	*Cracticus tibicen*	Australian magpie		C		55

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Artamidae	*Artamus personatus*	masked woodswallow		C		3
animals	birds	Artamidae	*Strepera graculina*	pied currawong		C		1
animals	birds	Artamidae	*Artamus cyanopterus*	dusky woodswallow		C		1
animals	birds	Artamidae	*Artamus cinereus*	black-faced woodswallow		C		63
animals	birds	Artamidae	*Artamus leucorynchus*	white-breasted woodswallow		C		22
animals	birds	Artamidae	*Artamus superciliosus*	white-browed woodswallow		C		5
animals	birds	Artamidae	*Cracticus nigrogularis*	pied butcherbird		C		65
animals	birds	Artamidae	*Artamus minor*	little woodswallow		C		29
animals	birds	Artamidae	*Cracticus torquatus*	grey butcherbird		C		2
animals	birds	Burhinidae	*Burhinus grallarius*	bush stone-curlew		C		1
animals	birds	Cacatuidae	*Cacatua galerita*	sulphur-crested cockatoo		C		46
animals	birds	Cacatuidae	*Cacatua sanguinea*	little corella		C		36/1
animals	birds	Cacatuidae	*Nymphicus hollandicus*	cockatiel		C		44
animals	birds	Cacatuidae	*Eolophus roseicapillus*	galah		C		72
animals	birds	Campephagidae	*Lalage sueurii*	white-winged triller		C		33
animals	birds	Campephagidae	*Coracina novaehollandiae*	black-faced cuckoo-shrike		C		66
animals	birds	Campephagidae	*Coracina papuensis*	white-bellied cuckoo-shrike		C		3
animals	birds	Campephagidae	*Coracina maxima*	ground cuckoo-shrike		C		4
animals	birds	Casuariidae	*Dromaius novaehollandiae*	emu		C		7
animals	birds	Charadriidae	*Vanellus miles*	masked lapwing		C		40
animals	birds	Charadriidae	*Elseyornis melanops*	black-fronted dotterel		C		48
animals	birds	Charadriidae	*Erythrogonys cinctus*	red-kneed dotterel		C		8
animals	birds	Charadriidae	*Vanellus miles miles*	masked lapwing (northern subspecies)		C		18
animals	birds	Charadriidae	*Charadrius ruficapillus*	red-capped plover		C		1
animals	birds	Ciconiidae	*Ephippiorhynchus asiaticus*	black-necked stork		NT		13
animals	birds	Cisticolidae	*Cisticola exilis*	golden-headed cisticola		C		1
animals	birds	Climacteridae	*Climacteris melanura*	black-tailed treecreeper		C		41/2
animals	birds	Columbidae	*Geophaps plumifera*	spinifex pigeon		C		34/1
animals	birds	Columbidae	*Geopelia striata*	peaceful dove		C		96
animals	birds	Columbidae	*Phaps histrionica*	flock bronzewing		C		1/1
animals	birds	Columbidae	*Phaps chalcoptera*	common bronzewing		C		25
animals	birds	Columbidae	*Ocyphaps lophotes*	crested pigeon		C		46
animals	birds	Columbidae	*Geopelia humeralis*	bar-shouldered dove		C		2
animals	birds	Columbidae	*Geopelia cuneata*	diamond dove		C		50
animals	birds	Columbidae	*Columba livia*	rock dove	Y			5
animals	birds	Coraciidae	*Eurystomus orientalis*	dollarbird		C		3
animals	birds	Corcoracidae	*Struthidea cinerea*	apostlebird		C		18
animals	birds	Corvidae	*Corvus orru*	Torresian crow		C		18
animals	birds	Corvidae	*Corvus bennetti*	little crow		C		4
animals	birds	Corvidae	*Corvus coronoides*	Australian raven		C		83/1
animals	birds	Corvidae	*Corvus sp.*					13
animals	birds	Cuculidae	*Eudynamys orientalis*	eastern koel		C		2
animals	birds	Cuculidae	*Cacomantis variolosus*	brush cuckoo		C		1
animals	birds	Cuculidae	*Centropus phasianinus*	pheasant coucal		C		9
animals	birds	Cuculidae	*Scythrops novaehollandiae*	channel-billed cuckoo		C		1
animals	birds	Cuculidae	*Chalcites basalis*	Horsfield's bronze-cuckoo		C		4

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Cuculidae	*Chalcites osculans*	black-eared cuckoo		C		1
animals	birds	Cuculidae	*Cacomantis pallidus*	pallid cuckoo		C		3
animals	birds	Estrildidae	*Taeniopygia guttata*	zebra finch		C		78
animals	birds	Estrildidae	*Poephila acuticauda*	long-tailed finch		C		13
animals	birds	Estrildidae	*Emblema pictum*	painted finch		C		25
animals	birds	Estrildidae	*Taeniopygia bichenovii*	double-barred finch		C		53
animals	birds	Estrildidae	*Neochmia ruficauda*	star finch		C		2
animals	birds	Estrildidae	*Heteromunia pectoralis*	pictorella mannikin		NT		4
animals	birds	Estrildidae	*Lonchura castaneothorax*	chestnut-breasted mannikin		C		2
animals	birds	Estrildidae	*Erythrura gouldiae*	Gouldian finch		E	E	1
animals	birds	Eurostopodidae	*Eurostopodus argus*	spotted nightjar		C		3
animals	birds	Falconidae	*Falco subniger*	black falcon		C		2
animals	birds	Falconidae	*Falco hypoleucos*	grey falcon		NT		2
animals	birds	Falconidae	*Falco berigora*	brown falcon		C		24/1
animals	birds	Falconidae	*Falco peregrinus*	peregrine falcon		C		1
animals	birds	Falconidae	*Falco cenchroides*	Nankeen kestrel		C		14
animals	birds	Falconidae	*Falco longipennis*	Australian hobby		C		8
animals	birds	Glareolidae	*Stiltia isabella*	Australian pratincole		C		5
animals	birds	Gruidae	*Grus rubicunda*	brolga		C		28
animals	birds	Halcyonidae	*Todiramphus sanctus*	sacred kingfisher		C		24
animals	birds	Halcyonidae	*Dacelo leachii*	blue-winged kookaburra		C		35
animals	birds	Halcyonidae	*Todiramphus pyrrhopygius*	red-backed kingfisher		C		14
animals	birds	Hirundinidae	*Hirundo neoxena*	welcome swallow		C		7
animals	birds	Hirundinidae	*Hirundo sp.*					5
animals	birds	Hirundinidae	*Petrochelidon ariel*	fairy martin		C		32
animals	birds	Hirundinidae	*Petrochelidon nigricans*	tree martin		C		10
animals	birds	Hirundinidae	*Cheramoeca leucosterna*	white-backed swallow		C		2
animals	birds	Jacanidae	*Irediparra gallinacea*	comb-crested jacana		C		5
animals	birds	Laridae	*Gelochelidon nilotica*	gull-billed tern		C		2
animals	birds	Laridae	*Chlidonias hybrida*	whiskered tern		C		4
animals	birds	Laridae	*Hydroprogne caspia*	Caspian tern		SL		39
animals	birds	Laridae	*Chroicocephalus novaehollandiae*	silver gull		C		19
animals	birds	Maluridae	*Malurus melanocephalus*	red-backed fairy-wren		C		7
animals	birds	Maluridae	*Malurus leucopterus*	white-winged fairy-wren		C		2
animals	birds	Maluridae	*Amytornis ballarae*	Kalkadoon grasswren		C		13
animals	birds	Maluridae	*Malurus lamberti*	variegated fairy-wren		C		29
animals	birds	Megaluridae	*Eremiornis carteri*	spinifexbird		C		4
animals	birds	Megaluridae	*Megalurus gramineus*	little grassbird		C		1
animals	birds	Megaluridae	*Cincloramphus cruralis*	brown songlark		C		4
animals	birds	Megaluridae	*Cincloramphus mathewsi*	rufous songlark		C		10
animals	birds	Meliphagidae	*Certhionyx variegatus*	pied honeyeater		C		1
animals	birds	Meliphagidae	*Philemon citreogularis*	little friarbird		C		37
animals	birds	Meliphagidae	*Ptilotula penicillatus*	white-plumed honeyeater		C		125/1
animals	birds	Meliphagidae	*Conopophila rufogularis*	rufous-throated honeyeater		C		20
animals	birds	Meliphagidae	*Acanthagenys rufogularis*	spiny-cheeked honeyeater		C		7
animals	birds	Meliphagidae	*Melithreptus albogularis*	white-throated honeyeater		C		4

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Meliphagidae	*Melithreptus gularis laetior*	golden-backed honeyeater		NT		1
animals	birds	Meliphagidae	*Epthianura aurifrons*	orange chat		C		11
animals	birds	Meliphagidae	*Cissomela pectoralis*	banded honeyeater		C		3
animals	birds	Meliphagidae	*Gavicalis virescens*	singing honeyeater		C		19
animals	birds	Meliphagidae	*Epthianura tricolor*	crimson chat		C		20
animals	birds	Meliphagidae	*Ptilotula plumulus*	grey-fronted honeyeater		C		21
animals	birds	Meliphagidae	*Manorina flavigula*	yellow-throated miner		C		76
animals	birds	Meliphagidae	*Grantiella picta*	painted honeyeater		V		5
animals	birds	Meliphagidae	*Sugomel niger*	black honeyeater		C		4
animals	birds	Meliphagidae	*Ptilotula keartlandi*	grey-headed honeyeater		C		38
animals	birds	Meliphagidae	*Ptilotula flavescens*	yellow-tinted honeyeater		C		6
animals	birds	Meliphagidae	*Lichmera indistincta*	brown honeyeater		C		92
animals	birds	Meliphagidae	*Melithreptus gularis*	black-chinned honeyeater		NT		7
animals	birds	Meliphagidae	*Philemon argenticeps*	silver-crowned friarbird		C		10
animals	birds	Meropidae	*Merops ornatus*	rainbow bee-eater		SL		76
animals	birds	Monarchidae	*Myiagra inquieta*	restless flycatcher		C		40
animals	birds	Monarchidae	*Grallina cyanoleuca*	magpie-lark		C		139
animals	birds	Motacillidae	*Anthus novaeseelandiae*	Australasian pipit		C		14
animals	birds	Nectariniidae	*Dicaeum hirundinaceum*	mistletoebird		C		42
animals	birds	Neosittidae	*Daphoenositta chrysoptera*	varied sittella		C		3
animals	birds	Oriolidae	*Oriolus sagittatus*	olive-backed oriole		C		18
animals	birds	Otididae	*Ardeotis australis*	Australian bustard		C		7
animals	birds	Pachycephalidae	*Colluricincla harmonica*	grey shrike-thrush		C		44
animals	birds	Pachycephalidae	*Oreoica gutturalis*	crested bellbird		C		9
animals	birds	Pachycephalidae	*Pachycephala rufiventris*	rufous whistler		C		54
animals	birds	Pardalotidae	*Pardalotus rubricatus*	red-browed pardalote		C		24
animals	birds	Pardalotidae	*Pardalotus striatus*	striated pardalote		C		74
animals	birds	Passeridae	*Passer domesticus*	house sparrow	Y			14
animals	birds	Pelecanidae	*Pelecanus conspicillatus*	Australian pelican		C		54
animals	birds	Petroicidae	*Petroica goodenovii*	red-capped robin		C		6/1
animals	birds	Petroicidae	*Melanodryas cucullata*	hooded robin		C		4
animals	birds	Petroicidae	*Microeca fascinans*	jacky winter		C		42
animals	birds	Phalacrocoracidae	*Phalacrocorax sulcirostris*	little black cormorant		C		48
animals	birds	Phalacrocoracidae	*Microcarbo melanoleucos*	little pied cormorant		C		57
animals	birds	Phalacrocoracidae	*Phalacrocorax varius*	pied cormorant		C		14
animals	birds	Phalacrocoracidae	*Phalacrocorax carbo*	great cormorant		C		25
animals	birds	Phasianidae	*Coturnix ypsilophora*	brown quail		C		5
animals	birds	Podargidae	*Podargus strigoides*	tawny frogmouth		C		6
animals	birds	Podicipedidae	*Podiceps cristatus*	great crested grebe		C		42
animals	birds	Podicipedidae	*Poliocephalus poliocephalus*	hoary-headed grebe		C		6
animals	birds	Podicipedidae	*Tachybaptus novaehollandiae*	Australasian grebe		C		76
animals	birds	Pomatostomidae	*Pomatostomus temporalis*	grey-crowned babbler		C		83
animals	birds	Psittacidae	*Polytelis alexandrae*	princess parrot		C	V	1
animals	birds	Psittacidae	*Melopsittacus undulatus*	budgerigar		C		40
animals	birds	Psittacidae	*Psitteuteles versicolor*	varied lorikeet		C		67
animals	birds	Psittacidae	*Barnardius zonarius*	Australian ringneck		C		36

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Psittacidae	*Barnardius zonarius macgillivrayi*	Cloncurry parrot		C		24/14
animals	birds	Psittacidae	*Aprosmictus erythropterus*	red-winged parrot		C		59/3
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus maculatus*	spotted bowerbird		C		64
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus nuchalis*	great bowerbird		C		8
animals	birds	Rallidae	*Porphyrio porphyrio*	purple swamphen		C		2
animals	birds	Rallidae	*Tribonyx ventralis*	black-tailed native-hen		C		1
animals	birds	Rallidae	*Gallinula tenebrosa*	dusky moorhen		C		11
animals	birds	Rallidae	*Fulica atra*	Eurasian coot		C		18
animals	birds	Recurvirostridae	*Himantopus himantopus*	black-winged stilt		C		52
animals	birds	Recurvirostridae	*Recurvirostra novaehollandiae*	red-necked avocet		C		2
animals	birds	Rhipiduridae	*Rhipidura leucophrys*	willie wagtail		C		149
animals	birds	Rhipiduridae	*Rhipidura albiscapa*	grey fantail		C		4
animals	birds	Scolopacidae	*Tringa nebularia*	common greenshank		SL		1
animals	birds	Scolopacidae	*Tringa stagnatilis*	marsh sandpiper		SL		1
animals	birds	Strigidae	*Ninox boobook*	southern boobook		C		6
animals	birds	Threskiornithidae	*Platalea regia*	royal spoonbill		C		5
animals	birds	Threskiornithidae	*Threskiornis molucca*	Australian white ibis		C		15
animals	birds	Threskiornithidae	*Platalea flavipes*	yellow-billed spoonbill		C		1
animals	birds	Threskiornithidae	*Threskiornis spinicollis*	straw-necked ibis		C		33
animals	birds	Threskiornithidae	*Plegadis falcinellus*	glossy ibis		SL		6
animals	birds	Turnicidae	*Turnix velox*	little button-quail		C		2
animals	insects	Lycaenidae	*Theclinesthes miskini miskini*	wattle blue (Australian subspecies)				1
animals	insects	Nymphalidae	*Euploea core corinna*	common crow				1
animals	insects	Nymphalidae	*Junonia villida calybe*	meadow argus				1
animals	insects	Nymphalidae	*Hypolimnas bolina nerina*	varied eggfly				1
animals	insects	Papilionidae	*Papilio aegeus aegeus*	orchard swallowtail (Australian subspecies)				1
animals	insects	Papilionidae	*Papilio demoleus sthenelus*	chequered swallowtail				1
animals	malacostracans	Parastacidae	*Cherax quadricarinatus*	redclaw				1
animals	mammals	Bovidae	*Bos sp.*	cattle	Y			1
animals	mammals	Emballonuridae	*Taphozous georgianus*	common sheathtail bat		C		1
animals	mammals	Emballonuridae	*Taphozous troughtoni*	Troughton's sheathtail bat		C		1/1
animals	mammals	Macropodidae	*Lagorchestes conspicillatus*	spectacled hare-wallaby		C		2
animals	mammals	Macropodidae	*Petrogale purpureicollis*	purple-necked rock-wallaby		V		9/1
animals	mammals	Macropodidae	*Macropus robustus*	common wallaroo		C		4
animals	mammals	Macropodidae	*Macropus rufus*	red kangaroo		C		1
animals	mammals	Macropodidae	*Macropus agilis*	agile wallaby		C		2
animals	mammals	Muridae	*Pseudomys johnsoni*			C		9
animals	mammals	Muridae	*Zyzomys argurus*	common rock-rat		C		3
animals	mammals	Pteropodidae	*Pteropus scapulatus*	little red flying-fox		C		1
animals	mammals	Tachyglossidae	*Tachyglossus aculeatus*	short-beaked echidna		SL		1
animals	mammals	Vespertilionidae	*Chalinolobus gouldii*	Gould's wattled bat		C		1
animals	mammals	Vespertilionidae	*Vespadelus finlaysoni*	Finlayson's cave bat		C		1/1
animals	ray-finned fishes	Ambassidae	*Ambassis macleayi*	Macleay's glassfish				14
animals	ray-finned fishes	Ambassidae	*Ambassis species*	northwest glassfish				27
animals	ray-finned fishes	Ambassidae	*Parambassis gulliveri*	giant glassfish				5

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	ray-finned fishes	Ambassidae	*Ambassis sp.*					31
animals	ray-finned fishes	Ariidae	*Neoarius leptaspis*	boofhead catfish				2
animals	ray-finned fishes	Centropomidae	*Lates calcarifer*	barramundi				23
animals	ray-finned fishes	Clupeidae	*Nematalosa erebi*	bony bream				706
animals	ray-finned fishes	Eleotridae	*Oxyeleotris selheimi*	blackbanded gudgeon				186
animals	ray-finned fishes	Eleotridae	*Oxyeleotris lineolata*	sleepy cod				22
animals	ray-finned fishes	Gobiidae	*Glossogobius aureus*	golden flathead goby				6
animals	ray-finned fishes	Gobiidae	*Glossogobius giuris*	tank goby				1
animals	ray-finned fishes	Melanotaeniidae	*Melanotaenia splendida inornata*	checkered rainbowfish				456
animals	ray-finned fishes	Plotosidae	*Anodontiglanis dahli*	toothless catfish				1
animals	ray-finned fishes	Terapontidae	*Leiopotherapon unicolor*	spangled perch				137
animals	ray-finned fishes	Terapontidae	*Hephaestus fuliginosus*	sooty grunter				21
animals	ray-finned fishes	Terapontidae	*Amniataba percoides*	barred grunter				202
animals	ray-finned fishes	Terapontidae	*Scortum ogilbyi*	Gulf grunter				1
animals	reptiles	Agamidae	*Ctenophorus caudicinctus*	ring-tailed dragon		C		1
animals	reptiles	Agamidae	*Pogona vitticeps*			C		3/1
animals	reptiles	Agamidae	*Amphibolurus gilberti*	Gilbert's dragon		C		3/2
animals	reptiles	Agamidae	*Tympanocryptis lineata*	lined earless dragon		C		1
animals	reptiles	Boidae	*Antaresia stimsoni*	Stimson's python		C		1
animals	reptiles	Boidae	*Aspidites melanocephalus*	black-headed python		C		1
animals	reptiles	Diplodactylidae	*Strophurus ciliaris*	spiny-tailed gecko		C		1/1
animals	reptiles	Elapidae	*Suta suta*	myall snake		C		1/1
animals	reptiles	Elapidae	*Pseudonaja nuchalis sensu lato*	western brown snake		C		1
animals	reptiles	Gekkonidae	*Heteronotia binoei*	Bynoe's gecko		C		2/1
animals	reptiles	Gekkonidae	*Gehyra versicolor*			C		2/2
animals	reptiles	Gekkonidae	*Gehyra robusta*			C		1
animals	reptiles	Pygopodidae	*Lialis burtonis*	Burton's legless lizard		C		2
animals	reptiles	Pygopodidae	*Delma nasuta*	sharp-snouted legless lizard		C		2
animals	reptiles	Pygopodidae	*Delma borea*			C		1
animals	reptiles	Pygopodidae	*Pygopus steelescotti*	northern hooded scaly-foot		C		1/1
animals	reptiles	Scincidae	*Cryptoblepharus plagiocephalus sensu lato*			C		1/1
animals	reptiles	Scincidae	*Tiliqua multifasciata*	Centralian blue-tongued lizard		C		3/2
animals	reptiles	Scincidae	*Tiliqua scincoides*	eastern blue-tongued lizard		C		1/1
animals	reptiles	Scincidae	*Ctenotus lateralis*			C		1
animals	reptiles	Scincidae	*Ctenotus hebetior*			C		1/1
animals	reptiles	Scincidae	*Egernia hosmeri*	Hosmer's skink		C		3/2
animals	reptiles	Varanidae	*Varanus mertensi*	Mertens' water monitor		C		1
animals	uncertain	Indeterminate	*Indeterminate*	Unknown or Code Pending		C		1
fungi	club fungi	Basidiomycota	*Polyporus*			C		1/1
fungi	sac fungi	Physciaceae	*Dirinaria confluens*			C		1/1
plants	ferns	Adiantaceae	*Cheilanthes brownii*			C		1/1
plants	ferns	Adiantaceae	*Cheilanthes nudiuscula*			C		1/1
plants	ferns	Adiantaceae	*Cheilanthes sieberi subsp. pseudovellea*			C		1/1
plants	ferns	Salviniaceae	*Salvinia molesta*	salvinia	Y			1/1
plants	higher dicots	Aizoaceae	*Trianthema triquetra*	red spinach		C		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera denticulata*	lesser joyweed		C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Amaranthaceae	*Aerva javanica*		Y			9/9
plants	higher dicots	Amaranthaceae	*Gomphrena arida*			C		2/2
plants	higher dicots	Amaranthaceae	*Gomphrena lanata*			C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus incanus*			C		2/2
plants	higher dicots	Amaranthaceae	*Ptilotus obovatus*			C		2/2
plants	higher dicots	Amaranthaceae	*Ptilotus spicatus*			C		1/1
plants	higher dicots	Amaranthaceae	*Achyranthes aspera*			C		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera nana*	hairy joyweed		C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus leucocoma*			C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus fusiformis*			C		2/2
plants	higher dicots	Amaranthaceae	*Ptilotus schwartzii*			C		1/1
plants	higher dicots	Amaranthaceae	*Amaranthus undulatus*			C		2/2
plants	higher dicots	Amaranthaceae	*Ptilotus maconochiei*			NT		1/1
plants	higher dicots	Amaranthaceae	*Gomphrena celosioides*	gomphrena weed	Y			1/1
plants	higher dicots	Amaranthaceae	*Ptilotus sessilifolius*			C		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera angustifolia*			C		1/1
plants	higher dicots	Apocynaceae	*Cryptostegia grandiflora*	rubber vine	Y			1/1
plants	higher dicots	Apocynaceae	*Sarcostemma brevipedicellatum*			C		1/1
plants	higher dicots	Apocynaceae	*Carissa lanceolata*			C		2/2
plants	higher dicots	Apocynaceae	*Calotropis procera*		Y			3/3
plants	higher dicots	Asteraceae	*Rhodanthe microglossa*	clustered sunray		C		1/1
plants	higher dicots	Asteraceae	*Streptoglossa bubakii*			C		1/1
plants	higher dicots	Asteraceae	*Acanthospermum hispidum*	star burr	Y			1/1
plants	higher dicots	Asteraceae	*Pterocaulon sphacelatum*	applebush		C		1/1
plants	higher dicots	Asteraceae	*Streptoglossa decurrens*			C		3/3
plants	higher dicots	Asteraceae	*Apowollastonia cylindrica*			C		1/1
plants	higher dicots	Asteraceae	*Blumea tenella*			C		1/1
plants	higher dicots	Asteraceae	*Pterocaulon serrulatum var. velutinum*			C		1/1
plants	higher dicots	Asteraceae	*Pterocaulon serrulatum var. serrulatum*			C		2/2
plants	higher dicots	Asteraceae	*Rutidosis helichrysoides subsp. acutiglumis*			C		1/1
plants	higher dicots	Asteraceae	*Peripleura obovata*			C		1/1
plants	higher dicots	Asteraceae	*Eclipta prostrata*	white eclipta		C		1/1
plants	higher dicots	Asteraceae	*Glossocardia*			C		1/1
plants	higher dicots	Asteraceae	*Pseudognaphalium luteoalbum*	Jersey cudweed		C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium haesum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium conocarpum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium styotrichum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium cunninghamii*			C		4/4
plants	higher dicots	Boraginaceae	*Trichodesma zeylanicum var. zeylanicum*			C		2/2
plants	higher dicots	Boraginaceae	*Heliotropium ballii*			C		2/2
plants	higher dicots	Byttneriaceae	*Melochia pyramidata*		Y			1/1
plants	higher dicots	Cactaceae	*Cylindropuntia fulgida var. mamillata*		Y			1/1
plants	higher dicots	Caesalpiniaceae	*Lysiphyllum cunninghamii*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Petalostylis cassioides*			C		4/4
plants	higher dicots	Caesalpiniaceae	*Senna planitiicola*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna notabilis*			C		1/1

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plants	higher dicots	Caesalpiniaceae	*Senna venusta*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna glutinosa subsp. pruinosa*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna artemisioides subsp. helmsii*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna artemisioides subsp. sturtii*			C		1/1
plants	higher dicots	Campanulaceae	*Lobelia arnhemiaca*			C		1/1
plants	higher dicots	Caryophyllaceae	*Polycarpaea breviflora*			C		1/1
plants	higher dicots	Caryophyllaceae	*Polycarpaea spirostylis subsp. glabra*			C		2/2
plants	higher dicots	Chenopodiaceae	*Salsola australis*			C		1/1
plants	higher dicots	Chenopodiaceae	*Einadia nutans*			C		2/2
plants	higher dicots	Chenopodiaceae	*Dysphania rhadinostachya subsp. rhadinostachya*			C		2/2
plants	higher dicots	Cleomaceae	*Cleome viscosa*	tick-weed		C		2/2
plants	higher dicots	Combretaceae	*Terminalia aridicola subsp. aridicola*			C		1/1
plants	higher dicots	Convolvulaceae	*Ipomoea muelleri*	poison morning-glory		C		2/2
plants	higher dicots	Convolvulaceae	*Ipomoea coptica*			C		1/1
plants	higher dicots	Convolvulaceae	*Polymeria longifolia*	polymeria		C		1/1
plants	higher dicots	Convolvulaceae	*Operculina aequisepala*			C		2/2
plants	higher dicots	Convolvulaceae	*Bonamia media var. media*			C		1/1
plants	higher dicots	Convolvulaceae	*Evolvulus alsinoides var. decumbens*			C		1/1
plants	higher dicots	Convolvulaceae	*Ipomoea nil*		Y			1/1
plants	higher dicots	Convolvulaceae	*Bonamia media*			C		1/1
plants	higher dicots	Cucurbitaceae	*Momordica balsamina*	balsam apple	Y			3/3
plants	higher dicots	Ebenaceae	*Diospyros humilis*	small-leaved ebony		C		1/1
plants	higher dicots	Elatinaceae	*Bergia trimera*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia tannensis subsp. eremophila*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia biconvexa*			C		1/1
plants	higher dicots	Euphorbiaceae	*Jatropha gossypiifolia*	bellyache bush	Y			2/2
plants	higher dicots	Euphorbiaceae	*Euphorbia australis var. subtomentosa*			C		2/2
plants	higher dicots	Fabaceae	*Indigofera hirsuta*	hairy indigo		C		1/1
plants	higher dicots	Fabaceae	*Cullen pustulatum*			C		1/1
plants	higher dicots	Fabaceae	*Cullen balsamicum*			C		5/5
plants	higher dicots	Fabaceae	*Cajanus pubescens*			C		2/2
plants	higher dicots	Fabaceae	*Vigna lanceolata*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia virens*			C		1/1
plants	higher dicots	Fabaceae	*Swainsona burkei*			C		2/2
plants	higher dicots	Fabaceae	*Glycine falcata*			C		2/2
plants	higher dicots	Fabaceae	*Indigofera linnaei*	Birdsville indigo		C		2/2
plants	higher dicots	Fabaceae	*Cajanus acutifolius*			C		2/2
plants	higher dicots	Fabaceae	*Cajanus lanuginosus*			C		3/3
plants	higher dicots	Fabaceae	*Alysicarpus muelleri*			C		1/1
plants	higher dicots	Fabaceae	*Crotalaria verrucosa*			C		1/1
plants	higher dicots	Fabaceae	*Indigofera pratensis*			C		4/4
plants	higher dicots	Fabaceae	*Galactia*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia lasiochlaena*			C		1/1
plants	higher dicots	Fabaceae	*Crotalaria novae-hollandiae subsp. novae-hollandiae*			C		2/2
plants	higher dicots	Fabaceae	*Tephrosia sp. (Musselbrook M.B.Thomas+ MRS472)*			C		3/3
plants	higher dicots	Fabaceae	*Tephrosia sp. (Adels Grove A.de Lestang 359)*			C		2/2

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plants	higher dicots	Fabaceae	*Tephrosia sp. (Magazine Hill P.Jones 365)*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia brachyodon var. longifolia*			C		4/4
plants	higher dicots	Fabaceae	*Crotalaria aridicola subsp. glabrata*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia rosea var. rosea*			C		1/1
plants	higher dicots	Fabaceae	*Rhynchosia minima var. australis*			C		1/1
plants	higher dicots	Fabaceae	*Vigna lanceolata var. lanceolata*			C		4/4
plants	higher dicots	Goodeniaceae	*Scaevola*			C		3/3
plants	higher dicots	Goodeniaceae	*Goodenia grandiflora*			C		1/1
plants	higher dicots	Goodeniaceae	*Goodenia fascicularis*			C		1/1
plants	higher dicots	Haloragaceae	*Myriophyllum verrucosum*	water milfoil		C		2/1
plants	higher dicots	Lamiaceae	*Clerodendrum floribundum*			C		1/1
plants	higher dicots	Lamiaceae	*Vitex benthamiana*			C		11/11
plants	higher dicots	Lamiaceae	*Mesosphaerum suaveolens*		Y			1/1
plants	higher dicots	Loranthaceae	*Lysiana subfalcata*			C		1/1
plants	higher dicots	Loranthaceae	*Decaisnina brittenii subsp. brittenii*			C		1/1
plants	higher dicots	Loranthaceae	*Lysiana spathulata subsp. spathulata*			C		3/3
plants	higher dicots	Loranthaceae	*Lysiana spathulata subsp. parvifolia*			C		1/1
plants	higher dicots	Loranthaceae	*Amyema sanguinea var. sanguinea*			C		1/1
plants	higher dicots	Lythraceae	*Ammannia multiflora*	jerry-jerry		C		2/1
plants	higher dicots	Malvaceae	*Abelmoschus ficulneus*	native rosella		C		1/1
plants	higher dicots	Malvaceae	*Hibiscus brachychlaenus*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus sturtii var. campylochlamys*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus meraukensis*	Merauke hibiscus		C		2/2
plants	higher dicots	Malvaceae	*Gossypium nelsonii*			C		1/1
plants	higher dicots	Malvaceae	*Gossypium australe*			C		2/2
plants	higher dicots	Malvaceae	*Hibiscus coatesii*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon hannii*			C		2/2
plants	higher dicots	Malvaceae	*Sida fibulifera*			C		3/3
plants	higher dicots	Malvaceae	*Sida goniocarpa*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia hemsleyi*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia tropica*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia acradenia*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia monticola*			C		2/2
plants	higher dicots	Mimosaceae	*Prosopis pallida*		Y			1/1
plants	higher dicots	Mimosaceae	*Acacia chisholmii*			C		9/9
plants	higher dicots	Mimosaceae	*Acacia melleodora*			C		5/5
plants	higher dicots	Mimosaceae	*Acacia orthocarpa*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia tenuissima*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia phlebocarpa*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia chippendalei*			C		1/1
plants	higher dicots	Mimosaceae	*Vachellia bidwillii*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia ancistrocarpa*			C		2/2
plants	higher dicots	Mimosaceae	*Neptunia dimorphantha*			C		1/1
plants	higher dicots	Mimosaceae	*Vachellia sutherlandii*			C		1/1
plants	higher dicots	Mimosaceae	*Neptunia gracilis forma gracilis*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia retivenea subsp. retivenea*			C		1/1

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plants	higher dicots	Mimosaceae	*Acacia victoriae subsp. fasciaria*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia limbata*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia salicina*	doolan		C		1/1
plants	higher dicots	Moraceae	*Ficus rubiginosa forma rubiginosa*			C		1/1
plants	higher dicots	Moraceae	*Ficus aculeata var. aculeata*			C		1/1
plants	higher dicots	Myrtaceae	*Lophostemon grandiflorus subsp. riparius*			C		2/2
plants	higher dicots	Myrtaceae	*Eucalyptus melanophloia subsp. nana*			C		2/2
plants	higher dicots	Myrtaceae	*Corymbia bella*			C		2/2
plants	higher dicots	Myrtaceae	*Corymbia aspera*			C		2/2
plants	higher dicots	Myrtaceae	*Melaleuca nervosa*			C		1/1
plants	higher dicots	Myrtaceae	*Corymbia terminalis*			C		3/3
plants	higher dicots	Myrtaceae	*Melaleuca bracteata*			C		3/2
plants	higher dicots	Myrtaceae	*Eucalyptus nudicaulis*			C		3/3
plants	higher dicots	Myrtaceae	*Melaleuca fluviatilis*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus leucophylla*			C		5/5
plants	higher dicots	Myrtaceae	*Melaleuca dissitiflora*			C		2/2
plants	higher dicots	Myrtaceae	*Melaleuca trichostachya*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus camaldulensis*			C		1
plants	higher dicots	Myrtaceae	*Lophostemon grandiflorus*			C		1
plants	higher dicots	Myrtaceae	*Eucalyptus pruinosa subsp. pruinosa*			C		1/1
plants	higher dicots	Nyctaginaceae	*Boerhavia schomburgkiana*			C		1/1
plants	higher dicots	Nyctaginaceae	*Boerhavia pubescens*			C		2/2
plants	higher dicots	Nyctaginaceae	*Boerhavia sp. (St George A.Hill AQ399299)*			C		1/1
plants	higher dicots	Pedaliaceae	*Josephinia eugeniae*	josephinia burr		C		1/1
plants	higher dicots	Pentapetaceae	*Melhania ovata*			C		1/1
plants	higher dicots	Phyllanthaceae	*Phyllanthus fuernrohrii*			C		1/1
plants	higher dicots	Phyllanthaceae	*Breynia oblongifolia*			C		1/1
plants	higher dicots	Phyllanthaceae	*Phyllanthus carpentariae*			C		1/1
plants	higher dicots	Phyllanthaceae	*Phyllanthus maderaspatensis*			C		1/1
plants	higher dicots	Plantaginaceae	*Stemodia viscosa*			C		3/3
plants	higher dicots	Polygonaceae	*Persicaria barbata*			C		2/1
plants	higher dicots	Portulacaceae	*Portulaca oligosperma*			C		1/1
plants	higher dicots	Portulacaceae	*Portulaca oleracea*	pigweed	Y			1/1
plants	higher dicots	Proteaceae	*Grevillea mimosoides*			C		1/1
plants	higher dicots	Proteaceae	*Hakea arborescens*			C		2/2
plants	higher dicots	Proteaceae	*Hakea lorea subsp. lorea*			C		4/4
plants	higher dicots	Rhamnaceae	*Alphitonia excelsa*	soap tree		C		1/1
plants	higher dicots	Rubiaceae	*Pavetta rupicola*			C		2/2
plants	higher dicots	Rubiaceae	*Kohautia australiensis*			C		1/1
plants	higher dicots	Rubiaceae	*Spermacoce auriculata*			C		1/1
plants	higher dicots	Santalaceae	*Santalum lanceolatum*			C		2/2
plants	higher dicots	Sapindaceae	*Dodonaea lanceolata var. lanceolata*			C		1/1
plants	higher dicots	Sapindaceae	*Dodonaea viscosa subsp. mucronata*			C		1/1
plants	higher dicots	Sapindaceae	*Dodonaea stenophylla*			C		1/1
plants	higher dicots	Scrophulariaceae	*Eremophila longifolia*	berrigan		C		1/1
plants	higher dicots	Scrophulariaceae	*Eremophila oppositifolia subsp. rubra*			C		1/1

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plants	higher dicots	Scrophulariaceae	*Eremophila latrobei subsp. latrobei*			C		3/3
plants	higher dicots	Solanaceae	*Solanum succosum*			C		2/2
plants	higher dicots	Solanaceae	*Solanum quadriloculatum*			C		4/4
plants	higher dicots	Solanaceae	*Solanum echinatum*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Triumfetta rupestris*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Corchorus pumilio*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Corchorus sericeus subsp. densiflorus*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Triumfetta marsupiata*			C		2/2
plants	higher dicots	Sterculiaceae	*Brachychiton collinus*			C		2/2
plants	higher dicots	Ulmaceae	*Trema tomentosa var. tomentosa*			C		1/1
plants	higher dicots	Ulmaceae	*Trema tomentosa*			C		1/1
plants	higher dicots	Verbenaceae	*Phyla nodiflora*	carpetweed		C		1/1
plants	higher dicots	Zygophyllaceae	*Tribulus cistoides*	bulls head vine		C		2/2
plants	higher dicots	Zygophyllaceae	*Tribulus terrestris*	caltrop		C		1/1
plants	higher dicots	Zygophyllaceae	*Tribulopis pentandra*			C		1/1
plants	lower dicots	Lauraceae	*Cassytha capillaris*			C		1/1
plants	monocots	Cyperaceae	*Cyperus brevifolius*	Mullumbimby couch	Y			1
plants	monocots	Cyperaceae	*Cyperus pulchellus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus vaginatus*			C		5/4
plants	monocots	Cyperaceae	*Cyperus difformis*	rice sedge		C		1/1
plants	monocots	Cyperaceae	*Cyperus rotundus*	nutgrass	Y			1/1
plants	monocots	Cyperaceae	*Cyperus iria*			C		1/1
plants	monocots	Cyperaceae	*Fimbristylis aestivalis*			C		1/1
plants	monocots	Najadaceae	*Najas tenuifolia*	water nymph		C		1/1
plants	monocots	Poaceae	*Themeda avenacea*			C		1/1
plants	monocots	Poaceae	*Themeda triandra*	kangaroo grass		C		2/2
plants	monocots	Poaceae	*Aristida pruinosa*			C		2/2
plants	monocots	Poaceae	*Digitaria brownii*			C		1/1
plants	monocots	Poaceae	*Mnesithea formosa*			C		1/1
plants	monocots	Poaceae	*Paspalidium rarum*			C		1/1
plants	monocots	Poaceae	*Triodia brizoides*			C		1/1
plants	monocots	Poaceae	*Triodia longiceps*	giant grey spinifex		C		1/1
plants	monocots	Poaceae	*Aristida latifolia*	feathertop wiregrass		C		1/1
plants	monocots	Poaceae	*Cenchrus setigerus*		Y			1/1
plants	monocots	Poaceae	*Chrysopogon fallax*			C		1/1
plants	monocots	Poaceae	*Echinochloa colona*	awnless barnyard grass	Y			2/1
plants	monocots	Poaceae	*Triodia mitchellii*	buck spinifex		C		1/1
plants	monocots	Poaceae	*Digitaria ctenantha*			C		2/2
plants	monocots	Poaceae	*Aristida longicollis*			C		2/2
plants	monocots	Poaceae	*Dichanthium fecundum*	curly bluegrass		C		4/4
plants	monocots	Poaceae	*Enneapogon asperatus*			C		3/3
plants	monocots	Poaceae	*Enneapogon nigricans*	niggerheads		C		1/1
plants	monocots	Poaceae	*Eragrostis basedowii*			C		1/1
plants	monocots	Poaceae	*Tripogon loliiformis*	five minute grass		C		1/1
plants	monocots	Poaceae	*Urochloa praetervisa*			C		1/1
plants	monocots	Poaceae	*Cymbopogon bombycinus*	silky oilgrass		C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	monocots	Poaceae	*Eragrostis leptocarpa*	drooping lovegrass		C		1/1
plants	monocots	Poaceae	*Heteropogon contortus*	black speargrass		C		2/2
plants	monocots	Poaceae	*Iseilema vaginiflorum*	red flinders grass		C		1/1
plants	monocots	Poaceae	*Bothriochloa ewartiana*	desert bluegrass		C		2/2
plants	monocots	Poaceae	*Enneapogon cylindricus*	jointed nineawn		C		1/1
plants	monocots	Poaceae	*Enneapogon eremophilus*			C		1/1
plants	monocots	Poaceae	*Enneapogon lindleyanus*			C		4/4
plants	monocots	Poaceae	*Enneapogon polyphyllus*	leafy nineawn		C		5/5
plants	monocots	Poaceae	*Paspalidium constrictum*			C		1/1
plants	monocots	Poaceae	*Pseudoraphis spinescens*	spiny mudgrass		C		1/1
plants	monocots	Poaceae	*Eriochloa pseudoacrotricha*			C		1/1
plants	monocots	Poaceae	*Urochloa gilesii var. gilesii*			C		1/1
plants	monocots	Poaceae	*Cynodon dactylon var. dactylon*		Y			1/1
plants	monocots	Poaceae	*Aristida holathera var. holathera*			C		1/1
plants	monocots	Poaceae	*Eriachne pulchella subsp. dominii*			C		1/1
plants	monocots	Poaceae	*Panicum decompositum var. tenuius*			C		1/1
plants	monocots	Poaceae	*Eriachne pulchella subsp. pulchella*			C		1/1
plants	monocots	Poaceae	*Eriachne mucronata forma (Alpha C.E.Hubbard 7882)*			C		2/2
plants	monocots	Poaceae	*Iseilema fragile*			C		1/1
plants	monocots	Poaceae	*Eragrostis olida*			C		1/1
plants	monocots	Poaceae	*Cynodon dactylon*		Y			1
plants	monocots	Poaceae	*Aristida exserta*			C		1/1
plants	monocots	Poaceae	*Triodia pungens*			C		3/3
plants	monocots	Poaceae	*Triodia molesta*			C		1/1
plants	monocots	Poaceae	*Sehima nervosum*			C		2/2
plants	monocots	Poaceae	*Eriachne obtusa*			C		1/1
plants	monocots	Poaceae	*Eulalia aurea*	silky browntop		C		2/2
plants	mosses	Bryophyte	*Bryophyte*			C		1/1

CODES

I - Y indicates that the taxon is introduced to Queensland and has naturalised.

Q - Indicates the Queensland conservation status of each taxon under the *Nature Conservation Act 1992.* The codes are Extinct in the Wild (PE), Endangered (E), Vulnerable (V), Near Threatened (NT), Least Concern (C) or Not Protected ( ).

A - Indicates the Australian conservation status of each taxon under the *Environment Protection and Biodiversity Conservation Act 1999.* The values of EPBC are Conservation Dependent (CD), Critically Endangered (CE), Endangered (E), Extinct (EX), Extinct in the Wild (XW) and Vulnerable (V).

Records – The first number indicates the total number of records of the taxon for the record option selected (i.e. All, Confirmed or Specimens).
This number is output as 99999 if it equals or exceeds this value. The second number located after the / indicates the number of specimen records for the taxon.
This number is output as 999 if it equals or exceeds this value.

Queensland Government

Wildlife Online Extract

Search Criteria:	Species List for a Defined Area
	Species: All
	Type: All
	Status: All
	Records: All
	Date: All
	Latitude: 19.7534 to 20.422
	Longitude: 139.8376 to 139.2124
	Email: hdick@aarc.net.au
	Date submitted: Tuesday 17 Jun 2014 16:59:23
	Date extracted: Tuesday 17 Jun 2014 17:00:15

The number of records retrieved = 475

Disclaimer

As the DSITIA is still in a process of collating and vetting data, it is possible the information given is not complete. The information provided should only be used for the project for which it was requested and it should be appropriately acknowledged as being derived from Wildlife Online when it is used.

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Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	amphibians	Bufonidae	*Rhinella marina*	cane toad	Y			1/1
animals	amphibians	Myobatrachidae	*Uperoleia trachyderma*	orange shouldered gungan		C		1/1
animals	birds	Acanthizidae	*Smicrornis brevirostris*	weebill		C		89
animals	birds	Acanthizidae	*Acanthiza chrysorrhoa*	yellow-rumped thornbill		C		4
animals	birds	Acanthizidae	*Gerygone fusca*	western gerygone		C		1
animals	birds	Accipitridae	*Milvus migrans*	black kite		C		8
animals	birds	Accipitridae	*Accipiter cirrocephalus*	collared sparrowhawk		C		3
animals	birds	Accipitridae	*Accipiter novaehollandiae*	grey goshawk		NT		1
animals	birds	Accipitridae	*Aquila audax*	wedge-tailed eagle		C		8
animals	birds	Accipitridae	*Haliaeetus leucogaster*	white-bellied sea-eagle		SL		2
animals	birds	Accipitridae	*Accipiter fasciatus*	brown goshawk		C		2
animals	birds	Accipitridae	*Haliastur sphenurus*	whistling kite		C		20
animals	birds	Acrocephalidae	*Acrocephalus australis*	Australian reed-warbler		SL		2
animals	birds	Aegothelidae	*Aegotheles cristatus*	Australian owlet-nightjar		C		2
animals	birds	Alcedinidae	*Ceyx azureus*	azure kingfisher		C		3
animals	birds	Anatidae	*Malacorhynchus membranaceus*	pink-eared duck		C		1
animals	birds	Anatidae	*Nettapus coromandelianus*	cotton pygmy-goose		NT		1
animals	birds	Anatidae	*Nettapus pulchellus*	green pygmy-goose		C		2
animals	birds	Anatidae	*Dendrocygna arcuata*	wandering whistling-duck		C		1
animals	birds	Anatidae	*Dendrocygna eytoni*	plumed whistling-duck		C		2
animals	birds	Anatidae	*Chenonetta jubata*	Australian wood duck		C		4
animals	birds	Anatidae	*Anas superciliosa*	Pacific black duck		C		5
animals	birds	Anatidae	*Aythya australis*	hardhead		C		3
animals	birds	Anatidae	*Anas gracilis*	grey teal		C		2
animals	birds	Anatidae	*Cygnus atratus*	black swan		C		1
animals	birds	Anhingidae	*Anhinga novaehollandiae*	Australasian darter		C		13
animals	birds	Ardeidae	*Nycticorax caledonicus*	Nankeen night-heron		C		3
animals	birds	Ardeidae	*Ardea modesta*	eastern great egret		SL		4
animals	birds	Ardeidae	*Ardea pacifica*	white-necked heron		C		8
animals	birds	Ardeidae	*Ardea intermedia*	intermediate egret		C		5
animals	birds	Ardeidae	*Egretta garzetta*	little egret		C		1
animals	birds	Ardeidae	*Egretta novaehollandiae*	white-faced heron		C		4
animals	birds	Ardeidae	*Ixobrychus flavicollis*	black bittern		C		2
animals	birds	Artamidae	*Cracticus nigrogularis*	pied butcherbird		C		16
animals	birds	Artamidae	*Artamus minor*	little woodswallow		C		5
animals	birds	Artamidae	*Artamus cinereus*	black-faced woodswallow		C		33
animals	birds	Artamidae	*Cracticus tibicen*	Australian magpie		C		11
animals	birds	Artamidae	*Artamus leucorynchus*	white-breasted woodswallow		C		9
animals	birds	Cacatuidae	*Nymphicus hollandicus*	cockatiel		C		12
animals	birds	Cacatuidae	*Cacatua sanguinea*	little corella		C		5
animals	birds	Cacatuidae	*Cacatua galerita*	sulphur-crested cockatoo		C		12
animals	birds	Cacatuidae	*Eolophus roseicapillus*	galah		C		13
animals	birds	Campephagidae	*Coracina papuensis*	white-bellied cuckoo-shrike		C		4
animals	birds	Campephagidae	*Lalage sueurii*	white-winged triller		C		9
animals	birds	Campephagidae	*Coracina novaehollandiae*	black-faced cuckoo-shrike		C		16
animals	birds	Casuariidae	*Dromaius novaehollandiae*	emu		C		1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Charadriidae	*Vanellus miles miles*	masked lapwing (northern subspecies)		C		4
animals	birds	Charadriidae	*Vanellus miles*	masked lapwing		C		3
animals	birds	Charadriidae	*Elseyornis melanops*	black-fronted dotterel		C		14
animals	birds	Ciconiidae	*Ephippiorhynchus asiaticus*	black-necked stork		NT		5
animals	birds	Climacteridae	*Climacteris melanura*	black-tailed treecreeper		C		45
animals	birds	Columbidae	*Geopelia cuneata*	diamond dove		C		10
animals	birds	Columbidae	*Geophaps plumifera*	spinifex pigeon		C		7
animals	birds	Columbidae	*Geopelia humeralis*	bar-shouldered dove		C		1
animals	birds	Columbidae	*Phaps chalcoptera*	common bronzewing		C		12
animals	birds	Columbidae	*Ocyphaps lophotes*	crested pigeon		C		10
animals	birds	Columbidae	*Geopelia striata*	peaceful dove		C		32
animals	birds	Columbidae	*Columba livia*	rock dove	Y			1
animals	birds	Coraciidae	*Eurystomus orientalis*	dollarbird		C		4
animals	birds	Corcoracidae	*Struthidea cinerea*	apostlebird		C		6
animals	birds	Corvidae	*Corvus sp.*					1
animals	birds	Corvidae	*Corvus bennetti*	little crow		C		1
animals	birds	Corvidae	*Corvus coronoides*	Australian raven		C		39
animals	birds	Corvidae	*Corvus orru*	Torresian crow		C		2
animals	birds	Cuculidae	*Cacomantis pallidus*	pallid cuckoo		C		1
animals	birds	Cuculidae	*Chalcites basalis*	Horsfield's bronze-cuckoo		C		3
animals	birds	Cuculidae	*Scythrops novaehollandiae*	channel-billed cuckoo		C		1
animals	birds	Cuculidae	*Centropus phasianinus*	pheasant coucal		C		1
animals	birds	Cuculidae	*Eudynamys orientalis*	eastern koel		C		2
animals	birds	Estrildidae	*Taeniopygia guttata*	zebra finch		C		19
animals	birds	Estrildidae	*Emblema pictum*	painted finch		C		2
animals	birds	Estrildidae	*Neochmia ruficauda*	star finch		C		1
animals	birds	Estrildidae	*Poephila acuticauda*	long-tailed finch		C		10
animals	birds	Estrildidae	*Lonchura castaneothorax*	chestnut-breasted mannikin		C		1
animals	birds	Estrildidae	*Heteromunia pectoralis*	pictorella mannikin		NT		4
animals	birds	Estrildidae	*Poephila cincta cincta*	black-throated finch (white-rumped subspecies)		E	E	1
animals	birds	Estrildidae	*Taeniopygia bichenovii*	double-barred finch		C		24
animals	birds	Eurostopodidae	*Eurostopodus argus*	spotted nightjar		C		2
animals	birds	Falconidae	*Falco berigora*	brown falcon		C		4
animals	birds	Falconidae	*Falco longipennis*	Australian hobby		C		2
animals	birds	Falconidae	*Falco cenchroides*	Nankeen kestrel		C		2
animals	birds	Gruidae	*Grus rubicunda*	brolga		C		2
animals	birds	Halcyonidae	*Todiramphus pyrrhopygius*	red-backed kingfisher		C		4
animals	birds	Halcyonidae	*Todiramphus sanctus*	sacred kingfisher		C		5
animals	birds	Halcyonidae	*Dacelo leachii*	blue-winged kookaburra		C		11
animals	birds	Hirundinidae	*Petrochelidon nigricans*	tree martin		C		1
animals	birds	Hirundinidae	*Petrochelidon ariel*	fairy martin		C		5
animals	birds	Jacanidae	*Irediparra gallinacea*	comb-crested jacana		C		4
animals	birds	Laridae	*Gelochelidon nilotica*	gull-billed tern		C		1
animals	birds	Laridae	*Hydroprogne caspia*	Caspian tern		SL		1
animals	birds	Maluridae	*Malurus melanocephalus*	red-backed fairy-wren		C		8

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Maluridae	*Amytornis dorotheae*	Carpentarian grasswren		NT		2
animals	birds	Maluridae	*Malurus lamberti*	variegated fairy-wren		C		38
animals	birds	Maluridae	*Amytornis ballarae*	Kalkadoon grasswren		C		19
animals	birds	Megaluridae	*Cincloramphus mathewsi*	rufous songlark		C		4
animals	birds	Megaluridae	*Eremiornis carteri*	spinifexbird		C		7
animals	birds	Meliphagidae	*Philemon citreogularis*	little friarbird		C		17
animals	birds	Meliphagidae	*Certhionyx variegatus*	pied honeyeater		C		1
animals	birds	Meliphagidae	*Acanthagenys rufogularis*	spiny-cheeked honeyeater		C		2
animals	birds	Meliphagidae	*Ptilotula penicillatus*	white-plumed honeyeater		C		27
animals	birds	Meliphagidae	*Conopophila rufogularis*	rufous-throated honeyeater		C		10
animals	birds	Meliphagidae	*Cissomela pectoralis*	banded honeyeater		C		1
animals	birds	Meliphagidae	*Ptilotula flavescens*	yellow-tinted honeyeater		C		11
animals	birds	Meliphagidae	*Philemon argenticeps*	silver-crowned friarbird		C		9
animals	birds	Meliphagidae	*Lichmera indistincta*	brown honeyeater		C		15
animals	birds	Meliphagidae	*Melithreptus gularis*	black-chinned honeyeater		NT		5
animals	birds	Meliphagidae	*Manorina flavigula*	yellow-throated miner		C		29
animals	birds	Meliphagidae	*Ptilotula plumulus*	grey-fronted honeyeater		C		78
animals	birds	Meliphagidae	*Gavicalis virescens*	singing honeyeater		C		15
animals	birds	Meliphagidae	*Stomiopera unicolor*	white-gaped honeyeater		C		6
animals	birds	Meliphagidae	*Ptilotula keartlandi*	grey-headed honeyeater		C		21
animals	birds	Meropidae	*Merops ornatus*	rainbow bee-eater		SL		23
animals	birds	Monarchidae	*Myiagra inquieta*	restless flycatcher		C		19
animals	birds	Monarchidae	*Grallina cyanoleuca*	magpie-lark		C		37
animals	birds	Motacillidae	*Anthus novaeseelandiae*	Australasian pipit		C		2
animals	birds	Nectariniidae	*Dicaeum hirundinaceum*	mistletoebird		C		12
animals	birds	Neosittidae	*Daphoenositta chrysoptera*	varied sittella		C		3
animals	birds	Oriolidae	*Oriolus sagittatus*	olive-backed oriole		C		7
animals	birds	Otididae	*Ardeotis australis*	Australian bustard		C		1
animals	birds	Pachycephalidae	*Colluricincla harmonica*	grey shrike-thrush		C		22
animals	birds	Pachycephalidae	*Oreoica gutturalis*	crested bellbird		C		3
animals	birds	Pachycephalidae	*Pachycephala rufiventris*	rufous whistler		C		25
animals	birds	Pardalotidae	*Pardalotus rubricatus*	red-browed pardalote		C		9
animals	birds	Pardalotidae	*Pardalotus striatus*	striated pardalote		C		27
animals	birds	Passeridae	*Passer domesticus*	house sparrow	Y			2
animals	birds	Pelecanidae	*Pelecanus conspicillatus*	Australian pelican		C		6
animals	birds	Petroicidae	*Melanodryas cucullata*	hooded robin		C		2
animals	birds	Petroicidae	*Microeca fascinans*	jacky winter		C		12
animals	birds	Phalacrocoracidae	*Phalacrocorax carbo*	great cormorant		C		1
animals	birds	Phalacrocoracidae	*Phalacrocorax sulcirostris*	little black cormorant		C		7
animals	birds	Phalacrocoracidae	*Microcarbo melanoleucos*	little pied cormorant		C		7
animals	birds	Phalacrocoracidae	*Phalacrocorax varius*	pied cormorant		C		1
animals	birds	Phasianidae	*Coturnix ypsilophora*	brown quail		C		4
animals	birds	Podargidae	*Podargus strigoides*	tawny frogmouth		C		2
animals	birds	Podicipedidae	*Tachybaptus novaehollandiae*	Australasian grebe		C		4
animals	birds	Pomatostomidae	*Pomatostomus temporalis*	grey-crowned babbler		C		29
animals	birds	Psittacidae	*Melopsittacus undulatus*	budgerigar		C		8

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Psittacidae	*Barnardius zonarius*	Australian ringneck		C		8
animals	birds	Psittacidae	*Psitteuteles versicolor*	varied lorikeet		C		11
animals	birds	Psittacidae	*Trichoglossus haematodus moluccanus*	rainbow lorikeet		C		1
animals	birds	Psittacidae	*Aprosmictus erythropterus*	red-winged parrot		C		20
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus nuchalis*	great bowerbird		C		5
animals	birds	Ptilonorhynchidae	*Ptilonorhynchus maculatus*	spotted bowerbird		C		8
animals	birds	Rallidae	*Fulica atra*	Eurasian coot		C		1
animals	birds	Rallidae	*Porzana pusilla*	Baillon's crake		C		1
animals	birds	Rallidae	*Gallinula tenebrosa*	dusky moorhen		C		1
animals	birds	Recurvirostridae	*Himantopus himantopus*	black-winged stilt		C		2
animals	birds	Rhipiduridae	*Rhipidura leucophrys*	willie wagtail		C		42
animals	birds	Rhipiduridae	*Rhipidura albiscapa*	grey fantail		C		1
animals	birds	Scolopacidae	*Tringa glareola*	wood sandpiper		SL		1
animals	birds	Strigidae	*Ninox connivens*	barking owl		C		1
animals	birds	Threskiornithidae	*Platalea regia*	royal spoonbill		C		3
animals	birds	Threskiornithidae	*Threskiornis spinicollis*	straw-necked ibis		C		4
animals	birds	Threskiornithidae	*Plegadis falcinellus*	glossy ibis		SL		1
animals	mammals	Canidae	*Canis lupus dingo*	dingo				1
animals	mammals	Macropodidae	*Macropus rufus*	red kangaroo		C		3
animals	mammals	Macropodidae	*Lagorchestes conspicillatus*	spectacled hare-wallaby		C		3
animals	mammals	Vespertilionidae	*Chalinolobus gouldii*	Gould's wattled bat		C		9/9
animals	ray-finned fishes	Ambassidae	*Ambassis species*	northwest glassfish				56
animals	ray-finned fishes	Ambassidae	*Ambassis macleayi*	Macleay's glassfish				250
animals	ray-finned fishes	Apogonidae	*Glossamia aprion*	mouth almighty				52
animals	ray-finned fishes	Ariidae	*Neoarius graeffei*	blue catfish				27
animals	ray-finned fishes	Belonidae	*Strongylura krefftii*	freshwater longtom				68
animals	ray-finned fishes	Centropomidae	*Lates calcarifer*	barramundi				8
animals	ray-finned fishes	Clupeidae	*Nematalosa erebi*	bony bream				351
animals	ray-finned fishes	Eleotridae	*Oxyeleotris selheimi*	blackbanded gudgeon				31
animals	ray-finned fishes	Eleotridae	*Oxyeleotris lineolata*	sleepy cod				97
animals	ray-finned fishes	Gobiidae	*Glossogobius aureus*	golden flathead goby				2
animals	ray-finned fishes	Melanotaeniidae	*Melanotaenia splendida inornata*	checkered rainbowfish				86
animals	ray-finned fishes	Terapontidae	*Hephaestus fuliginosus*	sooty grunter				29
animals	ray-finned fishes	Terapontidae	*Leiopotherapon unicolor*	spangled perch				10
animals	ray-finned fishes	Terapontidae	*Amniataba percoides*	barred grunter				178
animals	ray-finned fishes	Toxotidae	*Toxotes chatareus*	sevenspot archerfish				34
animals	reptiles	Agamidae	*Amphibolurus gilberti*	Gilbert's dragon		C		2/2
animals	reptiles	Agamidae	*Ctenophorus caudicinctus*	ring-tailed dragon		C		1/1
animals	reptiles	Crocodylidae	*Crocodylus johnstoni*	Australian freshwater crocodile		C		1
animals	reptiles	Elapidae	*Demansia flagellatio*			C		1
animals	reptiles	Elapidae	*Suta suta*	myall snake		C		1
animals	reptiles	Gekkonidae	*Gehyra robusta*			C		1/1
animals	reptiles	Scincidae	*Ctenotus pulchellus*			C		3/3
animals	reptiles	Scincidae	*Ctenotus striaticeps*			C		2/2
animals	reptiles	Scincidae	*Ctenotus lateralis*			C		1/1
plants	ferns	Adiantaceae	*Cheilanthes brownii*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Acanthaceae	*Nelsonia campestris*			C		2/2
plants	higher dicots	Amaranthaceae	*Ptilotus fusiformis*			C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus schwartzii*			C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus maconochiei*			NT		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera pungens*	khaki weed	Y			1/1
plants	higher dicots	Amaranthaceae	*Alternanthera sp. (Mt Isa R.L.Specht+ 49)*			C		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera angustifolia*			C		1/1
plants	higher dicots	Amaranthaceae	*Amaranthus interruptus*			C		1/1
plants	higher dicots	Amaranthaceae	*Ptilotus spicatus*			C		1/1
plants	higher dicots	Amaranthaceae	*Gomphrena lanata*			C		1/1
plants	higher dicots	Amaranthaceae	*Alternanthera denticulata*	lesser joyweed		C		1/1
plants	higher dicots	Amaranthaceae	*Amaranthus cochleitepalus*			C		1/1
plants	higher dicots	Apocynaceae	*Marsdenia viridiflora subsp. tropica*			C		1/1
plants	higher dicots	Apocynaceae	*Sarcostemma brevipedicellatum*			C		1/1
plants	higher dicots	Apocynaceae	*Carissa lanceolata*			C		1/1
plants	higher dicots	Asteraceae	*Pterocaulon serrulatum var. velutinum*			C		2/2
plants	higher dicots	Asteraceae	*Centipeda minima subsp. minima*			C		1/1
plants	higher dicots	Asteraceae	*Streptoglossa decurrens*			C		1/1
plants	higher dicots	Asteraceae	*Pterocaulon ciliosum*			C		2/2
plants	higher dicots	Asteraceae	*Tridax procumbens*	tridax daisy	Y			1/1
plants	higher dicots	Asteraceae	*Bidens bipinnata*	bipinnate beggar's ticks	Y			2/2
plants	higher dicots	Asteraceae	*Blumea saxatilis*			C		1/1
plants	higher dicots	Boraginaceae	*Trichodesma zeylanicum var. latisepalum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium cunninghamii*			C		2/2
plants	higher dicots	Boraginaceae	*Heliotropium tenuifolium*			C		3/3
plants	higher dicots	Boraginaceae	*Heliotropium tanythrix*			C		2/2
plants	higher dicots	Boraginaceae	*Heliotropium haesum*			C		1/1
plants	higher dicots	Boraginaceae	*Heliotropium ballii*			C		1/1
plants	higher dicots	Byttneriaceae	*Waltheria indica*			C		1/1
plants	higher dicots	Byttneriaceae	*Melochia pyramidata*		Y			1/1
plants	higher dicots	Caesalpiniaceae	*Senna glutinosa subsp. glutinosa*			C		1/1
plants	higher dicots	Caesalpiniaceae	*Senna notabilis*			C		3/3
plants	higher dicots	Caesalpiniaceae	*Senna venusta*			C		1/1
plants	higher dicots	Caryophyllaceae	*Polycarpaea corymbosa var. corymbosa*			C		2/2
plants	higher dicots	Chenopodiaceae	*Maireana villosa*			C		1/1
plants	higher dicots	Cleomaceae	*Cleome cleomoides*			C		1/1
plants	higher dicots	Cleomaceae	*Cleome viscosa*	tick-weed		C		1/1
plants	higher dicots	Combretaceae	*Terminalia canescens*			C		1/1
plants	higher dicots	Convolvulaceae	*Ipomoea polymorpha*			C		1/1
plants	higher dicots	Convolvulaceae	*Jacquemontia sp. (Fairview R.W.Johnson 4026)*			C		1/1
plants	higher dicots	Convolvulaceae	*Bonamia sp. (Musselbrook M.B.Thomas+ MRS639)*			C		1/1
plants	higher dicots	Convolvulaceae	*Jacquemontia paniculata var. tomentosa*			C		1/1
plants	higher dicots	Convolvulaceae	*Evolvulus alsinoides var. villosicalyx*			C		1/1
plants	higher dicots	Convolvulaceae	*Evolvulus alsinoides var. decumbens*			C		1/1
plants	higher dicots	Convolvulaceae	*Ipomoea antonschmidii*			NT		6/6
plants	higher dicots	Convolvulaceae	*Ipomoea lonchophylla*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Convolvulaceae	*Ipomoea muelleri*	poison morning-glory		C		2/2
plants	higher dicots	Convolvulaceae	*Ipomoea costata*			C		1/1
plants	higher dicots	Convolvulaceae	*Bonamia media*			C		3/3
plants	higher dicots	Cucurbitaceae	*Citrullus lanatus*		Y			1/1
plants	higher dicots	Cucurbitaceae	*Momordica balsamina*	balsam apple	Y			2/2
plants	higher dicots	Euphorbiaceae	*Microstachys chamaelea*			C		2/2
plants	higher dicots	Euphorbiaceae	*Euphorbia hassallii*			C		2/2
plants	higher dicots	Euphorbiaceae	*Euphorbia australis var. subtomentosa*			C		3/3
plants	higher dicots	Euphorbiaceae	*Euphorbia papillata var. papillata*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia trigonosperma*			C		1/1
plants	higher dicots	Euphorbiaceae	*Euphorbia hirta*		Y			2/2
plants	higher dicots	Euphorbiaceae	*Euphorbia coghlanii*			C		2/2
plants	higher dicots	Euphorbiaceae	*Ricinus communis*	castor oil bush	Y			1/1
plants	higher dicots	Fabaceae	*Tephrosia sp. (Magazine Hill P.Jones 365)*			C		2/2
plants	higher dicots	Fabaceae	*Tephrosia phaeosperma var. (Westmoreland S.Melville 967)*			C		3/3
plants	higher dicots	Fabaceae	*Cullen cinereum*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia virens*			C		3/3
plants	higher dicots	Fabaceae	*Rhynchosia minima*			C		1/1
plants	higher dicots	Fabaceae	*Desmodium muelleri*			C		1/1
plants	higher dicots	Fabaceae	*Indigofera colutea*	sticky indigo		C		1/1
plants	higher dicots	Fabaceae	*Indigofera hirsuta*	hairy indigo		C		1/1
plants	higher dicots	Fabaceae	*Indigofera linnaei*	Birdsville indigo		C		1/1
plants	higher dicots	Fabaceae	*Aeschynomene indica*	budda pea		C		2/2
plants	higher dicots	Fabaceae	*Galactia tenuiflora*			C		1/1
plants	higher dicots	Fabaceae	*Alysicarpus muelleri*			C		1/1
plants	higher dicots	Fabaceae	*Crotalaria verrucosa*			C		3/3
plants	higher dicots	Fabaceae	*Indigofera brevidens*			C		1/1
plants	higher dicots	Fabaceae	*Indigofera linifolia*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia delestangii*			C		4/4
plants	higher dicots	Fabaceae	*Tephrosia remotiflora*			C		1/1
plants	higher dicots	Fabaceae	*Aphyllodium biarticulatum*			C		1/1
plants	higher dicots	Fabaceae	*Galactia tenuiflora var. lucida*			C		1/1
plants	higher dicots	Fabaceae	*Galactia tenuiflora forma sericea*			C		1/1
plants	higher dicots	Fabaceae	*Sesbania cannabina var. cannabina*			C		1/1
plants	higher dicots	Fabaceae	*Galactia tenuiflora var. macrantha*			C		1/1
plants	higher dicots	Fabaceae	*Zornia muriculata subsp. angustata*			C		3/3
plants	higher dicots	Fabaceae	*Crotalaria aridicola subsp. glabrata*			C		1/1
plants	higher dicots	Fabaceae	*Crotalaria medicaginea var. neglecta*			C		2/2
plants	higher dicots	Fabaceae	*Tephrosia brachyodon var. longifolia*			C		1/1
plants	higher dicots	Fabaceae	*Tephrosia*			C		1/1
plants	higher dicots	Fabaceae	*Indigofera*			C		1/1
plants	higher dicots	Fabaceae	*Crotalaria dissitiflora subsp. rugosa*			C		1/1
plants	higher dicots	Goodeniaceae	*Goodenia strangfordii*			C		1/1
plants	higher dicots	Goodeniaceae	*Scaevola sp. (Mt Isa P.L.Harris 699)*			C		2/2
plants	higher dicots	Goodeniaceae	*Scaevola amblyanthera*			C		1/1

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plants	higher dicots	Goodeniaceae	*Goodenia ramelii*			C		2/2
plants	higher dicots	Haloragaceae	*Myriophyllum verrucosum*	water milfoil		C		1/1
plants	higher dicots	Lamiaceae	*Mesosphaerum suaveolens*		Y			1/1
plants	higher dicots	Lamiaceae	*Ocimum caryophyllinum*			C		1/1
plants	higher dicots	Lamiaceae	*Vitex benthamiana*			C		1/1
plants	higher dicots	Loganiaceae	*Mitrasacme connata*			C		1/1
plants	higher dicots	Loranthaceae	*Amyema sanguinea var. sanguinea*			C		1/1
plants	higher dicots	Loranthaceae	*Decaisnina brittenii subsp. brittenii*			C		1/1
plants	higher dicots	Loranthaceae	*Amyema quandang var. bancroftii*	broad-leaved grey mistletoe		C		1/1
plants	higher dicots	Loranthaceae	*Lysiana spathulata subsp. spathulata*			C		2/2
plants	higher dicots	Lythraceae	*Rotala mexicana*			C		1/1
plants	higher dicots	Malvaceae	*Sida*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus*			C		4/4
plants	higher dicots	Malvaceae	*Sida spinosa*	spiny sida	Y			1/1
plants	higher dicots	Malvaceae	*Abutilon hannii*			C		3/3
plants	higher dicots	Malvaceae	*Abutilon macrum*			C		1/1
plants	higher dicots	Malvaceae	*Sida cleisocalyx*			C		1/1
plants	higher dicots	Malvaceae	*Sida hackettiana*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon arenarium*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon otocarpum*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon malvifolium*	bastard marshmallow		C		1/1
plants	higher dicots	Malvaceae	*Hibiscus meraukensis*	Merauke hibiscus		C		1/1
plants	higher dicots	Malvaceae	*Hibiscus verdcourtii*			C		1/1
plants	higher dicots	Malvaceae	*Abutilon leucopetalum*			C		1/1
plants	higher dicots	Malvaceae	*Hibiscus pentaphyllus*			C		1/1
plants	higher dicots	Malvaceae	*Sida rohlenae subsp. rohlenae*			C		3/3
plants	higher dicots	Malvaceae	*Hibiscus sturtii var. campylochlamys*			C		2/2
plants	higher dicots	Malvaceae	*Sida sp. (Aramac E.J.Thompson+ JER192)*			C		1/1
plants	higher dicots	Malvaceae	*Sida sp. (Jericho E.J.Thompson+ JER117)*			C		1/1
plants	higher dicots	Malvaceae	*Sida sp. (Musselbrook M.B.Thomas+ MRS437)*			C		7/7
plants	higher dicots	Mimosaceae	*Acacia limbata*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia bivenosa*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia cambagei*	gidgee		C		1/1
plants	higher dicots	Mimosaceae	*Acacia shirleyi*	lancewood		C		2/2
plants	higher dicots	Mimosaceae	*Acacia acradenia*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia calligera*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia galioides*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia gonoclada*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia monticola*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia umbellata*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia chisholmii*			C		5/5
plants	higher dicots	Mimosaceae	*Acacia elachantha*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia hemignosta*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia lysiphloia*			C		8/8
plants	higher dicots	Mimosaceae	*Acacia megalantha*			C		2/2
plants	higher dicots	Mimosaceae	*Acacia orthocarpa*			C		3/3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Mimosaceae	*Acacia tenuissima*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia asperulacea*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia holosericea*			C		4/4
plants	higher dicots	Mimosaceae	*Acacia phlebocarpa*			C		3/3
plants	higher dicots	Mimosaceae	*Acacia stenophylla*	belalie		C		1/1
plants	higher dicots	Mimosaceae	*Acacia chippendalei*			C		1/1
plants	higher dicots	Mimosaceae	*Dichrostachys spicata*			C		1/1
plants	higher dicots	Mimosaceae	*Neptunia dimorphantha*			C		1/1
plants	higher dicots	Mimosaceae	*Vachellia sutherlandii*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia monticola x A.phlebocarpa*			C		3/3
plants	higher dicots	Mimosaceae	*Neptunia gracilis forma gracilis*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia victoriae subsp. fasciaria*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia sp. (Urandangi L.Pedley 2025)*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia drepanocarpa subsp. drepanocarpa*			C		1/1
plants	higher dicots	Mimosaceae	*Acacia sp. (Coolullah M.Lazarides 3988)*			C		6/6
plants	higher dicots	Moraceae	*Ficus aculeata var. aculeata*			C		1/1
plants	higher dicots	Myrtaceae	*Melaleuca argentea*	silver tea-tree		C		2/2
plants	higher dicots	Myrtaceae	*Corymbia terminalis*			C		3/3
plants	higher dicots	Myrtaceae	*Corymbia capricornia*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus herbertiana*	kalumburu gum		C		3/3
plants	higher dicots	Myrtaceae	*Melaleuca trichostachya*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus normantonensis*	Normanton box		C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus leucophylla x E.pruinosa*			C		1/1
plants	higher dicots	Myrtaceae	*Eucalyptus pruinosa subsp. pruinosa*			C		2/2
plants	higher dicots	Myrtaceae	*Eucalyptus camaldulensis subsp. obtusa*			C		1/1
plants	higher dicots	Myrtaceae	*Corymbia grandifolia subsp. grandifolia*			C		1/1
plants	higher dicots	Myrtaceae	*Lophostemon grandiflorus subsp. riparius*			C		2/2
plants	higher dicots	Myrtaceae	*Corymbia*			C		1/1
plants	higher dicots	Myrtaceae	*Corymbia aspera*			C		1/1
plants	higher dicots	Myrtaceae	*Calytrix brownii*			C		2/2
plants	higher dicots	Myrtaceae	*Corymbia polycarpa*	long-fruited bloodwood		C		1/1
plants	higher dicots	Onagraceae	*Ludwigia perennis*			C		1/1
plants	higher dicots	Pentapetaceae	*Melhania ovata*			C		1/1
plants	higher dicots	Phyllanthaceae	*Phyllanthus maderaspatensis*			C		2/2
plants	higher dicots	Phyllanthaceae	*Phyllanthus lacunarius*			C		1/1
plants	higher dicots	Phyllanthaceae	*Breynia oblongifolia*			C		1/1
plants	higher dicots	Picrodendraceae	*Petalostigma quadriloculare*			C		1/1
plants	higher dicots	Plantaginaceae	*Stemodia glabella*			C		2/2
plants	higher dicots	Plantaginaceae	*Stemodia lythrifolia*			C		1/1
plants	higher dicots	Plumbaginaceae	*Plumbago zeylanica*	native plumbago		C		2/2
plants	higher dicots	Polygalaceae	*Polygala pterocarpa*			C		1/1
plants	higher dicots	Polygalaceae	*Polygala*			C		1/1
plants	higher dicots	Proteaceae	*Grevillea dryandri subsp. dryandri*			C		1/1
plants	higher dicots	Proteaceae	*Grevillea wickhamii subsp. aprica*			C		4/4
plants	higher dicots	Proteaceae	*Hakea chordophylla*			C		1/1
plants	higher dicots	Proteaceae	*Hakea arborescens*			C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	higher dicots	Proteaceae	*Grevillea heliosperma*			C		2/2
plants	higher dicots	Rubiaceae	*Oldenlandia mitrasacmoides subsp. mitrasacmoides*			C		1/1
plants	higher dicots	Rubiaceae	*Oldenlandia argillacea*			C		1/1
plants	higher dicots	Rubiaceae	*Spermacoce auriculata*			C		2/2
plants	higher dicots	Rubiaceae	*Oldenlandia galioides*			C		1/1
plants	higher dicots	Rubiaceae	*Spermacoce argillacea*			C		1/1
plants	higher dicots	Sapindaceae	*Dodonaea lanceolata var. lanceolata*			C		1/1
plants	higher dicots	Scrophulariaceae	*Eremophila acrida*			C		1/1
plants	higher dicots	Solanaceae	*Solanum quadriloculatum*			C		2/2
plants	higher dicots	Solanaceae	*Solanum echinatum*			C		2/2
plants	higher dicots	Solanaceae	*Solanum succosum*			C		6/6
plants	higher dicots	Sparrmanniaceae	*Corchorus sericeus subsp. densiflorus*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Triumfetta marsupiata*			C		1/1
plants	higher dicots	Sparrmanniaceae	*Triumfetta rupestris*			C		2/2
plants	higher dicots	Sparrmanniaceae	*Triumfetta plumigera*			C		3/3
plants	higher dicots	Sparrmanniaceae	*Corchorus olitorius*	jute		C		1/1
plants	higher dicots	Sterculiaceae	*Brachychiton collinus*			C		1/1
plants	higher dicots	Violaceae	*Hybanthus enneaspermus*			C		2/2
plants	higher dicots	Violaceae	*Hybanthus aurantiacus*			C		1/1
plants	higher dicots	Zygophyllaceae	*Tribulopis pentandra*			C		2/2
plants	higher dicots	Zygophyllaceae	*Tribulopis solandri*			C		2/2
plants	lower dicots	Lauraceae	*Cassytha filiformis*	dodder laurel		C		1/1
plants	lower dicots	Papaveraceae	*Argemone ochroleuca subsp. ochroleuca*	Mexican poppy	Y			1/1
plants	monocots	Arecaceae	*Livistona rigida*			C		2/2
plants	monocots	Commelinaceae	*Commelina ensifolia*	scurvy grass		C		2/2
plants	monocots	Cyperaceae	*Cyperus bifax*	western nutgrass		C		2/2
plants	monocots	Cyperaceae	*Cyperus fulvus*			C		5/5
plants	monocots	Cyperaceae	*Scleria brownii*			C		2/2
plants	monocots	Cyperaceae	*Cyperus carinatus*			C		7/7
plants	monocots	Cyperaceae	*Cyperus difformis*	rice sedge		C		1/1
plants	monocots	Cyperaceae	*Cyperus vaginatus*			C		3/3
plants	monocots	Cyperaceae	*Cyperus nervulosus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus pulchellus*			C		1/1
plants	monocots	Cyperaceae	*Cyperus squarrosus*	bearded flatsedge		C		1/1
plants	monocots	Cyperaceae	*Fimbristylis elegans*			C		1/1
plants	monocots	Cyperaceae	*Fimbristylis macrantha*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis littoralis*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis microcarya*			C		1/1
plants	monocots	Cyperaceae	*Lipocarpha microcephala*			C		2/2
plants	monocots	Cyperaceae	*Fimbristylis depauperata*			C		1/1
plants	monocots	Cyperaceae	*Cyperus conicus var. conicus*			C		3/3
plants	monocots	Cyperaceae	*Cyperus betchei subsp. betchei*			C		1/1
plants	monocots	Cyperaceae	*Cyperus betchei subsp. commiscens*			C		4/4
plants	monocots	Cyperaceae	*Cyperus cunninghamii subsp. cheradicus*			C		3/3
plants	monocots	Cyperaceae	*Cyperus microcephalus subsp. microcephalus*			C		2/2
plants	monocots	Cyperaceae	*Cyperus iria*			C		2/2

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plants	monocots	Poaceae	*Aristida*			C		1/1
plants	monocots	Poaceae	*Eriachne mucronata forma (Burnham R.W.Purdie 1370)*			C		2/2
plants	monocots	Poaceae	*Eulalia aurea*	silky browntop		C		1/1
plants	monocots	Poaceae	*Sarga plumosum*			C		2/2
plants	monocots	Poaceae	*Eriachne obtusa*			C		1/1
plants	monocots	Poaceae	*Panicum effusum*			C		2/2
plants	monocots	Poaceae	*Sarga timorense*			C		1/1
plants	monocots	Poaceae	*Setaria surgens*			C		1/1
plants	monocots	Poaceae	*Triodia molesta*			C		1/1
plants	monocots	Poaceae	*Triodia pungens*			C		1/1
plants	monocots	Poaceae	*Aristida exserta*			C		3/3
plants	monocots	Poaceae	*Aristida ingrata*			C		1/1
plants	monocots	Poaceae	*Digitaria minima*			C		1/1
plants	monocots	Poaceae	*Eragrostis minor*	smaller stinkgrass	Y			1/1
plants	monocots	Poaceae	*Eriachne ciliata*			C		1/1
plants	monocots	Poaceae	*Iseilema fragile*			C		1/1
plants	monocots	Poaceae	*Aristida nitidula*			C		1/1
plants	monocots	Poaceae	*Aristida pruinosa*			C		1/1
plants	monocots	Poaceae	*Digitaria brownii*			C		2/2
plants	monocots	Poaceae	*Eragrostis fallax*			C		1/1
plants	monocots	Poaceae	*Mnesithea formosa*			C		1/1
plants	monocots	Poaceae	*Paspalidium rarum*			C		2/2
plants	monocots	Poaceae	*Triodia bitextura*			C		3/3
plants	monocots	Poaceae	*Triodia brizoides*			C		2/2
plants	monocots	Poaceae	*Urochloa piligera*			C		1/1
plants	monocots	Poaceae	*Arundinella setosa*			C		3/3
plants	monocots	Poaceae	*Digitaria ciliaris*	summer grass	Y			2/2
plants	monocots	Poaceae	*Echinochloa colona*	awnless barnyard grass	Y			2/2
plants	monocots	Poaceae	*Eriachne mucronata*			C		2/2
plants	monocots	Poaceae	*Eriachne pulchella*			C		1/1
plants	monocots	Poaceae	*Triodia mitchellii*	buck spinifex		C		1/1
plants	monocots	Poaceae	*Eragrostis cumingii*			C		2/2
plants	monocots	Poaceae	*Eragrostis speciosa*			C		1/1
plants	monocots	Poaceae	*Tragus australianus*	small burr grass		C		1/1
plants	monocots	Poaceae	*Bothriochloa pertusa*		Y			1/1
plants	monocots	Poaceae	*Dichanthium fecundum*	curly bluegrass		C		2/2
plants	monocots	Poaceae	*Enneapogon asperatus*			C		1/1
plants	monocots	Poaceae	*Enneapogon nigricans*	niggerheads		C		1/1
plants	monocots	Poaceae	*Eragrostis basedowii*			C		1/1
plants	monocots	Poaceae	*Eragrostis laniflora*			C		1/1
plants	monocots	Poaceae	*Eragrostis stagnalis*			C		1/1
plants	monocots	Poaceae	*Eragrostis tenellula*	delicate lovegrass		C		1/1
plants	monocots	Poaceae	*Iseilema macratherum*			C		1/1
plants	monocots	Poaceae	*Tripogon loliiformis*	five minute grass		C		1/1
plants	monocots	Poaceae	*Cymbopogon bombycinus*	silky oilgrass		C		2/2
plants	monocots	Poaceae	*Eragrostis desertorum*	woollybutt		C		1/1

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	monocots	Poaceae	*Paspalidium clementii*			C		1/1
plants	monocots	Poaceae	*Schizachyrium fragile*	firegrass		C		1/1
plants	monocots	Poaceae	*Aristida inaequiglumis*			C		1/1
plants	monocots	Poaceae	*Bothriochloa ewartiana*	desert bluegrass		C		1/1
plants	monocots	Poaceae	*Enneapogon lindleyanus*			C		2/2
plants	monocots	Poaceae	*Enneapogon polyphyllus*	leafy nineawn		C		2/2
plants	monocots	Poaceae	*Dactyloctenium radulans*	button grass		C		1/1
plants	monocots	Poaceae	*Digitaria nematostachya*			C		1/1
plants	monocots	Poaceae	*Pseudoraphis spinescens*	spiny mudgrass		C		1/1
plants	monocots	Poaceae	*Sporobolus actinocladus*	katoora grass		C		1/1
plants	monocots	Poaceae	*Sporobolus australasicus*			C		1/1
plants	monocots	Poaceae	*Eriachne pulchella subsp. dominii*			C		1/1
plants	monocots	Poaceae	*Eriachne pulchella subsp. pulchella*			C		1/1
plants	monocots	Poaceae	*Dichanthium sericeum subsp. sericeum*			C		1/1
plants	monocots	Poaceae	*Eriachne sp. (Dugald River B.K.Simon+ 3007)*			C		1/1
plants	monocots	Poaceae	*Eriachne mucronata forma (Alpha C.E.Hubbard 7882)*			C		1/1
plants	monocots	Potamogetonaceae	*Potamogeton crispus*	curly pondweed		C		1/1

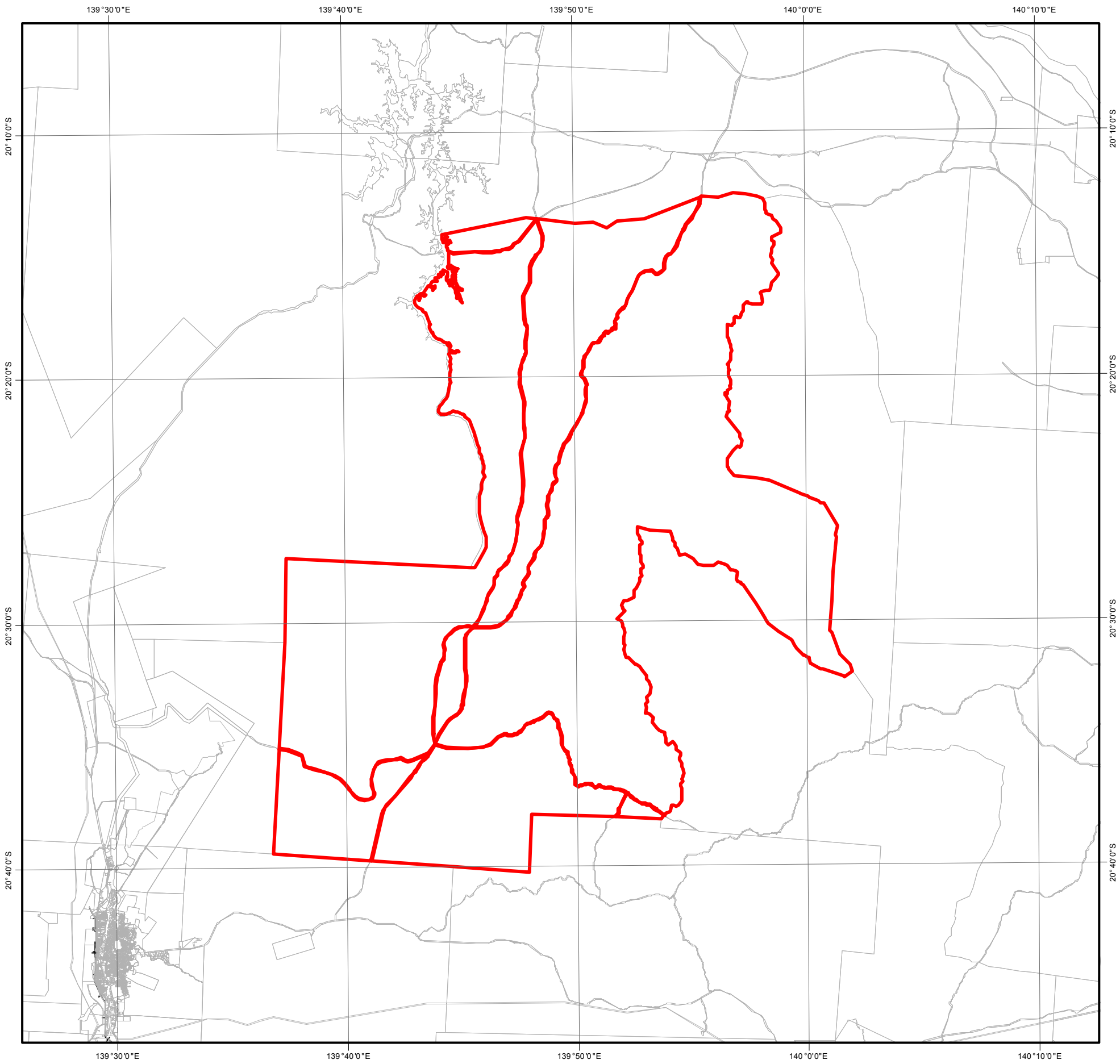
CODES

I - Y indicates that the taxon is introduced to Queensland and has naturalised.

Q - Indicates the Queensland conservation status of each taxon under the *Nature Conservation Act 1992.* The codes are Extinct in the Wild (PE), Endangered (E), Vulnerable (V), Near Threatened (NT), Least Concern (C) or Not Protected ( ).

A - Indicates the Australian conservation status of each taxon under the *Environment Protection and Biodiversity Conservation Act 1999.* The values of EPBC are Conservation Dependent (CD), Critically Endangered (CE), Endangered (E), Extinct (EX), Extinct in the Wild (XW) and Vulnerable (V).

Records – The first number indicates the total number of records of the taxon for the record option selected (i.e. All, Confirmed or Specimens).
This number is output as 99999 if it equals or exceeds this value. The second number located after the / indicates the number of specimen records for the taxon.
This number is output as 999 if it equals or exceeds this value.



Map of Referable Wetlands
Wetland Protection Areas

Requested By: ABUDDERY@AARC.NET.AU
Date: 25 Jun 14 Time: 14.51.12

Centred on Lot on Plan:
1 AA29

Selected Land Parcel

Cadastral Boundary

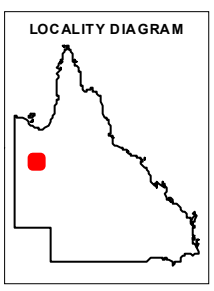
Wetland Protection Areas

Wetland

Trigger Area

Queensland Government

LOCALITY DIAGRAM



N

0 4400 8800 13200 17600 22000 m

This product is projected into GDA 1994 MGA Zone 54

Note:
This map shows the location of wetland protection areas which are defined under the Environmental Protection Regulation 2008. Within wetland protection areas, certain types of development involving high impact earthworks are made assessable under Schedule 3 of the Sustainable Planning Regulation 2009.

The Department of State Development Infrastructure and Planning is the State Assessment Referral Agency (SARA) under Schedule 7 of the Sustainable Planning Regulation 2009 for assessable development involving high impact earthworks within wetland protection areas. The Department of Environment and Heritage Protection is a technical agency.

The policy outcome and assessment criteria for assessing these applications are described in the State Development Assessment Provisions (SDAP) *Module 11: Wetlands and wild rivers*.

This map is produced at a scale relevant to the size of the lot on plan identified and should be printed at A4 size in portrait orientation. Consideration of the effects of mapped scale is necessary when interpreting data at a large scale.

For further information or assistance with interpretation of this product, please contact the Department of Environment and Heritage Protection at www.ehp.qld.gov.au or email planning.support@ehp.qld.gov.au.

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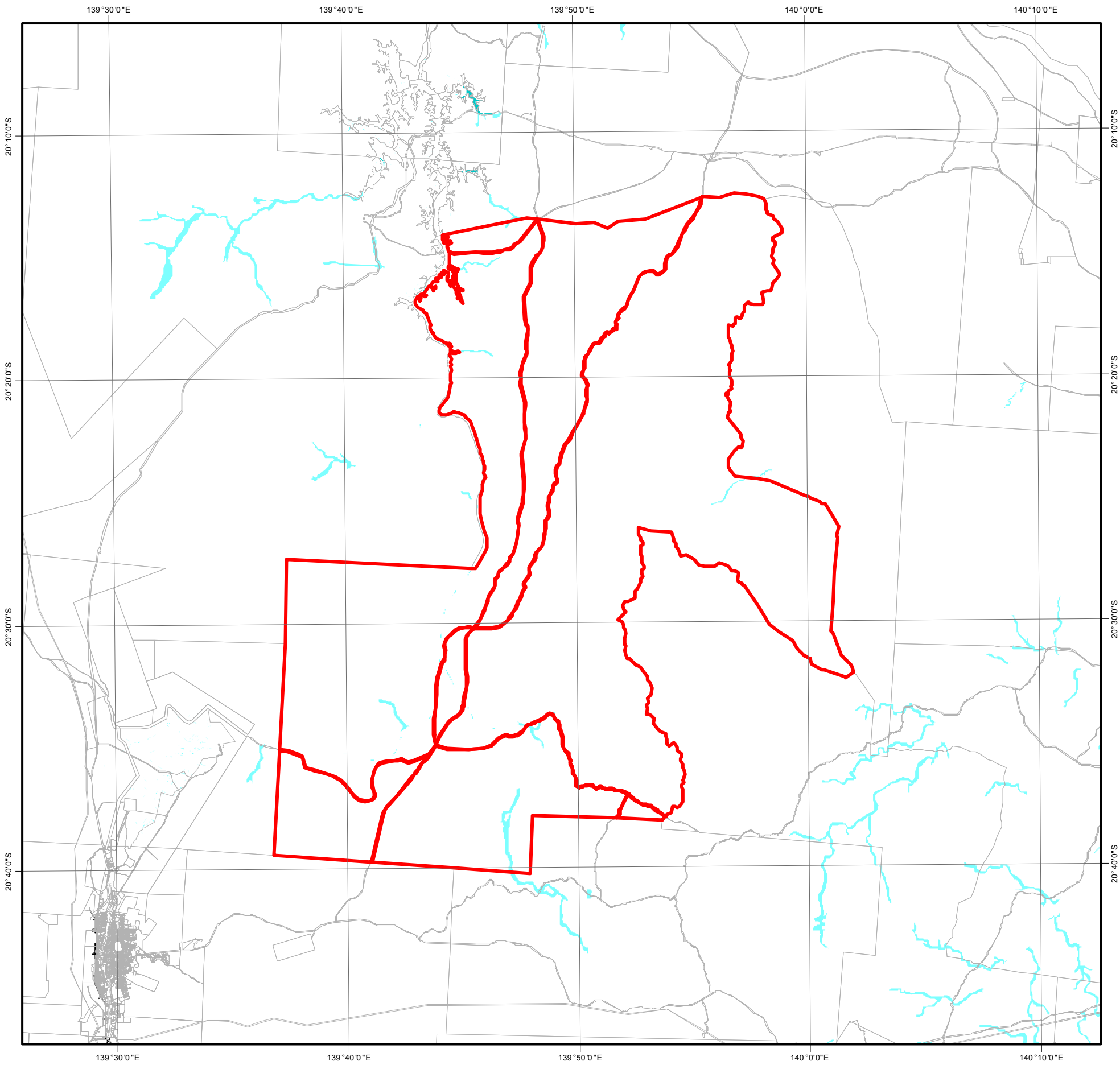


Map of Referable Wetlands for the Environmental Protection Act 1994

Requested By: ABUDDERY@AARC.NET.AU
Date: 25 Jun 14 Time: 14.51.18

Centred on Lot on Plan:
1 AA29

Selected Land Parcel

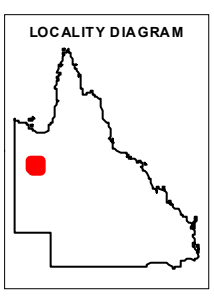
Cadastral Boundary

HES Wetland

GES Wetland

Queensland Government

LOCALITY DIAGRAM



N

0 4400 8800 13200 17600 22000 m

Note:
This map shows the location of wetlands on the Map of Referable Wetlands which are defined under the Environmental Protection Regulation 2008.

Wetlands are assessed for ecological significance using the environmental values for wetlands in section 81A of the Environmental Protection Regulation 2008. Wetlands are considered either High Ecological Significance (HES) or of General Ecological Significance (GES) for the purposes of the environmental values.

This map is produced at a scale relevant to the size of the lot on plan identified and should be printed at A4 size in portrait orientation. Consideration of the effects of mapped scale is necessary when interpreting data at a large scale.

For further information or assistance with interpretation of this product, please contact the Department of Environment and Heritage Protection at <www.ehp.qld.gov.au> or email <planning.support@ehp.qld.gov.au>

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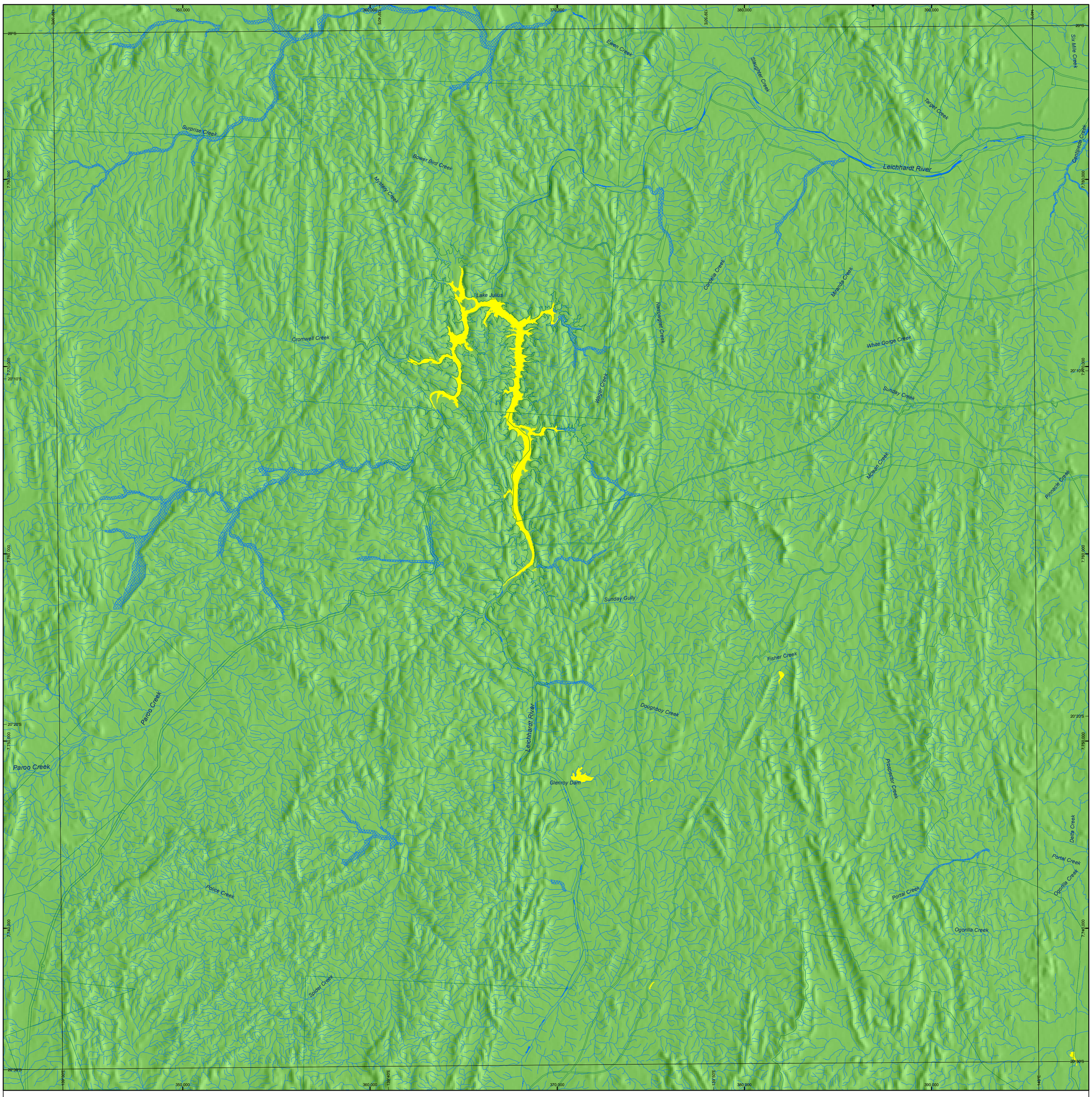
This product is projected into GDA 1994 MGA Zone 54



Water bodies and wetland regional ecosystems

Water bodies	Wetland regional ecosystem	
		Marine system (e.g. open ocean) Open ocean extending to the Queensland 3nm coastal limit. Includes shallow coastal indentations or bays without appreciable freshwater inflows, and coasts that are exposed to oceanic waves and currents. Water regimes are determined primarily by oceanic tides.
		Estuarine system (e.g. mangroves, salt flats and estuaries) Includes wetlands with oceanic water that are significantly diluted with freshwater derived from land drainage.
		Riverine system (e.g. river and creek channels) Wetlands and deepwater habitats contained within a channel. Due to scale constraints these areas may include fringing palustrine vegetation.
		Lacustrine system (e.g. lakes) Wetlands and deepwater habitats situated in a topographic depression or a dammed river channel. Includes areas where emergent perennial vegetation has less than 30% areal coverage and total waterbody area exceeds 8ha.
		Palustrine system (e.g. vegetated swamps) Wetlands dominated by persistent emergent vegetation or where water in deepest part of the basin is less than 2m, active wave formed shores or bedrock features are lacking.
		Wetland point features (e.g. springs, rockholes)
		Riverine system (drainage lines)

Areas that may include wetlands

Remnant regional ecosystem 51–80% wetland (mosaic units)

Remnant regional ecosystem 1–50% wetland (mosaic units)

The above descriptions are an abbreviated version of the full descriptions in the Wetland Mapping and Classification Methodology www.wetlandinfo.ehp.qld.gov.au

Wetlands

For the purposes of mapping and classification, wetlands are:
areas of permanent or periodic/intermittent inundation, with water that is static or flowing , fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6m. To be a wetland the area must have one or more of the following attributes:

i. at least periodically the land supports plants or animals that are adapted to and dependent on living in wet conditions for a t least part of their life cycle, or
ii. the substratum is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic condit ions in the upper layers, or
iii. the substratum is not soil and is saturat ed with water, or covered by water at some time.

Other Feature

- Towns
- Roads
- Cadastral boundaries (>0.5km² area)
- Built-up areas of Queensland
- Ocean outside 3nm limit
- Land at least 1km outside of Queensland

Queensland Wetlands 2009

MAP SERIES VERSION 3.0

PROSPECTOR
6857

N

Horizontal Datum: GDA 1994

Projection: Map Grid of Australia 1994 (MGA94 Zone 54)

0 2 4 6 8 10
Kilometres

Scale 1:100,000 at A1 size

Further information on wetland mapping (including methodology and digital data) is available from www.wetlandinfo.ehp.qld.gov.au

Accuracy information: The positional accuracy of wetland data mapped at a scale of 1:100,000 is +/-100m with a minimum polygon size of 5ha or 75m wide for linear features, except for areas along the east coast which are mapped at the 1:50,000 scale with a positional accuracy of +/-50m, with a minimum polygon size of 1ha or 35m wide for linear features. Wetlands smaller than 1ha are not delineated on the wetland data. Consideration of the effects of mapped scale is necessary when interpreting data at a larger scale, e.g. 1:25,000. For property assessment, digital linework should be used as a guide only. The extent of wetlands depicted on this map is based on rectified 2009 Landsat ETM+ imagery supplied by Statewide Landcover and Trees Study (SLATS), Department of Science, Information Technology, Innovation and the Arts (DSITIA). The extent of water bodies is based on the maximum extent of inundation derived from available Landsat imagery up to and including the 2009 imagery.

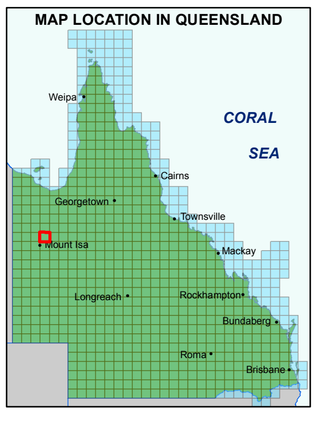
Data sources: Water body mapping derived from satellite imagery, DSITIA; regional ecosystem mapping, DSITIA; drainage mapping, Geoscience Australia (GA), Department of Defence and DSITIA; Roads, MapInfo Australia Pty Ltd, 2006; Towns and Built-up areas, GA, 2003; Coastline, GA, 2004; Queensland 3NM Limit, Australian Maritime Boundaries Information System (AMBIS), GA, 2001; Digital Cadastral Database (DCDB), Department of Natural Resources and Mines, July 2011; Springs database, Queensland Herbarium, 2011; SRTM 90m DEM, USGS/NASA, 2006. Landsat ETM+ imagery supplied by the Australian Centre for Remote Sensing (ACRES), Australian Surveying and Land Information Group (AUSLIG), Canberra. The satellite imagery used in this product has been pre-processed by SLATS, DSITIA.

Disclaimer: While every care is taken to ensure the accuracy of this product, the Queensland and Australian governments and MapInfo Australia Pty Ltd make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which might be incurred as a consequence of reliance on the product, or as a result of the product being inaccurate or incomplete in any way and for any reason.

Date of map production: April 2013 © The State of Queensland 2013

ADJOINING MAPS

MAP LOCATION IN QUEENSLAND



Australian Government

Queensland Government

Queensland Wetlands Program

Appendix B Water and Stream Sediment Laboratory Analysis

CERTIFICATE OF ANALYSIS

Work Order	: **EB1404926**	Page	: 1 of 12
Client	: **AUSTRALASIAN RESOURCE CONSULTANTS**	Laboratory	: Environmental Division Brisbane
Contact	: MS JULIE BYRD	Contact	: Customer Services
Address	: SUITE 5B 1 SWANN ROAD TARINGA QLD, AUSTRALIA 4068	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: jbyrd@aarc.net.au	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 07 32178772	Telephone	: +61 7 3243 7222
Facsimile	: +61 07 32178775	Facsimile	: +61 7 3243 7218
Project	: Copperchem Barbaa Aquatics	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 03-MAR-2014
Sampler	: Alannah Buddery	Issue Date	: 14-MAR-2014
Site	: ----		
		No. of samples received	: 16
Quote number	: BN/274/12	No. of samples analysed	: 16

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EA150H: Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1-2006 was not requested by the client. Typical sediment SPD values used for calculations and consequently NATA endorsement does not apply to hydrometer results.**
- **EG094 (Metals in Freshwater by ORC): It is recognised that EG094T (Total Metals by ORC) is less than EG094F (Dissolved Metals by ORC) for some samples. However, the difference is within experimental variation of the methods.**
- **Ionic balances are within acceptable limits as detailed in the 21st Ed. APHA "Standard Methods for the Examination of Water and Wastewater".**
- **It is recognised that EG020T (Total Metals) is less than EG020F (Dissolved Metals) for some samples. However, the difference is within experimental variation of the methods.**
- **TDS by method EA-015 may bias high due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.**

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Greg Vogel	Laboratory Manager	Brisbane Inorganics
Hamish Murray	Supervisor - Soils	Newcastle - Inorganics
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics
		WB Water Lab Brisbane

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	AQ1	AQ2	AQ3	AQ4	AQ5
			Client sampling date / time	24-FEB-2014 16:15	25-FEB-2014 10:00	25-FEB-2014 14:00	25-FEB-2014 15:15	27-FEB-2014 10:10
Compound	CAS Number	LOR	Unit	EB1404926-007	EB1404926-008	EB1404926-009	EB1404926-010	EB1404926-011
EA150: Particle Sizing								
+75µm	----	1	%	87	84	90	88	91
+150µm	----	1	%	83	72	86	75	86
+300µm	----	1	%	76	67	78	68	77
+425µm	----	1	%	68	58	70	54	69
+600µm	----	1	%	53	47	61	40	61
+1180µm	----	1	%	26	21	46	20	44
+2.36mm	----	1	%	8	7	33	9	34
+4.75mm	----	1	%	2	5	22	4	28
+9.5mm	----	1	%	<1	3	10	<1	22
+19.0mm	----	1	%	<1	<1	<1	<1	11
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	12.9	16.8	1.7	23.2	5.9
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	5	6	3	5	4
Silt (2-60 µm)	----	1	%	7	8	6	5	3
Sand (0.06-2.00 mm)	----	1	%	80	79	58	81	59
Gravel (>2mm)	----	1	%	8	7	33	9	34
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	7940	7970	9970	7710	16500
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	<5
Barium	7440-39-3	10	mg/kg	40	60	90	40	90
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	1
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	13	14	11	17	26
Cobalt	7440-48-4	2	mg/kg	16	12	14	15	26
Copper	7440-50-8	5	mg/kg	24	17	24	75	22
Iron	7439-89-6	50	mg/kg	24700	26900	35600	28800	53800
Lead	7439-92-1	5	mg/kg	<5	<5	<5	<5	<5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	AQ1	AQ2	AQ3	AQ4	AQ5
			Client sampling date / time	24-FEB-2014 16:15	25-FEB-2014 10:00	25-FEB-2014 14:00	25-FEB-2014 15:15	27-FEB-2014 10:10
Compound	CAS Number	LOR	Unit	EB1404926-007	EB1404926-008	EB1404926-009	EB1404926-010	EB1404926-011
EG005T: Total Metals by ICP-AES - Continued								
Manganese	7439-96-5	5	mg/kg	83	83	284	130	232
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	12	8	8	12	22
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Vanadium	7440-62-2	5	mg/kg	44	49	55	67	97
Zinc	7440-66-6	5	mg/kg	9	10	23	17	13
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	AQ6	AQ7	AQ8	AQ9	AQ10
			Client sampling date / time	27-FEB-2014 11:30	28-FEB-2014 09:10	28-FEB-2014 11:15	28-FEB-2014 13:20	28-FEB-2014 15:15
Compound	CAS Number	LOR	Unit	EB1404926-012	EB1404926-013	EB1404926-014	EB1404926-015	EB1404926-016
EA150: Particle Sizing								
+75µm	----	1	%	98	97	92	93	94
+150µm	----	1	%	97	96	86	91	90
+300µm	----	1	%	96	88	84	87	88
+425µm	----	1	%	95	76	79	80	84
+600µm	----	1	%	91	59	73	70	79
+1180µm	----	1	%	75	28	61	48	66
+2.36mm	----	1	%	60	9	50	31	52
+4.75mm	----	1	%	51	4	42	25	44
+9.5mm	----	1	%	40	3	32	19	39
+19.0mm	----	1	%	36	<1	24	14	32
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	18.5	12.1	19.0	12.8	13.2
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	1	2	3	4	3
Silt (2-60 µm)	----	1	%	1	1	4	3	3
Sand (0.06-2.00 mm)	----	1	%	38	88	42	62	42
Gravel (>2mm)	----	1	%	60	9	51	31	52
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	8500	8090	8800	9420	8540
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	6	<5
Barium	7440-39-3	10	mg/kg	60	40	70	40	40
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	16	11	17	20	17
Cobalt	7440-48-4	2	mg/kg	18	16	14	24	14
Copper	7440-50-8	5	mg/kg	10	90	21	23	12
Iron	7439-89-6	50	mg/kg	24800	27400	37000	26500	28800
Lead	7439-92-1	5	mg/kg	<5	<5	<5	<5	<5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	AQ6	AQ7	AQ8	AQ9	AQ10
			Client sampling date / time	27-FEB-2014 11:30	28-FEB-2014 09:10	28-FEB-2014 11:15	28-FEB-2014 13:20	28-FEB-2014 15:15
Compound	CAS Number	LOR	Unit	EB1404926-012	EB1404926-013	EB1404926-014	EB1404926-015	EB1404926-016
EG005T: Total Metals by ICP-AES - Continued								
Manganese	7439-96-5	5	mg/kg	403	132	436	138	98
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	11	15	9	12	10
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Vanadium	7440-62-2	5	mg/kg	48	48	71	68	50
Zinc	7440-66-6	5	mg/kg	11	12	16	11	12
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	AQ1	AQ2	AQ4	AQ6	AQ7
			Client sampling date / time	24-FEB-2014 16:20	25-FEB-2014 10:00	25-MAR-2014 15:10	27-FEB-2014 11:00	28-FEB-2014 08:15
Compound	CAS Number	LOR	Unit	EB1404926-001	EB1404926-002	EB1404926-003	EB1404926-004	EB1404926-005
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	169	184	262	226	199
EA015: Total Dissolved Solids								
Total Dissolved Solids @180°C	----	10	mg/L	126	129	174	140	137
EA025: Suspended Solids								
Suspended Solids (SS)	----	5	mg/L	<5	10	11	<5	7
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	66	71	70	53	44
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	83	90	106	91	81
Total Alkalinity as CaCO3	----	1	mg/L	83	90	106	91	81
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	<1	7	9	6
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	4	4	13	10	9
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	15	17	18	13	11
Magnesium	7439-95-4	1	mg/L	7	7	6	5	4
Sodium	7440-23-5	1	mg/L	6	8	25	24	22
Potassium	7440-09-7	1	mg/L	7	6	6	4	4
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.06	0.05	0.43	0.04	0.56
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.002	0.002	0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Barium	7440-39-3	0.001	mg/L	0.034	0.045	0.051	0.032	0.026
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	7440-48-4	0.001	mg/L	<0.001	0.001	<0.001	<0.001	<0.001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	0.003	0.002	0.025	0.003	0.009
Manganese	7439-96-5	0.001	mg/L	0.040	0.187	0.053	0.090	0.031

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	AQ1	AQ2	AQ4	AQ6	AQ7
			Client sampling date / time	24-FEB-2014 16:20	25-FEB-2014 10:00	25-MAR-2014 15:10	27-FEB-2014 11:00	28-FEB-2014 08:15
Compound	CAS Number	LOR	Unit	EB1404926-001	EB1404926-002	EB1404926-003	EB1404926-004	EB1404926-005
EG020F: Dissolved Metals by ICP-MS - Continued								
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	**0.001**	<0.001	<0.001
Iron	7439-89-6	0.05	mg/L	**3.23**	**1.30**	**0.60**	**0.36**	**0.59**
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	**0.50**	<0.01	**0.64**
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	**0.002**	**0.002**	**0.002**	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Barium	7440-39-3	0.001	mg/L	**0.039**	**0.048**	**0.053**	**0.033**	**0.028**
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	7440-48-4	0.001	mg/L	**0.002**	**0.002**	<0.001	<0.001	<0.001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	**0.003**	**0.002**	**0.032**	**0.002**	**0.012**
Manganese	7439-96-5	0.001	mg/L	**0.161**	**0.222**	**0.077**	**0.121**	**0.039**
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	**0.007**	<0.005	<0.005
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	7439-89-6	0.05	mg/L	**3.83**	**2.01**	**1.12**	**0.54**	**1.08**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG094F: Dissolved Metals in Fresh Water by ORC-ICPMS								

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	AQ1	AQ2	AQ4	AQ6	AQ7
			Client sampling date / time	24-FEB-2014 16:20	25-FEB-2014 10:00	25-MAR-2014 15:10	27-FEB-2014 11:00	28-FEB-2014 08:15
Compound	CAS Number	LOR	Unit	EB1404926-001	EB1404926-002	EB1404926-003	EB1404926-004	EB1404926-005
EG094F: Dissolved Metals in Fresh Water by ORC-ICPMS - Continued								
Selenium	7782-49-2	0.2	µg/L	<0.2	<0.2	0.3	0.3	0.3
Cadmium	7440-43-9	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Chromium	7440-47-3	0.2	µg/L	0.2	<0.2	0.3	<0.2	0.4
Copper	7440-50-8	0.5	µg/L	2.9	1.6	22.7	2.5	9.5
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	0.4	0.2	0.1
EG094T: Total metals in Fresh water by ORC-ICPMS								
Selenium	7782-49-2	0.2	µg/L	0.2	0.2	0.4	<0.2	0.3
Cadmium	7440-43-9	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Chromium	7440-47-3	0.2	µg/L	0.3	<0.2	0.6	<0.2	0.7
Copper	7440-50-8	0.5	µg/L	3.4	2.4	29.2	2.7	11.1
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	0.3	0.2	0.1
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	<0.01	0.02	<0.01	0.02	0.02
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	----	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	<0.01	<0.01	<0.01	0.02	0.09
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	<0.01	<0.01	0.02	0.09
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	1.0	1.1	0.7	0.5	0.4
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	1.0	1.1	0.7	0.5	0.5
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	0.33	0.18	0.08	0.05	0.07
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	0.22	0.03	<0.01	<0.01	0.02
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	1.77	1.91	2.63	2.29	2.00
Total Cations	----	0.01	meq/L	1.76	1.93	2.63	2.21	1.94

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	AQ8	----	----	----	----
			Client sampling date / time	28-FEB-2014 10:30	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1404926-006	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	137	----	----	----	----
EA015: Total Dissolved Solids								
Total Dissolved Solids @180°C	----	10	mg/L	96	----	----	----	----
EA025: Suspended Solids								
Suspended Solids (SS)	----	5	mg/L	6	----	----	----	----
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	27	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	46	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	46	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	6	----	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	10	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	6	----	----	----	----
Magnesium	7439-95-4	1	mg/L	3	----	----	----	----
Sodium	7440-23-5	1	mg/L	14	----	----	----	----
Potassium	7440-09-7	1	mg/L	4	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.37	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	----	----	----	----
Boron	7440-42-8	0.05	mg/L	<0.05	----	----	----	----
Barium	7440-39-3	0.001	mg/L	0.023	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	0.003	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	0.031	----	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	AQ8	----	----	----	----
			Client sampling date / time	28-FEB-2014 10:30	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1404926-006	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	----	----	----	----
Silver	7440-22-4	0.001	mg/L	<0.001	----	----	----	----
Iron	7439-89-6	0.05	mg/L	**0.37**	----	----	----	----
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.31**	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	----	----	----	----
Boron	7440-42-8	0.05	mg/L	<0.05	----	----	----	----
Barium	7440-39-3	0.001	mg/L	**0.023**	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.003**	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.051**	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.015**	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	----	----	----	----
Silver	7440-22-4	0.001	mg/L	<0.001	----	----	----	----
Iron	7439-89-6	0.05	mg/L	**0.57**	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EG094F: Dissolved Metals in Fresh Water by ORC-ICPMS								

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	AQ8	----	----	----	----
			Client sampling date / time	28-FEB-2014 10:30	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1404926-006	----	----	----	----
EG094F: Dissolved Metals in Fresh Water by ORC-ICPMS - Continued								
Selenium	7782-49-2	0.2	µg/L	**0.2**	----	----	----	----
Cadmium	7440-43-9	0.05	µg/L	<0.05	----	----	----	----
Chromium	7440-47-3	0.2	µg/L	**0.3**	----	----	----	----
Copper	7440-50-8	0.5	µg/L	**2.6**	----	----	----	----
Silver	7440-22-4	0.1	µg/L	<0.1	----	----	----	----
EG094T: Total metals in Fresh water by ORC-ICPMS								
Selenium	7782-49-2	0.2	µg/L	<0.2	----	----	----	----
Cadmium	7440-43-9	0.05	µg/L	<0.05	----	----	----	----
Chromium	7440-47-3	0.2	µg/L	**0.3**	----	----	----	----
Copper	7440-50-8	0.5	µg/L	**2.9**	----	----	----	----
Silver	7440-22-4	0.1	µg/L	<0.1	----	----	----	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	<0.01	----	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	----	0.01	mg/L	<0.01	----	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	**0.01**	----	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.01**	----	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**0.5**	----	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	**0.5**	----	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.04**	----	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	<0.01	----	----	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**1.33**	----	----	----	----
Total Cations	----	0.01	meq/L	**1.26**	----	----	----	----

CERTIFICATE OF ANALYSIS

Work Order	: **EB1416446**	Page	: 1 of 5
Client	: **AUSTRALASIAN RESOURCE CONSULTANTS**	Laboratory	: Environmental Division Brisbane
Contact	: MS JULIE BYRD	Contact	: Customer Services
Address	: SUITE 5B 1 SWANN ROAD TARINGA QLD, AUSTRALIA 4068	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: jbyrd@aarc.net.au	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 07 32178772	Telephone	: +61 7 3243 7222
Facsimile	: +61 07 32178775	Facsimile	: +61 7 3243 7218
Project	: Copperchem Barbara Aquatics	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 08-JUL-2014
Sampler	: Alanah Buddery	Issue Date	: 15-JUL-2014
Site	: ----		
		No. of samples received	: 4
Quote number	: BN/274/12	No. of samples analysed	: 4

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics
Andrew Epps	Senior Inorganic Chemist	WB Water Lab Brisbane
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **It is recognised that EG020-T (Total Metals by ICP-MS) is less than EG020-F (Dissolved Metals by ICP-MS) for some samples. However, the difference is within experimental variation of the methods.**
- **It is recognised that EG094-T (Total Metals in Freshwater) is less than EG094-F (Dissolved Metals in Freshwater) for some samples. However, the difference is within experimental variation of the methods.**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SW5	AQ1	AQ8	AQ11	----
			Client sampling date / time	05-JUL-2014 10:45	02-JUL-2014 11:00	03-JUL-2014 14:00	06-JUL-2014 10:30	----
Compound	CAS Number	LOR	Unit	EB1416446-001	EB1416446-002	EB1416446-003	EB1416446-004	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	1500	534	341	1020	----
EA015: Total Dissolved Solids								
Total Dissolved Solids @180°C	----	10	mg/L	871	376	172	615	----
EA025: Suspended Solids								
Suspended Solids (SS)	----	5	mg/L	136	44	<5	136	----
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	357	132	80	190	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	5	<1	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	550	166	117	371	----
Total Alkalinity as CaCO3	----	1	mg/L	550	166	122	371	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	7	26	4	4	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	124	25	21	48	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	82	30	17	43	----
Magnesium	7439-95-4	1	mg/L	37	14	9	20	----
Sodium	7440-23-5	1	mg/L	115	27	31	42	----
Potassium	7440-09-7	1	mg/L	89	33	11	138	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	<0.01	0.02	----
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Arsenic	7440-38-2	0.001	mg/L	0.004	0.001	<0.001	0.003	----
Boron	7440-42-8	0.05	mg/L	0.13	0.07	0.06	0.15	----
Barium	7440-39-3	0.001	mg/L	0.078	0.058	0.039	0.170	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
Cobalt	7440-48-4	0.001	mg/L	0.008	0.002	<0.001	0.003	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Copper	7440-50-8	0.001	mg/L	<0.001	0.002	0.002	0.003	----
Manganese	7439-96-5	0.001	mg/L	6.49	0.081	0.006	0.307	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SW5	AQ1	AQ8	AQ11	----
			Client sampling date / time	05-JUL-2014 10:45	02-JUL-2014 11:00	03-JUL-2014 14:00	06-JUL-2014 10:30	----
Compound	CAS Number	LOR	Unit	EB1416446-001	EB1416446-002	EB1416446-003	EB1416446-004	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Nickel	7440-02-0	0.001	mg/L	**0.002**	**0.002**	<0.001	**0.002**	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	----
Molybdenum	7439-98-7	0.001	mg/L	**0.003**	<0.001	<0.001	**0.002**	----
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Iron	7439-89-6	0.05	mg/L	**0.64**	**0.65**	**0.07**	**1.08**	----
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.36**	**0.03**	**0.02**	**0.25**	----
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Arsenic	7440-38-2	0.001	mg/L	**0.006**	**0.001**	<0.001	**0.005**	----
Boron	7440-42-8	0.05	mg/L	**0.06**	<0.05	<0.05	**0.07**	----
Barium	7440-39-3	0.001	mg/L	**0.516**	**0.068**	**0.039**	**0.205**	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
Cobalt	7440-48-4	0.001	mg/L	**0.012**	**0.003**	<0.001	**0.004**	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Copper	7440-50-8	0.001	mg/L	**0.004**	**0.003**	**0.002**	**0.009**	----
Manganese	7439-96-5	0.001	mg/L	**7.69**	**0.110**	**0.046**	**0.529**	----
Nickel	7440-02-0	0.001	mg/L	**0.003**	**0.002**	<0.001	**0.002**	----
Lead	7439-92-1	0.001	mg/L	**0.002**	<0.001	<0.001	<0.001	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----
Vanadium	7440-62-2	0.01	mg/L	**0.02**	<0.01	<0.01	**0.01**	----
Zinc	7440-66-6	0.005	mg/L	**0.010**	<0.005	<0.005	**0.009**	----
Molybdenum	7439-98-7	0.001	mg/L	**0.003**	<0.001	<0.001	**0.002**	----
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Iron	7439-89-6	0.05	mg/L	**30.0**	**2.09**	**0.16**	**5.27**	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
EG094F: Dissolved Metals in Fresh Water by ORC-ICPMS								

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SW5	AQ1	AQ8	AQ11	----
			Client sampling date / time	05-JUL-2014 10:45	02-JUL-2014 11:00	03-JUL-2014 14:00	06-JUL-2014 10:30	----
Compound	CAS Number	LOR	Unit	EB1416446-001	EB1416446-002	EB1416446-003	EB1416446-004	----
EG094F: Dissolved Metals in Fresh Water by ORC-ICPMS - Continued								
Selenium	7782-49-2	0.2	µg/L	0.8	0.3	0.3	0.5	----
EG094T: Total metals in Fresh water by ORC-ICPMS								
Selenium	7782-49-2	0.2	µg/L	0.9	0.4	0.3	0.4	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	11.5	6.34	0.09	3.88	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	----	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	<0.01	0.15	<0.01	<0.01	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	0.15	<0.01	<0.01	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	19.0	7.4	0.9	14.7	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	19.0	7.6	0.9	14.7	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	1.23	0.59	0.09	0.97	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	0.06	0.02	<0.01	<0.01	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	14.6	4.56	3.11	8.85	----
Total Cations	----	0.01	meq/L	14.4	4.67	3.22	9.15	----
Ionic Balance	----	0.01	%	0.74	1.14	1.66	1.68	----

CERTIFICATE OF ANALYSIS

Work Order	: **EB1416456**	Page	: 1 of 8
Amendment	: **1**		
Client	: **AUSTRALASIAN RESOURCE CONSULTANTS**	Laboratory	: Environmental Division Brisbane
Contact	: JULIE BYRD	Contact	: Customer Services
Address	: PO BOX 675 TOWNSVILLE QLD, AUSTRALIA 4810	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: jbyrd@aarc.net.au	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 07 47243555	Telephone	: +61 7 3243 7222
Facsimile	: ----	Facsimile	: +61 7 3243 7218
Project	: ----	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 10-JUL-2014
Sampler	: Al Buddery & H Dick	Issue Date	: 28-JUL-2014
Site	: ----		
		No. of samples received	: 12
Quote number	: ----	No. of samples analysed	: 12

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics
Hamish Murray	Supervisor - Soils	Newcastle - Inorganics
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EG005T (Total Metals) Sample EB1416456-011 shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.**
- **This report has been amended and re-released to allow the reporting of additional analytical data. Fe and Ag results have now been included on the report.**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	AQ 1	AQ 2	AQ 3	AQ 4	AQ 5
			Client sampling date / time	02-JUL-2014 11:00	02-JUL-2014 09:00	02-JUL-2014 16:00	02-JUL-2014 14:00	04-JUL-2014 10:30
Compound	CAS Number	LOR	Unit	EB1416456-001	EB1416456-002	EB1416456-003	EB1416456-004	EB1416456-005
EA150: Particle Sizing								
+75µm	----	1	%	64	88	83	98	91
+150µm	----	1	%	52	85	75	96	77
+300µm	----	1	%	48	81	70	94	70
+425µm	----	1	%	44	77	63	88	57
+600µm	----	1	%	40	67	55	76	43
+1180µm	----	1	%	35	35	40	48	22
+2.36mm	----	1	%	30	11	26	29	8
+4.75mm	----	1	%	23	3	17	18	3
+9.5mm	----	1	%	22	<1	7	15	<1
+19.0mm	----	1	%	19	<1	7	14	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	62.0	<1.0	<1.0	<1.0	<1.0
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	9	5	5	1	2
Silt (2-60 µm)	----	1	%	26	6	11	2	7
Sand (0.06-2.00 mm)	----	1	%	35	78	58	68	83
Gravel (>2mm)	----	1	%	30	11	26	29	8
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.56	2.69	2.81	2.77	2.86
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	19800	8350	12900	9510	15700
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	<5
Barium	7440-39-3	10	mg/kg	200	40	110	40	90
Beryllium	7440-41-7	1	mg/kg	1	<1	<1	<1	1
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	1
Chromium	7440-47-3	2	mg/kg	24	12	14	18	33
Cobalt	7440-48-4	2	mg/kg	22	12	18	23	32
Copper	7440-50-8	5	mg/kg	73	13	28	119	30

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	AQ 1	AQ 2	AQ 3	AQ 4	AQ 5
			Client sampling date / time	02-JUL-2014 11:00	02-JUL-2014 09:00	02-JUL-2014 16:00	02-JUL-2014 14:00	04-JUL-2014 10:30
Compound	CAS Number	LOR	Unit	EB1416456-001	EB1416456-002	EB1416456-003	EB1416456-004	EB1416456-005
EG005T: Total Metals by ICP-AES - Continued								
Iron	7439-89-6	50	mg/kg	52100	27600	43500	34600	82300
Lead	7439-92-1	5	mg/kg	7	<5	<5	<5	<5
Manganese	7439-96-5	5	mg/kg	459	85	350	185	211
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	18	8	11	15	25
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Vanadium	7440-62-2	5	mg/kg	70	41	73	77	150
Zinc	7440-66-6	5	mg/kg	30	10	30	20	14
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	AQ 6	AQ 7	AQ 8	AQ 9	AQ10
			Client sampling date / time	03-JUL-2014 10:45	03-JUL-2014 09:00	03-JUL-2014 14:00	05-JUL-2014 14:30	04-JUL-2014 13:00
Compound	CAS Number	LOR	Unit	EB1416456-006	EB1416456-007	EB1416456-008	EB1416456-009	EB1416456-010
EA150: Particle Sizing								
+75µm	----	1	%	93	94	95	92	89
+150µm	----	1	%	91	92	94	89	87
+300µm	----	1	%	88	90	93	87	84
+425µm	----	1	%	83	84	90	82	79
+600µm	----	1	%	73	70	84	72	72
+1180µm	----	1	%	41	34	64	51	52
+2.36mm	----	1	%	15	15	42	38	30
+4.75mm	----	1	%	5	7	25	31	18
+9.5mm	----	1	%	<1	3	13	25	16
+19.0mm	----	1	%	<1	3	13	25	16
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	7.2	<1.0	19.5	<1.0	<1.0
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	3	2	2	3	4
Silt (2-60 µm)	----	1	%	4	3	3	4	6
Sand (0.06-2.00 mm)	----	1	%	78	80	53	55	60
Gravel (>2mm)	----	1	%	15	15	42	38	30
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.75	2.76	2.78	2.74	2.74
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	9330	9210	7230	10800	12200
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	10	<5	<5	7	<5
Barium	7440-39-3	10	mg/kg	60	40	40	40	140
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	1
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	17	17	11	20	22
Cobalt	7440-48-4	2	mg/kg	26	26	10	26	14
Copper	7440-50-8	5	mg/kg	28	35	15	19	26

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	AQ 6	AQ 7	AQ 8	AQ 9	AQ10
			Client sampling date / time	03-JUL-2014 10:45	03-JUL-2014 09:00	03-JUL-2014 14:00	05-JUL-2014 14:30	04-JUL-2014 13:00
Compound	CAS Number	LOR	Unit	EB1416456-006	EB1416456-007	EB1416456-008	EB1416456-009	EB1416456-010
EG005T: Total Metals by ICP-AES - Continued								
Iron	7439-89-6	50	mg/kg	38800	36400	27300	29700	42900
Lead	7439-92-1	5	mg/kg	<5	<5	<5	<5	<5
Manganese	7439-96-5	5	mg/kg	200	146	206	142	398
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	12	13	8	12	17
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Vanadium	7440-62-2	5	mg/kg	71	68	63	74	73
Zinc	7440-66-6	5	mg/kg	22	13	14	13	17
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	AQ11	SW5	----	----	----
			Client sampling date / time	06-JUL-2014 10:30	05-JUL-2014 10:45	----	----	----
Compound	CAS Number	LOR	Unit	EB1416456-011	EB1416456-012	----	----	----
EA150: Particle Sizing								
+75µm	----	1	%	80	76	----	----	----
+150µm	----	1	%	74	71	----	----	----
+300µm	----	1	%	71	65	----	----	----
+425µm	----	1	%	66	60	----	----	----
+600µm	----	1	%	58	54	----	----	----
+1180µm	----	1	%	38	40	----	----	----
+2.36mm	----	1	%	20	22	----	----	----
+4.75mm	----	1	%	10	9	----	----	----
+9.5mm	----	1	%	<1	<1	----	----	----
+19.0mm	----	1	%	<1	<1	----	----	----
+37.5mm	----	1	%	<1	<1	----	----	----
+75.0mm	----	1	%	<1	<1	----	----	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	34.4	41.0	----	----	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	7	9	----	----	----
Silt (2-60 µm)	----	1	%	12	13	----	----	----
Sand (0.06-2.00 mm)	----	1	%	62	56	----	----	----
Gravel (>2mm)	----	1	%	19	22	----	----	----
Cobbles (>6cm)	----	1	%	<1	<1	----	----	----
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.65	2.59	----	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	15300	13300	----	----	----
Antimony	7440-36-0	5	mg/kg	<5	<5	----	----	----
Arsenic	7440-38-2	5	mg/kg	<5	<5	----	----	----
Barium	7440-39-3	10	mg/kg	80	80	----	----	----
Beryllium	7440-41-7	1	mg/kg	1	1	----	----	----
Boron	7440-42-8	50	mg/kg	<50	<50	----	----	----
Cadmium	7440-43-9	1	mg/kg	<1	<1	----	----	----
Chromium	7440-47-3	2	mg/kg	16	19	----	----	----
Cobalt	7440-48-4	2	mg/kg	18	21	----	----	----
Copper	7440-50-8	5	mg/kg	63	31	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	AQ11	SW5	----	----	----
			Client sampling date / time	06-JUL-2014 10:30	05-JUL-2014 10:45	----	----	----
Compound	CAS Number	LOR	Unit	EB1416456-011	EB1416456-012	----	----	----
EG005T: Total Metals by ICP-AES - Continued								
Iron	7439-89-6	50	mg/kg	50200	42300	----	----	----
Lead	7439-92-1	5	mg/kg	<5	<5	----	----	----
Manganese	7439-96-5	5	mg/kg	265	402	----	----	----
Molybdenum	7439-98-7	2	mg/kg	<2	<2	----	----	----
Nickel	7440-02-0	2	mg/kg	16	15	----	----	----
Selenium	7782-49-2	5	mg/kg	<5	<5	----	----	----
Silver	7440-22-4	2	mg/kg	<2	<2	----	----	----
Vanadium	7440-62-2	5	mg/kg	82	90	----	----	----
Zinc	7440-66-6	5	mg/kg	21	32	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	----	----	----

Appendix C Macroinvertebrate Analysis Results

Project							
Site		AQ8	SW5	AQ11 (edge)	AQ1 (bed)	AQ11 (Bed)	AQ1 (edge)
Date Collected		5/07/2014	5/07/2014	7/07/2014	5/07/2014	7/07/2014	5/07/2014
Platyhelminthes							
Annelida	Oligochaeta						
Hirudinea	Glossiphoniidae						
Hirudinea	Richardsonianidae						
Cnidaria	Hydridae						
Gastropoda	Lymnaeidae						
	Planorbidae						
	Viviparidae						
	Ancylidae						
Bivalvia	Hyriidae						
Crustacea	Isopoda						
Cladocera	Cladocera			2			
Copepoda	Copepoda			2		40	1
Ostracoda	Ostracoda						1
Isopoda	Isopoda						
Amphipoda							
Conchostraca	Conchostraca						
Decapoda	Atyidae						
	Palaemonidae						
	Parastacidae						
	Sundathelphusidae						
Acarina	Hydracarina			2	4	1	2
Coleoptera	Dytiscidae	15	22	32	15	33	30
	Hydrophilidae	2		2			23
	Hydrochidae	4		1			
	Gyrinidae	2	4		6		
	Noteridae						
	Scirtidae						
	Elmidae						
	Hydraenidae						
	Haliplidae						
	Chrysomeliidae						
	Staphylinidae						
	Spercheidae						
Collembola	Collembola						
Diptera							
Chironomidae	Chironominae			7	13	17	8
	Tanypodiinae	4		5	2	21	4
	Orthocladiinae	1					
	Ceratopogonidae						
	Simuliidae						
	Tabanidae			1			
	Stratiomyidae						
	Chaoboridae					1	
	Culicidae						2
Ephemeroptera	Baetidae			1			
	Caenidae	10					
	Leptophlebiidae						
Hemiptera							
	Corixidae	10	9	14			13
	Gerridae						9
	Mesoveliidae						1
	Nepidae						
	Notonectidae	3	12			1	
	Pleidae						
	Veliidae						
	Naucoridae						
	Hydrometridae						
	Belastomatidae						
Odonata	Gomphidae						
	Lindeniidae						
	Libellulidae	32	28				
	Urothemistidae						
	Hemicorduliidae						
	Undiff HUL	1					
	Aeshnidae	2					
Zygoptera	Protoneuridae						
	Coenagrionidae	1					
	Isostictidae						
	Undiff.						
Trichoptera	Leptoceridae	2		2			
	Ecnomidae						
	Hydroptilidae						
	Hydropsychidae						
Lepidoptera	Pyralidae						

Project											
Site		AQ7 Edge	AQ2 Bed	AQ6	AQ4 Bed	AQ4 Edge	AQ1 Edge	AQ8 Edge	AQ8 Bed	AQ7 Bed	Copper Cher
Date Collected		1/03/2014	26/02/2014	27/02/2014	26/02/2014		26/02/2014	1/03/2014	1/03/2014	1/03/2014	26/02/2014
Platyhelminthes											
Annelida	Oligochaeta	1									
Hirudinea	Glossiphoniidae										
	Richardsonianidae										
Cnidaria	Hydridae										
Gastropoda	Lymnaeidae										
	Planorbidae										1
	Viviparidae										
	Ancylidae										
Bivalvia	Hyriidae										
Crustacea	Isopoda										
Cladocera	Cladocera					1	5				5
Copepoda	Copepoda					1	7				20
Ostracoda	Ostracoda	1	1	2		12	7		6	61	
Isopoda	Isopoda										
Amphipoda	Amphipoda										
Conchostraca	Conchostraca										
Anostraca	Thamnocephalidae		3	2		1		1		1	
Decapoda											
	Palaemonidae										
	Parastacidae										
	Sundathelphusidae							2			
Acarina	Hydracarina		2								
Coleoptera	Dytiscidae	2	8	3		7	15	30	5	2	7	7
	Hydrophilidae	1		1				8	1			1
	Hydrochidae	1						1				
	Gyrinidae										1	1
	Noteridae											
	Scirtidae											
	Elmidae											
	Hydraenidae											
	Haliplidae											
	Chrysomelidae											
	Staphylinidae											
	Spercheidae											
Collembola	Collembola										1	
Diptera												
Chironomidae	Chironominae	5	10			2	1	5				19
	Tanypodiinae	4	3	3		1	12	2	3	33	15	9
	Orthocladiinae											
	Ceratopogonidae					3	1	1				
	Simuliidae											
	Tabanidae	2					2		1			
	Stratiomyidae											
	Syrphidae							1				
	Chaoboridae		8									3
	Culicidae											
Ephemeroptera	Baetidae	6		18		3	1	2	4	7	1	
	Caenidae										1	
	Leptophlebiidae											
Hemiptera												
	Corixidae	21	5	27		13	26	2	15	12	13	
	Gerridae											
	Mesoveliidae											
	Nepidae											
	Notonectidae	4	1	19		3		1	15	8	4	1
	Pleidae											
	Veliidae											
	Naucoridae											
	Hydrometridae											
	Belastomatidae											
Odonata	Gomphidae											
	Lindeniidae											
	Libellulidae	6	1	4		6	14		17	10	1	
	Urothemistidae						2					
	Hemicorduliidae								1			
	Undiff HUL									2		
	Aeshnidae											
Zygoptera	Protoneuridae											
	Coenagrionidae											
	Isostictidae											
	Undiff.											
Trichoptera	Leptoceridae						1					
	Ecnomidae											
	Hydroptilidae											
	Hydropsychidae											
Lepidoptera	Pyralidae											

Appendix D Flora Species List

Scientific Name	Common Name	NC Act/LP Act Status	EPBC Act Status	Wet Season									Dry Season											
				AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10	AQ1	AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10	AQ11	AQ12
Abutilon hannii		LC	NL														x							
Acacia chisholmii	Turpentine	LC	NL	X	X		X						X	X	x		x						x	
Acacia hemsleyi		LC	NL	X		X			x				X	X		X			x				x	
Acacia holosericea	Soapbush	LC	NL			X	X		X	X	X	X				X	x		x	x	x	x	x	x
Acacia melleodora		LC	NL			X										X			x					
Acacia monticola	Red Wattle	LC	NL															x						
Acacia phlebocarpa	Tabletop Wattle	LC	NL				X				X	X					x				x	x		
Acacia tenuissima	Narrow-leaved Wattle	LC	NL			X						X				X				x				
Acanthospermum hispidum	Star Burr	I	I											X										
Achyranthes aspera	Chaff Flower	LC	NL															x						
Alternanthera denticulata	Lesser Joyweed	LC	NL											x										x
Alternanthera sp. (Mt Isa R.L.Specht+ 49)		LC	NL	X	X	X					X	X	X	X	X				x	x		x	x	x
Amaranthus interruptus	Native Amaranth	LC	NL	X	X				X	X														
Ammania multiflora	Jerry-jerry	LC	NL																				x	
Aristida contorta	Kerosene Grass	LC	NL																			x		
Aristida inaequiglumis	Feathertop Three-awn	LC	NL												x	x								x
Aristida pruinosa	Gulf Wiregrass	LC	NL										X											
Atalaya hemiglauca	Whitewood	LC	NL	X	X				X			X	X		x	X	x		x		x	x		x
Boerhavia paludosa	Roly-poly Tar Vine	LC	NL								X													
Boerhavia pubescens		LC	NL												X		x	x						
Boerhavia schomburgkiana	Tar Vine	LC	NL	X	X	X	X	X	X	X	X	X	X											
Bonamia media	Common Bonamia	LC	NL										X			X		x					x	x
Bothriochloa ewartiana	Forest Bluegrass	LC	NL								X									X				
Brachiaria piligera	Hairy Arm Grass	LC	NL	X	X				X	X	X												x	
Brachyachne convergens	Common Native Couch	LC	NL	X					X				X	X	X				x					x
Brachychiton collinus	Hill Kurrajong	LC	NL					X										x						x
Bulbostylis barbata	Dainty Sedge	LC	NL												X			x						
Carissa lanceolata	Conkerberry	LC	NL		X	X				X	X	X		X	X	X				x	x	x	x	x
Cenchrus ciliaris	Buffel Grass	I	I	X	X	X	X		X				X	X	X	x	x				x			
Chamaecrista absus	Tropical Sensitive Pea	LC	NL					X			X	X												
Chamaesyce hirta	Asthma Plant	I	I		X			X	X				X				x		x	x			x	x
Cheilanthes brownii	Woolly Cloak Fern	LC	NL		X			X			X	X			X			x						
Chloris virgata	Feathertop Rhodes Grass	I	I										X	X		X	x		x				x	
Chrysopogon fallax	Golden Beard Grass	LC	NL										X	X	x	x	x		x		x	x		x
Cleome viscosa	Tickweed	LC	NL	X	X	X	X	X	X	X	X	X	X	X	x	x	x	x	x	x	x	x		x
Corchorus sericeus	Grey Jute	LC	NL													x								
Corchorus sidoides	Flannel Jute	LC	NL										X								x			
Corymbia aparrerinja	Ghost Gum	LC	NL												X		x					x		
Crotalaria dissitiflora subsp. *dissitiflora*	Grey Rattlepod	LC	NL			X																		
Crotalaria medicaginea	Trefoil Rattlepod	LC	NL	X	X				X		X				X			x					x	
Crotalaria novae-hollandiae subsp. *novae-hollandiae*	New Holland Rattlepod	LC	NL		X																			
Cryptostegia grandiflora	Rubber Vine	C2	WONS				X																	
Cucumis argentus		LC	NL																					x
Cucumis melo	Native Cucumber	LC	NL																				x	
Cymbopogon bombycinus	Lemon-scented Grass	LC	NL					X	X		X						x	x		x	x	x		

Scientific Name	Common Name	NC Act/LP Act Status	EPBC Act Status	Wet Season									Dry Season											
				AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10	AQ1	AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10	AQ11	AQ12
Cyperus iria	Variable Sedge	LC	NL																					x
Dactyloctenium radulans	Button Grass	LC	NL	X	X	X	X		X	X	X		X	X									x	
Dicanthium fecundum	Curly Bluegrass	LC	NL		X	X	X																	
Dicanthium sericeum	Queensland Bluegrass	LC	NL			X											x							
Digitaria bicornis	Hairy Finger Grass	LC	NL	X	X				X															
Digitaria ciliaris	Southern Crabgrass	I	I																					x
Digitaria ctenantha	Comb Finger Grass	LC	NL		X		X	X			X				X			x			x	x		
Echinochloa colona	Awnless Barnyard Grass	I	I																				x	
Enneapogon oblongus	Purple-head Nineawn	LC	NL				X	X	X						X		X	X	x		x	x	X	
Enneapogon polyphyllus	Leafy Nineawn	LC	NL		X					X	X	X					x							
Enteropogon ramosus	Twirly Windmill Grass	LC	NL	X	X	X							X	X	x	x	x		x					x
Eragrostis cumingii	Cuming's Lovegrass	LC	NL										X	X	x		x		x	x		x	x	x
Eragrostis leptocarpa	Drooping Lovegrass	LC	NL										X	X	x		x						x	
Eragrostis tenellula	Delicate Lovegrass	LC	NL																			x		
Eragrostis tenuifolia	Elastic Grass	I	I		X	X	X	X	X	X			X	X	x		x	x	x	x		x	x	x
Eremophila longifolia	Berrigan	LC	NL	X	X		X				X	X			X		x				x	x		
Eriachne obtusa	Northern Wanderrie Grass	LC	NL			X		X	X	X	X	X	X		x	x	x	x	x	x	x	x	x	x
Eucalyptus camaldulensis	River Red Gum	LC	NL	X		X	X	X	X				X	X		X	x	x	x				x	
Eucalyptus leucophylla	Cloncurry Box	LC	NL		X		X				X	X			x		x				x	x		x
Eulalia aurea	Silky Browntop	LC	NL			X	X		X	X	X		X		x	x	x	x		x	x	x		x
Euphorbia biconvexa		LC	NL		X	X		X		X	X						x				x	x		
Euphorbia tannensis subsp. *tannensis*	Bottletree Spurge	LC	NL														x							
Euphorbia trigonosperma		LC	NL															x						x
Evolvulus alsinoides	Tropical Speedwell	LC	NL		X						X		X	X	x	x	x		x		x	x	x	
Fimbristylis dichotoma	Common Fringe-sedge	LC	NL	X	X						X	X			x			x			x	x		
Fimbristylis microcarya		LC	NL																				X	
Flueggea virosa subsp. *melanthesoides*	White Currant Bush	LC	NL			X	X		X		X						x	x	x	x	x		x	x
Galactia tenuiflora	Galactia	LC	NL	X		X	X	X	X	X			X			X	x	x	x	x	x	x	x	x
Gossypium australe	Native Cotton	LC	NL	X	X		X				X			X	x	x	x	x	x	x	x			x
Grevillea mimosoides	Caustic Bush	LC	NL														x							
Hakea arborescens	Tree Hakea	LC	NL	X										X		X			x					
Hakea chordophylla	Bootlace Oak	LC	NL														x							
Heliotropium cunninghamii		LC	NL	X	X	X	X	X		X	X	X			x	X	x	x	x	x	x	x	x	x
Heteropogon contortus	Black Speargrass	LC	NL		X								X		x	X	x	x	x	x				x
Hybanthus aurantiacus	Orange Spadeflower	LC	NL		X															X				
Hybanthus enneaspermus	Purple Spadeflower	LC	NL		X				X		X													x
Indigofera colutea	Rusty Indigo	LC	NL								X						x							
Indigofera hirsuta	Hairy Indigo	LC	NL	X	X	X	X	X	X		X	X	X				x			x	x	x		x
Indigofera linifolia	Narrow-leaved Indigo	LC	NL							X			X	X	X	x	x		x	x	x	x	x	x
Indigofera linnaei	Birdsville Indigo	LC	NL		X					X	X	X									x	x	x	
Indigofera pratensis	Forest Indigo	LC	NL																		x			
Indigofera trita	Pale Indigo	LC	NL						X						x		x	x	x		x	x		
Ipomoea plebeia	Bellvine	LC	NL	X		X	X	X	X		X	X												
Ipomoea polymorpha		LC	NL																x					
Lophostemon grandiflorus	Northern Swamp Mahogany	LC	NL	X	X	X	X	X	X	X	X		X	X	X	X	x	x	x	x	x		x	x
Lysiphyllum cunninghamii	Bauhinia	LC	NL			X										x							x	
Malvastrum americanum	Malvastrum	I	I																				x	
Marsdenia viridiflora	Native Pear	LC	NL						X															

Scientific Name	Common Name	NC Act/LP Act Status	EPBC Act Status	Wet Season									Dry Season											
				AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10	AQ1	AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10	AQ11	AQ12
Maytenus cunninghamii	Yellow Berry Bush	LC	NL																		x			
Melaleuca bracteata	Black Tea-tree	LC	NL		X		X			X	X				x		x			x	x			x
Melhania oblongifolia	Velvet Hibiscus	LC	NL															x			x		x	
Neptunia dimorphantha	Sensitive Plant	LC	NL			X			X		X								x			x		x
Notoleptopus decaisnei var. *decaisnei*		LC	NL														x			x			x	
Ocimum tenuiflorum	Native Thyme	LC	NL								X		X										x	
Oxychloris scariosa	Winged Chloris	LC	NL			X																		
Panicum decompositum	Stargrass	LC	NL																			x		
Panicum effusum	Hairy Panic	LC	NL														x							x
Paspalidium constrictum	Knottybutt Grass	LC	NL	X	X		X	X	X	X	X		X	X						x				
Paspalidium distans		LC	NL									X												
Paspalidium rarum	Rare Paspalidium	LC	NL	X						X										x	x		x	
Pavetta rupicola	Rock Shrub	LC	NL															x					x	x
Perotis rara	Comet Grass	LC	NL		X			X			X													
Phyllanthus maderaspatensis	Spurge	LC	NL	X	X			X			X	X	X	X	X		x	x	x	x	x	x	x	x
Phyllanthus virgatus		LC	NL										X	X								x		x
Pluchea rubelliflora		LC	NL										X	X			x						x	x
Plumbago zeylanica	Plumbago	LC	NL															x						
Polymeria ambigua	Creeping Polymeria	LC	NL	X																				
Polymeria longifolia	Polymeria	LC	NL	X		X	X		X															
Portulaca filifolia	Slender Pigweed	LC	NL												x									
Portulaca oleracea	Pigweed	LC	NL							X	X	X										x		
Psydrax oleifolia	Canthium	LC	NL													x								
Pterocaulon serrulatum	Apple Bush	LC	NL														x							x
Rhynchosia minima	Rhyncho	LC	NL		X		X		X										x			x		
Santalum lanceolatum	Sandalwood	LC	NL																		x			
Sauropus trachyspermus	Slender Spurge	LC	NL	X																				
Sehima nervosum	White Grass	LC	NL			X	X	X	X	X										x				
Senna planiticola	Ant Bush	LC	NL															x						x
Sesbania javanica	Tall Sesbania Pea	LC	NL	X	X	X	X	X	X	X	X		X	X		X	x	x	x	x			x	x
Setaria surgens	Annual Pigeon Grass	LC	NL								X		X		X			x			x			
Sida acuta	Spinyhead Sida	I	I		X						X													
Sida cordifolia	Flannel Weed	I	I			X						X												
Sida fibulifera	Pin Sida	LC	NL																X					
Sida rhombifolia	Paddy's Lucerne	I	I										X											
Sida rohlenae	Shrub Sida	LC	NL										X											
Sida sp. (Musselbrook M.B.Thomas+ MRS437)		LC	NL													x						x		
Sida subspicata	Spiked Sida	LC	NL										X			X		x	x		x		x	
Solanum ellipticum	Potato Bush	LC	NL	X				X						X			x	x		x				x
Sorghum plumosum	Plume Sorghum	LC	NL							X		X												
Spermacoce auriculata		LC	NL							X						x					x			
Sphaeranthus indicus	Minty Pom-poms	LC	NL											X					x	x	x	x		
Sporobolus actinocladus	Katoora Grass	LC	NL		X										x							x		
Sporobolus australasicus	Australian Dropseed	LC	NL										X	X		x				x	x	x		
Tephrosia brachyodon var. *longifolia*	Narrow-leaved Tephrosia	LC	NL		X						X	X	X								x	x		
Tephrosia virens	Green Tephrosia	LC	NL					X										x						

Scientific Name	Common Name	NC Act/LP Act Status	EPBC Act Status	Wet Season									Dry Season											
				AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10	AQ1	AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10	AQ11	AQ12
Terminalia aridicola	Arid Peach	LC	NL		X		X	X	X		X	X		X	X		x	x	x		x	x		x
Themeda avenacea	Oat Grass	LC	NL		X																			
Themeda triandra	Kangaroo Grass	LC	NL				X		X						X		x				x			
Tinospora smilacina	Snake Vine	LC	NL	X	X	X	X	X	X		X													
Trema tomentosa	Poison Peach	LC	NL																					x
Trianthema triquetra	Red Spinach	LC	NL	X	X						X		X	X	X									
Tribulopsis pentandra		LC	NL	X			X			X	X	X												
Trichodesma zeylanicum	Camel Bush	LC	NL										X	X				x				x		x
Triodia longiceps	Giant Grey Spinifex	LC	NL										X											
Triodia pungens	Soft Spinifex	LC	NL	X	X		X		X		X				X	x	x	x	x	x	x			x
Triumfetta microcantha		LC	NL					X										x						
Vachellia bidwillii	Corkwood Wattle	LC	NL									X			X	X						x		
Vachellia farnesiana	Mimosa Bush	I	I		X	X			X	X			X			X			x	x			x	x
Vigna lanceolata	Maloga Bean	LC	NL	X	X	X	X	X	X	X	X		X				x	x	x				x	

C2 - Class 2 declared weed
I - Introduced
LC - Least Concern
NL - Not listed
WONS - Weed of National Significance

Appendix E Fauna Species List

Family	Scientific Name	Common Name	Status		Wet Season											Dry Season												
			NC Act	EPBC Act	AQ1	AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10	OPPS	AQ1	AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ10	AQ11	AQ12	OPPS
Crustaceans																												
Parathelphusidae	*Austrothelphusa transversa*	Inland Freshwater Crab	NL	NL	X	X																					X	
Fish																												
Terapontidae	*Leiopotherapon unicolor*	Spangled Perch	NL	NL	X											X												X
Reptiles																												
Agamidae	*Amphibolurus gilberti*	Gilbert's Dragon	LC	NL					X																		X	X
Boidae	*Liasis olivaceus*	Olive Python	LC	NL																			X					
Scincidae	*Carlia amax*		LC	NL							X										X			X				
Scincidae	*Cryptoblepharus metallicus*	Metallic Snake-eyed Skink	LC	NL	X																							
Scincidae	*Cryptoblepharus zoticus*	Agile Snake-eyed Skink	LC	NL																	X							
Scincidae	*Ctenotus lateralis*		LC	NL																				X				
Amphibians																												
Bufonidae	*Rhinella marina*	Cane Toad	I	I				X								X										X		
Hylidae	*Cyclorana australis*	Northern Snapping Frog	LC	NL				X		X																		
Hylidae	*Litoria caerulea*	Common Green Treefrog	LC	NL	X			X		X						X					X							
Hylidae	*Litoria rubella*	Ruddy Treefrog	LC	NL	X					X						X												
Myobatrachidae	*Platypectrum ornatum*	Ornate Burrowing Frog	LC	NL	X																							
Birds																												
Acanthizidae	*Smicrornis brevirostris*	Weebill	LC	NL	X	X			X	X	X	X	X	X	X	X	X		X	X	X	X		X		X		
Accipitridae	*Accipiter cirrocephalus*	Collared Sparrowhawk	LC	NL																			X			X		
Accipitridae	*Elanus axillaris*	Black-shouldered Kite	LC	NL					X	X		X	X															
Cacatuidae	*Cacatua sanguinea*	Little Corella	LC	NL												X												
Cacatuidae	*Nymphicus hollandicus*	Cockatiel	LC	NL						X																		
Campephagidae	*Coracina novaehollandiae*	Black-faced Cuckoo-shrike	LC	Ma		X							X											X				
Campephagidae	*Lalage sueurii*	White-winged Triller	LC	NL	X	X		X	X		X		X	X														
Charadriidae	*Elseyornis melanops*	Black-fronted Dotterel	LC	NL	X																							
Columbidae	*Geopelia cuneata*	Diamond Dove	LC	NL				X	X		X		X	X		X			X	X	X		X	X	X	X		
Columbidae	*Geophaps plumifera*	Spinifex Pigeon	LC	NL																			X					
Columbidae	*Geopelia striata*	Peaceful Dove	LC	NL	X	X	X	X			X	X				X			X	X		X	X	X		X	X	
Corcoracidae	*Eurystomus orientalis*	Dollarbird	LC	Ma									X															
Corcoracidae	*Struthidea cinerea*	Apostlebird	LC	NL	X																						X	
Corvidae	*Corvus orru*	Torresian Crow	LC	NL												X												
Cuculidae	*Eudynamys orientalis*	Eastern Koel	LC	NL	X	X																						
Dicaeidae	*Dicaeum hirundinaceum*	Mistletoebird	LC	NL													X											
Estrildidae	*Poephila acuticauda*	Long-tailed Finch	LC	NL																			X					
Estrildidae	*Taeniopygia bichenovii*	Double-barred Finch	LC	NL	X	X			X		X		X			X					X		X			X	X	X
Estrildidae	*Taeniopygia guttata*	Zebra Finch	LC	NL								X				X			X	X	X		X	X	X	X		X
Falconidae	*Falco berigora*	Brown Falcon	LC	NL								X																
Halcyonidae	*Todiramphus sanctus*	Sacred Kingfisher	LC	Ma	X	X																						
Megaluridae	*Cincloramphus mathewsi*	Rufous Songlark	LC	NL					X				X	X														
Meliphagidae	*Lichenostomus virescens*	Singing Honeyeater	LC	NL												X												
Meliphagidae	*Lichmera indistincta*	Brown Honeyeater	LC	NL					X		X	X	X										X					
Meliphagidae	*Melithreptus gularis laetior*	Golden-backed Honeyeater	NT	NL															X									
Meliphagidae	*Philemon citreogularis*	Little Friarbird	LC	NL	X					X	X		X		X	X												
Meliphagidae	*Ptilotula keartlandi*	Grey-headed Honeyeater	LC	NL					X	X						X							X					
Meropidae	*Merops ornatus*	Rainbow Bee-eater	LC	Mi, Ma	X			X		X																		X
Monarchidae	*Grallina cyanoleuca*	Magpie-lark	LC	Ma	X							X																
Monarchidae	*Myiagra inquieta*	Restless Flycatcher	LC	NL	X			X		X	X												X			X		
Pachycephalidae	*Colluricincla harmonica*	Grey Shrike-thrush	LC	NL								X													X			
Pachycephalidae	*Pachycephala rufiventris*	Rufous Whistler	LC	NL	X	X		X		X	X	X	X							X	X	X						
Pardalotidae	*Pardalotus striatus*	Striated Pardalote	LC	NL												X	X			X		X				X		X
Pomatostomidae	*Pomatostomus temporalis rubeculus*	Grey-crowned Babbler (north-western)	LC	NL	X	X				X					X	X												
Psittacidae	*Aprosmictus erythropterus*	Red-winged Parrot	LC	NL	X																							
Psittacidae	*Barnardius zonarius macgillivrayi*	Cloncurry Ringneck	LC	NL																				X			X	
Psittacidae	*Melopsittacus undulatus*	Budgerigar	LC	NL	X			X			X	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X
Ptilonorhynchidae	*Ptilonorhynchus maculatus*	Spotted Bowerbird	LC	NL									X			X							X					
Rhipiduridae	*Rhipidura albiscapa*	Grey Fantail	LC	NL															X			X						
Rhipiduridae	*Rhipidura leucophrys*	Willie Wagtail	LC	NL	X							X				X							X				X	
Mammals																												
Bovidae	*Bos taurus*	Cow	I	I		X																				X	X	
Canidae	*Canis familiaris*	Wild Dog	C2	I																X								
Macropodidae	*Macropus robustus*	Common Wallaroo	LC	NL												X										X		
Macropodidae	*Petrogale purpureicollis*	Purple-necked Rock-wallaby	V	NL						X											X							
Molossidae	*Mormopterus beccarii*	Beccari's freetail bat	LC	NL	X																							
Suidae	*Sus scrofa*	Feral Pig	C2	I																			X					
Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat	LC	NL	X			X		X		X																
Vespertilionidae	*Chalinolobus nigrogriseus*	Hoary Wattled Bat	LC	NL	X			?		X		X																
Vespertilionidae	*Nyctophilus* species		LC	NL	?																							
Vespertilionidae	*Scotorepens balstoni*	Inland Broad-nosed Bat	LC	NL	X							?																
Vespertilionidae	*Scotorepens greyii*	Little Broad-nosed Bat	LC	NL	X			?		X		X																
Vespertilionidae	*Vespadelus baverstocki*	Inland Forest Bat	LC	NL	?							X																
Vespertilionidae	*Vespadelus caurinus*	Northern Cave Bat	LC	NL								?																
Vespertilionidae	*Vespadelus finlaysoni*	Finlayson's Cave Bat	LC	NL						X		X																

? - Species possibly present, but not reliably identified
LC - Least Concern
V - Vulnerable
I - Introduced
NL - Not Listed
NT - Near threatened
C2 - Class 2 declared pest

Appendix F Bat Call Analysis Report

Microbat Call Identification Report

Prepared for ("Client"):	AustralAsian Resource Consultants
Survey location/project name:	Barbara (Mt Isa)
Survey dates:	Dry Season, July 2014
Client project reference:	
Job no.:	AARC1404
Report date:	28 July 2014

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Methods

Data receipt and post-processing

Bat call data were recorded over four nights using two Song Meter SM2BAT detectors (Wildlife Acoustics, USA). The detectors were programmed to operate between sunset and sunrise and to record the acoustic data as full-spectrum sound files (.WAV format).

Data received for analysis included the following:

Detector name	Recording dates	Site	Number of WAV files recorded
SM5	Nights of 2/7/14 and 3/7/14	AQ1	260
	Nights of 4/7/14 and 5/7/14	AQ6	388
SM10	Nights of 2/7/14 and 3/7/14	AQ4	47
	Nights of 4/7/14 and 5/7/	AQ8	501

All WAV files were post-processed with Wildlife Acoustics' *Kaliedoscope Version 2.0.3* to generate call sequence files in Anabat zero-crossing analysis (ZCA) format. This process yielded a total of 1552 sequence files for the four sites.

Bat call identification

All sequence files were analysed using *AnalookW* (Corben 2014) and a subset of files containing representative samples of all call types recorded at each site were selected for identification. Species identification was achieved manually by comparing the *AnalookW* call sonograms with those of regionally-relevant reference calls and with published call descriptions (e.g. Reinhold *et al.* 2001; Milne 2002; Pennay *et al*. 2004).

Species' identification was also guided by considering their probability of occurrence based on general distribution information (Churchill 2008; van Dyck *et al.* 2013) and/or database records obtained from Wildlife Online (http://www.ehp.qld.gov.au/wildlife/wildlife-online/index.html) and/or the Atlas of Living Australia (http://www.ala.org.au).

Reporting standard

The format and content of this report follows Australasian Bat Society standards for the interpretation and reporting of bat call data (Reardon 2003), available on-line at http://www.ausbats.org.au/.

Species nomenclature follows van Dyck *et al.* (2013).

Results & Discussion

The ZCA conversion process generated 1552 sequence files, more than half of which (911 files) were recorded at Site AQ8. The majority of recorded calls were produced by just a few species, so only 15% (228) of the sequence files were needed for identification.

At least seven species were recorded during the Barbara dry season survey; however a number of calls could not be reliably identified to species level due to similarities between call characteristics of some species that probably occur in the study area.

The seven positively identified species included six vespertilionids and one molossid (see Table 1). Another two vespertilionid species were possibly also present but not reliably identified. These unresolved species included:

- several brief and weak calls with steep linear pulses terminating around 35-40 kHz, which were possibly attributable to a *Nyctophilus* species (*N. arnhemensis, N. bifax* and *N. geoffroyi* all potentially occur in the study area); and
- a number of calls with steep FM-qCF pulses and characteristic frequency at 57-59 kHz, which may have been from *Vespadelus caurinus* (similar pulse shape but slightly higher frequency than the many calls with Fc=54-56 kHz that were more readily attributable to *V. finlaysoni*). However, the nearest records for *V. caurinus* are in the Boodjamulla National Park area, so these calls may simply be *V. finlaysoni* calls at the extreme upper limit of its frequency range.

The dry season survey (this report) failed to record a number of bats that were recorded during the wet season survey (Balance! Environmental report dated 26 May 2014), including one molossid (*Chaerephon jobensis*), three emballonurids (*Saccolaimus flaviventris, Taphozous georgianus* and *T. troughtoni*) and the dusky leaf-nosed bat (*Hipposideros ater*). It did, however, add a further two species (*Vespadelus baverstocki* and *V. finlaysoni*) to the total bat inventory for the survey area.

Table 1 Insectivorous bats recorded during the Barbara (Mt Isa) surveys, 2-6 July 2014.

♦ denotes species positively identified from call data.
□ denotes species possibly present, but not reliably identified.

Site:	AQ1	AQ4	AQ6	AQ8
VESPERTILIONIDAE				
Chalinolobus gouldii	♦	♦	♦	♦
Chalinolobus nigrogriseus	♦	□	♦	♦
Nyctophilus species	□			
Scotorepens balstoni	♦			□
Scotorepens greyii	♦	□	♦	♦
Vespadelus baverstocki	□			♦
Vespadelus caurinus				□
Vespadelus finlaysoni			♦	♦
MOLOSSIDAE				
Mormopterus beccarii	♦			

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Churchill, S. (2008). *Australian Bats*. Jacana Books, Allen & Unwin; Sydney.

Corben, C. (2014). *AnalookW for bat call analysis using ZCA*. Version 4.1b 19 May 2014.

Milne, D.J. (2002). *Key to the Bat Calls of the Top End of the Northern Territory.* Technical Report No. 71, Parks and Wildlife Commission of the Northern Territory, Darwin.

Pennay, M., Law, B. and Reinhold, L. (2004). *Bat Calls of New South Wales*. Department of Environment and Conservation, Hurstville.

Reardon, T. (2003). Standards in bat detector based surveys. *Australasian Bat Society Newsletter* **20**, 41-43.

Reinhold, L., Law, B., Ford, G. and Pennay, M. (2001). *Key to the bat calls of south-east Queensland and north-east New South Wales*. Department of Natural Resources and Mines, Brisbane.

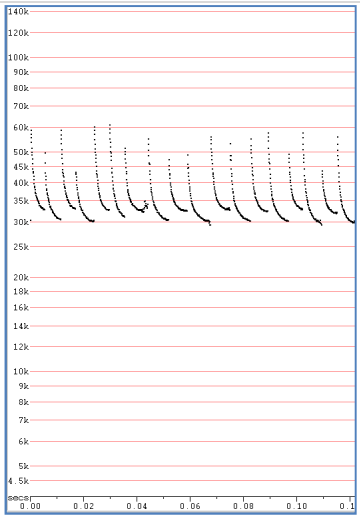
van Dyck, S., Gynther, I. and Baker, A. (eds.) (2013). *Field Companion to The Mammals of Australia*. New Holland; Sydney.

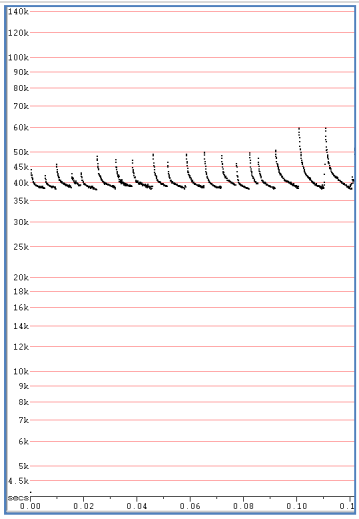
Glossary

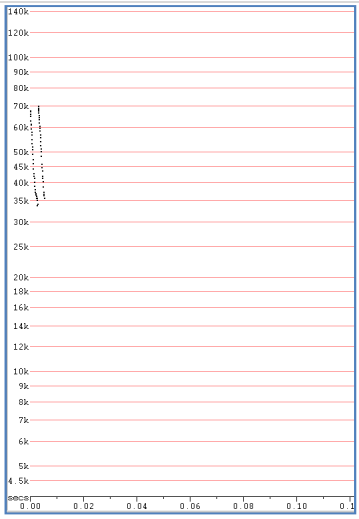
Technical terms used in this report are described in the following table.

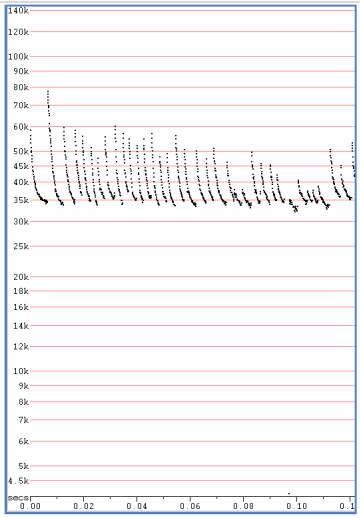
Approach phase	The part of a bat *call* emitted as the bat starts to home in on a detected prey item; a transitional series of *pulses* between the *search phase* and *feeding buzz*, that become progressively steeper and shorter in duration.
Call	Refers to a single bat call, made up of a series of individual sound *pulses* in one or more *phases* (*search, approach, feeding buzz*).
CF (=Constant Frequency)	A type of *pulse* in which the dominant component consists of a more-or-less 'pure tone' of sound at a Constant Frequency; with *shape* appearing flat on the sonogram. Often also contains a brief *FM* component at the beginning and/or end of the CF component (*viz.* FM-CF-FM).
Characteristic frequency (Fc)	The frequency of the flattest part of a *pulse*; usually the lowest frequency reached in the *qCF* component of a pulse. This is often the primary diagnostic feature for species identification.
Duration	The time period from the beginning of a *pulse* to the end of the pulse.
Feeding buzz	The terminal part of a *call*, following the *approach phase*, emitted as the bat catches a prey item; a distinctive, rapid series of very steep, very short-duration pulses.
FM (=Frequency Modulated)	A type of *pulse* in which there is substantial change in frequency from beginning to end; *shape* ranges from almost vertical and linear through varying degrees of curvature.
FC range	Refers to the range of frequencies occupied by the *characteristic frequency* section of *pulses* within a call or set of calls.
Frequency sweep or "band-width"	The range of frequencies through which a *pulse* sweeps from beginning to end; Maximum frequency (Fmax) – minimum frequency (Fmin).
Knee	The transitional part of a *pulse* between the initial (usually steeper) frequency sweep and the *characteristic frequency* section (usually flatter); time to knee (Tk) and frequency of knee (Fk) can be diagnostic for some species.
Pulse	An individual pulse of sound within a bat *call*; the *shape*, *duration* and *characteristic frequency* of a pulse are the key diagnostic features used to differentiate species.
Pulse body	The part of the *pulse* between the *knee* and *tail* and containing the *characteristic frequency* section.
Pulse shape	The general appearance of a *pulse* on the sonogram, described using relative terms related to features such as slope and degree of curvature. See also *CF, qCF* and *FM*.
qCF (=quasi Constant Frequency)	A type of *pulse* in which there is very little change in frequency from beginning to end; *shape* appears to be almost flat. Some pulses also contain an *FM* component at the beginning and/or end of the qCF component (*viz.* FM-qCF).
Search phase	The part of a bat *call* generally required for reliable species diagnosis. A consistent series of *pulses* emitted by a bat that is searching for prey or and/or navigating through its habitat. Search phase pulses generally have longer duration, flatter slope and more consistent shape than *approach phase* and *feeding buzz* pulses.
Sequence	Literally, a sequence of *pulses* that may be from one or more bats; but generally refers to a *call* or part (e.g. *phase*) of a call.
Tail	The final component of a *pulse*, following the *characteristic frequency* section; may consist of a short or long sweep of frequencies either upward or downward from the Fc; or may be absent.

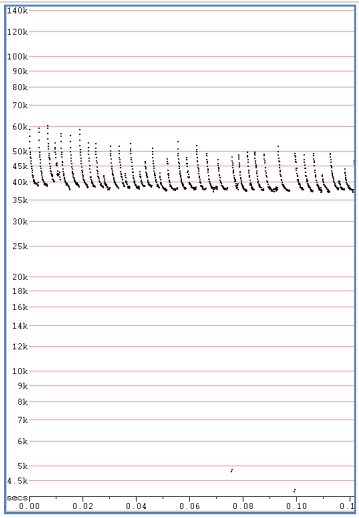
Appendix 1 Representative call sequences recorded at 'Barbara', 2-6 July 2014.
x-axis:10msec per tick; time between pulses removed. y-axis: $\log_{10}$ frequency (kHz)

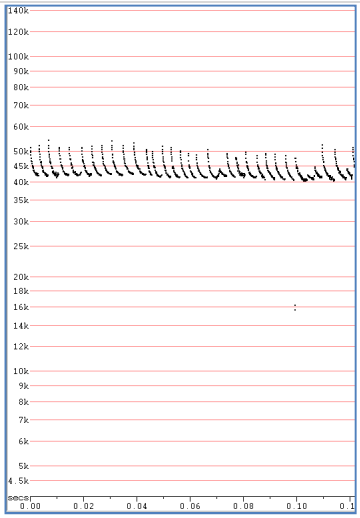

Chalinolobus gouldii

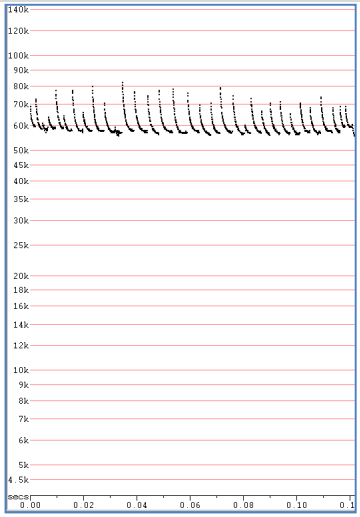

Chalinolobus nigrogriseus

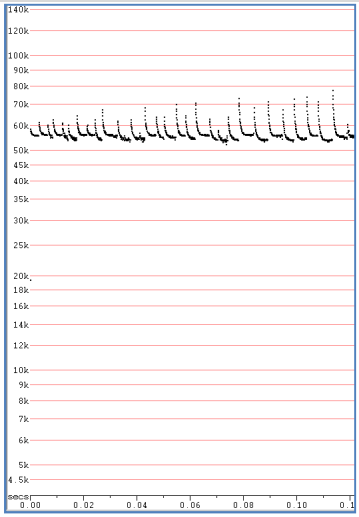

Possibly *Nyctophilus* species

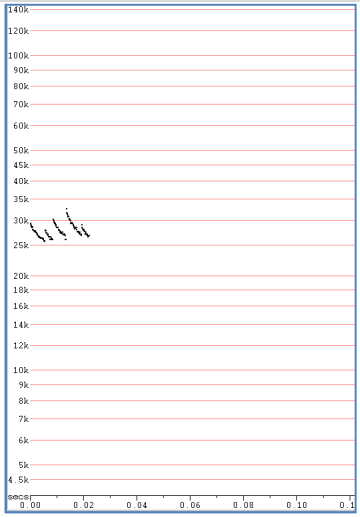

Scotorepens balstoni


Scotorepens greyii


Vespadelus baverstocki


Possibly *Vespadelus caurinus*


Vespadelus finlaysoni


Mormopterus beccarii

Appendix G Pest Fact Sheets

Department of Agriculture, Fisheries and Forestry
Biosecurity Queensland

Fact sheet

DECLARED CLASS 2 PEST ANIMAL

July 2014

Feral pig

Sus scrofa

Pigs (*Sus scrofa*) were introduced to Australia by early settlers. Subsequent accidental and deliberate releases resulted in the wild (feral) population establishing throughout Australia.

Feral pigs cause environmental and agricultural damage, spread weeds and can transmit exotic diseases such as leptospirosis and could spread foot-and-mouth disease.

Declaration details

Feral pigs are declared Class 2 pest animals under Queensland legislation. Declaration requires landholders to control declared pests on land under their control.

Description and general information

Feral pigs are typically smaller, leaner and more muscular than domestic pigs with well developed shoulders and necks, and smaller, shorter hindquarters.

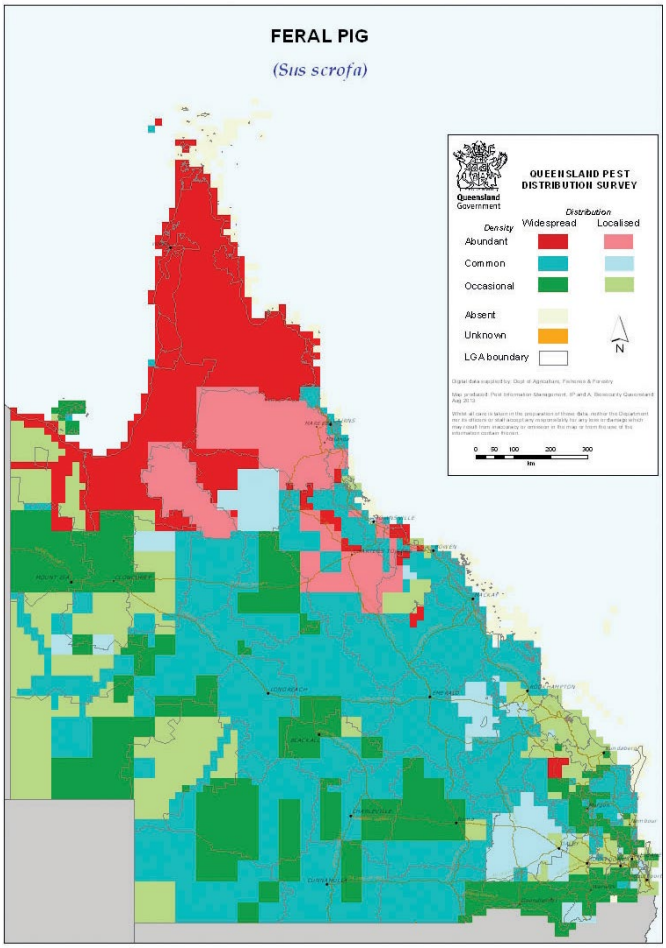
The body is usually covered in sparse, coarse hair and they have a longer, larger snout, longer tusks, a straighter tail and narrower back than domestic pigs. Feral pigs are mostly black, buff-coloured or spotted black and white.

Growth potential is similar to domestic pigs, although harsh environmental conditions tend to stunt development. Adult female feral pigs usually weigh 60–75 kg, while males usually weigh 90–110 kg. Older boars (razorbacks) can have massive heads and shoulders and a raised and prominent back bone that slopes steeply down to small hams and short hind legs. Some boars develop a crest or mane of stiff bristles extending from their neck down the middle of their back.

Feral pig wallow

Feral pig rooting

Map 1. Distribution of feral pigs in Queensland



Habitat and distribution

Feral pigs are found in all habitat types in Queensland. The greatest concentrations of feral pigs are on the larger drainage basins and swamp areas of the coast and inland. In hot weather, pigs need to remain near water.

Population estimates can be achieved by spotlighting, aerial survey or the use of motion cameras.

Evidence of feral pigs includes fresh digging or rooting of the ground, tracks and faeces on and off pads, mud or hair at holes in fences where pigs have pushed through, wallows, tusk marking and mud rubs on trees and fence posts and nests in vegetation made by sows before farrowing.

Biology and behaviour

Female and juvenile pigs usually live in small family groups with a home range of 2–20 km^2. Adult males are typically solitary, with a home range of 8–50 km^2. Range size varies with season, habitat, food availability and disturbance. Herds of 400 pigs have been recorded in Cape York.

Feral pigs are generally nocturnal, spending daylight hours sheltering in dense cover. Pigs are omnivorous, eating plants and animals and are extremely opportunistic feeders, exploiting any temporarily abundant food.

They prefer green feed and will eat grains, sugarcane and other crops, fruit and vegetables. They root extensively for tubers, worms and soil invertebrates.

Feral pigs have relatively high energy and protein requirements, particularly during pregnancy and lactation and often move to other parts of their home range during pregnancy.

Life cycle

Under good seasonal conditions, breeding occurs all year and sows can produce two litters per year. Adult females have a 21–day oestrus cycle, with a gestation period of about 113 days, producing a litter of 4–10 piglets. Sows can make nests of available vegetation just before farrowing. Nests sometimes have a domed roof and are usually less than 2 km from available water. Piglets normally spend the first 1–5 days of life inside the nest, with the sow nearby. Weaning occurs after 2–3 months. Sexual maturity is reached when sows weigh about 25 kg, usually around six months of age.

Mortality of juveniles is high if the mother's dietary protein intake is low (up to 100% mortality in dry seasons). Adult mortality does not vary as much with seasonal conditions, but few animals live more than five years.

Impacts

Pigs can damage almost all crops from sowing to harvest, starting with uprooting seed and seedlings to feeding on or trampling mature crop.

They feed on seed, sugar cane and grain crops (except safflower), fruit (especially banana, mango, papaw, macadamia and lychee) and vegetable crops. Research has shown feral pigs can take up to 40% of lambs.

Pastures are damaged by grazing and rooting and pigs can also transport weeds. Wallowing pigs damage and foul the water in tanks and bore drains and silt up troughs. They can also damage fences and dam walls.

Pig activity degrades water quality and the habitat for small terrestrial and aquatic animals. It also creates erosion and allows exotic weeds to establish. Predation of native fauna does occur and examination of faeces has shown remains of marsupials, reptiles, insects, and ground-nesting birds and their eggs.

Feral pig damage to river banks

Feral pig damage to sugar cane

Diseases and parasites

Feral pigs can carry many infectious diseases and internal and external parasites. Some are endemic (already present), while others are exotic to Australia.

Many of the diseases can spread to domestic pigs, other livestock and humans. Feral pigs can transmit sparganosis, melioidosis, leptospirosis, Q fever and brucellosis to humans.

To prevent contracting these diseases it is advisable to either avoid handling feral pigs or use suitable protective clothing (mask, goggles, strong rubber gloves and plastic apron and boots) to minimise contamination with blood, urine and faeces. Rare or undercooked meat should not be eaten; thoroughly cook meat to avoid contracting pathogens.

Control

Feral pigs are difficult to control because they are primarily nocturnal, breed rapidly, are generalist omnivores and have large home ranges and thus control programs need to be conducted over a wide area (often including several properties) to be effective.

Effective control requires an integrated, collaborative approach where all stakeholders participate in planning, implementation and evaluation of the actions taken.

Trapping

Trapping is an important technique that is most useful in populated areas, on smaller properties (‹5000 ha), and where there are low pig numbers. Trapping can be particularly useful in 'mopping up' survivors from baiting programs. It is most successful when food resources are limited.

Trigger mechanisms for pig traps can be made pig-specific and therefore pose little danger to wildlife or domestic animals.

Advantages

- This is the safest form of control and can be safely undertaken on closely populated areas.
- It's flexible and can be incorporated into routine property activities, making economical use of labour and materials.
- Carcasses can be safely disposed.
- Traps can be moved and re-used; good trapping makes use of opportunities as they arise.
- Normal pig behaviour is not altered, which allows a greater number of the total population in an area to be targeted.
- More humane to pigs and non-target species.
- The number of animals removed can be easily monitored.

Disadvantages

- Can be time consuming and expensive to construct and maintain.
- Must be checked regularly.
- Not practical for large-scale control.
- Some pigs are trap shy.

Tips

- Stop all activities that will disturb normal feeding (i.e. do not undertake any shooting or dogging).
- Pre-feeding (i.e. ensure that pigs are visiting trap and consuming bait) prior to activating traps is an essential part of successful trapping.
- Feeding sites should be placed where feral pigs are active (i.e. water points, holes in fences, areas containing old carcasses on which pigs have been feeding).
- Bait for traps must be food that pigs usually eat in that area. Pigs feeding on one crop (e.g. sugarcane) will often not take to alternative foods. However, new, novel baits are sometimes attractive (e.g. fermented grains).
- The trap can be built around the feeding site, with feeding within the trap undertaken for several nights before it is set.
- Set the trap every night and check each day. If the trap cannot be checked daily then shade and water must be provided.
- Continue to trap until no more pigs are caught. A change of bait can be tried. Again, feed for one or two nights before re-setting the trap.
- Traps may be left permanently in locations used by pigs and can be utilised when fresh signs of pigs appear.
- If the trap is to be moved, start feeding at the new site before re-locating the trap.

Design

There are several trap designs but all are principally an enclosed area with one-way gates (see Figure 1).

The main area of the trap can be any shape and be made from materials on the property. The best material is steel mesh with a grid 100 × 100 mm, with a minimum height of at least 1.5 m. Star pickets need to be placed no more than 1.5 m apart and imbedded far enough to ensure that adult pigs cannot push them over or lift them up out of the ground.

Alternative trap entrances

Funnel entrance

Formed by the two ends of the mesh forming a funnel, the ends are tied together at the top with wire or rope. The pig moves through the funnel forcing the bottom of the mesh ends apart and once it is in the trap the ends spring back together (see Figures 1 and 2).

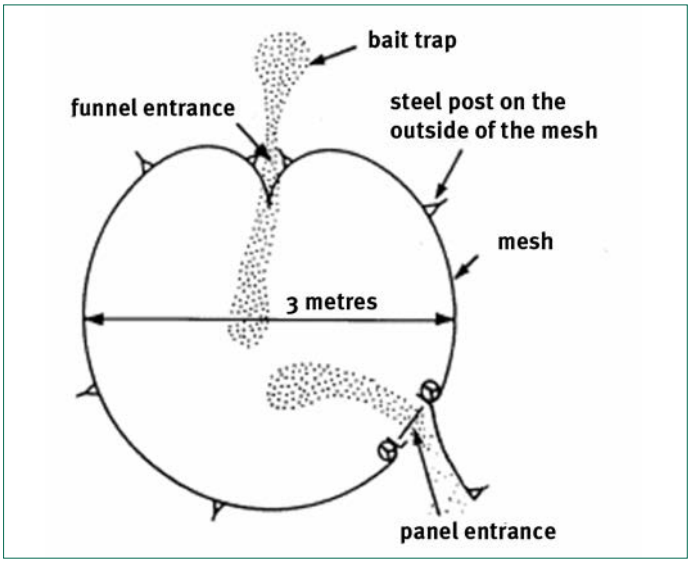


Figure 1. Alternative trap entrances – funnel entrance

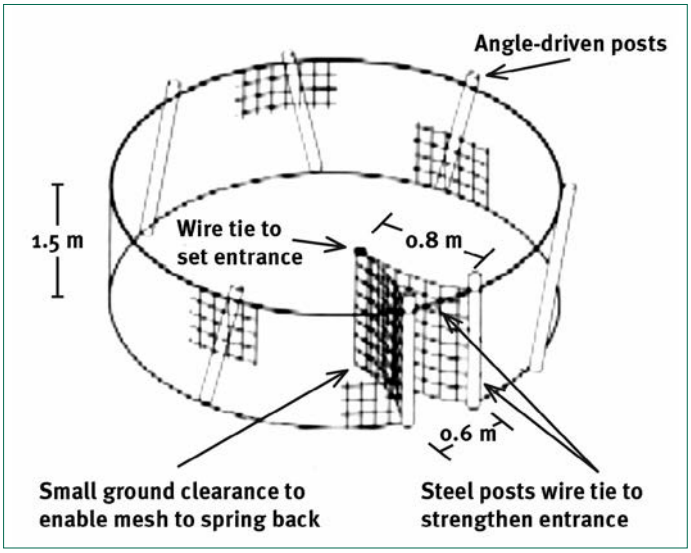


Figure 2. Silo trap with funnel entrance (14 m of silo mesh diameter about 4.5 m

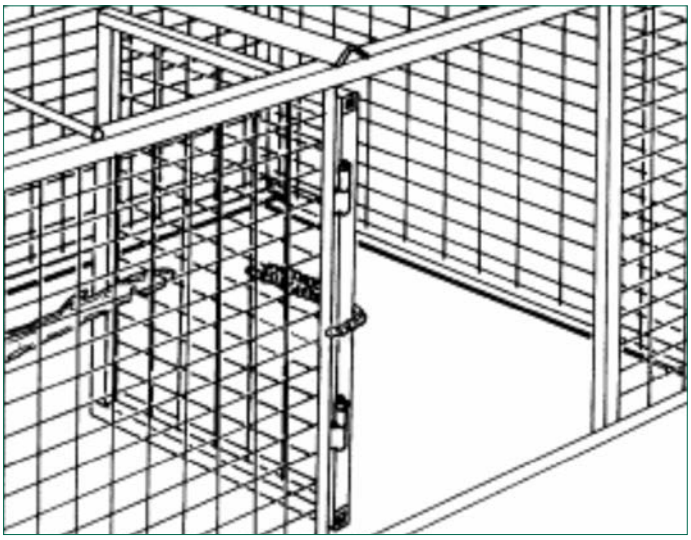


Figure 3. Pig-specific trigger

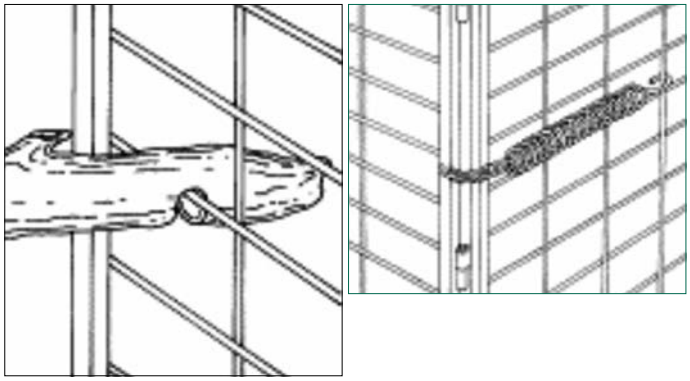


Figure 4. Close up of pig-specific trigger

Feral pig trap

Trapped feral pigs

Hog hopper – pig specific bait station

Tripped gate entrance

A side-hinged gate is pulled shut by springs and is held open by many systems that can be triggered to allow the gate to swing shut. Often trip wires or other systems are used; most of these systems are not selective for feral pigs and can be triggered by any animal attracted to the bait. Once triggered the trap is no longer effective in trapping pigs.

Pig-specific trigger

By far the simplest and most effective trigger system has the gate held open by a bar (often a branch or piece of wood) which is hooked over the wire on the gate and on the side panel (see Figure 3). For a close up of the pig specific trigger (see Figure 4).

Pigs rooting for feed in the trap lift the bar allowing the gate to swing shut. The specific feeding habit of pigs insures they are the only animals that lift the trigger bar.

The gate may be latched to prevent pigs from opening the door once triggered. However, this will prevent more pigs pushing their way in to join those inside.

Poisoning

Poisoning is the most effective control method available that can quickly reduce a pig population.

Sodium fluoroacetate (1080) can only be supplied by people approved under the Health (Drugs & Poisons) Regulation 1996 for the purpose of controlling declared pest animals. Your local government office should be able to assist you.

Pre-feeding is the most important step in ground-based poisoning operations. Free feeding with non-poisoned bait should be performed for several days prior to laying poisoned baits.

By selecting bait wisely, landholders can be species-selective in their poisoning program and avoid many of the unintentional effects of secondary poisoning.

Bait material such as fermented grains are very attractive to pigs. It is a good idea to establish a free feeding routine so that pigs are the only animals feeding, which helps to keep other non-targets away from the feeding site.

Other options (like pig-specific feeders) are now commercially available, and can assist in reducing non-target species access to bait. Other options include burying baits; feral pigs are one of the few animals that will dig up bait.

Aerial poisoning is also available and typically used for broadscale control in western and northern regional areas. Bait is distributed from an aircraft. This is particularly useful for covering large, remote, areas or restricted ground access. Aerial poisoning is a proven and cost-effective method for reducing pig populations.

A phosphorous-based poison is also available for use in Queensland.

Shooting and the use of dogs

Shooting pigs by helicopter is effective in areas where pigs exist in reasonable numbers and are observable from the air.

Ground shooting is not effective in reducing the pig population unless intense shooting is undertaken on a small, isolated and accessible population of pigs.

Dogs may be used to remove the few remaining pigs left after poisoning and trapping campaigns. Dogs are able to locate and flush pigs out of areas of thick cover. Dogs must not be used to hold or attack pigs.

Do not use dogs or shoot in areas before or during poisoning or trapping operations.

Fencing

Though an expensive option, fencing can offer successful pig control especially for high value crops grown on small areas. Research has indicated that the most successful pig-proof fences are also the most expensive.

The most effective pig-proof fences use fabricated sheep mesh held close to the ground by plain or barbed wire and supported on steel posts.

Electrifying a conventional fence greatly improves its effectiveness if used before pigs have established a path through the fence.

Pigs will often charge an electric fence and unless the fence incorporates fabricated netting they often successfully breach the fence.

For crop protection or to avoid lamb predation, pig-proof fences need to be constructed before the pigs become a problem. Once pigs have adjusted to feeding on grain or lambs in a particular paddock fencing may be ineffective.

Fertility control

There are currently no available means to deliver fertility control to feral pigs. Such a technique is likely to remain unavailable for practical use given the lack of suitable contraceptives, suitable delivery mechanisms, and concerns with non-target species.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland (call 13 25 23 or visit our website at www.biosecurity.qld.gov.au).

Visit www.biosecurity.qld.gov.au to download a copy of the feral pig control manual.

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Department of Agriculture, Fisheries and Forestry
Biosecurity Queensland

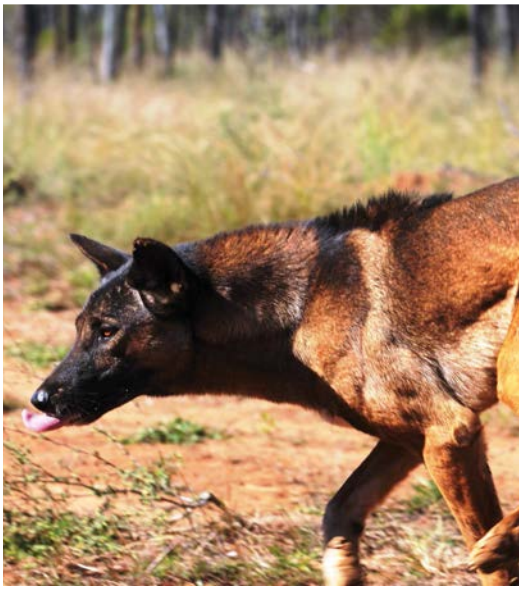
Fact sheet

DECLARED CLASS 2 PEST ANIMAL

July 2014

Wild dog control

Canis familiaris



The term wild dog refers collectively to purebred dingoes, dingo hybrids and domestic dogs that have escaped or been deliberately released.

Wild dog control methods include baiting, trapping, shooting, fencing, and the use of guardian animals to protect stock. A planned strategy using a combination of these methods that also considers wild dog behavior will enable effective management.

Declaration details

Wild dogs are a declared Class 2 pest animal under Queensland legislation. As such, all landholders in Queensland are required to reduce the number of wild dogs on their properties.

Management strategies

To increase wild dog control effectiveness, it is essential that control programs are coordinated among adjoining properties.

Queensland research has shown that in some situations wild dogs can quickly re-colonise baited areas due to a number of factors including inconsistent bait programs which do not provide comprehensive wild dog control across the landscape. Such programs may alter the dynamics of wild dog populations in the area. To prevent livestock attacks and enhance wild dog management, it is important for producers to work together using a variety of control methods.

Wild dog ecology and seasonal variations can also influence the likelihood of wild dogs coming into contact with a control tool. The timing of control should consider seasonal variations and the availability of water (where water is restricted) and then target watering points. Many land owners bait using 1080 twice a year to target wild dogs during peaks in activity associated with breeding (March/May) and then again in September/November to target pups and juveniles. However, baiting and trapping is recommended at all times when wild dogs are active.

Control

Baiting

Poison baits are the most economic, efficient and effective method of controlling wild dogs, especially in inaccessible or extensive areas. Baits can be laid quickly by hand, from vehicles and from aircraft.

Currently there are two poisons legally available for wild dog control. These are 1080 (sodium fluoroacetate) and strychnine.

Subject to restrictions, 1080 baits, either manufactured or prepared from fresh meat can be obtained through people approved under the Health (Drugs & Poisons) Regulation 1996. A permit from the Queensland Department of Health is required for land owners to purchase strychnine. Strychnine can be used both in baits and on traps. The use of both 1080 and strychnine require adherence to the associated conditions of supply.

The use of poison baits will control some but not all wild dogs. Baits should be used in conjunction with all other control tools and not be relied on as a total control method.

Meat baits are attractive both to wild dogs and a range of non-target species. When using meat baits, they can be strategically positioned as wild dogs' keen sense of smell enables them to find baits intentionally buried in sand or otherwise hidden under bushes or in hollow logs. Meat baits may also be tied to prevent their loss to non-target species.

These meat bait placement techniques help to:

- reduce the risk of poisoning non-target species
- increase wild dog contact, hence receiving a lethal dose
- minimise bait removal by non-target scavengers
- deter ants (ant-covered baits are believed to be less attractive to wild dogs).

Heavy rain within two weeks of baiting can leach 1080 from baits, but baits may still remain toxic for a considerable time.

Trapping

A key success to trapping wild dogs (using foot-hold traps) depends on the skill of the operator. Visit www.feral.org.au to watch a PestSmart video on best practice techniques for wild dog trapping.

For humane reasons and to prevent escape, poisoning traps with strychnine is recommended to quickly kill captured wild dogs. A properly poisoned trap becomes a lethal device rather than a holding device.

A mixture of dog faeces and urine is a popular lure used by trappers. Attractiveness of lures varies with seasons and locations. No single lure has yet been found that is consistently attractive to all wild dogs and repeated use of one lure can lead to aversion amongst remaining dogs.

Traps are best placed in areas of high wild dog activity (known as leads). Here the wild dog is most likely to find and investigate the decoy/odour.

A wild dog scent post (an area where urine or faeces have been deposited) can be found by walking with a domestic dog on a lead along a known pad. Trap placement in relation to the scent post can be optimised by observing the domestic dog's behaviour as it approaches. Factors to consider are:

- where on the bush it smells
- placement of feet while urinating/defecating/sniffing
- how it approaches and where it scratches in relation to the pad and scent post.

Padded, laminated or offset foot-hold traps, in a well tuned and functioning state are recommended.

Shooting

Shooting is an opportunistic method, mostly used for control of small populations or individual problem animals.

Fencing

Property fencing suitable to exclude wild dogs is expensive to build and requires continual maintenance to repair damage caused by fallen timber, fire, floods, feral and domestic animals, as well as vegetation regrowth. However, a properly maintained fence can restrict movement into an area where wild dogs have been controlled.

Electric fences suitable for wild dogs have been developed. Electrifying a fence creates a fear of the fence itself and deters wild dogs from approaching.

For property fencing to be successful, the fence must be maintained in good order and ongoing wild dog control conducted within the protected area to limit livestock impacts.

Fencing is the most effective method of protecting livestock and pets from wild dog attack on small acreage blocks.

A fence can also be a good area to place baits and traps when wild dogs are active.

Livestock guardian animals

Livestock guardian animals have been used to protect livestock from predators in Europe, Asia and America. Some producers in Queensland have decreased predation on sheep and goats using this method. The use of trapping and poisoning in conjunction with guardian animals must be well planned and managed to ensure guardian animal safety.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland (call 13 25 23 or visit our website at www.biosecurity.qld.gov.au).

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Biosecurity Queensland

Fact sheet
PEST ANIMAL
PA21 December 2013

Cane toad

Bufo marinus

The cane toad is not a declared pest in Queensland, so there is no legal requirement to control them.

Their original introduction in 1935 was to control agricultural pests, but they proved ineffective.

For the past 60 years, cane toads have been expanding their territory in Australia, and are capable of colonising at least four of the mainland Australian states.

As the toad's geographical range continues to expand, concern has increased about their detrimental environmental effects, particularly on the wetlands of the Northern Territory.

Studies into the feasibility of biological control have commenced.

History of introduction and spread

The cane toad or giant toad is an amphibian, native to Central and South America. Cane toads have been introduced throughout the world as a biological control for insect pests of agriculture, most notably sugarcane.

A consignment of cane toads from Hawaii was released into Queensland cane fields in 1935. The introduction was surrounded by controversy as to the potential costs and benefits to Australia.

It was hoped that the toad would control Frenchi and greyback beetles—pests of economic importance to the sugarcane industry.

By 1941, however, it had become evident that the cane toad was exerting only limited control over its intended prey. There were two main reasons for this:

- Greyback beetles are only rarely in contact with the ground and Frenchi beetles invade cane fields at a time when the toads are absent due to a lack of protective cover.
- The cane toad has a wide-ranging and indiscriminate diet, and it was not solely dependant upon its intended prey.

The unlimited food source, suitable environment and low rates of predation allowed dynamic reproduction and spread. Toads were recorded in Brisbane only 10 years after release. The toad continues to thrive and has now invaded the Northern Territory and New South Wales (see Map 1).

Map 1. Distribution of the cane toad in Australia

The cane toad's advance is only limited by environmental factors, such as the availability of water for breeding, tolerable temperatures, suitable shelter and availability of food.

Toads at the frontier of their range of expansion may be larger than those in established populations. This is most probably due to greater food supply, combined with a lower incidence of disease.

Description and general information

In comparison with native frog and toad species, adult cane toads have a distinctive head and face, and are large and heavily built creatures (adults may grow to 20 cm).

Following their aquatic larval stages (eggs and tadpoles), cane toads are generally encountered at night near any source of light. Cane toads are ground-dwelling—they are poor climbers and unable to jump very high.

A definite visor or awning extends over each eye and a high angular bony ridge extends from the eyes to the nose.

The parotid glands (see Figure 1) are perhaps the most characteristic feature of the adult cane toad. These glands are large, protuberant, and are situated on the head behind each ear. These glands carry a toxin.

Map 2. Distribution of the cane toad in Queensland

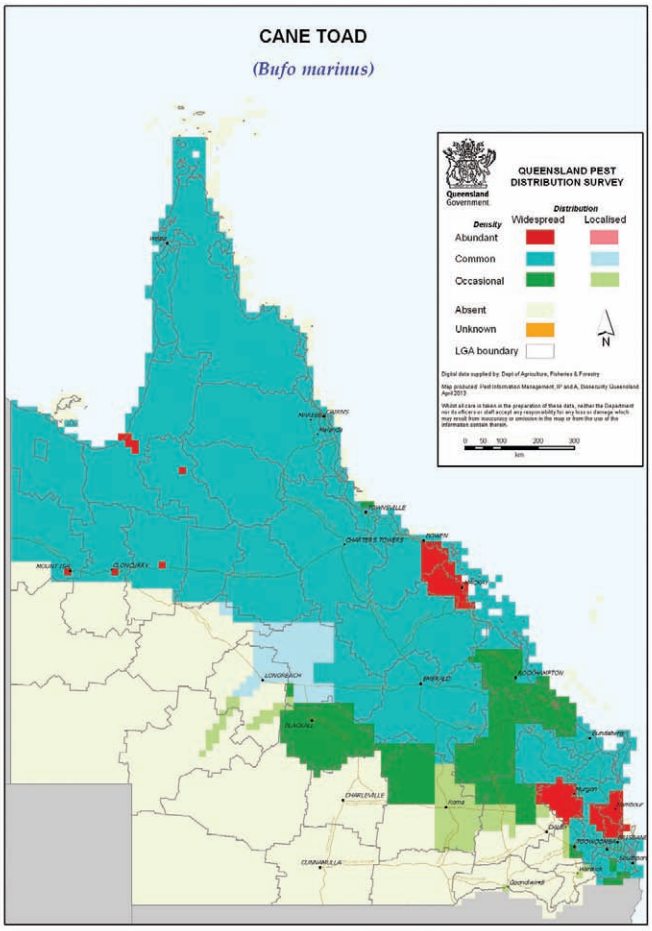
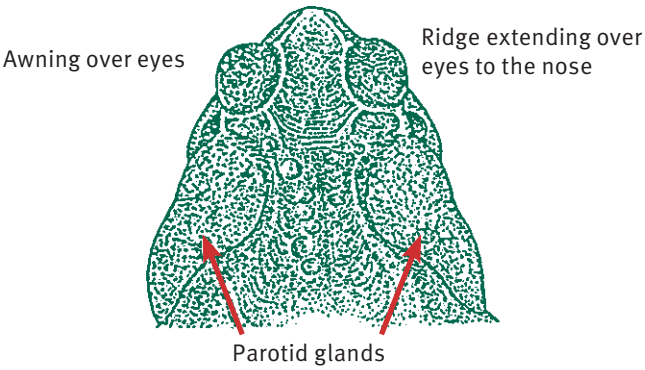


Figure 1. Distinguishing features of the cane toad



The cane toad's hands and feet are relatively small and lack discs at the tips of the digits. Webbing is absent between the fingers but is distinct and leathery between the toes.

Colouring on the dorsal (upper) surface may be brown, olive-brown or reddish-brown. The ventral (under) surface varies from white to yellow and is usually mottled with brown.

Warts are present on all cane toads; however, males possess more than females. Warts are dark brown at the caps.

Mating

Mating can occur at any time of the year and depends only on available food and permanent water. The mating call is a continuous purring trill that sounds like a running motor.

In situations where females are scarce or absent, male cane toads may have the ability to undergo a sex change to become fertile females; however, this has not been proved.

Eggs

Both cane toads and native frogs spawn in slow-moving or still water, but their eggs can be easily distinguished.

Cane toad eggs are laid in long, gelatinous 'strings' with the developing tadpoles appearing as a row of small black dots along the length. The strings are unique to cane toads, generally appearing as blobs of jelly attached to water plants or debris. Native frogs generally produce egg clusters as mounds of foam floating on the water surface.

Compared with native species, cane toad egg production is dynamic and a single clutch can contain up to 35 000 eggs. Remove any cane toad eggs found in the water and allow to dry out.

Figure 2. Drawing of toad spawn from *Wildlife of greater Brisbane*

Tadpoles

The cane toad is the only species in Australia that has a pure black tadpole. Native frogs have lighter-coloured undersides with a great range of colours and markings—cane toad tadpoles may turn paler colours to almost transparent at night.

Cane toad tadpoles are small and usually congregate in vast, slow-moving shoals. This 'shoaling' behaviour is uncharacteristic of most native species.

Unlike cane toad tadpoles, native species develop lungs at an early stage and periodically rise to the surface in order to exchange their lung gasses. Large groupings of tadpoles that do not break the water surface for air indicate cane toads.

Young toads

Following emergence from the water, the young toadlets usually congregate around the moist perimeter of the water body for about a week before they eventually disperse.

Young toads are very difficult to distinguish from the native *Uperoleiea* species, which also have parotid glands, but all *Uperolelea* species have bright red patches in the groin area.

Under ideal conditions toadlets may reach adult size within a year.

Toxicity

Bufo marinus produce venom in glands occurring in most of the skin on their upper surface. The venom is concentrated in the parotid glands as a creamy-white solution, which is released when the animal experiences extreme provocation or direct localised pressure (e.g. grasped by the mouth of a predator).

The parotid solution is highly toxic and when ingested it produces drastic acceleration of the heartbeat, shortness of breath, salivation and prostration. It is extremely painful if accidentally rubbed into the eye.

Ingestion of toads by domestic and most native animals can result in death. In some recorded cases, death has occurred within 15 minutes.

Field observations suggest that some predatory Australian species have learned how to feed safely on cane toads.

Birds have been observed flipping toads over to avoid the parotid glands. Predatory reptiles may have more trouble adapting, being unable to remove a toad from the mouth once they start feeding.

Effects on wildlife

The cane toad is poisonous at all stages of its life cycle and most native frog larvae and many aquatic invertebrates are dramatically affected by their presence.

Cane toads are voracious feeders that consume a wide variety of insects, frogs, small reptiles, mammals and even birds. Perhaps the only limiting factor to the prey taken is the width of the cane toad's mouth.

It has been suggested that cane toad competition for food and breeding grounds has been responsible for reducing the populations of some native frogs. However, many native frogs are arboreal (tree-dwelling) and occupy different niches. Cane toads don't have the native frogs' ability to 'shut down' during dry seasons when resources are limited.

Pressure from cane toads may displace native animals (frogs and other species) where they are already suffering due to manipulation of their habitat by humans and grazing animals. Animals that use waterholes as retreat sites during the dry season are especially vulnerable—toads will congregate here in large numbers.

Public health

Cane toads readily eat animal and human faecal material and, in areas of poor hygiene, they have been known to transmit disease such as salmonella.

Control

Control of cane toads is not enforced as there is currently no available effective broad scale control. Individuals and community groups have carried out removal campaigns to decrease numbers and slow the invasion front.

Fencing is recommended to keep toads out of ponds intended for native fish and frogs; a height of 50 cm is sufficient. Bird wire with 1 cm holes may keep toads out of an area.

Research indicates that spread can be delayed in semi-arid areas by blocking access to water holes.

Individual toads may be killed relatively humanely using a commercial spray available from hardware stores or may be stunned and decapitated (only by experienced operators). The removal of eggs from small water bodies such as frog ponds can be effective

Researchers have successfully mitigated impacts in recently colonised areas by 'training' predators however, large scale application of this technique is difficult.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland (call 13 25 23 or visit our website at www.biosecurity.qld.gov.au).

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Document No. 4405/1113

Barbara Copper Project

Assessment of Waste Rock Geochemistry

October 2014

Contents

1.0 Introduction 1

2.0 Selection and Preparation of Drill Core Samples 3

3.0 Geochemical Assessment Methodology 5

3.1 Sample Preparation 5
3.2 Laboratory Program 6
3.3 Analytical Methods 6

4.0 ARD Characteristics 10

4.1 Existing pH 10
4.2 ARD Classifications 11
4.3 Acid-Base Account Plot 12
4.4 ARD Classification Plot 12
4.5 Sulphur versus NAGpH 15
4.6 NAPP versus NAG 15
4.7 Reactivity of PAF Rock 17
4.8 Sulphur Forms 19
4.9 Acid Neutralisation Capacity 20
4.10 Carbon Forms and Reactivity of Neutralising Capacity 21

5.0 Elemental Characteristics of Waste Rock 25

5.1 Elemental Composition of Solids 25
5.2 Geochemical Abundance Indices 25
5.3 Salinity 29
5.4 Water Extractable Elements 30
5.5 Peroxide Extraction Results 32

6.0 Summary and Implications for Waste Rock Management 36

6.1 Summary and Findings 36
6.2 Operational Identification of PAF Waste 38
6.3 Implications for Waste Rock Management 38
6.4 Pit Water Quality 40

List of Tables (within text)

1: *Sulphur speciation results for PAF samples in the kinetic NAG testing program*

2: *Carbon speciation and Carbonate Neutralising Values for Barbara drill core samples*

3: *Readily-available neutralising capacity based on acid buffer characteristic curves*

List of Figures (within text)

1: *Conceptual mine layout for the Barbara site*

2: *Down hole depths of core samples selected for geochemical assessment*

3: *Drill collar plan for the Barbara site*

4: *Statistical summary of the existing pHs of Barbara drill core samples split by rock unit*

5: *Acid-base account plot for Barbara drill core samples split by material type*

(a) all samples (b) expanded scales

6: *ARD classification plot for Barbara drill core samples split by material type*

(a) all samples (b) expanded scales

7: *Plot of NAG versus NAPP for Barbara drill core samples*

(a) all samples (b) expanded scales

8: *Plot of NAG pH versus sulphur content for Barbara drill core samples containing less than 5 %S*

9: *Kinetic NAG pH profiles for Barbara drill core samples*

10: *Statistical summary of the ANCs of Barbara drill core samples split by ARD classification*

11: *Comparison of ANC and CNV for Barbara drill core samples*

12: *Acid buffer curves for Barbara drill core samples with high ANCs*

13: *Box plot of elemental concentrations in Barbara drill core samples representing waste*

14: *Box plot of elemental concentrations in Barbara drill core samples representing ore*

15: *Frequency distribution plot of GIAs in Barbara drill core samples representing waste*

16: *Frequency distribution plot of GIAs in Barbara drill core samples representing ore*

17: *Summary of the EC values for Barbara drill core samples split by rock unit*

18: *Box plot of elemental concentrations in water extracts of Barbara drill core waste samples*

19: *Box plot of elemental concentrations in water extracts of Barbara drill core ore samples*

20: *Box plot of elemental concentrations in acidified peroxide extracts of Barbara drill core samples*

21: *Box plot of elemental concentrations in non-acidic peroxide extracts of PAF Barbara drill core samples*

List of Appendices (after text)

A: Geological codes for the Barbara Project

B: Acid forming characteristics of Barbara drill core samples

C: Sequential NAG test results for Barbara drill core samples

D: Kinetic NAG test profiles for Barbara drill core samples

E: Acid buffer characteristic curves for Barbara drill core samples

F: Elemental compositions of Barbara drill core samples

G: Geochemical abundance indices for Barbara drill core samples

H: Water extract results for Barbara drill core samples

I: Peroxide extract results for Barbara drill core samples

1.0 Introduction

Environmental Geochemistry International Pty Ltd (EGi) was commissioned by joint venture partners CopperChem Ltd and Syndicated Metals Ltd (hereafter referred to as the Joint Venture) to carry out an assessment of waste rock geochemistry for the Barbara Copper Project, located in north-west Queensland, approximately 50 km east of Mount Isa. The main purpose of the assessment was to identify any geochemical characteristics that potentially could adversely impact the quality of waste dump drainage and therefore will have implications for the management of waste rock at the site.

The Barbara Copper Project will involve open pit development of the Barbara copper resource comprising approximately 800,000 tonnes grading 0.5 %Cu. The resource also has trace concentrations of gold, silver and cobalt. The mineralisation is structurally controlled by the Barbara Shear Zone and occurs as a series of sulphide lodes hosted within a package of rhyodacitic volcanic rocks intruded by dolerite dykes. Sulphide mineralisation comprises semi-massive pyrrhotite/pyrite with chalcopyrite and chalcopyrite stringer veins.

The footprint of the mined area will be about 18 ha and will comprise two adjoining open pits located along the N-S trending strike of the resource that extends over a distance of approximately 900 m. The North pit will have a maximum depth of about 50 m, and the South pit will reach a depth of about 130 m. The two pits will be mined concurrently over a period of approximately two years. A conceptual layout for the Barbara site is given in Figure 1.

The resource will be developed as a conventional bench mining operation using drill, blast, excavation, and dump truck haulage to run-of-mine (ROM) ore stockpiles. Excavated ore will be crushed on-site then transported off-site by road train for processing at either Copperchem's Great Australia Mine in Cloncurry or another third party processing facility in the region.

In addition to ore, the open pit will produce approximately 7.5 Mtpa of waste rock which will be placed in a stable land form adjacent to the open pit. The Joint Venture expect the majority of waste will be low sulphur rock, primarily high Ca+Mg basalts and mafics, low Ca+Mg felsic volcanics, and pedogenic carbonates. However, some sulphide rich waste zones occur immediately adjacent to the ore zone, primarily on the footwall, which may be mined as fresh waste or left in the end walls of the pit. Such material is considered high risk in relation to its potential for generation of acid rock drainage (ARD) if exposed to atmospheric conditions.

The geochemical assessment carried out by EGi involved analysis of drill core samples representing the range of waste rock lithologies that will be intersected during open pit mining of the Barbara copper resource. The main objectives of the geochemical assessment were as follows:

- To define the geochemical characteristics of waste rock and ore grade materials and provide sufficient data for a preliminary assessment of the likelihood of occurrence of acid generating rock types.
- To assess the forms and reactivities of the sulphide mineralisation within ore and waste rock, and to assess the likely time frames for any materials that are potentially acid forming (PAF) to acidify.

- To assess the forms and reactivities of the carbonate mineralisation within waste rock, and to assess the usefulness of these materials for control or mitigation of ARD generation, if required.
- To identify any elemental enrichments that could be environmentally significant, and to assess the potential for mobilisation of elements that could adversely impact drainage quality.

This report presents the results and findings of the geochemical assessment, and the implications for waste rock handling and management, and drainage water quality at the Barbara Copper Project.

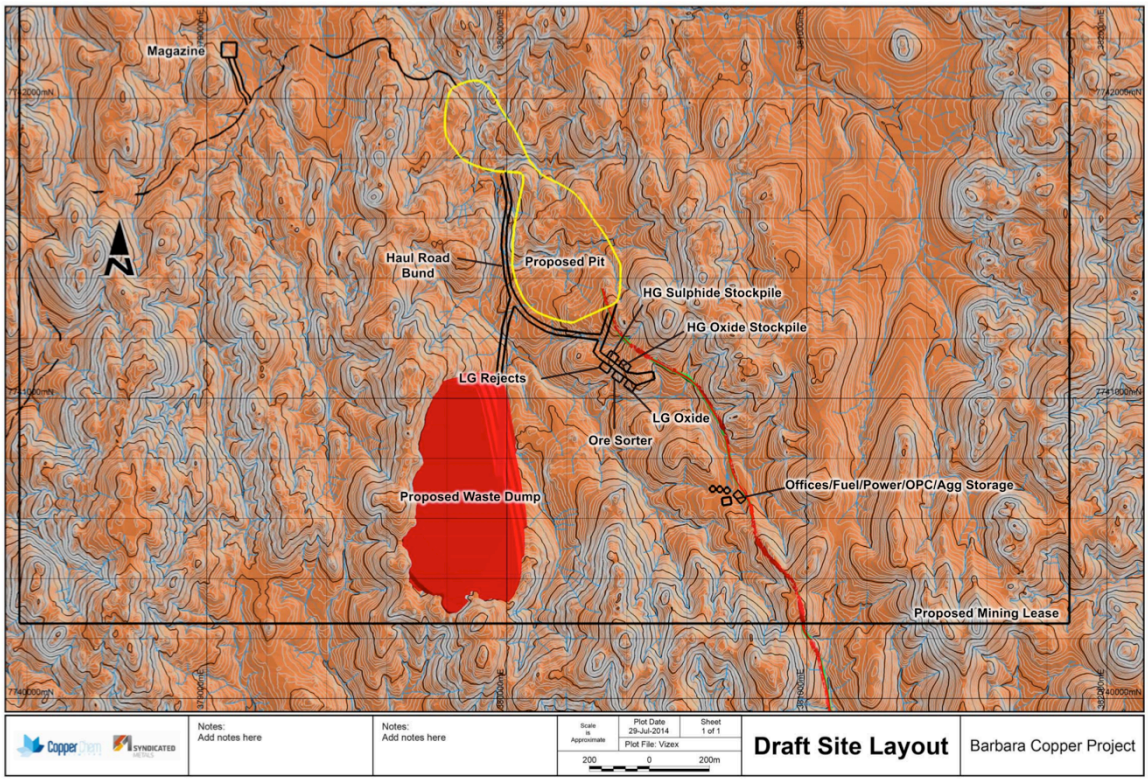


FIGURE 1: *Conceptual mine layout for the Barbara site*

2.0 Selection and Preparation of Drill Core Samples

A total of 121 drill core samples from 14 diamond drill holes were included in the geochemical assessment. The holes were drilled in February-March 2014 and were identified with the prefix BADD. The hole ID numbers: 015, 021, 023, 033, 034, 035, 036, 038, 042, 043, 045, 046, 049 and 080.

Each sample typically represented a 1 m interval of core, and a semi-regular sampling pattern was used to provide judicious spatial coverage of the northern and southern mining zones. Figure 2 shows a schematic of sample intervals that were tested, and a location plan for the drill hole collars is given in Figure 3.

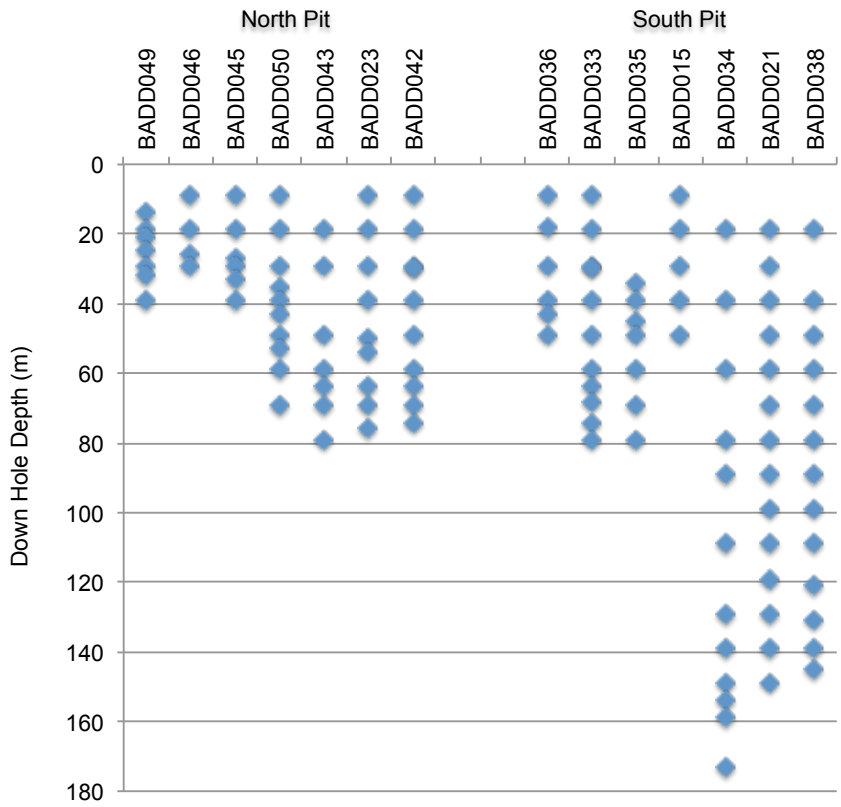


FIGURE 2: *Down hole depths of core samples selected for geochemical assessment*

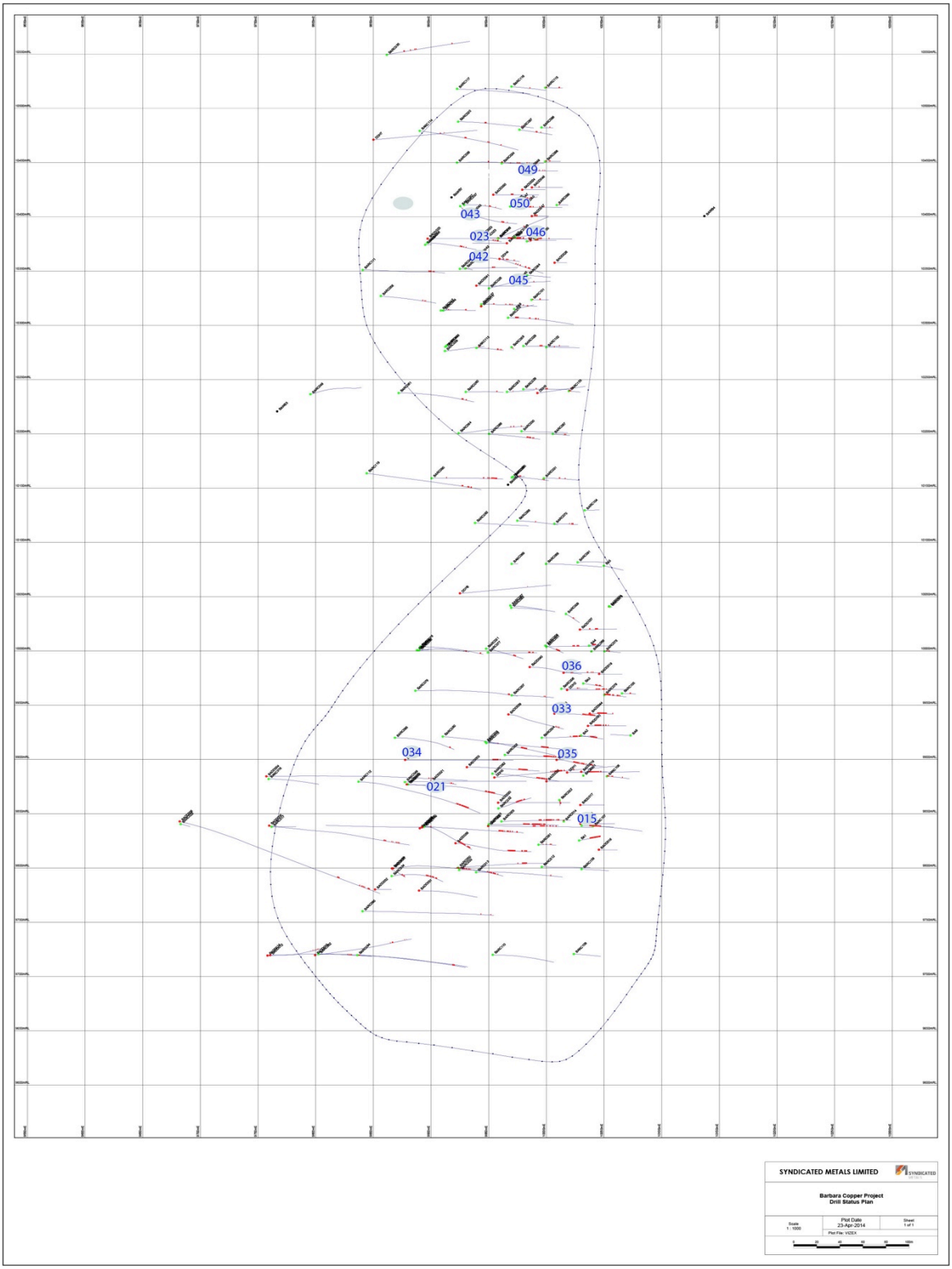


FIGURE 3: *Drill collar plan for the Barbara site*

The distribution of samples between rock types[1] was as follows:

Porphyritic Rhyolite (VFRD)	87 samples	Dolerite (IMD)	4 samples
Rhyolite (VFR)	3 samples	Mafic intrusive (IMO)	2 samples
Biotite Schist (XSB)	15 sample	Basalt (VMB)	2 samples
Biotite Chloritic Schist (XSBH)	1 sample	Psammite (XMO)	2 samples
Schist (XSO)	4 samples	Gossan (RZO)	1 sample

Most of the samples had low copper concentrations and were representative of material that will likely be mined as waste. The distribution of samples between waste and ore based on the current mine plan and a copper cut-off of 0.5 %Cu was as follows:

- Waste 94 samples
- Ore 27 samples

Three samples (8101, 8055, 8040) designated ore* in Appendix B were slightly below grade but were located within the ore zone and therefore would likely report as ore. Another sample (8068) designated ore** in Appendix B was a relatively minor interval of core with above grade copper located within the waste zone. It is possible such materials could report as waste or ore depending on actual mine planning.

3.0 Geochemical Assessment Methodology

3.1 Sample Preparation

Sample preparation was carried out by SGS Australia Pty Ltd in Townsville. Each sample was provided as a pulp (minus 75 µm) and as coarse residue (minus 3.35 mm).

Approximately half of the samples (primarily from zones of mineralisation) had previously been prepared and assayed for copper and a range of other elements by SGS as part of the Joint Venture's resource drilling program. These samples were despatched directly from SGS to EGi's laboratory in Sydney. The remaining samples (from non-mineralised zones) were sub-sampled by Joint Venture personnel from cores retained on site within the core storage facility. These samples were despatched to SGS for preparation, then pulps and coarse residues were forwarded to EGi for geochemical characterisation.

[1] A complete listing of rock type, mineral and weathering codes used by the Joint Venture is provided in Appendix A.

3.2 Laboratory Program

The static testing of each sample initially included analysis of the following acid-base parameters:

- Existing pH
- Electrical conductivity (EC)
- Total sulphur content
- Maximum potential acidity (MPA)
- Acid neutralising capacity (ANC)
- Net acid producing potential (NAPP)
- Net acid generation (NAG) capacity

Following review of the acid-base results, some samples were selected for more detailed analysis, which included one or more of the following:

- Solids multi-element analysis - 26 samples
- Water extractable elements - 26 samples
- Peroxide extractable elements - 12 samples
- Sequential NAG tests - 15 samples
- Kinetic NAG tests - 5 samples
- Sulphur Speciation - 5 samples
- Acid buffer characteristic curves - 5 samples
- Carbon Speciation - 5 samples

Most assays were carried out on pulp sub-samples. The only exception was the water extraction test where coarse residue was used.

3.3 Analytical Methods

Existing pH and Conductivity

The existing pH and salinity of each sample were determined by measuring the pH and EC of a suspension comprising 50 g of pulp sample in 100 mL of deionized water after a minimum of 1 hour of equilibration.

Sulphur and Carbon Analyses

Sulphur and carbon analyses were carried out by Australian Laboratory Services (ALS) in Brisbane, which is a NATA registered laboratory. This involved determination of the following:

- *Total sulphur* - Measured using a Leco sulphur analyser
- *Sulphate sulphur* - Samples were leached with hot HCl to remove acid-soluble sulphates. The amount of sulphate within the leachate was then determined by inductively coupled plasma atomic emission spectrometry (ICPAES).
- *Sulphide sulphur* - Calculated as the difference between Total-S and Sulphate-S values.
- C*hromium Reducible Sulphur* - Inorganic sulphur was reduced to H_2S by hot acidic $CrCl_2$ solution and the evolved H_2S gas trapped in zinc acetate solution as ZnS. the concentration of ZnS was subsequently quantified by idiometric titration. This method is designed to be selective for pyritic-sulphur, but may also include some elemental sulphur if present in a sample.
- *Total carbon* - Measured using a Leco carbon analyser
- *Organic-carbon* - Samples were digested with hot HCl to remove any acid soluble carbonates, then rinsed with distilled/deionised water to remove residual chloride. The acid-insoluble carbon remaining in the residue (which is predominantly organic-carbon) was then measured by Leco.
- *Inorganic-carbon* - Calculated as the difference between Total-C and Organic-C values.

Acid Neutralising Capacity

The ANC of a sample was determined using a modified Sobek Method. This method provides a direct measurement of the amount of acid that can be consumed by carbonate and other gangue minerals within a sample. A fizz test was initially carried out to provide a qualitative indication of the magnitude of neutralisation capacity. The fizz test involved addition of a few drops of acid to a small sub-sample of sample. A fizz rating was then assigned on the basis of the degree of fizzing, and based on the fizz rating, a known amount of acid was added to a known weight of pulverised material to produce a suspension with a pH in the range 1 to 2. The suspension was allowed to react for approximately 1 to 2 hours and then it is gently heated to complete the reaction. The amount of acid remaining after the reaction stage was determined by back-titration with sodium hydroxide. The amount of acid consumed by the sample (expressed in terms of kg H_2SO_4/t) was then determined by difference.

Maximum Potential Acidity

The MPA is the amount of acid that theoretically can be generated by a sample if all the sulphur occurs as reactive pyrite and there is complete oxidation of the pyrite according to the following reaction:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \Rightarrow Fe(OH)_3 + 2\ H_2SO_4$$

MPA is expressed in units of kg H_2SO_4/t. For the test samples the MPA values were calculated using the total sulphur contents as follows:

MPA (kg H_2SO_4/t) = Sulphur-%S x 30.6

Net Acid Producing Potential

The NAPP is the amount of acid that potentially can be produced by a sample after allowance for any ANC that the samples may also have. The NAPPs were calculated by subtracting the ANC values from the MPA values, with the results expressed in units of kg H_2SO_4/t.

Net Acid Generation (NAG) Test

The NAG test is a direct oxidation procedure for estimating the acid forming potential of a sample. The NAG test involved reaction of a 2.5 g sub-sample of pulverised material with 250 mL of 15% hydrogen peroxide, which acted as an oxidant to any sulphides present. The samples were allowed to react overnight to provide sufficient time for oxidation to occur. The reaction flasks were then gently heated for approximately 1 hour to decompose any residual peroxide. After cooling, the liquor pHs were recorded As both acid generation and acid neutralisation can occur simultaneously during a NAG test, the end result represents a direct measurement of the net amount of acid that a sample can generate. A sample is considered to be acid forming if the pH after reaction is less than pH 4.5. For such samples, the actual amount of acidity generated (expressed as kg H_2SO_4/t) is also determined by back-titration of the mixture to a pH 7 end-point.

Sequential NAG Test

With high sulphur samples (*i.e.* typically greater than 2 %S) the oxidation of sulphides is often not completed in a single-stage NAG test, and a sequential multi-stage procedure may be required to ensure all sulphides are fully oxidised. In the sequential NAG test, a 2.5 g sub-sample of pulverized material is reacted several times with successive 250 mL aliquots of 15% hydrogen peroxide. At the end of each stage, the sample is filtered to separate the solids and NAG liquor. The NAG liquor is then assayed for pH and acidity, as per a standard NAG test. The solids are recovered and the oxidation process continued by the addition of another aliquot of hydrogen peroxide. The overall NAG capacity of a sample is then determined by summing the individual acid capacities from each stage.

Kinetic NAG Tests

The kinetic NAG test provides an indication of the reactivity of the sulphides present in a sample, and in the case of a PAF sample it also provides an indication of the likely lag period for acid generation to occur under oxidising conditions. The kinetic NAG test is essentially the same as the standard NAG test, except that the kinetics of the peroxide oxidation reaction are indirectly monitored via continuous measurements of the pH and temperature of the NAG solution.

Acid Buffer Characteristic Curve

An acid buffer characteristic curve was produced by slowly titrating a sub-sample of pulverised material with dilute hydrochloric acid over a period of 16 to 24 hours. This titration method provides a far less aggressive treatment of a sample than that applied in the ANC method and hence provides a measure of the buffering provided by more soluble carbonates within a sample.

Multi-Element Analysis of Solids

Elemental analysis of solids was carried out by ALS. Samples were digested by multi-acid addition (*i.e.* hydrofluoric, nitric, perchloric and hydrochloric acids) and the digests were analysed using inductively coupled plasma mass spectrometry (ICPMS) for the following suite of elements: Al, As, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Sn, Sr, Th, U, and Zn. Mercury was also assayed but an aqua regia digestion was used to ensure minimal volatilisation followed by analysis using ICPMS.

Water Extractable Elements

The water-soluble components within the four waste rock sample were determined by EGi by extraction of a 150 g sub-sample of coarse residue (minus 3.35 mm) in 300 g of deionised water for 24 hours. The extractions were carried out in Teflon containers, which were slowly rotated on an end-over-end shaker throughout the equilibration period. At completion, the pH and EC of each extract were recorded then the liquor fractions were filtered through 0.45 micron membrane filters and preserved with a few drops of high purity HNO_3 acid. The filtered extracts were despatched to ALS for multi-element using a combination of ICPMS, and ICP atomic emission spectrometry (ICPAES).

Peroxide Extractable Elements

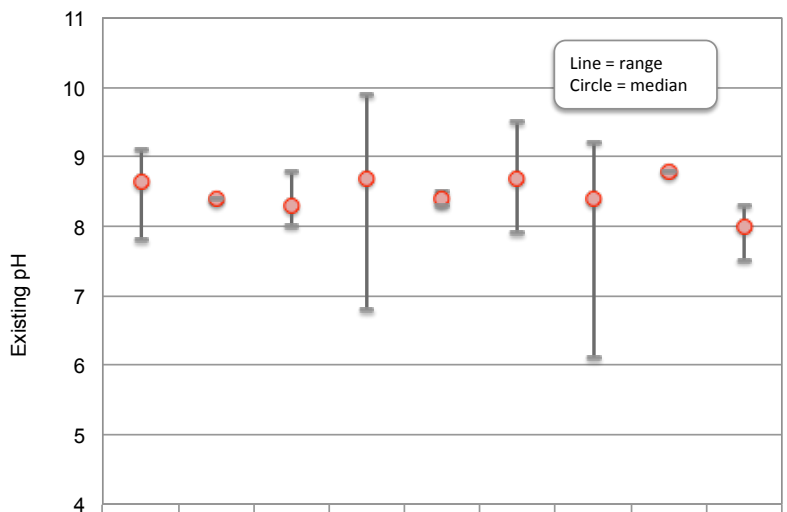
Elements that may be mobilised as a consequence of sulphide oxidation were determined by EGi by reacting a 2.5 g sub-sample of pulverised material with 250 mL of 15% hydrogen peroxide, as per the single-stage NAG test procedure described above. After completion of the oxidation reaction, the NAG liquor was re-adjusted to 250 mL with deionised water. A 100 mL sub-sample was then taken for determination of NAG pH, and a second 100 mL sub-sample was filtered through a 0.45 micron membrane filter, preserved with a few drops of high purity HNO_3 acid, and sent to ALS for multi-element analysis.

4.0 ARD Characteristics

The acid forming characteristics of the 121 drill core samples are tabulated in Appendix B. Most samples representing waste had low sulphur contents and were non-acid forming (NAF) but there were some waste samples from close to mineralised zones that had elevated sulphur contents and were potentially acid forming (PAF). As expected, ore samples had high sulphide contents and approximately half of the ore samples tested were PAF. Summaries of specific geochemical characteristics are given below.

4.1 Existing pH

All samples were naturally circum-neutral or slightly alkaline. The existing pHs of all samples were greater than 6, and all but five samples were greater than pH 7.5. Figure 4 shows a statistical summary of the existing pHs for each rock type. Overall the results suggest that initial drainage from run-of-mine waste rock will be circum-neutral or slightly alkaline.



	IMO	RZO	VFR	VFRD	VMB	XAO	XSB	XSBH	XSO
max	9.1	8.4	8.8	9.9	8.5	9.5	9.2	8.8	8.3
median	8.7	8.4	8.3	8.7	8.4	8.7	8.4	8.8	8.0
min	7.8	8.4	8.0	6.8	8.3	7.9	6.1	8.8	7.5

FIGURE 4: *Statistical summary of the existing pHs of Barbara drill core samples split by rock unit*

4.2 ARD Classifications

Both NAPP and NAG results were used to assign an ARD classification to each sample. As the NAG test is completely independent of the NAPP approach, the combination of the NAPP and NAG results provides greater certainty to the assessment of ARD potential. The ARD classification criteria were as follows:

- *Non-Acid Forming (NAF)* - negative NAPP and NAG=0 (or NAGpH≥4.5)
  Although sulphides may be present in such samples, the inherent ANC should be sufficient to neutralise any acid that might have been produced by sulphide oxidation.

- *Potentially Acid Forming (PAF)* - positive NAPP and positive NAG (or NAGpH<4.5)
  The exposure of such a material to atmospheric conditions is likely to result in sulphide oxidation, which in turn could result in acidification.

- Uncertain *(UC)* - when there was a disparity between the NAPP and NAG results and a definitive classification could not be assigned. For such samples column leach testing may be required to assign an ARD classification.

The ARD classifications assigned to the Barbara drill core samples are included in Appendix B. The distribution of samples between ARD classifications was as follows:

Waste Rock Samples (total=94)

- NAF 83 samples (89% of waste samples)
- PAF 7 samples (7%)
- UC 4 samples (4%)

Ore Samples (total=27)

- NAF 12 samples (44% of ore samples)
- PAF 15 samples (56%)

It should be noted that the percentages of NAF and PAF as given above apply to the dataset for this geochemical investigation and do not necessarily reflect the percentages of NAF and PAF waste or ore that will be mined. The actual volumes of NAF and PAF waste rock will need to be estimated by the Joint Venture by block modelling of the proposed pit. Notwithstanding this qualification, the results of the drill core testing program suggest that the majority of waste rock should be NAF, but some waste with the potential to generate ARD occurs within the Barbara mining shell. Most of the PAF waste samples were located within the northern mining zone.

The results also confirm that a significant percentage of ore is likely to be PAF, as would be expected for chalcopyrite/pyrite ore. However, it is worth noting that just under half of the ore samples tested, despite having high sulphur contents, were NAF due to the mineralised rock also having high to very high ANC.

4.3 Acid-Base Account Plot

Figure 5 shows a plot of ANC versus sulphur content for the drill core samples. This type of plot is commonly referred to as an acid-base account plot. Figure 5a shows all samples whilst Figure 5b is the same acid-base account plot with expanded scales to highlight samples that contained less than 3 %S and had ANCs less than 150 kg H_2SO_4/t.

The Figure 5 plots clearly illustrate the preponderance of drill core samples representing NAF waste, which plot above the NAPP=0 line shown in Figure 5. These samples have negative NAPPs and therefore theoretically have an excess of ANC over the acid potential of any contained sulphides. In most cases the waste NAF samples had low sulphur contents and also moderate to high ANCs, resulting in substantial negative NAPPs.

However, a small percentage of waste samples plot below the NAPP=0 line shown in Figure 5, suggesting that there may not be sufficient ANC in these samples to negate the acid potential of the contained sulphides. Similarly, approximately half of the ore samples clearly plot below the NAPP=0 line, most of which have high to very high acid potentials.

4.4 ARD Classification Plot

Figure 6 shows an ARD classification plot for the Barbara drill core samples. This type of plot illustrates the concurrence of the NAPP and NAG test results. Samples classified as NAF plot in the upper left quadrate of Figure 6. This quadrate denotes samples with a negative NAPP that also produce a negative response under NAG test conditions (*i.e.* the samples remained above pH 4.5 when oxidised). PAF samples plot in the lower right quadrate, which corresponds to positive NAPP and NAG test results. Again, most waste samples plot in the NAF quadrate, whereas the ore samples are distributed between the NAF and PAF quadrates.

There were four waste samples (8002, 8004, 8017 and 8031) that had low sulphur contents (0.10 to 0.26 %S) and small negative NAPPs (-1 to -6 kg H_2SO_4/t) that produced positive results when oxidised with peroxide in the NAG test in that they acidified to less than the pH 4.5. These four samples plot in the lower left "uncertain" quadrate. The positive NAG results suggest that some of the ANC in these samples may be only sparingly reactive under circum-neutral and weakly acidic conditions. Notwithstanding that the NAG results were positive, the amounts of acid generated were relatively minor (2 to 5 kg H_2SO_4/t) in comparison to other PAF samples. Column leach testing will be required to confirm whether the materials they represent are actually NAF or PAF.

It should be noted that sequential NAG testing was required to quantify the total acid generating capacities of samples with high to very high sulphur contents. As noted in Section 3.3, with high sulphur samples (*i.e.* typically greater than 2 %S) the oxidation of sulphides is often not completed in a single-stage NAG test, and a sequential multi-stage procedure may be required to ensure all sulphides are fully oxidised. Sequential NAG tests were run on 15 samples, with up to seven stages required for some samples. The results for each stage are tabulated in Appendix C, and the NAG results included in Appendix B that are based on the sequential method are marked with asterisks.

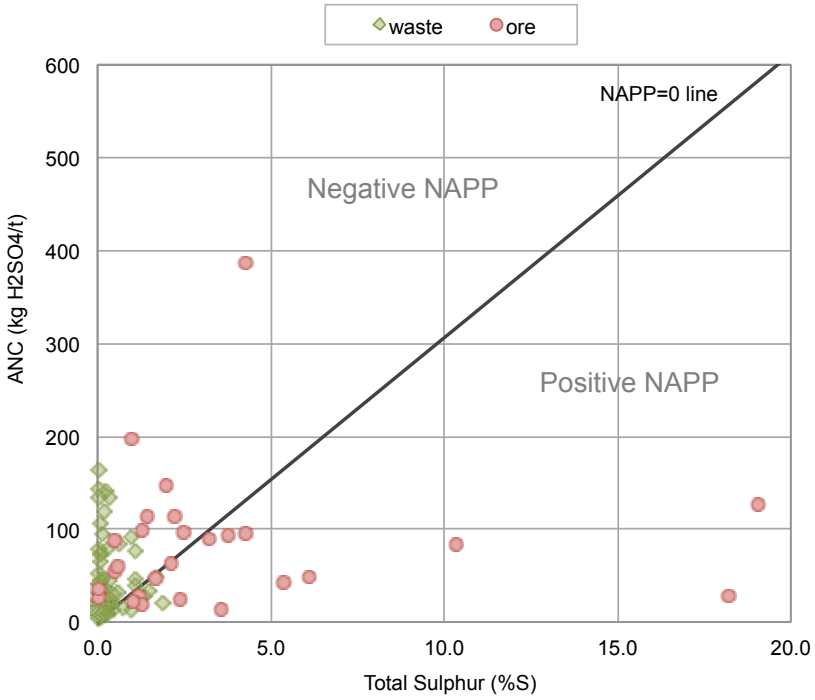


FIGURE 5a: *Acid-base account plot for Barbara drill core samples split by material type - all samples*

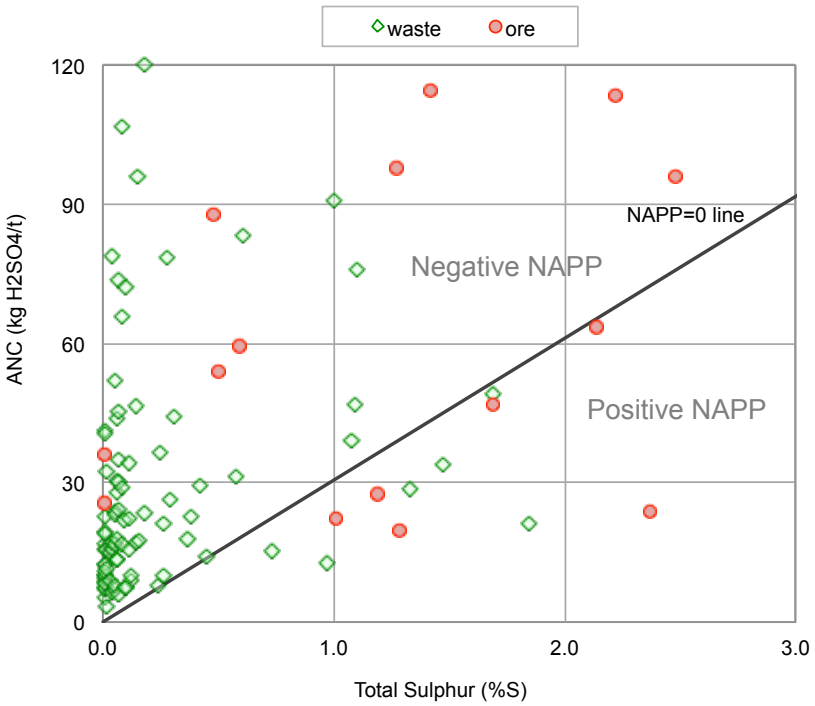


FIGURE 5b: *Acid-base account plot for Barbara drill core samples split by material type - expanded scales*

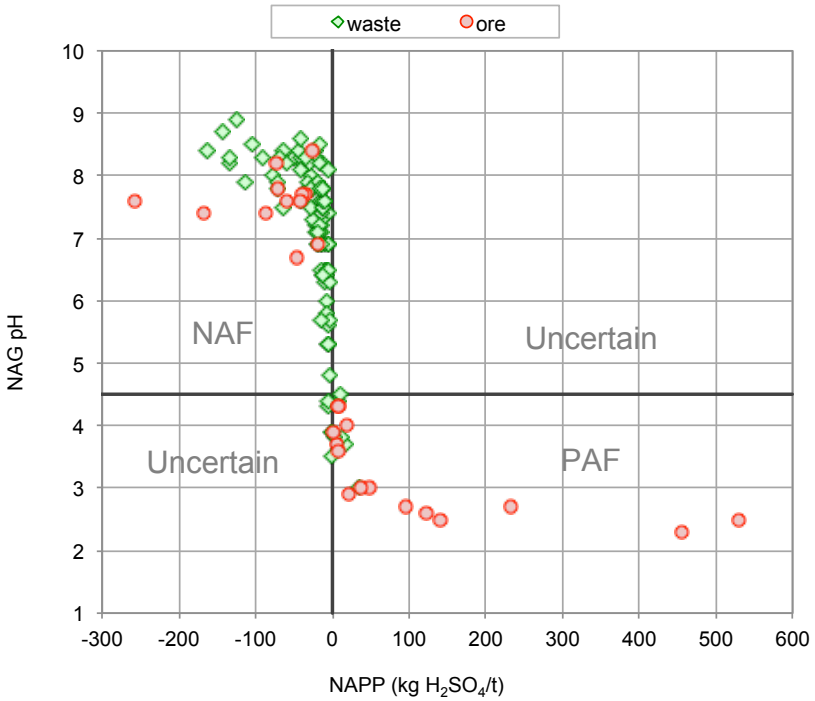


FIGURE 6a: *ARD classification plot for Barbara drill core samples split by material type - all samples*

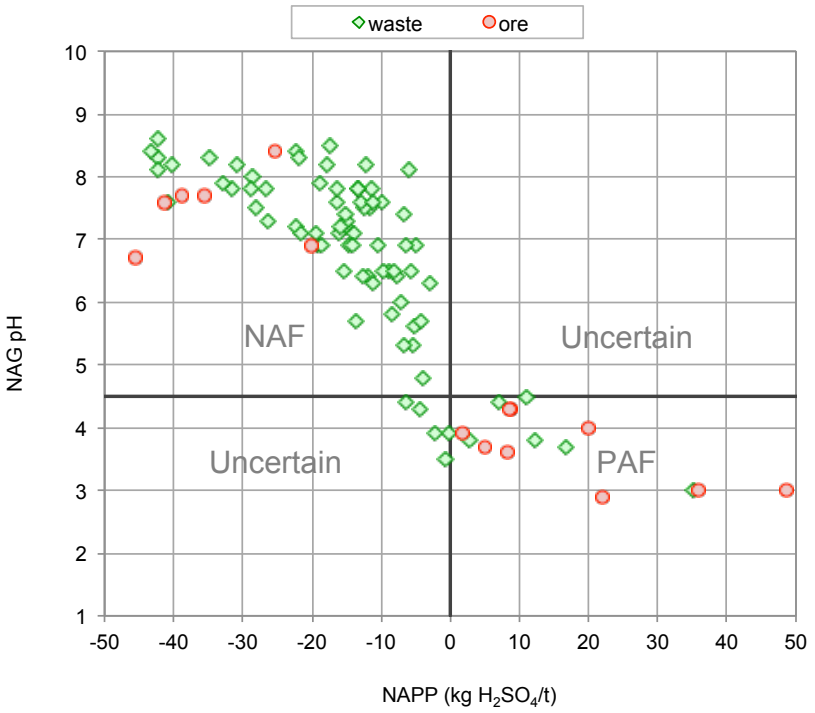


FIGURE 6b: *ARD classification plot for Barbara drill core samples split by material type - expanded scales*

4.5 Sulphur versus NAGpH

The relationship between sulphur content and NAG pH is shown in Figure 7. With the exception of the four "uncertain" waste samples all other waste and ore samples with sulphur contents less than 0.3 %S maintained a NAG pH greater than the 4.5 criterion for NAF when oxidised with peroxide. Furthermore, 12 of the 15 samples containing between 0.3 and 1.0 %S also had NAG pHs greater than 4.5.

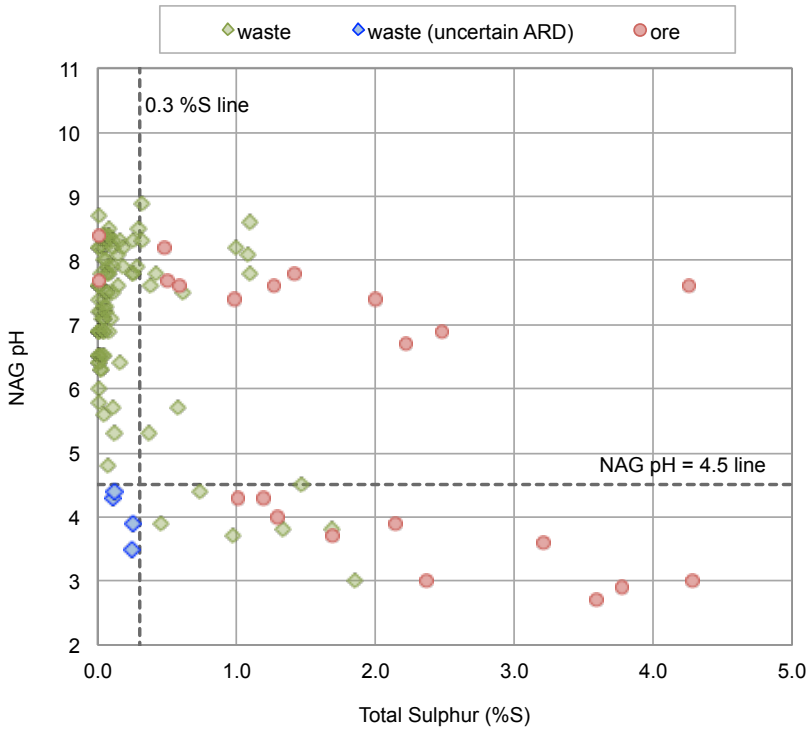


FIGURE 7: *Plot of NAG pH versus sulphur content for Barbara drill core samples containing less than 5 %S (Note: there were five ore samples containing more than 5 %S which had NAG pHs less than 4.5)*

4.6 NAPP versus NAG

The relationship between NAPP and NAG results is shown in Figure 8. Overall there was reasonable agreement between the magnitude of the NAG results based on direct oxidation of samples, and the NAPP values based on sulphur contents and ANCs. With the exception of the four *uncertain* samples, samples with negative NAPPs had zero NAG capacities, samples with positive NAPPs generated approximately the equivalent amount of acid when oxidised under NAG test conditions. The close agreement of positive NAPP and NAG values for samples with elevated sulphur contents is consistent with most of the sulphur occurring as sulphide, presumably as either chalcopyrite and/or pyrite.

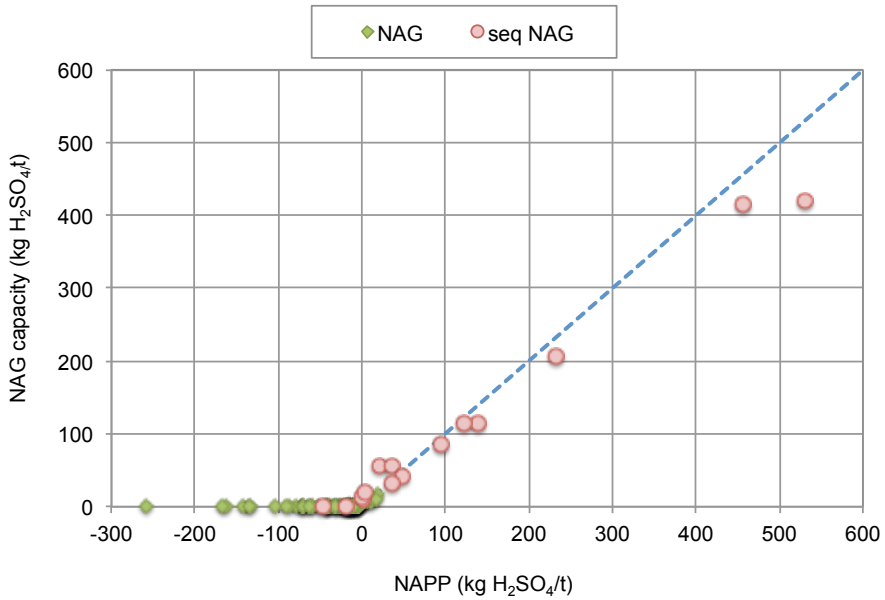


FIGURE 8a: *Plot of NAG versus NAPP for Barbara drill core samples - all samples*

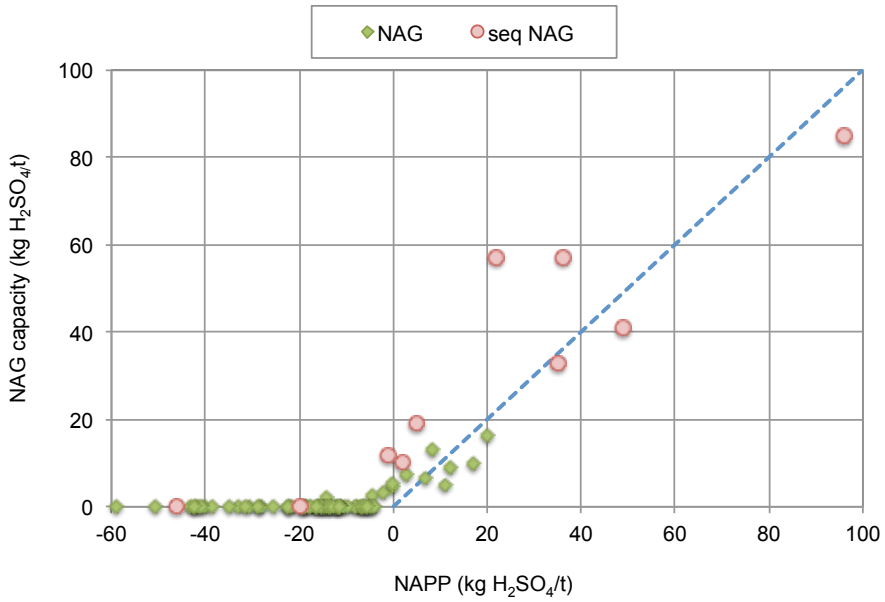


FIGURE 8b: *Plot of NAG versus NAPP for Barbara drill core samples - expanded scales*

4.7 Reactivity of PAF Rock

Kinetic NAG tests[2] were carried out on two ore and three waste samples to assess the reactivity of the sulphides present and to provide a qualitative assessment of the likely lag period for acid generation to occur under oxidising conditions. The acid-base characteristics of the five samples selected for kinetic NAG testing were as follows:

- Ore #8050 BADD035: 49-50m VFRD 3.59 %S, ANC=14 kg H_2SO_4/t, NAPP=96 kg H_2SO_4/t
- Ore #8112 BADD021: 139-140m XSB 5.37 %S, ANC=42 kg H_2SO_4/t, NAPP=122 kg H_2SO_4/t
- Waste #8066 BADD045: 27-28m XSB 0.73 %S, ANC=15 kg H_2SO_4/t, NAPP=7 kg H_2SO_4/t
- Waste #8092 BADD050: 39-40m VFRD 1.85 %S, ANC=21 kg H_2SO_4/t, NAPP=35 kg H_2SO_4/t
- Waste #8072 BADD046: 26-27m VFRD 1.47 %S, ANC=34 kg H_2SO_4/t, NAPP=11 kg H_2SO_4/t

The kinetic NAG test involves a similar procedure to the standard NAG test where a sample is oxidised using hydrogen peroxide, but with the addition that the pH and temperature of the NAG liquor are constantly recorded during the reaction phase of the test. The reaction kinetics are then extrapolated to the field situation using correlations previously derived from an extensive database comprising results of kinetic NAG tests, leach column tests, and field observations across a wide range of rock types.

Whilst kinetic NAG testing is not a replacement for column leach tests, the profiles obtained by the accelerated procedure provide a qualitative estimate of the lag period[3] to the extent that acidification of PAF rock is likely to occur rapidly (weeks to months), within the short term (many months to one or two years), or medium to long term (many years).

The individual kinetic NAG reaction profiles for the five samples are given in Appendix D, and a compilation of the NAG pH profiles for all five samples is given in Figure 9.

Ore Sample #8050

This sample had a below average ANC for ore and the kinetic NAG profile indicated rapid rates of sulphide oxidation and acid generation. The sample acidified to less than pH 4 within approximately 20 minutes of the peroxide being added, and to pH 3 after 40 minutes. The rapid acidification in the kinetic NAG test confirms the reactive nature of the sulphides present and suggests that any lag stage preceding acidification will be relatively short for ore with low ANC as represented by the test sample *i.e.* possibly weeks to months rather than years. The temperature of the NAG solution also provides an insight into sulphide reactivity (see Appendix D-1). The temperature of the NAG liquor increased markedly as the pH approached 3, reaching

2 The kinetic NAG test is an accelerated laboratory procedure which markedly differs to conventional kinetic methods such as column leach test where reactions occur in real time as a consequence of exposure to atmospheric oxygen.

3 The lag times provided in this report should be used as a guide only and are based on correlations previously derived by EGi from comparison of kinetic NAG profiles with results from real time testing of the same materials (*e.g.* leach column tests) and field observations at actual mine sites.

boiling point after about 50 minutes. Some of the initial temperature rise maybe attributed to the oxidation of pyrite, which is an exothermic (heat generating) process. However, as the oxidation process continues, there is an increasing tendency for the hydrogen peroxide to catalytically decompose, a process that is also exothermic. This markedly accelerates the heating of the NAG solution. The main catalyst for peroxide decomposition is usually dissolved iron that is released during pyrite oxidation.

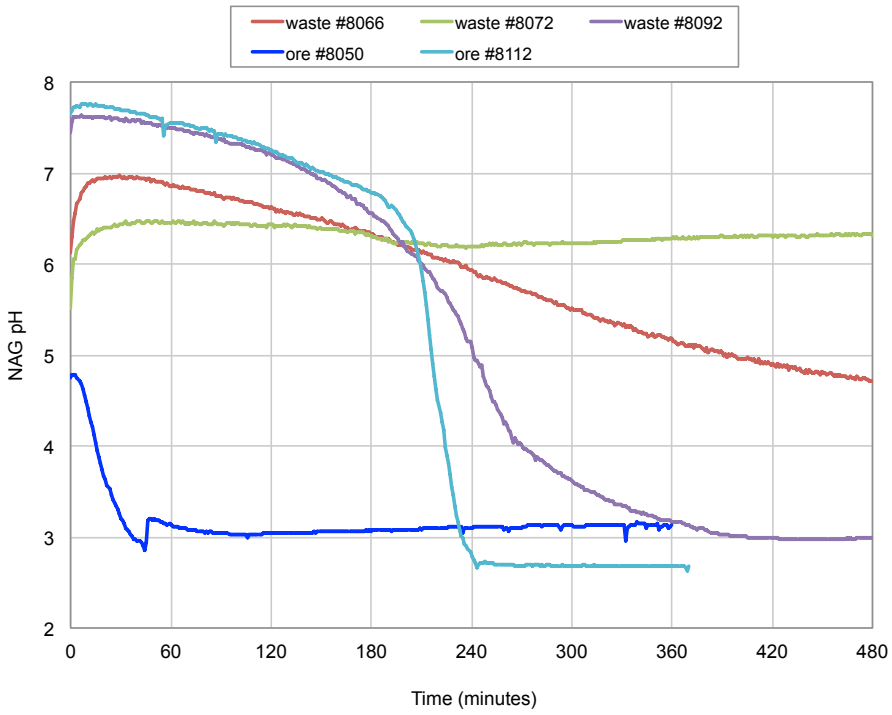


FIGURE 9: *Kinetic NAG pH profiles for Barbara drill core samples*

Ore Sample #8112

In contrast to the low ANC ore sample discussed above, sample #8112 took considerably longer to acidify under NAG test conditions, consistent with its higher ANC of 42 kg H_2SO_4/t. Although there was clear visual evidence of the peroxide reacting with the sample (*i.e.* strong fizzing), the pH remained circum-neutral for approximately three hours. During this lag phase the acid generated from sulphide oxidation was immediately neutralised by the inherent ANC of the sample. As a rule, such a slow response generally extrapolates to a lag time under field conditions of at least a year and possibly several years. This sample did eventually acidify to less than pH 3 (consistent with it being PAF) and as with the other ore sample the acidification was accompanied by a rapid increase in temperature (see Appendix D-2), albeit after approximately four hours of reaction.

Waste Sample #8066

The sulphur content and ANC for this sample were toward the lower ends of the respective ranges[4] for PAF waste. At the start of the test the pH initially increased slightly from around 6 up to 7, then very gradually decreased as sulphides were oxidised. It took more than 6 hours for the pH to reach 5, and the pH was 4.3 when the test was terminated after approximately 18 hours. No temperature change was detected for this sample. The reaction kinetics during the NAG test suggest that waste rock as represented by this sample would likely react only slowly if exposed to atmospheric conditions and remain circum-neutral for at least a year and probably several years.

Waste Sample #8092

The sulphur content of this waste sample was higher at 1.85 %S, but it also exhibited a long lag phase during the kinetic NAG test. The pH at the start of the test was 7.6, and the pH was buffered above 6 for more than three hours. The pH eventually decreased to approximately 3 after six hours, at which point the temperature increased sharply (see Appendix D-4). Again, the slow reaction kinetics observed in the NAG test suggest that such a long lag for material under field conditions, probably in the order of several years.

Waste Sample #8072

Although this sample had a significant sulphur content (1.47 %S) and was classified as PAF, it did not acidify to any significant extent during the kinetic NAG test, with the pH remaining at between 6 to 7. It was only when the sample was boiled[5] at the completion of the monitored reaction phase that the pH decreased to 4.5. The extended plateau exhibited in the kinetic NAG test is consistent with the presence of an above average ANC for waste of 34 kg H_2SO_4/t. Again, the reaction kinetics for this sample suggest that waste rock as represented by this sample would likely react only slowly if exposed to atmospheric conditions and remain circum-neutral for at least a year and probably several years.

4.8 Sulphur Forms

The five samples that were included in the kinetic NAG testing program were also submitted to ALS for determination of sulphur forms. The speciation scheme involved determination of total sulphur (by Leco), sulphate-sulphur (by hot HCl leach), sulphide-sulphur (by difference), and chromium reducible sulphur. The method used for chromium reducible sulphur is reportedly selective for pyritic-sulphur, but may also include some elemental sulphur if present in a sample.

The results of sulphur speciation are presented in Table 1. With all five samples there was only minimal sulphate present (*i.e.* between 0.03 to 0.19 %S). Consequently, it can be assumed that almost all of the sulphur in the test samples was sulphidic, and the chromium reducible concentrations were virtually identical to the sulphide values determined by difference from the total-S and sulphate-S results.

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4 The average ANC for PAF waste samples was 25 kg H_2SO_4/t and the range was 13 to 49 kg H_2SO_4/t.

5 The NAG liquor is boiled following the reaction phase of the NAG test to ensure complete oxidation of sulphides and to decompose any residual peroxide prior to final measurements of pH and acidity.

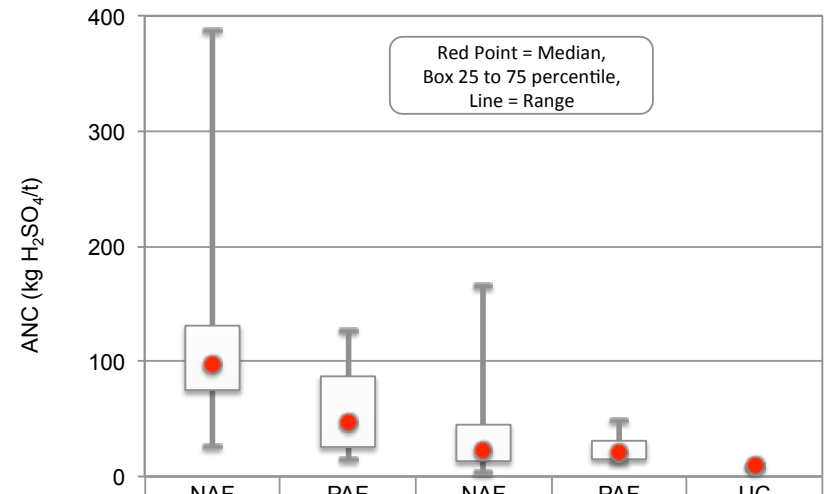
***TABLE 1**: Sulphur speciation results for PAF samples in the kinetic NAG testing program*

EGi id	Hole_ID	Interval (m)	Rock Type	Total Sulphur	Repeat Total-S	Sulphate Sulphur	Sulphide Sulphur	Cr-Red-S	ARD Class
				(%S)					
8050	BADD035	49-50	VFRD	3.59	3.53	0.19	3.34	3.46	PAF
8066	BADD045	27-28	XSB	0.73	0.76	0.03	0.73	0.76	PAF
8072	BADD046	26-27	VFRD	1.47	1.66	0.04	1.62	1.53	PAF
8092	BADD050	39-40	VFRD	1.85	1.93	0.06	1.87	1.77	PAF
8112	BADD021	139-140	XSB	5.37	5.54	0.06	5.48	5.51	PAF

* The repeat total sulphur assay was a component of the sulphur speciation scheme

4.9 Acid Neutralisation Capacity

The inherent neutralisation capacity of each sample was quantified using the Sobek procedure, which is the most widely used measure of neutralisation capacity for mine waste materials. Figure 10 shows a statistical plot of the ANC results for ore and waste samples split by ARD classifications.



	NAF ORE	PAF ORE	NAF WASTE	PAF WASTE	UC WASTE
25 percentile	75	26	13	15	
minimum	26	14	3	13	8
maximum	387	127	165	49	10
75 percentile	131	87	45	31	
median	98	47	23	21	9

***FIGURE 10:** Statistical summary of the ANCs of Barbara drill core samples split by ARD classification*

The ANCs of ore samples were typically in the moderate to high range. The median ANC for the NAF ore samples was particularly high at of 98 kg H_2SO_4/t, which equates to approximately 10 %$CaCO_3$ equivalent.

The median for the PAF ore samples was lower but still substantial at 47 kg H_2SO_4/t. In the latter case the ANCs were (by definition) less than the acid potentials of the contained sulphur, but they would be expected to produce long lag periods (i.e. delay to acid generation) if ore is exposed to atmospheric conditions. The median ANC of 47 kg H_2SO_4/t is sufficient to neutralise the acid that can be produced from oxidation of approximately 1.5 %S as pyrite or chalcopyrite, which would typically take in excess of a year to occur under field conditions. Furthermore, it is expected that the mixing of higher ANC NAF ores with PAF ores within ROM ore stockpiles would enhance the lag phase.

The ANCs of samples representing waste rock were typically lower than for ore. The ANCs of the relatively small numbers of PAF waste samples identified in this study ranged from 13 to 49 kg H_2SO_4/t and the median was 21 kg H_2SO_4/t. Although lower than for ore, the results of the kinetic NAG tests on three PAF waste samples (see Section 4.7) suggest that the ANC should still provide a reasonable lag if the rock is exposed to conditions conducive to sulphide oxidation.

4.10 Carbon Forms and Reactivity of Neutralising Capacity

Five samples with high ANCs were selected to assess carbon present speciation and to determine the reactivity of the carbonate mineralisation responsible for the ANC. They included our NAF waste samples and one sample representing PAF ore as follows:

- NAF Waste #8007 BADD034: 79-80 m VFRD ANC=165 kg H_2SO_4/t
- NAF Waste #8114 BADD038: 99-100 m XSB ANC=135 kg H_2SO_4/t
- NAF Waste #8080 BADD043: 59-60 m XSB ANC=134 kg H_2SO_4/t
- NAF Waste #8078 BADD042: 69-70 m VFRD ANC=76 kg H_2SO_4/t
- PAF Ore #8056 BADD033: 64-65 m VFRD ANC=95 kg H_2SO_4/t

Carbon Speciation

The speciation of carbon within the drill core samples involved measurements of total carbon and organic carbon. The difference between these two measurements was assumed to be inorganic carbon occurring in the form of carbonate, which typically accounts for most of the neutralisation capacity in samples with moderate to high ANCs. The carbon speciation results are tabulated in Table 2. The total-C concentrations ranged from 0.57 to 1.53 %C, virtually all of which occurred as inorganic carbon. These results confirm the presence of significant carbonate mineralisation within waste and ore grade materials with high ANCs.

***TABLE 2**: Carbon speciation and Carbonate Neutralising Values for Barbara drill core samples*

EGi id	Hole_ID	Interval (m)	Rock Type	Total Carbon (%C)	Organic Carbon (%C)	Inorganic Carbon (%C)	CNV	ANC	ARD Class
8080	BADD043	59-60	XSB	1.16	0.02	1.15	94	134	NAF
8078	BADD042	69-70	VFRD	0.57	0.02	0.56	46	76	NAF
8056	BADD033	64-65	VFRD	0.81	0.02	0.8	65	95	PAF
8007	BADD034	79-80	VFRD	1.53	0.03	1.5	123	165	NAF
8114	BADD038	99-100	XSB	1.14	0.02	1.14	93	135	NAF

Key
CNV = Carbonate Neutralising Value (kg H_2SO_4/t)
ANC = Acid Neutralising Capacity (kg H_2SO_4/t)

Carbonate Neutralising Value

The carbonate neutralising value (CNV) is an indirect measure of the inherent buffering capacity within a sample based on the inorganic carbon content. The CNV determination assumes that all inorganic carbon occurs as reactive carbonate, and it was calculated by multiplying the inorganic %C by 81.67. Figure 11 shows a plot of CNV versus ANC for the five drill core samples.

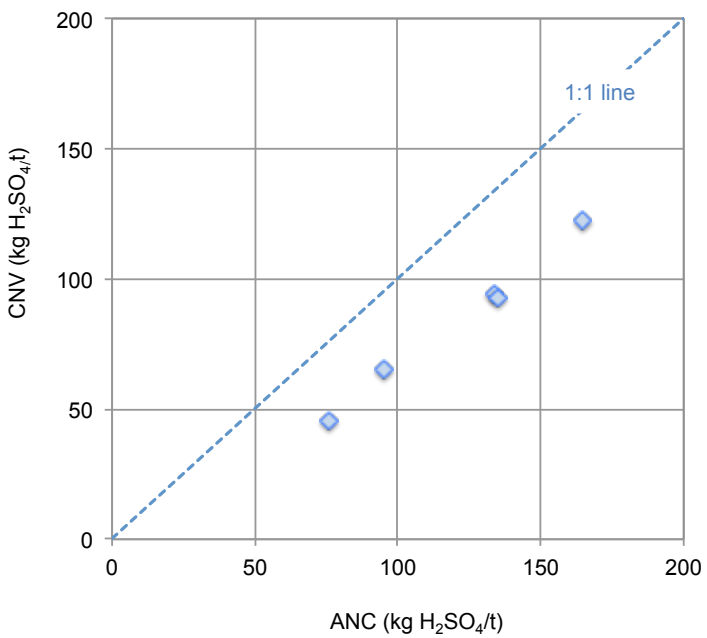


***FIGURE 11:** Comparison of ANC and CNV for Barbara drill core samples*

Overall, there was good agreement in the neutralisation potentials determined by the two methods, albeit that the ANCs were consistently higher for these samples. The source of the difference has not been determined. The correlation of CNV and ANC suggests that a relatively simple total carbon assay could be useful for operational differentiation of rock with moderate to high neutralisation capacity that would be suitable for use in mitigating the acid potential of PAF waste within the waste rock dump.

Acid Buffer Characteristic Curves

The buffer curves for the five samples were produced by recording the pH of sample suspensions titrated with dilute H_2SO_4 over a period of about 18 to 24 hours. The titration method provides a far less aggressive treatment of a sample than that applied in the ANC method (which involves reaction at around pH 1 to 2) and hence provides a measure of the buffering provided by more soluble carbonates within a sample. This type of buffering is typically characterised by a plateau at around circum-neutral pH at the start of the titration curve, and the extent of the plateau can be used as an indicator of the fraction of ANC that would likely be available to maintain pH neutral conditions, which is usually required if the material is to be used for ARD mitigation when it is essential to maintain low metal solubilities.

The buffer curves for individual sample are presented in Appendix E, together with buffer curves for reference samples representing limestone, dolomite, ferroan dolomite, magnesite and siderite. A compilation of the buffer curves for all five samples is also shown in Figure 12.

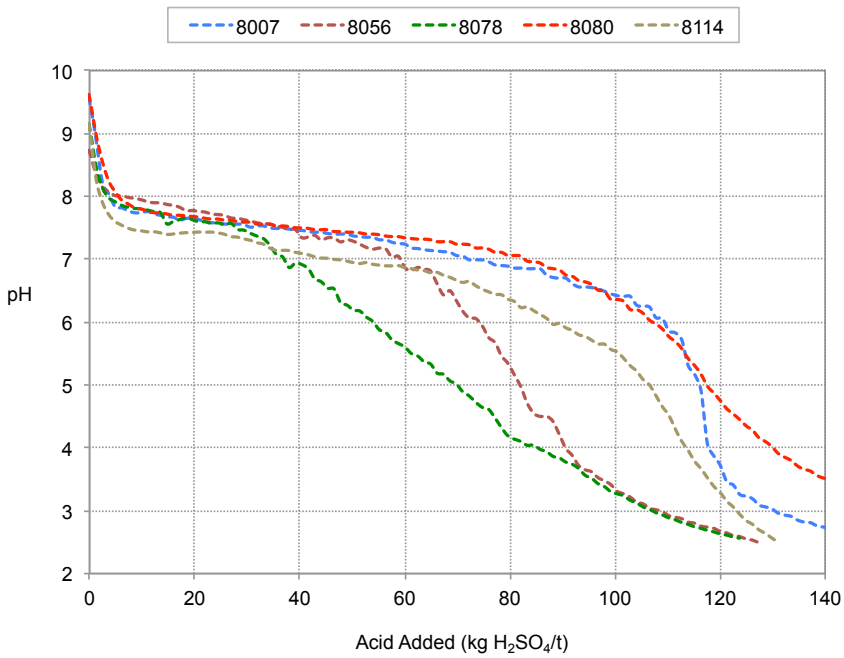


FIGURE 12: *Acid buffer curves for Barbara drill core samples with high ANCs*

All five samples produced well-defined buffer plateaus at between pH 6 to 8 that were characteristic of the buffering provided by limestone or dolomitic rock[6]. The curves suggest that most of calcareous minerals within the samples were reactive and would be readily available for pH buffering under circum-neutral conditions.

There is no definitive method of quantifying the fraction of ANC that is readily available, but a useful guide adopted by EGi is the amount of acid that is required to acidify a sample to pH 5, as this generally coincides with the point where the buffer curves begin to decline sharply. Table 3 gives the "readily-available" neutralising capacities (expressed as kg H_2SO_4/t) for the five samples based on the pH 5 criterion. The percentage of ANC that was readily available typically ranged from 70 to 93% of the ANCs measured using the Sobek method.

Overall, the results suggest that most of the neutralising capacity in rock with moderate to high ANC should be readily-available. It is therefore expected that NAF waste with similar characteristics to the test samples would be suitable for use in mitigating the ARD potential of PAF waste should it be encountered. This could include blending with PAF waste to negate its acid potential and/or construction of NAF layers encapsulating PAF waste within the dump. Further discussion on utilisation of carbonate rock for ARD control at Barbara is provided in Section 6.2.

***TABLE 3**: Readily-available neutralising capacity based on acid buffer characteristic curves*

EGi id	Hole_ID	Interval (m)	Rock Type	CNV	ANC	Readily Available ANC*	Percent Readily Available
8080	BADD043	59-60	XSB	94	134	118	88%
8078	BADD042	69-70	VFRD	46	76	71	93%
8056	BADD033	64-65	VFRD	65	95	82	86%
8007	BADD034	79-80	VFRD	123	165	116	70%
8114	BADD038	99-100	XSB	93	135	107	79%

Key
CNV = Carbonate Neutralising Value (kg H_2SO_4/t)
ANC = Acid Neutralising Capacity (kg H_2SO_4/t)
* Readily available based on tiration to pH 5

6 Calcite and limestone are usually readily available for neutralisation and can maintain a plateau at circum-neutral pH up until almost all of the ANC is consumed. Dolomite is also usually reactive, however the reactivity may decline when there is significant iron substitution, such as with ferroan dolomite. In contrast, magnesite and siderite are usually poorly reactive at circum-neutral pH, and significant dissolution of these carbonates often only occurs under laboratory conditions when the pH drops below about 4.

5.0 Elemental Characteristics of Waste Rock

5.1 Elemental Composition of Solids

Twenty-six samples from across the deposit were selected for multi-element analysis. The samples included 19 samples representing waste rock and seven representing ore grade materials. The distribution of samples between rock types was as follows:

Waste

- VFRD 14 samples (9 NAF / 2 UC / 3 PAF)
- VFR 1 sample (NAF)
- IMD 1 sample (NAF)
- XSB 1 sample (PAF)
- XAO 1 sample (NAF)

Ore

- VFRD 3 samples (1 NAF / 2 PAF)
- IMD 1 sample (NAF)
- XSB 2 samples (1 NAF / 1 PAF)
- XSO 2 samples (1 NAF / 1 PAF)

The analysis of the drill core samples included the following suite of elements: Al, As, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Sn, Sr, Th, U, and Zn

The elemental compositions of the 26 samples are tabulated in Appendix F, and statistical box plots of the results for waste and ore samples are given in Figures 13 and 14, respectively.

5.2 Geochemical Abundance Indices

To provide some relativity to the multi-element data, the compositions of the solids were compared to typical concentrations reported for soil in non-mineralised areas. The purpose of this comparison was to highlight any elements that were significantly enriched, especially elements that are generally regarded as environmentally important. The comparison is expressed as a Geochemical Abundance Index (GAI), which relates enrichment to the median soil abundance value using the formula:

$$GAI = \log_2 [C / (1.5*S)]$$

where C is the concentration of the element in the sample and S is the median soil[7] content for that element. It should be noted that median soil contents are based on typical values for soils from non-mineralised areas, and do not represent the actual soils occurring at the Barbara project area.

[7] References for median soil data were: (1) Bowen, H.J.M. (1997) Environmental Chemistry of the Elements. Academic Press, London. (2) Berkman, D.A. (1976) Field Geologists' Manual, The Australian Institute of Mining and Metallurgy, Parkville, Victoria, Australia

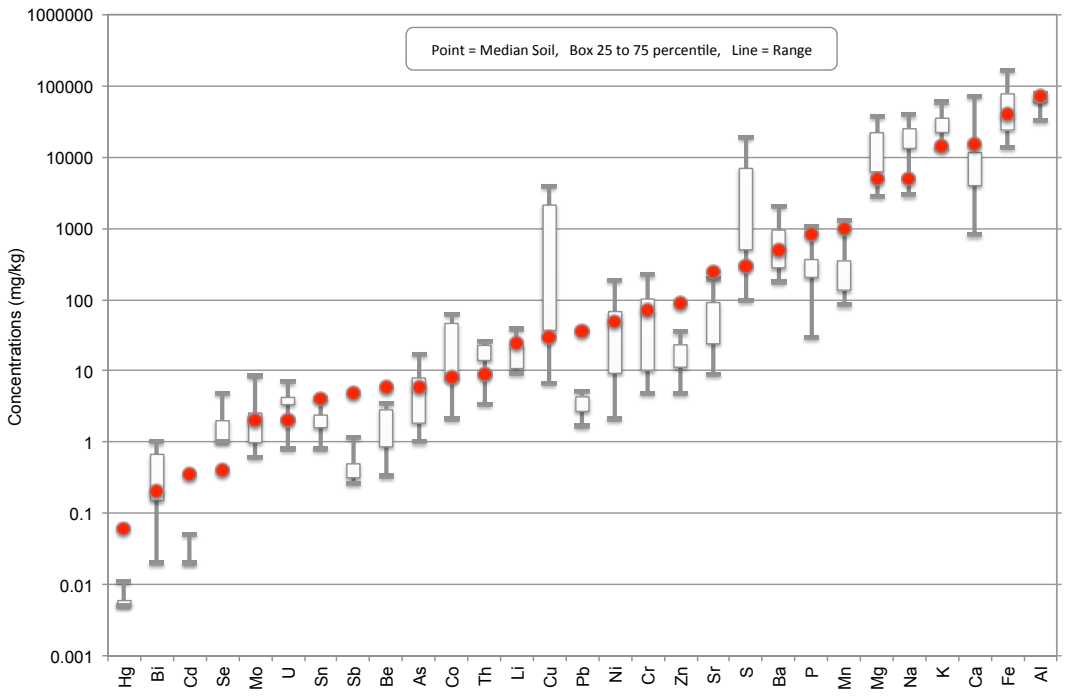


***FIGURE 13**: Box plot of elemental concentrations in Barbara drill core samples representing waste*

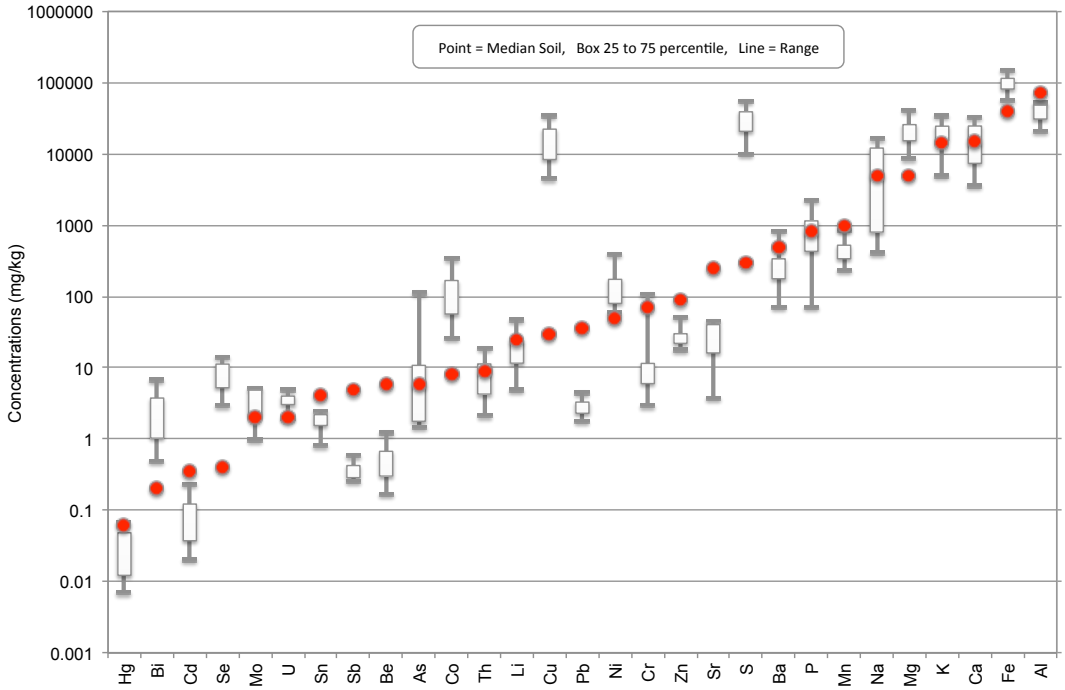


***FIGURE 14**: Box plot of elemental concentrations in Barbara drill core samples representing ore*

GAIs are truncated to integer increments (0 through to 6, respectively) where a GAI of 0 indicates the element is present at a concentration similar to, or less than, median soil abundance and a GAI of 6 indicates approximately a 100-fold, or greater, enrichment above median soil abundance.

The enrichment ranges for the GAI are as follows:

Little or No Enrichment
GAI = 0 < 3 times median soil

Minor Enrichment
GAI = 1 (3 to <6 times) or GAI=2 (6 to <12 times)

Significant Enrichment
GAI = 3 (12 to <24 times), 4 (24 to <48 times), 5 (48 to <96 times) or 6 (≥ 96 times)

The GAIs for the Barbara samples are given in Appendix G, and Figures 15 and 16 provide graphical summaries of the frequency of enrichment factors for each element for waste samples and ore samples, respectively.

Ore Samples

As would be expected, all of the ore samples assayed were significantly enriched (GAI≥3) with copper and sulphur, and most were significantly enriched with selenium, bismuth and cobalt. One of the seven ore samples (8112) was also significantly enriched with arsenic (114 mg/kg), and some samples exhibited minor enrichment (GAI of 1 or 2) with nickel.

Waste Rock Samples

Some waste rock samples were also significantly enriched with copper, sulphur and selenium relative to concentrations typically reported for background soil. In the case of copper the concentrations in the waste samples were generally markedly less than in ore, but high in comparison to soil in non-mineralised areas.

There was also evidence of minor enrichment (GAI of 1 or 2) of some waste samples with bismuth and cobalt, but otherwise the results suggest that other environmentally important elements typically occurred at concentrations approximating background soil. They included antimony, arsenic, cadmium, chromium, lead, manganese, mercury, nickel, tin and zinc.

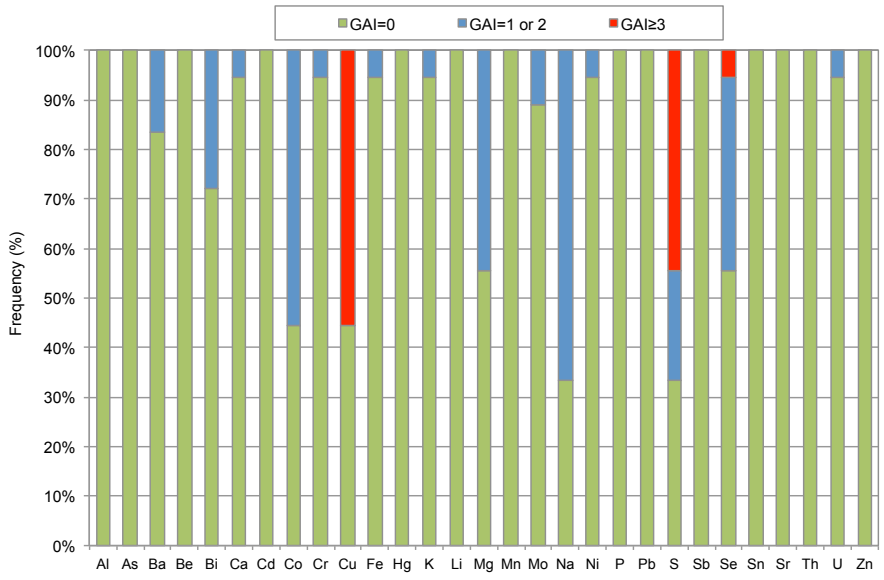


***FIGURE 15**: Frequency distribution plot of GIAs in Barbara drill core samples representing waste*

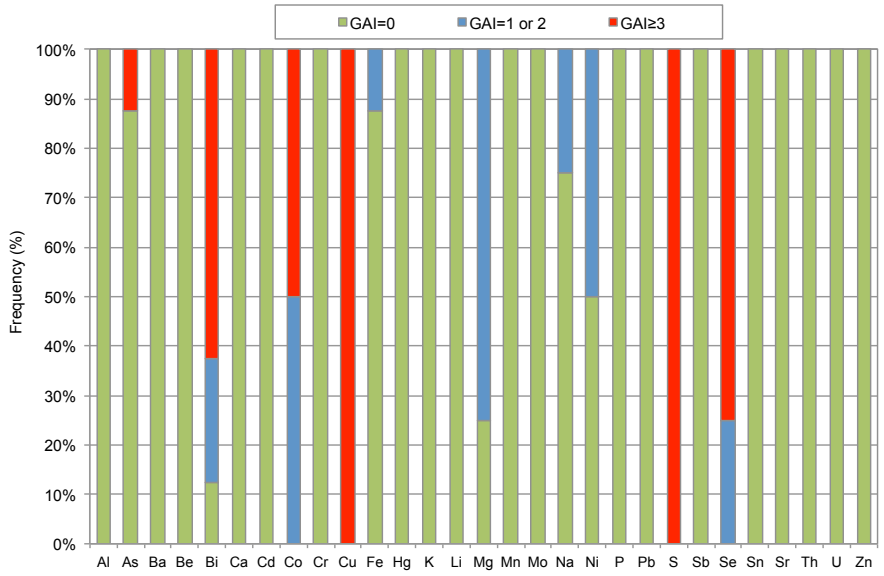


***FIGURE 16**: Frequency distribution plot of GIAs in Barbara drill core samples representing ore*

5.3 Salinity

The ECs of all drill core samples were measured as part of the initial acid-base characterisation to provide an indirect measure of content of soluble salts with freshly mined rock, and to assess the potential for development of saline drainage if the material is exposed to atmospheric conditions. The ECs were measured on 1:2 (w/w) suspensions of pulp samples equilibrated for at least one hour. Figure 17 shows a statistical plot of the EC values for different Barbara rock units.

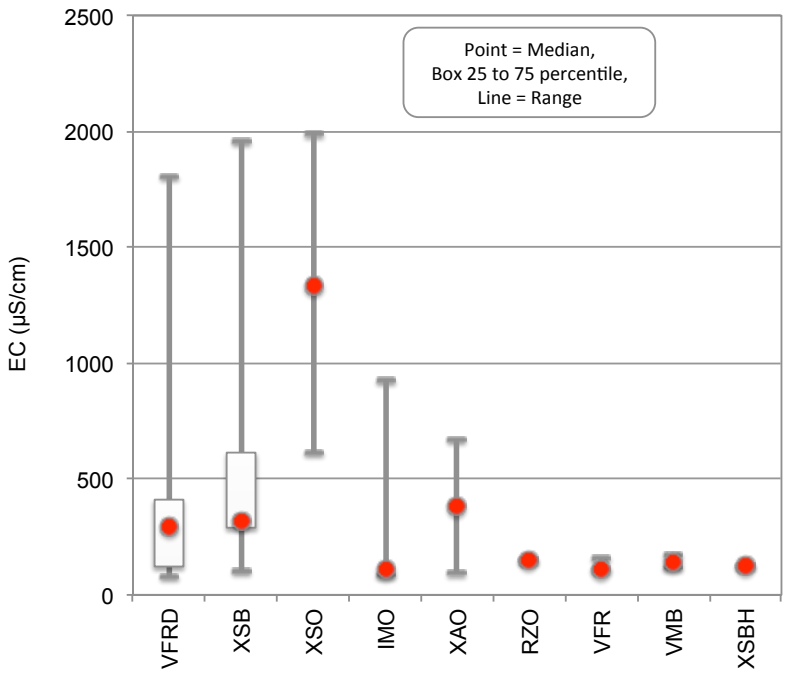


***FIGURE 17**: Summary of the EC values for Barbara drill core samples split by rock unit*

For VFRD, which is the dominant waste unit, the ECs were generally indicative of low concentrations of dissolved salts. Approximately 72% of the 87 samples from this unit had ECs of less than 400 µS/cm, which generally signifies that a sample is *non-saline*. A further 21% had ECs between 400 and 800 µS/cm which signifies that a sample is *slightly saline*. These results, together with the existing pH results discussed in Section 4.1, suggest that drainage from freshly mined, run-of-mine waste rock will be circum-neutral or slightly alkaline and have relatively low concentrations of soluble salts.

Thirteen of the 121 drill core samples tested did have ECs exceeding 800 µS/cm, suggesting that materials as represented by those samples could initially leach some soluble salts if exposed to atmospheric conditions. All but one of the 13 samples were representative of ore with high to very high sulphur contents. The samples with ECs exceeding 800 µS/cm were from the VFRD (1 waste and 5 ore samples), XSO (3 ore samples), XSB (3 ore samples), and IMD (1 ore sample) rock units.

5.4 Water Extractable Elements

The elemental assays discussed above provide an indication of elements that are enriched within the solids relative to concentrations typically found in non-mineralised soil. However, a significant GAI does not necessarily mean that an element will be a concern for water quality, and similarly, a low GAI value does not necessarily mean that an element will not be of environmental concern.

The potential for leaching of metals, metalloids and other elements of environmental interest was assessed using two leaching procedures. The first was batch extractions with deionised water to provide insights into solutes that might be released from freshly mined NAF and PAF materials immediately following exposure to atmospheric conditions, and hence provide an indication of the quality of drainage that might ensue a rainfall event.

The second leaching test involved extraction with hydrogen peroxide. The peroxide extractions were focused on PAF materials and the aim was to provide an indication of drainage quality from sulphidic rock after prolonged exposure resulting in significant sulphide oxidation and potential acidification. The results of the peroxide extractions are discussed in Section 5.5.

Water extraction tests were carried out on the same selection of 26 samples that were assayed for multi-elements, which included 18 samples representing waste rock and 8 samples representing ore grade materials. The tests water extractions were carried out on crushed coarse residue (minus 3.35 mm) at a solid:water ratio of 1:2. The use of deionised water meant that extraction occurred at the existing pH of a sample. The analysis of the water extracts included the following suite of elements: Ag, Al, As, B, Ba, Be, Ca, Cd, Cl, Co, Cr, Cu, F, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Sn, SO_4, Sr, Th, U, and Zn.

The results of the water extraction tests are provided in Appendix G, and statistical box plots of the results for waste and ore samples are given in Figures 18 and 19, respectively. The main findings of the water extraction tests involving waste rock and ore grade samples were as follows:

Waste Rock Samples

- The water extracts of all of the 18 waste samples were slightly alkaline, with pHs ranging from 8.6 to 9.0 and the median was 9.0.
- The ECs were low, with values ranging from 78 to 645 µS/cm and a median of only 200 µS/cm. This again indicates that drainage from freshly mined waste rock as represented by the test samples will have low concentrations of soluble salts.
- For the majority of waste samples the dominate ions released into solution were potassium (median 25 mg/L), sodium (median 11 mg/L), sulphate (median 13 mg/L) and chloride (median 13 mg/L).
- Sulphate concentrations for PAF waste were, on average, slightly higher than for NAF waste. Other differences were relatively minor.

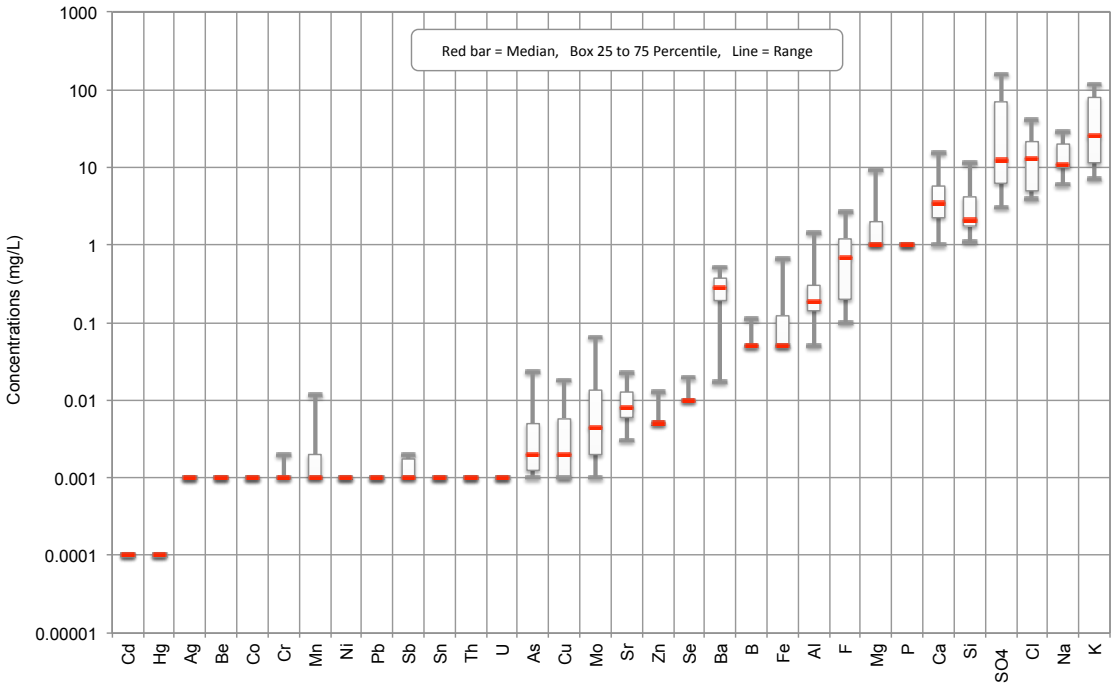


***FIGURE 18**: Box plot of elemental concentrations in water extracts of Barbara drill core waste samples*

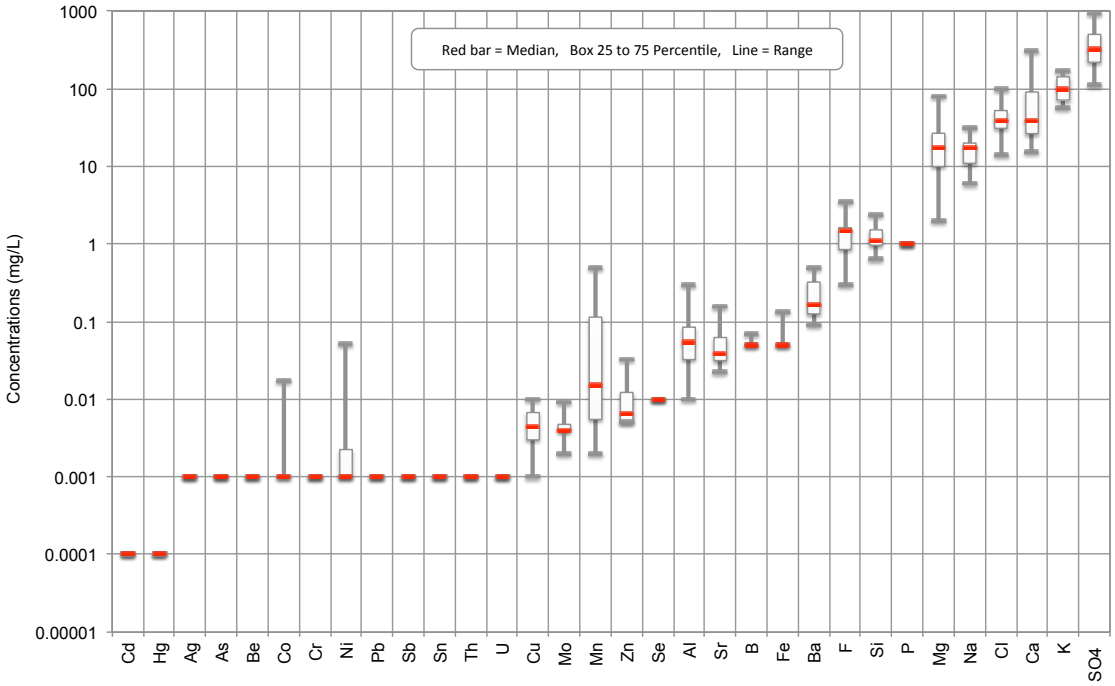


***FIGURE 19**: Box plot of elemental concentrations in water extracts of Barbara drill core ore samples*

- There were trace concentrations of aluminium in most extracts (median 0.19 mg/L), but the concentrations of copper and other environmentally important elements were low, and in most cases the concentrations were close to, or below, the analytical detection limits.
- The median concentrations of environmentally important elements in the water extracts of waste samples were as follows:
  - ≤ 0.0001 mg/L Hg, Cd
  - ≤ 0.001 mg/L Cr, Co, Mn, Ni, Pb, Sb, Sn
  - ≤ 0.002 mg/L As, Cu
  - ≤ 0.005 mg/L Mo, Zn:
  - ≤ 0.01 mg/L Se
- The low concentrations of soluble copper (and other metals) are consistent with the alkaline pH of waste rock samples, as the solubilities of most metals are highly pH dependent and typically are only sparingly soluble at circum-neutral or slightly alkaline pH.

Ore Samples

- Although the ore samples had significant sulphur contents and four of the eight were PAF, the compositions of the water extracts were in most respects similar in composition to the extracts of the waste rock samples, the only real difference being higher concentrations of sulphate (median 380 mg/L versus 13 mg/L for waste) and magnesium (median 18 mg/L versus 1 mg/L for waste). The higher concentrations of sulphate and calcium are consistent with the higher ECs reported for some ore samples as discussed in Section 5.3.
- Otherwise, all the ore extracts were slightly alkaline and the concentrations of environmentally important elements were low, with the possible exception of manganese which for the ore samples exhibited a median concentration of 0.16 mg/L compared to 0.001 mg/L for the waste samples.

The composition of a water extract basically represents a state of chemical equilibration between the liquor and solids phases at the natural pH of the material. The results are therefore generally applicable to the same material in the field when freshly mined. This being so, the results of the water extractions tests suggest drainage from freshly mined waste rock will typically be slightly alkaline and have low concentrations of soluble salts, and metals.

Similarly, it is expected that the drainage from stockpiles of recently mined ROM ore would be alkaline and have low concentrations of dissolved metals, but there could be some leaching of sulphate from high grade ores.

5.5 Peroxide Extraction Results

The purpose of the peroxide extractions was to provide indicative data on any metals or metalloids that might be released from sulphidic waste rock or ore grade materials as represented by the samples if there was prolonged exposure to atmospheric conditions leading to extensive sulphide oxidation and, in the case of PAF rock, development of acidic conditions. The potential for generation of ARD by some rock has

implications for the quality of pit water where sulphidic rock is exposed on final walls, and for the qualities of drainages from the waste rock dump or ROM ore stockpiles.

The peroxide extractions were based on the single-stage NAG test. As described previously in this report, the NAG test involves reaction of a sample with hydrogen peroxide to rapidly oxidise any sulphides that are present. Normally only the pH and acidity of the NAG solution are measured following the oxidation stage, but with these tests a sub-sample of the NAG solution was filtered and then assayed for multi-elements to discern the extent of any elemental releases from the samples as a consequence of sulphide oxidation. The peroxide extracts were assayed for the same suite of elements as the water extracts, namely: Ag, Al, As, B, Ba, Be, Ca, Cd, Cl, Co, Cr, Cu, F, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Sn, SO_4, Sr, Th, U, and Zn.

Peroxide extractions were carried out on a selection of 12 samples that included six samples representing ore, all of which were classified PAF, and six samples representing waste, five of which were PAF and the classification of the sixth was uncertain (UC).

The compositions of the 12 peroxide extracts are tabulated in Appendix I.

All of the waste samples acidified to some extent during peroxide extraction, with the final pHs ranging from 3.0 to 4.6. With the ore samples, four acidified during peroxide extraction to pHs between 2.9 to 4.3. The other two ore sample (8039 and 8056) remained circum-neutral (pH 7.7 and 7.8), notwithstanding that both had high sulphide contents (4.28 and 3.77 %S) and were classified as PAF based on positive NAPP and NAG test results. The lack of acidification during the peroxide extraction tests can be attributed to the two samples having high ANCs (95 and 93 kg H_2SO_4/t). As was discussed in Section 4.1, such samples typically require a multiple sequential extractions to induce an acidic state.

Unlike the water extract results discussed in Section 5.4, the compositions of peroxide extractions are not directly meaningful for the field situation because they are a function of both the volume of peroxide used per unit weight of sample and the amounts of elements released from a sample as a consequence of sulphide oxidation. The 100 mL/g used for the peroxide extraction is high in comparison to leach rates typically used in long term, column leach tests. The leach rates for columns routinely run by EGi typically average around 50 to 100 mL/kg/week, which over a five year period equates to a ratio of around 20:1. Therefore, to provide some relativity of the data to the field situation and also "average" leachate quality that might be expected from the same samples under standard column leach test conditions, a 5-times scaling factor[8] was applied to concentrations reported for the peroxide extracts.

[8] This scaling factor is based on the premise that for typical mine rock containing (say) 1 to 2 %S as pyrite it typically takes several years to substantially complete the oxidation process under the typical leach column set-up used by EGi. Assuming a five-year period and an average leaching rate during that period of 75 mL/kg/week gives an effective ratio of liquor to solids after five years of approximately 20:1, which is about five-times lower than the ratio for the peroxide extraction test. Clearly, a single scaling factor will not be appropriate for all material types given that geochemical behaviour under column leach conditions depends on a number of variables including sulphide content, the extent of any lag period, and the reactivity of the sulphides present. From past experience, EGi has determined that concentrations in peroxide extractions carried out at a solid to liquor ratio of 1:100 are typically between 3 to 10 times lower than average concentrations typically recorded for leachates from the same materials in standard column leach tests. Therefore, peroxide extract concentrations typically need to be increased in the order of 5-times to provide a reasonable guide to what might be expected from column leach tests.

Figure 20 is a statistical box plot of the scaled compositions of the peroxide extracts for the 10 samples that did acidified (which includes both waste and ore), and Figure 21 gives the same type of plot for the two ore samples that remained circum-neutral.

As expected, the extracts of samples that acidified had high concentrations of sulphate, iron and aluminium, which are the major elements commonly observed in ARD from PAF rock. There were also high concentrations of dissolved copper. The median and maximum scaled concentrations for these elements for the 10 samples were approximately:

- sulphate 1700 mg/L median 4848 mg/L maximum
- copper 130 mg/L 790 mg/L
- iron 35 mg/L 635 mg/L
- aluminium 35 mg/L 74 mg/L.

There were also releases of other environmentally important elements, albeit at concentrations one or two orders of magnitude less than copper. For example:

- cobalt 1 mg/L median 10 mg/L maximum
- manganese 4 mg/L 16 mg/L
- nickel 3 mg/L 12 mg/L
- zinc 1 mg/L 2 mg/L.

There were also significant releases of calcium (median 138 mg/L) and magnesium (median 47 mg/L) that presumably resulted from the reaction of ANC by some of the acid produced by sulphide oxidation.

Elements that were not released to any significant extent in comparison to the metal mentioned above included:

- mercury median ≤0.0005 mg/L
- antimony, cadmium, lead & tin median ≤0.005 mg/L
- chromium median <0.01 mg/L
- arsenic median 0.02 mg/L
- selenium median 0.2 mg/L

The results for the two PAF ore samples that remained circum-neutral provide an indication of conditions that might apply during the lag phase, when the initial acid produced by sulphide oxidation is being neutralised by the inherent ANC of the material. Although results are available for two samples only, they indicate significant releases of sulphate (1580 & 1835 mg/L) and calcium (555 and 655 mg/L) consistent with acid generation then neutralisation by carbonate mineralisation. There was also some copper release (13 and 0.6 mg/L) but only low concentrations of iron and aluminium, consistent with the low solubilities of these two elements at circum-neutral pH.

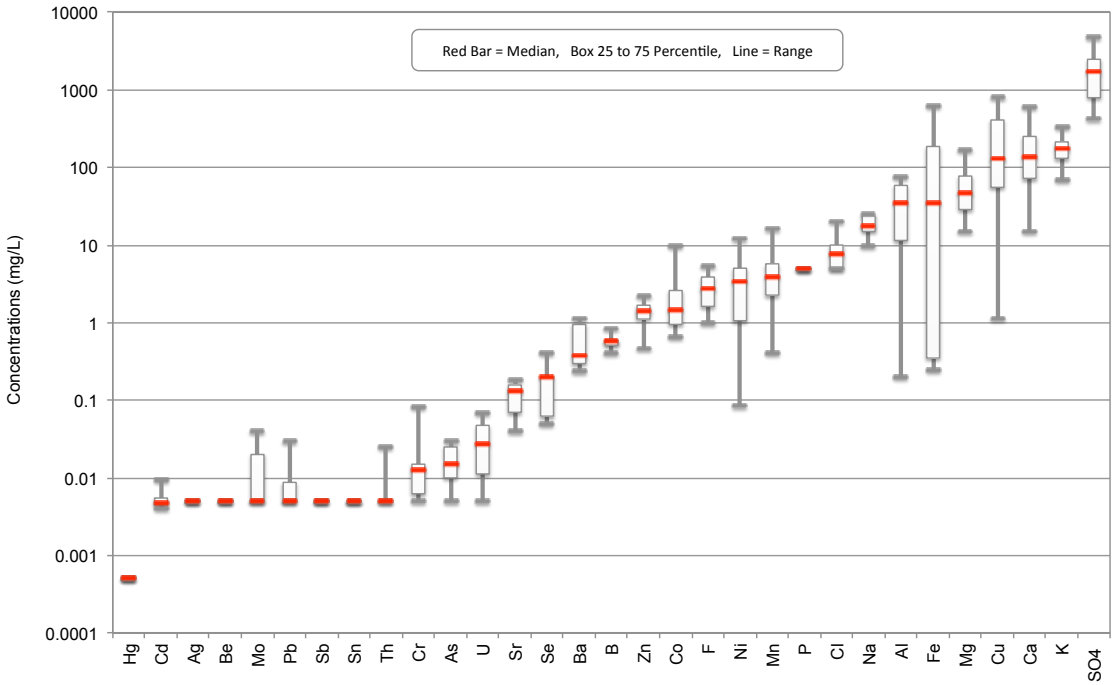


FIGURE 20: *Box plot of elemental concentrations in acidified peroxide extracts of Barbara drill core samples (with a 5-times scaling factor applied)*

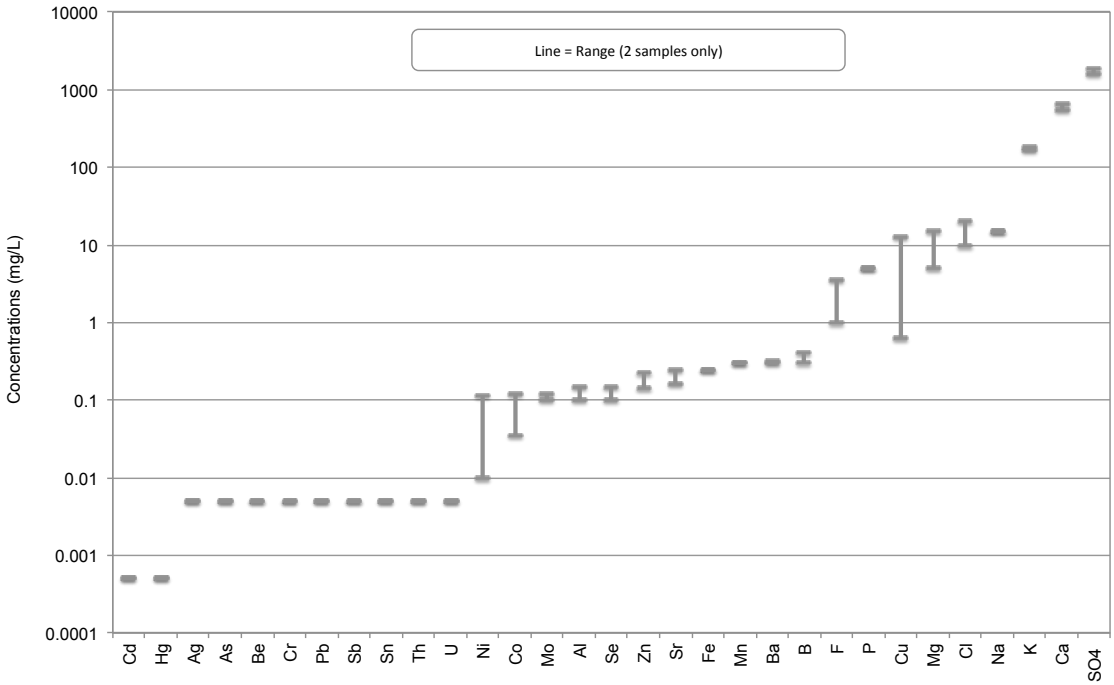


FIGURE 21*: Box plot of elemental concentrations in non-acidic peroxide extracts of PAF Barbara drill core samples*

6.0 Summary and Implications for Waste Rock Management

6.1 Summary and Findings

This report presents the results from static testing of drill core samples for the Barbara Copper Project. The main aims of the geochemical testing program were to define the range of acid forming characteristics likely to be exhibited by waste rock and ore grade materials, and to assess the implications for the quality of mine drainage, with particular emphasis on the potential for generation of ARD and release of environmentally important elements from the waste rock dump and within the final pit void. The assessment program and the main findings were as follows:

Assessment Program

- The geochemical assessment was based on testing of a total of 121 drill core samples from 14 diamond drill holes.
- The samples were selected by EGi in consultation with the Joint Venture and were considered to be representative of the range of rock types that will be mined during the Barbara Project.
- The selection of samples included representative samples of waste and ore grade materials. Approximately three-quarters of the samples were waste and one-quarter ore.
- The dominant rock types were porphyry rhyolites (90 samples) and biotite schists (20 samples). There were also limited numbers of samples representing numerous minor rock units that included dolerite (4 samples), basalt (2 samples), mafic intrusive (2 samples), psammite (2 samples) and gossan (1 sample).
- It should be noted that the proportional representation of samples across different lithologies does not necessarily correspond with the relative amounts of these materials that will be mined as waste, or the relative amounts that will be exposed on pit walls within the final void. Such estimates will require a much greater sampling intensity than that carried out for this exploratory ARD assessment study.
- The acid forming characteristics of all samples were determined using standard static testing procedures. They included determination of existing pH, EC, sulphur content, ANC, MPA, NAPP, and NAG capacity. Other testing carried out on selected samples included sequential NAG tests, kinetic NAG tests, acid buffer curves, multi-element analysis, and water and peroxide extraction tests.

Geochemistry of Waste

- Although the Barbara Project will involve the mining and processing sulphidic ore, the results of this study suggest that the majority of waste rock will have a low sulphur content and will be NAF.

- Waste from the near-surface weathered zone will likely have little ANC and hence will essentially be barren with respect to both acid generation potential and acid neutralisation potential.
- Most other NAF waste rock should have moderate ANC that will be at least several times greater than any acid that might be produced from any contained sulphides. It is expected that drainage from run-of-mine NAF waste rock will be neutral to slightly alkaline and have low concentrations of soluble salts and environmentally important metals and metalloids.
- Approximately 20% of NAF waste samples had ANCs exceeding 50 kg H_2SO_4/t. Such material would be ideally suited to ARD mitigation measures if required, such as blending with, or encapsulation of, PAF waste.
- Some PAF waste samples with elevated sulphur contents (*i.e.* 0.71 to 4.27 %S) were identified in this study. At this stage there are insufficient samples to ascertain the overall occurrence of PAF waste for the proposed pit, but most of the PAF waste samples in this study were located in the northern mining zone and it is expected that most PAF waste will be localised and close to the ore zones and not widely distributed throughout the entire mining area.
- The results of the kinetic NAG tests suggest sulphide mineralisation in PAF waste is reactive and will oxidise if the material is exposed to atmospheric conditions. However, a lag period of at least a year, and possibly several years can be expected for typical PAF waste with an ANC of more than 20 kg H_2SO_4/t. During this lag period it is expected that any drainage resulting from exposure to atmospheric conditions would remain circum-neutral but would likely have elevated concentrations of sulphate and calcium. There may also be some release of copper, but only low concentrations of iron and aluminium would be expected commensurate with the low solubilities of these two elements at circum-neutral pH.
- In the event of long term exposure of PAF waste leading to development of acid conditions there would likely be significant increases in the concentrations of dissolved metals within drainage. In addition to copper, iron and aluminium, there would likely be significant concentrations of cobalt, manganese, nickel and zinc.

Geochemistry of Ore Grade Materials

- As would be expected, most of the 27 ore samples tested in this study had high to very high sulphide contents but only half were classified as PAF.
- The occurrence of NAF ore can be attributed to moderate to high ANC. The median ANC for the NAF ore samples close to 100 kg H_2SO_4/t, which equates to approximately 10 %$CaCO_3$ equivalent.
- Most of the PAF ore samples tested in this study also had significant ANC, with a median for the test samples close to 50 kg H_2SO_4/t. An ANC of this magnitude would be expected to significantly delay formation of acid conditions.
- Based on the results of this study a lag of at least a year would be expected for ROM ore. Given that ore will be trucked off-site for processing, it is expected that the residence times for ore stockpiles on site would be shorter than the expected average lag period for ROM ore.

- It is expected that the drainage from stockpiles of recently mined ROM ore will be alkaline and have low concentrations of dissolved metals, but there could be some leaching of sulphate from high grade ores.
- However, in the event that high sulphide ore is exposed long term there would be a significant risk of generation of low pH, high sulphate drainage with high concentrations of environmentally important elements. As such, from an environmental viewpoint it would be advisable to preferentially transport high sulphide ore off-site as soon as possible.

6.2 Operational Identification of PAF Waste

- The methods used in this study to assign NAF/PAF classifications provide the most accurate means of assessing the acid forming potential, and the results of this study provided an indication of the occurrence of materials with ARD potential. However, it is expected that the NAPP and NAG data currently available will not be sufficient for detailed block modelling of the Barbara resource in relation to NAF/PAF waste classification.
- Furthermore, implementation of a selective handling strategy will require development of protocols to ensure PAF rock can be identified prior to mining so that problematic waste can be handled and placed within the dump in a correct manner.
- A protocol based on total sulphur content may be sufficient for development of a preliminary waste schedule, and/or may be adequate for operational use. It is understood that a sulphur database of considerable size already exists that could be used for modelling and planning purposes.
- Based on the results of this study it is recommended that a sulphur cutoff value of 0.3 %S is initially used for NAF/PAF classification of waste rock.
- A cut-off of 0.3 %S will capture almost all rock with a significant ARD risk, and provide a degree of conservatism in that many of the samples in this study containing more than 0.3 %S were NAF.
- A few samples containing less than 0.3 %S did acidified slightly under NAG test conditions and their ARD classifications were uncertain. In the event that some waste containing less than 0.3 %S was PAF, the total amount of acid it could produce would be low, and most likely negated as a consequence of general mixing with run-of-mine NAF rock during excavation and dumping operations.
- During operations, additional samples for confirmation of sulphur content can be taken from grade control holes, blast holes, and/or channel and face samples from benches.

6.3 Implications for Waste Rock Management

- A detailed NAF/PAF waste schedule for the project is not yet available but preliminary block modelling of the Barabara deposit by the Joint Venture indicates that approximately 85-90% of total waste rock will have a total sulphur content of less than 0.3 %S. As noted above, a cutoff of 0.3 %S is considered to be conservative in relation to NAF/PAF classification, hence the preliminary indication is that less than 15% of waste rock will be PAF. The high ratio of NAF to PAF waste rock means problematic material can be accommodated within the core of the waste rock dump in a

manner that provides long-term geochemical stability, thereby limiting the potential for sulphide oxidation or metals leaching.

- Preliminary block modelling also indicates that most waste with a sulphur content exceeding 0.3 %S is localised around the ore zone, which will simplify operational identification of PAF material requiring selective handling and management.
- Notwithstanding these expectations, there will be a need for diligent management of any waste rock that is identified as PAF to obviate the ARD risk. The overall goal of waste rock management at the Barbara site must be to place all PAF waste rock within the final dump landform so that long-term generation of ARD from the PAF rock does not occur or is restricted to a rate that can be readily assimilated *in-situ* by the surrounding NAF material so the resultant dump seepage is of a quality that will not adversely impact the downstream environment.
- As most NAF waste rock is expected to have at least moderate ANC, there may be opportunities for blending of high ANC NAF waste with PAF waste to negate some or all of its acid potential. However, true blending is often difficult to achieve operationally, and to be effective there usually needs to be a considerable excess of carbonate mineralisation contained within the NAF material to ensure there is sufficient fines with reactivities to match potential acid generation rates of the finer fractions of PAF waste likely to be produced during mining, hauling and dumping. This generally means that the blending rate of high ANC NAF material needs to be at least several times greater than the amount theoretically needed to equal the acid potential of the PAF rock overall.
- It is therefore recommended that the management of PAF waste rock at Barbara is primarily based on segregation and selective placement of PAF rock within the dump in a manner that limits oxygen contact and leaching of PAF material within the dump, thereby limiting the exposure of PAF rock to conditions that are conducive to ARD generation processes. This is best achieved by placement of PAF waste in small compacted cells or lifts with encapsulating layers comprising compacted NAF waste.
- The design and scale of PAF cells will depend on the relative amounts of PAF and NAF rock, the NAF/PAF production schedule, and the ability to construct compacted cells or layers in a timely manner. Specific criteria for selective PAF waste placement can be developed when the production schedule for NAF/PAF waste rock becomes available.
- Cells of PAF rock can be constructed by running out the load or paddock dumping the waste rock. This approach requires a higher degree of effort, but rock generally needs to be leveled and compacted in small lifts to create cells that have a permeability that limits the transfer of oxygen.
- Although PAF waste is expected to exhibit a lag of a year or more it would be preferable from an environmental perspective to close out PAF cells as soon as possible, and prior to any expectation of seasonal rain.
- Ideally, higher ANC NAF material should be placed immediately over PAF cells to provide some additional alkalinity to any water that does leach down into cells, prior to further encapsulated by layers comprising compacted run-of-mine NAF waste.

- T o provided a high level of geochemical stability, high ANC NAF rock can be interlayered with PAF material in small lifts to produce a cell that, overall, is non-acid forming. An overall ANC/MPA ratio for each cell of greater than 3 is generally recommended.
- It is essential that no PAF waste rock is placed within the outer zones of dumps where convective transport of oxygen can occur. Also, PAF rock should be excluded from under final outer slopes as this will facilitate final closure by reducing the need for infiltration control on slopes.

6.4 Pit Water Quality

- The potential for exposure of some PAF rock around the pit shell has implications for pit water quality, especially late in mine life and closure. The current level of knowledge of Barbara pit geochemistry, geomorphology and hydrogeology is not sufficient for detailed modelling of pit water quality, but it seems likely that some sulphide mineralisation will be exposed on the final pit floor and footwall benches as these final surfaces will be close to ore zones.
- In the longer term, it is expected that exposed PAF rock will produce localised ARD during rainfall events, and that the resultant pit drainage could have elevated concentrations of sulphate, iron, aluminium and copper, and possibly other environmentally important elements.
- The impact on pit water quality overall will depend on the extent of PAF rock exposure relative to total pit area. If PAF rock represents only a small fraction of total pit wall area then it is likely that any ARD produced would be diluted and neutralised to some extent by the much larger volume of alkaline runoff from NAF rock around the pit.
- During operations, the use of high ANC waste for sheeting roads within the pit will also provide additional alkalinity to mine drainage to mitigate any ARD inputs.
- It is recommended that more detailed investigation of the geology and geochemistry of the final pit shell is carried out, with particular emphasis on the final pit floor and footwall benches. Such investigation should be carried out during the early stages of operations to allow sufficient time for mine planning to minimise the extent of exposure of PAF material in the final shell and/or for planning the management of PAF material within the waste rock dump.
- The prediction of pit water quality during operations and post mining will require development of a hydrogeochemical model that integrates geochemical processes such as pyrite oxidation, acid generation and metals solubility with hydrologic factors relating to surface water fluxes (rainfall and evaporation) and groundwater fluxes within the pit limits.

APPENDICES

Appendix A

Geological Codes for the Barbara Copper Project

VOO	VOLCANIC ROCKS
VOX	volcanic breccia
VFO	**FELSIC VOLCANIC**
VFR	RHYOLITE
VFRD	rhyo-dacite
VFRP	porphyritic rhyolite
VFD	DACITE
VFDP	porphyritic dacite
VFP	PORPHYRITIC FELSIC VOLCANIC
VKO	**ALKALIC VOLCANIC**
VKT	TRACHYTE
VKTA	trachy-andesite
VKN	PHONOLITE
VKH	SHOSHONITE
VKP	PORPHYRITIC ALKALIC VOLCANIC
VIO	**INTERMEDIATE VOLCANIC**
VIA	ANDESITE
VIAP	porphyritic andesite
VIB	BASALTIC ANDESITE
VIP	PORPHYRITIC INTERMEDIATE VOLCANIC
VMO	**MAFIC VOLCANIC**
VMH	HAWAIITE
VMB	BASALT
VMBT	tholeitic basalt
VMBM	high magnesian basalt
VMBO	olivine basalt
VMBL	pillow basalt/Spillite
VMBV	vesicular basalt
VMBX	basaltic breccia
VMBP	porphyritic basalt
VMK	KOMATIITIC BASALT
VMP	PORPHYRITIC MAFIC VOLCANIC
VUO	**ULTRAMAFIC VOLCANIC**
VUB	BASINITE
VUK	KOMATIITE
VUKO	olive-phyric komatiite
VUX	PYROXENITE
VUS	SERPENTINITE
VUP	PERIDOTITE
VUL	LHERZOLITE
OOO	Unknown Rock
NS	No sample

YOO	PYROCLASTIC ROCKS
YOA	pyroclastic agglomerate
YOT	pyroclastic tuff
YFO	**FELSIC PYROCLASTIC**
YFI	FELSIC IGNIMBRITE
YFA	FELSIC VOLCANIC AGGLOMERATE
YFP	FELSIC PUMICE
YFS	FELSIC SCORIA
YFT	FELSIC TUFF
YFTL	felsic lapilli-tuff
YFTX	felsic tuff-breccia
YIO	**INTERMEDIATE PYROCLASTIC**
YII	INTERMEDIATE IGNIMBRITE
YIA	INTERMEDIATE VOLCANIC AGGLOMERATE
YIP	INTERMEDIATE PUMICE
YIS	INTERMEDIATE SCORIA
YIT	INTERMEDIATE TUFF
YITL	intermediate lapilli-tuff
YITX	intermediate tuff-breccia
YMO	**MAFIC PYROCLASTIC**
YMA	MAFIC VOLCANIC AGGLOMERATE
YMS	MAFIC SCORIA
YMT	MAFIC TUFF
YMTL	mafic lapilli-tuff
YMTX	mafic tuff-breccia
YOU	**ULTRAMAFIC PYROCLASTIC**
YUA	ULTRAMAFIC VOLCANIC AGGLOMERATE
YUS	ULTRAMAFIC SCORIA
YUT	ULTRAMAFIC TUFF

IOO	INTRUSIVE ROCKS
IOX	intrusive breccia
IOP	porphyry (undifferentiated)
IOG	pegmatite (undifferentiated)
IFO	**FELSIC INTRUSIVE**
IFG	GRANITE
IFGA	albite-granite
IFGP	porphyritic granite
IFGB	Biotite Granite
IFGL	Leuco - Biotite Granite
IFM	MONZOGRANITE
IFMP	porphyritic monzogranite
IFD	GRANODIORITE
IFDP	porphyritic granodiorite
IFT	TONALITE
IFJ	TRONDJHEMITE
IFP	FELSIC PORPHYRY
IFPG	felsic pegmatite
IKO	**ALKALIC INTRUSIVE**
IKC	CARBONATITE
IKS	SYENITE
IKSG	syenogranite
IKSF	alkali-feldspar syenite/granite
IKSQ	quartz-syenite
IKSN	nepheline-syenite
IKSP	porphyritic syenite
IKH	SHOSHONITE
IKK	KIMBERLITE
ILO	LAMPROPHYRE
IIO	**INTERMEDIATE INTRUSIVE**
IIM	MONZONITE
IIMQ	quartz-monzonite
IIMP	porphyritic monzonite
III	MONZODIORITE
IIIQ	quartz-monzodiorite
IIIP	porphyritic monzodiorite
IID	DIORITE
IIDM	Micro-diorite
IIDQ	quartz-diorite
IIDP	porphyritic diorite
IMO	**MAFIC INTRUSIVE**
IMA	ANORTHOSITE
IMN	NORITE
IMD	DOLERITE
IMDQ	quartz-dolerite
IMDG	granophyric-dolerite
IMDM	magnesian dolerite
IMG	GABBRO
IMGQ	quartz-gabbro
IMGN	gabbronorite
IMGO	olivene-gabbro
IMT	TROCTOLITE
IMP	MAFIC PORPHYRY
IUO	**ULTRAMAFIC INTRUSIVE**
IUH	HORNBLENDITE
IUW	WEBSTERITE
IUX	PYROXENITE
IUXO	orthpyroxenite
IUXC	clinopyroxenite
IUXM	olivene-pyroxenite
IUS	SERPENTINITE
IUP	PERIDOTITE
IUL	LHERZOLITE
IUZ	HARZBURGITE
IUD	DUNITE

SOO	SEDIMENTARY ROCKS
SCO	**CONGLOMERATE**
SCB	BOULDER CONGLOMERATE
SCC	PEBBLE/COBBLE CONGLOMERATE
SCV	VOLCANIC CONGLOMERATE
SCX	CONGLOMERATE-BRECCIA
SSO	**COARSE CLASTIC SEDIMENT**
SSA	ARENITE
SSAQ	quartz-arenite
SSAC	calc-arenite
SSAL	lithic arenite
SSS	SANDSTONE
SSV	VOLCANIC SANDSTONE
SSR	GRITSTONE
SWO	**GREYWACKE**
SWQ	QUARTZ-WACKE
SWK	FELDSPAR-WACKE
SWT	TURBIDITE/BEDDED-WACKE
SWV	VOLCANIC-WACKE
SVO	**FRAGMENTAL VOLCANICLASTIC SEDIMENT**
SVX	FRAGMENTAL VOLCANICLASTIC BRECCIA
SVZ	FRAGMENTAL SULFIDIC VOLCANICLASTIC SEDIMENTS
SIO	**SILTSTONE**
SIC	CALCAREOUS SILTSTONE
SIV	VOLCANIC SILTSTONE
SIY	CLAYSTONE
SIM	MUDSTONE
SIMV	VOLCANIC MUDSTONE
SHO	**SHALE**
SHC	CALCAREOUS SHALE
SHF	FERRUGINOUS SHALE
SHG	GRAPHITIC SHALE
SHGZ	sulfidic graphitic shale
SHV	VOLCANIC SHALE
SLO	**CARBONATE SEDIMENT**
SLL	LIMESTONE
SLM	MARL
SLD	DOLOMITE
STO	**CHERT**
STF	BANDED IRON FORMATION
STFX	BIF - oxide facies
STFZ	BIF - sulfide facies
	BIF - Silicate Facies
	BIF- Carbonate Facies
STZ	SULFIDIC CHERT
SEO	**EVAPORITE**
SHE	HALITE
SEG	GYPSUM
SBO	**BIOGENIC SEDIMENT**
SBC	COAL
SBL	LIGNITE
SBP	PHOSPHORITE/PHOSPHATE ROCK

XOO	METAMORPHIC ROCKS
XKO	**Calc Silicate**
XKP	**Scopolitic Calc Silicate**
XKR	**Red rock Calc Silicate**
XKA	**Actinolite Calc Silicate**
XKN	ENDOSKARN
XKS	EXOSKARN
XHO	**HORNFELS**
XAO	**AMPHIBOLITE**
XQO	**QUARTZITE**
XMO	**PSAMMITE**
XPO	**PELITE**
XYO	**PHYLLITE/SLATE**
XLD	**DOLOMITIC MARBLE**
XSO	**SCHIST**
XSA	AMPHIBOLE SCHIST
XSB	BIOTITE SCHIST
XSBH	biotite-chlorite schist
XSBQ	biotite-quartz schist
XSH	CHLORITE SCHIST
XSHC	chlorite-carbonate schist
XSHA	chlorite-amphibole schist
XST	TALC SCHIST
XSTH	talc-chlorite schist
XSTC	talc-carbonate schist
XSTA	talc-amphibole schist
XSM	MUSCOVITE SCHIST
XSMQ	quartz-muscovite schist
XSS	SERICITE SCHIST
XSC	CARBONATE SCHIST
XGO	**GNEISS**
XGQ	QUARTZOFELDSPATHIC GNEISS
XGM	PSAMMITIC GNEISS
XGP	PELITIC GNEISS
XGI	MIGMATITE
XGG	GRANULITE
XGGF	felsic granulite
XGGI	intermadiate granulite
XGGM	mafic granulite
XEO	**ECLOGITE**

ZOO	STRUCTURE/VEIN/ALTERATION ROCKS
ZBO	**BRECCIA**
ZBT	TECTONIC BRECCIA
ZBH	HYDROTHERMAL BRECCIA
VOX	VOLCANIC BRECCIA
IOX	INTRUSIVE BRECCIA
ZMO	**MYLONITE**
ZVO	**VEIN**
ZVQ	VEIN QUARTZ
ZVQC	quartz-carbonate vein
ZVC	VEIN CARBONATE
ZVZ	VEIN SULFIDE
ZVZP	pyrite-dominant vein
ZVZY	pyhotite-dominant vein
ZVZC	chalcopyrite-dominant vein
ZZO	**MASSIVE SULFIDE**
ZZP	PYRITE-DOMINANT MASSIVE SULFIDE
ZZY	PYRHOTITE-DOMINANT MASSIVE SULFIDE
ZZC	CHALCOPYRITE-DOMINANT MASSIVE SULFIDE
ZZE	PENTLANDITE-DOMINANT MASSIVE SULFIDE
ZZS	SPHALERITE-DOMINANT MASSIVE SULFIDE

ROO	REGOLITH DEPOSITS
RRO	**RESIDUAL REGOLITH (undifferentiated)**
RTO	**TRANSPORTED REGOLITH (undifferentiated)**
RTA	ALLUVIUM
RTC	COLLUVIUM
RFO	**FERRICRETE**
RSO	**SILCRETE**
RCO	**CALCRETE**
RZO	**GOSSAN**

HOO	HUMAN DISTURBED GROUND
HMO	**MINING AREA/DEBRIS**
HMV	OPEN STOPE/VOID
HMS	FILLED STOPE
HMF	FILLED/RECONTOURED GROUND
HMD	DRILLHOLE/CASING
HNC	New code

Appendix B

Acid Forming Characteristics of Barbara Drill Core Samples

APPENDIX B: Acid forming characteristics of Barbara drill core samples

EGi id	Assay Lab id	Hole_ID	From (m)	To (m)	Rock Type	Copper (%)	Material Type	pH	EC (µS/cm)	Sulphur (%S)	MPA (kg H_2SO_4/t)	ANC (kg H_2SO_4/t)	ANC/MPA Ratio	NAPP (kg H_2SO_4/t)	NAG (kg H_2SO_4/t)	NAGpH	ARD Classification
8098	SM005760	BADD049	14	15	VFRD	0.2	waste	9.2	378	0.25	8	142	19	-135	0	8.3	NAF
8099	SM005766	BADD049	19	20	VFRD	0.05	waste	8.8	525	0.06	2	13	7	-12	0	7.5	NAF
8100	SM005768	BADD049	21	22	VFRD	0.70	ore	9.2	485	1.19	36	28	0.8	9	8	4.3	PAF
8101	SM005772	BADD049	25	26	VFRD	0.49	waste **	9.3	475	0.48	15	88	6	-73	0	8.2	NAF
8102	SM005778	BADD049	29	30	VFRD	0.09	waste	8.2	212	0.14	4	17	4	-13	0	7.6	NAF
8103	SM005782	BADD049	32	33	VMB	0.06	waste	8.3	176	0.08	2	29	12	-27	0	7.8	NAF
8104	SM005789	BADD049	39	40	VMB	0.01	waste	8.5	116	0.06	2	28	15	-26	0	7.3	NAF
8036	SM007874	BADD050	9	10	VFRD	0.005	waste	9.0	119	0.05	2	7	5	-6	0	6.5	NAF
8037	SM007875	BADD050	19	20	VFRD	na	waste	7.8	107	0.10	3	7	2.4	-4	0	5.7	NAF
8090	SM005700	BADD050	29	30	VFRD	0.14	waste	9.5	379	0.58	18	31	1.8	-14	0	5.7	NAF
8091	SM005709	BADD050	35	36	VFRD	0.25	waste	8.6	301	1.69	52	49	0.9	3	7	3.8	PAF
8092	SM005713	BADD050	39	40	VFRD	0.17	waste	9.1	512	1.85	57	21	0.4	35	33 *	3.0	PAF
8093	SM005717	BADD050	43	44	VFRD	0.39	waste	8.7	376	1.33	41	29	0.7	12	9	3.8	PAF
8094	SM005723	BADD050	49	50	VFRD	0.08	waste	9.8	366	0.97	30	13	0.4	17	10	3.7	PAF
8095	SM005729	BADD050	53	54	VFRD	0.24	waste	9.9	408	0.38	12	23	2.0	-11	0	7.6	NAF
8096	SM005735	BADD050	59	60	VFRD	0.03	waste	8.9	411	0.16	5	17	4	-13	0	6.4	NAF
8097	SM005745	BADD050	69	70	VFRD	0.03	waste	9.0	391	0.42	13	29	2.3	-16	0	7.8	NAF
8011	SM006213	BADD043	19	20	VFR	na	waste	8.3	112	0.07	2	30	14	-28	0	7.5	NAF
8012	SM006223	BADD043	29	30	VFR	na	waste	8.0	114	0.11	3	22	7	-19	0	7.9	NAF
8013	SM006243	BADD043	49	50	IMD	0.008	waste	7.8	109	0.07	2	74	34	-72	0	7.8	NAF
8080	SM005487	BADD043	59	60	XSB	0.01	waste **	9.1	712	0.04	1	134	109	-133	0	8.2	NAF
8081	SM005495	BADD043	64	65	XSO	1.0	ore	8.3	851	2.37	73	24	0.3	49	41 *	3.0	PAF
8082	SM005500	BADD043	69	70	VFRD	0.23	waste	8.4	595	0.28	9	79	9	-70	0	7.9	NAF
8083	SM005512	BADD043	79	80	VFRD	0.01	waste	7.8	725	0.03	1	15	16	-14	0	7.1	NAF
8014	SM006255	BADD023	9	10	IMO	0.02	waste	7.9	87	0.05	2	17	11	-15	0	7.4	NAF
8015	SM006265	BADD023	19	20	IMO	0.01	waste	8.8	122	0.06	2	30	17	-29	0	8.0	NAF
8028	SM007866	BADD023	29	30	XAO	0.04	waste	9.5	92	0.04	1	79	64	-78	0	8.0	NAF
8084	SM005624	BADD023	39	40	XAO	0.01	waste	7.9	670	0.02	1	32	53	-32	0	7.8	NAF
8085	SM005639	BADD023	50	51	IMD	0.89	ore	8.6	929	3.21	98	90	0.9	8	12 *	3.6	PAF
8086	SM005643	BADD023	54	55	VFRD	0.69	ore	8.3	896	1.27	39	98	2.5	-59	0	7.6	NAF
8087	SM005653	BADD023	64	65	VFRD	0.92	ore	8.2	878	1.69	52	47	0.9	5	19 *	3.7	PAF
8088	SM005660	BADD023	69	70	VFRD	0.36	waste **	8.4	885	0.61	19	83	4	-65	0	7.5	NAF
8089	SM005667	BADD023	76	77	VFRD	0.01	waste	9.6	239	0.12	4	9	2.5	-5	0	5.3	NAF
8070	SM005412	BADD046	9	10	XSB	1.11	ore	9.1	303	0.01	0	26	84	-25	0	8.4	NAF
8071	SM005424	BADD046	19	20	VFRD	0.06	waste	8.3	376	0.18	6	23	4	-18	0	8.2	NAF
8072	SM005431	BADD046	26	27	VFRD	0.37	waste **	8.6	645	1.47	45	34	0.8	11	5	4.5	PAF
8073	SM005435	BADD046	29	30	VFRD	0.13	waste **	8.9	521	0.45	14	14	1.0	0	5	3.9	PAF

APPENDIX B: *Continued*

EGi id	Assay Lab id	Hole_ID	From (m)	To (m)	Rock Type	Copper (%)	Material Type	pH	EC (µS/cm)	Sulphur (%S)	MPA (kg H_2SO_4/t)	ANC (kg H_2SO_4/t)	ANC/MPA Ratio	NAPP (kg H_2SO_4/t)	NAG (kg H_2SO_4/t)	NAGpH	ARD Classification
8000	SM004847	BADD042	9	10	XSBH	na	waste	8.8	131	0.01	0	23	74	-22	0	7.2	NAF
8001	SM004857	BADD042	19	20	IMD	na	waste	9.1	91	0.01	0	12	40	-12	0	6.4	NAF
8002	SM004867	BADD042	29	29.6	IMD	na	waste	8.7	107	0.12	4	10	3	-6	2	4.4	UC
8035	SM007873	BADD042	29.6	30	VFRD	na	waste	8.8	113	0.02	1	12	19	-11	0	6.3	NAF
8074	SM005443	BADD042	39	40	VFRD	0.01	waste	8.8	416	0.07	2	6	2.8	-4	0	4.8	NAF
8075	SM005455	BADD042	49	50	VFRD	0.21	waste **	8.7	296	1.09	33	47	1.4	-13	0	7.8	NAF
8076	SM005465	BADD042	59	60	VFRD	0.20	waste	8.5	346	0.31	9	44	5	-35	0	8.3	NAF
8077	SM005470	BADD042	64	65	VFRD	0.18	waste **	8.6	355	0.29	9	26	3	-17	0	8.5	NAF
8078	SM005478	BADD042	69	70	VFRD	0.22	waste **	9.0	436	1.10	34	76	2.3	-42	0	8.6	NAF
8079	SM005483	BADD042	74	75	VFRD	0.00	waste	9.2	676	0.05	2	24	16	-22	0	8.4	NAF
8064	SM005367	BADD045	9	10	XSB	0.17	waste	8.4	515	0.01	0	41	135	-41	0	7.6	NAF
8065	SM005379	BADD045	19	20	VFRD	0.03	waste	8.6	469	0.01	0	5	17	-5	0	6.9	NAF
8066	SM005387	BADD045	27	28	XSB	0.28	waste	8.9	311	0.73	22	15	0.7	7	7	4.4	PAF
8067	SM005389	BADD045	29	30	VFRD	0.03	waste **	8.7	325	0.02	1	16	26	-15	0	7.2	NAF
8068	SM005393	BADD045	33	34	VFRD	1.09	ore	7.5	334	1.01	31	22	0.7	9	13	4.3	PAF
8069	SM005400	BADD045	39	40	XSB	0.01	waste	9.2	321	0.09	3	22	8	-19	0	7.1	NAF
8032	SM007870	BADD036	9	10	VFRD	0.005	waste	9.4	92	0.01	0	10	33	-10	0	7.6	NAF
8033	SM007871	BADD036	18	19	VFRD	na	waste	9.2	109	0.01	0	12	41	-12	0	8.2	NAF
8060	SM005326	BADD036	28.92	30	VFRD	0.05	waste	8.7	342	0.07	2	24	11	-22	0	8.3	NAF
8061	SM005338	BADD036	39	40	VFRD	0.05	waste **	7.9	316	0.06	2	13	7	-11	0	7.8	NAF
8062	SM005343	BADD036	43	44	XSB	0.42	ore *	8.7	481	1.00	31	91	3	-60	0	8.2	NAF
8063	SM005349	BADD036	49	50	XSB	0.01	waste **	8.3	476	0.08	2	17	7	-14	0	6.9	NAF
8024	SM004889	BADD033	9	10	VFRD	0.00	waste	8.6	124	0.01	0	7	23	-7	0	7.4	NAF
8025	SM004899	BADD033	19	20	VFRD	0.008	waste	9.2	103	0.07	2	35	16	-33	0	7.9	NAF
8003	SM004909	BADD033	29	29.5	VFRD	0.00	waste	8.6	109	0.04	1	16	13	-15	0	7.3	NAF
8029	SM007867	BADD033	29.5	30	VFRD	0.00	waste	9.3	88	0.01	0	17	54	-16	0	7.6	NAF
8030	SM007868	BADD033	39	40	VFRD	0.005	waste	9.2	131	0.25	8	36	5	-29	0	7.8	NAF
8054	SM005261	BADD033	49	50	VFRD	0.77	ore	9.2	296	0.98	30	197	7	-167	0	7.4	NAF
8055	SM005271	BADD033	59	60	VFRD	0.41	ore*	9.1	288	0.59	18	59	3	-41	0	7.6	NAF
8056	SM005278	BADD033	64	65	VFRD	3.34	ore	8.4	1460	4.28	131	95	0.7	36	57 *	3.0	PAF
8057	SM005282	BADD033	68	69	VFRD	1.42	ore	8.6	376	2.22	68	114	1.7	-46	0 *	6.7	NAF
8058	SM005288	BADD033	74	75	VFRD	0.02	waste	8.5	385	0.26	8	21	2.7	-13	0	7.8	NAF
8059	SM005293	BADD033	79	80	VFRD	0.06	waste	8.3	412	1.08	33	39	1.2	-6	0	8.1	NAF

APPENDIX B: *Continued*

EGi id	Assay Lab id	Hole_ID	From (m)	To (m)	Rock Type	Copper (%)	Material Type	pH	EC (µS/cm)	Sulphur (%S)	MPA (kg H_2SO_4/t)	ANC (kg H_2SO_4/t)	ANC/MPA Ratio	NAPP (kg H_2SO_4/t)	NAG (kg H_2SO_4/t)	NAGpH	ARD Classification
8004	SM004929	BADD034	19	20	VFRD	na	waste	8.5	111	0.10	3	8	2.5	-5	3	4.3	UC
8005	SM004949	BADD034	39	40	VFR	na	waste	8.8	161	0.01	0	20	64	-19	0	6.9	NAF
8006	SM004969	BADD034	59	60	VFRD	na	waste	8.5	125	0.05	2	52	34	-51	0	8.3	NAF
8007	SM004989	BADD034	79	80	VFRD	na	waste	8.3	131	0.05	2	165	108	-163	0	8.4	NAF
8008	SM004999	BADD034	89	90	VFRD	0.01	waste	8.6	119	0.08	2	107	44	-104	0	8.5	NAF
8009	SM006019	BADD034	109	110	VFRD	na	waste	8.4	124	0.01	0	143	468	-143	0	8.7	NAF
8010	SM006039	BADD034	129	130	VFRD	na	waste	8.5	126	0.04	1	16	13	-15	0	6.9	NAF
8031	SM007869	BADD034	139	140	VFRD	na	waste	9.3	88	0.26	8	10	1.3	-2	3	3.9	UC
8043	SM005121	BADD034	149	150	VFRD	0.05	waste **	8.0	251	0.06	2	18	10	-16	0	7.2	NAF
8044	SM005127	BADD034	154	155	XSB	0.88	ore	7.2	246	2.48	76	96	1.3	-20	0 *	6.9	NAF
8045	SM005132	BADD034	159	160	XSB	0.52	ore	7.3	288	4.26	130	387	3	-257	0	7.6	NAF
8046	SM005151	BADD034	173	174	VFRD	0.01	waste	7.9	292	0.05	2	8	5	-6	0	6.9	NAF
8047	SM005164	BADD035	34	35	VFRD	4.15	ore	6.8	1810	6.12	187	48	0.3	139	115 *	2.5	PAF
8048	SM005169	BADD035	39	40	VFRD	1.36	ore	8.0	426	1.99	61	148	2.4	-87	0	7.4	NAF
8049	SM005176	BADD035	45	46	XSO	0.97	ore	7.9	612	1.29	39	20	0.5	20	16	4.0	PAF
8050	SM005180	BADD035	49	50	VFRD	1.96	ore	8.2	1040	3.59	110	14	0.1	96	85 *	2.7	PAF
8051	SM005192	BADD035	59	60	VFRD	0.13	waste	8.5	476	0.15	5	96	21	-91	0	8.3	NAF
8052	SM005204	BADD035	69	70	VFRD	0.32	waste	8.8	411	0.37	11	18	1.6	-7	0	5.3	NAF
8053	SM005214	BADD035	79	80	VFRD	0.02	waste	9.9	355	0.04	1	17	14	-16	0	7.1	NAF
8016	SM006392	BADD021	19	20	VFRD	na	waste	9.0	121	0.04	1	6	5	-5	0	5.6	NAF
8017	SM006402	BADD021	29	30	VFRD	na	waste	8.9	78	0.24	7	8	1.1	-1	5	3.5	UC
8018	SM006412	BADD021	39	40	XSB	na	waste	8.4	103	0.05	2	23	15	-22	0	7.1	NAF
8019	SM006422	BADD021	49	50	XSB	na	waste	8.6	101	0.01	0	19	62	-19	0	6.9	NAF
8020	SM006432	BADD021	59	60	VFRD	na	waste	8.5	91	0.01	0	7	24	-7	0	6.0	NAF
8021	SM006442	BADD021	69	70	VFRD	na	waste	9.0	112	0.01	0	9	28	-8	0	5.8	NAF
8022	SM006452	BADD021	79	80	VFRD	na	waste	8.8	121	0.08	2	66	27	-64	0	8.4	NAF
8023	SM006462	BADD021	89	90	VFRD	na	waste	8.7	115	0.10	3	72	24	-69	0	8.3	NAF
8026	SM007864	BADD021	99	100	VFRD	na	waste	9.0	101	0.11	3	34	10	-31	0	8.2	NAF
8027	SM007865	BADD021	109	110	VFRD	na	waste	9.1	95	0.14	4	46	11	-42	0	8.1	NAF
8110	SM007596	BADD021	119	120	VFRD	0.007	waste	8.2	329	0.01	0	9	30	-9	0	6.5	NAF
8111	SM007606	BADD021	129	130	XSB	12.4	ore	6.1	1960	18.2	557	27	0.05	530	420 *	2.5	PAF
8112	SM007619	BADD021	139	140	XSB	1.08	ore	8.9	852	5.37	164	42	0.3	122	115 *	2.6	PAF
8113	SM007630	BADD021	149	150	XSB	3.47	ore	7.8	1520	19.05	583	127	0.2	456	414 *	2.3	PAF

APPENDIX B: *Continued*

EGi id	Assay Lab id	Hole_ID	From (m)	To (m)	Rock Type	Copper (%)	Material Type	pH	EC (µS/cm)	Sulphur (%S)	MPA (kg H_2SO_4/t)	ANC (kg H_2SO_4/t)	ANC/MPA Ratio	NAPP (kg H_2SO_4/t)	NAG (kg H_2SO_4/t)	NAGpH	ARD Classification
8105	SM005838	BADD015	9	10	VFRD	0.01	waste	8.6	125	0.02	1	3	6	-3	0	6.3	NAF
8106	SM005850	BADD015	19	20	RZO	3.03	ore	8.4	151	0.01	0	36	118	-36	0	7.7	NAF
8107	SM005860	BADD015	29	30	VFRD	0.11	waste	8.7	145	0.18	6	120	22	-114	0	7.9	NAF
8108	SM005872	BADD015	39	40	VFRD	0.02	waste	8.9	232	0.03	1	9	10	-8	0	6.5	NAF
8109	SM005882	BADD015	49	50	VFRD	0.00	waste	7.8	242	0.01	0	10	32	-10	0	6.5	NAF
7994	SM004768	BADD038	19	20	VFRD	na	waste	8.9	121	0.01	0	8	26	-8	0	6.4	NAF
7995	SM004788	BADD038	39	40	VFRD	na	waste	8.7	129	0.07	2	45	21	-43	0	8.4	NAF
7996	SM004798	BADD038	49	50	VFRD	na	waste	9.2	117	0.01	0	41	133	-40	0	8.2	NAF
7997	SM004808	BADD038	59	60	VFRD	na	waste	9.2	107	0.06	2	44	24	-42	0	8.3	NAF
7998	SM004818	BADD038	69	70	VFRD	na	waste	9.0	135	0.11	3	16	5	-12	0	7.5	NAF
7999	SM004828	BADD038	79	80	VFRD	na	waste	8.9	126	0.01	0	11	35	-10	0	6.9	NAF
8034	SM007872	BADD038	89	90	VFRD	na	waste	8.9	126	0.01	0	16	51	-15	0	6.5	NAF
8114	SM007811	BADD038	99	100	XSB	0.11	waste	8.3	291	0.32	10	135	14	-125	0	8.9	NAF
8038	SM005069	BADD038	109	110	XSO	8.18	ore	7.5	1990	10.35	317	84	0.3	233	206 *	2.7	PAF
8039	SM005083	BADD038	121	122	XSO	3.32	ore	8.1	1810	3.77	115	93	0.8	22	57 *	2.9	PAF
8040	SM005093	BADD038	131	132	VFRD	0.24	waste ***	7.6	345	0.50	15	54	4	-39	0	7.7	NAF
8041	SM005101	BADD038	139	140	VFRD	1.08	ore	7.5	222	1.42	43	114	2.6	-71	0	7.8	NAF
8042	SM005107	BADD038	145	146	VFRD	1.08	ore	7.4	265	2.14	65	64	1.0	2	10 *	3.9	PAF

Key Lithology

IMD	Dolerite	**VMB**	Basalt
IMO	Mafic Intrusive	**XAO**	Amphibolite
RZO	Gossan	**XSB**	Biotite schist
VFR	Rhyolite	**XSBH**	Biotite-chlorite schist
VFRP	Porphyritic rhyolite	**XSO**	Schist

Key ARD Parameters

pH	Existing pH (1:2 extract)	**NAPP**	Net Acid Producing Potential (kg H_2SO_4/t)
EC	Electrical Conductivity (µS/cm))	**NAG**	Net Acid Generation capacity (kg H_2SO_4/t)
MPA	Maximum Potential Acidity (kg H_2SO_4/t)		(* signifies sequential NAG result)
ANC	Acid Neutralising Capacity (kg H_2SO_4/t)	**NAG pH**	pH of NAG liquor
Ratio	Ratio of ANC to MPA results		

Material Type

ore*	Below grade sample but sample occurs within the 0.5 %Cu halo
waste **	Waste sample that occurs on the edge of ore zone
waste ***	Small waste band within ore zone

Key ARD Classification

NAF	Non-Acid Forming
PAF	Potentially Acid Forming
UC	Uncertain

Appendix C

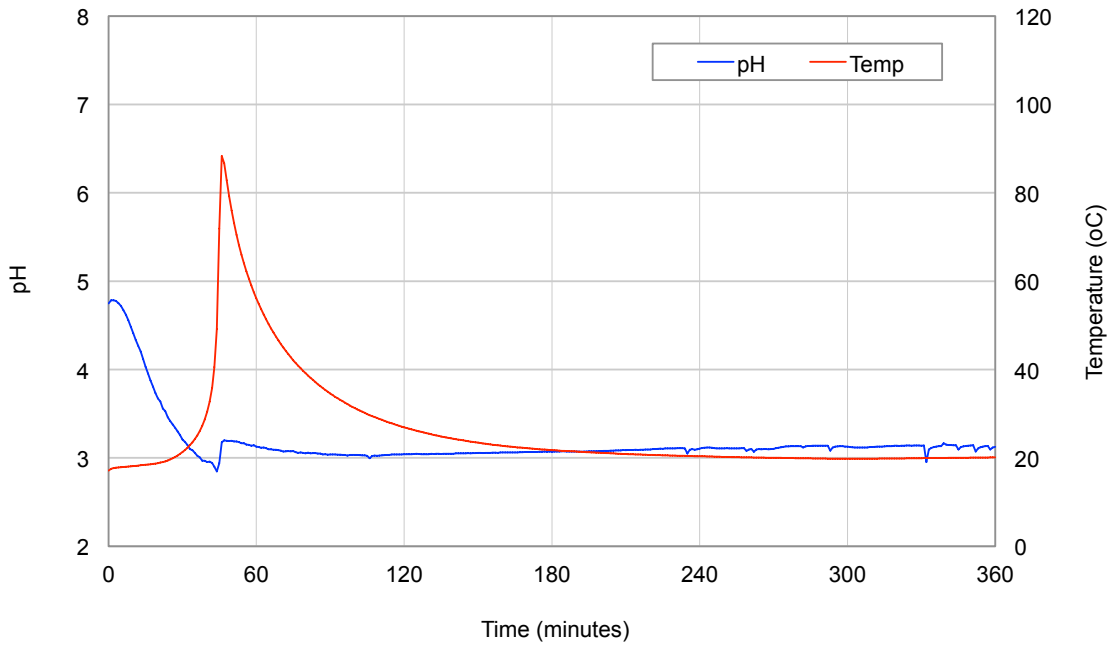
Sequential NAG Test Results for Barbara Drill Core Samples

APPENDIX C: Sequential NAG test results for Barbara drill core samples

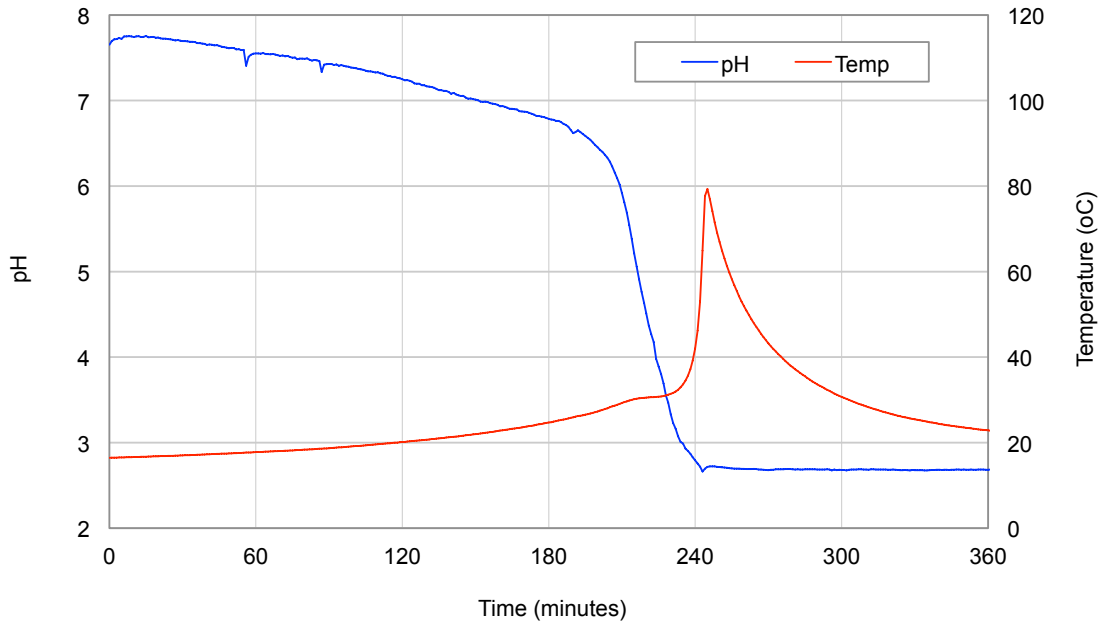
EGi id	Sulphur (%S)	ANC	NAPP	Parameter	NAG pH for each Stage							TOTAL NAG
		kg H_2SO_4/t			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	
8038	10.35	84	233	NAGpH	3.5	3.3	2.7	2.9	3.2	3.4	4.2	206
				NAG	80	52	33	25	12	3	1	
8039	3.77	93	22	NAGpH	7.5	6.4	6.9	6.5	4.1	2.9	3.7	57
				NAG	-	-	-	-	36	17	4	
8042	2.14	64	2	NAGpH	6.9	4.6	3.9	3.9	4.2			10
				NAG	-	-	5	3	2			
8044	2.48	96	-20	NAGpH	7.3	7.1	7.2	6.9	6.9			0
				NAG	-	-	-	-	-			
8047	6.12	48	139	NAGpH	3.4	2.8	2.5	3.1	3.9			115
				NAG	47	33	23	10	2			
8050	3.59	14	96	NAGpH	3.2	2.8	2.7	3.7	4.5			85
				NAG	42	23	17	3	-			
8056	4.28	95	36	NAGpH	7.6	7.1	7.2	6.9	3.6	3	3.6	57
				NAG	-	-	-	-	36	16	5	
8057	2.22	114	-46	NAGpH	7.8	7.4	7.6	7.3	6.9			0
				NAG	-	-	-	-	-			
8081	2.37	24	49	NAGpH	3.3	3.0	3.5	4.8	6.2			41
				NAG	23	14	4	-	-			
8085	3.21	99	-1	NAGpH	7.3	7.2	6.9	5.9	4.2	3.6	4.8	12
				NAG	-	-	-	-	9	3	-	
8087	1.69	47	5	NAGpH	6.9	4.2	3.7	4.0	4.3			19
				NAG	-	9	6	3	1			
8092	1.85	21	35	NAGpH	3.0	3.0	3.5	4.5	4.9			33
				NAG	20	9	4	-	-			
8111	18.2	27	530	NAGpH	2.7	2.6	2.5	2.7	2.9	2.9	3.2	420
				NAG	142	100	66	51	35	17	9	
8112	5.37	42	122	NAGpH	2.8	2.6	2.6	3.8	4.1			115
				NAG	52	41	17	3	2			
8113	19.05	127	456	NAGpH	3.4	2.8	2.3	2.7	2.8	2.6	2.9	414
				NAG	36	62	72	86	74	67	17	

Appendix D

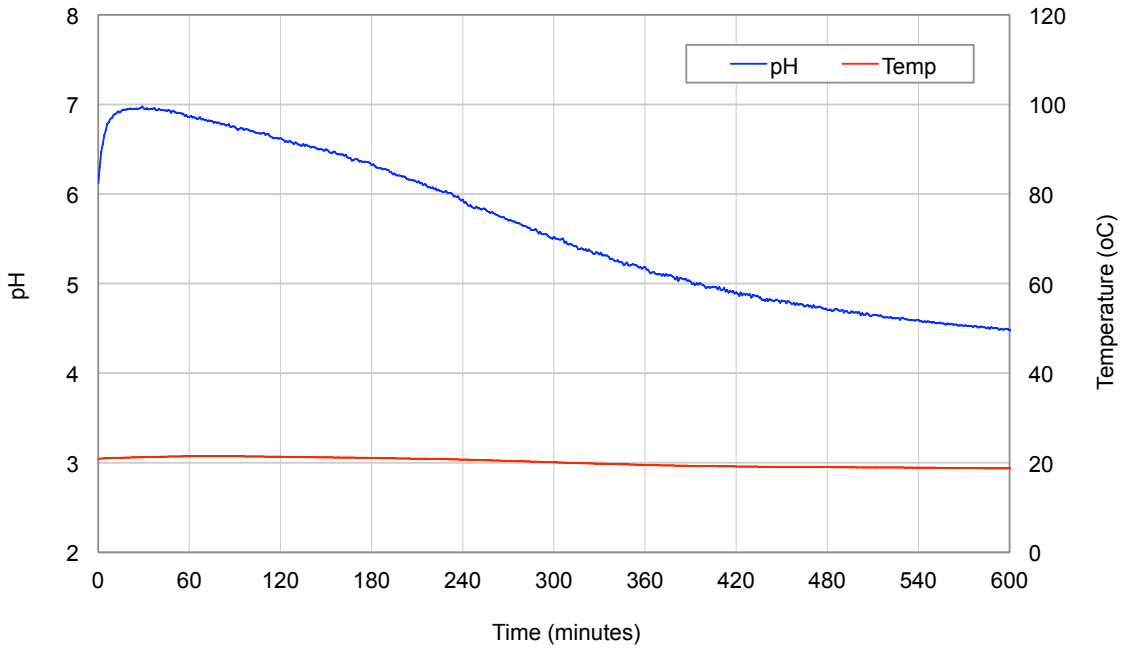
Kinetic NAG Test Profiles for Barbara Drill Core Samples



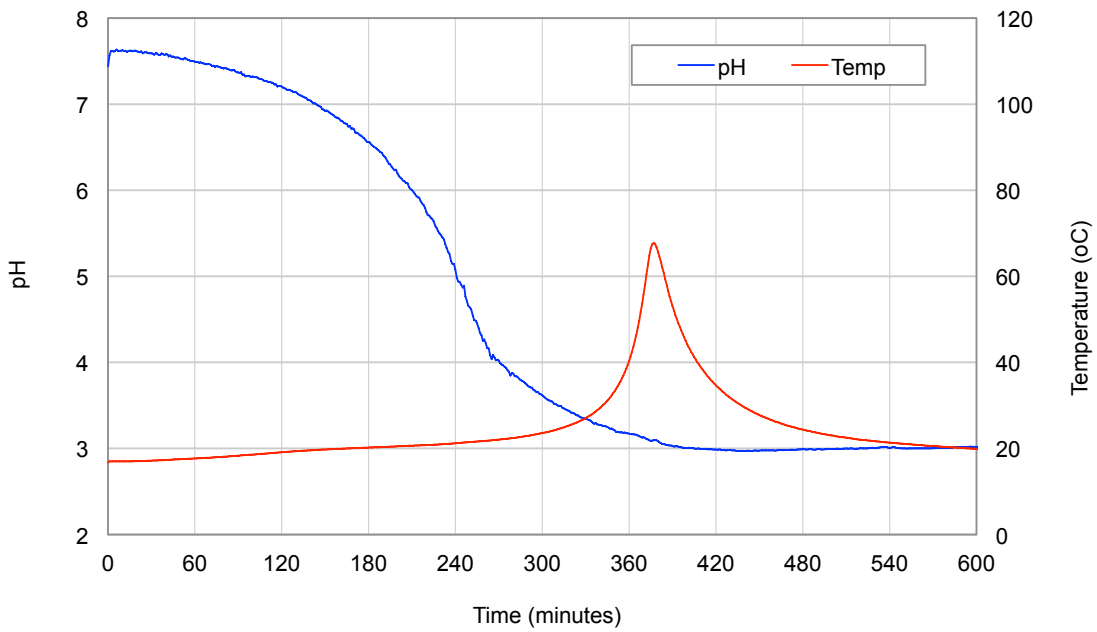
APPENDIX D-1: Kinetic NAG test profiles for Barabara drill core sample BADD035: 49-50m
[Ore #8050, VFRD, 3.59 %S, ANC = 14 kg H_2SO_4/t, NAPP = 96 kg H2SO4/t]



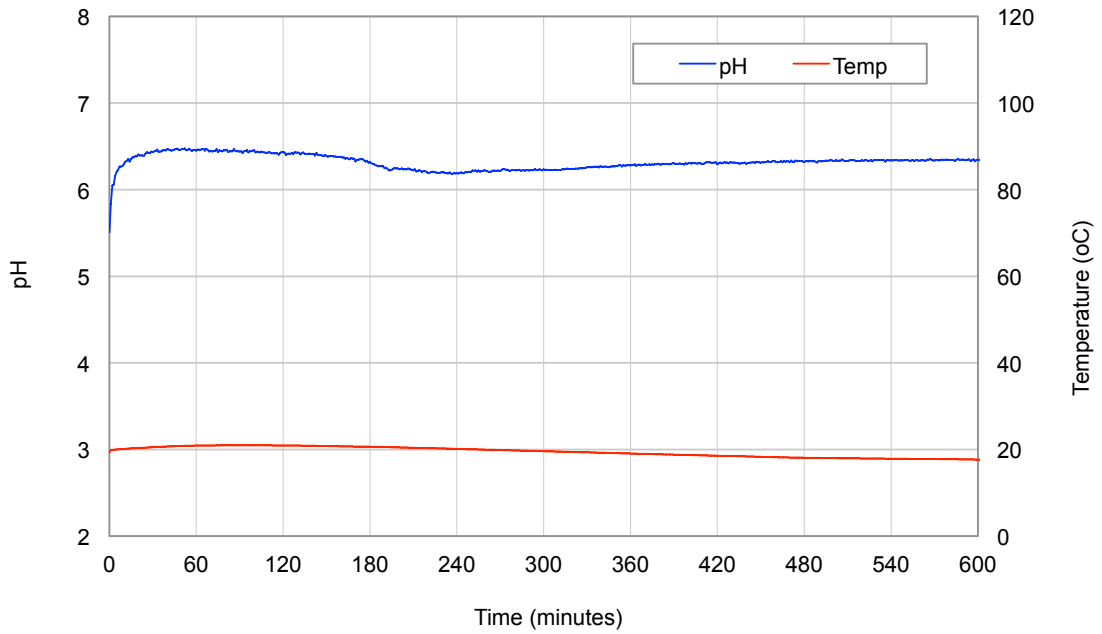
APPENDIX D-2: Kinetic NAG test profiles for Barbara drill core sample BADD021: 139-140m
[Ore #8112, XSB, 5.37 %S, ANC = 42 kg H_2SO_4/t, NAPP = 122 kg H2SO4/t]



APPENDIX D-3: Kinetic NAG test profiles for Barbara drill core sample badd045: 27-28m
[Waste #8066, XSB, 0.73 %S, ANC = 15 kg H_2SO_4/t, NAPP = 7 kg H2SO4/t]



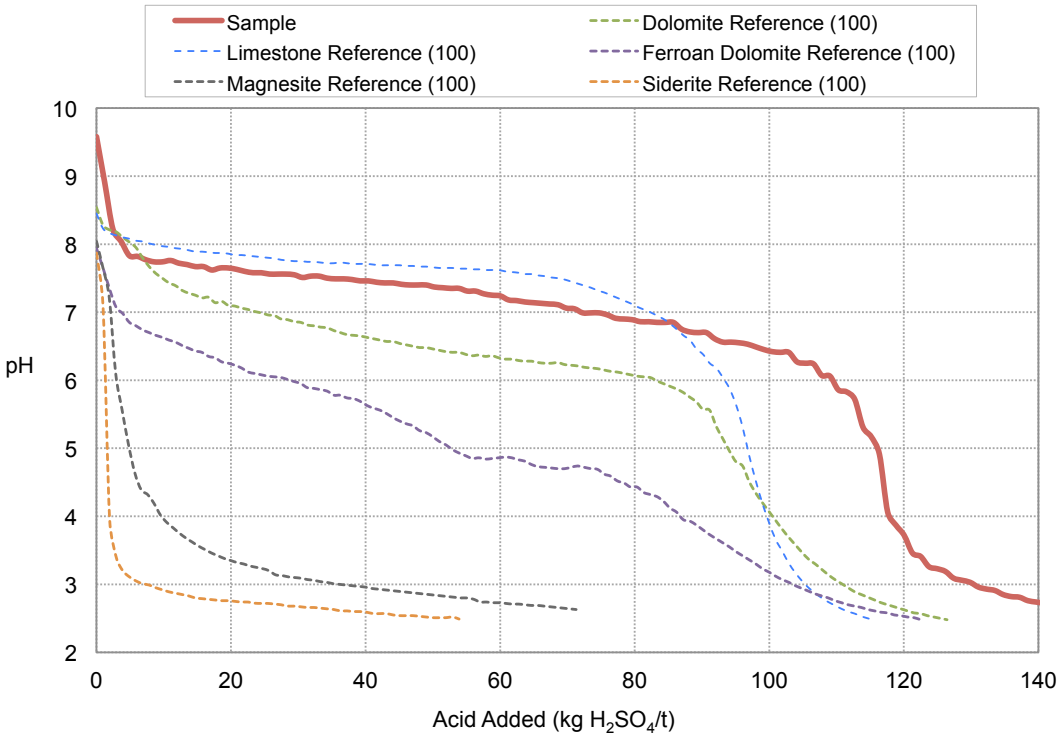
APPENDIX D-4: Kinetic NAG test profiles for Barbara drill core sample BADD050: 39-40m
[Waste #8092, VFRD, 1.85 %S, ANC = 21 kg H_2SO_4/t, NAPP = 35 kg H2SO4/t]



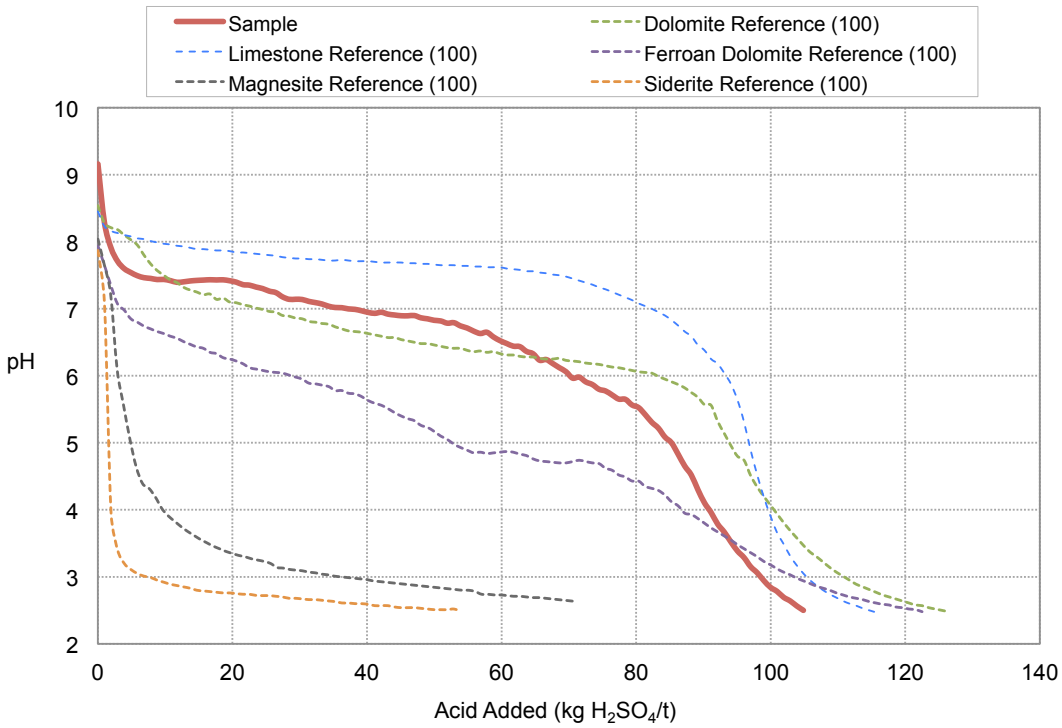
APPENDIX D-4: Kinetic NAG test profiles for Barbara drill core sample BADD046: 26-27m
[Waste #8072, VFRD, 1.47 %S, ANC = 34 kg H_2SO_4/t, NAPP = 11 kg H2SO4/t]

Appendix E

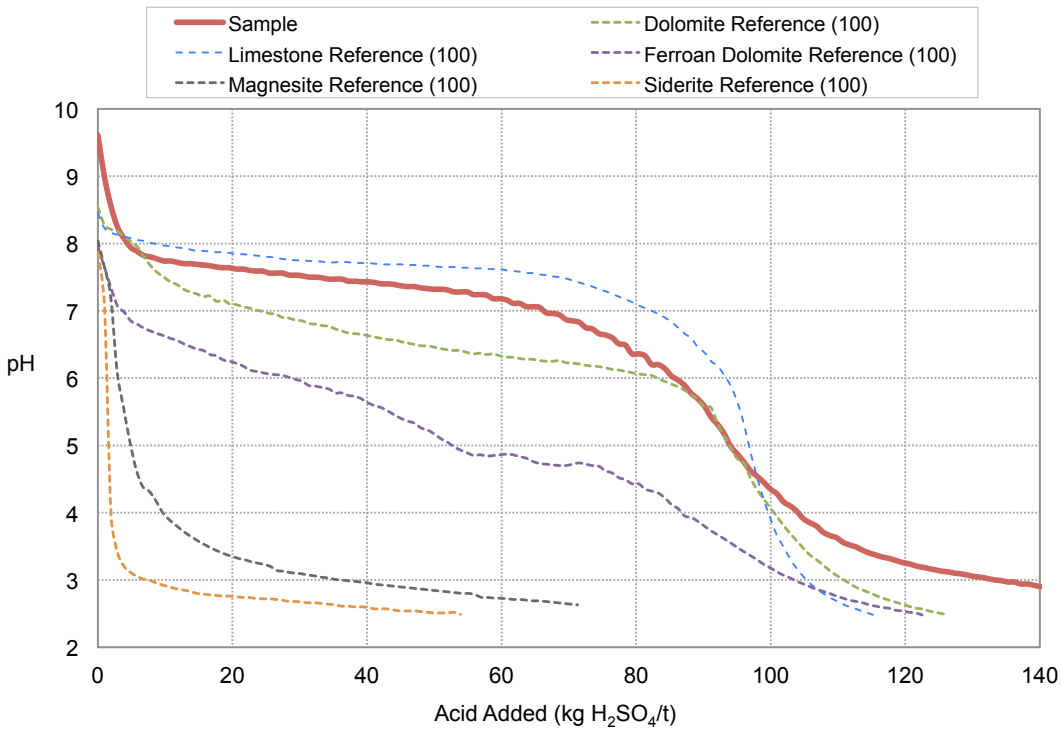
Acid Buffer Characteristic Curves for Barbara Drill Core Samples



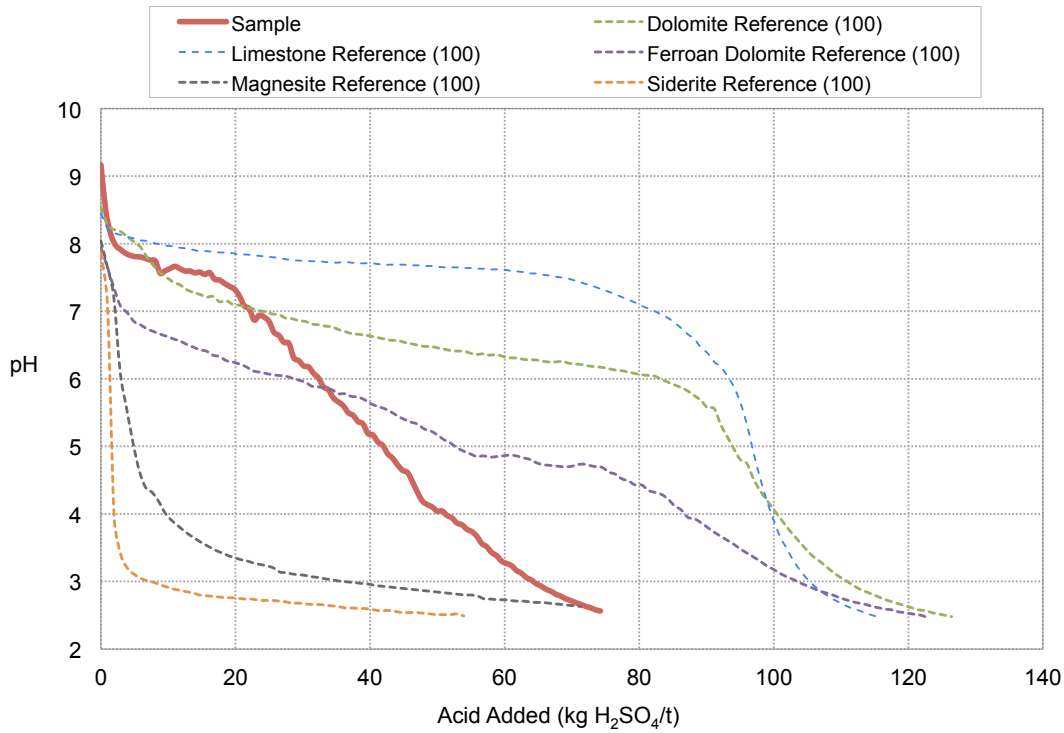
APPENDIX E-1: Acid buffer characteristic curve for Barbara drill core sample BADD034: 79-80m
[NAF Waste #8007, VFRD, ANC = 165 kg H_2SO_4/t]



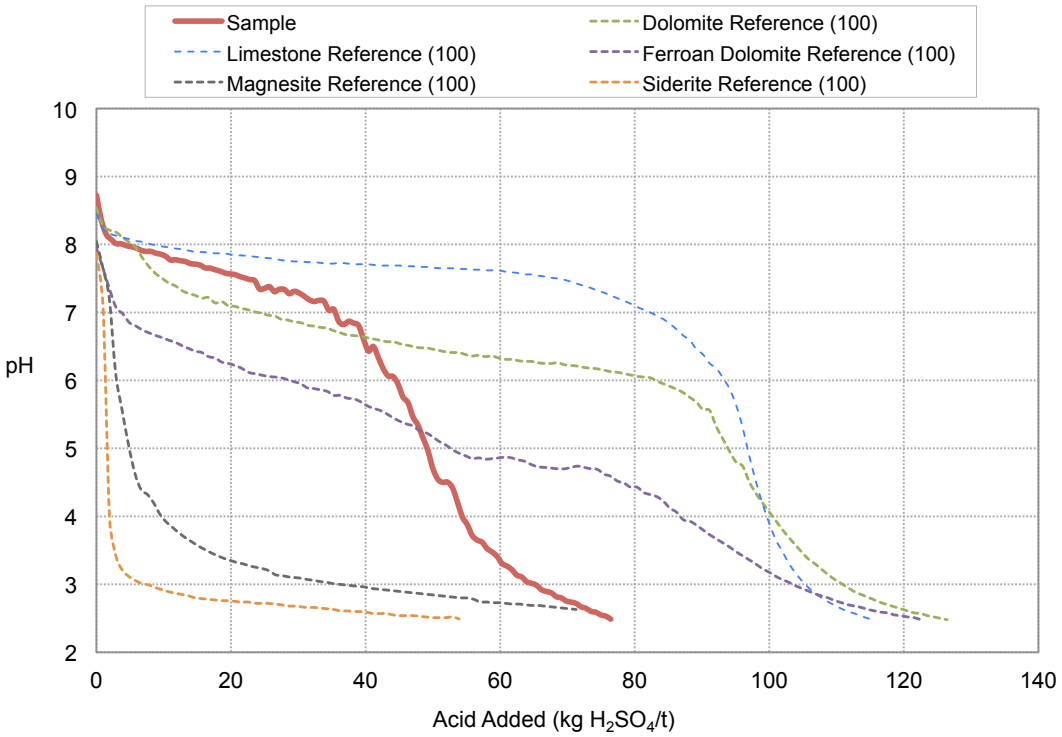
APPENDIX E-2: Acid buffer characteristic curve for Barbara drill core sample BADD038: 99-100m
[NAF Waste #8114, XSB, ANC = 135 kg H_2SO_4/t]



APPENDIX E-3: Acid buffer characteristic curve for Barbara drill core sample BADD043: 59-60m
[NAF Waste #8080, XSB, ANC = 134 kg H_2SO_4/t]



APPENDIX E-4: Acid buffer characteristic curve for Barbara drill core sample BADD042: 69-70m
[NAF Waste #8078, VFRD, ANC = 76 kg H_2SO_4/t]



APPENDIX E-4: Acid buffer characteristic curve for Barbara drill core sample BADD033: 64-65m
[PAF Ore #8056, VFRD, ANC = 95 kg H_2SO_4/t]

Appendix F

Elemental Compositions of Barbara Drill Core Samples

APPENDIX F: *Elemental compositions of Barbara drill core samples*

Element	Lithology	VFRD	IMD	VFR	VFRD	VFRD	XAO	VFRD	VFRD	VFRD	VFRD	XSB	VFRD	VFRD
	Type	waste	waste	waste	waste	waste	waste	waste	waste	waste	waste	waste	waste	waste
	Hole	BADD038	BADD042	BADD034	BADD021	BADD021	BADD023	BADD033	BADD034	BADD036	BADD035	BADD045	BADD046	BADD042
	Interval (m)	49-50	19-20	39-40	29-30	79-80	29-30	39-40	139-140	18-19	69-70	27-28	26-27	69-70
	EGi Code	7996	8001	8005	8017	8022	8028	8030	8031	8033	8052	8066	8072	8078
	ARD Class	NAF	NAF	NAF	UC	NAF	NAF	NAF	UC	NAF	NAF	PAF	PAF	NAF
Al	%	7.4	6.9	6.6	6.9	6.8	7.6	6.7	6.6	7.9	5.9	5.7	3.6	3.2
As	mg/kg	1	2	1	8	3	7	10	17	5	2	4	3.3	12.6
Ba	mg/kg	1110	880	660	410	970	200	1940	520	2100	860	520	270	180
Be	mg/kg	3	3	3	3	3	1	0.9	2	3	2	1.4	0.6	0.6
Bi	mg/kg	0.02	0.07	0.04	0.2	0.06	0.4	0.5	1.0	0.1	0.2	0.7	0.8	0.7
Ca	%	1.8	0.4	0.4	0.5	2.6	7.2	1.0	0.2	1.2	0.1	0.2	0.6	1.4
Cd	mg/kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.05	0.02	0.03	0.02
Co	mg/kg	4	8	2	14	5	47	36	25	6	18	37	62	50
Cr	mg/kg	107	92	183	85	83	226	104	123	96	9	6	10	5
Cu	mg/kg	7	48	7	9	17	78	1260	613	33	3150	2,770	3,860	2,300
Fe	%	2.4	2.1	1.4	2.0	2.4	9.4	2.6	2.4	2.6	4.7	6.7	8.0	6.7
Hg	mg/kg	0.005	0.006	0.005	0.005	0.005	0.005	0.006	0.005	0.005	0.006	0.009	0.006	0.006
K	%	3.8	2.5	2.4	1.4	3.2	1.4	4.0	1.7	2.5	3.8	2.5	2.4	2.0
Li	mg/kg	10	12	10	11	12	13	10	16	19	23	35	20	29
Mg	%	0.3	1.1	0.3	1.0	0.3	3.8	0.9	1.1	0.5	3.3	2.3	1.9	2.0
Mn	mg/kg	207	116	94	121	351	1320	221	86	366	181	252	322	400
Mo	mg/kg	3	2	8	3	2	0.6	9	1	0.7	5	2	2	1
Na	%	2.4	2.4	2.6	4.0	1.9	1.7	2.2	3.5	2.5	0.6	1.3	0.6	0.4
Ni	mg/kg	10	9	25	10	7	94	11	7	7	25	51	143	66
P	mg/kg	340	250	30	310	300	760	310	280	370	250	140	190	350
Pb	mg/kg	4	2	3	4	4	5	4	3	5	4	4	2	2
S	%	0.01	0.01	0.01	0.24	0.08	0.04	0.25	0.26	0.01	0.37	0.73	1.47	1.1
Sb	mg/kg	0.3	0.3	0.5	0.5	0.4	1.2	0.5	0.6	0.5	0.4	0.5	0.3	0.5
Se	mg/kg	1	1	1	1	1	2	1	1	1	1	2	4	3
Sn	mg/kg	2	3	4	2	2	2	1	2	2	2	2	1	1
Sr	mg/kg	124	77	63	114	96	193	76	55	166	12	19	9	9
Th	mg/kg	24	23	20	21	24	3	22	22	26	18	20	10	7
U	mg/kg	4	4	4	4	4	0.8	4	4	3	6	7	3	2
Zn	mg/kg	21	36	24	16	17	34	7	7	15	28	12	18	21

Underline signifies that the concentration was less than the indicated analytical detection limit

APPENDIX F: *Continued*

Element	Lithology	VFRD	VFRD	VFRD	VFRD	VFRD	XSO	VFRD	VFRD	XSB	XSO	IMD	VFRD	XSB
	Type	waste	waste	waste	waste	waste	ore	ore	ore	ore	ore	ore	ore	ore
	Hole	BADD023	BADD050	BADD050	BADD050	BADD050	BADD038	BADD035	BADD033	BADD036	BADD043	BADD023	BADD049	BADD021
	Interval (m)	76-77	29-30	39-40	49-50	53-54	121-122	49-50	64-65	43-44	64-65	50-51	21-22	139-140
	EGi Code	8089	8090	8092	8094	8095	8039	8050	8056	8062	8081	8085	8100	8112
	ARD Class	NAF	NAF	PAF	PAF	NAF	NAF	PAF	NAF	NAF	PAF	NAF	PAF	PAF
Al	%	6.8	5.4	5.7	6.5	6.7	2.0	2.6	4.6	5.1	5.0	4.3	5.2	3.3
As	mg/kg	10.8	2.9	2	2.5	1.5	12	10	2	1.8	1.5	3.5	9.1	114
Ba	mg/kg	1580	270	310	220	540	110	70	360	330	280	260	830	200
Be	mg/kg	2.9	0.8	0.8	1.2	0.3	0.3	0.3	0.4	0.4	0.9	0.6	1.3	0.2
Bi	mg/kg	0.3	0.4	0.9	0.5	0.4	6	3	7	0.9	1.1	3.1	0.5	3.0
Ca	%	0.2	0.8	0.6	0.6	0.7	3.3	0.4	2.6	2.4	0.8	1.8	0.6	1.8
Cd	mg/kg	0.02	0.02	0.02	0.02	0.02	0.16	0.11	0.23	0.02	0.08	0.04	0.04	0.03
Co	mg/kg	8	54	52	42	45	177	165	26	45	93	158	61	346
Cr	mg/kg	7	11	20	15	51	11	11	10	105	6	13	3	6
Cu	mg/kg	71	1,405	1,630	766	2,280	31,200	19,250	34,600	4,540	9,750	8,930	6,600	10,400
Fe	%	1.8	6.2	11.7	10.3	16.2	7.7	8.3	11.1	11.4	9.0	11.9	5.8	15.2
Hg	mg/kg	0.005	0.005	0.007	0.005	0.011	0.048	0.019	0.068	0.007	0.018	0.013	0.01	0.05
K	%	3.6	2.5	2.9	2.2	6.1	0.6	0.5	2.4	1.9	1.9	2.7	3.4	2.1
Li	mg/kg	9	24	23	14	39	5	8	17	47	20	36	13	20
Mg	%	0.5	2.7	2.0	1.2	3.7	1.1	2.2	1.7	4.1	1.8	3.6	0.9	1.9
Mn	mg/kg	96	299	346	233	561	415	483	508	859	284	571	238	357
Mo	mg/kg	0.6	3	2	2	0.8	5	4	5	2	2	5	1.0	5
Na	%	2.1	1.5	1.9	3.0	0.3	0.5	0.1	1.1	0.04	1.7	0.2	1.6	0.1
Ni	mg/kg	2	69	187	43	84	100	165	72	83	162	202	59	395
P	mg/kg	120	170	440	370	1060	2240	1050	1180	1140	370	1060	70	450
Pb	mg/kg	5	3	3	3	2	2	3	3	4	2	3	5	2
S	%	0.12	0.58	1.85	0.97	0.38	3.77	3.59	4.28	1.00	2.37	3.21	1.19	5.37
Sb	mg/kg	0.5	0.3	0.3	0.4	0.3	0.3	0.6	0.3	0.3	0.3	0.4	0.6	0.3
Se	mg/kg	1	2	5	2	2	11	11	12	3	6	8	3	14
Sn	mg/kg	3	2	2	3	4	2	1	3	0.8	2	2	2	2
Sr	mg/kg	62	41	47	65	15	31	4	45	5	44	20	39	20
Th	mg/kg	24	15	14	17	6	4	5	10	2	14	8	18	4
U	mg/kg	4	5	4	4	3	2	4	4	3	4	5	4	2
Zn	mg/kg	5	14	11	9	27	42	25	51	23	18	25	19	26

Underline signifies that the concentration was less than the indicated analytical detection limit

Appendix G

Geochemical Abundance Indices for Barbara Drill Core Samples

APPENDIX G: *Geochemical abundance indices for Barbara drill core samples*

Element	Median Soil Content	VFRD	IMD	VFR	VFRD	VFRD	XAO	VFRD	VFRD	VFRD	VFRD	XSB	VFRD	VFRD
		waste	waste	waste	waste	waste	waste	waste	waste	waste	waste	waste	waste	waste
		BADD038	BADD042	BADD034	BADD021	BADD021	BADD023	BADD033	BADD034	BADD036	BADD035	BADD045	BADD046	BADD042
		49-50	19-20	39-40	29-30	79-80	29-30	39-40	139-140	18-19	69-70	27-28	26-27	69-70
		7996	8001	8005	8017	8022	8028	8030	8031	8033	8052	8066	8072	8078
		NAF	NAF	NAF	UC	NAF	NAF	NAF	UC	NAF	NAF	PAF	PAF	NAF
Al	7.1 %	0	0	0	0	0	0	0	0	0	0	0	0	0
As	6 mg/kg	0	0	0	0	0	0	0	0	0	0	0	0	0
Ba	500 mg/kg	0	0	0	0	0	0	1	0	1	0	0	0	0
Be	6 mg/kg	0	0	0	0	0	0	0	0	0	0	0	0	0
Bi	0.2 mg/kg	0	0	0	0	0	0	0	1	0	0	1	1	1
Ca	1.5 %	0	0	0	0	0	1	0	0	0	0	0	0	0
Cd	0.4 mg/kg	0	0	0	0	0	0	0	0	0	0	0	0	0
Co	8 mg/kg	0	0	0	0	0	1	1	1	0	0	1	2	2
Cr	70 mg/kg	0	0	0	0	0	1	0	0	0	0	0	0	0
Cu	30 mg/kg	0	0	0	0	0	0	4	3	0	6	5	6	5
Fe	4 %	0	0	0	0	0	0	0	0	0	0	0	0	0
Hg	0.06 mg/kg	0	0	0	0	0	0	0	0	0	0	0	0	0
K	1.4 %	0	0	0	0	0	0	0	0	0	0	0	0	0
Li	25 mg/kg	0	0	0	0	0	0	0	0	0	0	0	0	0
Mg	0.5 %	0	0	0	0	0	2	0	0	0	2	1	1	1
Mn	1000 mg/kg	0	0	0	0	0	0	0	0	0	0	0	0	0
Mo	2 mg/kg	0	0	1	0	0	0	1	0	0	0	0	0	0
Na	0.5 %	1	1	1	2	1	1	1	2	1	0	0	0	0
Ni	50 mg/kg	0	0	0	0	0	0	0	0	0	0	0	0	0
P	800 mg/kg	0	0	0	0	0	0	0	0	0	0	0	0	0
Pb	35 mg/kg	0	0	0	0	0	0	0	0	0	0	0	0	0
S	0.03 %	0	0	0	2	0	0	2	2	0	3	4	5	4
Sb	5 mg/kg	0	0	0	0	0	0	0	0	0	0	0	0	0
Se	0.4 mg/kg	0	0	0	0	0	1	0	0	0	0	1	2	2
Sn	4 mg/kg	0	0	0	0	0	0	0	0	0	0	0	0	0
Sr	250 mg/kg	0	0	0	0	0	0	0	0	0	0	0	0	0
Th	9 mg/kg	0	0	0	0	0	0	0	0	0	0	0	0	0
U	2 mg/kg	0	0	0	0	0	0	0	0	0	0	1	0	0
Zn	90 mg/kg	0	0	0	0	0	0	0	0	0	0	0	0	0

Median soil data from:
Bowen, H.J.M. (1979) Environmental Chemistry of the Elements. Academic Press, London.
Berkman, D.A. (1976) Field Geologists' Manual, The Australian Institute of Mining and Metallurgy, Vic.

* Geochemical Abundance Indices (GAI)
GAI=0 represents <3 times median soil content
GAI=1 represents 3 to 6 times
GAI=2 represents 6 to 12 times
GAI=3 represents 12 to 24 times
GAI=4 represents 24 to 48 times
GAI=5 represents 48 to 96 times
GAI=6 represents more than 96 times

APPENDIX G: *Continued*

Element	VFRD	VFRD	VFRD	VFRD	VFRD	XSO	VFRD	VFRD	XSB	XSO	IMD	VFRD	XSB
	waste	waste	waste	waste	waste	ore	ore	ore	ore	ore	ore	ore	ore
	BADD023	BADD050	BADD050	BADD050	BADD050	BADD038	BADD035	BADD033	BADD036	BADD043	BADD023	BADD049	BADD021
	76-77	29-30	39-40	49-50	53-54	121-122	49-50	64-65	43-44	64-65	50-51	21-22	139-140
	8089	8090	8092	8094	8095	8039	8050	8056	8062	8081	8085	8100	8112
	NAF	NAF	PAF	PAF	NAF	NAF	PAF	NAF	NAF	PAF	NAF	PAF	PAF
Al	0	0	0	0	0	0	0	0	0	0	0	0	0
As	0	0	0	0	0	0	0	0	0	0	0	0	3
Ba	1	0	0	0	0	0	0	0	0	0	0	0	0
Be	0	0	0	0	0	0	0	0	0	0	0	0	0
Bi	0	0	1	0	0	4	3	4	1	1	3	0	3
Ca	0	0	0	0	0	0	0	0	0	0	0	0	0
Cd	0	0	0	0	0	0	0	0	0	0	0	0	0
Co	0	2	2	1	1	3	3	1	1	2	3	2	4
Cr	0	0	0	0	0	0	0	0	0	0	0	0	0
Cu	0	4	5	4	5	6	6	6	6	6	6	6	6
Fe	0	0	0	0	1	0	0	0	0	0	0	0	1
Hg	0	0	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	1	0	0	0	0	0	0	0	0
Li	0	0	0	0	0	0	0	0	0	0	0	0	0
Mg	0	1	1	0	2	0	1	1	2	1	2	0	1
Mn	0	0	0	0	0	0	0	0	0	0	0	0	0
Mo	0	0	0	0	0	0	0	0	0	0	0	0	0
Na	1	0	1	2	0	0	0	0	0	1	0	1	0
Ni	0	0	1	0	0	0	1	0	0	1	1	0	2
P	0	0	0	0	0	0	0	0	0	0	0	0	0
Pb	0	0	0	0	0	0	0	0	0	0	0	0	0
S	1	3	5	4	3	6	6	6	4	5	6	4	6
Sb	0	0	0	0	0	0	0	0	0	0	0	0	0
Se	0	1	3	1	1	4	4	4	2	3	3	2	4
Sn	0	0	0	0	0	0	0	0	0	0	0	0	0
Sr	0	0	0	0	0	0	0	0	0	0	0	0	0
Th	0	0	0	0	0	0	0	0	0	0	0	0	0
U	0	0	0	0	0	0	0	0	0	0	0	0	0
Zn	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix H

Water Extract Results for Barbara Drill Core Samples

APPENDIX H: *Water extract results for Barbara drill core samples*

Element	Lithology	VFRD	IMD	VFR	VFRD	VFRD	XAO	VFRD	VFRD	VFRD	VFRD	XSB	VFRD	VFRD
	Type	waste	waste	waste	waste	waste	waste	waste	waste	waste	waste	waste	waste	waste
	Hole	BADD038	BADD042	BADD034	BADD021	BADD021	BADD023	BADD033	BADD034	BADD036	BADD035	BADD045	BADD046	BADD042
	Interval (m)	49-50	19-20	39-40	29-30	79-80	29-30	39-40	139-140	18-19	69-70	27-28	26-27	69-70
	EGi Code	7996	8001	8005	8017	8022	8028	8030	8031	8033	8052	8066	8072	8078
	ARD Class	NAF	NAF	NAF	UC	NAF	NAF	NAF	UC	NAF	NAF	PAF	PAF	NAF
pH		9.2	9.1	8.8	8.9	9.0	9.5	9.2	9.3	9.2	9.9	8.9	8.6	9.0
EC	µS/cm	117	91	161	78	112	92	131	88	109	355	311	645	436
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.52	0.09	0.21	0.15	0.18	0.23	0.14	0.19	0.25	0.9	0.05	0.05	0.08
As	mg/l	0.002	0.002	0.002	0.005	0.002	0.002	0.006	0.006	0.005	0.004	0.001	0.001	0.001
B	mg/l	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.11	0.05	0.05	0.05
Ba	mg/l	0.2	0.2	0.3	0.3	0.4	0.4	0.44	0.2	0.3	0.1	0.27	0.20	0.51
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	5	3	5	3	7	4	6	2	4	1	3	15	10
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	5	4	11	4	5	4	14	6	4	16	24	41	37
Co	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001
Cu	mg/l	0.006	0.007	0.015	0.00	0.001	0.001	0.002	0.001	0.003	0.018	0.001	0.005	0.003
F	mg/l	0.4	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.8	1.2	1.1	1.8	1
Fe	mg/l	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.49	0.05	0.05	0.05
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	16	10	16	7	17	11	13	7	7	79	44	117	83
Mg	mg/l	1	1	1	1	1	1	2	1	2	1	2	9	5
Mn	mg/l	0.004	0.001	0.004	0.001	0.002	0.001	0.001	0.001	0.012	0.002	0.001	0.003	0.002
Mo	mg/l	0.014	0.021	0.012	0.001	0.002	0.001	0.011	0.002	0.005	0.041	0.065	0.025	0.004
Na	mg/l	8	11	14	10	8	6	10	11	11	11	23	17	16
Ni	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01
Si	mg/l	2	2	1	1	2	1	2	2.8	4	4	2	2	2
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	6	4	11	7	5	3	12	9	5	71	70	159	75
Sr	mg/l	0.011	0.006	0.009	0.007	0.013	0.008	0.020	0.006	0.021	0.003	0.008	0.022	0.014
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.013	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

* Underline indicates that element at or below analytical detection limit.

APPENDIX H: *Continued*

Element	Lithology	VFRD	VFRD	VFRD	VFRD	VFRD	XSO	VFRD	VFRD	XSB	XSO	IMD	VFRD	XSB
	Type	waste	waste	waste	waste	waste	ore	ore	ore	ore	ore	ore	ore	ore
	Hole	BADD023	BADD050	BADD050	BADD050	BADD050	BADD038	BADD035	BADD033	BADD036	BADD043	BADD023	BADD049	BADD021
	Interval (m)	76-77	29-30	39-40	49-50	53-54	121-122	49-50	64-65	43-44	64-65	50-51	21-22	139-140
	EGi Code	8089	8090	8092	8094	8095	8039	8050	8056	8062	8081	8085	8100	8112
	ARD Class	NAF	NAF	PAF	PAF	NAF	NAF	PAF	NAF	NAF	PAF	NAF	PAF	PAF
pH		9.6	9.5	9.1	9.8	9.9	8.1	8.2	8.4	8.7	8.3	8.6	9.2	8.9
EC	µS/cm	239	379	512	366	408	1808	1036	1463	481	851	929	485	852
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.32	0.18	0.16	0.54	1.4	0.01	0.01	0.05	0.06	0.04	0.07	0.13	0.29
As	mg/l	0.023	0.002	0.001	0.007	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
B	mg/l	0.1	0.08	0.05	0.06	0.05	0.07	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Ba	mg/l	0.18	0.31	0.48	0.02	0.1	0.1	0.1	0.12	0.42	0.15	0.17	0.5	0.3
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	2	3	12	2	2	311	48	184	29	60	29	15	19
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	34	12	23	17	16	43	14	38	40	28	81	32	100
Co	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.017	0.001	0.001	0.001	0.001	0.001	0.001
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.002	0.002	0.001	0.002	0.006	0.009	0.01	0.005	0.001	0.003	0.004	0.003	0.0
F	mg/l	0.6	1.2	2.4	1.6	2.7	0.9	0.3	1.6	0.7	1.4	1.7	1.6	3.5
Fe	mg/l	0.19	0.13	0.05	0.33	0.65	0.05	0.05	0.05	0.05	0.05	0.05	0.13	0
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	33	80	102	63	105	91	65	137	57	108	161	74	168
Mg	mg/l	1	1	3	1	1	32	79	19	11	16	25	2	7
Mn	mg/l	0.001	0.001	0.001	0.001	0.002	0.20	0.494	0.086	0.006	0.024	0.007	0.002	0.004
Mo	mg/l	0.003	0.01	0.002	0.004	0.002	0.004	0.007	0.004	0.004	0.004	0.009	0.002	0.004
Na	mg/l	25	21	21	29	7	20	8	17	6	32	12	20	18
Ni	mg/l	0.001	0.001	0.001	0.001	0.001	0.002	0.053	0.001	0.001	0.003	0.001	0.001	0.001
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	10	4	2	11	8	1.5	2	1	1	1	1	2	1
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	13	70	154	55	53	952	428	727	110	369	287	123	253
Sr	mg/l	0.008	0.006	0.012	0.003	0.003	0.154	0.043	0.103	0.034	0.049	0.032	0.030	0.022
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.02	0.033	0.007	0.005	0.01	0.006	0.005	0.005

* Underline indicates that element at or below analytical detection limit.

Appendix I

Peroxide Extract Results for Barbara Drill Core Samples

APPENDIX I: *Peroxide extract results for Barbara drill core samples*

Element	Lithology	VFRD	VFRD	XSB	VFRD	VFRD	VFRD	XSO	VFRD	VFRD	XSO	VFRD	XSB
	Type	waste	waste	waste	waste **	waste	waste	ore	ore	ore	ore	ore	ore
	Hole	BADD021	BADD034	BADD045	BADD046	BADD050	BADD050	BADD038	BADD035	BADD033	BADD043	BADD049	BADD021
	From (m)	29-30	139-140	27-28	26-27	39-40	49-50	121-122	49-50	64-65	64-65	21-22	139-140
	EGi Code	8017	8031	8066	8072	8092	8094	8039	8050	8056	8081	8100	8112
	ARD Class	PAF	UC	PAF	PAF	PAF	PAF	PAF*	PAF	PAF*	PAF	PAF	PAF
NAGpH		3.4	3.8	4.6	4.6	3.0	3.6	7.7*	3.2	7.8*	3.5	4.3	2.9
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	5	3	0.04	2	13	12	0.02	11	0.03	10	1	15
As	mg/l	0.006	0.003	0.001	0.002	0.006	0.005	0.001	0.002	0.001	0.003	0.002	0.005
B	mg/l	0.2	0.1	0.08	0.1	0.1	0.1	0.08	0.1	0.06	0.1	0.1	0.1
Ba	mg/l	0.2	0.2	0.2	0.06	0.06	0.2	0.06	0.05	0.06	0.08	0.07	0.05
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	6	3	16	51	39	16	131	14	111	48	68	117
Cd	mg/l	0.0009	0.0009	0.0009	0.001	0.0008	0.0008	0.0001	0.0019	0.0001	0.0017	0.0011	0.0011
Cl	mg/l	4	1	1	2	1	1	2	2	4	1	2	2
Co	mg/l	0.2	0.1	0.1	0.3	0.3	0.3	0.01	1.1	0.02	0.6	0.3	1.9
Cr	mg/l	0.02	0.011	0.001	0.001	0.003	0.003	0.001	0.002	0.001	0.002	0.001	0.003
Cu	mg/l	0	7	20	33	19	9	0.1	158	3	92	53	96
F	mg/l	0.6	0.2	0.3	0.5	1	1	0.2	0.2	0.7	0.4	0.7	0.8
Fe	mg/l	1	0.1	0.05	0.05	40	14	0.05	52	0.05	28	0.05	127
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	14	14	26	36	39	35	37	27	34	44	48	65
Mg	mg/l	3	5	10	34	9	8	3	21	1	16	4	14
Mn	mg/l	0.1	0.1	0.4	1.1	1.0	0.5	0.1	3	0.1	1.2	0.6	2
Mo	mg/l	0.008	0.005	0.005	0.001	0.001	0.001	0.02	0.001	0.02	0.001	0.001	0.001
Na	mg/l	5	4	2	3	4	5	3	3	3	3	5	2
Ni	mg/l	0.02	0.02	0.2	1.0	1.4	0.4	0.002	1.0	0.02	1.0	0.3	2.5
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.006	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.002
Sb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.04	0.04	0.02	0.02	0.05	0.03	0.04	0.04	0.08
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	90	84	133	366	404	236	367	654	316	526	315	968
Sr	mg/l	0.03	0.01	0.02	0.01	0.03	0.03	0.05	0.01	0.03	0.03	0.03	0.04
Th	mg/l	0.001	0.001	0.001	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.005
U	mg/l	0.001	0.003	0.001	0.01	0.01	0.006	0.001	0.014	0.001	0.008	0.002	0.01
Zn	mg/l	0.4	0.1	0.2	0.3	0.3	0.09	0.03	0.4	0.05	0.2	0.3	0.3

Underline indicates that element at or below analytical detection limit.

* Samples 8039 and 8056 were classified as PAF based on NAPP and Sequential NAG testing but they did not acidify in the single stage peroxide leach.

URS

Report

Barbara Copper Project

AUSTRALIA

Waste Rock Management Plan

3 October 2014
42627360/001/2

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TABLE OF CONTENTS

1 INTRODUCTION 1
1.1 Objectives 1
2 SITE DESCRIPTION 2
2.1 Physical Setting 2
2.2 Climate 2
2.3 Geology 2
3 WASTE ROCK CHARACTERISATION 3
3.1 Waste Rock Geochemistry 4
3.2 Ore Geochemistry 4
3.3 Geotechnical Properties 5
3.4 Waste Rock Quantities 5
3.5 Waste Rock Geochemical Model 6
4 WASTE ROCK MANAGEMENT 7
4.1 Waste Rock Classification 7
4.2 Waste Rock Mining and Segregation 7
4.3 Waste Rock Monitoring and Reporting 8
4.3.1 Field-Based Testing 8
4.3.2 Laboratory-Based Testing 8
4.3.3 Visual Inspections 9
4.3.4 Reporting 9
5 WASTE ROCK DUMP DESIGN 10
5.1 Waste Storage 10
5.2 Waste Rock Dump Dam 11
5.3 Surface Water Management 11
5.4 Waste Rock Placement 11
5.5 Construction Considerations 12
6 DECOMMISSIONING AND CLOSURE 13
7 REFERENCES 14
8 LIMITATIONS 15

TABLES

Table 3-1 Waste rock types analysed for 3
Table 3-2 Estimated waste rock volumes 5
Table 4-1 Barbara Copper Project Waste Rock Classification System 7

FIGURES

Figure 3-1 Waste rock mining schedule during the life of the mining operation 6

APPENDICES

Appendix A Cross-Sections through the Barbara Deposit Showing Distribution of Waste Rock and Ore

Appendix B Conceptual Waste Rock Dump Design

Appendix C Field pH Peroxide Test (pH_{FOX})

1 INTRODUCTION

The purpose of the Waste Rock Management Plan (WRMP) is to provide a framework for management of waste rock for the proposed Barbara Copper Project. The WRMP specifies how environmental issues related to identifying, handling and containment of waste rock will be managed during the mine life cycle. The WRMP also outlines the performance objectives and how these will be measured, monitored and reported.

This WRMP is based on the results of initial geochemical testing and classification of waste rock, and provides further details to general commitments made in the Plan of Operations related to waste rock management for inclusion in an environmental authority application.

The WRMP may be revised as required during operations as additional information becomes available such as those obtained through the monitoring procedures identified in this plan.

1.1 Objectives

The objective of the WRMP is to ensure environmentally safe and effective management of waste rock generated during mining operations. To achieve this objective, the WRMP details a practical basis whereby management measures can be part of the mine planning that includes:

- Waste rock characterisation
- Waste rock management
- Waste rock dump conceptual design
- Monitoring and reporting
- Decommissioning and closure.

2 SITE DESCRIPTION

2.1 Physical Setting

The Barbara Copper Project is located in the Shire of Mount Isa in northwest Queensland, approximately 60 kilometres (km) northeast of the town of Mount Isa. The region is characterised by thin rocky soil cover overlying bedrock. Rugged bedrock outcroppings are common. Vegetation is primarily spinifex with some shrubs and few trees.

The Barbara Copper Project straddles EPM19733 and EPM16112. The Barbara Copper Project will involve open pit development of the Barbara copper deposit, which also contains trace concentrations of gold, silver and cobalt. Mining will occur on two adjoining open pits (Barbara North Pit and Barbara South Pit) located along the North-South trending strike of the deposit, which extends over a distance of approximately 900 m. The two pits will be mined concurrently over a period of approximately 18 months.

Groundwater levels measured in 2014 within the BCP site ranged from 8.26m to 25.96m below ground surface (RLA, 2014). The nearest reading to the WRD was 25.96m bgs. No shallow aquifers were identified.

2.2 Climate

The regional climate in northwest Queensland is classed as hot semi-arid. Based on climate data collected at Mount Isa airport (Bureau of Meteorology 2014) from 1966 to 2014, the mean maximum and minimum temperature are 31.8 degrees Celcius (°C) and 17.2 °C, respectively. The mean annual rainfall is 459.3 millimetres (mm), with most rain falling between December and March. Throughout the year evaporation exceeds rainfall.

2.3 Geology

The Barbara deposit lies within the Mount Isa Inlier. The copper-gold-silver-cobalt mineralisation is structurally controlled by the Barbara Shear Zone and occurs as a series of sulfide lodes hosted within a package of felsic volcanic rocks intruded by dolerite dykes. Sulfide mineralisation comprises semi-massive pyrrhotite/pyrite with chalcopyrite and chalcopyrite stringer veins. Two phases of mineralisation occur with a low grade copper-cobalt phase overprinted with a later coarse grained, chalcopyrite-gold-silver phase which forms both hangingwall and footwall zones of higher grade mineralisation.

The majority of waste will be low sulfur rock, primarily high calcium/magnesium basalts and mafics, low calcium/magnesium felsic volcanics, and pedogenic carbonates. However, some sulfide rich waste zones occur immediately adjacent to the ore zone, primarily on the footwall, which may be mined as fresh waste or left in the end walls of the pit. This sulfide rich material can generate acid and metalliferous drainage (AMD) if exposed to atmospheric conditions.

3 WASTE ROCK CHARACTERISATION

A waste rock geochemical assessment has been completed (EGi 2014) that defines the geochemistry of waste rock materials associated with the proposed Barbara Copper Project. The assessment involved the analysis of 121 drill core samples from 14 diamond drill holes, representing the range of waste rock lithologies that will be intersected during open pit mining operations.

Each sample typically represented a 1 m interval of core, and a semi-regular sampling pattern was used to provide judicious spatial coverage of the North Pit and South Pit mining areas. The waste rock sample types analysed are shown in Table 3-1. Most of the samples had low copper concentrations and were representative of material that will likely be mined as waste. Based on the current mine plan and a copper cut-off of 0.3 % copper (Cu), thirty-one samples were classed as ore and 90 samples were classed as waste rock.

The waste rock assessment program focussed on predicting the:

- Acid generation due to the exposure of sulfide minerals in the waste rock to atmospheric oxygen and water, which can form sulfuric acid (H_2SO_4) and lead to acid drainage.
- Potential for waste rock to leach of metals (metalliferous drainage) and salts (saline drainage).

Table 3-1 Waste rock types analysed for

Lithology	Number of Samples
Porphyritic Rhyolite (VFRD)	87
Dolerite (IMD)	4
Rhyolite (VFR)	3
Mafic intrusive (IMO)	2
Biotite Schist (XSB)	15
Basalt (VMB)	2
Biotite Chloritic Schist (XSBH)	1
Psammite (XMO)	2
Schist (XSO)	4
Gossan (RZO)	1

The static geochemical testing of waste rock samples included:

- pH and electrical conductivity (EC) measurements based on a 1:2 solid to deionised water extraction
- Acid-base accounting to determine the net acid producing potential (NAPP) based on total sulfur concentrations, maximum potential acidity (MPA) and acid neutralising capacity (ANC) measurements.
- Total metal analysis of the bulk waste rock sample, and multi-element analysis of leachates generated by the 1:2 solid to deionised water extraction.
- Single stage net acid generation (NAG), and kinetic NAG measurements.

3.1 Waste Rock Geochemistry

The key findings of the EGi (2014) waste rock geochemical assessment include the following:

- Majority of waste rock will have a low sulfur content and will be non-acid forming (NAF). Eighty-seven per cent of waste rock samples were NAF and 13% PAF based on a total sulfur cut-off of 0.3%.
- Waste from the near-surface weathered zone will likely have little ANC and hence will essentially be barren with respect to both acid generation potential and acid neutralisation potential.
- Most other NAF waste rock should have moderate ANC that will be at least several times greater than any acid that might be produced from any contained sulphides.
- Drainage from NAF waste rock is expected to be neutral to slightly alkaline and have low concentrations of soluble salts and environmentally important metals and metalloids.
- Approximately 20% of NAF waste samples have ANC that exceed 50 kg H_2SO_4/t. Such material would be ideally suited to ARD mitigation measures if required, such as blending with, or encapsulation of, PAF waste.
- Some PAF waste samples with elevated sulfur contents (i.e. 0.71 to 4.27 % sulfur (%S)) were identified, with most of the PAF waste samples located in the northern mining zone and it is expected that most PAF waste will be localised and close to the ore zones and not widely distributed throughout the entire mining area.
- Sulfide mineralisation in PAF waste is reactive (based on kinetic NAG tests) and will oxidise if the material is exposed to atmospheric conditions. However, a lag period of at least a year, and possibly several years can be expected for typical PAF waste with an ANC of more than 20 kg H_2SO_4/t.
- During this lag period it is expected that any drainage resulting from exposure to atmospheric conditions during this lag period would remain circum-neutral, but likely to contain elevated concentrations of sulphate and calcium and copper.
- Significant increases in the concentrations of dissolved metals (Cu, iron (Fe), aluminium (Al), cobalt (Co), managanese (Mn), nickel (Ni) and Zinc (Zn)) within drainage is likely in the event of long term exposure of PAF waste leading to development of acid conditions.

3.2 Ore Geochemistry

The key findings of the EGi (2014) waste rock geochemical assessment include the following:

- Most of the ore samples tested in this study had high to very high sulphide contents, but only approximately 56% were classified as PAF. The remaining 44% were classified as NAF.
- Median ANC for the NAF ore samples close to 100 kg H2SO4/t, which equates to approximately 10 %CaCO3 equivalent.
- Median ANC for PAF ore was approximately 50 kg H_2SO_4/t. An ANC of this magnitude would be expected to significantly delay formation of acid conditions.
- Based on the results of this study a lag of at least a year would be expected for ROM ore. Given that ore will be trucked off-site for processing, it is expected that the residence

times for ore stockpiles on site would be shorter than the expected average lag period for ROM ore.

- Drainage from stockpiles of recently mined ROM ore is expected to be alkaline and have low concentrations of dissolved metals, but there could be some leaching of sulfate from high grade ores.
- Significant risk of generation of low pH, high sulfate drainage with high concentrations of environmentally important elements is expected in the event that high sulfide ore is exposed long term.

3.3 Geotechnical Properties

The NAF rock is primarily comprised of fresh, felsic to mafic volcanic rock. Although the waste rock has not been subjected to geotechnical testing, it is conservatively assumed the mined waste rock will be able to maintain an angle of repose of 37 degrees (°) on the working face of the waste rock dump.

3.4 Waste Rock Quantities

The estimated total amount of waste rock expected to be mined from the Barbara Copper Project is summarised in Table 3-2. The estimated mineral waste volumes were calculated based on the current final pit shell designs (19 September 2014) and the available mining block models.

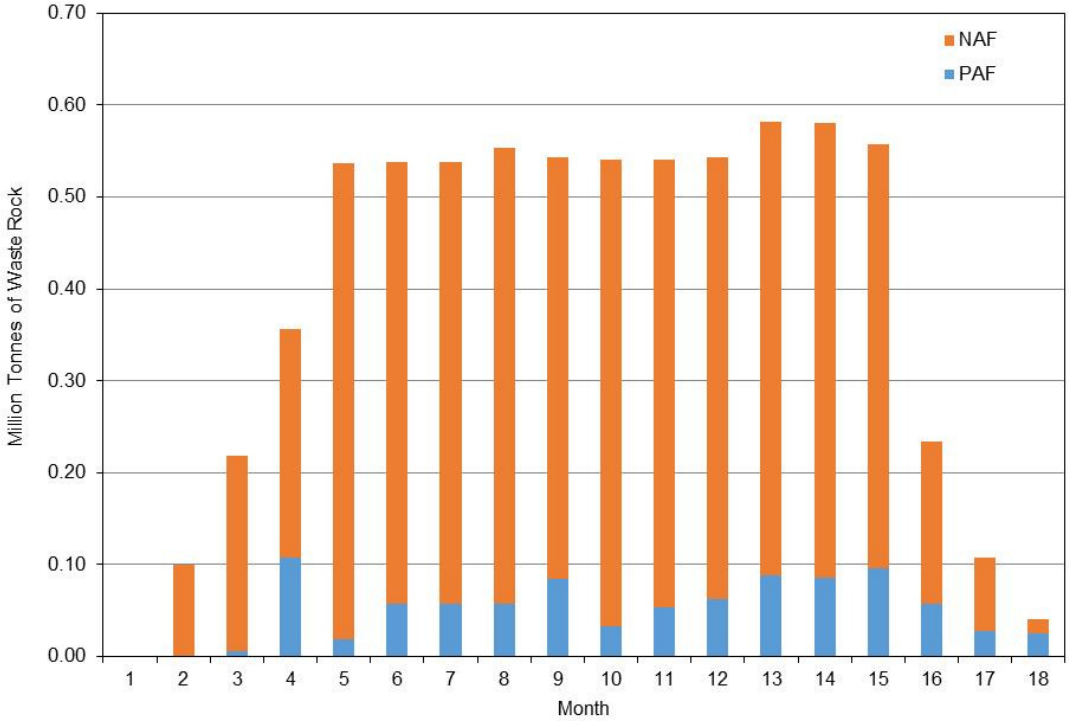
The total amount of waste rock generated by the Barbara Copper Project is estimated at 8 million tonnes (Mt), with approximately 13% expected to be PAF based on total sulfur cut-off of 0.3%.

Table 3-2 Estimated waste rock volumes

Total Waste Rock (million tonnes)	Waste Rock Volume (million cubic metres)	Waste Type	Total Amount (Mt)	Total Volume (million cubic metres)
8	3.0 (in-situ) 3.9 (loose)	PAF	1.0	0.39 (in-situ) 0.51 (loose)
		NAF	7.0	2.64 (in-situ) 3.43 (in-situ)

The management of AMD will involve development of the mining waste schedule for life of the mining operation. The mining waste schedule identifies the volume and timing of extraction of NAF and PAF waste rock, and will be used to design the waste rock dump to limit its exposure to oxidation of PAF material during and post mining. Figure 3-1 shows the waste rock mining schedule during the life of the operation.

Figure 3-1 Waste rock mining schedule during the life of the mining operation



3.5 Waste Rock Geochemical Model

A waste rock block model has been developed to provide a basis for the initial mine planning for the proposed Barabra Copper Project. The waste rock block model was based on data compiled from 150 drill holes that form the resource definition database comprising 3906 total sulfur assays using a sulfur cut-off at <0.3%S.

Cross-sections through the Barbara ore deposit showing the distribution of the NAF and PAF waste and ore units are provided in Appendix A.

4 WASTE ROCK MANAGEMENT

Waste rock which will be placed in an out-of-pit waste rock dump located approximately 500m from the South Pit. NAF waste rock materials, with suitable geotechnical properties, will be used for construction of the ROM pad, access and haul roads, process areas and office areas. The remainder of the NAF will be used to encapsulate PAF waste in the waste rock dump.

There may be an opportunity to move some potentially acid generating waste rock into the Barbara North Pit; however, the feasibility of this management strategy is yet to be determined.

4.1 Waste Rock Classification

The proposed Barbara Copper Project waste rock classification system consists of two waste rock material types that are defined by the total sulfur concentrations (Table 4-1).

Table 4-1 Barbara Copper Project Waste Rock Classification System

Total Sulfur Concentration	Waste Description	Estimated Delay to Onset of AMD
≥ 0.3%	PAF	Approximately 1 year, and possibly several years
< 0.3%	NAF	-

4.2 Waste Rock Mining and Segregation

Based on the outcomes of the EGi (2014) geochemical assessment program, the recommended management of PAF waste rock for the Barbara Copper Project is mainly based on segregation and selective placement of PAF waste rock within the waste rock dump in a manner that limits its exposure to conditions (i.e. atmospheric oxygen and water) that are conducive to AMD generation and leaching processes.

The key to the success of this WRMP is to identify the various waste rock material types in the field and at the active mining face. This approach will require a material identification system, including:

- Survey control on a daily basis (or as required) based on material movement records.
- Maintaining an up to date waste rock block model.
- Mapping of pit walls and mined faces according to the lithological domains used on-site.
- Blasthole sampling and logging to assist in this waste characterisation.
- Visual inspections, sampling and field-based testing to differentiate NAF and PAF material.
- Confirmatory laboratory-based analysis of selected samples to support field-based testing.

Blast hole cuttings would be collected during blasting operations for analysis at the onsite laboratory or similar facility. A sample density of 1 in 10 blast holes is considered adequate to perform the required waste rock segregation, recognising that the number of blast hole samples collected would depend on the geologic conditions within the blast area and the blast hole pattern.

The blast hole samples would be subjected to field-based testing, with selected samples submitted for laboratory-based testing for NAPP and NAG testing (see Section 4.3). Based on the results, the material will be classified as one of the two waste rock material types (i.e NAF or PAF). The sampling and testing will be completed on the same schedule as ore determination (if practically possible) in order to be effectively included in the mine planning process.

Records of the type of waste rock material loaded into the haul trucks, the volume of each waste rock type mined during each shift, movement and its final destination will be kept. This methodology will provide control such that waste rock types are mined and delivered to the correct location within the waste rock dump.

All of the above information will be used to assist in updating the waste rock mining schedule and quantities, and the waste rock block model.

4.3 Waste Rock Monitoring and Reporting

The waste rock management strategy involving selectively handling and placement of NAF and PAF waste rock will not be solely dependent on a laboratory-based analysis as this is subject to significant delays, leading to the potential to misplace PAF waste rock within the waste rock dump. To this end, field-based testing of waste rock material during mining operations is critical to the success of the WRMP.

4.3.1 Field-Based Testing

The main field indicator for the selective handling of PAF waste rock is related to the ability of sulfide minerals within the waste rock to generate acid, thus the field test method is designed to predict the potential to generate acidity. This method is based on field procedures originally developed for acid sulfate soils in Queensland (Ahern *et al* 1998). The field-based methodology is provided in Appendix C.

It should be noted that the analysis of waste rock samples using the field based testing method will need to be calibrated against laboratory results prior to operational implementation.

4.3.2 Laboratory-Based Testing

Selected waste rock samples will be analysed at a National Association of Testing Authorities Australia registered laboratory for the following:

- NAPP (including total sulfur, MPA and ANC)
- Single stage NAG measurements

The results will be used as a quality control process to confirm and support field-based testing.

4.3.3 Visual Inspections

Suitably qualified mine geologists will carry out weekly visual inspections on each area of the waste rock dump to evaluate the performance and condition of the facility. The toes of the waste rock dump would be checked for seepage, and if seepage is observed, the specific location and flow rate will be recorded, and a sample would be collected for water quality analysis in accordance with the Environmental Monitoring Plan for the Barbara Copper Project. These inspections will also occur as soon as practicable (e.g. when conditions are safe) after significant rainfall events.

4.3.4 Reporting

The results of the visual inspections and all field-based and laboratory-based analysis will be recorded and documented in a suitable storage system developed for the Barbara Copper Project.

5 WASTE ROCK DUMP DESIGN

The waste rock dump is designed to be a permanent storage for waste rock mined from the Barbara Copper Project. The waste dump design is based on the mining waste schedule and involves selective mining and placement of waste rock to form a waste rock dump that encapsulates the PAF material with NAF waste. The key objective of the waste rock dump design is to ensure that the final landform is safe, stable and non-polluting.

The waste rock dump design features the following items:

- NAF base
- PAF cell
- Crowned covers
- Benched batters
- Surface drainage measures
- Containment of sediment and affected waters in a dam located at the downstream toe of the waste rock dump

The conceptual design of the waste rock dump, prepared by URS, is shown in drawings 42627360-001 and 42627360-002 provided in Appendix B. The conceptual design is based on the 3-D computer-aided design (CAD) of the waste rock dump prepared by AMC Consultants Pty Ltd. Detailed design of the WRD will be required prior to commencement of WRD construction.

5.1 Waste Storage

The waste rock dump is conceptually designed as a low-profile structure to encapsulate PAF in NAF. Based on a 30% swell factor, the waste rock dump is designed to contain 3.00 million lcm of NAF plus 0.36 million lcm of PAF, for a total of 3.36 million lcm. NAF used for construction materials outside the waste rock dump amount to 0.31 million lcm, which is separate from the 3.00 million lcm reporting to the waste rock dump. The waste rock dump is approximately 28m high (measured from the crest to lowest toe) and covers a footprint of 22.95 Ha.

Prior to placement of any PAF materials, the NAF base will be constructed to provide a platform upon which the PAF will be placed. The concept design considered the phasing of NAF and PAF generation from the mine, which indicates there will be sufficient NAF mined to build the NAF base prior to PAF being mined. The purpose of the NAF base is to elevate the PAF to limit exposure to waters that may enter the waste rock dump and percolate along the original ground surface. This is a reasonable measure as the NAF will not be capped to limit infiltration. The minimum required thickness of NAF base beneath the PAF cell is 5 m.

The entire waste rock dump footprint, including the NAF base, must be cleared of vegetation and stripped of topsoil for later use during rehabilitation. Topsoil will require careful stockpile management to limit damage to the topsoil and to protect against erosion. Foundation preparation is generally not required due to the thin soil cover and hard bedrock foundation.

Placement of PAF onto the NAF base may begin once the WRD Dam is commissioned. Surface waters that pass over or through the PAF must be managed to prevent discharge to the creeks, hence the inclusion of the WRD in the defence measures.

The external batters will be at the angle of repose. Each 10 m high lift will be stepped inward by 10m to create and overall batter of approximately 2.4H:1V.

5.2 Waste Rock Dump Dam

A dam positioned downstream of the waste rock dump footprint is specified for containment of surface runoff and sediment. The nominal capacity required is 40 ML, which is approximately 20% of the design storage allowance (DSA) storage requirement. The remainder of the DSA storage requirement will be available in other storages, including the mine pit. The nominal location of the waste rock dump dam is shown in Drawing 42627360-001 (Appendix B).

The waste rock dump will be located outside the annual exceedance probability (AEP) of 1 in 100 year flood extents of the drainage path that passes the toe of the waste rock dump. The waste rock dump Dam will be comprised of NAF waste rock and lined on the upstream face to prevent water from percolating through the structure. Details of the waste rock dump dam are not provided at this time, however the dam would likely be constructed from locally available materials such as rock fill fitted with an upstream impermeable liner.

5.3 Surface Water Management

Management of surface water runoff is required during operation and for the final landform. The NAF base is to be graded to shed water away from the PAF area during operation.

Once the waste rock dump reaches the ultimate height, the surface is to be crowned to promote direct surface water falling on the waste rock dump toward the edges. The crown of the surface follows the centreline of the PAF cell. The final surface will be capped with a material that will limit infiltration and promote water shedding. The PAF area will be capped with topsoil overlying growth medium overlying a Barrier Layer. The topsoil will be spread to mimic the existing natural soil profile; if the natural topsoil cover is sporadic then the WRD cover will be the same. The growth medium acts as a growth medium for roots to penetrate the Barrier Layer. The Barrier Layer is intended to limit infiltration and to resist erosion, and will be comprised of fine material selectively sourced from the NAF material. The Barrier Layer is not expected to be a clay material. The NAF cover is similar to the PAF cover minus the Barrier Layer.

Drainage ditches are specified along the edges of the waste rock dump to channel clean surface runoff and runoff from the waste rock dump cover toward the waste rock dump Dam via the drainage chutes.

5.4 Waste Rock Placement

Generally, it is anticipated that paddock tipping will be used initially. Once an area is built up to 10m, end tipping will progress to form each NAF lift. PAF waste rock may be placed by paddock or end tipping, but must be located within the central portion of the NAF base to keep the PAF Cell at least 5m from the crest of the WRD.

5.5 Construction Considerations

The waste rock dump construction is divided into three sequential phases: clearing and stripping, placement during operations, and closure capping. The following items need to be considered for construction:

- Construction materials from NAF need to be identified and quantified during planning and design stages.
- Waste rock identification management is required throughout the mine operation to ensure PAF is properly stored.
- Dumping schedules must consider the mine schedule to avoid the situation where PAF cell growth exceeds the NAF base capacity.
- Monitoring is required to ensure the waste rock lift heights agree with the dumping plan.
- Careful scheduling is required to prevent misplacement of PAF and to meet the design requirements.
- It is recommended to employ full-time management of the WRD operation during all stages of construction to ensure final closure requirements and objectives are met.
- Dump performance monitoring and documentation including stability, erosion, and consolidation.
- Environmental monitoring of conditions at the dump including seepage water, surface water, and waste rock identification are required to verify environmental performance objectives are met.

6 DECOMMISSIONING AND CLOSURE

The decommissioning and closure design includes armouring, capping and revegetation elements placed in a layered sequence to limit erosion and infiltration and promote growth of targeted vegetation, and a surface water management system to convey runoff. These design elements are intended to create a final landform that is safe, stable and non-polluting. To this end, the following items are included in the closure design:

- Capping system: specified to promote growth of endemic vegetation and water shedding.
- Surface water management: drainage ditches western flank, and potion of the eastern flank, and drainage chutes at the groin near the WRD toe to convey runoff and limit erosion.
- Reconfiguration of the WRD Dam into a sediment catchment dam to provide sediment collection but not to retain water.

7 REFERENCES

Ahern, C.R., Ahern, M.R. and Powell, B. (1998). *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998. QASSIT*, Department of Natural Resources, Resource Sciences Centre, Indooroopilly.

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8 LIMITATIONS

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of CopperChem Limited and only those third parties who have been authorised in writing by URS to rely on the report.

It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Purchase Order Terms and Conditions.

The methodology adopted and sources of information used by URS are outlined in this the Report.

Where this report indicates that information has been provided to URS by third parties, URS has made no independent verification of this information unless required as part of the agreed scope of work. URS assumes no liability for any inaccuracies in or omissions to that information.

This Report was prepared between August and October 2014. The information in this report is considered to be accurate at the date of issue and is in accordance with conditions at the site at the dates sampled. Opinions and recommendations presented herein apply to the site existing at the time of our investigation and cannot necessarily apply to site changes of which URS is not aware and has not had the opportunity to evaluate. This document and the information contained herein should only be regarded as validly representing the site conditions at the time of the investigation unless otherwise explicitly stated in a preceding section of this report. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

This report contains information obtained by inspection, sampling, testing or other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. The borehole logs indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the uniformity of conditions and on the frequency and method of sampling as constrained by the project budget limitations. The behaviour of groundwater and some aspects of contaminants in soil and groundwater are complex. Our conclusions are based upon the analytical data presented in this report and our experience. Future advances in regard to the understanding of chemicals and their behaviour, and changes in regulations affecting their management, could impact on our conclusions and recommendations regarding their potential presence on this site.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, URS must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time.

Therefore this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.

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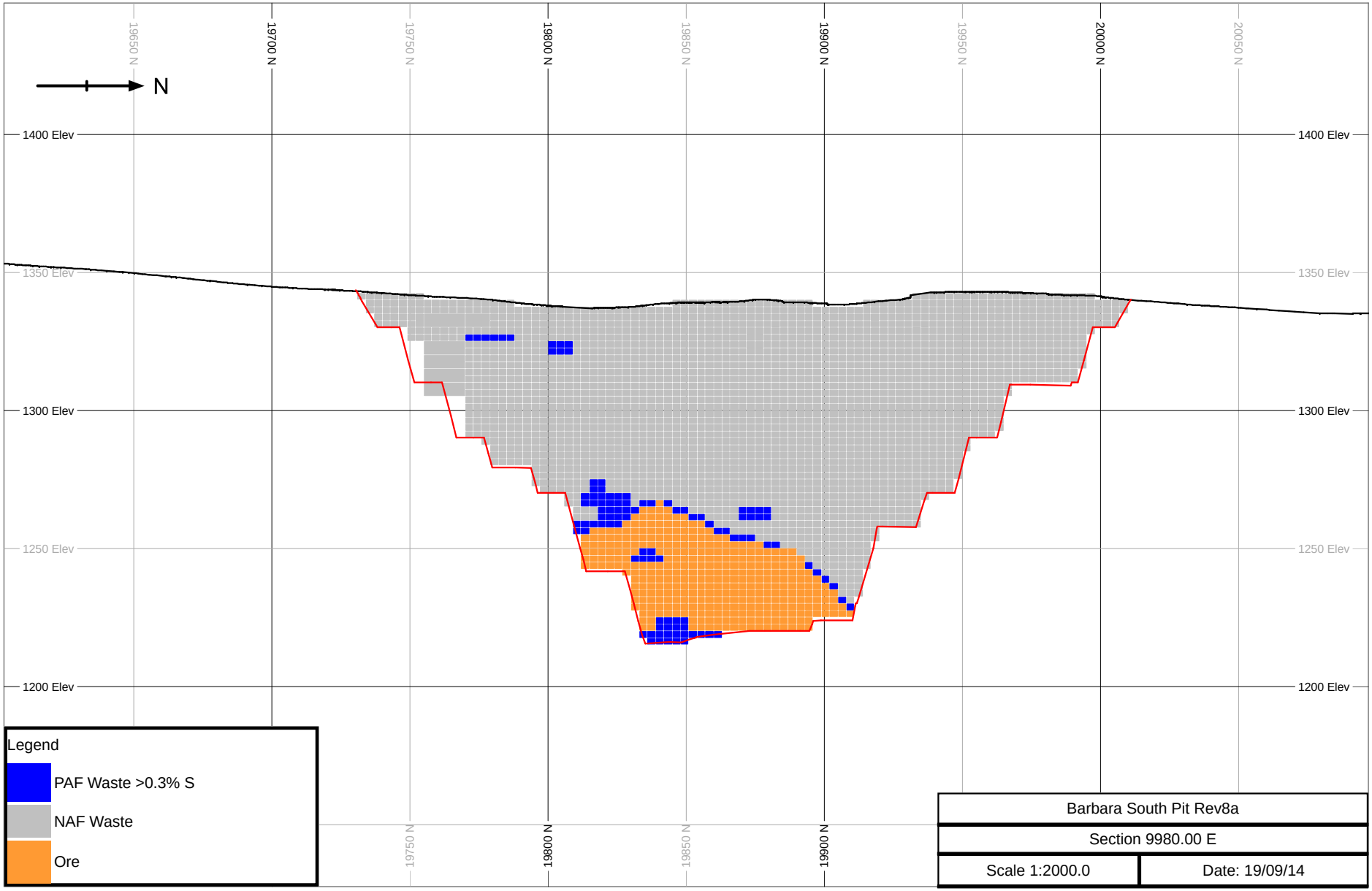
APPENDIX A CROSS-SECTIONS THROUGH THE BARBARA DEPOSIT SHOWING DISTRIBUTION OF WASTE ROCK AND ORE



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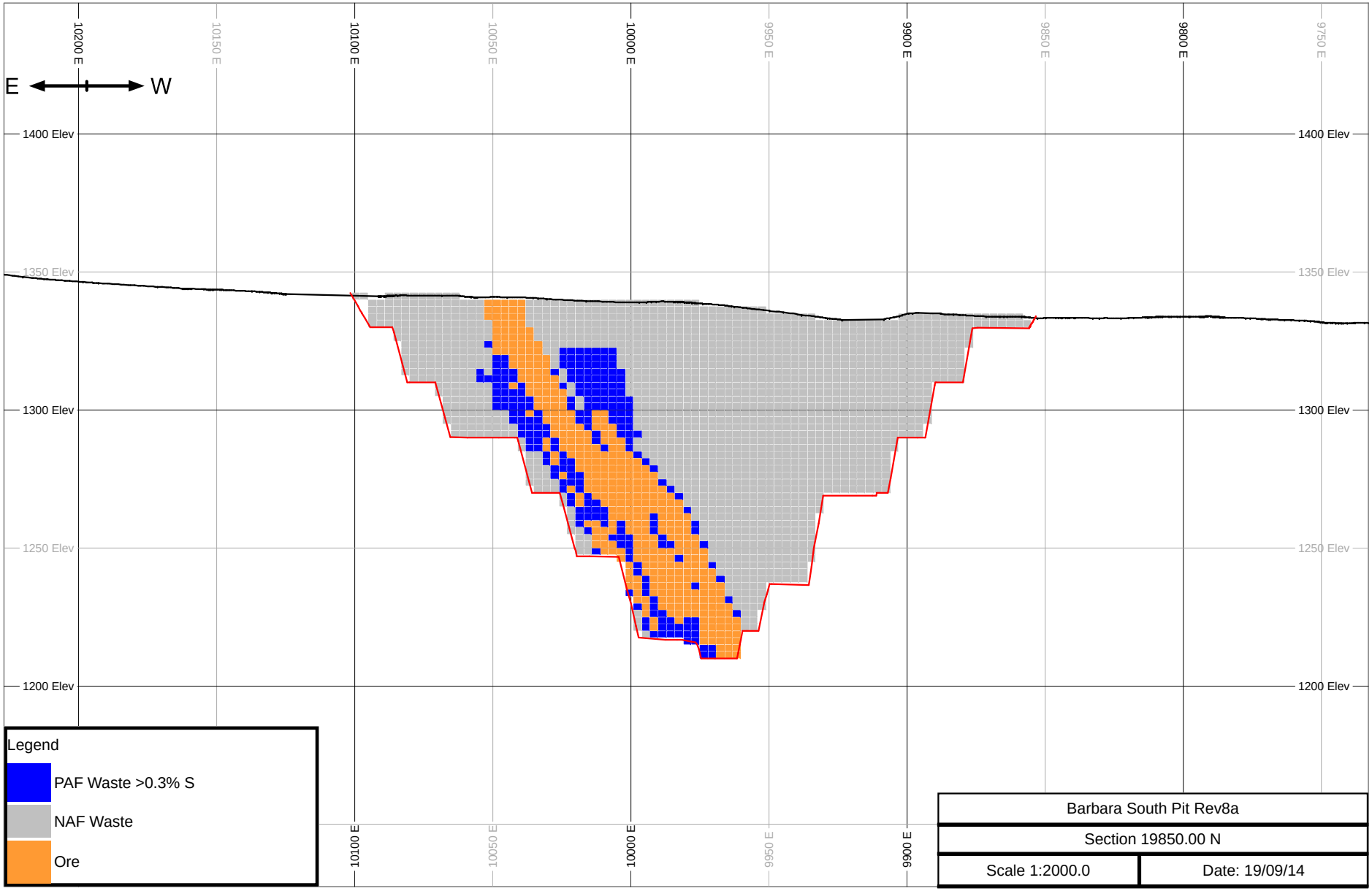

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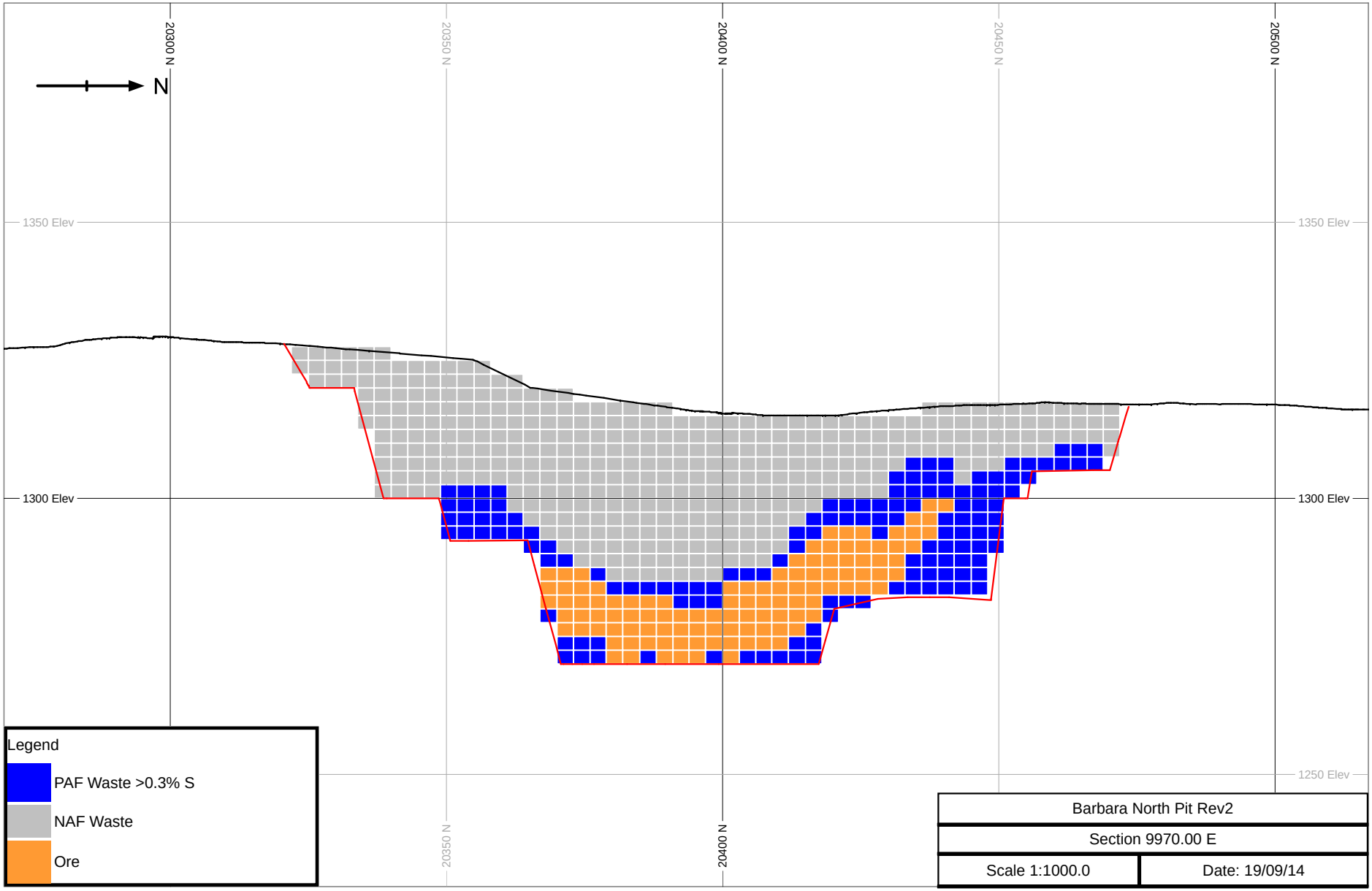

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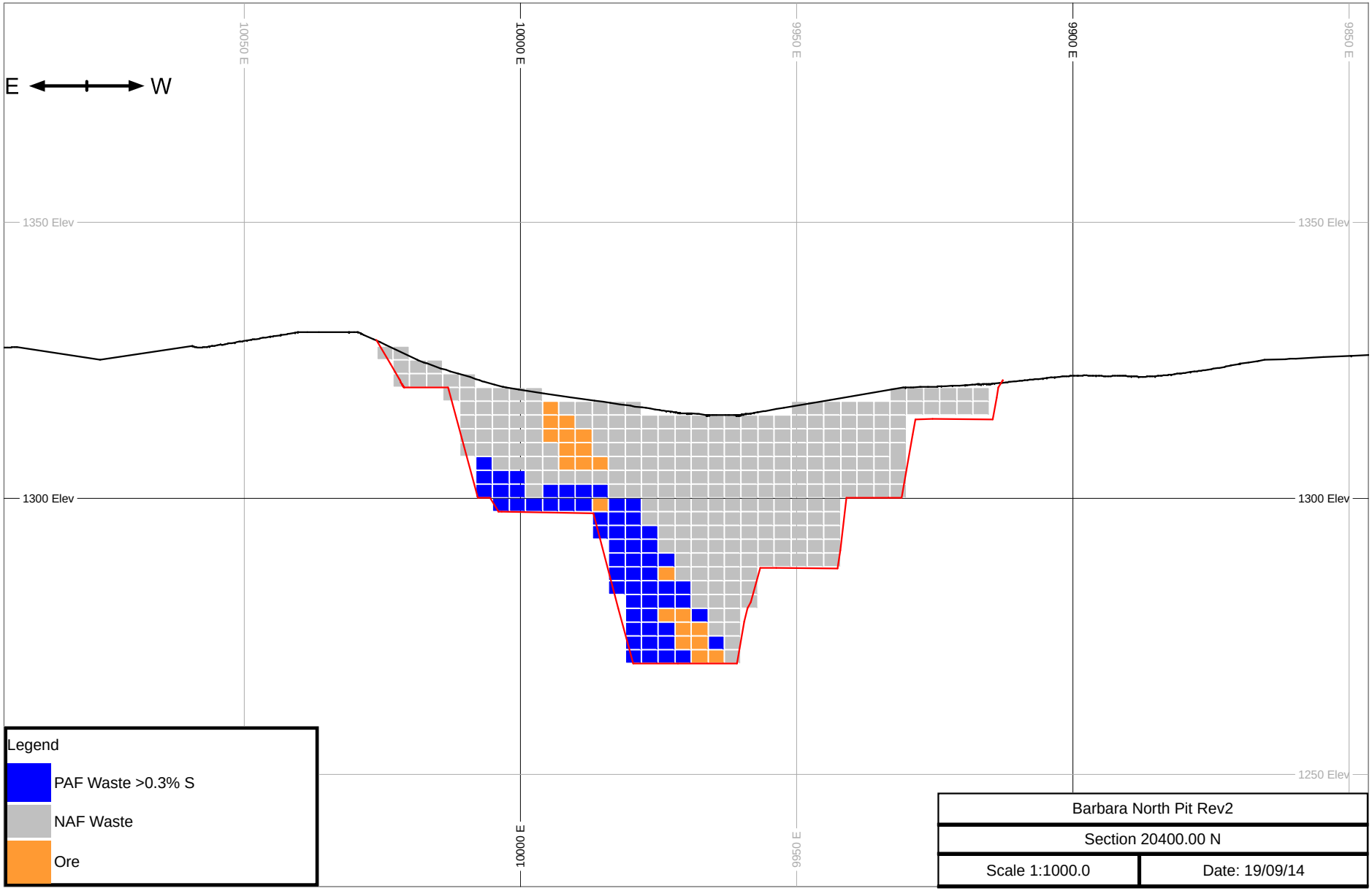

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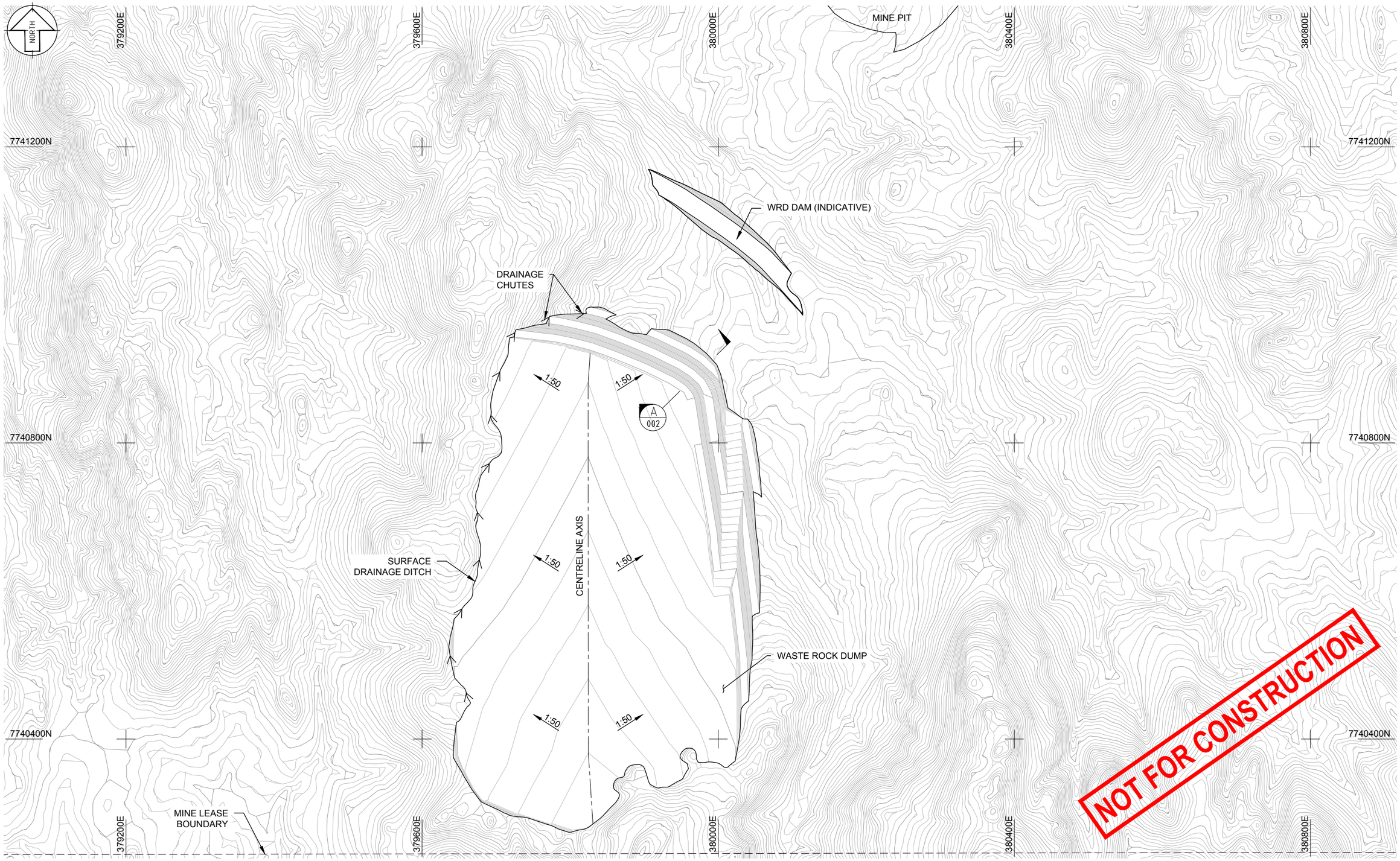
APPENDIX B CONCEPTUAL WASTE ROCK DUMP DESIGN



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NOTES:

1. WRD LAYOUT PROVIDED BY AMC Pty Ltd.
2. CONTOUR INTERVAL IS 1m.

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Rev	Revision Description	Designed	Drawn	Checked	Approved	Date
B	REVISED WRD FOOTPRINT	TA	BH			02.10.14
A	DRAFT	TA	BH			12.08.14

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Original Size A1

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Copper Chem

BARBARA COPPER PROJECT WRMP

GENERAL ARRANGEMENT

Status **FINAL**
Drawing Number **42627360-001**
Revision **B**

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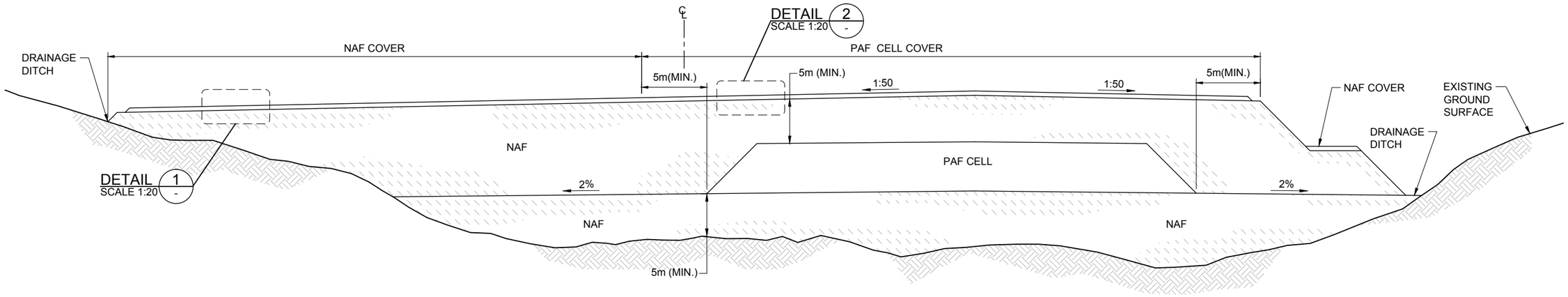

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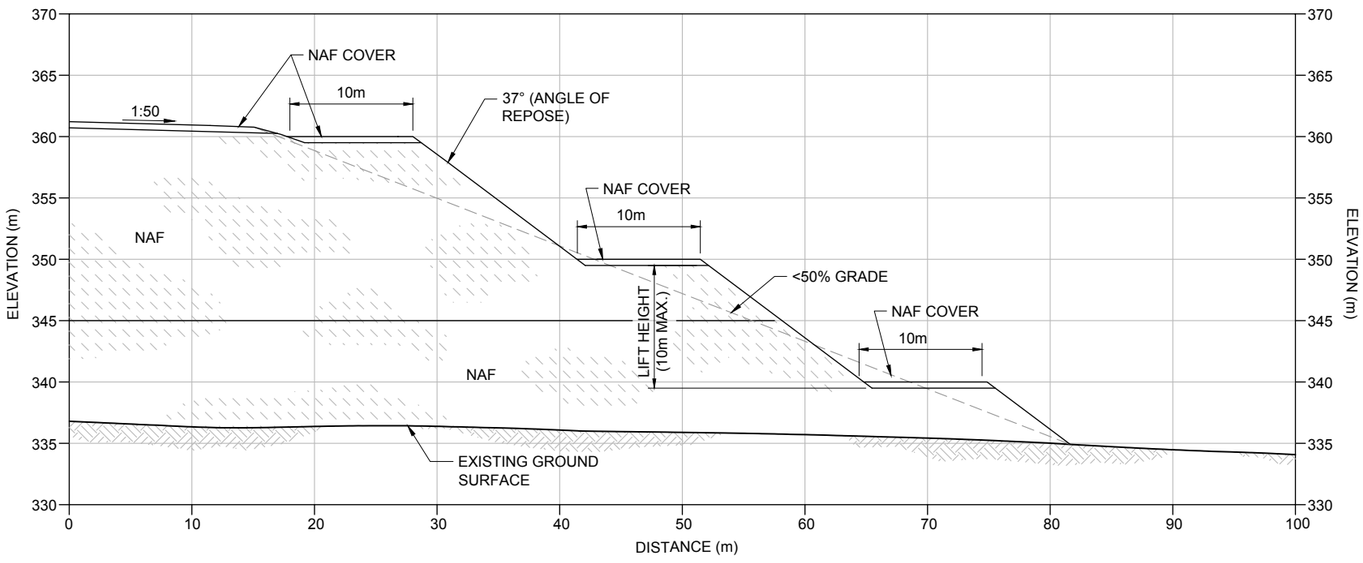

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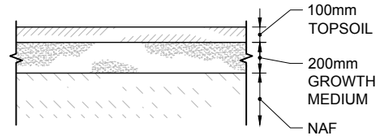

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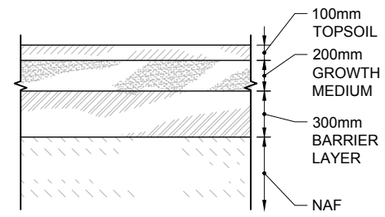

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DIMENSIONS ARE IN METRES

Rev	Revision Description	Designed	Drawn	Checked	Approved	Date
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A	DRAFT	TA	BH			12.08.14

Sheet 001
Scales 1:XXX A1 1:XXX A3
Original Size A1

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Copper Chem

BARBARA COPPER PROJECT WRMP

SECTIONS AND DETAILS

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APPENDIX C FIELD pH PEROXIDE TEST (pH_{FOX})

The procedure for the field pH peroxide test (pH_{FOX}) is outlined below:

1 Adjust the pH of the hydrogen peroxide to pH 4.5–5.5 before going into the field.
2 Calibrate battery powered field pH meter according to manufacturer's instructions.
3 Prepare the test tubes in the test tube rack. Make sure the rack is marked with the depths so there is not confusion about the top and bottom of the drill interval being assessed. It is important to use heat-resistant test tubes for the pH_{FOX} test as the reaction can generate considerable heat (up to 90 °C). It is recommended that a tall, wide tube be used for this test as considerable bubbling may occur, particularly on highly sulfidic or organic samples.
4 Conduct pH_{FOX} tests at intervals on the drill intervals of 1 m to a maximum of 5 m composite and at least one per rock unit whichever is lesser. Do NOT composite different lithologies.
5 Remove approximately 1 level teaspoon of sample from the fine grained blast hole or drill cuttings. Place approximately half teaspoon of the sample into the pH_{FOX} test tube for the corresponding depth test.
6 Add a few millilitres of 30% H_2O_2 (adjusted to pH 4.5–5.5) to the sample (sufficient to cover the sample with peroxide) using a plastic pipette and stir the mixture. Do NOT add the peroxide to the test tube in which the pHF test was conducted, that is, the pH_{FOX} test tube should not have any deionised water in it. Beakers can be used, however glass is usually easily broken when conducting field work, and when multiple tests are being conducted it is difficult to handle large beaker sizes efficiently. Do NOT add more than a few millilitres at a time. This will prevent overflow and wastage of peroxide. A day's supply of peroxide should be allowed to reach room temperature prior to use (cold peroxide from the fridge may be too slow too react).
7 Rate the reaction of soil and peroxide using a reaction scale (see Table C-1)
8 Ideally, allow approximately 15 minutes for any reactions to occur. If substantial sulfides occur, the reaction will be vigorous and may occur almost instantly. In this case, it may not be necessary to stir the mixture. Careful watch will be needed in the early stages to ensure that there is no cross contamination of samples in the test tube rack. If the reaction is violent and the sample peroxide mix is escaping from the test tube, a small amount of deionised water (or demineralised water; not tap water) can be added (using a wash bottle) to cool and calm the reaction. Usually this controls overflow. Do NOT add too much deionised water as this may dilute the mixture and affect the pH value. It is important to only use a small amount of soil otherwise violent reactions will overflow and the sample will be lost.
9 Steps 6 to 8 may be repeated until the sample peroxide mixture reaction has slowed. This will ensure that most of the sulfides have reacted. In the lab this procedure would be repeated until no further reaction occurs, however in the field, best judgement is recommended. Usually one or two extra additions of a few millilitres of peroxide are sufficient.
10 If there is no initial reaction, individual test tubes containing the sample peroxide mixture can be placed into a container of hot water (especially in cooler weather) or in direct sunlight. This will encourage the initial reaction to occur. When the sample starts to 'bubble', remove the test tube immediately from the hot water and replace into test tube rack.
11 Wait for the sample peroxide mixture to cool (may take up to 10 minutes). The reactions often exceed 90ºC. Placing an electrode into these high temperature situations may result

in physical damage and inaccurate readings. Check the temperature range of the pH meter and probe to see what temperature is suitable. Note that a more exact pH is achieved if a temperature probe is also used; however, this may be impractical in some field situations.

12 Use an electronic pH meter (preferred method) to measure the pH_{FOX}. Rinse probe in deionised water before placing in the solution. Place a spear point electrode into the test tube, ensuring that the spear point is totally submerged in the sample:peroxide mixture. Never stir the mixture with the electrode. This will damage the semi-permeable glass membrane.

13 Wait for the reading to stabilise and record the pH_{FOX} measurement.

14 All measurements should be recorded on a data sheet.

15 Rinse pH probe in deionised water.

16 Rinse thoroughly all test tubes and racks with copious quantities of water. Use a test tube brush to remove the residue in the tube. Always wear gloves and eye protection when washing out the test tubes.

Table-C-1 pH_{FOX} Reaction Rating Scale and Interpretation

Reaction Rating	Reaction Rating	Indicative pH After Oxidation (pH_{FOX})	Interpretation
0	No reaction	> 5.5	NAF
1	Slight reaction	5.0 to 5.5	PAF
2	Medium reaction	4.5 to 5.0	PAF
3	High reaction	3.0 to 4.5	PAF
4	Very vigorous reaction, gas evolution and heat generation commonly >80 °C	< 3.0	PAF

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Kinetic Column Leach Testing of Waste Rock and ROM Oxide

Final Report - September 2020

ROUND OAK MINERALS

BARBARA COPPER PROJECT

S4405 / J000325 / R1382

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Kinetic Column Leach Testing of Waste Rock and ROM Oxide

ROUND OAK MINERALS - BARBARA COPPER PROJECT

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CONTENTS

LIST OF FIGURES ..... **III**

LIST OF TABLES ..... **III**

LIST OF ABBREVIATIONS ..... **IV**

EXECUTIVE SUMMARY ..... **VI**

1. INTRODUCTION **8**

2. SAMPLE COLLECTION AND DESCRIPTIONS **8**

3. SAMPLE PREPARATION **10**

4. GEOCHEMICAL CHARACTERISATION METHODOLOGY **10**

5. GEOCHEMICAL CHARACTERISTICS OF TEST SAMPLES **13**

5.1. Acid Forming Characteristics 13

5.2. Sulphur Speciation 16

5.3. Sulphur Reactivity 17

5.4. Carbonate Neutralising Value 18

5.5. Acid Buffer Characteristics 18

5.6. Multi-Element Analysis of Solids 19

6. COLUMN LEACH TEST METHODOLOGY **21**

6.1. Column Setup and Leaching Regime 21

6.2. Leaching Regime 22

6.3. Leachate Analysis 23

7. COLUMN LEACH TEST RESULTS **23**

7.1. First Flush 23

7.2. Weeks 4 to 52 23

7.2.1. PAF1 Column 23

7.2.2. NAF1 and NAF2 Columns 25

7.2.3. NAF4 Column 26

7.2.4. Oxide ROM1 and ROM2 Columns 27

8. SUMMARY AND IMPLICATIONS **28**

APPENDIX A **30**

APPENDIX B **38**

LIST OF FIGURES

Figure 1: *Sample location plan for Barbara waste rock and ROM oxide samples* 9
Figure 2: *Acid-base account plot for Barbara waste rock and ROM oxide samples* 15
Figure 3: *ARD classification plot for Barbara waste rock and ROM oxide samples* 15
Figure 4: *Sulphur speciation in column leach test samples* 16
Figure 5: *Photograph showing sulphide mineralisation in sample NAF4* 16
Figure 6: *Monitored NAG pH profiles PAF waste rock and low-grade ore samples* 17
Figure 7: *Comparison of CNV and ANC results for column leach test samples* 18
Figure 8: *Acid buffer characteristic curve for sample NAF4 with an ANC of 75 kg H_2SO_4/t* 19
Figure 9: *Photograph of column leach test setup - side view* 21
Figure 10: *Photograph of column leach tests - top view* 22
Figure 11: *Photograph of column housing with crushed sample* 22

LIST OF TABLES

Table 1: *Descriptions of Barbara waste rock and ROM oxide samples* 9
Table 2: *Acid forming characteristics of Barbara waste rock and ROM oxide samples* 14
Table 3: *Elemental compositions of Barbara waste rock and ROM oxide samples* 20
Table 4: *Composition of initial flush from Barbara column leach tests* 24

LIST OF ABBREVIATIONS

ABBREVIATIONS USED IN GEOCHEMICAL ASSESSMENT

ARD	Acid Rock Drainage
AMD	Acid, Metalliferous and Saline Drainage
NMD	Neutral and Metalliferous Drainage
ABA	Acid Base Account
$pH_{1:2}$	pH of a sample slurry with a solid to water ratio of 1:2 (by weight)
$EC_{1:2}$	Electrical Conductivity of a sample slurry with a solid to water ratio of 1:2 (by weight)
ESP	Exchangeable Sodium Percentage
ECEC	Effective Cation Exchange Capacity
S	Sulphur
CRS	Chromium Reducible Sulphur
KCl	Potassium Chloride
H_2SO_4	Sulphuric Acid
SO_4	Sulphate
$CaCO_3$	Calcium Carbonate
ANC	Acid Neutralising Capacity in kg H_2SO_4/t
ANC_{ABCC}	Acid Neutralising Capacity in kg H_2SO_4/t estimated from ABCC testing
CNV	Carbonate Neutralising Value in kg H_2SO_4/t
MPA	Maximum Potential Acidity, calculated from total S in kg H_2SO_4/t
NAPP	Net Acid Producing Potential, calculated from ANC and total S (or MPA) in kg H_2SO_4/t.
NAG	Net Acid Generation (test)
NAGpH	pH of NAG solution before titration
$NAG_{(pH4.5)}$	NAG acidity titrated to pH 4.5 in kg H_2SO_4/t
$NAG_{(pH7.0)}$	NAG acidity titrated to pH 7.0 in kg H_2SO_4/t
ABCC	Acid Buffering Characteristic Curve
GAI	Geochemical Abundance Index based on multi-elements of solids
PAF	Potentially Acid Forming
PAF-LC	Potentially Acid Forming - Low Capacity
NAF	Non Acid Forming
UC	Uncertain
AC	Acid Consuming

UNITS OF MEASUREMENTS

%	Percentage
°C	Degrees Celsius
dS	Deci Siemen
µS	Micro Siemen
µm	Micrometre
mm	Millimetre
m	Metre
mg	Milligram
g	Gram
kg	Kilogram
t	Tonne
L	Litre
ml	Millilitre

OTHER ABBREVIATIONS

ALS	Australian Laboratory Services
EGi	Environmental Geochemistry International Pty Ltd
IRL	International Resource Laboratories Pty Ltd

EXECUTIVE SUMMARY

This report presents the results and findings of column leach tests involving waste rock and ROM oxide samples from the Barbara mine site. The columns were laboratory scale and leaching of the test samples was carried out under controlled conditions. There were six column tests, one involving waste rock that was potentially acid forming (PAF), three representing non-acid forming (NAF) waste rock, and two representing ROM Oxide. The characteristics of the test materials were as follows:

- **PAF1** - PAF waste rock with elevated copper (0.79%Cu) and high sulphur (2.49 %S). Also some ANC (17 kg H_2SO_4/t) likely to delay the onset of acidification.
- **NAF1** - NAF waste rock with low copper content (0.02%Cu) and low sulphur (0.05 %S).
- **NAF2** - NAF waste rock with low copper content (0.02%Cu) and low sulphur (0.1 %S).
- **NAF4** - NAF waste rock with high copper content (1.05%Cu), high sulphur content (1.32 %S) and high ANC (75 kg H_2SO_4/t).
- **ROM1** - ROM oxide with high copper (0.53 %Cu) but low sulphur (0.05 %S) and classified NAF.
- **ROM2** - ROM oxide with high copper (0.95 %Cu) but low sulphur (0.1 %S) and classified NAF.

Five tests (PAF1, NAF1, NAF2, ROM1 and ROM2) ran continuously for 12 months. The sixth test initially involved a sample representing low sulphur NAF waste (referred to as NAF3) but to expand the geochemical range of test materials this sample was replaced after 8 weeks with a sample representing high sulphur NAF waste (NAF4). The subsequent leaching of NAF4 extended for 12 months. The main findings were as follows:

High Sulphur PAF Waste Rock as Represented by PAF1

The PAF1 sample representing PAF waste rock did not acidify during the 12 months test period, confirming a lag period of at least a year for this type of material. There was no evidence of significant leaching of copper or other environmentally important elements, with concentrations in leachate typically close to, or less than the limits of analytical detection. However, there was significant release of sulphate, indicating sulphide oxidation did occur during the test at a moderate rate. Over the 12 month test period the total release of sulphur was equivalent to approximately 0.03 %S. Assuming the sulphur occurred in the sample as pyrite, the release of sulphur equates to an acid generation potential of 0.9 kg H_2SO_4/t. Whilst significant, this amount of acid generation represents only a small portion of the MPA of PAF1 of 75 kg H_2SO_4/t. Therefore, after 12 months of leaching the PAF1 sample was still in the early stages with respect to sulphide oxidation and acid generation/neutralisation. As there was no evidence of any decrease in leachate pH or alkalinity during the test, and the original ANC of 17 kg H_2SO_4/t was only depleted by 5% during the 12 month period, it is likely that the lag period for waste rock as represented by PAF1 would extend for several years. During this lag period it is expected that leaching of copper would remain limited as the solubility of copper is pH-dependent. Under alkaline conditions, most of the copper released as a consequence of the oxidation of chalcopyrite should continue to re-precipitate as copper oxy-hydroxide onto waste rock surfaces. It is expected significant copper release will only occur from this type of waste rock toward the end of the lag phase when the pH of the material begins to decrease below about 6.

High Sulphur NAF Waste Rock as Represented by NAF4

The NAF4 sample represents high sulphur rock that also has moderate to high ANC and is overall NAF. The column leach test on this sample confirmed generation of alkaline drainage during the 12 month test period. There was evidence of a moderate rate of sulphide oxidation but, notwithstanding an ore-grade copper content of 1.06%Cu, there was only limited leaching of copper, with concentrations in leachate of around 0.2 to 0.4 mg/L. Given the solubility of copper is pH-dependent, there is no reason to expect any significant increase in the rate of copper leaching from this type of waste rock over the longer term, assuming the material remains circum-neutral. Apart from some copper, there was no evidence of leaching of environmentally important elements such as arsenic, cadmium, mercury, lead, zinc.

Low Sulphur NAF Waste Rock as Represented by NAF1 and NAF2

Samples NAF1 and NAF2 represent typical low sulphur, NAF waste rock at the Barbara site. In most respects, these waste rock samples can be considered geochemically benign in that the sulphide-sulphur contents were negligible and the neutralising capacities were low. Copper was slightly elevated in comparison to typical background soil, as was arsenic in NAF2, but otherwise there were no significant (GAI≥2) elemental enrichments of environmental importance.

The results of the column leach tests were consistent with the benign nature of this type of NAF waste rock. Leachates from both these columns were circum-neutral and there were only low rates of leaching of sulphate. Although copper contents were slightly elevated, there was no evidence of significant copper release, with concentrations in leachates typically less than 0.005 mg/L. However, there was minor leaching of arsenic from NAF2, with concentrations typically around 0.03 mg/L in leachates collected during the latter half of the test. And, as with other samples, the concentrations of other environmentally elements were typically close to, or less than the respective analytical detection limits.

Low Sulphur/High Copper ROM Oxide as Represented by ROM1 and ROM2

In most respects the geochemical characteristics of the samples representing ROM Oxide were similar to low sulphur NAF waste, the only difference being the copper contents of the ROM oxide samples were much higher at approximately 0.53 and 0.95%Cu, respectively. Given the low sulphur contents it can be assumed most, and probably all, of the copper occurred in oxide forms. There was some leaching of copper during the column leach tests, with concentrations in leachate typically varying between 0.1 to 1.0 mg/L. Given the weathered nature of ROM Oxide and the likelihood that the solubility of copper in such waste will be pH-dependent, it is reasonable to assume the leaching of copper from material as represented by ROM1 and ROM2 over the long term would remain much the same as the chemistry of leachate from the column tests, that is slightly alkaline, low in soluble salts, and apart from some copper, have only trace concentrations of other environmentally important elements including antimony, arsenic, cadmium, cobalt, mercury, lead, selenium and zinc.

1. INTRODUCTION

This report presents the results and findings of a column leach test program involving samples representing waste rock and ROM oxide at the Barbara Copper Project, located in north-west Queensland, approximately 50 km east of Mount Isa. The column test program was commissioned by Round Oak Minerals to better understand the geochemical behaviours of different types of waste rock and ROM oxide when exposed to atmospheric conditions. The program was co-ordinated by Environmental Geochemistry International Pty Ltd (EGi) and involved a series of six laboratory-scale, leach columns setup at EGi's geochemical laboratory in Sydney.

The column leach test is a kinetic based procedure in which samples are exposed to atmospheric conditions and allowed to react at naturally occurring rates, thereby providing data on geochemical behaviour that can be applied to analogous field situations. The exposure and drainage conditions imposed in the column test method are intentionally conducive to sulphide oxidation, and the rate of leaching is standardised so that the chemical behaviours of materials with different geochemical characteristics can be directly compared. Because of the kinetic nature the column tests, they are commonly run for a year or more to allow sufficient time for oxidation reactions and other chemical processes to become fully established.

The primary objectives of the Barbara column leach program were to quantify:

- the reactivities of sulphide mineralisation within waste rock when exposed to atmospheric conditions;
- rates of acid generation by potentially acid forming (PAF) samples under atmospheric conditions;
- the duration of lag periods preceding acidification; and
- the potential for leaching of environmentally significant elements from all types of waste rock and ROM oxide.

The column leach tests commenced on 30 August 2019, with leaching extending over 12 months during which a total of thirteen leachate collections were made. This report describes the geochemical characteristics of the test samples and the results of the column leach tests during the 12 months of testing.

2. SAMPLE COLLECTION AND DESCRIPTIONS

Six samples were initially collected by Round Oak personnel from within the South pit in July 2018 and were despatched to the EGi laboratory in Sydney for testing late. The samples were tentatively labelled by Round Oak as PAF1, PAF2, NAF1, NAF2, ROM Oxide1 and ROM Oxide2. These labels reflected the material types they were judged to represent.

Following the initial geochemical characterisation of the six samples by EGI, the PAF2 sample was re-labelled as NAF3 as it was found to have a low sulphur content and was definitively classified as non-acid forming (NAF).

Subsequently, another two samples were despatched to EGi in November 2019, one of which contained visible sulphide mineralisation and was selected for column leach testing as a replacement for the low sulphur NAF3 sample to expand the range of material types is the column leach program. Geochemical characterisation of this additional sample confirmed it had a high sulphide content, but it also had a significant acid neutralising capacity (ANC) and overall was NAF. It was therefore labelled NAF4.

Sample descriptions and location plan as provided by Round Oak for the original six samples are presented in **Table 1** and **Figure 1**, respectively.

Table 1: *Descriptions of Barbara waste rock and ROM oxide samples*

Material Class	Location	Northing	Easting	Depth in Pit	Geological Description
PAF1	South Pit	380252	7741437	330 RL	Oxidise sample quartz sericite schist, minor secondary copper.
NAF1	South Pit	380184	7741440	330 RL	Biotite schist
NAF2	South Pit	380122	7741495	325 RL	Biotite schist
NAF3 (previously PAF2)	South Pit	380193	7741549	325 RL	Oxidise sample quartz sericite schist with secondary copper, malachite and azurite.
NAF4	South Pit	na	na	na	na
ROM Oxide1	South Pit	380298	7741497	325 RL	Sample collected at the southern end of the shear zone and outside the ore zone. Very oxidised samples with minor secondary copper, malachite and azurite.
ROM Oxide2	South Pit	380224	7741519	325 RL	Sample collected from the hanging wall of the shear zone. Mainly oxidised schist, with secondary copper, malachite and azurite.

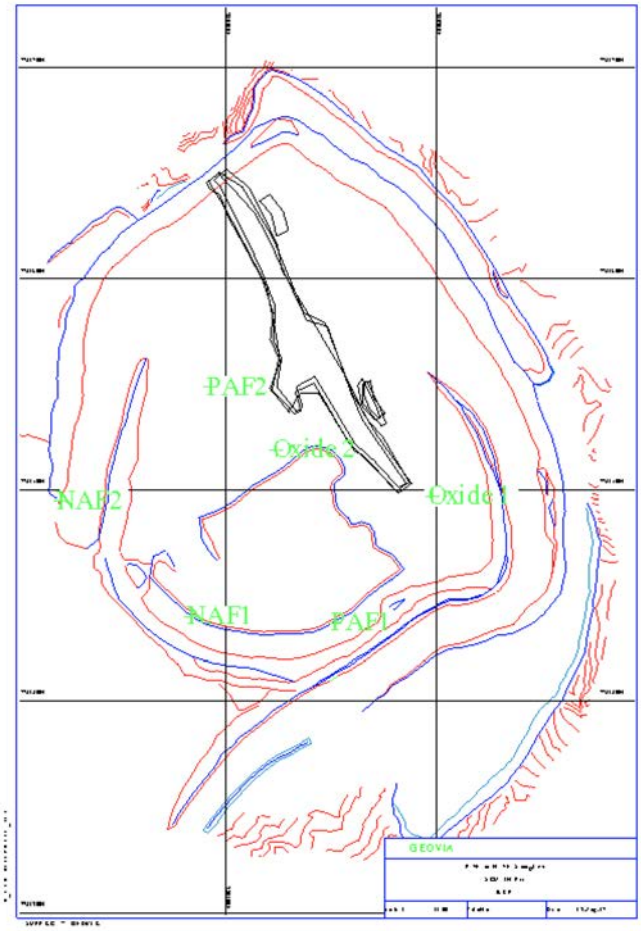

Figure 1: *Sample location plan for Barbara waste rock and ROM oxide samples*

3. SAMPLE PREPARATION

Each sample comprised approximately 10 kg of rock pieces. Following inspection of the samples they were despatched to International Resource Laboratories (IRL) Services for sample preparation, which involved crushing to minus 4 mm size for use in the column leach tests. A sub-sample of crushed sample was also pulverised for initial geochemical characterisation analyses.

4. GEOCHEMICAL CHARACTERISATION METHODOLOGY

The geochemical characterisation of the Barbara samples included analysis or calculation of the following parameters using standard methods[1] commonly used to define the geochemical properties of mine waste materials. Sulphur and carbon assays and multi-element scans were carried out by Australian Laboratory Services (ALS). All other assays were carried out by the EGi Laboratory.

Total sulphur

Measured by direct high temperature combustion, oxidation and infra-red detection using Leco induction furnace.

Sulphate-sulphur

A 2 g sub-sample of pulverised material was batch extracted for one hour with 80 ml of 1M KCl solution that was purged with argon gas for 30 minutes prior to use. The extract was filtered and the filtrate analysed for dissolved sulphate.

Sulphide-sulphur

Calculated as the difference between Total-S and Sulphate-S values.

Chromium Reducible Sulphur

Inorganic sulphur was reduced to H_2S by hot acidic $CrCl_2$ solution and the evolved H_2S gas trapped in zinc acetate solution as ZnS. The concentration of ZnS was subsequently quantified by idiometric titration. This method is designed to be selective for pyritic-sulphur, but may include some elemental sulphur if present.

Total Carbon Content

Total carbon content was measured using a Leco carbon analyser.

---

1 ***INAP (2009)**. The Global Acid Rock Drainage (GARD) Guide. Produced by the International Network for Acid Prevention.* http://www.gardguide.com

***AMIRA International (2002)**. ARD Test Handbook. Project P387A Prediction & Kinetic Control of Acid Mine Drainage. Prepared by Ian Wark Research Institute & Environmental geochemistry International Pty Ltd, May 2002.*

Maximum Potential Acidity

The MPA is the amount of acid (expressed as kg H_2SO_4/t) that theoretically can be generated by a sample when all sulphur occurs as reactive pyrite and there is complete oxidation of the pyrite to acid (H_2SO_4) and ferric hydroxide according to the following reaction:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \Rightarrow Fe(OH)_3 + 2\ H_2SO_4$$

Based on the stoichiometry of this reaction, the one mole of pyrite (or two moles of sulphur) will produce two moles of sulphuric acid. This means, for example, a sample containing 1 %S as pyrite could potentially produce 30.6 kg H_2SO_4/t with complete oxidation of the pyrite. MPA is commonly calculated using a total sulphur content, however if a significant portion of the sulphur occurs as sulphate the MPA will be over-estimated as sulphate does not contribute to acid forming potential. For the column test samples more accurate estimates of MPA were obtained by multiplying the sulphide-sulphur contents (as %S) by a factor of 30.6.

Acid Neutralising Capacity

ANC was determined using a modified Sobek Method[2]. This method provides a direct measurement of the amount of acid that can be consumed by carbonate and other gangue minerals within a sample. A fizz test was initially carried out to provide a qualitative indication of the magnitude of neutralisation capacity. This involved the addition of one or two drops of 1:3 HCl (approximately 8% HCl) to approximately 0.5 g of pulverised sample. The degree of "fizzing" was assessed and a fizz rating between 0 and 5 was assigned, where 0 signifies no visible reaction and 5 signifies very strong reaction. The fizz rating was then used to determine the strength and amount of acid required in the Sobek method to produce a suspension with a pH in the range 1 to 2. These ranges from 4 mL of 0.5 M HCl for a fizz rating of zero up to 60 mL of 1.0 M HCl for a fizz rating of 5. The suspension was allowed to react for approximately 1 to 2 hours, then the flask placed on a hot-plate and the suspension heated to 80 to 90°C for another 1 or 2 hours to complete the reaction. The amount of acid remaining after the reaction stage was determined by back-titration with sodium hydroxide. The amount of acid consumed by the sample (expressed in terms of kg H_2SO_4/t) was then determined by difference.

Carbonate Neutralising Value

The carbonate neutralising value (CNV) is an indirect measure of the neutralisation capacity within a sample based on the carbon content of a sample. The calculation assumes the carbon occurs exclusively as carbonate, and CNV is commonly expressed in terms of the amount of sulphuric acid that theoretically could be neutralised by the carbonate within a sample per unit weight (kg H_2SO_4/t). The calculation of CNV is based on the stoichiometry of the following reaction:

$$CaCO_3 + H_2SO_4 \Rightarrow Ca^{2+} + SO_4^{2-} + H_2O + CO_{2\,(g)}$$

where the main reaction products are calcium, sulphate, water and carbon dioxide gas. This reaction indicates that the one mole of carbon (as carbonate) will neutralise one mole of sulphuric acid. This means for a sample containing 1 %C as carbonate the CNV will be approximately 81.67 kg H_2SO_4/t. A total carbon assay is commonly

---

2 The most widely used method for assessing the inherent acid neutralising capacity (ANC) of a sample is the modified Sobek method (*Sobek, A.A., W.A. Schuller, J.R. Freeman, and R.M. Smith (1978). Field and Laboratory Methods Applicable to Overburdens and Minesoils. U.S. Environmental Protection Agency 600/2-78-054, Washington DC*).

used to calculate CNV although for materials where significant carbon occurs in organic forms the use of an inorganic-carbon contents should be used.

Net Acid Producing Potential

The NAPP is the amount of acid (kg H_2SO_4/t) that potentially could be produced by a sample after allowance for any ANC that the sample has. The NAPP of each sample was calculated by subtracting the ANC from the MPA value.

Net Acid Generation (NAG) Test

The NAG test is a direct oxidation procedure for estimating the acid forming potential of a sample. The NAG test involved reaction of a 2.5 g sub-sample of pulverised material with 250 mL of 15% hydrogen peroxide, which acted as an oxidant to any sulphides present. The samples were allowed to react overnight to provide sufficient time for oxidation to occur. The reaction flasks were then gently heated for approximately 1 hour to assist with decomposition of any residual peroxide. After cooling, the liquor pHs were recorded. As both acid generation and acid neutralisation can occur simultaneously during a NAG test, the end result represents a direct measurement of the net amount of acid that a sample can generate. A sample is considered to be acid forming if the pH after reaction is less than pH 4.5. For such samples, the actual amount of acidity generated (expressed as kg H2SO4/t) was also determined by back-titration of the mixture to a pH 7 end-point.

Monitored NAG Tests

A monitored NAG test was carried out on sample PAF1. The monitored NAG test provides an indication of the reactivity of the sulphides present in a sample, and in the case of a PAF sample it also provides an indication of the likely lag period for acid generation to occur under oxidising conditions. The monitored NAG test is essentially the same as the standard NAG test, except that the kinetics of the peroxide oxidation reaction are indirectly monitored via continuous measurements of the pH and temperature of the NAG solution.

Acid Buffer Characteristic Curve

An acid buffer characteristic curve was produced for sample NAF4 by slowly titrating a sub-sample of pulverised material with dilute hydrochloric acid over a period of 16 to 24 hours. The incremental additions of acid range from 0.1 mL of 0.1 M HCl per 60 seconds for samples with low ANC, and up to 0.1 mL of 0.5 M HCl per 60 seconds for samples with ANCs exceeding 100 kg H_2SO_4/t. This titration method provides a far less aggressive treatment of a sample than that applied in the ANC method and hence provides a measure of the buffering provided by more soluble carbonates within a sample.

Multi-Element Analysis of Solids

Samples were digested by multi-acid addition (*i.e.* hydrofluoric, nitric, perchloric and hydrochloric acids) and the digests were analysed using inductively coupled plasma mass spectrometry (ICPMS) for the following suite of elements: Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Sn, Sr, Th, U, and Zn. Mercury was also assayed but an aqua regia digestion was used to ensure minimal volatilisation followed by analysis using ICPMS.

5. GEOCHEMICAL CHARACTERISTICS OF TEST SAMPLES

5.1. Acid Forming Characteristics

Table 2 presents the acid forming characteristics of each sample. Acid-base account and ARD classification plots are also presented in **Figure 2** and **Figure 3**, respectively. The main findings are as follows:

PAF1

The sample labelled PAF1 had a high sulphur content (2.49 %S), most of which was present as sulphide. It also had some ANC (17 kg H_2SO_4/t), albeit relatively low and significantly less than the acid potential of the sulphide present. The NAPP was definitively positive (58 kg H_2SO_4/t) and the sample acidified to pH 3.4 under NAG test conditions. The ANC has potential to delay the onset of acidification of this material type when exposed to atmospheric conditions, but the positive NAPP and NAG test results suggest such material would likely generate acidic drainage in the longer term.

NAF1

The results for sample NAF1 were consistent with it being NAF. It had a low sulphur content (0.05 %S), relatively low ANC (15 kg H2SO4/t) and negative NAPP and NAG test results.

NAF2

The results for sample NAF2 were similar to NAF1. The sulphur content was low (0.1 %S), as was the ANC (15 kg H_2SO_4/t). The NAPP was negative NAPP and the sample did not acidify under NAG test conditions.

NAF3

Similarly, the sulphur content of sample NAF3 was negligible (0.02 %S), the ANC relatively low (11 kg H_2SO_4/t), and both the NAPP and NAG were negative.

NAF4

In contrast, sample NAF4 did have a significant sulphur content (1.32 %S), almost all of which was sulphidic. This sample also had a high copper content (1.06 %Cu) and it is likely that most of the sulphur was present as copper sulphide. Notwithstanding the high sulphide content, NAF4 also had a moderate to high ANC (75 kg H_2SO_4/t), which exceeded the acid potential of the sulphide present and consequently produced a negative NAPP (-36 kg H_2SO_4/t). The NAG test result was also consistent with this sample being NAF.

ROM1 & ROM2

There were only trace concentrations of sulphur in the two ROM Oxide samples, and both samples had negative NAPP and NAG test results. The ANCs were also low (7 and 10 kg H_2SO_4/t). Overall the results suggest both samples are essentially benign with respect to acid potential and neutralisation potential, which is consistent with their oxide descriptions.

Table 2: *Acid forming characteristics of Barbara waste rock and ROM oxide samples*

Parameter	Unit	Waste PAF1	Waste NAF1	Waste NAF2	Waste NAF3*	Waste NAF4	ROM OXIDE1	ROM OXIDE2
Sulphur Speciation								
- Total-S	(%S)	2.49	0.05	0.10	0.02	1.32	0.05	0.16
- Sulphate-S	(%S)	0.04	0.01	0.01	0.02	0.04	0.01	0.02
- Sulphide-S	(%S)	2.45	0.04	0.09	0	1.28	0.04	0.14
- Cr Reducible-S	(%S)	1.83	0.07	0.08	0.02	1.24	0.06	0.19
Carbon Speciation								
- Total-C	(%C)	0.17	0.16	0.14	0.05	0.83	0.04	0.09
- Organic-C	(%C)	0.07	0.02	0.02	0.02	0.08	0.02	0.03
- Inorganic-C	(%C)	0.10	0.14	0.12	0.03	0.75	0.02	0.06
Copper								
- Total-Cu	(%Cu)	0.788	0.019	0.022	0.315	1.055	0.532	0.947
Neutralising Characteristics								
- ANC (Sobek)	(kg H_2SO_4/t)	17	15	15	11	75	7	10
- CNV	(kg H_2SO_4/t)	8	11	10	2	61	2	5
Acid Generating Characteristics								
- MPA	(kg H_2SO_4/t)	75	1	3	0	39	1	4
- NAPP	(kg H_2SO_4/t)	58	-14	-12	-11	-36	-6	-6
- NAG (to pH4.5)	(kg H_2SO_4/t)	5	0	0	0	0	0	0
- NAG (to pH7)	(kg H_2SO_4/t)	15	0	0	0	0	0	0
- NAGpH		3.4	7.1	7.5	7.2	7.3	8.0	7.5
ARD Classification		**PAF**	**NAF**	**NAF**	**NAF**	**NAF**	**NAF**	**NAF**

* NAF3 - Initially labelled PAF2 when sampled at site but subsequently classified as NAF

Abbreviations

CNV = Carbonate Neutralising Value
ANC = Acid Neutralising Capacity
MPA = Maximum Potential Acidity
NAPP = Net Acid Producing Potential
(MPA and NAPP values calculated using Sulphide-S)
NAG = Net Acid Generation capacity
NAGpH = pH of NAG liquor
NAF = Non-Acid Forming
PAF = Potentially acid forming

Methods

Total sulphur - Measured using a Leco sulphur analyser

Sulphate-sulphur - Sample leached with hot HCl to remove acid-soluble sulphates. The amount of sulphate within the leachate is then determined by ICPAES.

Sulphide-sulphur - Calculated as the difference between Total-S and Sulphate-S values.

Cr Reducible S - Sample reacted with hot acidic CrCl2 to reduce (non-sulphate) inorganic sulphur forms to H_2S which are trapped in zinc acetate solution and determined.

Total carbon - Measured using a Leco carbon analyser

Organic-carbon - Hot HCl to remove any carbonates, then rinsed with distilled water. The residual carbon in the residue (i.e. acid-insoluble carbon) then measured by Leco.

Inorganic-carbon - Calculated as the difference between Total-C and Organic-C values.

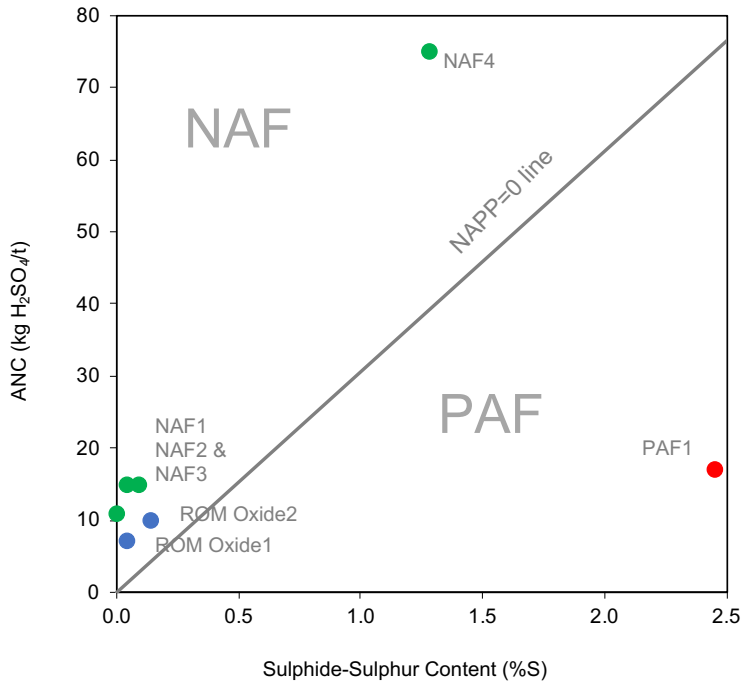

Figure 2: *Acid-base account plot for Barbara waste rock and ROM oxide samples*

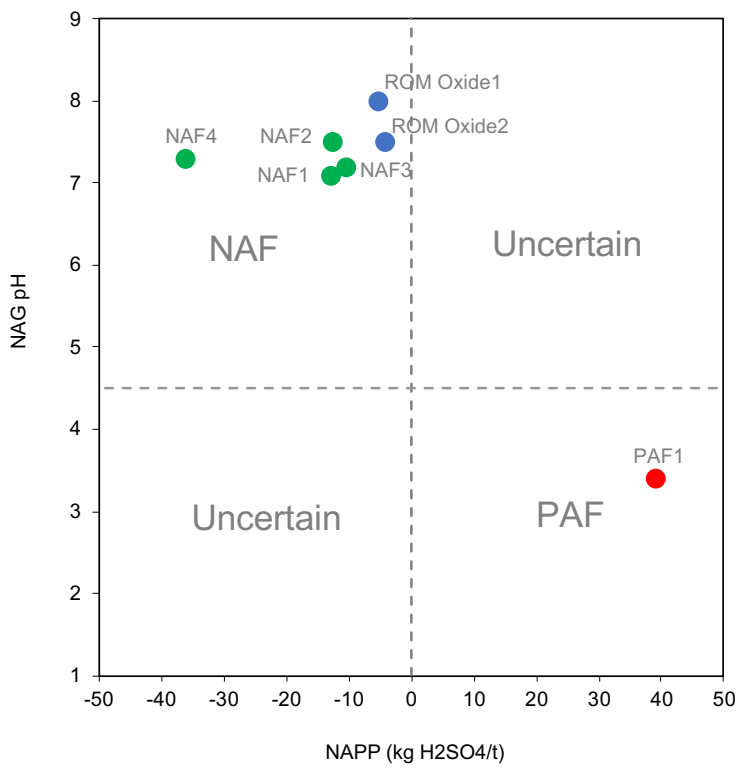

Figure 3: *ARD classification plot for Barbara waste rock and ROM oxide samples*

5.2. Sulphur Speciation

The test samples were analysed for total sulphur and also sulphur forms, which allowed differentiation of the sulphur between sulphide that has acid potential, and sulphate which does not contribute to acid forming potential. Two samples, PAF1 and NAF4, had significant sulphur contents, and with both samples most of the sulphur was sulphidic. Also, both samples had elevated copper contents suggesting the presence of significant copper sulphide mineralisation. **Figure 4** shows the estimated distribution of sulphur in PAF1 and NAF4 based on the sulphur speciation and copper assays.

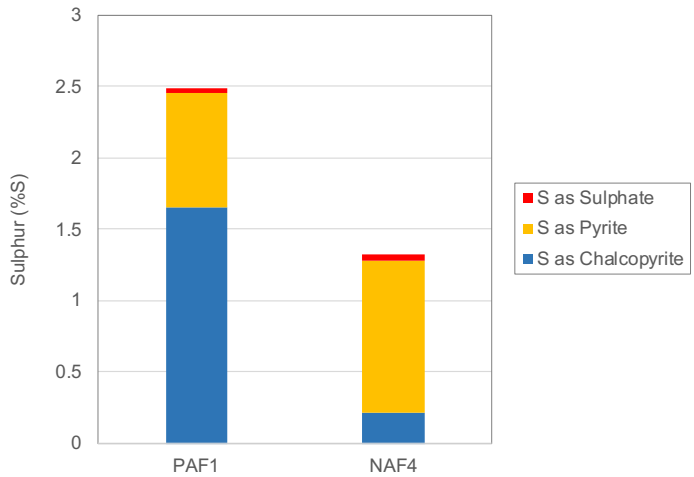

Figure 4: *Sulphur speciation in column leach test samples*

PAF1 had a copper content of 0.79 %Cu. Assuming all the copper was present as chalcopyrite ($CuFeS_2$) the amount of sulphur associated with the chalcopyrite would be 0.80 %S. This represents approximately one-third of 2.45 % sulphide-%S content of PAF1. Pyrite likely accounted for the remaining 1.69 %sulphide-S.

Copper mineralisation was also evident in NAF4 (see **Figure 5**), which had a copper content of 1.05 %Cu. This equates to 1.06 %S as chalcopyrite. With NAF4 the sulphide-sulphur content was only slightly higher at 1.32 %S, hence potentially most of the sulphide in NAF4 occurred as chalcopyrite, with only 0.22 %S present as pyrite.

Figure 5: *Photograph showing sulphide mineralisation in sample NAF4*

5.3. Sulphur Reactivity

The monitored NAG test was used to provide an indication of the reactivity of sulphides in the PAF1 sample (**Figure 6**). The monitored NAG test is an accelerated procedure which, in addition to sulphide reactivity, provides an indication of the likely lag period for acid generation to occur under oxidising conditions. The monitored NAG test is similar to the standard NAG test where a sample is oxidised with hydrogen peroxide, but with the added feature that the pH and temperature of the NAG liquor are constantly recorded during the reaction phase of the test.

The pH at the start of the monitored NAG test on PAF1 was 5.0, and it remained close to pH 5 for approximately 20 minutes. The initial pH plateau represents a lag in acidification that can be attributed to the sample having an ANC of 17 kg H_2SO_4/t. During this lag most of the acid generated from sulphide oxidation was neutralised. Over the next 90 minutes the pH steadily decreased to around pH 3. During this phase there was noticeable "fizzing" of the NAG liquor produced by the reaction of peroxide with sulphides exposed on particle surfaces. As the pH decreased there was a concurrent increase in the temperature of the NAG liquor, which effectively reached boiling point after approximately 115 minutes of reaction time. Some of the temperature rise can be attributed to the oxidation of pyrite, which is an exothermic (heat generating) process, but most is associated with catalytic decomposition of the peroxide, a process that is also exothermic[3]. The catalyst for the decomposition reaction is typically dissolved iron released during pyrite oxidation, although other metals such as copper can also contribute. As such, the occurrence of a temperature peak is often a further indication of sulphide reactivity in that it reflects increasing concentrations of reaction products.

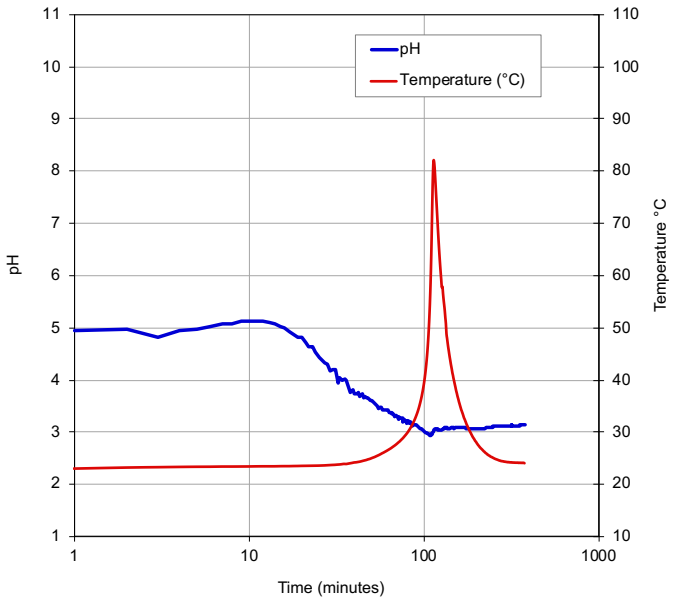

Figure 6: *Monitored NAG pH profiles PAF waste rock and low-grade ore samples*

[3] The temperature spike recorded in this and other monitored NAG tests is primarily an artefact of the test procedure as most heat is generated by the decomposition of the peroxide. Under field conditions the oxidation of sulphides involves atmospheric oxygen, and the rates of oxidation are typically orders-of-magnitude slower than in the NAG test where rates are highly accelerated by use of peroxide. Under field conditions the heat generated by the exothermic oxidation of pyritic material can be dissipated throughout a larger rock mass, which typically limits temperature rise. However, it can be the case that self-heating of highly sulphidic materials can occur within a waste rock dump if conditions are conducive to oxidation, especially if the generation of heat promulgates convective air movement through outer zones of the dump. If the material has a very high sulphide content and is also carbonaceous then spontaneous combustion can also occur under some situations.

Overall, the monitored NAG profile for sample PAF1 indicates the sulphidic mineralisation within the sample was reactive, however the 20 minute lag at the start of the test suggests that acidification of such material would likely take some time to occur (many months and possibly years) under field conditions.

5.4. Carbonate Neutralising Value

The capacity of a sample to inherently neutralise any acid that might be generated by the oxidation of pyrite and other sulphides is usually quantified using the Sobek ANC method which involves the addition of acid to a sample and measurement of the amount of acid consumed. As the ANC of a sample is commonly associated with the presence of carbonate mineralisation, the inorganic carbon content of a sample can also provide a secondary measure of neutralisation potential. With this alternate approach the result is commonly referred to as the carbonate neutralising value (CNV). **Figure 7** shows a comparison of the ANC and CNV results for the samples included in the column leach test study.

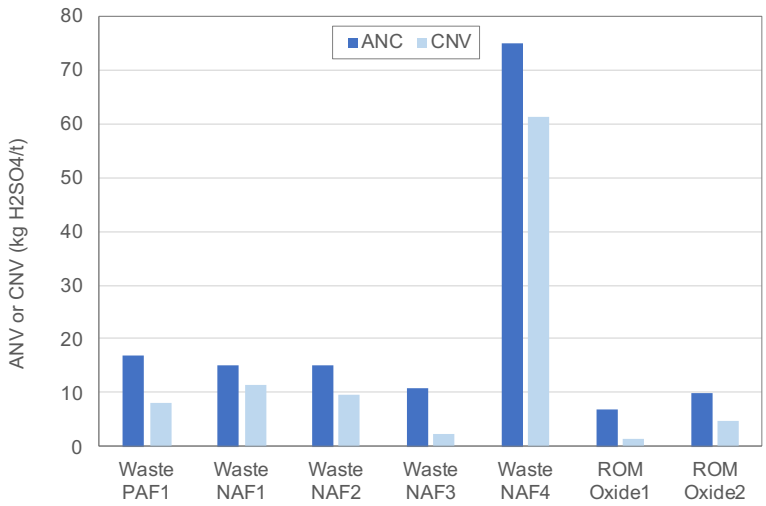

Figure 7: *Comparison of CNV and ANC results for column leach test samples*

For the Barbara samples the CNVs were consistently smaller than the corresponding ANCs, but overall there was reasonable agreement when considered over the range of values exhibited by the samples. This suggests carbonate mineralisation (e.g. calcite, limestone or dolomite) was a significant contributor to the neutralising capacity of most of the samples, and particularly NAF4 which had the highest ANC. However, for samples with very low ANCs some neutralisation could derive from of other gangue minerals such as silicates.

5.5. Acid Buffer Characteristics

The only sample in the column test program with a significant ANC was samples NAF4, which also had a high copper sulphide content. An acid buffer curve for NAF4 is shown in **Figure 8**. The acid buffer curve provides an indication of the reactivity of mineralisation providing neutralisation capacity with a sample. The titration method used to produce a buffer curve is not as aggressive in terms of acid addition as the standard ANC method, and hence it provides a measure of the buffering provided by more soluble carbonates within a sample. This can be important for NAF samples that also have high sulphide contents, as differential reactivities of sulphide and carbonates may result in leachate chemistries that are inconsistent with NAPP values.

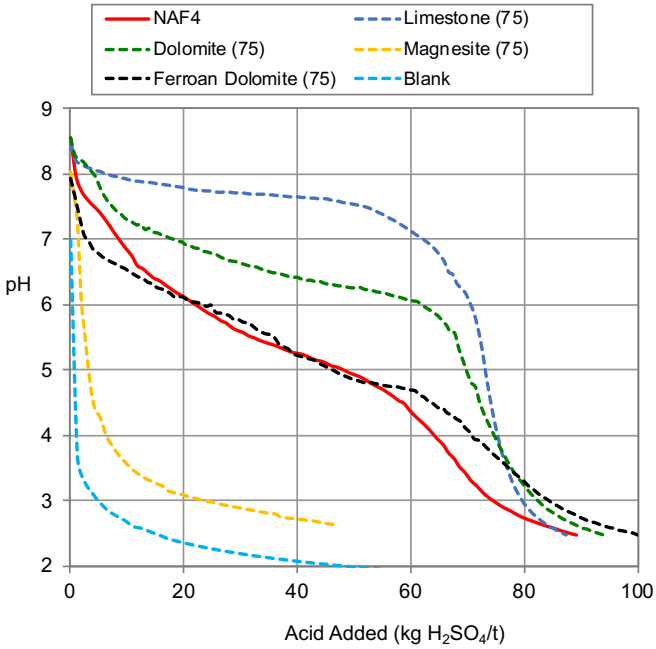

Figure 8: *Acid buffer characteristic curve for sample NAF4 with an ANC of 75 kg H_2SO_4/t*
(reference standards also have ANC equivalent of 75 kg $H2SO_4$/t)

For comparison purposes, Figure 8 also includes buffer curves for reference samples representing limestone, dolomite, ferroan-dolomite, magnesite and siderite. Limestone (or calcite) is usually readily available for neutralisation and can maintain a plateau at circum-neutral pH up until almost all of the ANC is consumed. Dolomite is also usually reactive, however the reactivity may decline when there is significant iron substitution, such as with ferroan dolomite. In contrast, magnesite is usually poorly reactive at circum-neutral pH, and significant dissolution of magnesite often only occurs under laboratory conditions when the pH drops below about 4. The buffer curve for NAF4 follows closely that of ferroan-dolomite.

5.6. Multi-Element Analysis of Solids

Elemental analysis of solids was carried out by ALS. Samples were digested by multi-acid addition (*i.e.* hydrofluoric, nitric, perchloric and hydrochloric acids) and digests were analysed using inductively coupled plasma mass spectrometry (ICPMS) for the following suite of elements: Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Sn, Sr, U, and Zn. Mercury was also assayed but an aqua regia digestion was used to ensure minimal volatilisation followed by analysis using ICPMS. The multi-element composition of each sample is given in **Table 3,** together with corresponding Geochemical Abundance Indices (GAI)**.** The purpose of GAIs is to identify elements that occur at concentrations significantly greater than median background soil abundance values, where:

- GAI of 0 indicates the element is present at a concentration similar to, or less than, median soil abundance,
- GAI of 1 or 2 represent minor enrichment of an element, and
- GAI of 3 to 6 represent significant enrichment above median soil abundance.

As might be expected, copper was enriched to varying extents in all samples. The copper contents of PAF1 (7,880 mg/kg), NAF4 (10,550 mg/kg), ROM oxide1 (5,320 mg/kg) and ROM oxide2 (9,470 mg/kg) were particularly high. The copper contents of NAF1 (194 mg/kg) and NAF2 (223 mg/kg) were much lower, but still relatively high in comparison

with typical background soil with a median of only 30 mg/kg. The analyses of solids also indicate enrichments of some other elements that may be potentially important environmentally:

	Significant (GAI≥3)	*Minor (GAI 1 or 2)*
PAF1	Cu, Co, Se, S	As, Mg, Ni
NAF1	-	Cu
NAF2	-	Cu, As, Co, Cr, Mg
NAF3	Cu	Co, Mg
NAF4	Cu, S	Co, Mg, Se
ROM Oxide1	Cu	Co, Mg, Se
ROM Oxide2	Cu	Co, Mg, Se

Table 3: *Elemental compositions of Barbara waste rock and ROM oxide samples*

Element	Unit	Limit of Detection	Elemental Composition							*Median Soil Content	Geochemical Abundance Indices						
			PAF1	NAF1	NAF2	NAF3*	NAF4	ROM1	ROM2		PAF1	NAF1	NAF2	NAF3	NAF4	ROM1	ROM2
Al	%	0.01	5.42	6.87	7.75	6.43	5.88	5.77	6.62	7.1	0	0	0	0	0	0	0
Ca	%	0.01	0.52	0.74	0.52	0.65	2.39	0.68	1.25	1.5	0	0	0	0	0	0	0
Fe	%	0.01	6.94	2.22	5.17	5.40	10.85	7.08	9.69	4	0	0	0	0	0	0	0
K	%	0.01	2.22	3.01	2.65	1.48	2.93	1.48	1.90	1.4	0	0	0	0	0	0	0
Mg	%	0.01	2.01	0.69	4.10	1.67	3.76	2.34	2.73	0.5	**1**	0	**2**	**1**	**2**	**1**	**1**
Na	%	0.01	1.56	2.85	1.49	2.50	0.95	1.51	1.36	0.5	**1**	**1**	0	**1**	0	**1**	0
S	%	0.01	2.49	0.05	0.10	0.02	1.32	0.05	0.16	0.07	**4**	0	0	0	**3**	0	0
As	mg/kg	0.2	53	2	27	9	1	9	11	6	**2**	0	**1**	0	0	0	0
Ba	mg/kg	10	570	880	820	490	470	370	450	500	0	0	0	0	0	0	0
Be	mg/kg	0.05	1	2	2	1	1	1	1	6	0	0	0	0	0	0	0
Cd	mg/kg	0.02	0.08	0.02	0.02	0.03	0.12	0.02	0.04	0.4	0	0	0	0	0	0	0
Co	mg/kg	0.11	179	6	45	62	57	51	85	8	**3**	0	**1**	**2**	**2**	**2**	**2**
Cr	mg/kg	1	59	60	303	111	173	133	156	70	0	0	**1**	0	0	0	0
Cu	mg/kg	0.2	7880	194	223	3150	10550	5320	9470	30	**6**	**2**	**2**	**6**	**6**	**6**	**6**
Hg	mg/kg	0.005	0.008	0.005	0.005	0.005	0.018	0.005	0.014	0.06	0	0	0	0	0	0	0
Mn	mg/kg	5	231	180	412	432	754	441	698	1000	0	0	0	0	0	0	0
Mo	mg/kg	0.05	2	0.6	0.5	1	1.86	2	2	2	0	0	0	0	0	0	0
Ni	mg/kg	0.2	230	4	103	41	60	52	87	50	**1**	0	0	0	0	0	0
P	mg/kg	10	350	300	270	310	450	500	590	800	0	0	0	0	0	0	0
Pb	mg/kg	0.5	3	6	2	4	2	3	3	35	0	0	0	0	0	0	0
Sb	mg/kg	0.05	0.3	0.3	0.3	0.5	0.3	0.4	0.5	1	0	0	0	0	0	0	0
Se	mg/kg	1	7	1	1	1	4	2	3	0.4	**3**	0	0	0	**2**	**1**	**2**
Sn	mg/kg	0.2	1	2	1	1	2.2	1	2	4	0	0	0	0	0	0	0
Th	mg/kg	0.01	13	19	14	14	4	9	7	9	0	0	0	0	0	0	0
U	mg/kg	0.1	4	4	2	3	3	4	4	2	0	0	0	0	0	0	0
Zn	mg/kg	2	15	13	45	11	43	18	20	90	0	0	0	0	0	0	0

* NAF3 - Initially labelled PAF2 when sampled at site but subsequently classified as NAF

GAI Enrichment Factors

GAI = 0 Little or No Enrichment: < 3 times median soil

GAI=1 o, Minor Enrichment: 1=3 to 6 times, 2=6 to 12 times

GAI 3 to Significant Enrichment: 3=12 to 24 times, 4=24 to 48 times, 5= 48 to 96 times, or 6 ≥ 96 times

**** Median soil data from:***

Bowen, H.J.M. (1979) Environmental Chemistry of the Elements. Academic Press, London.

Berkman, D.A. (1976) Field Geologists' Manual, The Australian Institute of Mining and Metallurgy,Australia.

6. COLUMN LEACH TEST METHODOLOGY

6.1. Column Setup and Leaching Regime

The setup of the column leach tests was similar to that which was used for previous samples from Round Oak's Wallace North Project. Each column comprised 2.0 kg (dry weight) of solids housed within a plastic Buchner funnel measuring 174 mm in diameter and 100 mm in height. The funnel configuration provides a free-draining condition and a relatively high exposure area per unit mass of sample, thereby providing conditions amenable to sulphide oxidation.

The column setup at the EGi laboratory is shown in **Figures 9 to 11.** The columns were positioned on a rack beneath heat lamps that maintained a surface temperature of about 30 to 35 ºC for approximately 8 hours each day. The purpose of the lamps was to enhance drying of the samples between water additions to ensure there was air-filled porosity within the samples into which atmospheric oxygen could diffuse, thereby providing conditions amenable to sulphide oxidation.

Figure 9: *Photograph of column leach test setup - side view*

Figure 10: *Photograph of column leach tests - top view*

Figure 11: *Photograph of column housing with crushed sample*

6.2. Leaching Regime

Immediately following setup, each column was flushed with 800 mL of deionised water and first-flush leachates were collected three days later for analysis. Thereafter, the columns operated on a four-week leach cycle. During the first three weeks of each cycle the samples were moistened by a once weekly addition of deionised water at a rate equivalent to 100 mL/kg/week, with almost all the water initially retained by the samples, then lost via evaporation. On the fourth week of each cycle the samples were flushed with deionised water at a rate equivalent to 400 mL/kg/week, and leachates collected over the following few days in plastic containers positioned beneath the columns. The weight of leachate collected was recorded (typically around 500 mL for a 2 kg column) and subsamples then taken for analysis.

6.3. Leachate Analysis

The analysis of leachates included measurements of pH, electrical conductivity (EC), and acidity or alkalinity. A subsample of each leachate was also filtered (0.45 µm Millipore membrane) and preserved prior to despatch to ALS for elemental analysis. Leachates from all columns were analysed for Ag, Al, As, B, Ba, Be, Ca, Cd, Cl, Co, Cr, Cu, F, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Si, Sn, SO_4, Sr, Th, Tl, U and Zn.

7. COLUMN LEACH TEST RESULTS

Leach column testing commenced on 30 August 2019. The initial six samples included NAF3, but the column leach test involving NAF3 was stopped after the leachate collection on Week 8, and replaced by a new column comprising NAF4 which commenced on 29 November 2019. The decision to replace NAF3 with NAF4 provided greater variation in the rock types being tested in that NAF4 had high sulphur, high ANC and high copper content, whereas NAF3 had a low sulphur content similar to NAF2.

7.1. First Flush

The chemistries of the first-flush leachates are given in **Table 4**. The concentrations of sulphate in the initial leachates from PAF1 and NAF4 were significantly higher than for the other samples, consistent with these two samples having much higher sulphur contents than the other samples in the test program (i.e. 61 mg/L for PAF1 and 113 mg/L for NAF4, compared to 2 to 19 mg/L for other samples). Otherwise the chemistries of the first-flush leachates were similar in that they were:

- alkaline (pHs ranging between 7.7 and 8.5 and alkalinities between 28 and 68 mg $CaCO_3$/L),
- low in soluble salts (ECs of 109 to 278 µS/cm),
- had only trace concentrations of aluminium (0.2 to 0.5 mg/L), iron (0.2 to 0.5 mg/L), and manganese (0.01 to 0.07 mg/L), and
- the concentrations of most other dissolved metals and metalloids were typically close to, or below the limits of analytical detection. This included arsenic (≤0.006 mg/L), cadmium (<0.0001 mg/L), chromium (<0.001 mg/L), lead (<0.001 mg/L), mercury (<0.0001 mg/L) and zinc (≤0.008 mg/L).

7.2. Weeks 4 to 52

Leachate assay data for the Barbara column leach tests are tabulated in **Appendix A**. Also, time series plots for leachate pH, EC, acidity/alkalinity, sulphate, calcium, magnesium, iron, aluminium, arsenic, copper, cobalt, manganese and zinc are presented in **Appendix B.** The main findings were as follows:

7.2.1. PAF1 Column

- The pH of leachate from PAF1 remained circum-neutral during the 12 months of testing, signifying the sample was still in the lag phase. This lag is consistent with the findings of the monitored NAG test. The pH fluctuated between 6.8 and 7.7 during the test, and the median was 7.4. Although the pH remained circum-neutral, the alkalinity of leachate was relatively low, fluctuating between 11 to 19 mg $CaCO_3$/L during the 12 month test period.

Table 4: *Composition of initial flush from Barbara column leach tests*

Parameter	Unit	Limit of Reporting	Waste PAF1	Waste NAF1	Waste NAF2	Waste NAF3*	Waste NAF4	ROM OXIDE1	ROM OXIDE2
pH		0.01	7.7	8.5	8.2	7.9	7.9	8.0	8.2
EC	µS/cm	1	231	119	111	109	531	136	278
Alkalinity	mg/L **	1	29	40	31	28	32	34	68
Acidity	mg/L	1	-	-	-	-	-	-	-
Major Elements									
SO4	mg/L	1	61	6	3	2	113	6	19
Cl	mg/L	1	6	6	4	8	28	9	17
Ca	mg/L	1	14	4	4	1	43	3	4
K	mg/L	1	11	11	10	2	17	3	4
Mg	mg/L	1	8	1	1	1	12	3	4
Na	mg/L	1	14	11	7	17	30	22	49
P	mg/L	1	1	1	1	1	<1	1	1
Si	mg/L	0.1	0.7	0.9	0.5	2	0.6	2	3
Minor Elements									
Al	mg/l	0.01	0.2	0.5	0.4	0.3	0.07	0.3	0.4
As	mg/l	0.001	0.001	0.002	0.002	0.006	0.001	0.005	0.005
B	mg/l	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Ba	mg/l	0.001	0.03	0.01	0.02	0.01	0.03	0.01	0.03
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Co	mg/l	0.001	0.04	0.001	0.001	0.003	0.001	0.001	0.002
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.001	0.08	0.01	0.02	0.09	0.005	0.14	0.21
Fe	mg/l	0.05	0.2	0.4	0.3	0.4	0.05	0.4	0.5
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Mn	mg/l	0.001	0.07	0.01	0.01	0.03	0.06	0.03	0.03
Mo	mg/l	0.001	0.003	0.005	0.002	0.002	0.002	0.006	0.007
Ni	mg/l	0.001	0.05	0.001	0.001	0.001	0.005	0.001	0.001
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.01
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.008	0.005	0.005	0.005	0.005	0.005	0.005

* NAF3 - Initially labelled PAF2 when sampled at site but subsequently classified as NAF

** *Alkalinity and acidity expressed as mg CaCO3/L*

*** *Underline indicates concentration is less than the limit of analytical reporting*

- The release of sulphate from PAF1 also remained relatively low during the 12 months, varying between 155 and 334 mg/L, and averaging 233 mg/L. The average sulphate release rate (SRR) for the 12 month was approximately 16 mg/kg/week, which correspond to an intrinsic oxidation rate for sulphide in the column of approximately 2.5×10^{-8} kg O_2/m^3/sec. This represents a relatively slow rate of sulphide oxidation, notwithstanding that the sample contained 2.47 %S almost exclusively as sulphide.
- Even though pyrite oxidation occurred to some extent during the test, albeit at a slow rate, there was no evidence of leaching of iron which, together with sulphate, are the main reaction products from pyrite oxidation. After the initial flush the concentrations of iron in leachate were typically less than the 0.05 mg/L analytical detection limit. Given the sample remained circum-neutral, it can be expected that any iron that was released as a consequence of oxidation of pyrite or chalcopyrite would have re-precipitated within the column as iron oxy-hydroxide, most likely as coatings on particle surfaces.
- Similarly, there was little leaching of copper despite the sample containing significant chalcopyrite and having a total copper content of 7,880 mg/kg. The concentrations of copper in leachate fluctuated between 0.03 to 0.13 mg/L and averaged 0.05 mg/L. The relatively low copper concentrations may partly reflect the low rates of sulphide (chalcopyrite) oxidation during the test period, but the low concentrations are also consistent with the fact that copper, like iron, exhibits very low solubility under circum-neutral and alkaline conditions. Therefore, even though it is likely chalcopyrite was oxidising to some extent it is also likely most of the copper released from the chalcopyrite re-precipitated as copper oxy-hydroxide onto particle surfaces in the column. It is expected much higher copper concentrations would occur in leachate from PAF1 if the test was extended beyond the lag phase and the pH decreased below about 6.
- Other significantly enriched elements in PAF1 include cobalt and selenium, and there was minor sample enrichment with arsenic and nickel. During the 12 month test period the concentrations of arsenic in leachate were less than the analytical detection limit of 0.001 mg/L, and only trace concentrations were recorded for cobalt (average 0.01 mg/L), nickel (average 0.01 mg/L) and selenium (average 0.02 mg/L). Similarly, there was only minor leaching of manganese (average 0.05 mg/L) and aluminium (average 0.05 mg/L).
- The concentrations of other environmentally important metals also remained low, and in most cases the concentrations were less than the analytical detections limits. Such was the case for cadmium (≤0.0002 mg/L), mercury (<0.0001 mg/L), lead (<0.001 mg/L), antimony (<0.001 mg/L), chromium (<0.001 mg/L) tin (<0.001 mg/L), and zinc (<0.005 mg/L).

7.2.2. NAF1 and NAF2 Columns

- Samples NAF1 and NAF2 produced leachates during the 12 month test period that were essentially the same. Leachate from both these columns were slightly alkaline, with pHs typically between 7.3 to 7.6, and alkalinities around 20 to 30 mg $CaCO_3$/L.
- Sulphate concentrations were low, with NAF1 leachate averaging only 20 mg/L and NAF2 only slightly higher at 47 mg/L. The average sulphate release rate for NAF1 was only 2 mg/kg/week, and the corresponding IOR was 3.0×10^{-9} kg O_2/m^3/sec, which is effectively negligible. Similarly, for NAF2 the average sulphate release rate was only 4 mg/kg/week, and the IOR was 5.7×10^{-9} kg O_2/m^3/sec. These results indicate that sulphide oxidation was essentially non-existent in NAF1 and NAF2.
- The major cation in leachates from NAF1 and NAF2 was calcium, averaging 11 mg/L for NAF1 and 21 mg/L for NAF2.
- Although the copper contents of the NAF1 and NAF2 samples were slightly elevated in comparison to typical background soil, there was no evidence of significant copper release, with concentrations in NAF1 leachates

typically less than the detection limit of 0.001 mg/L. With NAF2 the concentrations in leachate typically ranged from 0.001 to 0.005 mg/L.

- Similarly, although the cobalt and chromium contents of NAF2 were slightly elevated compared to background soil there was no evidence of significant leaching of these two metals, with the concentrations in leachate consistently less than the analytical detection limit of 0.001 mg/L.
- However, there was minor leaching of arsenic from NAF2, with concentrations in leachate trending slightly higher during the first six months of testing, then stabilising at around 0.03 mg/L during the second six months.
- The concentrations of other environmentally elements were typically close to, or less than the respective analytical detection limits, including cadmium (<0.0001 mg/L), mercury (<0.0001 mg/L, and lead (0.001 mg/L).

7.2.3. NAF4 Column

- As noted above, the leach test involving NAF3 was terminated after 8 weeks and was replaced by NAF4. This change meant that the leach test on NAF4 trailed the other five column tests by 12 weeks.
- Sample NAF4 differed from NAF1 and NAF2 in that it had much higher contents of sulphur (1.32 %S) and copper (1.05 %Cu). Based on copper content, the NAF4 sample was likely more representative of ore grade material than typical waste rock.
- Like all other samples, the pH of leachate from NAF4 remained slightly alkaline during the 52 weeks of testing, with the pH ranging from 7.1 to 7.6 and the alkalinity remaining relatively steady at between 19 to 30 mg $CaCO_3$/L.
- Although NAF4 remained slightly alkaline, there was significant release of sulphate during the test consistent with sulphide oxidation occurring. Between weeks 4 to 52 the average concentration of sulphate was 452 mg/L, and the average sulphate release rate was 32 mg/kg/week. This corresponds to an IOR of 4.8×10^{-8} kg O_2/m^3/sec, which is in the moderate range for sulphidic rock.
- As well as sulphate there was also significant leaching of calcium, with the concentrations in leachate averaging 146 mg/L during the 52 week test period. The release of calcium likely reflects carbonate minerals within the NAF4 sample reacting with the acidity generated by sulphide oxidation. This process is consistent with NAF4 having a relatively high ANC of 75 kg H_2SO_4/t and a CNV of 61 kg H_2SO_4/t (see Section 5.1). There was also some magnesium release (average 29 mg/L), suggesting the carbonate mineralisation in NAF4 may have been partially dolomitic. This is supported by the acid buffer curve for NAF4 which indicated reactivity consistent with dolomite (see Section 5.5).
- Although NAF4 had a high copper content, the concentrations of copper in leachate were relatively minor at around 0.01 to 0.04 mg/L. The relatively low concentrations of soluble copper can likely be attributed to the circum-neutral pH, with any copper released from oxidation of chalcopyrite being reprecipitated as copper oxy-hydroxide within the column.
- Similarly, there was virtually no leaching of iron. Like copper, any iron released from oxidation of chalcopyrite (or pyrite) would have reprecipitated as iron oxy-hydroxide in-situ under the prevailing circum-neutral pH condition of the test material.
- There was some leaching of manganese (typically around 0.2 mg/L) but otherwise no significant leaching of other environmentally important metals or metalloids, with concentrations in leachate close to, or less than, the analytical limits.

7.2.4. Oxide ROM1 and ROM2 Columns

- The two ROM oxide samples also had high copper contents (0.53 and 0.95 %Cu, respectively), but unlike NAF4 the sulphur contents were low (0.05 and 0.16 %S, respectively). Therefore it can be assumed that the copper occurred in oxide forms, hence the description of these two samples as ROM oxide.
- Both samples remained circum-neutral during the 12 months of testing. The pHs of leachates from both samples fluctuated between 7.3 to 8.0, and the alkalinities averaged at 24 and 34 mg $CaCO_3$/L, respectively.
- There was some release of sulphate during the first few months, but concentrations in leachate decreased with time. Overall, there was only minimal leaching of sulphate from ROM1 (average 23 mg/L), consist with the very low sulphur content of this sample. Sulphate concentrations in leachate from ROM2 were slightly higher (average 62 mg/L), but still relatively low in comparison to what typically occurs with acidic drainage from PAF rock.
- The average sulphate release rate for ROM1 between weeks 4 to 52 was only 1.5 mg/kg/week and the corresponding IOR was only 2.3×10^{-9} kg O_2/m^3/sec. These values are consistent with sulphide oxidation being negligible. The values for ROM2 were only slightly higher at 4.0 mg/kg/week and 6.1×10^{-9} kg O_2/m^3/sec, respectively.
- There was evidence of some leaching of copper, with concentrations in leachate typically varying between 0.1 to 1.0 mg/L. As the copper in ROM1 and ROM2 was probably present in oxide forms, the results for these two samples likely indicate pH-dependent solubility control for copper release. If that was the case, the leaching of copper from ROM Oxide as represented by ROM1 and ROM2 over the long term should not vary significantly above the range exhibited during the test, assuming the pH remains circum-neutral, which would be expected given the low sulphur content and NAF classification.
- Although both ROM oxide samples exhibited minor enrichment with cobalt compared to background soil, there was no evidence of significant leaching, with cobalt concentrations in leachate remaining less than 0.01 mg/L.
- Similarly, there was no evidence of significant leaching of arsenic with concentrations ranging from 0.002 to 0.006 mg/L, and concentrations of cadmium, mercury, lead, and zinc were consistently less than the limits of analytical detection.

8. SUMMARY AND IMPLICATIONS

This report presents the results and findings of column leach tests involving waste rock and ROM oxide samples from the Barbara mine site. The columns were laboratory scale and leaching of the test samples was carried out under controlled conditions. There were six column tests, one involving waste rock that was PAF, three representing NAF waste rock, and two representing ROM oxide. Five tests (PAF1, NAF1, NAF2, ROM1 and ROM2) ran continuously for 12 months. The sixth test initially involved a sample representing low sulphur NAF waste (NAF3) but to expand the geochemical range of test materials this sample was replaced after 8 weeks with a sample representing high sulphur NAF waste (NAF4). The subsequent leaching of NAF4 extended for 12 months. The main findings were as follows:

High Sulphur PAF Waste Rock as Represented by PAF1

The PAF1 sample representing PAF waste rock did not acidify during the 12 months test period, confirming a lag period of at least a year for this type of material. However, there was significant release of sulphate, indicating sulphide oxidation did occur during the test. The lag phase exhibited by PAF1 was consistent with the reaction profiles exhibited by the sample in the monitored NAG test.

Over the 12 month test period the total release of sulphur was equivalent to approximately 0.03 %S. Assuming the sulphur occurred in the sample as pyrite, the release of sulphur equates to an acid generation potential of 0.9 kg H_2SO_4/t. Whilst significant, this amount of acid generation represents only a small portion of the MPA of PAF1 of 75 kg H_2SO_4/t.

The amount of ANC depleted during the test can also be estimated based on leachate alkalinity and the release of calcium and magnesium. These parameters equate to a loss of ANC of 0.9 kg H_2SO_4/t, the same as the acid potential of reacted sulphide.

Therefore, it can be concluded that after 12 months of leaching the PAF1 sample was still in the early stages with respect to sulphide oxidation and acid generation/neutralisation. As there was no evidence of any decrease in leachate pH or alkalinity during the test, and the original ANC of 17 kg H_2SO_4/t was only depleted by 5% during the 12 month period, it is likely that the lag period for waste rock as represented by PAF1 would extend for several years.

It is expected that leaching of copper would remain limited throughout the lag period as the solubility of copper is pH-dependent. Under alkaline conditions, most of the copper that is released as a consequence of oxidation of chalcopyrite will continue to re-precipitate as copper oxy-hydroxide onto waste rock surfaces. It is expected significant copper release will only occur toward the end of the lag phase when the pH of the material begins to decreased below about 6.

High Sulphur NAF Waste Rock as Represented by NAF4

The NAF4 sample represents high sulphur rock that also has moderate to high ANC and is overall NAF. The column leach test on this sample confirmed generation of alkaline drainage during the 12 month test period. There was evidence of a moderate rate of sulphide oxidation but, notwithstanding an ore-grade copper content of 1.06%Cu, there was only limited leaching of copper, with concentrations in leachate around 0.1 to 0.4 mg/L. Given the solubility of copper is pH-dependent, there is no reason to expect any significant increase in the rate of copper leaching from this type of waste rock over the longer term, assuming the material remains circum-neutral. Apart from some copper, there was no evidence of leaching of environmentally important elements such as arsenic, cadmium, mercury, lead, zinc.

Low Sulphur NAF Waste Rock as Represented by NAF1 and NAF2

Samples NAF1 and NAF2 represent typical low sulphur, NAF waste rock at the Barbara site. In most respects, these waste rock samples can be considered geochemically benign in that the sulphide-sulphur contents were negligible and the neutralising capacities were low. Copper was slightly elevated in comparison to typical background soil, as was arsenic in NAF2, but otherwise there were no significant (GAI≥2) elemental enrichments of environmental importance.

The results of the column leach tests were consistent with the benign nature of this type of NAF waste rock. Leachate from both these columns were circum-neutral and there were only low rates of leaching of sulphate. Although copper contents were slightly elevated, there was no evidence of significant copper release, with concentrations in leachates typically less than 0.005 mg/L. However, there was minor leaching of arsenic from NAF2, with concentrations typically around 0.03 mg/L in leachates collected during the latter half of the test. And, as with other samples, the concentrations of other environmentally elements were typically close to, or less than the respective analytical detection limits.

Low Sulphur/High Copper ROM Oxide as Represented by ROM1 and ROM2

The geochemical characteristics of two samples representing ROM oxide were similar to low sulphur NAF waste, except for copper contents which were much higher at approximately 0.53 and 0.95%Cu. Given the low sulphur contents it can be assumed most, and probably all, of the copper occurred in oxide forms. There was some leaching of copper during the column leach tests, with concentrations in leachate typically varying between 0.1 to 1.0 mg/L. Given the weathered nature of ROM Oxide and the likelihood that the solubility of copper in such waste will be pH-dependent, it is reasonable to assume the leaching of copper from material as represented by ROM1 and ROM2 over the long term would remain much the same as the chemistry of leachate from the column tests. That is, slightly alkaline, low in soluble salts, and apart from some copper, have trace concentrations of environmentally important elements including antimony, arsenic, cadmium, cobalt, mercury, lead, selenium and zinc.

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APPENDIX A

Leachate Assay Results for Column Leach Tests

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APPENDIX A-1: Leachate assay results for the Barbara column leach tests: PAF1

Parameters		Sample #16993 - PAF1														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	612	496	489	477	553	555	551	542	543	546	545	549	555	559	535
pH	-	7.7	7.7	7.3	7.3	6.8	7.1	7.2	7.3	7.4	7.4	7.5	7.4	7.4	7.5	7.3
EC	µS/cm	231	496	621	625	381	395	391	429	445	441	436	376	371	366	444
Alkalinity	mg/l	29	15	19	16	18	11	14	14	16	13	15	16	17	22	16
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.07	0.11	0.04	0.04	0.01	0.01	0.04	0.03	0.02	0.02	0.02	0.03	0.04	0.02	0.03
As	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
B	mg/l	0.05	0.05	0.28	0.08	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.07
Ba	mg/l	0.03	0.02	0.04	0.04	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.024
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	44	54	67	40	89	85	76	80	80	77	60	70	67	68
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	6	5	2	1	1	1	1	1	1	1	1	1	1	2
Co	mg/l	0.001	0.013	0.018	0.020	0.007	0.02	0.01	0.01	0.007	0.008	0.008	0.006	0.007	0.007	0.011
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.01	0.13	0.06	0.05	0.03	0.07	0.05	0.04	0.038	0.030	0.033	0.031	0.033	0.028	0.048
F	mg/l	0.3	0.9	1.0	0.8	0.5	0.6	0.4	0.4	0.6	0.3	0.4	0.2	0.3	0.3	0.5
Fe	mg/l	0.05	0.21	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	14	16	14	11	18	15	14	14	15	13	12	12	13	14
Mg	mg/l	12	29	28	30	17	28	20	15	15	14	12	8	8	8	18
Mn	mg/l	0.06	0.14	0.08	0.07	0.03	0.05	0.05	0.04	0.04	0.044	0.04	0.036	0.04	0.04	0.05
Mo	mg/l	0.002	0.006	0.004	0.003	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.003	0.002	0.003	0.003
Na	mg/l	30	19	15	13	6	9	6	5	3	3	2	2	1	1	7
Ni	mg/l	0.005	0.017	0.024	0.027	0.009	0.020	0.012	0.006	0.005	0.004	0.005	0.004	0.004	0.004	0.011
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.06	0.04	0.04	0.02	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02
Si	mg/l	0.6	1.1	1.9	1.5	1.0	1.4	3.4	1.5	1.5	1.8	1.3	1.5	1.5	1.6	1.6
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	247	310	275	157	273	334	265	228	233	185	164	155	197	233
Sr	mg/l	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.10	0.09	0.09	0.08	0.08	0.08	0.10
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-2: Leachate assay results for the Barbara column leach tests: NAF1

Parameters		Sample #16995 - NAF1														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	614	503	496	491	549	551	548	546	549	551	555	557	560	561	540
pH	-	8.5	8.1	7.6	7.5	7.3	7.4	7.4	7.5	7.6	7.6	7.7	7.6	7.6	7.6	7.6
EC	µS/cm	119	126	135	139	105	121	126	142	152	140	139	128	125	131	131
Alkalinity	mg/l	40	26	27	23	19	26	22	19	24	22	23	21	22	25	23
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.1	0.3	0.3	0.3	0.1	0.2	0.2	0.23	0.17	0.19	0.15	0.15	0.16	0.14	0.2
As	mg/l	0.001	0.001	0.002	0.003	0.002	0.003	0.004	0.003	0.003	0.004	0.003	0.003	0.003	0.003	0.003
B	mg/l	0.05	0.05	0.3	0.08	0.05	0.18	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08
Ba	mg/l	0.032	0.003	0.006	0.005	0.003	0.003	0.003	0.005	0.003	0.003	0.003	0.002	0.003	0.002	0.003
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	5	8	10	10	12	10	16	12	14	12	12	14	11	11
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	2	5	1	1	1	1	1	1	1	1	1	1	1	1
Co	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.005	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F	mg/l	0.3	0.2	0.3	0.2	0.1	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Fe	mg/l	0.1	0.2	0.2	0.1	0.05	0.1	0.1	0.1	0.08	0.05	0.08	0.05	0.05	0.05	0.10
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	10	14	6	8	7	4	6	5	5	4	4	3	3	6
Mg	mg/l	12	2	2	1	1	1	1	1	1	1	1	1	1	1	1
Mn	mg/l	0.06	0.07	0.07	0.04	0.03	0.02	0.007	0.005	0.004	0.002	0.002	0.002	0.001	0.001	0.019
Mo	mg/l	0.002	0.015	0.009	0.008	0.008	0.005	0.005	0.007	0.007	0.004	0.003	0.004	0.004	0.004	0.006
Na	mg/l	30	9	5	4	4	6	2	4	2	2	1	1	1	1	3
Ni	mg/l	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1.000
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	0.6	0.9	1.5	0.9	0.7	1.1	3	1.1	0.9	1.1	0.7	1.0	1.0	1.0	1.2
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	19	30	17	24	21	33	36	16	18	12	9	11	10	20
Sr	mg/l	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.006	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.01	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-3: Leachate assay results for the Barbara column leach tests: NAF2

Parameters		Sample #16996 - NAF2														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	602	510	500	496	512	515	520	532	535	539	542	551	559	563	529
pH	-	8.2	8.0	7.5	7.5	7.3	7.4	7.5	7.5	7.6	7.5	7.6	7.5	7.5	7.6	7.5
EC	µS/cm	111	149	179	175	139	141	145	210	222	225	221	196	187	182	182
Alkalinity	mg/l	31	31	29	24	20	22	27	21	23	26	25	23	24	25	25
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.07	0.32	0.29	0.22	0.10	0.18	0.17	0.17	0.14	0.14	0.09	0.15	0.13	0.14	0.17
As	mg/l	0.001	0.006	0.015	0.021	0.018	0.030	0.030	0.033	0.035	0.036	0.029	0.034	0.029	0.029	0.027
B	mg/l	0.05	0.05	0.3	0.1	0.05	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08
Ba	mg/l	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	6	11	17	13	20	21	29	30	35	28	21	23	20	21
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	5	2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1
Co	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.01	0.003	0.005	0.005	0.001	0.004	0.003	0.005	0.004	0.002	0.005	0.003	0.002	0.005	0.004
F	mg/l	0.3	0.3	0.4	0.3	0.1	0.2	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.2
Fe	mg/l	0.1	0.2	0.2	0.1	0.05	0.1	0.1	0.1	0.07	0.06	0.08	0.07	0.07	0.07	0.10
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	16	14	14	10	13	10	9	10	11	9	8	7	7	11
Mg	mg/l	12	3	4	4	3	4	3	4	3	4	3	2	2	2	3
Mn	mg/l	0.06	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.003	0.002	0.002	0.002	0.001	0.001	0.008
Mo	mg/l	0.002	0.01	0.008	0.008	0.005	0.005	0.004	0.007	0.006	0.007	0.004	0.004	0.004	0.005	0.006
Na	mg/l	30	10	6	5	3	4	2	2	2	4	1	1	1	1	3
Ni	mg/l	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.003	0.003	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	0.6	0.9	1.6	1.1	0.9	1.2	3.4	1.4	1.3	1.6	1.2	1.7	1.4	1.4	1.5
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	30	52	52	36	50	65	74	59	64	43	26	30	29	47
Sr	mg/l	0.09	0.01	0.02	0.03	0.02	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.02	0.02	0.03
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-4: Leachate assay results for the Barbara column leach tests: NAF3 (previously PAF2)

Parameters		Sample #16994 - NAF3														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	609	510	499	Column terminated	-	-	-	-	-	-	-	-	-	-	505
pH	-	7.9	8.1	7.7		-	-	-	-	-	-	-	-	-	-	7.9
EC	µS/cm	109	101	96		-	-	-	-	-	-	-	-	-	-	99
Alkalinity	mg/l	28	28	34		-	-	-	-	-	-	-	-	-	-	31
Acidity	mg/l	-	-	-		-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Al	mg/l	0.07	0.4	1.0		-	-	-	-	-	-	-	-	-	-	0.7
As	mg/l	0.001	0.01	0.01		-	-	-	-	-	-	-	-	-	-	0.012
B	mg/l	0.05	0.05	0.3		-	-	-	-	-	-	-	-	-	-	0.16
Ba	mg/l	0.03	0.009	0.01		-	-	-	-	-	-	-	-	-	-	0.011
Be	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Ca	mg/l	43	1	1		-	-	-	-	-	-	-	-	-	-	1
Cd	mg/l	0.0001	0.0001	0.0001		-	-	-	-	-	-	-	-	-	-	0.0001
Cl	mg/l	28	5	3		-	-	-	-	-	-	-	-	-	-	4
Co	mg/l	0.001	0.003	0.003		-	-	-	-	-	-	-	-	-	-	0.003
Cr	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Cu	mg/l	0.005	0.1	0.2		-	-	-	-	-	-	-	-	-	-	0.14
F	mg/l	0.3	0.8	0.8		-	-	-	-	-	-	-	-	-	-	0.8
Fe	mg/l	0.05	0.5	1.1		-	-	-	-	-	-	-	-	-	-	0.8
Hg	mg/l	0.0001	0.0001	0.0001		-	-	-	-	-	-	-	-	-	-	0.0001
K	mg/l	17	1	3		-	-	-	-	-	-	-	-	-	-	2
Mg	mg/l	12	1	1		-	-	-	-	-	-	-	-	-	-	1
Mn	mg/l	0.06	0.02	0.02		-	-	-	-	-	-	-	-	-	-	0.02
Mo	mg/l	0.002	0.01	0.01		-	-	-	-	-	-	-	-	-	-	0.011
Na	mg/l	30	16	15		-	-	-	-	-	-	-	-	-	-	16
Ni	mg/l	0.005	0.001	0.002		-	-	-	-	-	-	-	-	-	-	0.002
P	mg/l	1	1	1		-	-	-	-	-	-	-	-	-	-	1
Pb	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Sb	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Se	mg/l	0.01	0.01	0.01		-	-	-	-	-	-	-	-	-	-	0.01
Si	mg/l	1	3	5		-	-	-	-	-	-	-	-	-	-	3.965
Sn	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
SO_4	mg/l	113	6	8		-	-	-	-	-	-	-	-	-	-	7
Sr	mg/l	0.09	0.002	0.003		-	-	-	-	-	-	-	-	-	-	0.003
Th	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Tl	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
U	mg/l	0.001	0.001	0.001		-	-	-	-	-	-	-	-	-	-	0.001
Zn	mg/l	0.005	0.005	0.005		-	-	-	-	-	-	-	-	-	-	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-5: Leachate assay results for the Barbara column leach tests: NAF4

Parameters		Sample #17920 - NAF4														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	593	552	561	552	556	554	558	552	556	561	560	563	561	566	558
pH	-	7.9	7.1	7.3	7.4	7.4	7.6	7.5	7.5	7.4	7.4	7.6	7.5	7.5	7.6	7.4
EC	µS/cm	531	649	616	611	776	795	784	769	711	689	655	550	530	530	667
Alkalinity	mg/l	32	20	24	19	21	23	28	25	24	26	30	30	29	28	25
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.07	0.02	0.04	0.01	0.02	0.02	0.02	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.02
As	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
B	mg/l	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Ba	mg/l	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.03	0.02	0.02	0.02	0.02
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	57	150	170	144	162	165	217	167	103	147	160	131	122	146
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	30	34	27	14	6	3	2	1	1	1	1	1	1	9
Co	mg/l	0.001	0.001	0.001	0.002	0.0	0.002	0.003	0.005	0.004	0.002	0.003	0.003	0.002	0.002	0.002
Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.005	0.009	0.02	0.02	0.02	0.026	0.026	0.036	0.026	0.021	0.023	0.017	0.014	0.019	0.021
F	mg/l	0.3	0.3	0.6	0.6	0.6	0.8	0.5	0.1	0.4	0.3	0.4	0.4	0.4	0.3	0.4
Fe	mg/l	0.05	0.05	0.11	0.05	0.06	0.05	0.05	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.06
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	17	30	24	22	22	22	25	23	14	18	18	17	16	21
Mg	mg/l	12	22	38	40	35	37	36	42	28	14	22	22	19	18	29
Mn	mg/l	0.06	0.07	0.1	0.2	0.2	0.21	0.21	0.38	0.26	0.13	0.23	0.19	0.13	0.13	0.19
Mo	mg/l	0.002	0.004	0.003	0.004	0.003	0.003	0.002	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.002
Na	mg/l	30	32	37	32	21	15	9	7	4	2	2	1	1	1	13
Ni	mg/l	0.005	0.001	0.002	0.001	0.001	0.001	0.001	0.002	0.003	0.001	0.002	0.002	0.001	0.001	0.001
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	0.6	0.5	1.0	2.5	0.9	0.9	1.1	1.0	1.0	0.7	1.0	1	1	1	1.0
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	224	482	615	533	551	531	628	499	244	443	434	365	331	452
Sr	mg/l	0.09	0.11	0.19	0.21	0.15	0.16	0.14	0.17	0.14	0.07	0.11	0.10	0.08	0.08	0.13
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-6: Leachate assay results for the Barbara column leach tests: ROM1

Parameters		Sample #16997 - ROM1														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	603	499	503	499	495	500	510	521	525	528	536	540	550	553	520
pH	-	8.0	8.0	7.8	7.7	7.3	7.3	7.4	7.5	7.6	7.5	7.6	7.6	7.5	7.7	7.6
EC	µS/cm	136	131	185	183	158	162	169	141	156	155	149	138	129	128	153
Alkalinity	mg/l	34	30	25	22	20	24	25	23	25	24	26	24	25	24	24
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.1	0.7	2	0.5	0.4	0.7	1	0.6	0.9	0.9	1.0	0.7	0.8	0.71	0.86
As	mg/l	0.001	0.005	0.006	0.005	0.004	0.006	0.006	0.004	0.004	0.004	0.003	0.004	0.003	0.003	0.004
B	mg/l	0.05	0.05	0.3	0.2	0.09	0.3	0.1	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.10
Ba	mg/l	0.03	0.02	0.04	0.03	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.03
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	2	4	6	5	5	3	3	3	2	3	2	2	3	3
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	3	2	2	1	3	1	1	1	1	1	1	1	1	1
Co	mg/l	0.001	0.002	0.005	0.002	0.001	0.003	0.004	0.004	0.006	0.008	0.006	0.005	0.007	0.007	0.005
Cr	mg/l	0.001	0.001	0.003	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.002	0.002	0.004	0.001	0.002
Cu	mg/l	0.005	0.4	0.6	0.3	0.1	0.4	0.5	0.5	0.8	1.0	0.8	0.6	1.0	0.8	0.6
F	mg/l	0.3	2	2	1	1	1	0.7	0.5	0.8	0.5	0.1	0.3	0.3	0.3	0.8
Fe	mg/l	0.05	1	3	0.6	0.5	0.9	1.5	0.8	1.2	1.1	1.4	0.9	1.1	0.96	1.1
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	3	4	4	4	5	3	3	3	3	3	3	3	3	3
Mg	mg/l	12	2	4	6	5	5	3	2	3	2	3	2	3	3	3
Mn	mg/l	0.06	0.04	0.05	0.02	0.01	0.03	0.04	0.05	0.06	0.08	0.07	0.05	0.07	0.07	0.05
Mo	mg/l	0.002	0.02	0.01	0.01	0.009	0.006	0.004	0.003	0.004	0.002	0.001	0.001	0.001	0.001	0.005
Na	mg/l	30	18	24	24	18	16	13	10	10	8	7	6	6	6	13
Ni	mg/l	0.005	0.001	0.003	0.001	0.001	0.002	0.002	0.001	0.002	0.002	0.003	0.001	0.004	0.002	0.002
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	1	5	6	6	6	7	14	5	5	6	4	4	4	4	6
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	22	62	58	44	31	32	16	12	8	5	4	4	4	23
Sr	mg/l	0.09	0.008	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Th	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

APPENDIX A-7: Leachate assay results for the Barbara column leach tests: ROM2

Parameters		Sample #16998 - ROM2														Average (wks 4-52)
		Initial	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32	Week 36	Week 40	Week 44	Week 48	Week 52	
Volume	mls	611	509	502	497	508	510	516	525	521	525	531	540	545	551	522
pH	-	8.2	8.0	7.6	7.6	7.51	7.55	7.58	7.6	7.6	7.5	7.5	7.5	7.4	7.5	7.6
EC	µS/cm	278	318	348	342	330	339	341	275	286	288	280	255	225	221	296
Alkalinity	mg/l	68	51	40	37	37	32	30	28	33	30	31	29	28	32	34
Acidity	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ag	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	mg/l	0.1	0.8	2.0	0.2	0.3	0.3	0.4	0.2	0.3	0.6	0.5	0.4	0.6	0.3	0.5
As	mg/l	0.001	0.006	0.006	0.003	0.003	0.003	0.004	0.003	0.003	0.004	0.003	0.003	0.002	0.002	0.003
B	mg/l	0.05	0.05	0.2	0.1	0.06	0.07	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.07
Ba	mg/l	0.03	0.03	0.04	0.03	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.03
Be	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Ca	mg/l	43	5	7	12	12	10	9	8	10	6	7	6	6	7	8
Cd	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cl	mg/l	28	3	3	1	1	1	1	1	1	1	1	1	1	1	1
Co	mg/l	0.001	0.004	0.004	0.001	0.001	0.001	0.001	0.001	0.002	0.005	0.004	0.003	0.006	0.003	0.003
Cr	mg/l	0.001	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu	mg/l	0.005	0.5	0.5	0.1	0.1	0.2	0.2	0.2	0.2	0.6	0.5	0.3	0.7	0.3	0.3
F	mg/l	0.3	3	2	2	1.4	1.3	1.0	0.8	1.2	0.7	0.1	0.4	0.4	0.4	1.1
Fe	mg/l	0.05	1	2	0.3	0.3	0.4	0.4	0.3	0.3	0.6	0.7	0.5	0.7	0.5	0.6
Hg	mg/l	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	mg/l	17	5	8	7	8	9	7	5	6	5	4	5	4	4	6
Mg	mg/l	12	5	8	10	12	10	8	7	8	5	6	5	5	5	7
Mn	mg/l	0.06	0.04	0.03	0.006	0.002	0.01	0.01	0.01	0.012	0.04	0.03	0.02	0.05	0.022	0.021
Mo	mg/l	0.002	0.01	0.01	0.008	0.007	0.005	0.003	0.003	0.004	0.002	0.001	0.001	0.001	0.001	0.005
Na	mg/l	30	47	45	41	34	27	24	19	20	13	12	10	8	8	24
Ni	mg/l	0.005	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001
P	mg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sb	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Se	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l	0.6	6	6	5	5	5	17	4	4	5	3	4	3	4	5.463
Sn	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_4	mg/l	113	79	120	121	115	77	88	63	55	25	19	15	13	20	62
Sr	mg/l	0.09	0.02	0.04	0.05	0.04	0.03	0.04	0.03	0.04	0.02	0.03	0.03	0.02	0.03	0.031
Th	mg/l	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tl	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
U	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zn	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Underline indicates that the concentration is less than the limit of detection

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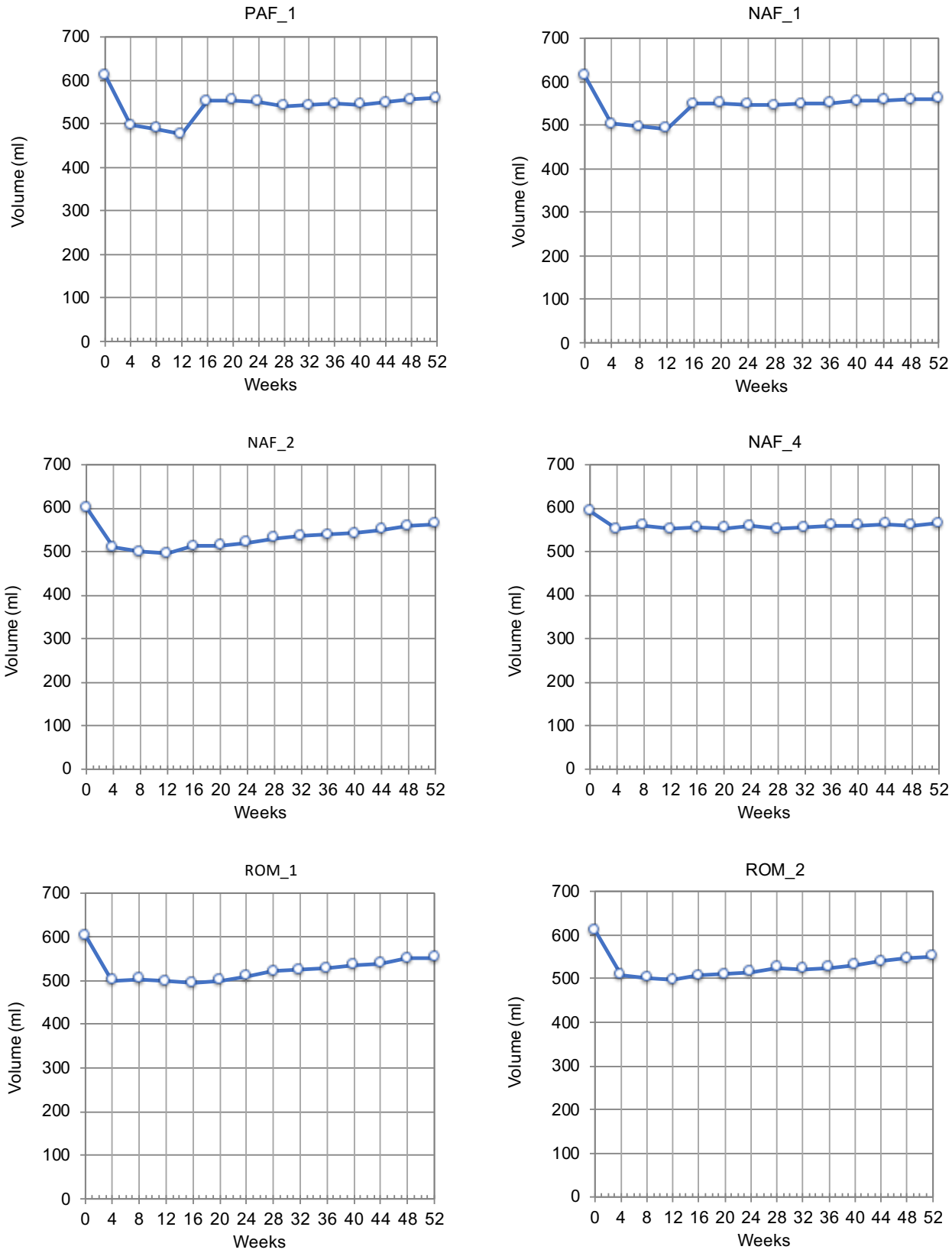
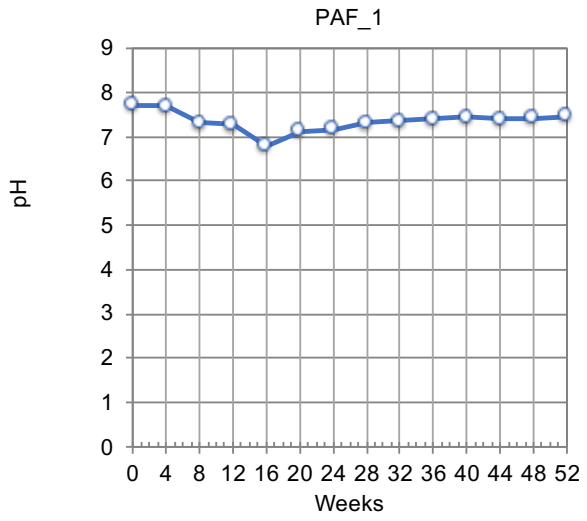
APPENDIX B

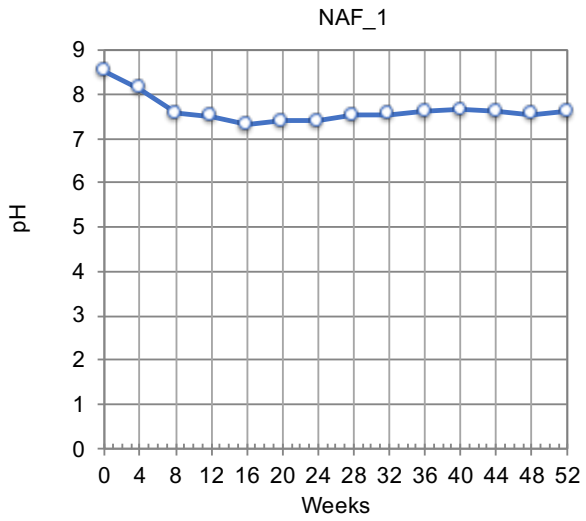
Time Series Plots for Selected Column Leachate Parameters

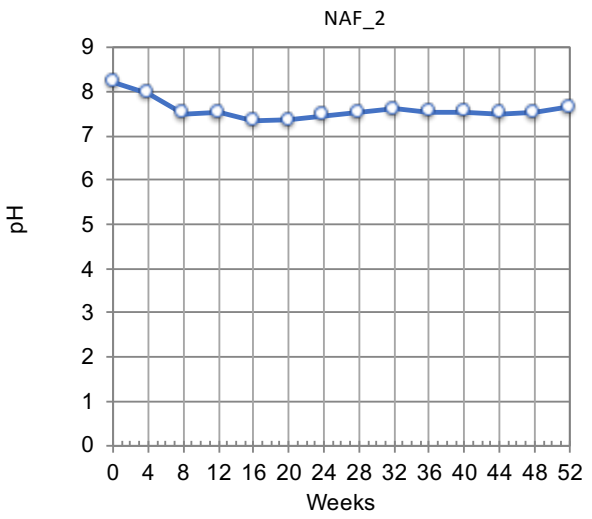
BARBARA COPPER PROJECT

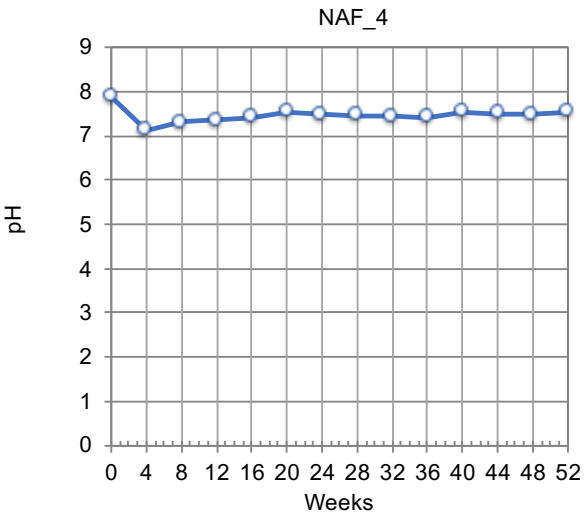


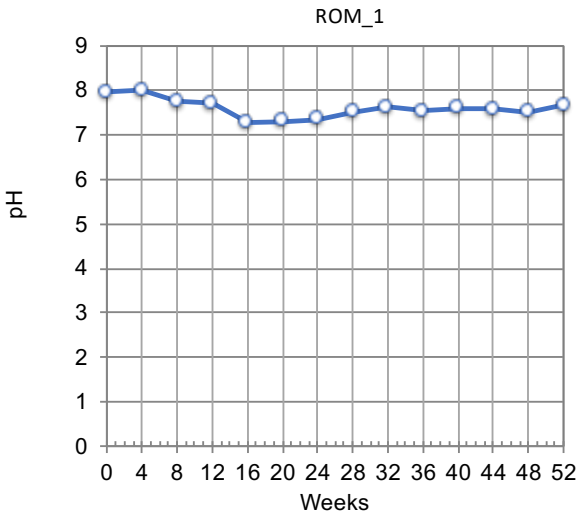
APPENDIX B: Leachate quality versus time for Barbara column leach tests
Volume (ml)

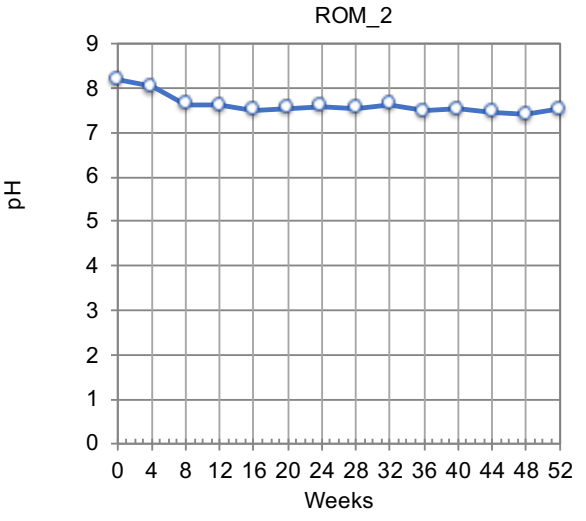






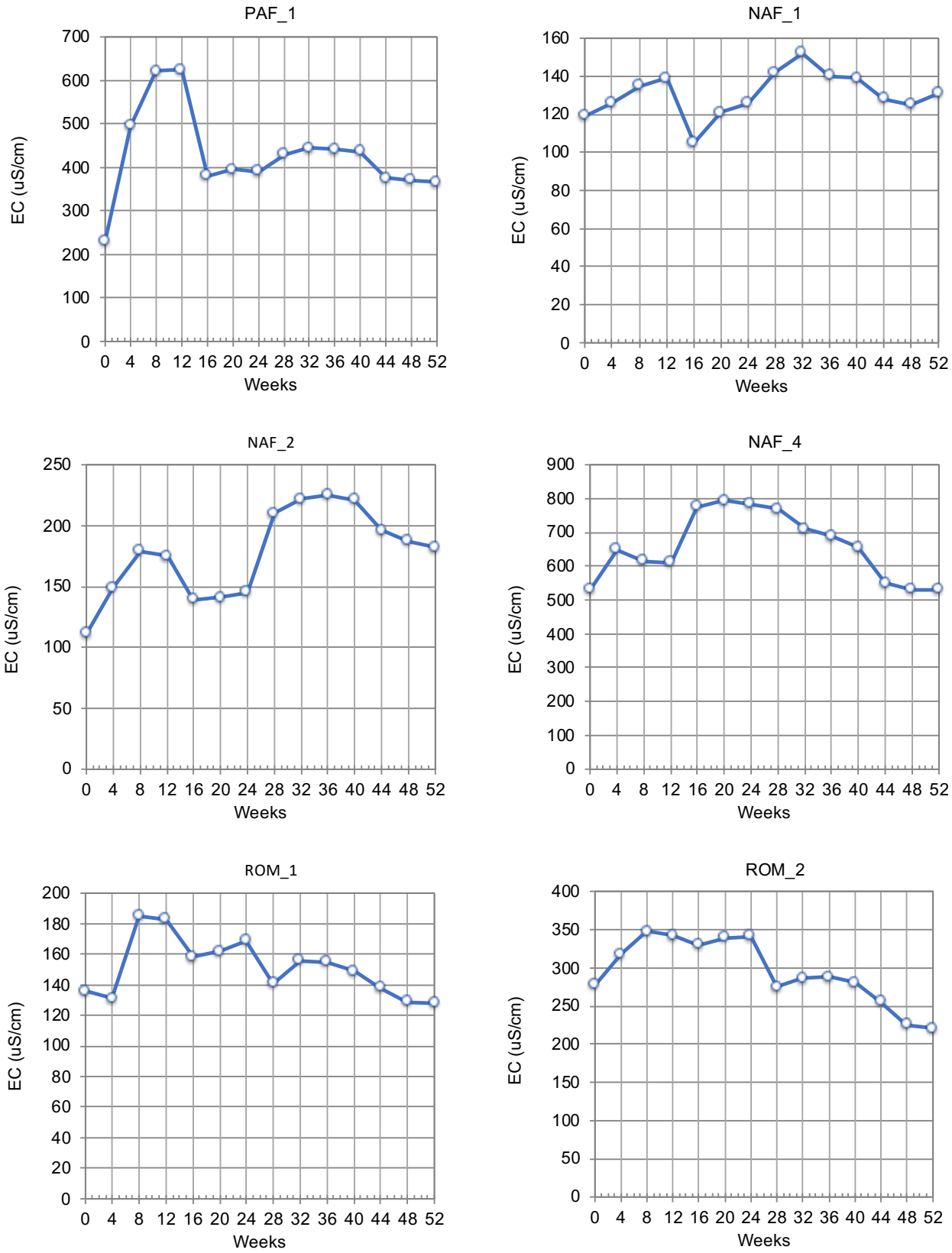




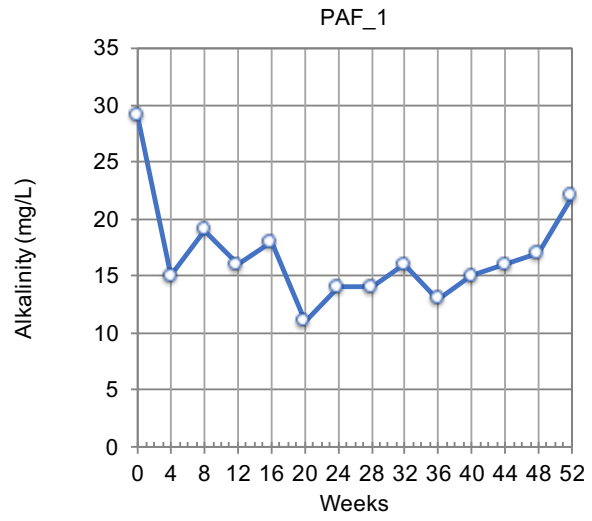


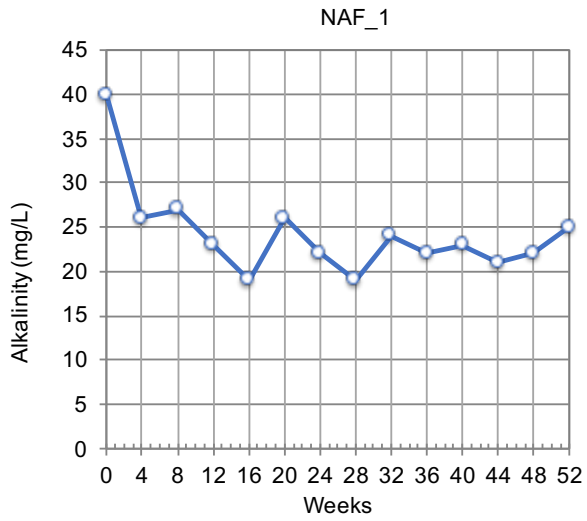
APPENDIX B: Leachate quality versus time for Barbara column leach tests

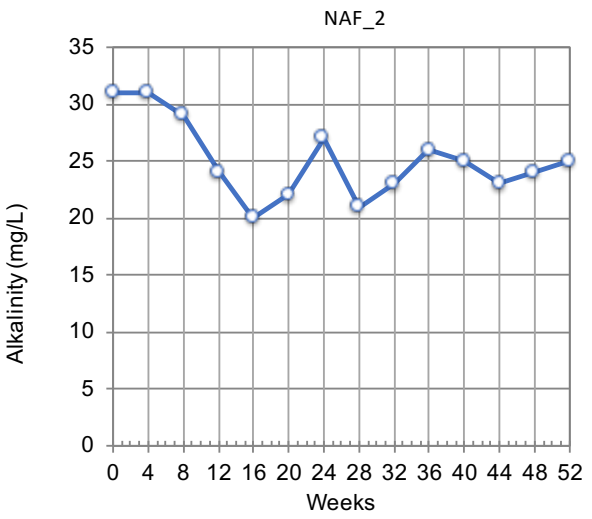
pH

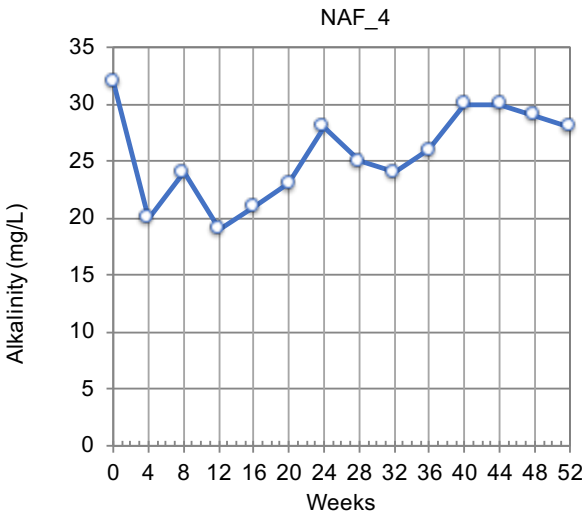


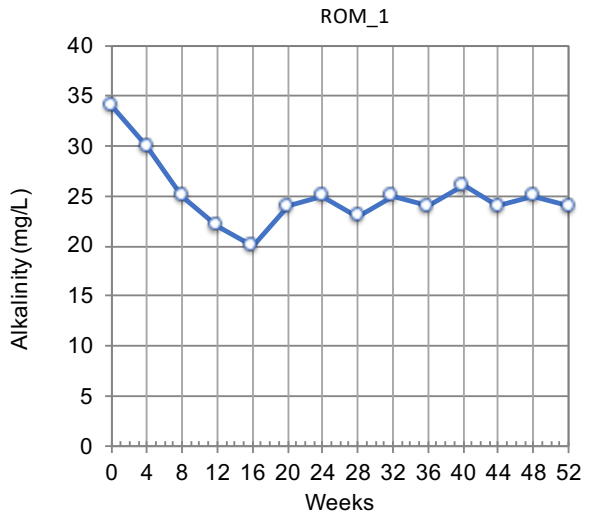
APPENDIX B: Leachate quality versus time for Barbara column leach tests
EC (uS/cm)

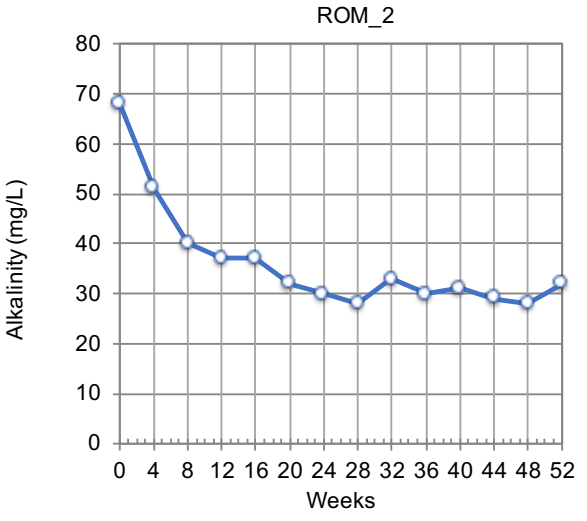




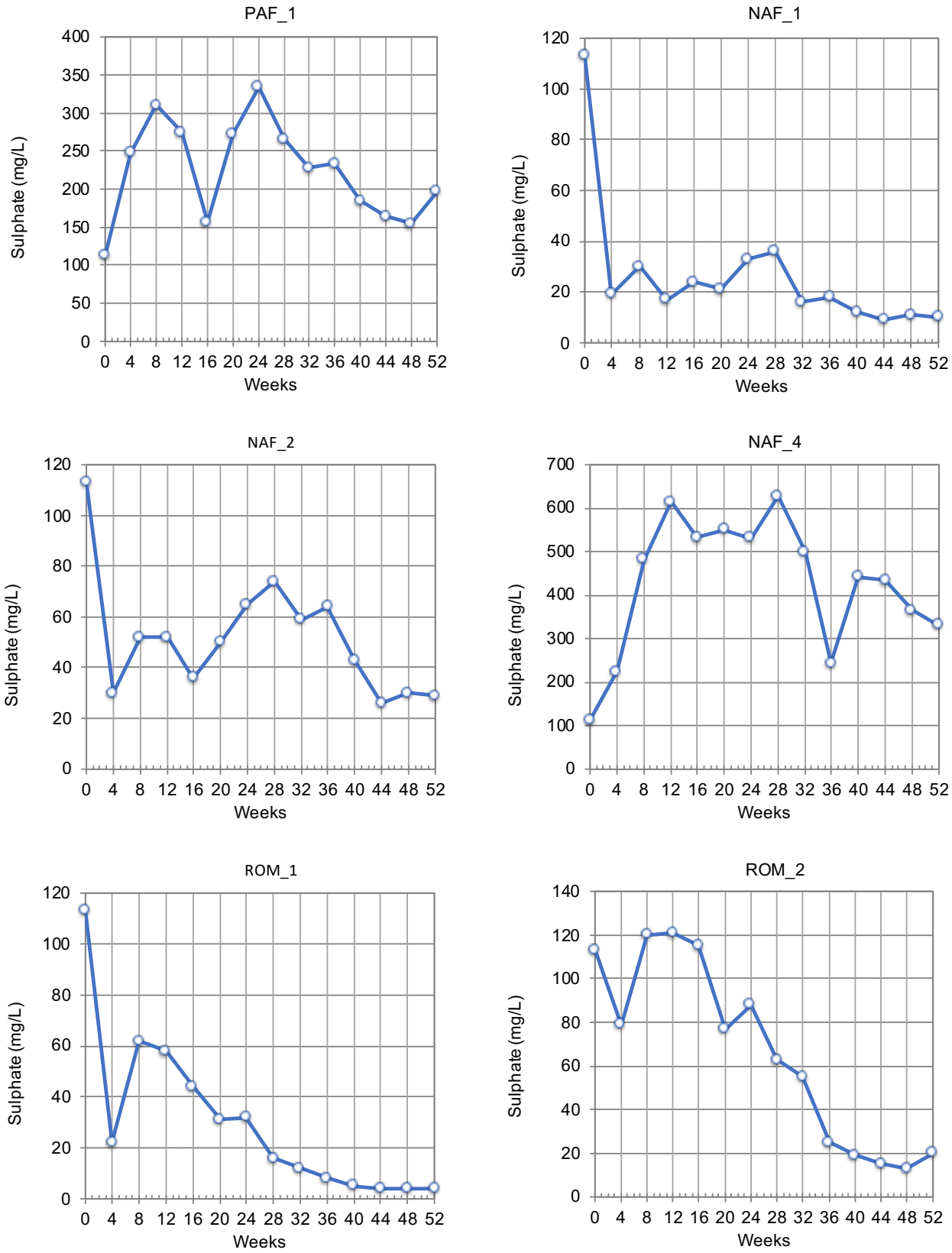




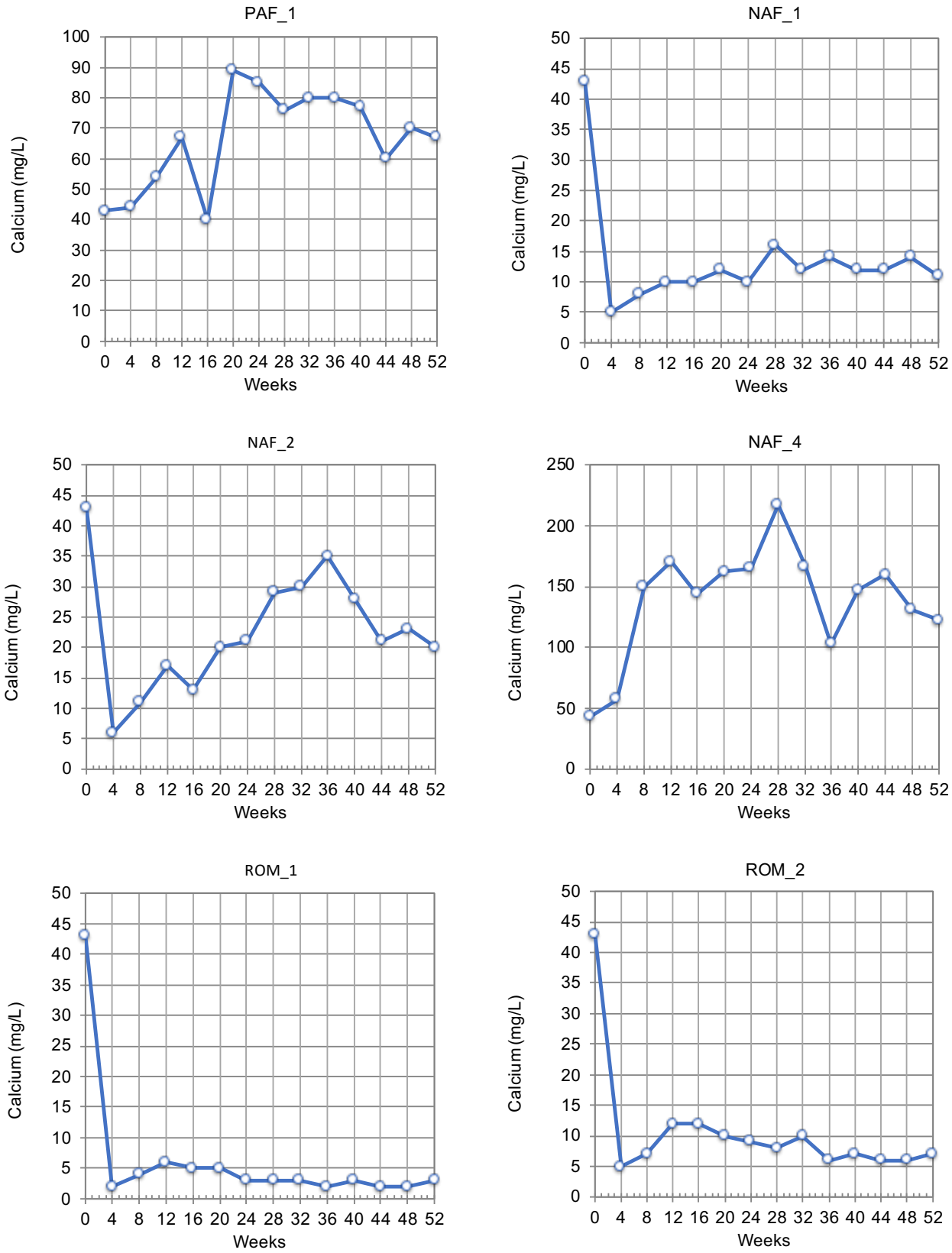




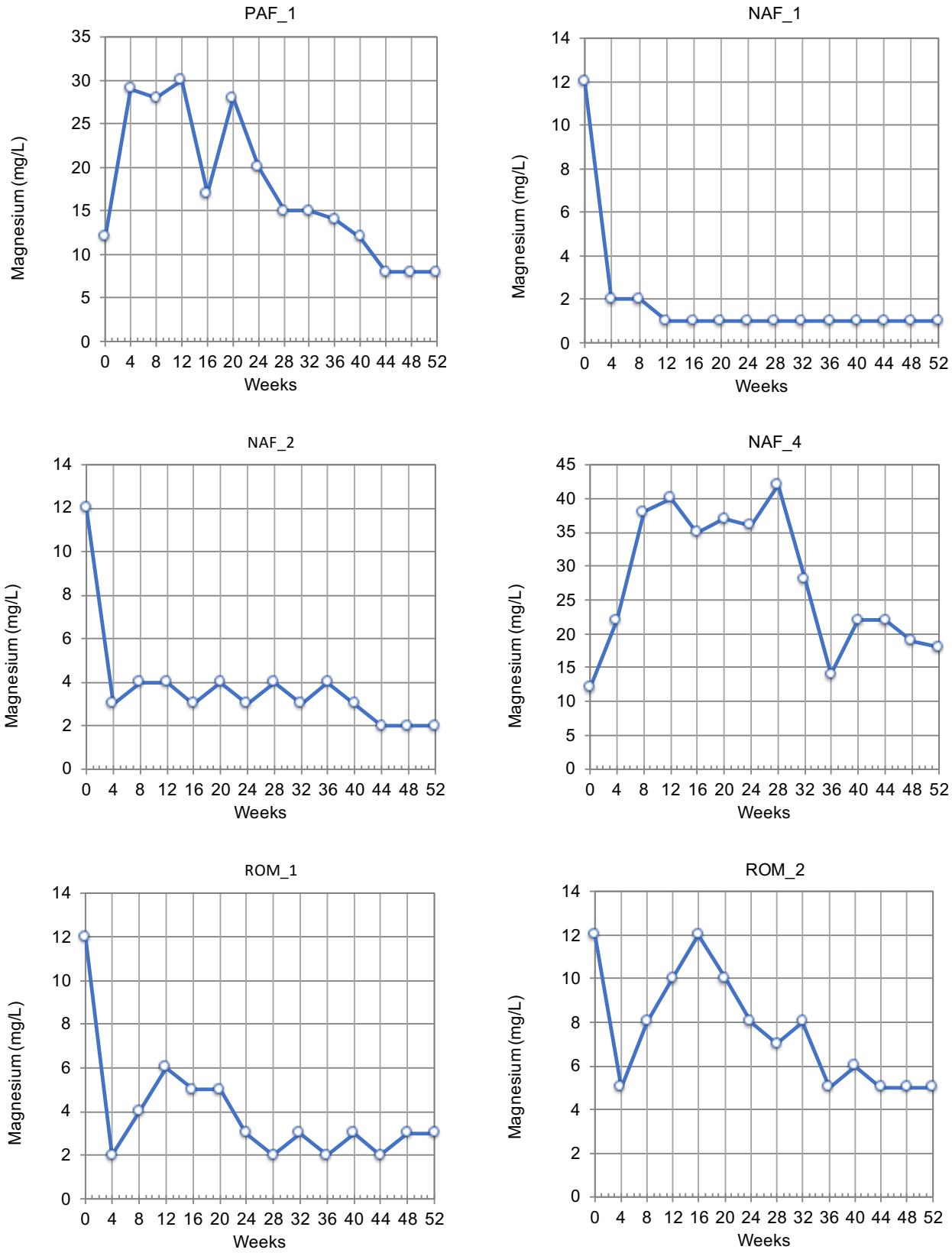
APPENDIX B: Leachate quality versus time for Barbara column leach tests
Alkalinity (mg/L)



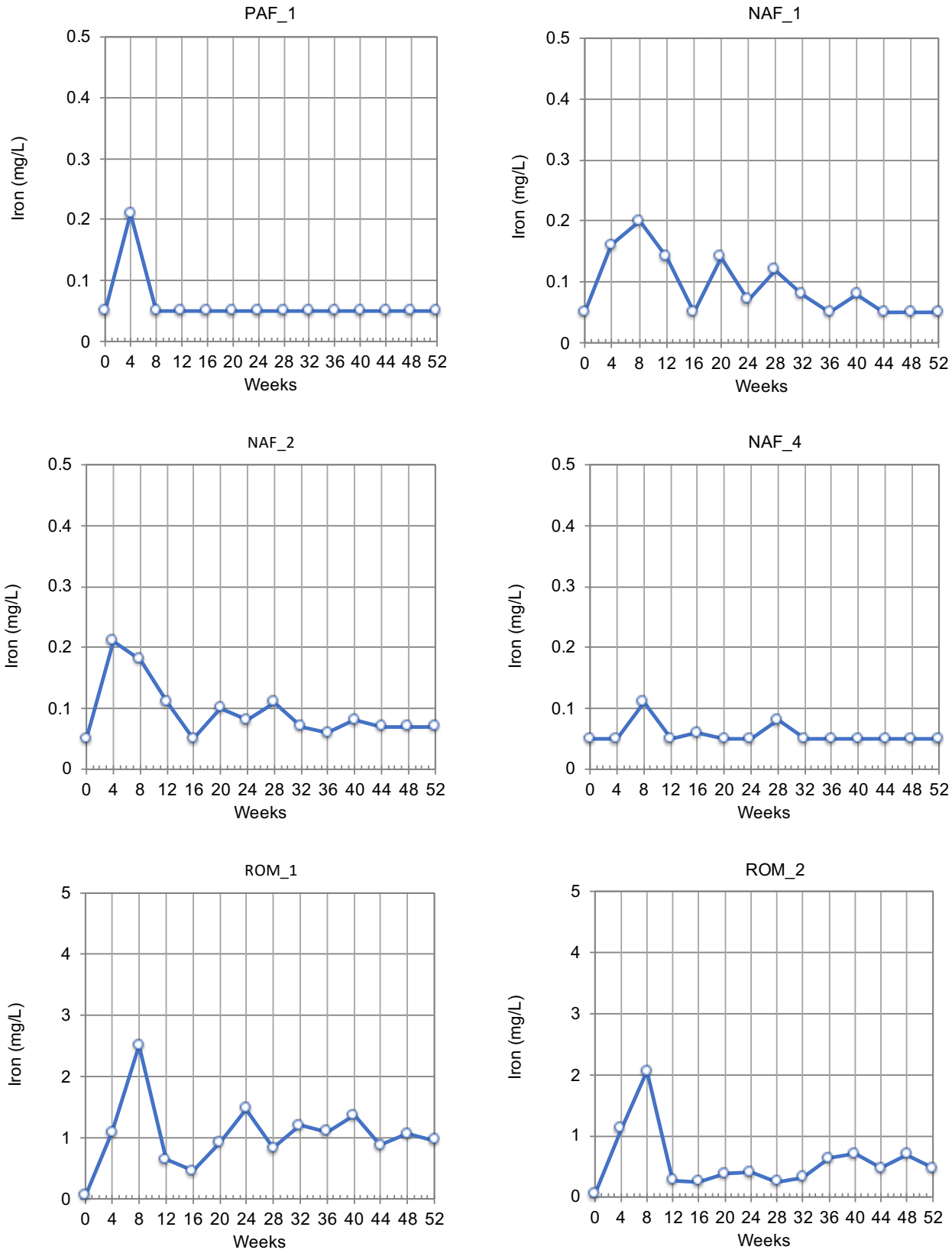
APPENDIX B: Leachate quality versus time for Barbara column leach tests
Sulphate (mg/L)



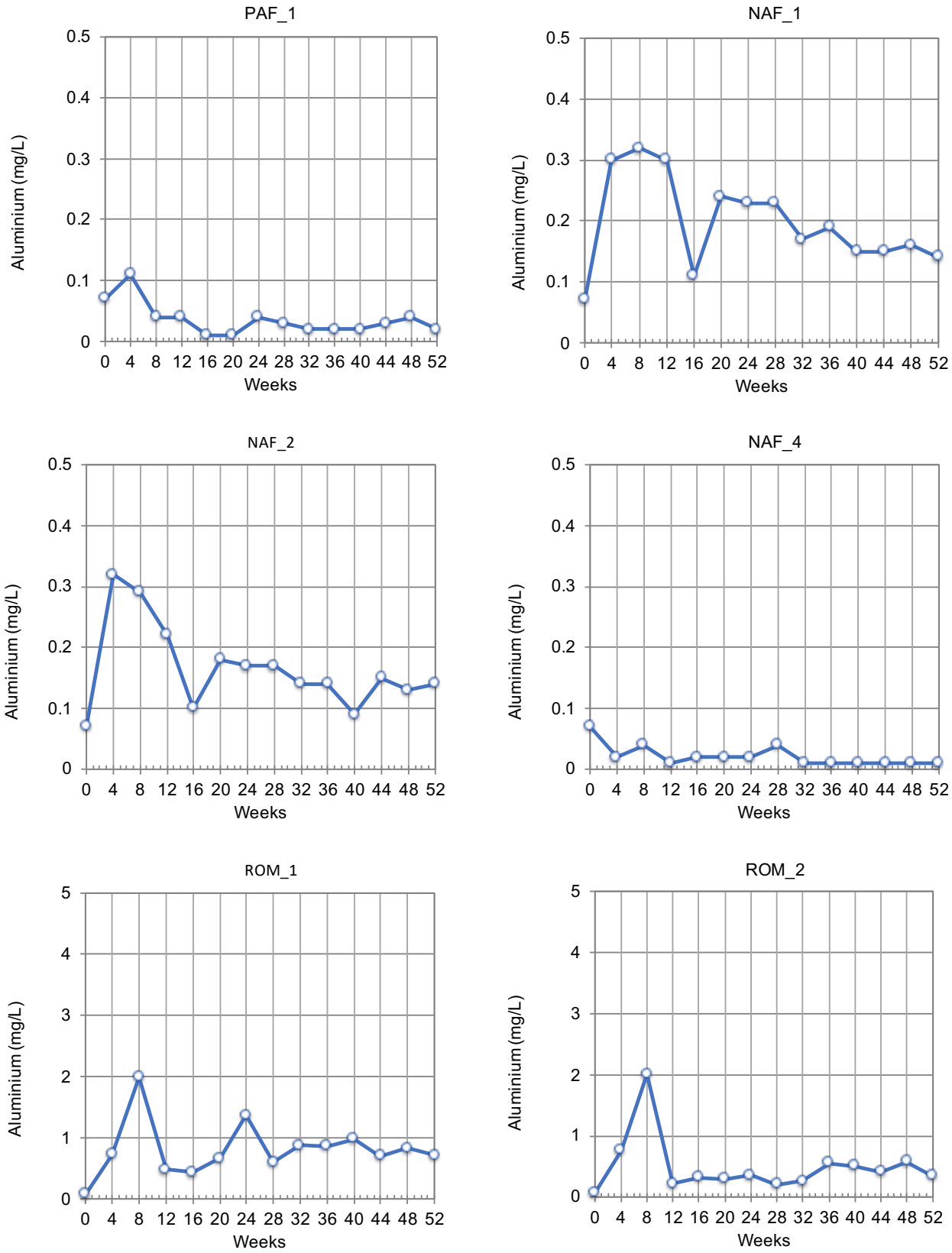
APPENDIX B: Leachate quality versus time for Barbara column leach tests
Calcium (mg/L)



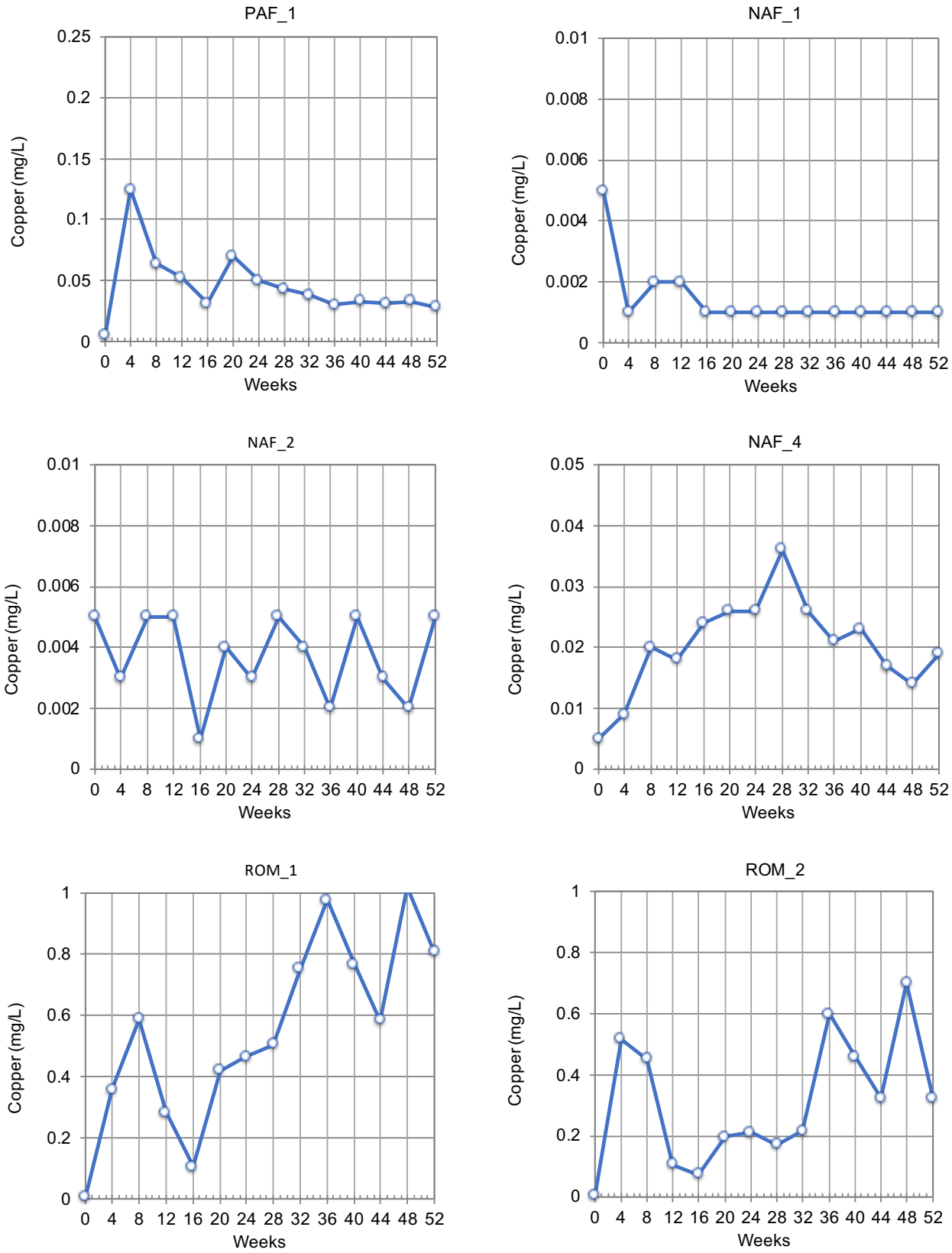
APPENDIX B: Leachate quality versus time for Barbara column leach tests
Magnesium (mg/L)



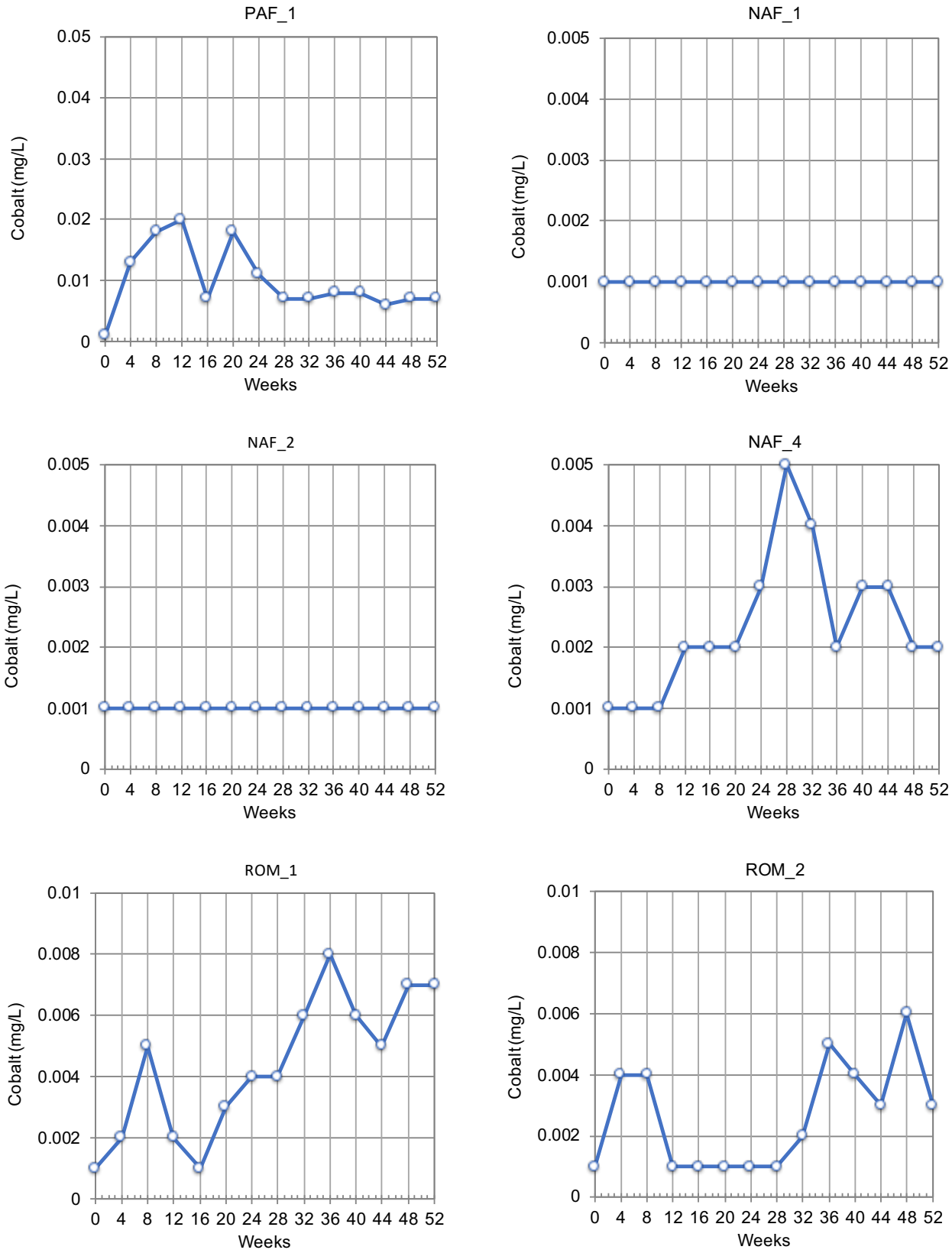
APPENDIX B: Leachate quality versus time for Barbara column leach tests
Iron (mg/L)



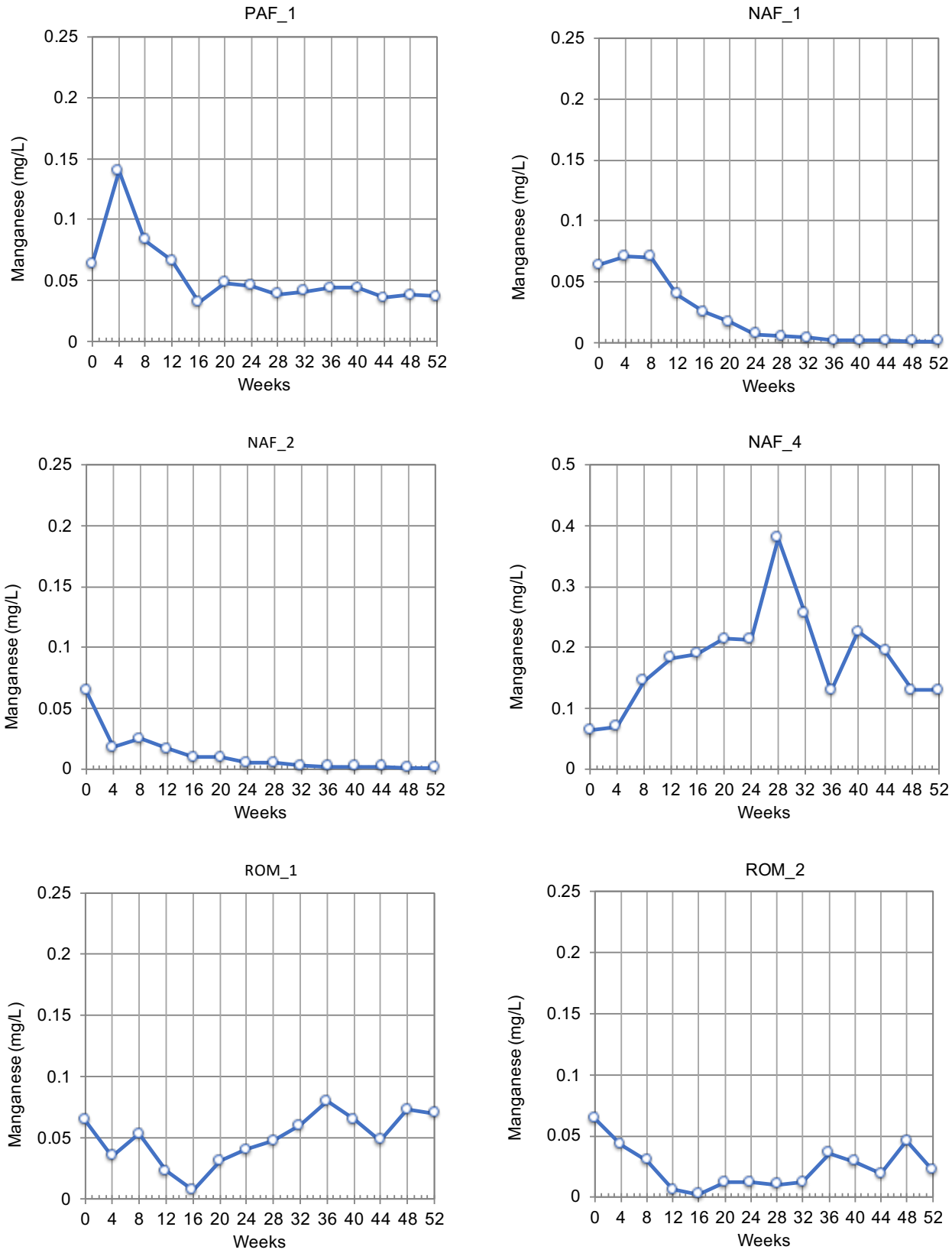
APPENDIX B: Leachate quality versus time for Barbara column leach tests
Aluminium (mg/L)



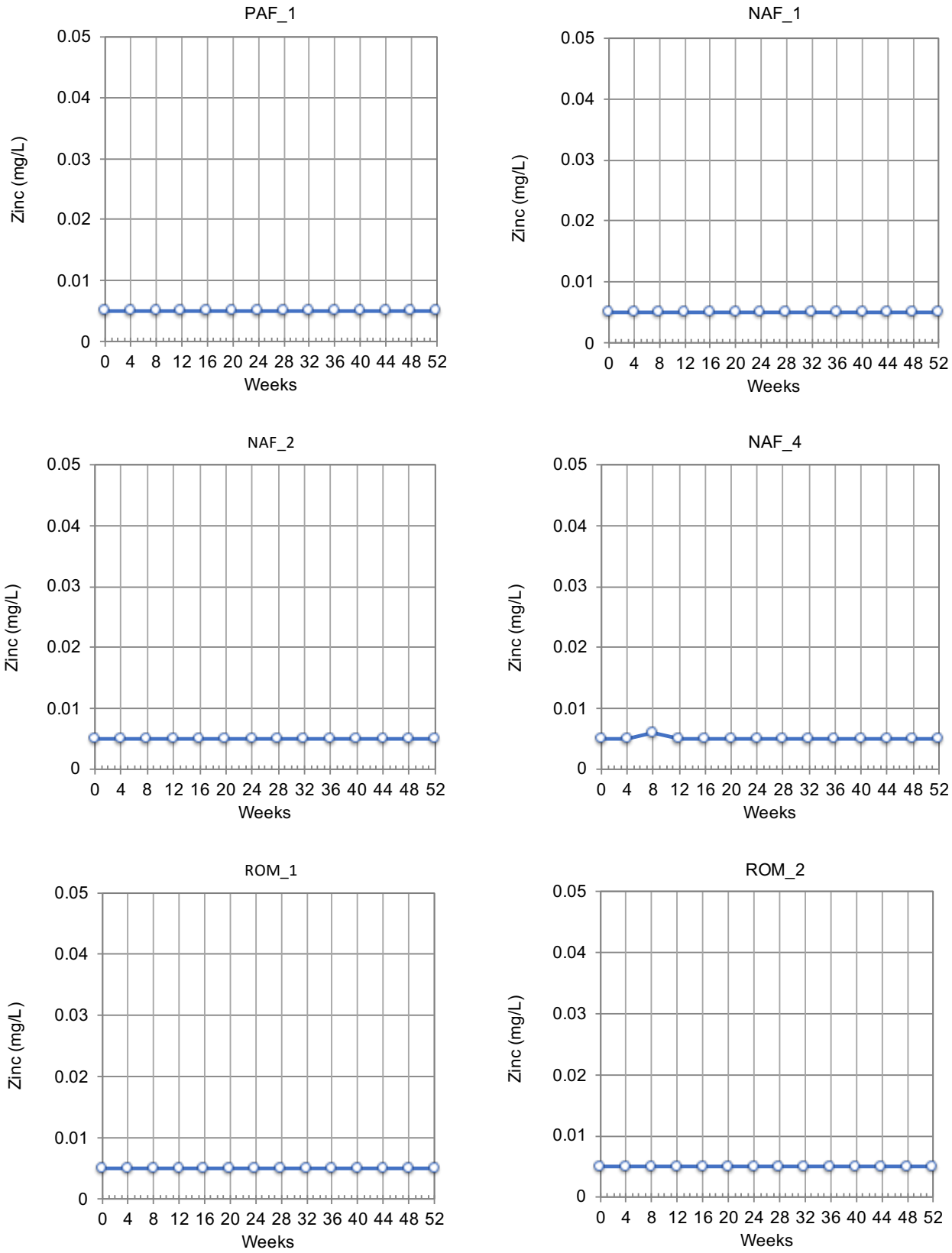
APPENDIX B: Leachate quality versus time for Barbara column leach tests
Copper (mg/L)



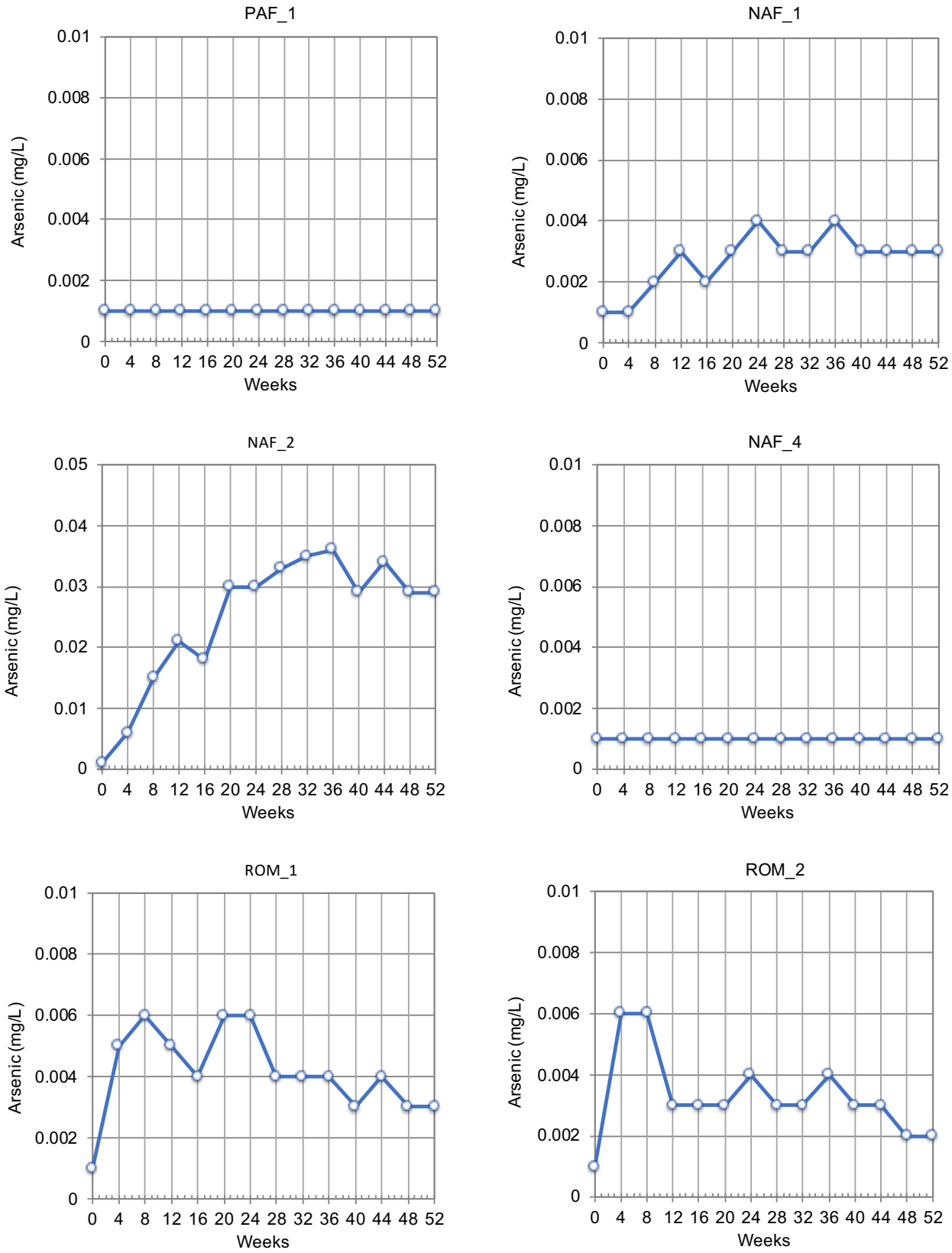
APPENDIX B: Leachate quality versus time for Barbara column leach tests
Cobalt (mg/L)



APPENDIX B: Leachate quality versus time for Barbara column leach tests
Manganese (mg/L)



APPENDIX B: Leachate quality versus time for Barbara column leach tests
Zinc (mg/L)



APPENDIX B: Leachate quality versus time for Barbara column leach tests
Arsenic (mg/L)

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AIR QUALITY MONITORING PROGRAM

VERSION	DESCRIPTION	POSITION	REVIEWER	DATE

TABLE OF CONTENTS

1 INTRODUCTION 3
1.1 Purpose 3
1.2 Scope 3
1.3 Round Oak Document Library 3
2 AIR QUALITY CRITERIA 3
2.1 Legislation and Standards 3
2.2 Environmental Authority Trigger Levels 4
3 AIR QUALITY MANAGEMENT 4
3.1 Air Quality Impact Assessment 4
3.2 Dust Mitigation Measures 5
4 AIR QUALITY MONITORING 7
4.1 Dust Deposition Gauges 7
4.2 Gravimetric Dust Monitoring 9
4.3 Compliants ManAgement 9
5 PEOPLE 10
5.1 Organisational Structure and Accountability 10
6 RISK IDENTIFICATION AND ASSESSMENT 11
7 REPORTING 11
8 CHANGE MANAGEMENT 12

1 INTRODUCTION

This Air Quality Monitoring Program (AQMP) has been designed specifically for the Barbara Copper Project (the Project) by Round Oak Minerals Pty Ltd (ROM). The AQMP was prepared to provide guidance for the management of the site and to help meet the Projects environmental conditions set in the Environmental Authority (EA) EPML02840015.

The Project is located approximately 40 kilometres (km) north east of Mt Isa. It is located within the Mt Isa City Council area. The main objective for the AQMP is to ensure that emissions from the Project do not cause unacceptable impacts to the surrounding community and environment. This will be accomplished by establishing an air quality monitoring protocol to evaluate compliance against relevant criteria. As the Project progresses the AQMP will be updated as necessary.

1.1 PURPOSE

The overall purpose of the AQMP Is to:

- Manage and minimise the impact of dust emissions from the Project on the community and environment;
- Establish an air quality monitoring program to assess the impacts of mining construction and operations on surrounding sensitive receptors against the specific air quality criteria set out in Schedule B of the Project's approval conditions (the EA);
- Investigate complaints relating to dust in a timely manner and devise mitigation measures that deal effectively with the causes of legitimate complaints;
- Detail actions and responsibilities in the event of an exceedance of a dust trigger level or a legitimate complaint; and
- Outline investigation, reporting and management requirements in respect to air quality management.

1.2 SCOPE

The AQMP contains the management of air quality characteristics during, exploration, construction and operation of the Project. It has been designed to comply with conditions B1 and B2 of the projects EA:

B1 *The activities must not cause an exceedance of the air quality objectives specifie in Table B1 beyond the boundaries of any mining lease/s listed on this environmental authority*

B2 *Prior to commencing the mining activity, the environmental authority must ensyre that an air quality monitoring program is developed and implemented by an appropriately qualified person that is capable of determining compliance with condition B1 of this environmental authority.*

1.3 ROUND OAK DOCUMENT LIBRARY

INX InTuition® shall be used as the Round Oak Minerals Document Library for controlling standards, procedures, guidelines, forms and other controlled documents in accordance with the Document and Record Management Procedure.

InTuition® provides workers including Round Oak Minerals employees, contractors and visitors access to the latest controlled versions of documents.

All documents controlled on InTuition® will be reviewed based on the frequency assigned to the document to ensure currency of information.

2 AIR QUALITY CRITERIA

2.1 LEGISLATION AND STANDARDS

The relevant legislation required for addressing all aspects of the AQMP for the Project are:

- Environmental Protection Act 1994 (EP Act) and
- Environmental Protection (Air) Policy 2008 (EPP (Air)).

The EP Act places emphasis on managing Queensland's environment within the principles of ecological sustainable development. The EP Act imposes a 'General Environmental Duty' on all individuals and organisations, requiring them to take reasonable measures to avoid environmental harm.

The EPP (Air) identifies environmental values that should be protected under the EP Act and provides starting indicators and air quality objectives that can be employed to protect the particular environmental values. The EPP Air also contains a framework for making consistent and informed decisions about the air environment.

Guidelines considered in the AQMP included Model mining conditions (DEHP, 2013) and the Good Practise guide for assessing and managing the environmental effects of dust emissions (NZME, 2001).

2.2 ENVIRONMENTAL AUTHORITY TRIGGER LEVELS

The relevant trigger levels are shown in Table 1 below. If dust emissions cause environmental nuisance at a sensitive receptor and trigger a complaint, the EA holder must provide evidence that particulate emissions due to mining activities from the mine are not exceeding the EA trigger levels. Should particulate emissions be proven to be above EA trigger levels during an investigation following a complaint, the holder is subject to a non-compliance with the EA.

Table 1: Air Quality Trigger Levels

PARAMETER	MEASUREMENT PERIOD	AIR QUALITY OBJECTIVE
Arsenic and it's compounds as arsenic	Average over annual calendar period	Must not exceed background levels 250 µm/m^2/day
Cadmium and its compounds as cadmium		
Copper and its compounds as copper		
Lead and its compounds as lead		
Dust deposition (total insoluble matter)		120 µm/m^2/day
Arsenic and it's compounds as arsenic		Must not exceed background levels

3 AIR QUALITY MANAGEMENT

3.1 AIR QUALITY IMPACT ASSESSMENT

The only significant potential air quality impact is dust from mining activities, particularly wheel generated dust emissions at peak production. In any earthworks, dust is a potential contaminant of air quality. Oxides of carbon, nitrogen and sulphur would also be emitted in vehicular emissions; however, these emissions

are expected to be minor. The amount, composition and size of the Project's dust emissions will be influenced by a number of factors, including the nature of the source materials disturbed or handled, the intensity of on-site activities, the climatic conditions being experienced and the degree of dust mitigation measures being applied during the operation.

Mining activities with the potential to generate significant airborne particulate matter during the Project's operation include:

- Wheel generated dust emissions from vehicle movements on unsealed roads;
- Dust from clearing activities;
- Dust generated from exposed soil in disturbed area;
- Dust from blasting and mining of open cut pits, and
- Dust from materials handling, crushing, dumping on the leases.

3.2 DUST MITIGATION MEASURES

Dust mitigation measures proposed by ROM were considered when estimating the extent of dust emissions from the Project.

3.2.1 Trafficable Areas

Trafficable areas that are in frequent use will be monitored for the generation of excessive dust and where required maintained sufficient to prevent the generation of dust. This applies to:

- Haul roads for ore and overburden;
- The precinct of the ROM;
- Areas where loaders are operating;
- Maintenance areas; and
- Other major roads (heavy equipment roads) on the mine site.

Vehicles will remain within identified trafficable areas unless there is a valid reason to travel 'off road'. Under normal circumstances, dust that carries higher than the height of the tray of a dump truck is unacceptable and additional dust control measures should be implemented.

Vehicles will be operated at speeds which avoid the generation of excessive dust, 20 km/hr at administration and 40km/hr around site where sign posted.

Any spilt ore or copper concentrate shall be graded off the road surface as soon as possible, so as to minimise the chance of fines and dust being generated. Graded ore should be pushed into a heap where it can be recovered.

3.2.2 Disturbed Areas

Disturbance areas void of cover systems will be kept to a minimum. Vegetation clearing and topsoil stripping is to be conducted immediately before overburden stripping begins.

As far as possible:

- Vegetation clearing and topsoil stripping will be avoided when wind conditions and low moisture promote the generation of dust;
- Bulldozers, loaders and haul trucks will be operated in a manner that will minimise generation of dust;
- Cleared vegetation will be windrowed to reduce surface wind speeds; and
- A water cart will be deployed where practicable to dampen dusty areas.

Dust control measures will include the use of water sprays, minimising drop heights when handling soil and waste rock and avoiding double handling of materials wherever practicable.

Topsoil stockpiles will be located, formed and vegetated to minimise the generation of dust. Alternatively, topsoil will be placed directly on to rehabilitation areas where possible.

Rehabilitation of disturbed areas will be performed when practicable. The forming of final surfaces will be avoided during dry and windy weather. During topsoil stripping haul roads, reclamation and spreading sites will be watered as required to minimise airborne dust. Topsoil operations will be assessed prior for wetting down of the impacted areas prior to topsoiling activities being undertaken.

3.2.3 Loader / Shovel Operations

Loader and shovel operators will avoid the generation of excessive dust by:

- Minimising drop heights placing material into haul trucks; and
- Avoiding overloading haul trucks to limit spillage during transit.

3.2.4 Mining Equipment

Persons operating trucks, earthmoving or loading equipment shall ensure the cab windows are closed so cab dust (air con) filter systems can operate effectively during operations as appropriate to the machine.

Maintenance of vehicle cab dust filter systems shall be done regularly to ensure the system remains effective. Vehicle operators shall report defective cab dust filter systems in accordance with a preventative maintenance schedule.

Truck drivers shall remain within the dust filtered cab whenever the truck is being loaded or discharging a load.

3.2.5 Drilling

Drilling rigs will be fitted with effective dust control and collection equipment. Dust curtains, water sprays and air extraction systems will be employed wherever practicable.

Drill cuttings, including dust cones, should be wetted down to prevent dust generation. Care should be taken when moving drilling equipment not to disturb drill cuttings.

Wetting down of drill pads and adjacent hardstand areas will assist in reducing airborne dust.

In the event of defects that prevent the effective operation of a drill rig dust suppression system the drill rig operator shall cease operations until the defect is rectified.

3.2.6 Stemming and Blasting

Blasting will be carried out in accordance with the Drill and Blast Procedure to control dust. In particular, blasting will not be conducted during weather conditions that are inconsistent with corporate guidelines for blasting or likely to impact adversely on sensitive receivers.

3.2.7 Waste Rock Dump

Disused roads shall be windrowed off as appropriate to prevent vehicular access and the production of airborne dust. Access roads, traffic, tip and work areas of active waste rock dumps shall be wet down as required to minimise the production of airborne dust.

Waste rock tipping operations at an elevated height, exposed to strong winds shall be scheduled to minimise the amount of airborne dust produced. Waste rock dump rehabilitation shall be programmed as an integral part of the mining operation to minimise sources of airborne dust.

The estimated reduction in dust emissions achieved by the application of the control measures are presented in Table 2.

Table 2: Control Measures included in Emission Estimations

ACTIVITY / AIR EMISSION SOURCE	CONTROL MEASURE	REDUCTION
Exposed Areas	Rehabilitation	60%

ACTIVITY / AIR EMISSION SOURCE	CONTROL MEASURE	REDUCTION
Haul Roads - Sealed and Unsealed	Dust suppression watering	75%
Crusher	Watering at both ends	50%

4 AIR QUALITY MONITORING

4.1 DUST DEPOSITION GAUGES

Dust deposition gauges will be implemented during all stages of mining at various locations around the Barbara Copper Project. The monthly dust deposition monitoring program will measure dust deposition (fall out) data for the management of nuisance based air quality issues in accordance with *AS/NZS 3580.10.1:2016: Methods for sampling and analysis of ambient air: Determination of particulate matter - Deposited matter - Gravimetric method*. This will be achieved by sampling dust particulate matter at the designated dust deposition monitoring locations every 30 days following the methodology outlined below.

The dust deposition gauges will provide deposited dust samples (total solids) in g/m^2/month. The analysis of samples will be undertaken at a NATA accredited laboratory. Samples will also be analysed for ash content, combustible matter, total soluble matter and total insoluble matter to assist in determining possible contamination and dust sources.

Dust deposition monitoring is currently being undertaken at three locations around Barbara Copper Project. Monitoring of dust deposition will be continued at these locations throughout the duration of the Project. The locations of the dust deposition monitoring stations are outlined in Table 3.

If considered necessary, due to an irregular event or as part of complaint management, additional dust deposition gauges can be installed at other sensitive receptors to manage the circumstance.

Table 3: Passive Dust Gauge Monitoring Locations

SITE ID	LATITUDE (GDA94 Z54)	LONGITUDE (GDA94 Z54)	LOCATION DESCRIPTION
BDG01	-20.4252	139.8711	East of Mining Lease
BDG02	-20.4307	139.8596	Near Site Administration
BDG03	-20.4040	139.8382	North-west of Infrastructure Area

4.1.1 Depositional Dust Monitoring

AS/NZS 3580 identifies the equipment to use in collecting a dust sample and how to use it. The key equipment is a deposit gauge, which comprises a 150 ± 10mm diameter funnel inserted into a glass bottle (at least 4L in size) through a rubber stopper (see Figure 1). Note the NATA accredited laboratory will provide the bottles. Replacement rubber stoppers can be purchased from the laboratory as well.

Set up the deposit gauge and stand so that the height of the top of the funnel is 2m ± 0.2m above the ground level of the immediate surrounding area.

The glass bottle may also collect rainwater and other material such as bugs and leaf litter, etc. This does not contaminate the sample and should not be removed in the field. However, it is recommended that the type of any contamination be noted for each sample on a piece of paper at the time of collection (for example, note the presence of bird droppings, leaf litter, sticks, spider webs, Christmas beetles, etc. or whether the bottle was broken). This record may help explain unusual results (such as high insoluble matter) during laboratory analysis.

- After 30 days ± 2 days, wash any deposited matter in the funnel into the glass bottle using distilled water;
- Remove the funnel and seal the glass bottle with a lid;
- Identify the glass bottle with a label showing site location, the date sampling began and ended, and the funnel diameter to the nearest millimetre; and
- Insert a clean funnel into a fresh glass bottle.

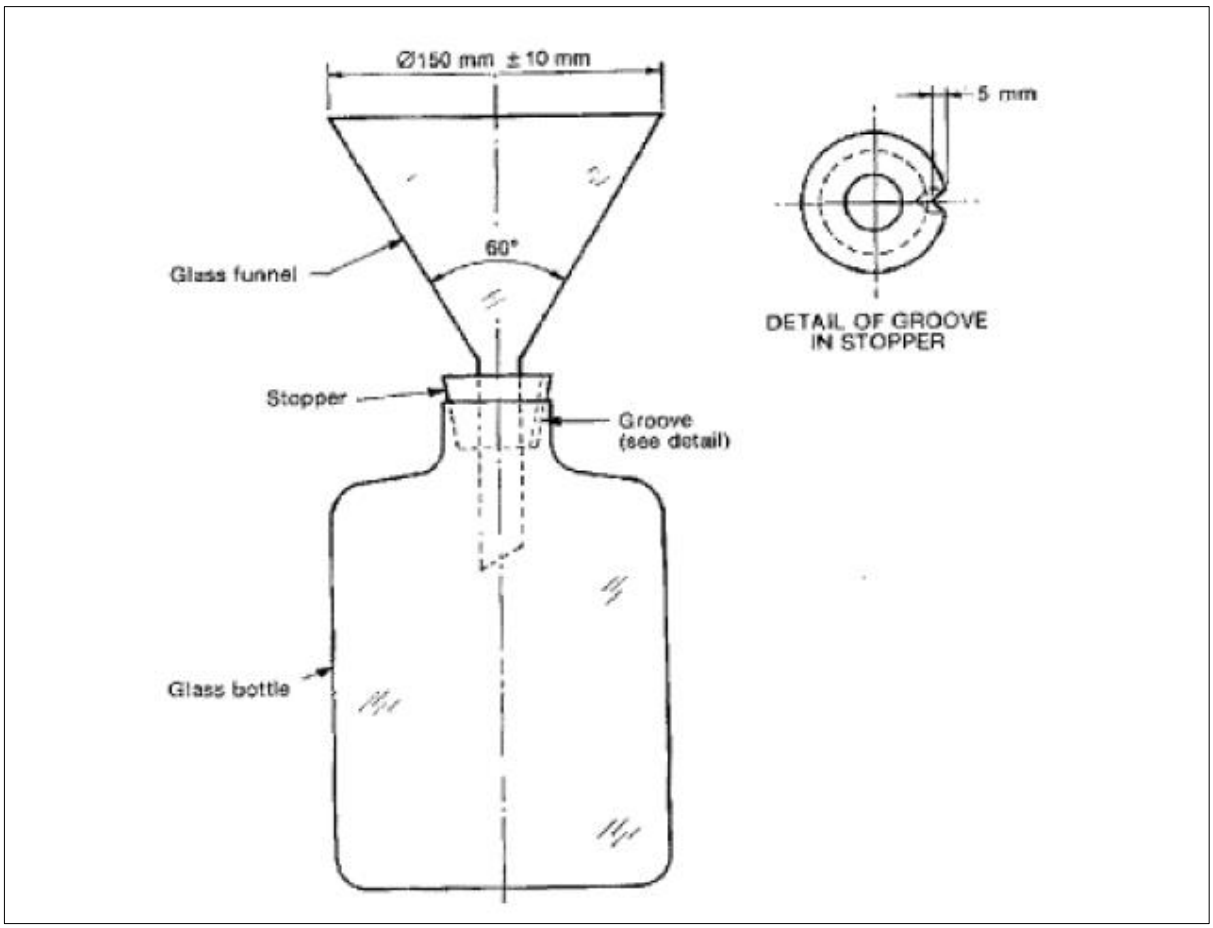


Figure 1: Typical Depositional Dust Bottle

Figure 2: Dust bottle in Stand and (2) Bottles for change out

4.2 GRAVIMETRIC DUST MONITORING

This method determines average dust concentrations and comprises the collection of dust by drawing a constant flow rate of ambient air through a filter. Data is usually collected over a 24 hour period and results are expressed in $g/m^3/24hr$ (i.e. mass of dust per volume of air per 24 hrs). A selective inlet may be fitted to a high volume sampler to restrict the particle size being sampled (for example, to ensure only PM_{10} particles are sampled).

When coupled with a wind direction vane or matched with records of wind data, this method enables determination of dust levels from a particular event or source. It also gives an indication of the potential health effects of the dust because it allows measurement of fine and very fine particles in the atmosphere.

Should gravimetric dust sampling become a requirement for the site technical experts will be contacted in the first instance to develop and implement a sampling program.

4.3 COMPLIANTS MANAGEMENT

A legible record of all concerns made by the public will be kept on site by Round Oak Minerals. Each concern received in relation to the Project will be formally documented and a record of the following information will be maintained for legal and compliance purposes.

- The date and time of concern;
- The nature of concern (e.g. dust);
- The method by which the concern was received (e.g. telephone);
- The name and title of the person who receives the concern;
- The personal details of the complainant, if made available, or if no details were provided, a note to that effect;
- The action taken in relation to the concern, including any follow-up contact, the outcome of investigations and any required on-going actions;
- Reasoning for why no action was taken; and
- The final status of the concern (e.g. resolved, continuing or unresolved).

Follow up actions taken by an environmental consultant in relation to air quality (dust) concerns may include depending on circumstances:

- A site inspection of the complainant's residence;
- An investigation of meteorological conditions at the time of the incident;
- An investigation of potential dust generating sources in the vicinity of the complainant's residence; and
- If the complainant's residence is outside the Project's proactive air quality monitoring network, installation of an applicable monitoring station at the complainant's residence (e.g. dust deposition gauge); and
- If required, engagement of an air quality specialist to assist the concerns investigation process.

5 PEOPLE

5.1 ORGANISATIONAL STRUCTURE AND ACCOUNTABILITY

Round Oak has a process for establishing and maintaining an organisational structure with clear roles, responsibilities, authorities, and expectations. The Organisational structure provides clear accountability for deliverables.

Employees have written job descriptions and those descriptions are communicated to them.

5.1.1 Structure

Round Oak operates from its head office located in Brisbane, Queensland. At the Group level, the HSEC Manager has overall responsibility for HSEC functions.

At operational level, the assigned Site Manager (e.g. General Manager/SSE/Registered Mine Manager) has overall responsibility for HSEC performance. In addition, HSEC site personnel have a line responsibility to the Site Manager and a reporting function to the HSEC Manager.

The responsibility and authority pertaining to HSEC performance of key personnel, specialists and sub-contractors is described below. These responsibilities are categorised in relation to relevant positions and will be issued as part of the site induction.

5.1.2 Responsibilities

Responsibilities of key positions are described within Position Descriptions and the Management Structure Management Plan. Some selected responsibilities for positions are provided below.

Site Manager / Site Senior Executive (SSE)

The SSE is responsible for:

- Approve procedure and revisions;
- Provide adequate resources to ensure that effective dust control processes are used and that all identified hazards and risks are effectively controlled; and
- Ensure that the risk to persons and the environment from operations generating dust is at an acceptable level.

Corporate HSEC Team

The Corporate HSEC Team is responsible for:

- Informing site management of any changes to legal and other requirements;
- Providing advice for training and awareness programs;
- Providing HSEC management system standards and associated documents;
- Providing HSEC support.

Environmental Advisor

The Environmental Advisor Officer has direct reporting line to the Group HSEC Manager and a functional reporting link to the SSE and is responsible for the following:

- Ensuring data collected/reported and associated records maintained;
- Consulting with the SSE/Site Manager on air quality matters;
- Assisting with site inspections and audits;
- Liaising with workers on air quality management measures;
- Facilitating the implementation of environmental improvements and initiatives where practicable; and
- ensuring non-conformances and environmental incidents are identified, reported and suitable corrective actions are determined and completed.

Supervisors

Supervisors are responsible for:

- Utilise processes to identify hazards which may impact on the health and safety of the employees, the environment and the local community;
- Communicate the dust control procedures, process and potential effects to staff and to seek feedback;
- Staff are adequately trained, qualified and competent to perform duties;
- Actively participate in decisions involving the procurement of new plant and equipment; and
- Ensure that all identified hazards and risks are effectively controlled.

General Responsibilities of all Workers

All workers have a general environmental duty. Workers must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practicable measures to prevent or minimise the harm. All Workers are responsible for:

- Utilise processes to identify hazards and control risks associated with assets;
- Communicate issues or concerns as appropriate; and
- Hazard / Near miss reporting.

6 RISK IDENTIFICATION AND ASSESSMENT

Generation and ineffective control of environmental dust pose a risk to:

- Health of workers and surrounding neighbours (sensitive receptors);
- Smothering of surrounding vegetation and contaminated run-off entering receiving waters; and,
- Environmental nuisance to public amenity.

7 REPORTING

7.1.1 Monthly Reporting

A monthly review of all air quality monitoring results will take place to ensure best practice management and compliance with air quality criteria. The data collected will contribute to the Project's internal monitoring and reporting system and be reported to the Project's management team on a regular basis.

In the event that a complaint regarding dust emissions is made to ROM by a sensitive receptor, and/or monitoring indicates the air quality criteria have been exceeded, an investigation would be undertaken (in accordance with the TARP) to identify the cause of the exceedance. If the exceedance is found to be

attributed to mining activities, Round Oak Minerals will implement dust mitigation measures so that dust emissions generated by the mining activities do not exceed criteria

7.1.2 Air Quality Management Plan Review

The Environmental Management Plan shall will be reviewed in response to events, changes in legislation, change in operations, findings of inspections and audits and management reviews.

8 CHANGE MANAGEMENT

The Change Management process includes the consideration for safety and health risks arising from significant changes to process, equipment, people, work environment, work conditions and work hours.

Change shall be managed in accordance with the Change Management Procedure.

Evidence showing consideration of safety and health risk assessment and management shall be maintained. As a minimum, this can be demonstrated through the following processes and records:

- Development, completion and review of JSA, work procedures and processes;
- Completion of Change Management Form or event in InControl®;
- Communication of relevant information between affected parties through meeting minutes, newsletters, emails, memos, notifications, inductions and orientations;
- Review of feedback; and
- Review of key documents such as management plans, structural and layout drawings, location maps showing changes affecting safety and health.

GROUNDWATER MANAGEMENT PROGRAM

VERSION	DESCRIPTION	POSITION	REVIEWER	DATE
1.0	Barbara GMWP	Senior Environmental and Community Advisor	Environment and Community Coordinator	
1.0	Barbara GMWP Annual Review	Senior Environmental and Community Advisor	Senior Environmental and Community Advisor	November 2021

TABLE OF CONTENTS

1 INTRODUCTION 3
- 1.1 Background 3
- 1.2 Objective 3

2 PROJECT AND SITE CHARACTERISTICS 4
- 2.1 Project overview 4
- 2.2 Climate 4

3 GEOLOGICAL AND HYDROGEOLOGICAL SETTING 5
- 3.1 Hydrology and topography 5
- 3.2 Geology 5
- 3.3 Hydrogeology 6
- 3.4 Hydrogeochemistry 7
- 3.5 Groundwater Flow 7
- 3.6 Surface water Interactions 7
- 3.7 Environmental values 7

4 POTENTIAL IMPACTS 8
- 4.1 Nature and extent of activities 8
- 4.2 Potential impacts on groundwater levels 8
- 4.3 Potential impacts on groundwater quality 9

5 CONCEPTUAL SITE MODEL 9

6 GROUNDWATER MONITORING AND MANAGEMENT PROGRAM 11
- 6.1 Overview 11
- 6.2 Existing monitoring network 11
- 6.3 Monitoring and sampling methodology 12
- 6.4 Monitoring data management 13
- 6.5 Quality assurance and quality control 13

7 GROUNDWATER IMPACT TRIGGERS AND INVESTIGATION PROTOCOLS 14
- 7.1 Groundwater exceedance notification 14
- 7.2 Groundwater quality triggers and limits 14
- 7.3 Groundwater level triggers 15
- 7.4 Groundwater investigation procedures 15

8 REVIEW AND IMPROVEMENT PROCESS 15
- 8.1 Groundwater monitoring program review 15
- 8.2 Bore replacement and decommissioning 16

9 REFERENCES 17

1 INTRODUCTION

This Groundwater Management Plan (GWMP) was developed for the Barbara Copper Project (BCP) to meet the requirements of conditions E16-18 of the Barbara Environmental Authority (EA) EPML02840015, dated 3 February 2020.

1.1 BACKGROUND

The conditions of the Barbara EA state the following:

E16 A Groundwater Management Program must be developed, documented and implemented by appropriately qualified persons

E17 The Groundwater Management Program required by Condition E16 must:

a) Identify potential sources of contamination to groundwater from the activity; and

b) Ensure that all potential groundwater impacts due to the activity are identified, monitored and mitigated;

c) Documented sampling and monitoring methodology; and

d) Ensure that adequate groundwater monitoring and data analysis is undertaken to achieve the following objectives:

i. Detect any impacts to groundwater levels due to the activity;

ii. Detect any impacts to groundwater quality due to the activity;

iii. Determine compliance with condition E11 and E12; and

iv. Determine trends in groundwater quality; and

e) Include an appropriate quality assurance and quality control program; and

f) Include a conceptual site model; and

g) Include a review process to identify improvements to the program that includes and addresses any comments provided by the administering authority.

This document serves to meet the requirements of these conditions.

1.2 OBJECTIVE

This GWMP has been prepared to monitor and manage the potential impacts on groundwater at and surrounding the Barbara Copper Project. It outlines the groundwater monitoring plan and associated groundwater impact criteria that will trigger further assessment and groundwater impact management.

The document has been prepared based on the potential impacts to groundwater identified in the Barbara Plan of Operations (2019) and Barbara Groundwater Assessment Report (2014).

2 PROJECT AND SITE CHARACTERISTICS

2.1 PROJECT OVERVIEW

The Barbara Copper Project is wholly owned by Round Oak Minerals and is located approximately 60km north-east of Mount Isa in North West Queensland. The Project operates within mining lease (ML) 90241, which covers approximately 1,761 hectares (ha) and targets copper ore and trace gold through open cut mining. The ore is transported offsite be processed at a third-party processing facility in the region.

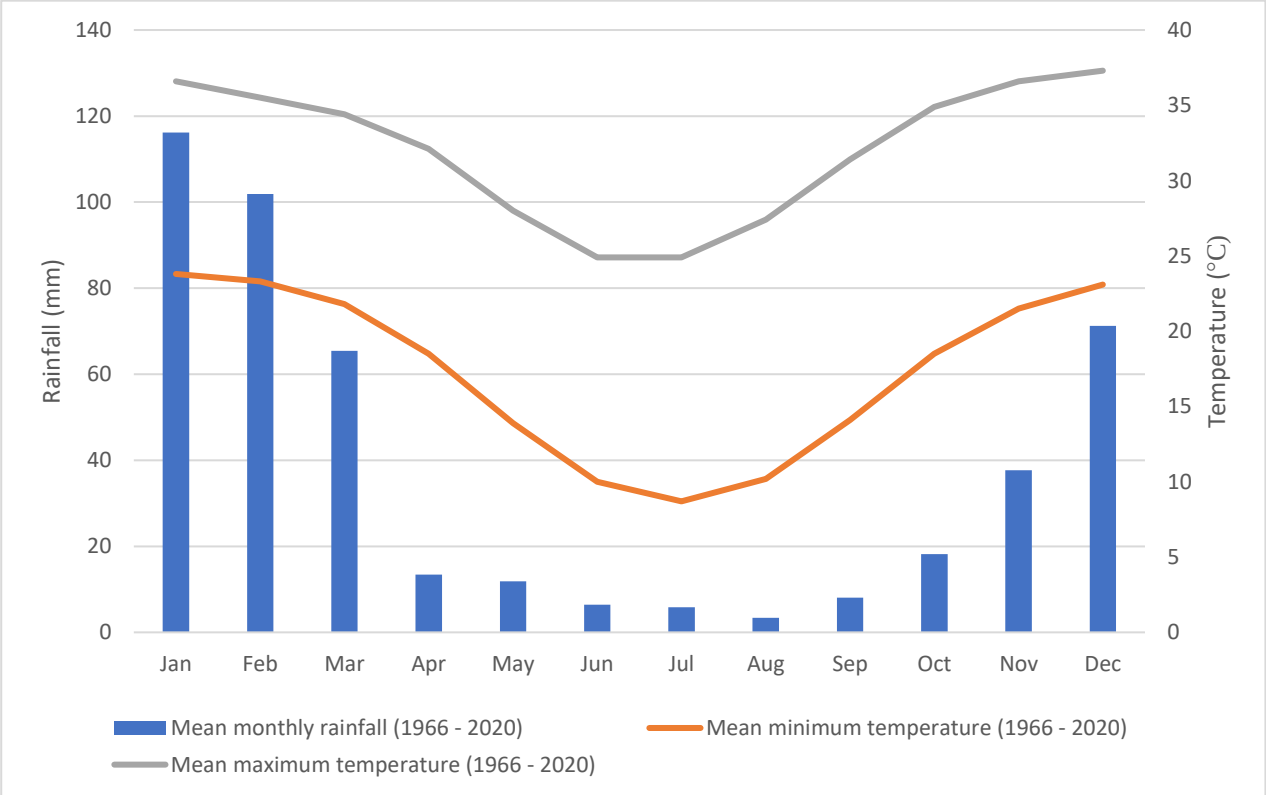
Onsite activities commenced in February 2019 and will continue until approximately December 2020.

The site layout and mining infrastructure is outlined in **Figure 1.**

2.2 CLIMATE

The semi-arid to arid Mount Isa region is described as having a tropical continental climate (Bureau of Meteorology, Australia – Koppen Australian climate classification scheme). The wet season extends from December to March and delivers most of the yearly rainfall. Dry season months are characterised by relatiely low rainfall.

Climate data for the Barbara Copper Project were taken from the Bureau of Meterology (BoM0. The nearest BoM meteorological station to the operation is Mt Isa Airport (Station 029127). Based on the available data, the average maximum temperature varies from 24.9°C in July to 37.3°C in December, whereas average minimum temperature ranged from 8.7°C in July to 23.8°C in January (Error! Reference source not found.).



3 GEOLOGICAL AND HYDROGEOLOGICAL SETTING

3.1 HYDROLOGY AND TOPOGRAPHY

The Barbara Groundwater Assessment Report (2014) describes the topography and drainage characteristics of the Barbara area as containing three main landform types. These are erosional hills, ridges and plateaus and colluvial footslopes and alluvial channels. The area is dominated by exposed and subcropping Proterozoic rocks forming the hills and plateaus that dominate the landscape. Small areas of proximal colluvium are found as footslopes flanking the sides of the ridges and at the base of scarps. Minimal alluvial sediments are found in immature drainage systems.

The are no major watercourses in the vicinity of the operation although there are several minor, ephemeral tributaries that traverse the mining lease. Drainage channels tend to flow to the northwest, down gradient from the steeper hills located in the southern and central sections of the mining lease area. The deposition of alluvium within drainage systems is minimal.

3.2 GEOLOGY

3.2.1 Regional Geology

The Barbara Copper Project orebody is hosted within the Leichardt Metamorphics. At the operation, the Leichardt Metamorphics are steeply dipping at angles of up to 70 degrees and highly sheared. The orebody is located within what is informally termed as the Barbara Shear Zone. The area is structurally complex with structural repetition of stratigraphic units and wrench faulting common.

3.2.2 Local Geology

The Barbara Groundwater Assessment Report (2014) describes the local geology in the Barbara areas as comprising Proterozoic rocks of the Mount Isa Inlier. Rock types at Barbara include Felsic Volcanics (forming in the hills), dolerite/amphibolite (in the drainages/valleys) and basalt (forming plateaus). The Felsic Volcanics dip at 60 degrees towards the northeast and the dolerites are sub-vertical within the project area. These three rock types are resistant to weathering and extensive outcrop occurs throughout the area.

3.2.3 Geochemistry

An assessment of geochemical characteristics of waste rock and ore material at Barbara was conducted by the Environmental Geochemistry International Pty Ltd (EGI). A total of 121 drill core samples from 14 locations were analysed. Most samples representing waste had low sulphur contents and were non-acid forming (NAF) but there were some waste samples from close to mineralised zones that had elevated sulphur contents and were potentially acid forming (PAF). Ore samples had high sulphide contents and approximately half of the ore samples tested were PAF.

The Australian Standard Leaching Procedure testing on waste rock samples showed that all of the freshly mined waste rock is expected to be alkaline, with pH values ranging between 8.6 -9.0.

Sulphate concentrations for PAF waste were, on average, slightly higher than for NAF waste. Other differences were relatively minor. There were trace concentrations of aluminium in most extracts (median 0.19 mg/L), but the concentrations of copper and other environmentally important elements were low, and in most cases the concentrations were close to, or below, the analytical detection limits.

The Australian Standard Leaching Procedure testing on ore material recorded that all samples were slightly alkaline and that the concentrations of environmentally important elements were low, with the possible exception of manganese which for the ore samples exhibited a median concentration of 0.16 mg/L compared to 0.001 mg/L for the waste samples (EGI, 2014).

3.3 HYDROGEOLOGY

3.3.1 Aquifer characteristics

Occurrence and Extent

The primary aquifer at the Barbara Copper Project occurs within the Leichardt Metamorphics, generally at the base of the weathered zone. There is very little regolith across the project area and no regolith aquifer was identified. Alluvial deposits within drainage systems in the project vicinity are recorded as minimal.

Groundwater level measurements recorded in exploration drill holes during 2013 indicated that the median depth to groundwater at the Barbara deposit was approximately 12m below ground surface. Aquifer intervals and airlift yields for six bores in the Barbara project area indicate that groundwater is mainly found below the regolith (**Table 1**).

Table 1 - Aquifer intervals and airlift yields (RLA, 2014)

Bore	Total depth (m)	Aquifer intervals (m)	Airlift yield (l/s)	Total airlift yield (l/s)
BAWB01	104	22-23	0.6	1.1
		34-35	0.3	
		43-44	0.2	
BAWB02	104	No aquifer intervals encountered	-	-
BAWB03	104	No aquifer intervals encountered	-	-
BAWB04	100	No aquifer intervals encountered	-	-
BAWB05	102	39-40	0.2	0.3
		49-51	0.1	
BAWC071	146	19-22	0.5	0.8
		108-109	0.3	

Hydrogeological parameters

Given the arid climate and skeletal soils at the Barbara Copper Project, rainfall infiltration is considered to be minimal, with the vast majority of water lost by evaporation and transpiration. From exploration drilling logs and data recorded during the construction of groundwater monitoring bores in 2014, it is considered that direct rainfall recharge mechanism to the Leichardt Metamorphics aquifer at BCP is episodic recharge via lineaments aligned with watercourses (RLA, 2014).

Hydraulic conductivity values were first obtained through slug (falling head) tests conducted at four monitoring bores. Hydraulic conductivity values are regarded as extremely low to locally high (**Table 2**).

Table 2 - Hydraulic conductivity values calculated from slug tests at Barbara monitoring bores (RLA, 2014)

Bore	Hydraulic conductivity (m/d)	Hydraulic conductivity (m/s)	Qualitative description
BAWB01	8.00E+02	9.26E-03	Locally high
BAWB02	1.93E-05	2.23E-10	Extremely low
BAWB04	1.98E-03	2.29E-08	Very low

BAWB05	6.86E-04	7.94E-09	Very low

3.4 HYDROGEOCHEMISTRY

Chemical groundwater analysis conducted at the Barbara deposit indicated that the groundwater in the Barbara monitoring bores is predominantly of calcium bicarbonate and mixed calcium sodium bicarbonate type.

There is no indication of high sulphate content in the groundwater, even in the groundwater from bore BAWB02, which is in the Green Zone orebody, or from bores BAWB07 and BARC071, which are in the Barbara orebody (WMV, 2019).

3.5 GROUNDWATER FLOW

The contours and potentiometric surface profile (**Figures 1** and **2**) show that, providing there is hydraulic continuity throughout Leichardt Metamorphics, groundwater flow will be from south-west to north-east within the project area. There is also considered to be little or no potential for the development of alluvial aquifers within the project area (RLA, 2014).

3.6 SURFACE WATER INTERACTIONS

There is little regolith at the Barbara Copper Project site and no regolith aquifers have been identified. Groundwater levels at the Barbara Copper Project occur at minimum of 8m below surface level. The drainage features at BCP are immature and only incised to a shallow depth. None of the drainage incision reaches 8m depth. Therefore, there can be no groundwater to surface water interactions within the project area (RLA, 2014).

3.7 ENVIRONMENTAL VALUES

Environmental values (EVs) for water are those qualities that allow a waterbody or groundwater aquifers to support aquatic ecosystems and human water uses (EHP, 2014). The EVs of a system require protection from anthropogenic effects to ensure healthy aquatic ecosystems and waters are safe for community use (EHP, 2014). The *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EPP Water) was designed to provide guidance in achieving the objectives of the *Environmental Protection Act 1994* with respect to water and wetlands. The EPP Water provides a framework for the identification of EVs of Queensland waters, in order to protect the water environment while allowing for ecologically sustainable development. The EPP Water notes that EVs and water quality objectives (WQOs) are being progressively determined for different areas in Queensland. WQOs define objectives for physical, chemical and biological characteristics of water. The Project falls within the Southern Gulf Catchments region as relevant to the EPP Water, for which specific water and wetland EVs attribution and water quality planning is currently under development. The EPP Water defines EVs for waters and wetlands as:

a) for high ecological value waters—the biological integrity of an aquatic ecosystem that is effectively unmodified or highly valued; or

b) for slightly disturbed waters—the biological integrity of an aquatic ecosystem that has effectively unmodified biological indicators, but slightly modified physical, chemical or other indicators; or

c) for moderately disturbed waters—the biological integrity of an aquatic ecosystem that is adversely affected by human activity to a relatively small but measurable degree; or

d) for highly disturbed waters—the biological integrity of an aquatic ecosystem that is measurably degraded and of lower ecological value than waters mentioned in paragraphs (a) to (c); or

e) for waters from which aquatic foods intended for human consumption are taken—the suitability of the water for producing the foods for human consumption; or

f) for waters that may be used for aquaculture—the suitability of the water for aquacultural use; or

g) for waters that may be used for agricultural purposes—the suitability of the water for agricultural purposes; or

h) or waters that may be used for recreation or aesthetic purposes—the suitability of the water for—

   (i) primary recreational use; or

   (ii) secondary recreational use; or

   (iii) visual recreational use; or

i) for waters that may be used for drinking water—the suitability of the water for supply as drinking water having regard to the level of treatment of the water; or

j) for waters that may be used for industrial purposes—the suitability of the water for industrial use; or

k) the cultural and spiritual values of the water.

As specific environmental values are "currently under development" within the Gulf region, the following are deemed most relevant to the site:

- aquatic ecosystems (slightly-moderately disturbed systems);
- agriculture uses (stock water);
- secondary recreation;
- visual recreation;
- cultural and spiritual values.

Stygofauna has been detected in groundwater, with relatively low abundance and diversity at the family level (AARC, 2014). Post-mine land use is expected to be low-intensity grazing. Based on these observations, it is considered groundwater has environmental values for aquatic ecosystems protection (due to the presence of stygofauna) and for livestock drinking (due to the proposed grazing land use).

4 POTENTIAL IMPACTS

4.1 NATURE AND EXTENT OF ACTIVITIES

As per the *Plan of Operations* (BCP, 2019), the major activities that will be conducted on the Barbara mining lease are as follows:

- Open-cut mining using conventional drill and blast, load and haul;
- Dewatering of groundwater to allow mining and reuse on-site; and
- On-site out-of-pit waste rock dump.

4.2 POTENTIAL IMPACTS ON GROUNDWATER LEVELS

Groundwater levels surrounding the Barbara project can be potentially impacted by the removal of water from the mined open pit area. It is anticipated that as a result of pit dewatering there will be a cone of groundwater level depression that will extend approximately 1km along the Barbara Shear Zone from the centre of the pits (RLA, 2014). The nearest privately-owned stockwatering bore (RN 70146) is located approximately 1.5km from the North Pit. Considering the lack of groundwater use within the area, this presents a very low overall risk to the groundwater resources in the area.

4.3 POTENTIAL IMPACTS ON GROUNDWATER QUALITY

Groundwater quality can be potentially impacted due to:

4.3.1 Infiltration through Waste Rock Dump

Characterisation of the waste rock dump indicates that rainwater encountering waste rock will most likely be non-acid forming (NAF) with low sulphur content (EGI, 2014).

83 of the 94 waste rock samples tested were classified as non-acid forming and recorded low sulphur concentrations (EGI, 2014). The absence of potentially acid-forming material and the negligible amount of sulphur in most waste rock samples implies that oxidation reactions should be minimal.

The Australian Standard Leaching Procedure test on waste rock samples showed that some waste rock samples were significantly enriched with copper, sulphur and selenium relative to concentrations typically reported for background soil (EGI, 2014). It is expected that drainage from NAF waste rock will be neutral to slightly alkaline and have low concentrations of soluble salts and environmentally important metals and metalloids.

In the event of long-term exposure of PAF waste leading to development of acid conditions there would likely be significant increases in the concentrations of dissolved metals within drainage. In addition to copper, iron and aluminium, there would likely be significant concentrations of cobalt, manganese, nickel and zinc. Given, the high ratio of NAF to PAF waste rock at the Barbara project, problematic material is accommodated within the core of the waste rock dump in a manner that provides long-term geochemical stability and limits the potential for sulphide oxidation or metals leaching.

4.3.2 Storage of mine-affected water

The two open pits are proposed to remain as open final voids. Therefore, after the completion of mining, the pits are expected to store water. It is expected that evaporation rates in these pit lakes will exceed the rate of inflow and, as a result, the water level in the pits will always remain lower than the surrounding groundwater table (RLA, 2014).

There is also a sediment dam onsite. The likelihood of seepage from this dam is very low, as it has been HDPE lined. This dam will be retained to evaporate stormwater runoff from the rehabilitated waste rock dump. Water quality monitoring will be ongoing to determine the quality of the water in the pits and sediment dam prior to decommissioning.

5 CONCEPTUAL SITE MODEL

A summary of groundwater modelling is provided below:

- The groundwater flows towards the centre of the mining lease towards the location of the South and North pit. The contours and the potentiometric surface profile show that, providing that the hydraulic continuity exists through the Leichardt Metamorphics, groundwater flow will be from south-west to north-east within the Barbara Shear Zone (RLA, 2014).
- The central segment is the approximate location of the North and South pits. The positioning of the bores is such that groundwater will flow generally towards this central segment from each bore.
- The groundwater level data from the Barbara deposit highlighted that the depth of groundwater is a minimum of and that the potentiometric surface contours flow away drainage systems and towards the location of the pits.

- No groundwater-surface water interaction is expected in the alluvium due to the large thickness of the confining unit.
- Potential impacts to the groundwater aquifer include drawdown. The distance to the nearest privately-owned stockwater bore is approximately 1.5km, which is beyond the radius of drawdown influence (approximately 1km).

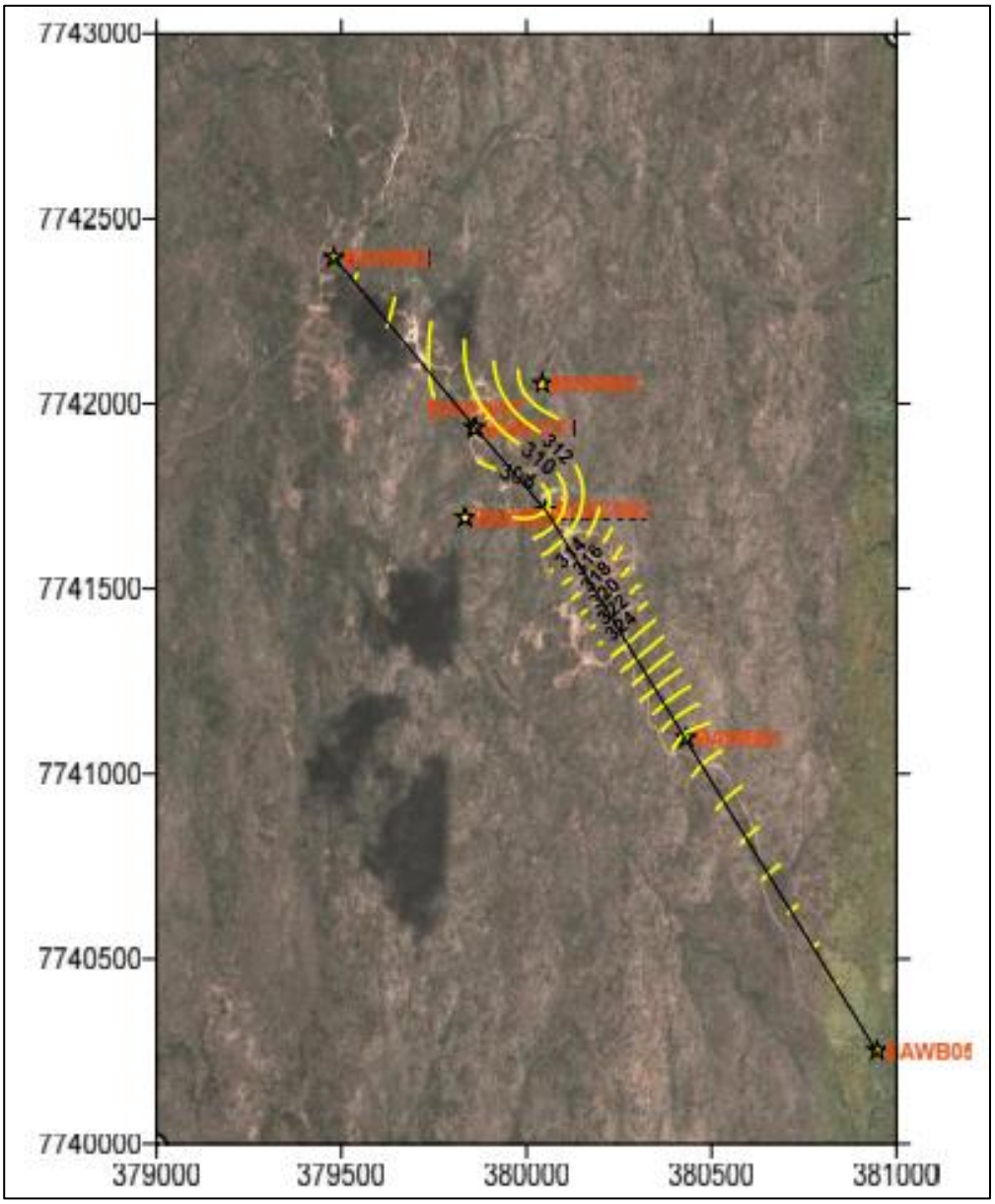


Figure 1 - Potentiometric contours at Barbara Copper Project (RLA, 2014)

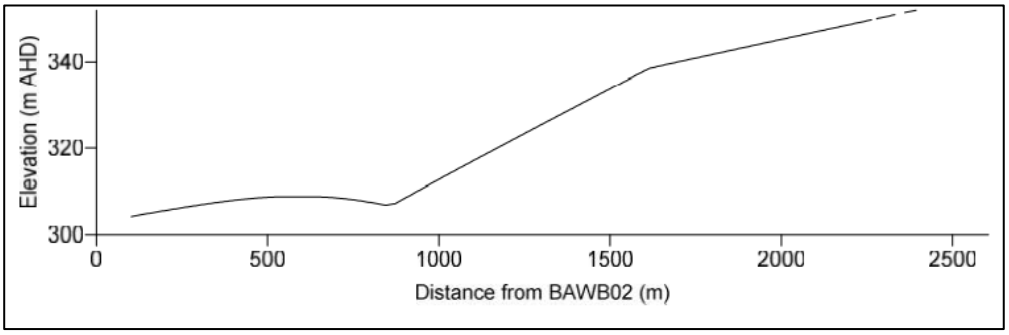


Figure 2 - Potentiometric surface profile from BAWB02 to BAWB05 (RLA, 2014)

6 GROUNDWATER MONITORING AND MANAGEMENT PROGRAM

6.1 OVERVIEW

The GWMP for the Project includes procedures and processes required to assess the potential impacts of mining activities on groundwater resources. The establishment and implementation of the GWMP will evolve and respond to the various stages of the mining project. It will be reviewed to ensure the program remains reflective of the different project phases, including operations and post-closure activities.

The GWMP has been developed for the Project to detect any changes to groundwater quantity or quality due to mining activities. The GWMP has been developed by taking into consideration the current suitability of groundwater for agricultural use, aquatic ecosystems protection (due to the presence of stygofauna) and for stock water drinking. In accordance with the regulatory requirements specified in condition E17 of the EA, the GMP must:

- Identify potential sources of contamination to groundwater from mining activities.
- Ensure that all potential groundwater impacts due to the activity are identified, monitored, and mitigated.
- Document sampling and monitoring methodology.
- Ensure that adequate groundwater monitoring and data analysis is undertaken to achieve the following objectives:
    - Detect any impacts to groundwater levels due to the activity.
    - Detect any impacts to groundwater quality due to the activity.
    - Determine compliance with condition E11 and E12 of the EA.
    - Determine trends in groundwater quality.
- Include an appropriate quality assurance and quality control program.
- Include a conceptual groundwater model.
- Include a review process to identify improvements to the program.

6.2 EXISTING MONITORING NETWORK

There are eighteen monitoring bores included in the EA monitoring framework for the Project (**Table 3**), comprising ten compliance bores and eight seepage monitoring bores.

Table 3 - Barbara groundwater monitoring criteria

Monitoring Point	Location (GDA94, Zone 54)		Surface RL (m)	Total Depth (mbgl)	Screened Interval (mbgl)	Monitoring frequency	
	Easting	Northing				Standing water level	Groundwater quality
Compliance bores							
BAWB05	380948	7740252	377.32	102	35-102	Monthly	Quarterly
Bore E	380022	7738827	334.23	85	28-83		
BAWB01	380432	7742097	352.68	104	20-101		
BAWB02	379480	7742395	310.59	104	96-102		
BAWB03	379834	7741692	329.50	104	50-102		
BAWB04	380043	7742054	329.14	100	94-100		
BAWB07	379849	7741936	328.74	127	18-146		
BAWBR1	380292	7740939	334.49	14	5-6		
BAWBR2	379912	7741279	322.98	14	2-3		
BAWBR3	379991	7741485	326.02	14	3-4		
Seepage monitoring bores							
Seepage bore 1a	380084	7741046	336.82	6	1-5	Monthly	Quarterly
Seepage bore 1b	380084	7741048	336.49	16	5-15		
Seepage bore 2a	380025	7741117	331.22	6	1-5		
Seepage bore 2b	380023	7741116	331.34	16	5-15		
Seepage bore 3a	379985	7741133	332.189	6	1-5		
Seepage bore 3b	379986	7741135	331.96	16	5-15		
Seepage bore 4a	380711	7740798	355.06	6	1-5		
Seepage bore 4b	380711	7740800	355.11	16	5-15		

6.3 MONITORING AND SAMPLING METHODOLOGY

As per condition E10 of the EA, the groundwater quality and standing water levels (SWLs) must be monitored:

- At the locations specified in Table E5 of the EA (Error! Reference source not found.);
- At the frequencies specified in Table E5 (Error! Reference source not found.); and
- For the quality characteristics identified in table E6 of the EA.

Groundwater monitoring and sampling will be conducted by a suitably qualified and experienced professional in accordance with the Queensland Department of Environment and Science (DES) Monitoring and Sampling Manual (DES, 2018; or subsequent updated versions), the Geoscience Australia Groundwater Sampling and Analysis – A Field Guide (Sundaram et al. 2009), and the Australian/New Zealand Standard (AS/NZS) 5667.11:1998 for water quality – sampling Part 11 guidance on sampling groundwater.

As per condition A5 of the EA, all monitoring activities, records, and reports required by this environmental authority or related to environmental management of the activities must be:

- Carried out by an appropriately qualified person;
- Kept for a period of not less than five years; and
- Provided to the administering authority in the specified format within 10 business days of a request.

6.4 MONITORING DATA MANAGEMENT

The data gathered from the groundwater monitoring will be collated into a database which will include:

- A site plan showing sampling location;
- Periodic photos from sampling locations during sampling event;
- Tabulated results of the monitoring compared with applicable background levels;
- All data collected during each monitoring round;
- A record of the chain of custody of the samples from sampling through to analysis; and
- Laboratory analysis certificates.

6.5 QUALITY ASSURANCE AND QUALITY CONTROL

The DES Monitoring and Sampling Manual (DES, 2018) provides guidance on the types of quality control measures and the frequency of collection of quality control samples.

The following quality assurance and control measures are proposed for its GWMP:

- Field blank (one per trip or one per 20 samples)
- Blind duplicates (one per 10 samples)

Field blanks are used to estimate the contamination of a sample during the collection procedure. They are prepared in the field in the same manner as the sample. The sample will be taken from MilliQ water. For example, if a sample is field filtered, the field blank will also be filtered. It is recommended that water is supplied by the testing laboratory.

Blind duplicates are to be taken at the same time as the sample. It is recommended that the same bottle type be collected one after the other. The date and time of the sample should not be disclosed to the laboratory. Interpretation is based on the reproducibility assessment method, which provides a measure of precision. The analytical values from the original sample and its duplicate are compared by calculating the relative per cent difference (RPD) for each parameter as follows:

$$RPD(\%) = [\frac{Sample - Duplicate}{Mean\ of\ sample\ and\ Duplicate}] * 100$$

The RPD then uses the limit of reporting (LOR) to identify thresholds for valid reproducibility. These include:

- Mean of sample and duplicate <10 times LOR: There is no RPD limit (i.e. reproducibility is valid)
- 10 times LOR < Mean of sample and replicate < 20 times LOR: The RPD range limit is 0%-50% for a valid duplicate
- Mean of sample and replicate > 20 times LOR: The RPD range limit is 0% - 20% for a valid duplicate.

If the RPD exceeds the threshold percentage, the results are considered unreliable and require further investigation. Only one duplicate sample is needed to be collected per sampling event.

7 GROUNDWATER IMPACT TRIGGERS AND INVESTIGATION PROTOCOLS

7.1 GROUNDWATER EXCEEDANCE NOTIFICATION

Groundwater quality limits (as Limit A and Limit B) are discussed in Table E6 of the EA. As per condition E11 and E12 of the EA, groundwater measured from any compliance bore specified in Table E5 must not exceed the corresponding Limit A specified in Table E6 on any five consecutive sampling occasions, and Limit B specified in Table E6 on any three consecutive sampling occasions.

Condition E13 states "*If groundwater measured from any compliance bore specified in Table E5 exceeds the corresponding Limit B specified in Table E6 on any one sampling occasion the environmental authority holder must resample the groundwater within the compliance bore for all exceeding parameters within ten business days of receipt of results.*"

Condition A9 of the EA states that the environmental authority holder must notify the administering authority within 24 hours of becoming aware of any emergency, incident, sample result or event which does or may contravene a condition of this environmental authority.

It is recommended that the administering authorities should be notified in accordance with condition A9 if groundwater measured from any compliance bore specified in Table E5 exceeded the corresponding Limit A specified in Table E6 on any five consecutive sampling occasions, and Limit B specified in Table E6 on any three consecutive sampling occasions.

Condition E13 states that if groundwater measured from any compliance bore specified in Table E5 exceeds the corresponding Limit B in Table E6 on any one sampling occasion the environmental authority holder must resample the groundwater within the compliance bore for all exceeding parameters within ten business days of receipt of results.

7.2 GROUNDWATER QUALITY TRIGGERS AND LIMITS

Groundwater contaminant limits have been set based on the following:

- Default ANZG (2018) guideline values for freshwater aquatic ecosystems for 95% species protection for slightly to moderately disturbed ecosystem.
- Site-specific values based on 80th and 95th percentiles.

The shallow groundwater trigger levels and water quality objectives outlined in Table E6 of the EA have been set based on the following:

- ANZECC (2000) value for 95% species protection, Table 3.4.1, measured as 'dissolved' metals.
- Derived from site-specific values, based off dissolved concentration of metals (80th percentile).
- Derived from site-specific values, based off dissolved concentration of metals (95th percentile).
- Based off ANZECC (2000) low reliability metals and metalloids, Section 8.3.7.1

7.3 GROUNDWATER LEVEL TRIGGERS

No condition outlining triggers for groundwater level is included in the EA. However, SWL will be monitored monthly for interpretation purposes only in accordance with condition E10 of the EA.

7.4 GROUNDWATER INVESTIGATION PROCEDURES

Condition A10 of the EA states that *"Within 10 business days following the initial notification of an emergency or incident, or receipt of monitoring results, whichever is the latter, further written advice must be provided to the administering authority, including the following:*

a) Results and interpretation of any samples taken and analysed

b) Outcomes of actions taken at the time to prevent or minimise unlawful environmental harm; and

c) Proposed actions to prevent a recurrence of the emergency or incident."

Exceedances notified to the administering authorities must be investigated as per condition A10 of the EA for monitoring bores listed in Table E5 of the EA.

Condition E13 also states that if the concentration of a contaminant measured at a compliance bore or seepage bore exceeds any trigger level specified in Table E6 on any one sampling occasion, the holder of this environmental authority must resample for all exceeding parameters within ten business days of receipt of the initial results.

8 REVIEW AND IMPROVEMENT PROCESS

8.1 GROUNDWATER MONITORING PROGRAM REVIEW

In accordance with Condition E18, the GWMP will be reviewed on an annual basis by an appropriately qualified person to determine whether the program continues to meet the requirements stated in Condition E17 of the EA. The review process may include the following:

- An assessment of the outcome of the GWMP against the objectives outlined in the Barbara EA;
- A review of the adequacy of the monitoring locations, sampling frequency and groundwater quality triggers specified in the Barbara EA;
- Recommendations for any required variations to the extent of monitoring program and any required increase in monitoring bore locations off-lease to monitor quality impacts adequately;
- Revision of monitoring parameters and sampling frequency; and
- Expanding the existing groundwater monitoring network over time to enable ongoing groundwater impact evaluations.

This GWMP may be updated as required or revised based on the outcomes of the review process. The administering authority will be consulted in relation to any significant changes proposed to the GWMP. The document will be made readily available to the administering authority on request.

8.2 BORE REPLACEMENT AND DECOMMISSIONING

The Barbara Copper Project will proactively maintain the groundwater monitoring network, replacing any bores as necessary and will use the review of monitoring data to inform the location of any additional monitoring bores if required.

Bore construction and decommissioning will be undertaken in accordance the Minimum Construction Requirements for Water Bores in Australia (NUDLC, 2011) and in accordance with Condition E14, must be undertaken in a manner that:

- Prevents contaminants entering the groundwater;
- Ensures the integrity of the bores to obtain representative groundwater samples from the target aquifer; and
- Maintains the hydrological environment within the aquifer.

For all existing monitoring bores and new monitoring bores being installed, a bore drill log must be kept in accordance with requirements specified in condition E15 of the EA (including bore location, construction details, and hydrogeological and stratigraphic information).

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REPORT

ROUND OAK MINERALS PTY LTD

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BARBARA COPPER PROJECT

Water Management Plan Update

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TABLE OF CONTENTS

1 INTRODUCTION 1
1.1 Purpose 1
1.2 Report Structure 2

2 PROJECT BACKGROUND 3
2.1 Project Development 3
2.2 Site Infrastructure 4
2.2.1 North Pit 4
2.2.2 South Pit 5
2.2.3 WRD Sediment Dam 5
2.2.4 Light Infrastructure Area 5
2.2.5 ROM Pad and Road Train Loading Area 5
2.2.6 Magazine 6
2.3 Site Schedule 6
2.4 Hydrological Characteristics and Topography 6
2.4.1 Regional Context 6
2.4.2 Site Context 7
2.4.3 Climatic Conditions 8
2.4.4 Hydrogeology 9

3 INTERGRATED WATER MANAGEMENT STRATEGY 10
3.1 Objective 10
3.2 Environmental Values and Beneficial Users 10
3.3 Water Management Areas 12
3.4 Potential Contaminant Sources 13
3.4.1 Waste Rock and Ore Geochemical Characterisation 13
3.4.1.1 Initial Drainage 13
3.4.1.2 Acid Mine Drainage 13
3.4.1.3 Elemental Characterisation 15
3.4.1.4 Saline Drainage 16
3.4.2 Contaminants Associated with Non-Mining Areas 17
3.4.3 Ore Processing / Beneficiation 17
3.4.3.1 Summary of Potential Contaminants 17
3.5 Water Management Strategies 18
3.5.1 Classification of Extracted Mining Units 18
3.5.2 Water 19
3.5.3 Other Contaminants 20
3.5.3.1 Hydrocarbons 20
3.5.3.2 Sewage and Sewage Effluent 20

4 HYDRAULIC DESIGN ASPECTS 21
4.1 Regulated Structures 21
4.2 Consequence Category Re-assessment 21
4.3 Hydraulic Performance Criteria 22
4.3.1 Regulatory Requirement 22
4.3.2 Design Storage Allowance 22
4.3.3 Mandatory Reporting Level 22
4.3.4 Emergency Spillway Sizing 23

4.4 Site Drainage 24
4.4.1 General 24
4.4.2 North Pit Diversion Drains 24
4.4.3 South Pit Diversion Drain 24
4.4.4 WRD Sediment Dam Drainage 24
4.5 Pumped Transfer Lines 24
4.6 Erosion and Sediment Control Measures 25

5 WATER BALANCE MODEL 26
5.1 Objective 26
5.1.1 Site Development and Simulation Staging 26
5.1.2 Model Configuration 26
5.1.3 Modelled Conditions 26
5.2 Input Data 27
5.2.1 Site Infrastructure 27
5.2.2 Modelled Site Process Flow Configuration 27
5.2.3 Input Climatic Data & Surface Runoff Model 29
5.2.4 Modelled Water Inflows 31
5.2.5 Modelled Water Outflows 31
5.3 Results 32
5.3.1 North Pit 32
5.3.2 South Pit 33
5.3.3 WRD Sediment Dam 34
5.3.4 Spill Probability 34

6 MONITORING AND REVIEW 35
6.1 Stored Water Quality Monitoring 35
6.2 Surface Water Quality Monitoring 35
6.2.1 Release Water Quality Monitoring 35
6.2.2 Receiving Water Quality Monitoring 35
6.3 Groundwater Quality Monitoring 35
6.4 Water Management Plan Review 35

7 EMERGENCY CONTINGENCY PLAN 37
7.1 Extreme/Prolonged Rainfall 37
7.2 Other Incidents Causing Environmental Harm 37
7.2.1 Spills or Leaks 37
7.2.2 Erosion or Damage to Site Infrastructure 37
7.2.3 Pumps 37
7.2.4 Inability to access control and monitoring points in all weather conditions. .. 38
7.3 Responsibilities 38

8 REFERENCES 39

FIGURES

FIGURE 001 SITE LAYOUT PLAN
FIGURE 002 STORMWATER CATCHMENT PLAN

TABLES

Table 1 Site Development Schedule 6
Table 2 Water Management Areas 12
Table 3 Waste Rock Classifications 14
Table 4 AMD Samples - Acid Generation Lag Time 15
Table 5 Elemental Ore Characteristics 16
Table 6 Elemental Waste Characteristics 16
Table 7 DSA Volume for the Regulated Structures 22
Table 8 Mandatory Reporting Levels (MRLs) 23
Table 9 Regulated Structures - Minimum Emergency Spillway Geometry 24
Table 10 Adopted WBM Performance Criteria 26
Table 11 Site Structures - WBM Input Data 27
Table 12 Site Structures - Modelled Pump Transfers 29
Table 13 Site Water Balance - Rainfall and Evaporation Input Data 29
Table 14 AWBM Model Parameters 30
Table 15 Site Structures - Catchment Areas 31
Table 16 Modelled Scenarios - Spill Probabilities 34

PLATES

Plate 1 Site Location 3
Plate 2 Leichhardt River Basin Catchment Map 7
Plate 3 Local Watercourses in the Barbara Area 8
Plate 4 Mean Rainfall and Evaporation 9
Plate 5 AMD Characterisation of Barbara Copper Project Samples - EGi (2014) 14
Plate 6 Barbara Copper Project - EPML02840015 - Hydraulic Performance Criteria 21
Plate 7 Site Water Management Strategy 28
Plate 8 Schematic of the AWBM Rainfall-Runoff Model 30
Plate 9 North Pit - Modelled Storage Volume 32
Plate 10 South Pit - Modelled Storage Volume 33
Plate 11 WRD Sediment Dam - Modelled Storage Volume 34

APPENDICES

Appendix A – Pump Transfer Plan
Appendix B – Stage Storage Curves

1 INTRODUCTION

The Barbara Copper Project (BCP) is located approximately 60km northeast of Mt Isa in north-western Queensland, within the Leichhardt River Basin. The site operates under Environmental Authority (EA) EPML02840015 (Effective Date – 30 October 2019), issued by the Department of Environment and Science (DES, 2019a). Development of the project site commenced in March 2019. The key water management features incorporated in the water management system at the project includes the following:

- North Pit;
- South Pit;
- Waste Rock Dump (WRD) Sediment Dam; and
- Diversion drains and bunds.

Round Oak Minerals Pty Ltd (Round Oak) has engaged ATC Williams Pty Ltd (ATCW) to update the Water Management Plan (WMP) for the site. A WMP was originally developed by URS (now known as AECOM) in 2014 during the conceptual stage of the project. That WMP was updated by ATCW in 2018 (ATCW, 2018) during the detailed design phase.

Construction of the WRD Sediment Dam was completed in August 2019, with both the North Pit and South Pit under excavation. In September 2019, excavation of the North Pit was temporarily halted to allow it to be used for water storage during the upcoming wet season. This WMP updates the 2018 WMP (ATCW, 2018), with the as constructed structure details as at October 2019. The expected life of mine (LoM) is less than 2 years (March 2019 – November 2020).

1.1 Purpose of the Water Management Plan

The purposes of this WMP document are listed below.

(i) Comply with the licence conditions under the EA.
(ii) Outline the control measures to be implemented to prevent detrimental impact on receiving waters.
(iii) Provide site personnel with a guide to ensure effective water management.

The scope has been prepared to satisfy the conditions outlined in the DES (2012) guideline *Preparation of Water Management Plans for Mining Activities*. The WMP includes the following:

(a) Contaminant Source Study (Section 3);
(b) A study of the Environmental Values and Water Quality Objectives (Section 3);
(c) Site Water Balance and Model (Section 4);
(d) Water Management System (Section 3,4,5,6);
(e) Saline and Metalliferous, Drainage Prevention and Management Measures (Section 3);
(f) Acid Rock Drainage Prevention and Management Measures (if applicable) (Section 3);
(g) Emergency and Contingency Planning; (Section 8); and
(h) Monitoring and Review (Section 7).

1.2 Report Structure

The structure of this report, to address the scope of the WMP, is as follows:

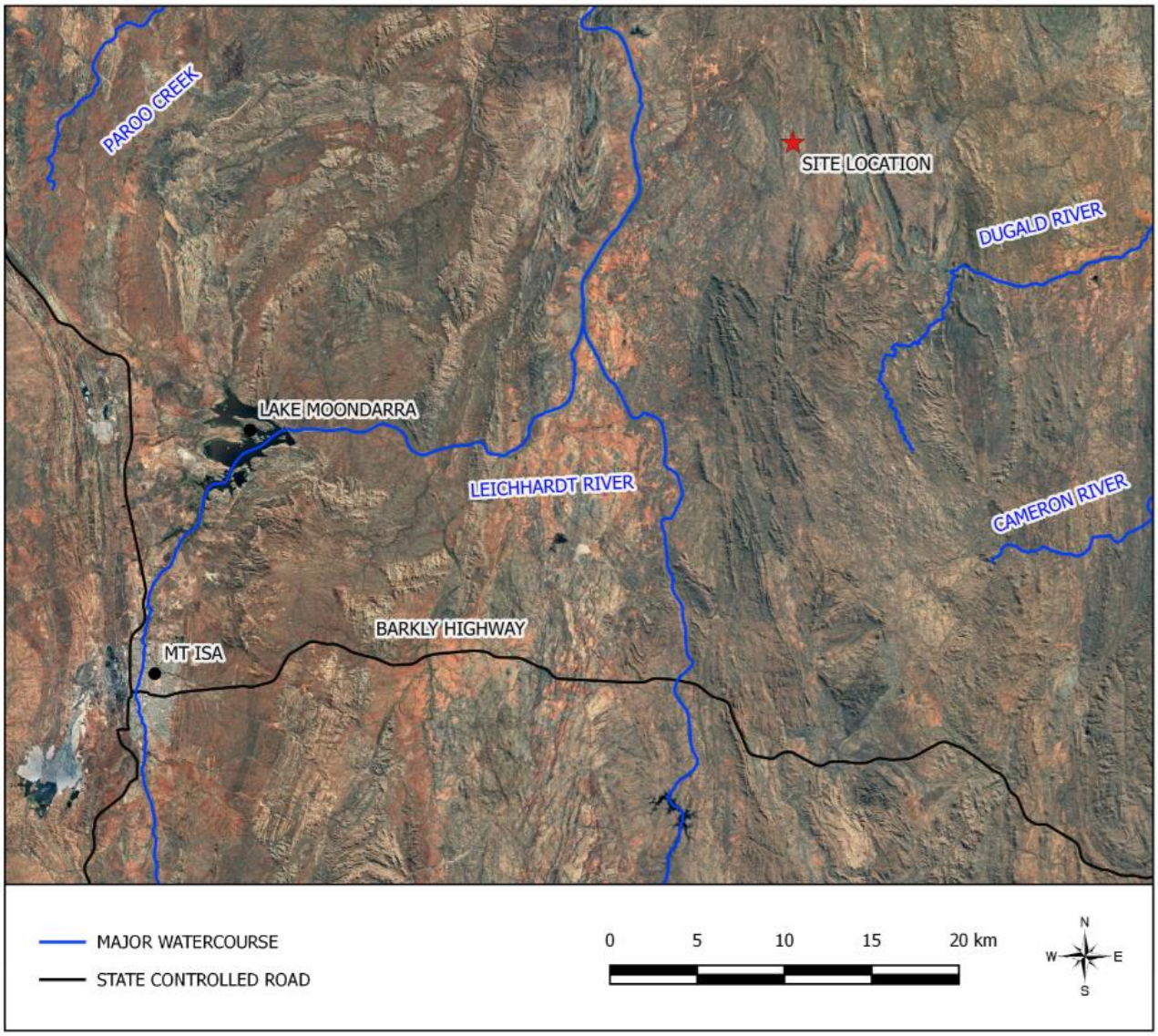
Section 2.0	-	Provides a description of the project in the context of the site water management strategy and the site setting, including the climatic and hydrological conditions.
Section 3.0	-	Presents an overview of expected site water quality and contaminant types. It includes details the water management strategy for the site as well as identification of potential Environmental Values.
Section 4.0	-	Outlines hydraulic license conditions regarding the Design Storage Allowance, Extreme Storm Storage and Mandatory Reporting Level.
Section 5.0	-	Presents details of site water balance modelling carried out for the site, including a review of overall hydrological performance based on the adopted water management layout.
Section 6.0	-	Details site water monitoring and review requirements.
Section 7.0	-	Provides an overview of the Emergency and Contingency procedures for the site.

2 PROJECT BACKGROUND

2.1 Project Development

The BCP is located approximately 60km northeast of Mt Isa in north-western Queensland. Primary access to the site comprises a 10km unsealed access track, via Lake Julius Road. Mining operations and construction commenced in March 2019, incorporating conventional open cut and excavation methods. It is understood that no processing is to occur at the site, with extracted ore to be transported by road train to processing sites at Malaco's Mt Cuthbert Mine and Glencore's Mt Isa Mine. Consequently, the site development includes a run-of-mine (ROM) pad and haul road infrastructure, but does not include processing or a tailings storage facility. The location of the BCP in a regional context is shown on **Plate 1**.

Plate 1
Site Location



Source: Google Earth Satellite (accessed 6 November 2018)

2.2 Site Infrastructure

The general layout of the site is depicted in **Figure 001**. The BCP incorporates the following key infrastructure:

- North Pit;
- South Pit;
- Waste Rock Dump (WRD);
- Waste Rock Dump Sediment Dam (WRD Sediment Dam);
- Light Infrastructure Area (LIA);
- Run-of-Mine (ROM) Pad, which includes the Road Train Loading Area (RTLA); and
- Magazine.

Other elements include:

- Haul roads and tracks
- Diversion drains
- Sewage treatment facility

The configuration of key site infrastructure is listed in the following sections. Pit geometry elevations were supplied by Round Oak in Mine Datum (AHD +1000m). The elevations listed below have been translated to reflect Australian Height Datum (AHD), by subtracting 1,000m. Refer also to **Table 2** (Section 3.3) for maximum licenced areas of disturbance.

The general layout of the site is depicted in **Figure 001**.

2.2.1 North Pit

The open-cut pit is located downstream of the rest of the site, with two diversion channels (ATCW, 2019) to redirect flows around the pit extents. The current configuration of the pit, as at 22 October 2019 is summarised below:

- Pit rim elevation — RL 316 m
- Approx. pit depth — 16 m
- October 2019 constructed pit rim capacity — 129.1 ML
- Pit extents — 1.5 ha
- Catchment area — 3.3 ha

A 1ML nominal sump is located at the base of the North Pit to collect rainfall that reports to the pit. The water is this sump is used for dust suppression.

2.2.2 South Pit

The open-cut pit is located to the east of the main creek alignment. The South Pit has a diversion drain on its east side to collect and convey clean surface flows from the adjacent hills to an alternative creek to the north of the pit. Site impacted catchment runoff from the ROM Pad/RTLA and the eastern portion of the WRD that flows along the haul road is diverted into the South Pit. The configuration of the pit as at 22 October 2019 is summarised below:

- Pit Rim Elevation — RL 334m
- Approx. Pit Depth — 34m
- Ultimate Pit Rim Storage Capacity — Approx. 3.3GL
- October 2019 Constructed Pit Rim Capacity — 995.4ML
- Pit Extents — 6.4ha
- Catchment Area — 21.0ha

A 1ML nominal sump is located at the base of the South Pit to collect rainfall that reports to the pit from the ROM Pad/RTLA and the haul road. It is expected that under extreme rainfall conditions the sump volume of 1ML will be exceeded, and thus water will spill into the South Pit. Round Oak have advised that operations will cease during inundation of the South Pit. Water from the South Pit sump is pumped to the North Pit.

2.2.3 WRD Sediment Dam

The WRD Sediment Dam is located directly downstream of the WRD and acts as a collection point for any surface runoff from the WRD. In previous documentation, the WRD Sediment Dam has been referred to as the 'WRD Dam'. The original dam was proposed as an earthen fill embankment lined with a Bituminous Geomembrane (BGM) liner. The constructed structure comprises two earthen fill embankments lined with a geomembrane and cushioning geotextile. The configuration of the dam is summarised below.

- Embankment Crest Elevation — RL 338.3m AHD
- Full Supply Level — RL 337m AHD
- Maximum Storage Capacity — 131.9ML
- Sediment Dam Extents — 3.0ha
- Catchment Area — 29.4ha

2.2.4 Light Infrastructure Area

The LIA is located south-east of the South Pit. The location is utilised as a general purpose area for mining plant, storage of equipment and materials. Runoff from the LIA is contained locally through bunding. Round Oak have advised that under extreme rainfall conditions, runoff will be conveyed to the South Pit via a surface drain alongside the haul road.

2.2.5 ROM Pad and Road Train Loading Area

The ROM Pad and RTLA are located adjacent to the South Pit. This location is utilised for temporary storage of excavated ore and waste prior to classification and haul/disposal. Runoff from the area drains to the South Pit.

2.2.6 Magazine

The explosives magazine is located to the north-west of the North Pit. The magazine area is bunded and is not included in the surface water transfer system.

2.3 Site Schedule

The site development timeline, as specified by Round Oak, is listed in **Table 1.**

Table 1
Site Development Schedule

Estimated Timing	Actual Timing	Infrastructure
Jan – Feb 2019	Jan – Feb 2019	Site access road, raw water tank installation
		Haul roads
		Topsoil stripping & stockpiling
		Surface water diversion features around site
		Diversion channel west of North Pit
		WRD preparation
		WRD Sediment Dam
		ROM pad & road train loading area
		Light infrastructure area & sewage treatment facility
		Explosives magazine
		Pump transfer network
Feb 2019	Feb 2019	Operations commence – South Pit
Jul 2019	Sep 2019	Operations commence – North Pit
Sep 2019	Oct 2019	Operations suspended – North Pit*
Oct 2019	Oct 2019	North Pit prepared for mine water storage for wet season
Jan 2020		North Pit operations resume
Sep 2020	-	Operations cease – South Pit
Oct 2020	-	Discontinue pumped transfers of site water, gravity flows commence to south pit
Oct 2020	-	Progressive rehabilitation

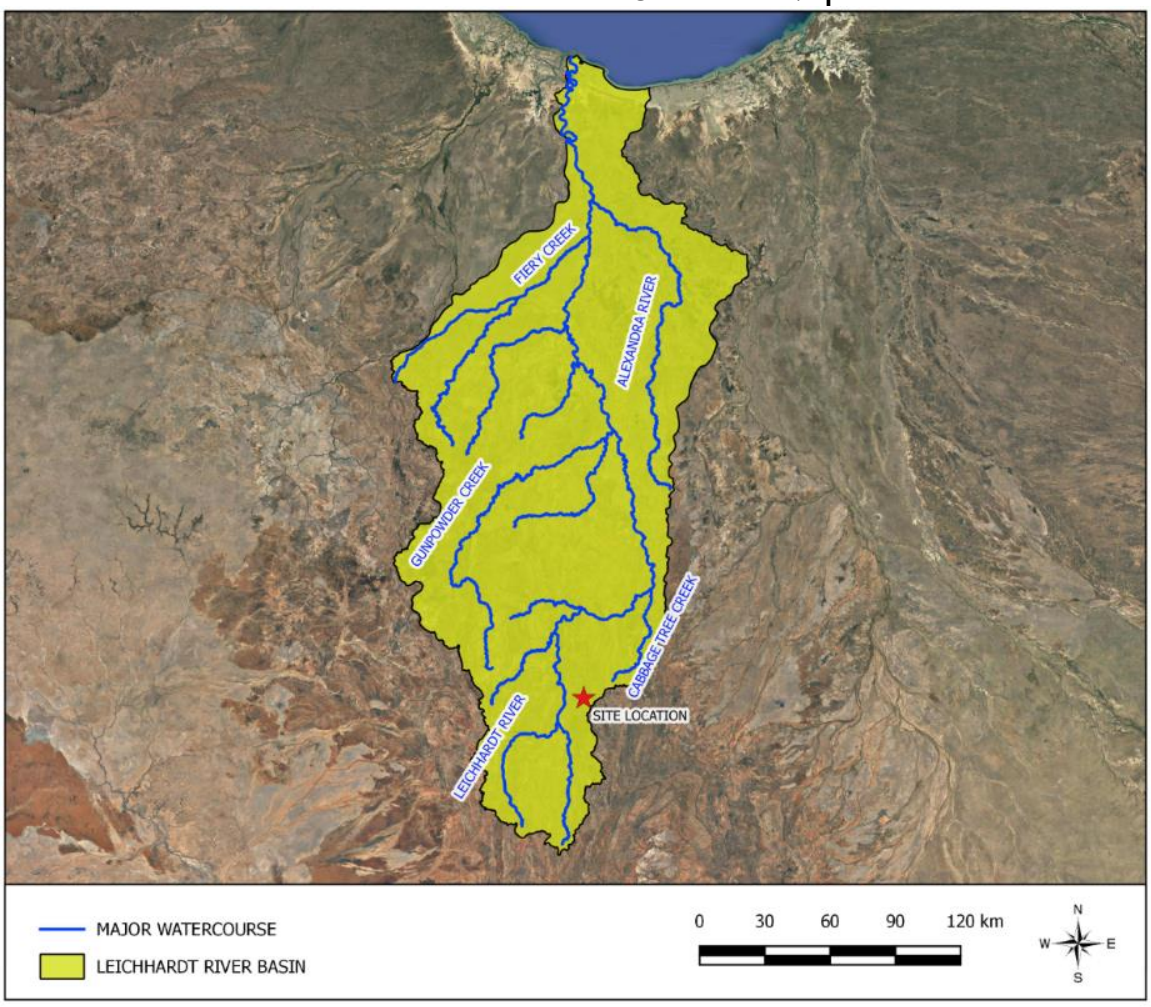
*At October 2019, the North Pit has reached a total volume of 129.1ML out of a design volume of 193.9ML.

2.4 Hydrological Characteristics and Topography

2.4.1 Regional Context

The BCP is situated within the Leichhardt River Basin (refer **Plate 2**). The Leichhardt River is formed in the Selwyn ranges at an approximate elevation of RL 405 m, falling over its 630km length to discharge into the Gulf of Carpentaria to the north. Julius Dam is located some 30km downstream of the project, at the confluence of the Leichhardt River and Paroo Creek. Lake Julius has a capacity of approximately 107.5GL and is listed in the Commonwealth's Directory of Nationally Important Wetlands.

Plate 2
Leichhardt River Basin Catchment Map



Source: Google Earth Satellite (accessed 6 November 2018)

2.4.2 Site Context

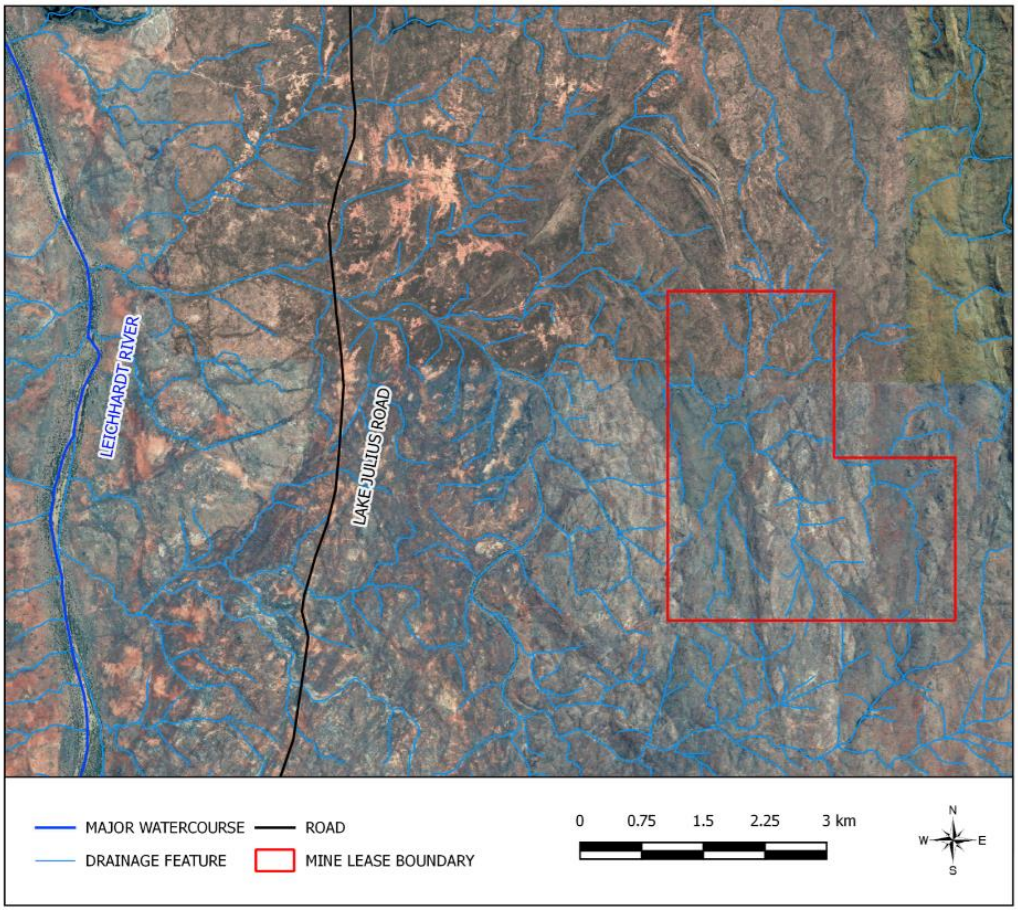
The topography and drainage characteristics of the local area surrounding the BCP has been described by Syndicated Metals Ltd (2014), and for the purposes of this plan is reproduced below.

"There are three main landform types in the Barbara area. These are: erosional hills, ridges and plateaus, colluvial foot slopes and alluvial channels. The area is dominated by exposed and sub cropping Proterozoic *rocks forming hills and plateaus. Small areas of proximal colluvium are found as foot slopes flanking the sides of ridges and at the base of scarps. Minimal alluvial sediments are found in immature drainage systems.*

There are no major [drainage or riverine features] *in the Barbara area; however, there are several minor, ephemeral tributaries which run through the site. Drainages tend to drain to the northwest, down from the steeper hills found in the south and through the Barbara area. Deposition of alluvium within drainage systems is minimal and there are no palaodrainages present in the area."*

The network of local ephemeral watercourses within the BCP region are depicted on **Plate 3**.

Plate 3
Local Watercourses in the Barbara Area

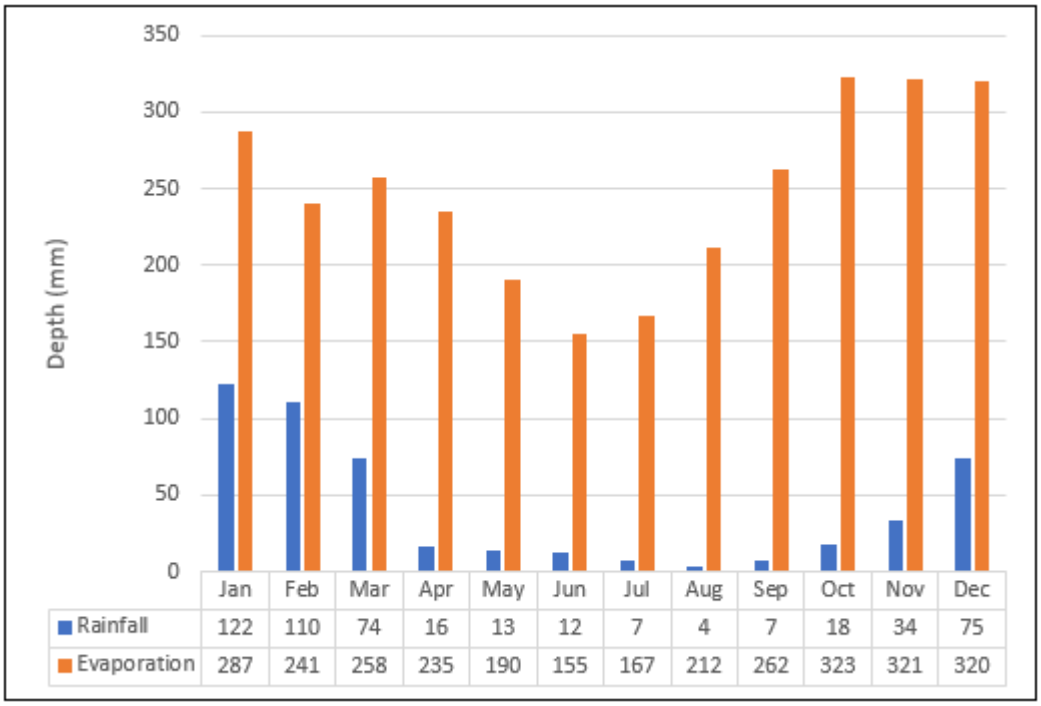


Source: Google Earth Satellite (accessed 6 November 2018)

2.4.3 Climatic Conditions

Located in north-western Queensland, the BCP is subject to a semi-arid tropic environment. The nearest meteorological weather station to the site, with greater than 2 years of rainfall records, is the Bureau of Meteorology's (BoM) West Leichhardt weather station (No. 029121) located some 25km to the south-west of the site. The average annual rainfall in the region is approximately 432mm. The West Leichhardt station does not have long term evaporation data – a key factor in the assessment of surface water management. Therefore, for the purposes of this assessment evaporation data has been sourced from a SILO Data Drill specific to the site location. The average total annual evaporation for the site is 2,971mm. **Plate 4** summarises the average rainfall and evaporation for all months of the year for the site. From the SILO Data Drill series, only data ranging from 1970 to 2019 was plotted, as Class A evaporation pan data is only available in the region for this period.

Plate 4
Mean Rainfall and Evaporation



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	122	110	74	16	13	12	7	4	7	18	34	75
Evaporation	287	241	258	235	190	155	167	212	262	323	321	320

Plate 4 indicates that evaporation potential exceeds mean monthly rainfall throughout the entire year. On an average monthly basis, maximum evaporation occurs later in the year (October to December). During the dry season months, evaporation is significantly lower, with the lowest monthly total typically occurring in June.

The climate at the site is associated with highly variable rainfall conditions. Mean values indicate a distinct pattern with lower rainfall conditions associated with the winter months, and higher values associated with the summer months. The wet season occurs between December and March, with 77% of mean annual rainfall occurring during these months, peaking in January, as shown on **Plate 4**.

2.4.4 Hydrogeology

Site characterisation of site hydrogeology has been undertaken by Rob Lait & Associates, with documentation under *Barbara Copper Project – Hydrogeological Report* (RLA, 2014).

The predominant landforms in the area comprise erosional topographic features, colluvial foot slopes and alluvial channels. Fractured rock aquifer systems are located at variable depths, typically where mineralisation / veins occur. Airlift testing conducted at the site suggests variable depletion rates (RLA, 2014).

Productive aquifer systems at the site intersect mineralised zones.

3 INTERGRATED WATER MANAGEMENT STRATEGY

3.1 Objective

An objective of this Plan is to maintain the biological integrity of surface water and groundwater at the BCP and to ensure the quality of water does not adversely affect environmental values or the health, welfare and amenity of people and land users by meeting statutory requirements and acceptable standards.

3.2 Environmental Values and Beneficial Users

Schedule 1 of the *Environmental Protection (Water) Policy 2009* (EPP Water) (DES, 2018) defines waters which are managed pursuant to the *Environmental Protection Act 1994* (EP Act) (Qld Parliament, 2018). Under this policy, Environmental Values (EV's) are defined, with Water Quality Objectives (WQO's) developed in accordance with the downstream values and users.

Review of Schedule 1 indicates that the Leichhardt Basin (Gulf of Carpentaria drainage division) does not currently have gazetted and mapped EV's or WQO's. Notwithstanding, generalised assessment under the EPP Water can be based on the nature of the receiving environment.

Based upon the hydrological domains downstream of the BCP location and potential downstream users, classification of the Environmental Values (EV's) for the downstream environment may include (Sustainable Minerals Institute, 2012):

- Aquatic Ecosystems;
- Stock Water;
- Irrigation;
- Recreation and Aesthetics;
- Fishing;
- Water Sports;
- Drinking Water; and
- Cultural and Spiritual Values.

Drainage paths downstream of the site location are described in **Section 2**, with principal features including:

- **Minor Drainage Paths**
  A series of minor drainage paths convey waters from the site location to a confluence point with the Leichhardt River, located some 10km to the west of site (as measured longitudinally in the invert of the drainage path). These drainage paths are unmapped on the Queensland Government Watercourse Identification Map (WIM).

- **Leichhardt River**
  The source of the Leichhardt River is located some 15km to the south of Mount Isa with the headwaters forming at the base of the Selwyn Mountain range. The Leichardt River is dammed at Mt Isa by the Moondarra Dam. Downstream of the Moondarra Dam, the Leichhardt River flows east, then north. The longitudinal distance between the Moondarra Dam wall and the Minor Drainage Paths-Leichardt River confluence point is some 40km. The Leichhardt River contributes to the Lake Julius Dam reservoir, some 15km to the north (longitudinally) of this confluence.

The Leichhardt River is an ephemeral Gulf river, and flow behaviour is dependent on rainfall conditions. Rainfall is typically heaviest in the summer period, as illustrated on Plate 4.

- **Lake Julius**
  Lake Julius has been formed by a concrete dam structure, featuring a series of arches and buttresses. The lake was formed by the damming of the Leichhardt and Paroo Rivers. The capacity to Full Supply Level is some 107.5GL. The owner/operator of Lake Julius and the Julius Dam is SunWater.

  Lake Julius is considered the practical end-point of the downstream environment. The large volume of the lake dilutes and allows for sedimentation of many contaminants, and so limits their potential to be mobilised further downstream.

  Downstream of the Julius Dam, the Leichhardt River continues north. A series of lesser Gulf rivers join the Leichhardt River as it flows towards the Gulf of Carpentaria, discharging in the vicinity of Burketown.

Additionally, areas downstream of the BCP are defined as slightly-moderately disturbed through historical and current mining and stocking activities. For example, the Leichhardt River has a significant history of contamination upstream of the site location, with riverine tailings discharge occurring at Mt Isa in the 1940's and discharge of process water continuing throughout the 1950's and 1960's (Sustainable Minerals Institute, 2012). Although river-bed sediment removal programs have significantly improved the amenability of the Leichhardt River, a slightly-moderately disturbed classification is considered appropriate.

3.3 Water Management Areas

The operation of the BCP is expected to include the following activities and infrastructure, much of which is relevant to Water Management, as detailed in **Table 2**.

Table 2
Water Management Areas

Defined Water Management Area	Name of disturbance area	Maximum licenced area of disturbance (ha)	Purpose
Active Mining Area	Run-of-mine (ROM pad)	3.5	Temporary storage, crushing and handling of ore
Active Mining Area	Road train loading area	1	Loading of ore for transport off-site
*Active Mining Area	North Pit	1.5	Mining of ore and site water management. Note: The North Pit is a regulated dam.
Active Mining Area	South Pit	6	Mining of ore and site water management. Note: The South Pit is a regulated dam.
Active Mining Area	Waste Rock Dump (WRD)	23	Storage and disposal of waste rock
NA	ROM pad dam	0.6	*NA - no longer part of project*
Non-Mining Area	WRD Sediment Dam	4	Water management for stormwater runoff from the WRD area
Non-Mining Area	Diversion drain	0.5	Water management to prevent stormwater runoff entering mine workings
Non-Mining Area	Topsoil stockpiles	2.5	Storage of topsoil for site rehabilitation works
Non-Mining Area	Access Road, Haul Roads and tracks	20.5	Site access
Non-Mining Area	Light Infrastructure Area: including Administration buildings, Fuel storage, Power facility and Workshop area	2.5	Site administration, Fuel Storage and power generation, Maintenance and storage
Non-Mining Area	Sewage treatment facility	0.5	Treatment of sewage
Non-Mining Area	Explosives magazine	0.5	Storage of explosives (not relevant to water management)

Table 2 is adapted from Table A1 of EPML02840015 (Date Effective: 30 October 2019)
*Operations of the North Pit have been temporarily suspended to provide wet season storage. The North Pit will resume operations in 2020.

3.4 Potential Contaminant Sources

The BCP predominantly involves two open cut pit developments, disposal of overburden waste rock material, handling of extracted ore and subsequent transportation offsite. Accordingly, the principal contaminant sources on site are the extracted waste rock and ore material from the North and South Pit.

Potential secondary contaminant sources are associated with secondary activities and infrastructure, such as road infrastructure, fuel storage and drainage work.

3.4.1 Waste Rock and Ore Geochemical Characterisation

Characterisation of the material to be extracted from the pits and described in this section has been taken from the following key reference:

- EGi (2014), *Barbara Copper Project – Assessment of Waste Rock Geochemistry*, Environmental Geochemistry International Pty Ltd, October 2014 (D/N 4405/1113)

EGi (2014) details a geochemistry investigation conducted in February and March 2014, involving 121 drill core samples obtained from 14 drill holes. The drill holes were located across the footprint of the North and South Pit.

EGi noted that a mining block model was not available to map geochemistry results to specific mining units. The pit development has changed significantly since EGi's 2014 assessment.

Standard geochemical analyses of drill samples were undertaken by EGi, with outcomes categorised based upon a 0.5% Copper (Cu) grade cut-off threshold for ore. In total, 27 samples were classified as ore, and 94 samples were classified as waste.

3.4.1.1 Initial Drainage

Initial drainage tests were also performed by EGi, to provide an indication of the pH level expected from runoff reporting from waste and ore surfaces. The test method is designed to emulate 'first flush' runoff water quality, based upon a short duration contact time between rainwater and waste/ore.

The initial drainage analyses undertaken indicate that first flush surface runoff was expected to be circum-neutral to slightly alkaline (pH generally ≥ 7.5). It was concluded that the acidity/alkalinity of the initial drainage was not considered to be a significant water quality issue.

3.4.1.2 Acid Mine Drainage

Characterisation of Net Acid Producing Potential (NAPP) and Net Acid Generation (NAG) properties of the samples was undertaken to examine the potential for Acid Mine Drainage (AMD). AMD is the process by which sulphides oxidise when in contact with water and oxygen and form sulphuric acid. AMD is generally released over the longer term and is considered separately to 'first flush' runoff water quality. Some materials may exhibit both the capacity to generate acid, and to neutralise acid (Acid Neutralising Capacity, or ANC), with the final classification based on the overall properties of the sample (rather than sulphide content independently).

Based upon the analyses undertaken, the samples were classified by EGi as being:

- Non-Acid-Forming (NAF)
  The sample is not expected to generate acid in excess of the available ANC.
- Potentially-Acid-Forming (PAF)
  The sample may form sulphuric acid when in prolonged contact with water and oxygen.
- Uncertain (UC)
  The sample may or may not form acid.

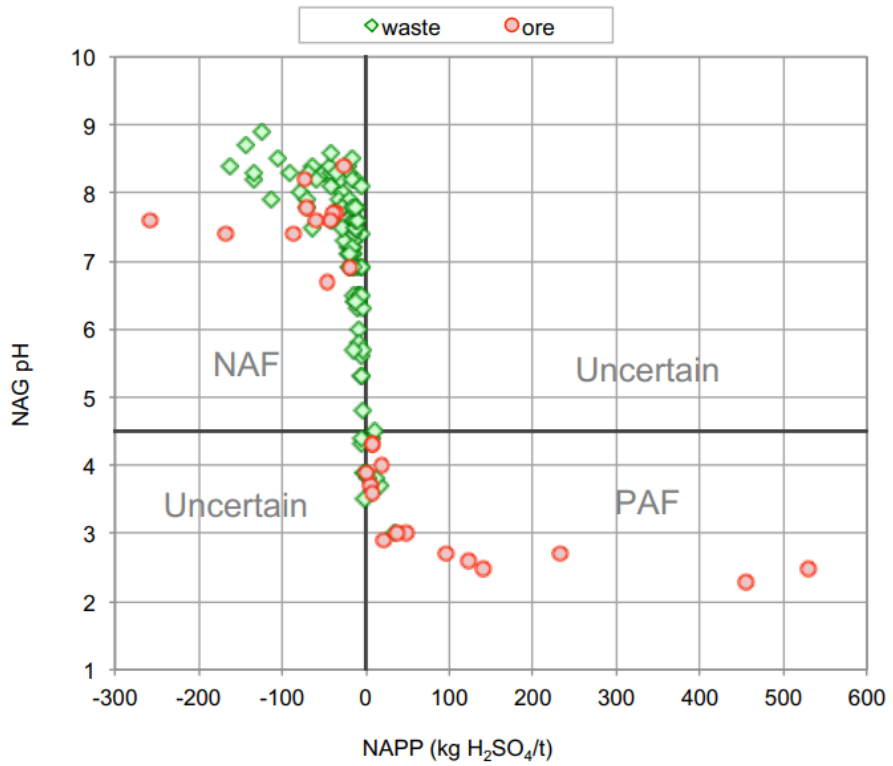
Based upon the acid forming properties, water which remains in contact with material for medium-long term durations, may exhibit acid mine drainage.

The determined classifications, based upon the NAPP and NAG testing, are detailed in **Table 3**.

Table 3
Waste Rock Classifications

Waste / Ore	Classification	Number of Analyte Results	Proportion
Waste Rock (Cu ≤ 0.5% Grade)	PAF	7	7%
	NAF	83	89%
	UC	4	4%
Ore (Cu > 0.5% Grade)	PAF	15	56%
	NAF	12	44%

Plate 5
AMD Characterisation of Barbara Copper Project Samples - EGi (2014)



Reproduced from Figure 6a, EGi (2014)

Additional kinetic NAG analyses were conducted for five samples (three waste, two ore), to provide an indication of the lag time before significant acid generation occurs. Accordingly, the five samples analysed were PAF samples. The determined outcomes are presented in **Table 4**.

Table 4
AMD Samples – Acid Generation Lag Time

Sample	Final pH	Lag Time
Ore #8050	3.1	Weeks to months
Ore #8112	2.7	At least a year to several years
Waste #8066	4.7	At least a year to several years
Waste #8092	3.0	Several years
Waste #8072	6.3	At least a year to several years

Reproduced from EGi (2014)

Overall, lag times for samples classified as PAF were significant, and likely to exceed a year.

Of the two analysed PAF ore samples, one was highly reactive (Ore #8050), with generation of acid expected to occur within weeks of being exposed to atmospheric conditions (water and oxygen).

NAF waste rock materials were analysed to exhibit limited ANC, so that blending of NAF and PAF samples may not result in significant changes to acid generation characteristics of the blended material, compared to the PAF material alone.

3.4.1.3 Elemental Characterisation

Characterisation of the elements within each sample was undertaken using a geochemical abundance index approach (GAI). Under this approach, the abundance of minerals within a sample is compared to reference materials (which do not feature abundance or enrichment of specific elements).

The elements analysed included: Al, As, Ba, Be, Bi, Cu, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Sn, Sr, Th, U and Zn.

Elements which were considered to be minor enriched or greater by EGi (2014), are listed in **Table 5** and **6**.

Table 5
Elemental Ore Characteristics

Material	Element	Abundance (Ratio of Sample : Reference Material)	GAI	Description
Ore	Copper	≥24	≥3	Abundant
	Sulphur	≥24	≥3	Abundant
	Selenium	12 - 24	3	Significant enrichment
	Bismuth	12 - 24	3	Significant enrichment
	Cobalt	12 - 24	3	Significant enrichment
	Arsenic	12 - 24	3*	Significant enrichment
	Nickel	6 - 12	2**	Minor enrichment

*1 of 7 ore samples was classified as having a GAI of 3 for Arsenic, with 6/7 samples classified as having a GAI of 0 (Little to no enrichment)
**2 of 7 ore samples were classified as having a GAI of 2 for Nickel, with 5/7 samples classified as having a GAI of 0 (Little to no enrichment)

Table 6
Elemental Waste Characteristics

Material	Element	Abundance (Ratio of Sample : Reference Material)	GAI	Description
Waste	Copper	12 - 24	3	Significant enrichment
	Sulphur	12 - 24	3	Significant enrichment
	Selenium	12 - 24	3	Significant enrichment
	Bismuth	6 - 12	2	Minor enrichment
	Cobalt	6 - 12	2	Minor enrichment

3.4.1.4 Saline Drainage

Analyses of Electrical Conductivity (EC) were performed to provide an indication of the expected salinity of water coming into contact with waste and ore materials, with the following outcomes determined:

- 72% of analyses, generally comprising the predominant waste unit (Porphyritic Rhyolite), resulted in an electrical conductivity of less than 400 µS/cm, representative of 'non-saline water'.
- 21% of analyses resulted in an EC between 400 and 800 µS/cm, representative of 'slightly-saline water'.
- 13 of analyses conducted were classified indirectly as 'saline' (≥800 µS/cm). It is noted that 12 of the 13 analyses resulting in a 'saline' classification comprised high sulphur ore materials.

Based upon the EGi (2014) results, it was concluded that saline drainage was not considered a significant water quality issue, with respect to waste rock materials. Drainage from ore materials will be potentially saline.

3.4.2 Contaminants Associated with Non-Mining Areas

Contaminants associated with non-mining-areas, relevant to water management, include the following:

- **Gross Sediment & Suspended Sediment**
  A variety of mining activities have the capacity to result in mobilisation of sediment from shallow surfaces and sub-soils as a result of construction and disturbance authorised by the site EA.
  In general, water quality issues arising from sediment mobilisation relate to turbidity (water clarity).
  Sedimentation is a natural process, however mining activities have the capacity to cause erosion and mobilisation of sediment at increased levels.

- **Hydrocarbons**
  Hydrocarbons (diesel) will necessarily be stored and utilised on site to operate mining plant. Hydrocarbons stored at the LIA present a potential point source contaminant (i.e. they may impact a localised area).

- **Sewage**
  Any sewage generated onsite is to be kept separate from the water management system, with release in accordance with license conditions of the site EA.

3.4.3 Ore Processing / Beneficiation

Chemical processing/beneficiation of ore is not licensed for the BCP. Accordingly, there are no processing-based contaminant sources stored or used on-site.

3.4.3.1 Summary of Potential Contaminants

3.4.3.1.1 Waste Rock

Potential contaminants at the BCP predominantly relate to the mineral extraction activities within the North and South Pit.

Based upon the geochemistry investigation conducted by EGi (2014), potential water quality issues and contaminants relating to waste rock material may include the following:

- Copper, Sulphur, Selenium
  - Significantly Enriched
- Bismuth, Cobalt
  - Enriched
- Acid Generation
  - Most samples tested were NAF, however approximately 10% of samples tested were classified as PAF. Lag times for significant acid generation to occur (based on 3 samples) are expected to exceed one (1) year.

Suspended sediments from runoff generated from the WRD are likely to be elevated compared to non-mine impacted waters.

3.4.3.1.2 Ore

Water quality issues may relate to the ore streams extracted from the North and South Pit developments, as follows:

- Copper, Sulphur
  - Abundant
- Selenium, Bismuth, Cobalt, Arsenic
  - Significantly Enriched
- Nickel
  - Minor enrichment
- Acid Generation
  - Some 56% of the ore samples tested were classified as PAF. Lag times for significant acid generation (based on two samples) varied from 'weeks' to 'years'.

3.5 Water Management Strategies

3.5.1 Classification of Mined Material

Based upon the potential contaminant sources present at the BCP, materials classified as ore streams by EGi (2014) typically exhibit a greater capacity to produce contaminants, compared to waste rock materials. Furthermore, ore streams were generally classified as Potentially-Acid-Forming (PAF), whereas waste streams were generally classified as Non-Acid-Forming (NAF).

Processing of ore and disposal of ore by-products will not occur at the BCP, with processing instead occurring at Malaco's Mt Cuthbert Mine and Glencore's Mt Isa Mines.

Strategies for classifying and managing extracted material will comprise the following:

- **Initial Classification**
  Noting that significant acid formation may occur from PAF ore materials within a week of exposure to rainfall and oxygen, analysis of material upon extraction is to occur within 3 days, to allow sufficient time for appropriate disposal and management.

- **Ore**
  Management of extracted ore material within the BCP will comprise temporary storage with the ROM Pad and Road Train Loading Area, prior to haulage. Ore stockpiles should be assumed to contain PAF materials, with acid generation possible within a week of exposure to rainfall. Accordingly, water expressing from any ore stockpile is required to be contained. Ore material, once removed from the Mining Lease, are considered out of scope of this Water Management Plan.

- **Waste Units**
  Based upon a 0.3% Sulphur content threshold, EGi estimated that some 15% of the tested samples would be classified as PAF. Waste material extracted from the pits require classification into PAF and NAF units, with additional disposal requirements relating to PAF material.

  The classification of waste material is to occur based upon a developed block model assigned to mining material, or analysis of material upon extraction. Significant acid formation may occur within a year of exposure to atmospheric conditions. Therefore, sufficient disposal is considered to comprise dumping within an encapsulated PAF cell,

constructed within the WRD. PAF Waste material are to be disposed of within an encapsulated cell within 6 months of initial extraction.

3.5.2 Water

Based upon the potential contaminants, and downstream EV's, the following water types have been defined for the BCP:

- **Mine Affected Water (MAW)**
  - **Description of Expected Water Quality Issues**
    Water potentially impacted by exposure to mine waste and ore.
    MAW may contain elevated concentrations of Copper, Sulphur, Selenium, Bismuth, Cobalt, Arsenic and Nickel.
    Quantities of suspended sediments are potentially elevated.
    Acid generation from PAF extracted mining units may impact MAW.

    Defined Locations & Origins
    North Pit, South Pit, ROM Pad, Road Train Loading Area, WRD, WRD Sediment Dam, LIA (primarily hydrocarbons and sediment, refer below and Section 3.5.3.1)

    Management
    MAW is to be conveyed, via safe, effective and non-eroding hydraulic controls, to authorised containment structures within the BCP (WRD Sediment Dam, South Pit and North Pit).
    MAW inventories will be managed by evaporative losses from the North Pit, South Pit and WRD Sediment Dam.

- **Sediment Affected Water (SAW)**
  Description of Expected Water Quality Issues
  Water potentially impacted by elevated suspended sediments and associated water quality issues.

  Defined Location & Origins
  Magazine, roads and any other disturbed areas not defined as an active mining surface.
  Any area identified during operation as impacted by erosion or scour.

  Management
  SAW management will primarily revolve around the implementation of an effective Erosion and Sediment Control Plan, as mandated by the site EA, condition E17, to reduce the potential for erosion and promote the settlement of suspended sediments prior to discharge to downstream environments via safe, effective and non-eroding hydraulic controls.
  Management of SAW is predominantly expected to comprise the implementation of Erosion and Sediment Control (ESC) measures and activities such as silt fencing, compaction, remediation of scour locations, seeding, rock armouring and level spreaders.

- **Clean-Water**
  Description of Expected Water Quality Issues
  None – representative of natural conditions.

Defined Locations & Origins
Areas located upstream of the site, or site areas that are not disturbed (and do not report through a disturbed area).

Management
Clean Water is to be conveyed, via safe, effective and non-eroding hydraulic controls, to the downstream environment.
The principal goal of the water management strategy is to minimise the collection of Clean Water within site structures.
The principal management activity relating to Clean Water is the installation, inspection and maintenance of Clean Water drainage and diversionary infrastructure.

3.5.3 Other Contaminants

3.5.3.1 Hydrocarbons

Hydrocarbons represent a point source contaminant, with impacts typically arising from accidental spillage or leakage from containment tanks. Standard effective management for hydrocarbons involves the installation of a localised containment bund to retain hydrocarbons in the event of a tank leak.

3.5.3.2 Sewage and Sewage Effluent

Sewage and sewage effluent comprise another contaminant source.

It is noted that the release of sewage is conditioned within the EA under conditions C1 and C2. As the release of sewage is licensed, and sewage is not to be mixed with any site waters, it is considered that sewage does not comprise a contaminant with respect to the site regulated structures.

4 HYDRAULIC DESIGN ASPECTS

4.1 Regulated Structures

As required by Condition H1 of the EA, structures on-site which contain or control liquids (i.e. dams and related hydraulic infrastructure) require a Consequence Category Assessment (CCA), to determine whether the structure comprises a 'regulated structure' as defined by the "Manual for Assessing Consequence Categories and Hydraulic Performance of Structures" (the Manual) (DES, 2016).

The structures listed in **Table 6** are already licensed by the site EA, having been assessed during previous phases of the BCP development. The project no longer includes the ROM Dam because the South Pit sump now provides containment for runoff from the ROM Pad. When necessary, runoff from the ROM Pad can be managed through pump transfer to the North Pit and/or WRD Sediment Dam, to allow ongoing mining and mineral extraction within the South Pit.

Plate 6
Barbara Copper Project - EPML02840015 - Hydraulic Performance Criteria

Table H1 **Table H1 – Hydraulic performance criteria ('Table H1')**

Name of dam	Consequence category	Hydraulic performance criteria		
		Spillway capacity	Design Storage Allowance	Mandatory Reporting Level
North Pit	Significant	1:100 to 1:1000 AEP 72 hour duration storm event	1:20 AEP 2 month wet season	1:10 AEP 72 hour duration storm event
South Pit	Significant	1:100 to 1:1000 AEP72 hour duration storm event	1:20 AEP 2 month wet season	1:10 AEP 72 hour duration storm event
WRD Dam	Significant	1:100 to 1:1000 AEP72 hour duration storm event	1:20 AEP 2 month wet season	1:10 AEP 72 hour duration storm event
ROM Dam	Significant	1:100 to 1:1000 AEP72 hour duration storm event	1:20 AEP 2 month wet season	1:10 AEP 72 hour duration storm event

Reproduced from the site EA (EPML02840015).

Table H1 contains an error in specifying the spillway capacity performance criteria. For all dams, the criteria should read "1:100 to 1:1000 critical duration storm event".

4.2 Consequence Category Re-assessment

Should the function, geometry or contained contents of a regulated structure on-site materially change, reassessment of the CCA of site structures is required, as outlined in the EA (EPML02840015). There have been no material changes to any of the regulated structures since the EA was issued.

Additionally, any new structures onsite (such as dams or levees), which meet the definition of a structure, as defined by Structures which are dams or levees constructed as part of environmentally relevant activities (DES, 2017), will require assessment. No new regulated structures have been constructed at the site since the EA was issued.

4.3 Hydraulic Performance Criteria

4.3.1 Regulatory Requirement

Section 2.2.2.2 of the Manual outlines the process for Managing design storage allowance and extreme storm storage in integrated water management systems.

4.3.2 Design Storage Allowance

A key requirement of the Manual is the estimation of a Design Storage Allowance (DSA). DSA is defined as "*an available volume provided in a dam as at 1 November each year in order to prevent a discharge from that dam up to a specified annual exceedance probability (AEP).*" (DES, 2016).

The regulated structures requiring containment are listed within **Table 7**. It is noted that the DSA volume relating to some structures cannot be accommodated without transfer, necessitating consideration of DSA sharing via the installed pump and transfer system. The need to share DSA's triggers a requirement to prepare a system design plan (Refer Section 2.2.2.2 of the Manual). This is discussed further in **Section 5.2.2**.

Table 7
DSA Volumes for the Regulated Structures

Regulated Dam	North Pit	South Pit	WRD Sediment Dam	Total
DSA Criteria	Significant	Significant	Significant	
Critical Wet Period	2-Months	2-Months	2-Months	
Rainfall Total	677.2 mm	677.2 mm	677.2 mm	
Catchment Area	3.3 ha	21.0 ha	29.0 ha	
Runoff Coefficient	1.0	1.0	1.0	
DSA Volume	22.4 ML	142.2 ML	196.4 ML	361.0 ML
Capacity	129.1 ML	995.4 ML	131.9 ML	1256.5 ML
Capacity - DSA Vol	107 ML	823 ML	-64.5 ML*	895.5 ML

*The required DSA volume for the WRD Sediment Dam exceeds the design capacity of the storage. Pump transfer within the WBM indicates that the current pump transfer configuration is able to facilitate the DSA volume through transfer to other storages.

4.3.3 Mandatory Reporting Level

The site EA and the Manual define the level corresponding to the Extreme Storm Storage (ESS) as the Mandatory Reporting Level (MRL). Should the MRL be exceeded, in any circumstances, notification to DES is required, as per the site EA.

The location of the MRL must be clearly marked and be visible on each structure. The MRL's of each structure were confirmed during the inspections (16th October 2019) and associated reporting in *Barbara Copper Project - 2019 Annual Inspection of Regulated Structures* (ATCW, 2019). The determined 2019/2020 MRLs of the as constructed configuration for each structure are listed in **Table 8.**

Table 8
Mandatory Reporting Levels (MRLs)

Regulated Dam	North Pit	South Pit	WRD Sediment Dam
Consequence Category	Significant	Significant	Significant
Final Design Capacity	193.9 ML	3528.0 ML	131.9 ML
Total Catchment Area (incl. Extents)	3.3 ha	21.0 ha	29.0 ha
Runoff Coefficient	1.0	1.0	1.0
Extreme Storm Storage (ESS) Criteria	1:10 AEP 72 Hour Duration Storm Event	1:10 AEP 72 Hour Duration Storm Event	1:10 AEP 72 Hour Duration Storm Event
ESS Rainfall Depth	228.0 mm	228.0 mm	228.0 mm
Freeboard	0.3 m	0.4 m	0.3 m
Emergency Spillway Invert	RL 316.0 m	RL 334.0 m	RL 337.0 m
Adopted Mandatory Reporting Level	RL 315.6 m	RL 333.2 m	RL 334.3 m

4.3.4 Emergency Spillway Sizing

As specified by Table H1 of the EA (**Plate 6**), the site regulated structures require an emergency spillway for flood conveyance.

The emergency spillway geometries were designed utilising a simplified routing spreadsheet, which calculates flow rate according to the broad crested weir equation. The following parameters were utilised in sizing the spillways.

- Rainfall Data — BOM IFD (2016) Rare Estimates
- Catchment Losses — Nil (Catchment was assumed to be fully saturated Prior to design event)
- Coefficient of Weir Discharge — 1.45

The emergency spillway geometries are presented in **Table 9.**

Table 9
Regulated Structures - Minimum Emergency Spillway Geometry

Parameter	WRD Sediment Dam	South Pit	North Pit
Design Criteria	1:1000 AEP	1:1000 AEP	1:1000 AEP
Spillway Width	20.0 m	5.0 m	2.0 m
Spillway Elevation (AHD)	RL 337.0 m	RL 334.0 m	RL 316.0 m
Estimated Flow Depth	0.6 m	0.6 m	0.4 m
Dry Freeboard	0.4 m	0.4 m	0.3 m
Total Spillway Depth	1.0 m	1.0 m	0.7 m

The geometries of the spillways for the North Pit and South Pit allow for controlled releases rather than uncontrolled releases of excess stored waters.

4.4 Site Drainage

4.4.1 General

Control of the three water types, MAW, SAW and clean water, is required across the site. Clean water diversion drainage and containment drainage are illustrated on **Figure 001**.

4.4.2 North Pit Diversion Drains

There are several diversion drains around the North Pit. These are:

- A diversion drain and associated levee have been constructed to the west of the North Pit to convey the creek, including clean runoff from the WRD Sediment Dam, around the Pit.
- A diversion drain and associated levee have been constructed to the north of the Pit.
- A small diversion drain on the eastern side of the North Pit collects surface runoff from the eastern hills and conveys it to the diversion drain to the north of the Pit.

4.4.3 South Pit Diversion Drain

The South Pit diversion drain has been constructed to the east of the South Pit to divert clean surface runoff to the north of the South Pit, where it passes beneath the haul road and enters the creek diversion drain to the west of the North Pit.

4.4.4 WRD Sediment Dam Drainage

In the event of a spillway release form the WRD Sediment Dam, flows drain to the north, whereupon the enter the creek diversion drain to the west of the North Pit.

4.5 Pumped Transfer Lines

Pumped transfer lines from the WRD Sediment Dam to the North Pit and South Pit sumps have been installed. The relevant activation and deactivation levels and cease pumping logic are listed in **Table 12** and discussed in **Section 0**.

4.6 Erosion and Sediment Control Measures

As per condition E17 of the site EA, an Erosion and Sediment Control Plan is required for all stages of the mining plan.

5 WATER BALANCE MODEL

5.1 Objective

A Water Balance Model (WBM) has been developed to assess the performance of the site water management infrastructure and management systems, principally over the regulatory wet season.

Noting Table H1 of the EA (**Plate 6**), the Design Storage Allowance hydraulic performance criteria relating to each 'Significant' consequence regulated structure on site is the effective management of a 1:20 AEP 2 month wet season event (critical duration event). The principal measure output from a WBM is the modelled spill probability of a structure. Therefore, to measure the performance of regulated structures over the wet season, an equivalent probability to the DSA requirement was adopted for the spill probability criteria, as shown in **Table 10.**

Table 10
Adopted WBM Performance Criteria

DSA Hydraulic Performance Criteria – 'Significant' Consequence Structure	Equivalent WBM Performance Criteria
1:20 AEP, 2 month [critical duration] wet season	Equivalent Spill Probability ≤5% Measured over the regulatory wet season period.

5.1.1 Site Development and Simulation Staging

The WRD Sediment Dam and the North Pit function together to provide water storage for site impacted water. As at October 2019, the South Pit had reached an excavated volume of approximately 1GL of total available storage, out of a final design volume of 3.3GL. The final design volume will be available when excavation of the South Pit has been completed, which is estimated to be in October 2020.

The water balance model reflects the as constructed volumes in the North Pit, South Pit and WRD Sediment Dam. The model also reflects that there is no stored water in any structure at the start of the simulation (reflective of site conditions on 30 October 2019).

It has been assumed that during excavation of the pits, the respective pit is kept effectively empty of water, operating with an approximate 1ML sump for temporary, site impacted stormwater runoff storage.

5.1.2 Model Configuration

The water balance model was developed using GoldSim Pro, a dynamic probabilistic simulation program. The model uses a range of parameters to represent the catchment surface water flow system, being routed through a time series of daily rainfall data to estimate daily runoff.

The simulation for the WBM runs for a duration of 2 years. For the purpose of the WBM, it is assumed that all storages are empty (dry) at the commencement of the model, representative of the current site conditions.

5.1.3 Modelled Conditions

In order to define the water management strategy for the BCP, the current site configuration was adopted from the as constructed details provided in October 2019.

5.2 Input Data

5.2.1 Site Infrastructure

The site infrastructure listed in **Table 11** was modelled, with relevant data utilised within the model sourced from **Section 2**.

Table 11
Site Structures – WBM Input Data

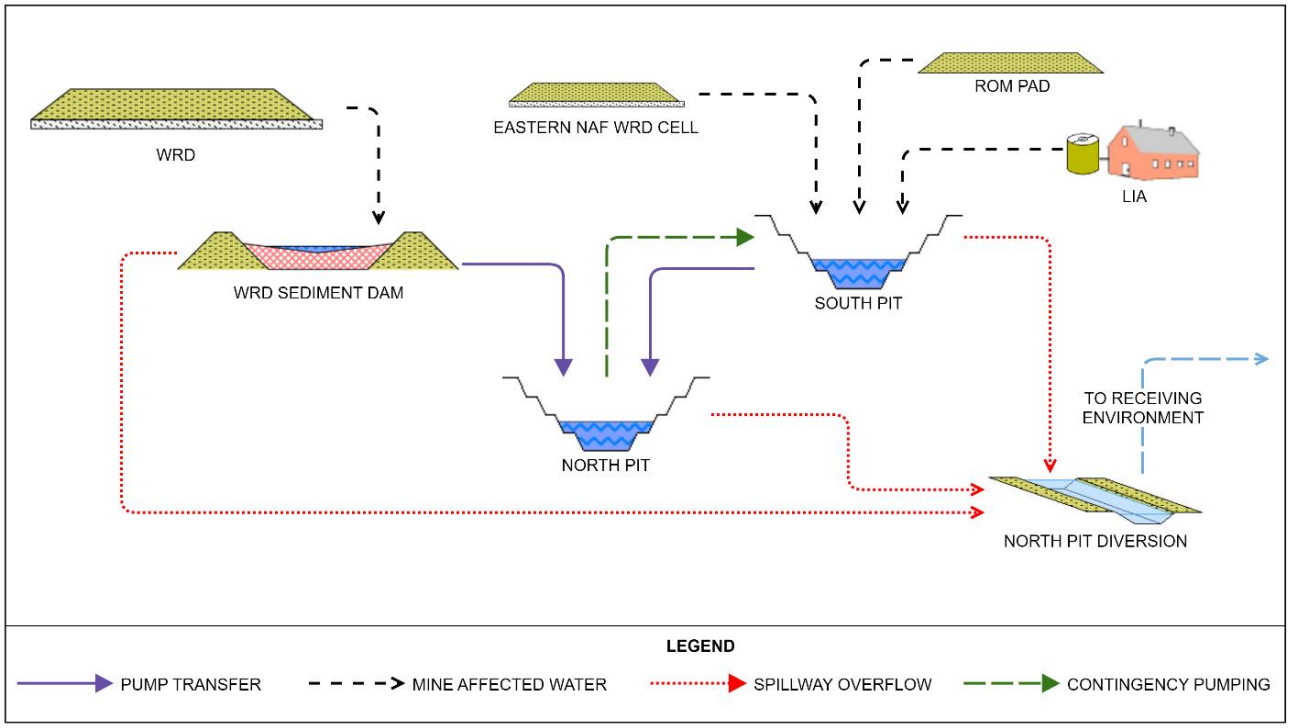
Structure Data	Units	North Pit	South Pit	WRD Sediment Dam
Capacity	ML	129.1	995.4	131.9
Water Surface Area at Full Supply Level	ha	1.6	6.4	3.0
Full Supply Level	RL m	316.1	334.0	337.0
Initial Water Elevation	RL m	Empty	Empty	Empty
Pan Evaporation Factor	-	0.8	0.8	0.9
External Catchment Area	ha	1.8	14.6	26.4*

*While the WRD does not currently occupy the full 26.4 ha catchment, the model has assumed the entire catchment to be fully impacted by waste rock, which will occur as the WRD is extended during the mining operation.

5.2.2 Modelled Site Process Flow Configuration

The WBM was developed based on the site elements and interactions between storages, as advised by Round Oak. The connections and modelled transfers are depicted in **Plate 7.**

Plate 7
Site Water Management Strategy



The process flow configuration was provided by Round Oak, utilising the North Pit as the final site storage for transfer from the WRD Sediment Dam and South Pit. Should the dams spill, flows from the WRD Sediment Dam and South Pit would enter the diversion drain to the west of the North Pit. prior to reporting to the receiving environment.

Pumped transfer of site impacted stormwater runoff was based on the design configuration listed in the "Mine Infrastructure Site Layout Plan" (AECOM, 2019), provided in **Appendix A**. The current site configuration has the South Pit pump as a permanent structure. Having the south pit pump as a trailer mounted pump would provide the site with the capability to provide intermediate relief and redundancy under the failure scenario of other pumps being inoperable. The layout of the installed pump and pipeline transfer system has not changed from the design layout in **Appendix A**.

The adopted pumping levels and parameters for each storage are listed in **Table 12**. The Stage Storage Curves for the North Pit, South Pit and WRD Sediment Dam are contained in **Appendix B**.

Table 12
Site Structures - Modelled Pump Transfers

Structure Data	South Pit	North Pit	WRD Sediment Dam
Pump Configuration	HL110m Diesel Pump	90kW Pump	8kW Pump
Modelled Pump Flow Rate	20 L/s	100 L/s	20 L/s
Activation Level	Maintain Empty	RL 314m	RL 334m
Deactivation Level		RL 313m	RL 335m
Cease Pumping Logic	When water exceeds RL 315m AHD within the North Pit.	Risk of overtopping within South Pit	When water exceeds RL 315m AHD within the North Pit.
Operational Pump Destination	North Pit	-	North Pit
Contingency Pump Destination	-	South Pit (if required)	-

5.2.3 Input Climatic Data & Surface Runoff Model

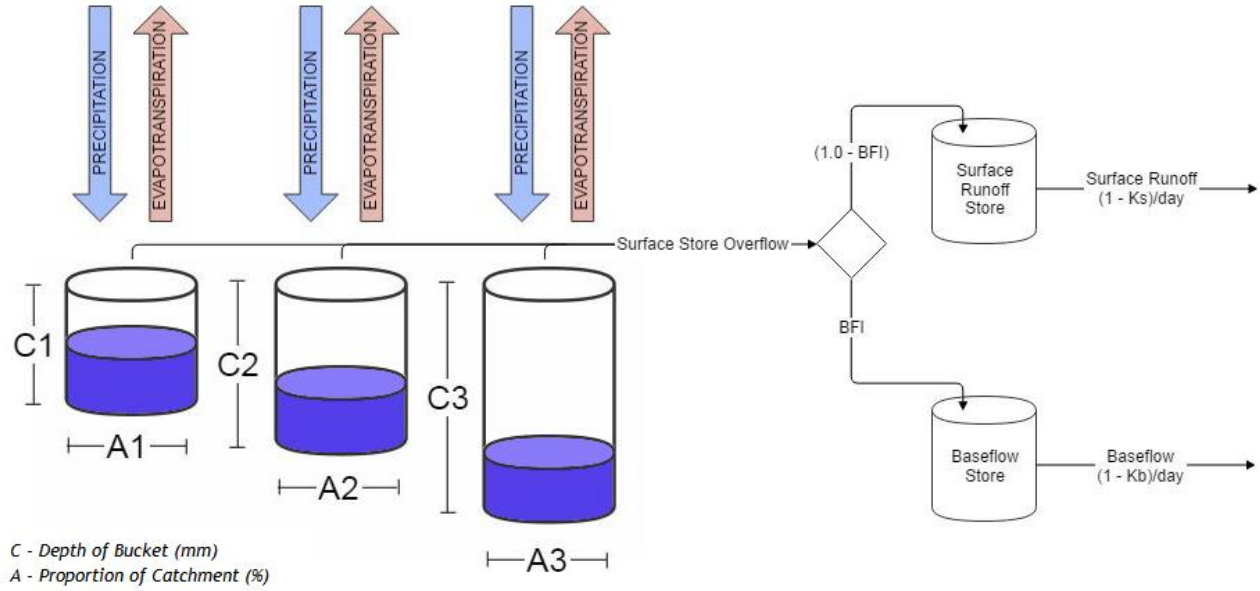
Climatic input data (daily rainfall, evaporation and evapotranspiration) derived for the site location was obtained from the SILO Data Drill Program (DES, 2019), from 1889 to 2019. SILO Data Drills provide an uninterrupted climate record for modelling, derived from real weather station observations within the region. The sourced data utilised in the WBM is detailed in **Table 13.**

Table 13
Site Water Balance - Rainfall and Evaporation Input Data

Climate Data	Data Source	Comments
Daily Rainfall Rate (mm/day)	Rainfall data obtained from the SILO Data Drill Program for the Site Location (1889 - 2019)	Applied over dam surface areas, and as an input parameter for the estimation of surface runoff (AWBM).
Daily Evaporation Rate (mm/day)	Continuous record from SILO Data Drill formed by conjoining: CLIMARC estimates (1889 – 1957) and Class A Evaporation Data from proximate weather stations within the region (1889 – 2019).	Evaporation Data is scaled by evaporation factors for each site storage to reflect water storage conditions and expected water quality.
Daily Evapo-transpiration Rate (mm/day)	As calculated by the FAO short crop reference methodology, assuming a wind speed of 2 m/s.	PET is calculated based on temperature, vapour pressure and solar global exposure parameters derived from climatic data, and is adopted as a reasonable estimate of potential evapotranspiration losses from ground surfaces within the surface runoff model.

The Australian Water Balance Model (AWBM) was utilised to simulate daily runoff from rainfall generated within the various sub-catchment types that are present on the project site. **Plate 8** represents a schematic of the AWBM model, reproduced from Boughton (2009).

Plate 8
Schematic of the AWBM Rainfall-Runoff Model



Where:
C1 – C3 = Surface Storage Capacities
A1 – A3 = Partial Areas Represented by Surface Storages
BFI = Baseflow Index
K_b = Daily Baseflow Recession Constant
BS = Current Volume in Baseflow Store
K_S = Daily Surface Flow Recession Constant
S = Current Volume in Surface Store Routing

The catchment types and AWBM model parameters used to simulate these different catchment types and the average yields from these catchment areas are summarised in **Table 14.** Model parameters have been selected based on experience with similar water balance model studies, and are considered to be conservative in the context of this uncalibrated model.

Table 14
AWBM Model Parameters

AWBM Parameters	Split Areas (sum=1.0)			Storage Capacities (mm)			Ks (day-1)	BFI	Kb (day-1)
	A1	A2	A3	C1	C2	C3			
Natural	13.4	43.3	43.3	12	120	250	0	0	1
Hardstand	10	0	0	10	-	-	0	0	1
Waste	20	80	0	10	300	-	0	0	1
Open Cut	10	90	0	5	20	-	0	0	1

Site catchment areas were delineated based upon the following survey sources:

- Barbara Aerial Survey Lidar DTM (26/11/18) provided by Round Oak;
- As Constructed Survey data for the WRD Sediment Dam (19/08/19), North Pit (23/10/19) and South Pit (23/10/19); and,
- Shuttle Radar Topography Mission (SRTM) Hydro Enforced 1 Second DEM (Geoscience Australia, 2018)

The delineated catchment areas are depicted on **Figure 002** and detailed in **Table 15.**

Table 15
Site Structures - Catchment Areas

Structure Data	North Pit	South Pit	WRD Sediment Dam
Natural	-	2.0 ha	-
Hardstand	1.8 ha	5.9 ha	-
Waste	-	2.8 ha	26.4 ha
Open Cut	-	3.9 ha	-
Finished Surface Area	1.5 ha	6.4 ha	3.0 ha
Total Area	3.3 ha	21.0 ha*	29.4 ha

*Comprised of Catchments B, G, J and K from **Figure 002**.

5.2.4 Modelled Water Inflows

As advised by Round Oak, external inflows to site structures include surface runoff and groundwater inflow. The current excavations in the North and South Pits do not show evidence of infiltration from the groundwater table. Groundwater inflows previously adopted from RLA (2014) were not adopted for the modelling.

5.2.5 Modelled Water Outflows

With reference to the previous iteration of the Water Management Plan (URS, 2014), an average outflow rate exceeding 400m^3/day was utilised to represent dust suppression demands. In order to maintain a conservative assessment, dust suppression and washdown water usage was modelled at a rate of 200m^3/day on dry days (<5mm total rainfall depth).

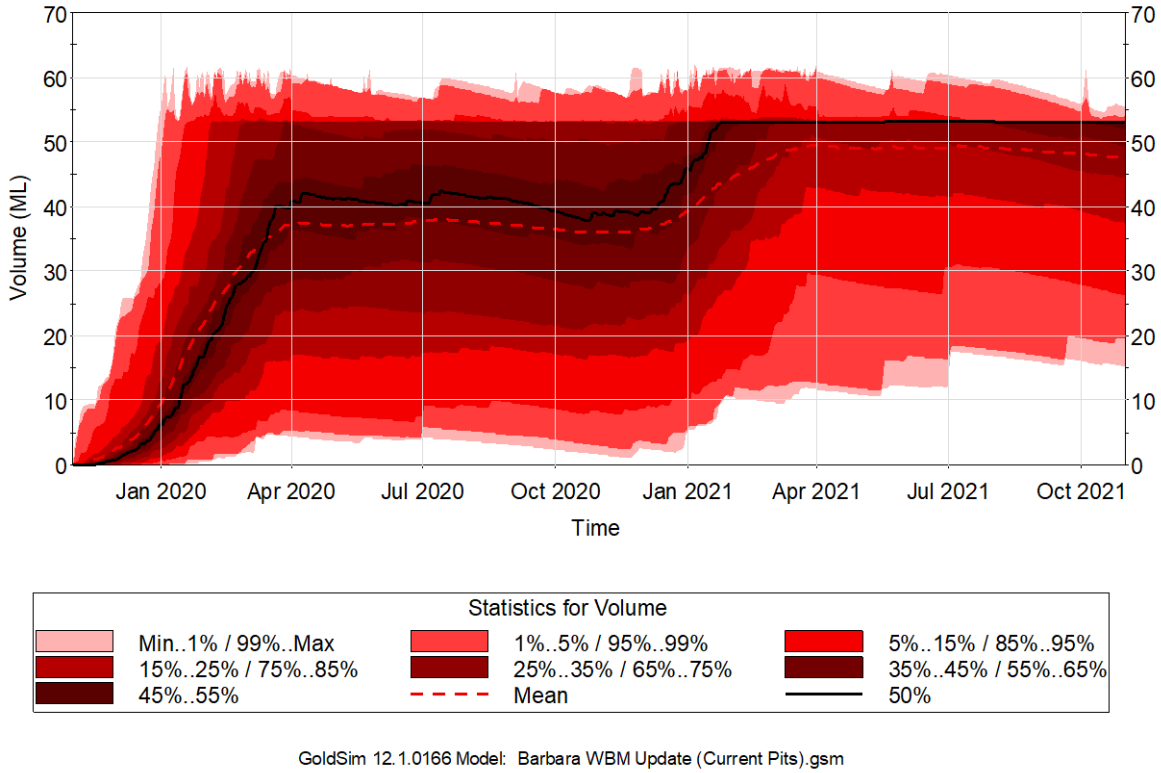
5.3 Results

5.3.1 North Pit

Plate 9 indicates there are significant inflows to the North Pit as a result of pump transfer from the WRD Sediment Dam. It is noted that the storage within the pit could rise significantly, subject to prolonged or extreme rainfall conditions, however, these rainfall conditions exceed the site EA containment requirements.

Overall, the water balance of the North Pit is shown to increase the stored volume by a mean of approximately 48ML in the two years of the simulation.

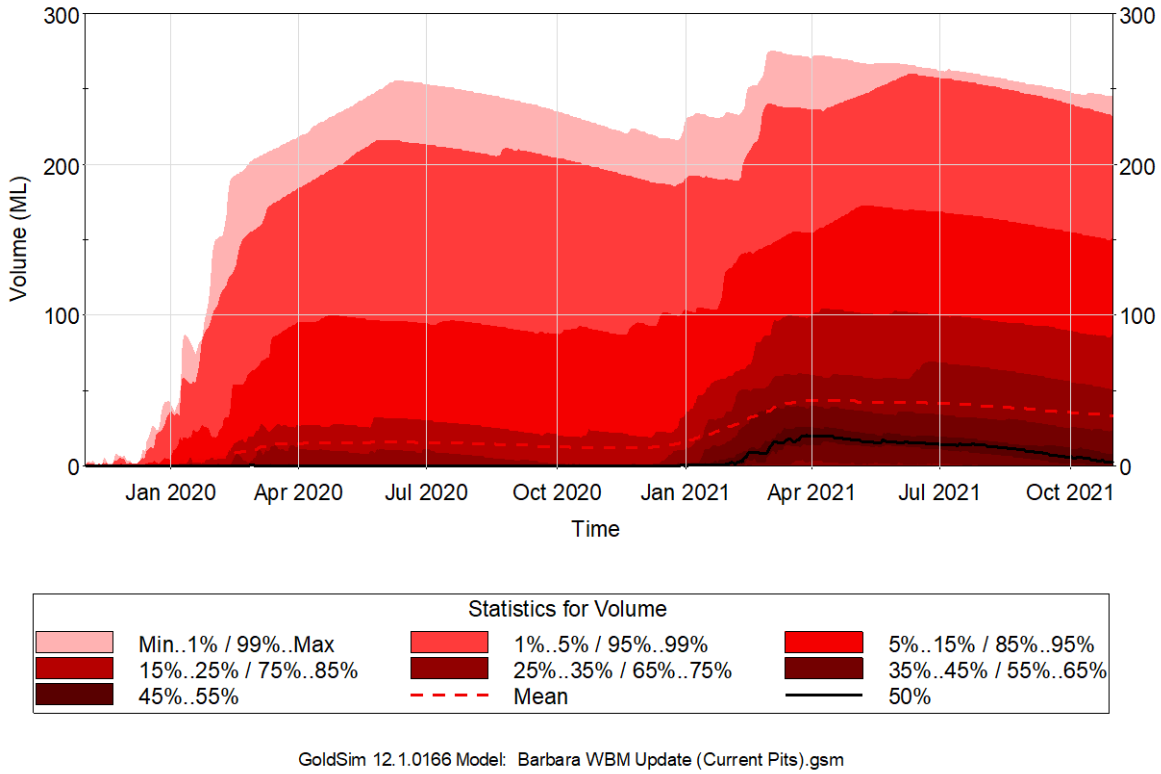
Plate 9
North Pit - Modelled Storage Volume



5.3.2 South Pit

The South Pit is modelled to be effectively dewatered in rainfall events equal to the sites EA containment requirements, as can be seen in **Plate 10**. The higher percentile wet seasons result in some accumulation of water within the pit, primarily due to an inability to pump to the North Pit after it reaches the cease pumping level. This suggests that the pit sump capacity may be exceeded in extreme rainfall sequences. This may require operations in the South Pit to cease when the 1ML sump volume is exceeded. Once the stored volumes are contained within the 1ML sump, operations within the South Pit can re-commence.

Plate 10
South Pit - Modelled Storage Volume

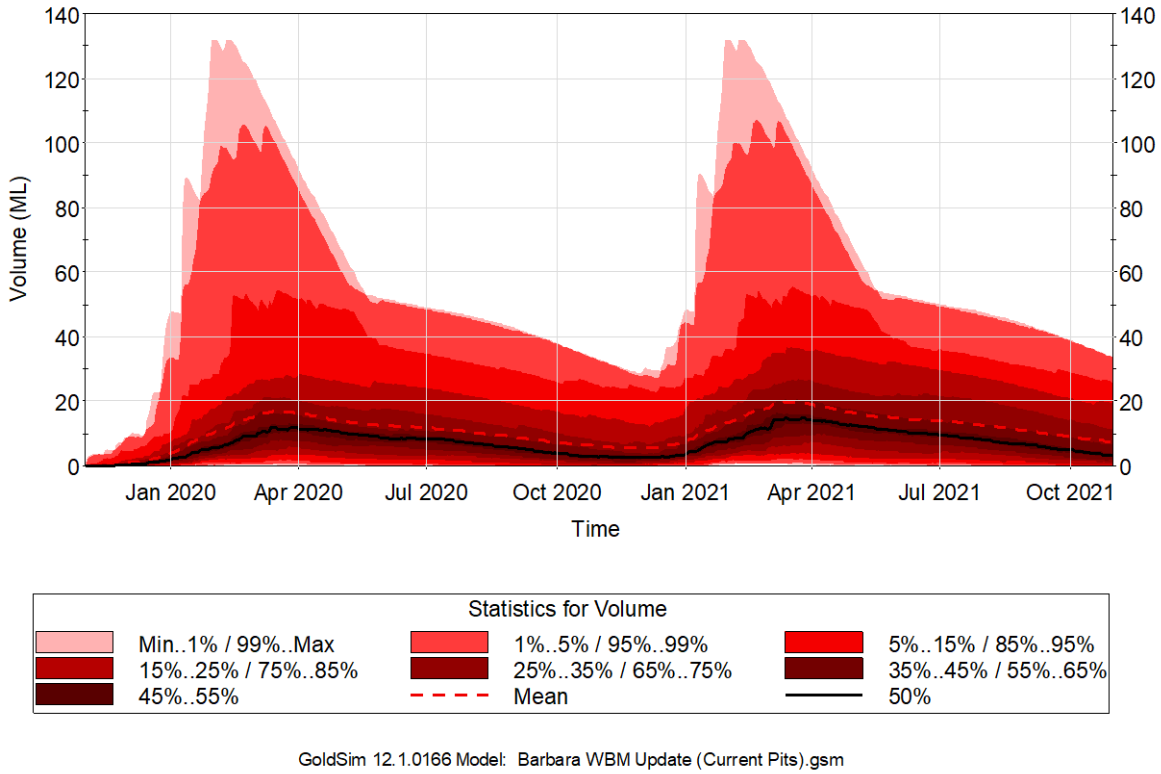


5.3.3 WRD Sediment Dam

The WRD Sediment Dam is modelled to effectively contain runoff reporting from the WRD. The modelled pump configuration is set up to transfer water to the North Pit and maintain relatively low levels within the WRD Sediment Dam. This is to reduce the likelihood of a spill in a storm event due to the large upstream catchment reporting to the WRD Sediment Dam.

The net mean increase in stored volume at the end of the 2 year simulation is approximately 9ML, as shown in **Plate 11**.

Plate 11
WRD Sediment Dam - Modelled Storage Volume



5.3.4 Spill Probability

For the as constructed conditions detailed in **Table 11** and the operating conditions listed in **Table 12**, based upon the modelling undertaken, the adopted containment criteria for the regulated structures are met, as shown in **Table 16**.

Table 16
Modelled Scenarios - Spill Probabilities

	North Pit	South Pit	WRD Sediment Dam
Spill Probability	<1.0%	<1.0%	<1.0%

6 MONITORING AND REVIEW

Water quality monitoring at the BCP is required in accordance with the EA to identify any potential influence or threat to receiving waters. Monitoring requirements in relation to both clean (diverted) water and site water management systems are outlined in the EA.

6.1 Stored Water Quality Monitoring

Water quality monitoring is to occur within each water storage on site, with the data being reviewed against the contaminant limits outlined in the EA.

Stored water quality monitoring is to be undertaken to demonstrate compliance with defined contaminant limits. It is a requirement that these limits are achieved. If exceedance is recorded, practicable measures should be implemented to prevent access to stored water by all livestock and to minimise access by native fauna.

6.2 Surface Water Quality Monitoring

6.2.1 Release Water Quality Monitoring

Surface water monitoring requirements are specified in the EA under Conditions E5 to E7. Authorised release locations for the site are identified in the EA corresponding to the release locations of relevant site storages. Authorised release points are defined by Condition E2 (and Table E1) of the EA.

Surface water quality monitoring will be conducted for off-lease discharge events, i.e. each single or continuous event at which flow reports from each defined release site, with the monitoring frequency specified in the EA.

6.2.2 Receiving Water Quality Monitoring

Receiving water monitoring and downstream compliance monitoring sites and water quality limits associated with release events are outlined in the EA.

Round Oak is responsible for carrying out investigations into receiving water quality during and after any spill events in accordance with ANZECC methodology. This monitoring is to determine if there is any potential for environmental harm downstream of the site due to a release of potentially contaminated water.

6.3 Groundwater Quality Monitoring

Groundwater monitoring requirements are specified in the EA under Conditions E8 to E13. Groundwater quality triggers and monitoring bore locations are specified in Table E5-6 (of the EA).

Should an exceedance of a groundwater quality trigger contained within Table E6 of the EA occur, an exceedance investigation must be carried out, pursuant to Condition E11 of the EA.

6.4 Water Management Plan Review

In conjunction with annual Dam Safety Inspections, the hydraulic performance requirements for each structure are reviewed and updated to identify possible short-comings. This inspection is to be completed before 1 November each year.

The EA does not specify a formal frequency for review of the entire site Water Management Plan, however, reviews should be undertaken as deemed necessary to ensure measures, practices and procedures are carried out effectively to ensure minimal risk of environmental harm.

7 EMERGENCY CONTINGENCY PLAN

The following scenarios have been identified as potential events or incidents that would fall under this emergency and contingency management plan.

7.1 Extreme/Prolonged Rainfall

Rare rainfall events or prolonged conditions may cause a number of incidents to occur. In the event of an exceedance of the rainfall intensity and duration adopted to design the water management structures, the critical or "worst case" scenario would involve:

- overflow from the North/South Pit system or WRD Sediment Dam.

Under these conditions, failure and/or overtopping of water management structures may result in flooding of downstream areas within the flow path, as well as the release of contaminants to the receiving environment. In this event, a risk to any personnel working within the area would also be present. Any structures at risk of flooding would need to be evacuated and vital equipment removed from the area.

As detailed in Section 5.3, any spilling from structures on site would exceed the containment requirements of the EA.

7.2 Other Incidents Causing Environmental Harm

7.2.1 Spills or Leaks

Spills or leaks may occur from tanks, pipes or other mine infrastructure and instrumentation during any weather conditions, particularly under strong winds or other destructive conditions, where tanks can by propelled and pipes (above ground) can burst. The release of hydrocarbons is of particular concern to the receiving environment.

In the event of an incident, the assessment of potential environmental impact stemming from spills, leaks and their associated effects is to be made, irrespective of the volume of the spill occurring.

Notification to downstream stakeholders must occur for any degree of off-lease environmental impact. Notification and consultation with environmental authorities and specialists is an inbuilt feature of standard operating directives for spill incidents.

7.2.2 Erosion or Damage to Site Infrastructure

Water management infrastructure such as dams, embankments and drains may be subject to erosion, particularly during storm events or overtopping. Regular inspections are required to ensure infrastructure is operable and free of damage, with immediate remedial actions required should any damage be found.

7.2.3 Pumps

Back-up pumps and generators are to be made available in case of pump failure during extreme events. The additional pumps and generators are to be available while the failed pumps are being repaired.

7.2.4 Inability to access control and monitoring points in all weather conditions.

Four-wheel drive (4WD) vehicles are to be retained on site for the purpose of accessing control and monitoring points during and after storm events.

7.3 Responsibilities

It is the responsibility of the Site General Manager to ensure all elements of the water management plan are implemented. This includes ensuring all ongoing monitoring of the water management infrastructure is completed as outlined in the EA, and all required inspections, reviews and reporting are undertaken and submitted to DES in the specified and appropriate timeframes.

8 REFERENCES

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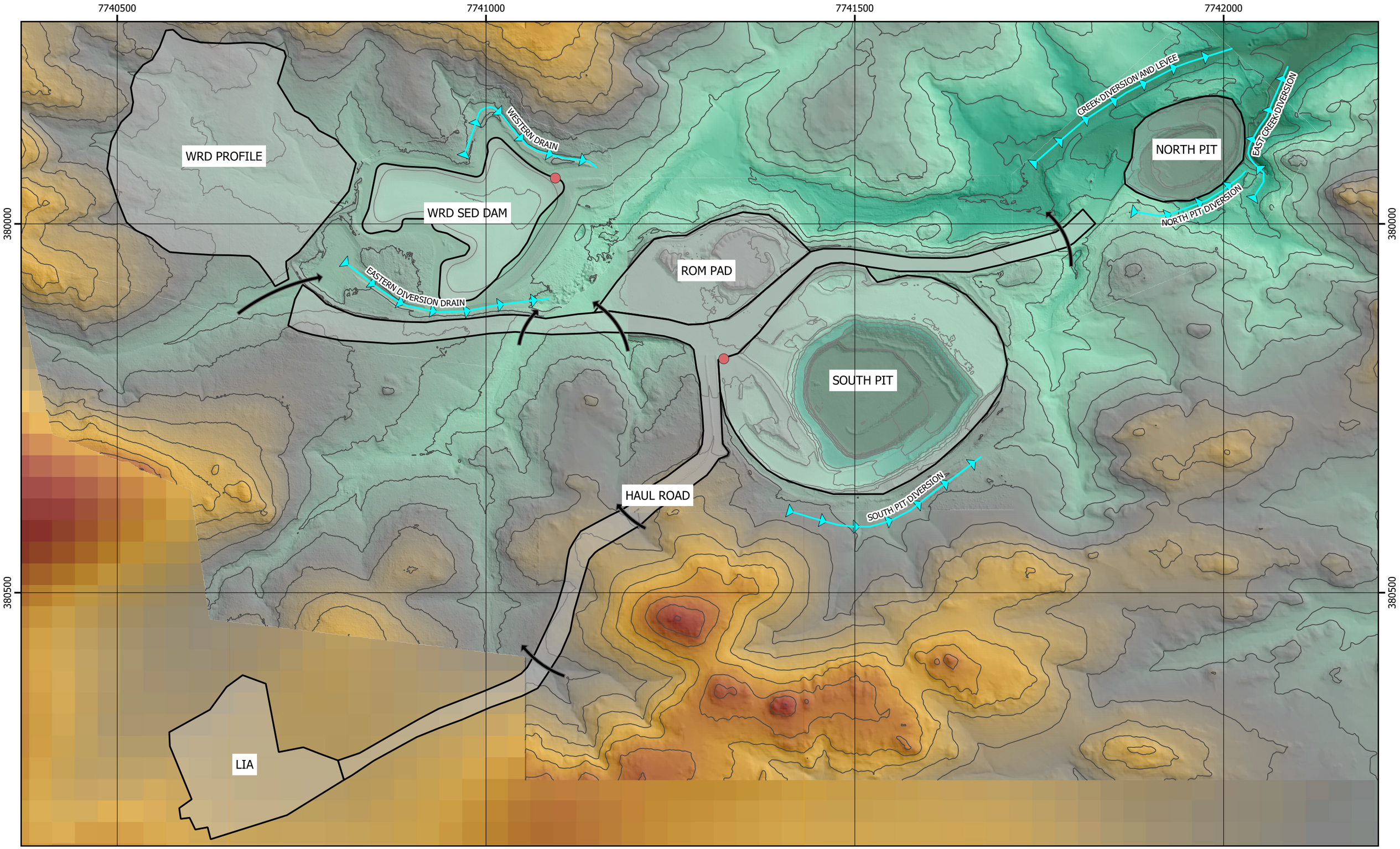
FIGURES



LEGEND

- 5m CONTOURS
- CURRENT SITE LAYOUT EXTENTS
- CULVERT STRUCTURE
- CLEAN WATER DIVERSION
- EMERGENCY SPILLWAY LOCATIONS

ELEVATION (m RL)

- 311 RL.m
- 329.6 RL.m
- 348.1 RL.m
- 366.7 RL.m
- 385.2 RL.m

ROUND OAK MINERALS - BARBARA COPPER PROJECT

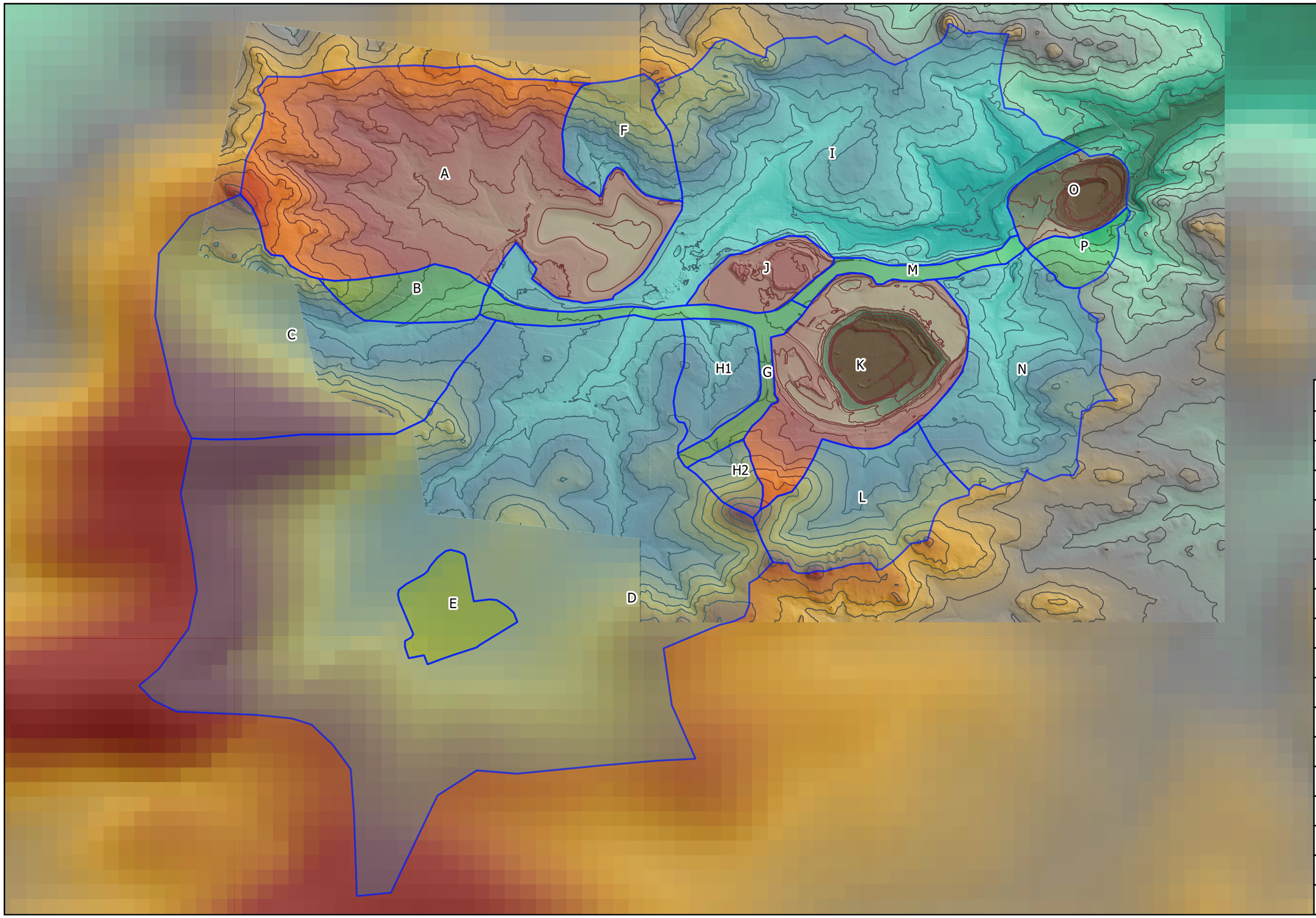
FIGURE 001
SITE LAYOUT PLAN

0 0.05 0.1 0.15 0.2 km

ATC Williams

DATE: 2019-11-26

CRS: GDA94 / MGA Zone 55



Name	Area	Type
A	29.4 ha	Impacted
B	2.8 ha	Sediment
C	19.3 ha	Clean
D	78.8 ha	Clean
E	3.1 ha	Sediment
F	4.3 ha	Clean
G	3.2 ha	Sediment
H1	3.3 ha	Clean
H2	1.3 ha	Clean
I	32.2 ha	Clean
J	2.7 ha	Impacted
K	12.3 ha	Impacted
L	7.8 ha	Clean
M	1.5 ha	Sediment
N	12 ha	Clean
O	3.3 ha	Impacted
P	1.5 ha	Sediment

LEGEND

- CLEAN WATER
- MINE IMPACTED WATER
- SEDIMENT RUNOFF
- 5m CONTOURS

ELEVATION (m RL)

- 311 RL.m
- 329.6 RL.m
- 348.1 RL.m
- 366.7 RL.m
- 385.2 RL.m

ROUND OAK MINERALS - BARBARA COPPER PROJECT

FIGURE 002
STORMWATER CATCHMENT PLAN

0 0.1 0.2 0.3 0.4 km

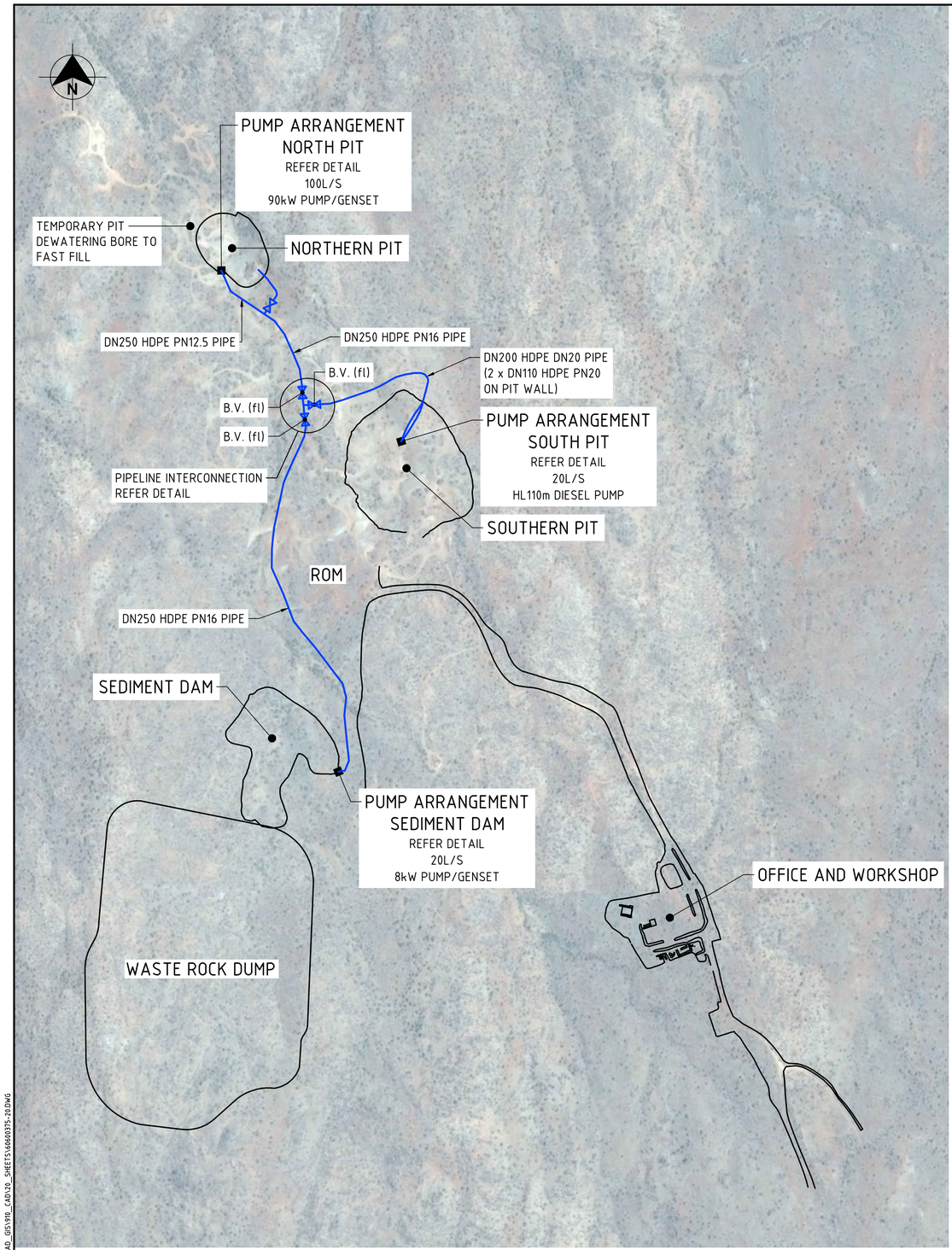
ATC Williams

DATE: 2019-11-25

CRS: GDA94 / MGA Zone 55

APPENDICES

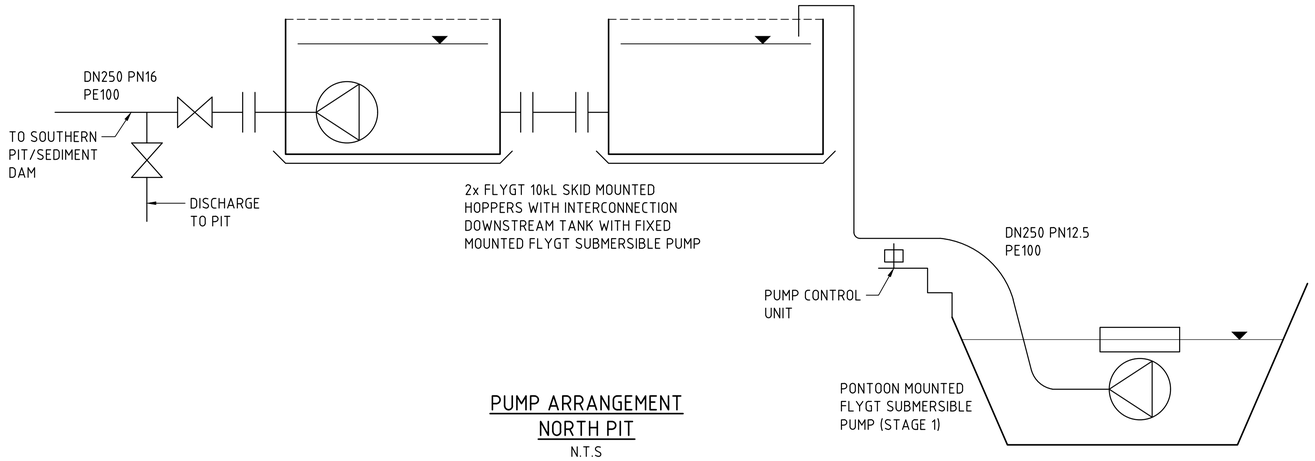
APPENDIX A



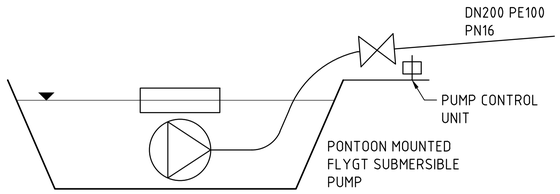
LAYOUT PLAN
SCALE W

LEGEND

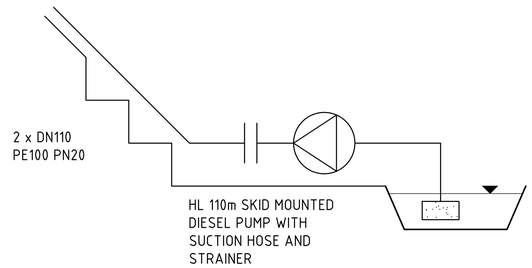
R.V.	REFLUX VALVE
B.V.	BUTTERFLY VALVE
DN	NOMINAL DIAMETER



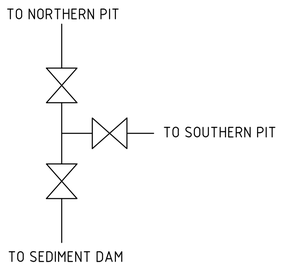
PUMP ARRANGEMENT
NORTH PIT
N.T.S



PUMP ARRANGEMENT
SEDIMENT DAM
N.T.S



PUMP ARRANGEMENT
SOUTH PIT
N.T.S



PIPELINE
INTERCONNECTION
N.T.S

NOTE:

- DESIGN DETAILS SHOWN HERE HAVE BEEN PROVIDED BY OTHERS. AECOM DOES NOT TAKE RESPONSIBILITY FOR THEIR SUITABILITY OR ACCURACY.

NOT FOR CONSTRUCTION

This drawing is confidential and shall only be used for the purposes of this project.

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD
A	CJM	28.08.19	CLIENT REVIEW	

Scale
SCALE W 0 100 200 250m
1 : 10000 (A3) 1 : 5000 (A1)

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED		CHECKED	
DRAWN		CHECKED	
APPROVED		DATE	

AECOM

RPEQ No.
AECOM Australia Pty Ltd A.B.N. 20 093 846 925

Round Oak MINERALS

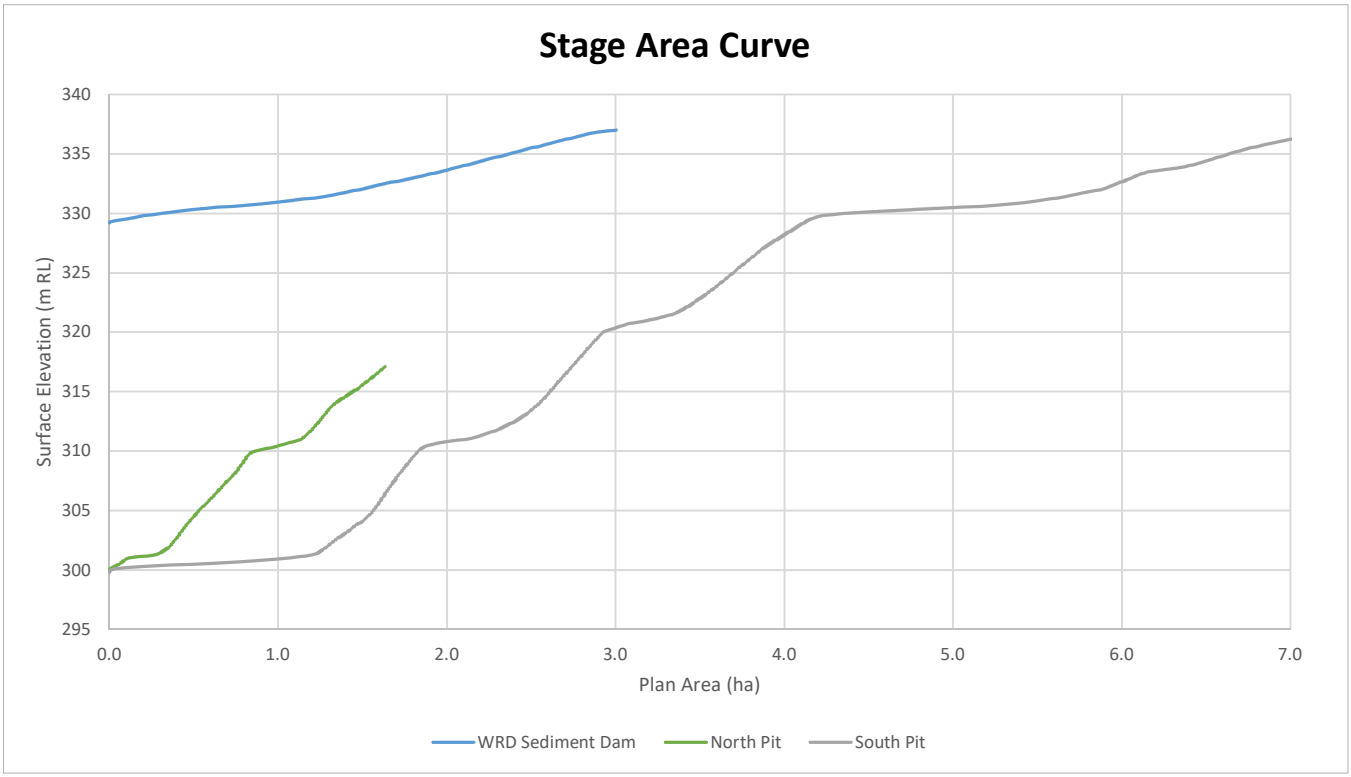
BARBARA MINES - ROUND OAK MINERALS

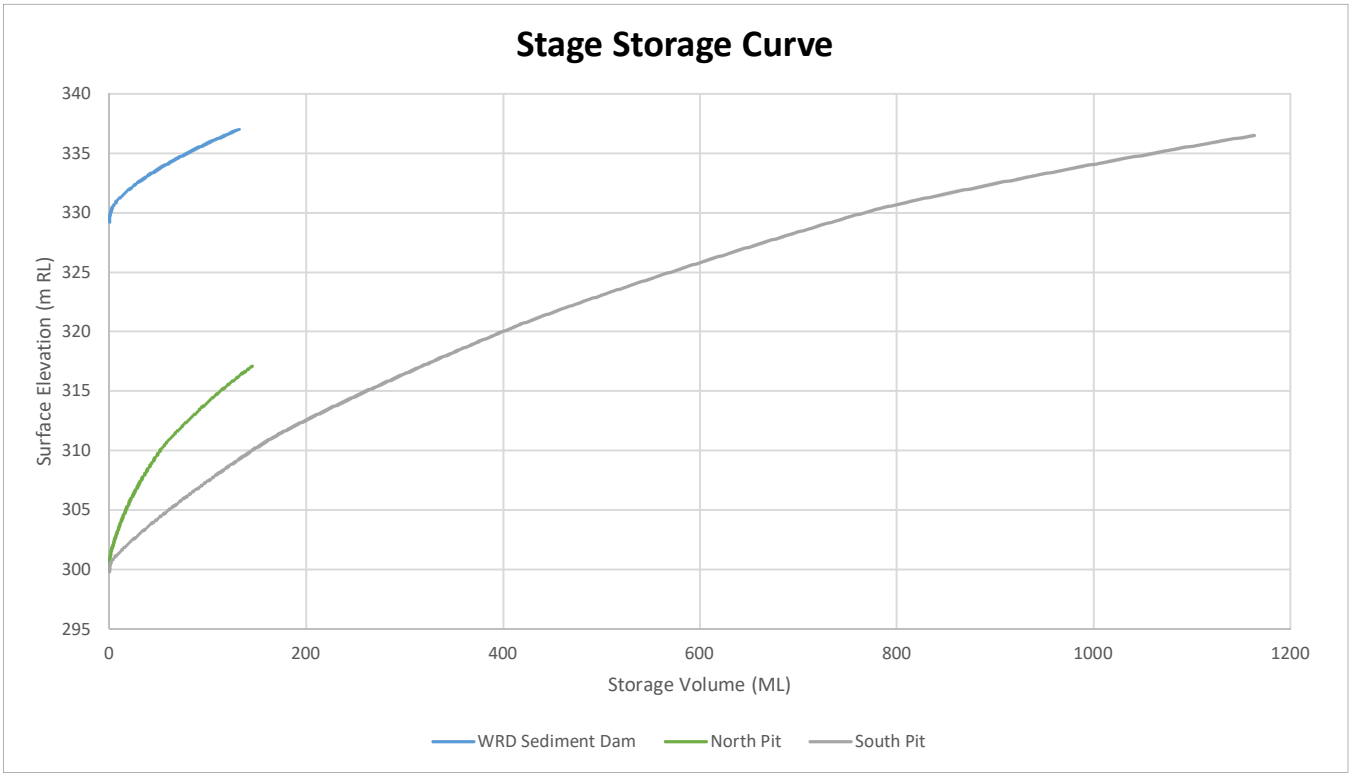
MINE INFRASTRUCTURE
SITE LAYOUT PLAN

Status	Drg No.	Rev.
PRELIMINARY	60600375-20	A

LAST MODIFIED:16/12/2019 10:20 AM
CAD REF:P:\066X\60600375\900_CAD_GIS\900_CAD\20_SHEETS\60600375-20.DWG

APPENDIX B


Stage Area Curve
Surface Elevation (m RL)
340
335
330
325
320
315
310
305
300
295
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Plan Area (ha)
WRD Sediment Dam
North Pit
South Pit


Stage Storage Curve
Surface Elevation (m RL)
340
335
330
325
320
315
310
305
300
295
0
200
400
600
800
1000
1200
Storage Volume (ML)
WRD Sediment Dam
North Pit
South Pit

Sed Dam				Nth Pit				Sth Pit			
Height	Volume	Plan area	Slope area	Height	Volume	Plan area	Slope area	Height	Volume	Plan area	Slope area
329.2	0	0	0	300	0	0.035	0.035	299.8	0	0.019	0.02
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329.8	543.746	2079.471	2083.096	300.6	193.29	668.091	674.794	300.4	532.6	3622.998	3638.597
329.9	774.891	2565.618	2570.754	300.7	265.243	773.627	782.303	300.5	958.982	4916.882	4940.12
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336.5	117493.7	27866.79	28498.23
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306.7	26707.23	6477.203	7172.646
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306.9	28014.96	6601.35	7325.825
307	28678.39	6665.711	7404.957
307.1	29348.01	6727.126	7481.269
307.2	30023.85	6790.433	7559.662
307.3	30706.22	6858.823	7643.36
307.4	31395.58	6930.586	7730.67
307.5	32092.55	7010.492	7826.302
307.6	32797.49	7086.044	7917.639
307.7	33509.73	7157.47	8005.001
307.8	34228.88	7225.52	8089.281
307.9	34954.58	7287.937	8168.185
308	35686.52	7351.809	8248.758
308.1	36424.69	7410.959	8324.796
308.2	37168.63	7468.433	8399.223
308.3	37918.32	7525.414	8473.257
308.4	38673.7	7582.473	8547.447
308.5	39434.83	7640.004	8622.218
308.6	40201.49	7692.601	8692.127
308.7	40973.37	7743.853	8760.738
308.8	41750.3	7794.698	8828.992
308.9	42532.26	7844.218	8895.963
309	43319.12	7893.606	8962.908
309.1	44110.9	7941.679	9028.605
309.2	44907.42	7989.617	9094.15
309.3	45708.87	8038.704	9160.86
309.4	46515.13	8086.496	9226.201
309.5	47326.25	8137.1	9294.211
309.6	48142.4	8185.43	9359.705
309.7	48963.42	8236.056	9427.198
309.8	49790.22	8309.252	9516.829
309.9	50627.46	8449.23	9672.741
310	51482.3	8650.965	9889.615
310.1	52361.92	8981.752	10234.91
310.2	53277.45	9309.195	10576.16
310.3	54222.83	9588.207	10867.79
310.4	55195.62	9859.106	11150.91
310.5	56194.62	10122.23	11426.25
310.6	57220.51	10403.13	11719.26
310.7	58272.16	10640.86	11969.51
310.8	59353.72	10979.53	12321.36
310.9	60464.72	11218.78	12573.82
311	61593.12	11342.37	12711.3
311.1	62732.7	11446.18	12829.94
311.2	63881.98	11538.04	12937.42
311.3	65040.04	11621.77	13037.48
311.4	66206.1	11698.59	13131.37
311.5	67379.67	11773.48	13224.02
311.6	68560.82	11849.41	13318.37
311.7	69749.28	11918.89	13406.77
311.8	70944.52	11986.28	13493.55
311.9	72146.4	12050.55	13577.62
312	73354.64	12114.38	13661.56

305.6	69789.41	15948.88	17359.01
305.7	71386.75	15997.29	17443.4
305.8	72988.76	16043.71	17525.71
305.9	74595.72	16094.74	17612.51
306	76207.66	16143.02	17696.5
306.1	77824.32	16190.52	17779.74
306.2	79445.68	16236.03	17861.06
306.3	81071.51	16281.27	17942.1
306.4	82702.04	16330.66	18027.22
306.5	84337.57	16379.13	18111.33
306.6	85977.74	16424.84	18192.6
306.7	87622.72	16474.56	18277.87
306.8	89272.6	16523.42	18362.23
306.9	90927.42	16574.31	18448.51
307	92587.57	16627.5	18536.97
307.1	94252.85	16678.06	18622.7
307.2	95923.16	16727.9	18707.58
307.3	97598.46	16779.04	18793.69
307.4	99278.84	16828.24	18877.83
307.5	100964.2	16878.49	18962.89
307.6	102654.6	16928.82	19047.91
307.7	104350	16978.79	19132.42
307.8	106050.3	17027.33	19215.37
307.9	107755.5	17079.05	19301.43
308	109466.2	17134.65	19391.26
308.1	111182.5	17191.51	19482.2
308.2	112904.5	17248.49	19573.14
308.3	114632.2	17306.14	19664.7
308.4	116365.7	17363.38	19755.78
308.5	118104.8	17417.98	19844.15
308.6	119849.3	17473.77	19933.55
308.7	121599.6	17529.6	20022.9
308.8	123355.3	17586.02	20112.78
308.9	125116.8	17642.88	20202.97
309	126883.8	17698.16	20291.5
309.1	128656.4	17754.62	20381.06
309.2	130434.7	17810.99	20470.22
309.3	132218.8	17869.37	20561
309.4	134008.7	17929.9	20653.5
309.5	135804.6	17988.76	20743.97
309.6	137606.6	18050.86	20837.17
309.7	139414.8	18113.16	20930.04
309.8	141229.2	18174.58	21021.56
309.9	143050	18242.58	21119.16
310	144877.8	18314.85	21220.42
310.1	146713.2	18393.37	21327.39
310.2	148556.6	18478.92	21440.89
310.3	150409.5	18580.34	21569.71
310.4	152273	18699.58	21715.65
310.5	154153.4	18925.15	21967.73
310.6	156061.7	19256.73	22326.11
310.7	158004.4	19604.75	22701.7
310.8	159987	20065.11	23190.77
310.9	162020.9	20630.37	23786.39
311	164110.3	21127	24314.93
311.1	166240.7	21471.11	24692.27
311.2	168402.5	21750.6	25005.95
311.3	170590	21991.87	25281.95
311.4	172800.4	22224.1	25549.91
311.5	175034.3	22444.3	25806.89
311.6	177288.4	22636.28	26036.58
311.7	179561.2	22819.44	26258.55
311.8	181851.7	22990.32	26469.19

312.1	74569.28	12178.81	13746.46
312.2	75790.43	12242.93	13831.41
312.3	77017.71	12302.79	13912.45
312.4	78251	12362.83	13993.91
312.5	79490.26	12423.93	14076.69
312.6	80735.66	12483.18	14157.89
312.7	81986.98	12542.59	14239.51
312.8	83244.16	12599.98	14319.36
312.9	84506.97	12656.45	14398.55
313	85775.45	12713.29	14478.3
313.1	87049.62	12769.93	14558.08
313.2	88329.53	12827.48	14638.91
313.3	89615.04	12883.48	14718.31
313.4	90906.32	12942.39	14800.61
313.5	92203.49	13001.18	14882.72
313.6	93506.67	13061.39	14966.23
313.7	94815.82	13122.46	15050.49
313.8	96131.25	13187.4	15138.38
313.9	97453.34	13256.41	15230.15
314	98783.65	13353.99	15350.28
314.1	100124.3	13455.99	15474.58
314.2	101475.3	13566.16	15606.89
314.3	102838.2	13685.03	15747.91
314.4	104211.7	13787.42	15872.28
314.5	105595.3	13885.98	15992.55
314.6	106988.9	13982.59	16110.67
314.7	108392.4	14088.06	16237.4
314.8	109807	14202.1	16372.36
314.9	111232.9	14315.42	16506.47
315	112670.7	14445.32	16657.21
315.1	114121.1	14559.97	16792.73
315.2	115582.1	14659.39	16913.26
315.3	117052.9	14755.7	17031.12
315.4	118533	14846.53	17143.86
315.5	120022.2	14936.38	17255.87
315.6	121520.2	15024.18	17365.95
315.7	123027.2	15115.29	17479.29
315.8	124543.3	15208.81	17594.9
315.9	126069	15303.72	17711.83
316	127603.5	15385.5	17815.65
316.1	129146.1	15468.61	17920.76
316.2	130699	15582.65	18056.48
316.3	132262.1	15676.82	18171.98
316.4	133834.2	15768.8	18285.11
316.5	135415	15845.69	18383.03
316.6	137003.5	15922.22	18480.74
316.7	138599.5	15997.26	18577.2
316.8	140203.1	16077.32	18678.88
316.9	141814.8	16157.47	18780.64
317	143434.6	16240.62	18885.28
317.1	145063.2	16334.24	19000.29

311.9	184159.1	23156.69	26676.29
312	186482.9	23318	26879.09
312.1	188822.4	23469.21	27072.36
312.2	191176.4	23610.52	27256.24
312.3	193544.3	23746.95	27435.45
312.4	195925.9	23885.56	27617.07
312.5	198321.4	24025.59	27800.5
312.6	200730.6	24154.48	27972.75
312.7	203152	24274.55	28135.67
312.8	205585.3	24391.39	28294.9
312.9	208029.9	24496.85	28441.99
313	210484.4	24591.83	28578.07
313.1	212948	24681.37	28708.52
313.2	215420.7	24772.51	28840.58
313.3	217902.4	24860.89	28970.12
313.4	220393	24951.57	29102.29
313.5	222892.6	25039.05	29231.11
313.6	225400.8	25125.16	29358.31
313.7	227917.4	25206.79	29480.92
313.8	230442.2	25289.84	29604.68
313.9	232975.5	25376.24	29731.48
314	235517.4	25460.26	29855.51
314.1	238067.3	25535.1	29970.06
314.2	240624.3	25605.14	30079.66
314.3	243188.3	25674.68	30188.68
314.4	245759.2	25741.93	30295.58
314.5	248336.5	25804.93	30398.33
314.6	250920.2	25868.39	30501.69
314.7	253510.1	25929.99	30603.27
314.8	256106.2	25990.51	30703.8
314.9	258708.3	26051.09	30804.33
315	261316.3	26110.55	30903.85
315.1	263930.4	26171.05	31004.43
315.2	266550.6	26231.15	31104.56
315.3	269176.6	26290.93	31204.35
315.4	271808.7	26349.44	31302.82
315.5	274446.7	26410.26	31403.7
315.6	277090.7	26469.77	31503.26
315.7	279740.6	26529.95	31603.29
315.8	282396.7	26591.73	31704.93
315.9	285058.9	26652.14	31805.02
316	287727.2	26715.22	31907.53
316.1	290401.9	26776.86	32008.36
316.2	293082.6	26839.77	32110.26
316.3	295769.9	26903.87	32213.07
316.4	298463.5	26968.23	32315.97
316.5	301163.4	27031.1	32417.29
316.6	303869.7	27093.91	32518.53
316.7	306582.2	27155.35	32618.37
316.8	309300.7	27215.89	32717.18
316.9	312025.4	27278.16	32817.5
317	314756.4	27341.22	32918.54
317.1	317493.7	27405.09	33020.08
317.2	320237.4	27468.88	33121.24
317.3	322987.4	27532.38	33221.98
317.4	325743.7	27593.38	33320.14
317.5	328506.2	27656.31	33420.2
317.6	331275	27719.92	33520.91
317.7	334050.2	27782.35	33620.23
317.8	336831.5	27843.22	33717.95
317.9	339618.8	27904.44	33815.86
318	342412.4	27965.92	33913.91
318.1	345212	28026.66	34011.1

318.2	348017.7	28088.53	34109.16
318.3	350829.7	28150.77	34207.32
318.4	353647.9	28213.24	34305.48
318.5	356472.4	28276.68	34404.21
318.6	359303.2	28339.43	34502
318.7	362140.2	28400.96	34598.4
318.8	364983.4	28462.81	34694.95
318.9	367832.8	28525.66	34792.28
319	370688.5	28588.64	34889.49
319.1	373550.5	28651.48	34986.29
319.2	376418.9	28716.32	35084.76
319.3	379293.9	28782.89	35184.7
319.4	382175.5	28849.37	35284.14
319.5	385063.7	28916.6	35383.89
319.6	387958.8	28984.61	35483.93
319.7	390860.7	29052.51	35583.49
319.8	393769.4	29123.54	35685.73
319.9	396685.3	29194.85	35787.71
320	399608.6	29271.6	35894.34
320.1	402540.2	29372.46	36024.37
320.2	405486.9	29576.83	36257.01
320.3	408457	29828.18	36535.61
320.4	411452.1	30063.1	36796.85
320.5	414469.8	30306.51	37065.81
320.6	417513.4	30548.17	37332.43
320.7	420578.2	30751.17	37559.42
320.8	423667	31065.01	37896.89
320.9	426795.9	31507.1	38362.49
321	429967.2	31905.83	38783.92
321.1	433175.8	32253.74	39154.36
321.2	436417.1	32571.36	39494.34
321.3	439688.9	32857.27	39802.62
321.4	442987.8	33113.51	40081.59
321.5	446310	33325.19	40316.9
321.6	449652.2	33514.36	40530.53
321.7	453011.8	33676.58	40717.98
321.8	456387	33826.33	40893.67
321.9	459776.5	33961.89	41056.01
322	463179.1	34086.46	41208.17
322.1	466593.5	34202.32	41352.44
322.2	470019.6	34318.82	41498.06
322.3	473456.9	34427.56	41636.62
322.4	476905	34534.7	41774.12
322.5	480363.9	34642.24	41912.59
322.6	483833.3	34744.05	42045.88
322.7	487312.7	34844.8	42178.49
322.8	490802.2	34945.66	42311.56
322.9	494302.3	35056.43	42454.78
323	497813.3	35162.61	42593.59
323.1	501334.7	35265.46	42729.4
323.2	504866.2	35362.31	42859.63
323.3	508407.1	35458.76	42989.9
323.4	511957.7	35552.47	43117.73
323.5	515517.7	35648.13	43247.58
323.6	519087.1	35739.87	43373.65
323.7	522665.7	35831.07	43499.52
323.8	526253.3	35920.96	43624.36
323.9	529849.9	36010.11	43748.58
324	533455.3	36098.8	43872.4
324.1	537069.6	36187.39	43996.25
324.2	540692.8	36274.42	44118.58
324.3	544324.6	36363.23	44242.88
324.4	547965.3	36450.55	44366.03

324.5	551614.6	36535.71	44487.25
324.6	555272.5	36621.41	44609.15
324.7	558938.9	36707.7	44731.88
324.8	562614	36794.18	44854.88
324.9	566297.7	36879.27	44976.6
325	569989.9	36964.68	45098.84
325.1	573690.5	37047.37	45218.63
325.2	577399.4	37130.55	45339.25
325.3	581116.7	37213.71	45460.21
325.4	584842.2	37296.13	45580.84
325.5	588575.9	37378.63	45701.93
325.6	592318	37463.46	45825.57
325.7	596068.7	37551.64	45952.7
325.8	599828.2	37639.38	46079.6
325.9	603596.5	37726.31	46205.96
326	607373.6	37815.79	46335.04
326.1	611159.9	37907.94	46467.03
326.2	614954.9	37994.17	46593.36
326.3	618758.8	38082.93	46722.29
326.4	622571.5	38169.9	46849.6
326.5	626392.8	38256.68	46976.87
326.6	630222.9	38345.03	47105.79
326.7	634061.7	38431.55	47232.92
326.8	637909.1	38514.82	47356.8
326.9	641764.8	38600.55	47483.11
327	645629.1	38687.02	47610.01
327.1	649502.2	38773.18	47736.49
327.2	653383.9	38865.73	47869.34
327.3	657276.2	38978.91	48022.99
327.4	661179.5	39086.35	48170.89
327.5	665093.5	39197.98	48323.03
327.6	669019.9	39329.83	48495.5
327.7	672959.1	39450.62	48657.01
327.8	676909.8	39564.28	48811.38
327.9	680871.7	39673.84	48961.76
328	684844.6	39784.68	49113.38
328.1	688828.9	39899.54	49268.9
328.2	692824.6	40015.64	49425.58
328.3	696832.1	40135.01	49585.64
328.4	700851.4	40249.21	49740.71
328.5	704881.9	40362.47	49895.1
328.6	708923.9	40475.78	50049.74
328.7	712977.1	40589.47	50204.8
328.8	717041.7	40702.27	50359.03
328.9	721117.5	40815.09	50513.37
329	725204.6	40926.48	50666.4
329.1	729302.8	41038.35	50820.16
329.2	733412.4	41153.99	50977.65
329.3	737533.5	41269.37	51134.88
329.4	741666.4	41386.65	51294.03
329.5	745812.2	41543.87	51493.3
329.6	749977	41752.81	51744.75
329.7	754163.9	41996.33	52031.45
329.8	758378	42297.12	52376.19
329.9	762628.9	42763.12	52887.27
330	766937.2	43474.18	53645.13
330.1	771341.6	44684.09	54903.88
330.2	775877	46049.42	56318.94
330.3	780558	47570.58	57890.13
330.4	785391	49083.76	59454.12
330.5	790372.7	50474.48	60896.12
330.6	795477.6	51633.95	62106.75
330.7	800691.4	52615.73	63139.47

330.8	805994.4	53449.74	64023.63
330.9	811379	54223.05	64846.88
331	816832.3	54808.43	65482.4
331.1	822337.4	55290.66	66015.44
331.2	827890.4	55766.1	66542.13
331.3	833488.2	56190.11	67017.82
331.4	839126.9	56577.16	67456.87
331.5	844803.2	56948.83	67880.93
331.6	850516.1	57305.04	68290.24
331.7	856264.1	57658.37	68697.44
331.8	862047.9	58021.45	69115.22
331.9	867871.5	58457.87	69607.21
332	873734.3	58763.04	69968.55
332.1	879621.2	58973.51	70235.44
332.2	885528.7	59175.15	70493.99
332.3	891456.1	59371.16	70747.47
332.4	897402.5	59556.22	70990.38
332.5	903367.4	59740.35	71232.27
332.6	909350.3	59914.98	71464.34
332.7	915350	60080.47	71687.02
332.8	921366.3	60246.71	71910.47
332.9	927400	60429.75	72150.78
333	933451.8	60605.99	72384.4
333.1	939521.5	60788.1	72624.17
333.2	945609.7	60975.28	72869.52
333.3	951716.6	61162.35	73115.25
333.4	957842.1	61347.41	73359.25
333.5	963986.4	61540.92	73612.01
333.6	970167.4	62147.8	74279.01
333.7	976409.7	62682.25	74874.73
333.8	982707.4	63271.82	75526.96
333.9	989058.2	63719.74	76038.57
334	995445.3	64011.3	76394.39
334.1	1001859	64263.69	76711.41
334.2	1008298	64506.5	77019.21
334.3	1014760	64746.07	77323.85
334.4	1021247	64989.49	77632.87
334.5	1027758	65234.13	77943.7
334.6	1034294	65467.45	78243.47
334.7	1040851	65685.44	78528.08
334.8	1047430	65895.61	78805.02
334.9	1054031	66110.25	79086.48
335	1060653	66334.12	79377.1
335.1	1067298	66569.67	79679.22
335.2	1073970	66878.67	80054.65
335.3	1080672	67162.02	80403.96
335.4	1087402	67427.33	80735.39
335.5	1094157	67680.3	81054.53
335.6	1100939	67946.04	81386.78
335.7	1107748	68242.62	81750.3
335.8	1114587	68547.58	82122.44
335.9	1121461	68922.16	82564.74
336	1128371	69287.62	82998.28
336.1	1135318	69649.28	83427.92
336.2	1142301	70009.57	83855.7
336.3	1149320	70377.43	84290.5
336.4	1156378	70786.62	84765.96
336.5	1163475	71127.15	85171.12

BARBARA COPPER PROJECT
EROSION AND SEDIMENT CONTROL PLAN

PREPARED FOR

ROUND OAK MINERALS

November 2019

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BARBARA COPPER PROJECT
EROSION AND SEDIMENT
CONTROL PLAN

INDEX

1.0 INTRODUCTION 1

1.1 PURPOSE 1

1.2 SCOPE 1

2.0 PROJECT DESCRIPTION 2

2.1 SITE BACKGROUND 2

2.1.1 Site Infrastructure 2

2.1.2 Regional Context 2

2.2 LOCAL CLIMATE 2

2.3 SOIL AND LAND SUITABILITY ASSESSMENT 3

3.0 PROJECT LAYOUT 4

3.1 MINING AREAS 4

3.2 NON-MINING AREAS 4

4.0 PROJECT WATER MANAGEMENT 5

4.1 STORMWATER CONTROL STRATEGIES 5

5.0 EROSION AND SEDIMENT CONTROL APPROACH 7

5.1 SOURCES OF EROSION AND SEDIMENT 7

5.2 CONTROL APPROACH 7

5.3 OBJECTIVES AND TARGETS 7

6.0 EROSION RISK ASSESSMENT 9

6.1 METHODOLOGY 9

6.1.1 Rainfall Erosivity 10

6.1.2 Soil Erodibility 10

6.1.3 Length and Slope 10

6.1.4 Ground Cover 10

6.1.5 Supporting Practises 10

6.2 RESULTS 11

7.0 PROPOSED CONTROL MEASURES 12

7.1 CONSTRUCTION AND OPERATION PHASES 12

7.1.1 Diversion of clean water 12

7.1.2 Sediment Dam 12
7.1.3 Perimeter bunds 12
7.1.4 Sediment fences & Coir logs 12
7.1.5 Traffic 14
7.2 REHABILITATION AND CLOSURE 14
8.0 ADMINISTRATION 15
8.1 MONITORING AND MAINTENANCE 15
8.1.1 General 15
8.2 CORRECTIVE ACTIONS 15
8.3 RECORDS 15
8.4 REPORTING 15
8.4.1 Internal 15
8.4.2 Regulatory Authority 15
8.5 REVIEW 16
8.6 RESPONSIBILITIES 16
9.0 REFERENCES 17

LIST OF FIGURES

Figure 1 Mean monthly rainfall and evaporation for Mt Isa (BOM stations 29126, 29125, 29127) 3
Figure 2 Project Water Separation 13

LIST OF TABLES

Table 1 Soil unit description 3
Table 2 ESCP objectives 8
Table 3 IECA erosion risk categories (2008) 9
Table 4 Soil erodibility (K) 10
Table 5 Risk assessment results 11
Table 6 Roles and responsibilities 16

LIST OF APPENDICES

Appendix A ATC William: Barbara Copper Project - Water Management Plan ..... A

LIST OF ABBREVIATIONS

AARC	AARC Environmental Solutions
ASRIS	Australian Soil Resource Information System
ATCW	ATC Williams
DES	Department of Environment and Science
EA	Environmental Authority
ESCP	Erosion and Sediment Control Plan
IECA	International Erosion Control Association
LIA	Light Infrastructure Area
MAW	Mine Affected Water
ML	Mining Lease
PMLUP	Post Mine Land Use Plan
RE	Regional Ecosystem
ROM	Round Oak Minerals
RoM	Run of Mine
RTLA	Road Train Loading Area
RUSLE	Revised Universal Soil Loss Equation
SAW	Sediment Affected Water
SLSA	Soil Land Use Suitability Assessment
SMU	Soil Management Unit
The Project	Barbara Copper Project
WMP	Water Management Plan
WRD	Waste Rock Dump

1.0 INTRODUCTION

AARC Environmental Solutions Pty Ltd (AARC) was commissioned by Round Oak Minerals Pty Ltd (ROM) to develop an Erosion and Sediment Control Plan (ESCP) for their Barbara Copper Project (the Project). This ESCP has been prepared in accordance with Environmental Authority (EA) No. EPML02840015 condition E17 as stated below.

> *An Erosion and Sediment Control Plan must be developed, documented and implemented by an appropriately qualified person for all stages of the mining activities to minimise erosion and the release of sediment to receiving waters.*

1.1 PURPOSE

The purpose of this document is to outline strategies to prevent and/or minimise erosion and the release of sediment into receiving waters, and the contamination of stormwater runoff.

1.2 SCOPE

The Project consists of a single Mining Lease (ML) in north-west Queensland; ML90241. The ESCP specifies erosion and sediment control measures appropriate for the construction and operational stages of the mine life. The process for developing the ESCP has included:

- The identification of areas of potential erosion risk arising from stormwater runoff for all Project stages;
- An assessment of the erosional risks related to the Project; and
- Nomination of appropriate erosion and sediment control measures applicable to the identified areas of erosion risk and having the objective of reducing the potential for Project to impact the receiving environment.

2.0 PROJECT DESCRIPTION

The Project is located within the Mt Isa local government area and can be accessed via Lake Julius / Kajabbi road from the Barkly Highway approximately 60 kilometres (km) to the north-east of Mt Isa. The current Plan of Operations is valid until 31 May 2022. The Project comprises two open cut pits that will target 818,000 tonnes of copper ore and trace amounts of gold over 18 months. Ore is mined and transported off-site via road train to a regional, third-party processing facility.

2.1 SITE BACKGROUND

2.1.1 Site Infrastructure

Major components of the Project's water management system as outlined in the ATC Williams (ATCW) Water Management Plan (WMP) include the North Pit, the South Pit and the Waste Rock Dump (WRD) Sediment Dam. Clean water diversion drains are used to reduce the volume of stormwater runoff accessing disturbed areas and requiring subsequent treatment.

2.1.2 Regional Context

The project is located within the Leichardt River Basin which flows from the Selwyn Ranges into the Gulf of Carpentaria. The Project site does not have any permanent surface water but includes a number of ephemeral drainage lines which exit the site to the north-west before joining the Leichardt River. The Leichardt River itself is an ephemeral river depending on rainfall conditions for flow events. The Lake Julius Dam, situated on the Leichardt and Paroo Rivers, approximately 25 km downstream from the Project site is the effective end-point of the downstream environment as any contaminants would be contained within the dam rather than moving further downstream.

Historically, the Leichardt river has experienced contamination upstream from the Project location and grazing and historical mining activities have resulted in disturbances to the downstream environment (Noller 2009).

2.2 LOCAL CLIMATE

The Project is located in north-west Queensland where the climate is described as 'tropical continental' being governed by latitude, elevation and distance from the coast environment. The nearest meteorological station is West Leichardt (209121), however this station does not contain records for long term evaporation. Given this, data from three stations near Mt Isa (29126, 29125, 29127) were used to determine monthly averages for rainfall and evaporation. The climate in this area is characterised by high variations of rainfall with a wet season typically between November and March. Mean annual rainfall when averaged across the three meteorological stations is 427 mm with approximately 80% of this falling during the wet season. Evaporation rates exceed rainfall throughout the year contributing to the semi-arid environment. Monthly rainfall and evaporation are shown in Figure 1.

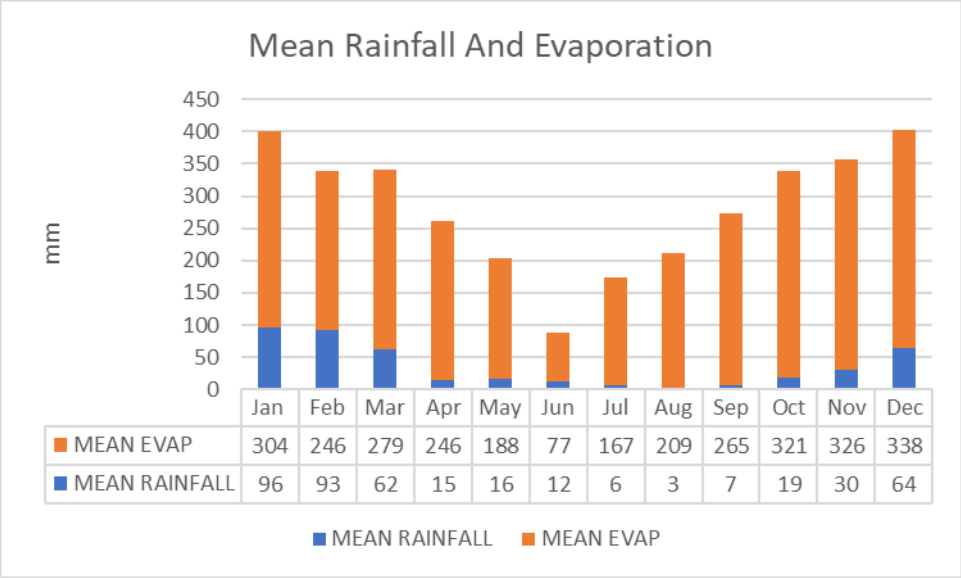

Figure 1 Mean monthly rainfall and evaporation for Mt Isa (BOM stations 29126, 29125, 29127)

2.3 SOIL AND LAND SUITABILITY ASSESSMENT

AARC was previously engaged to undertake a Soil and Land Suitability Assessment (SLSA) at the Project site. The field survey found that the site was dominated by moderately undulating lands with rocky outcrops and quartz gravels dominated by shallow gravel strewn loam. Three main Soil Management Units (SMU) were identified as depicted in Table 1.

Table 1 Soil unit description

Soil Unit	Description
SMU1 – River Red Gum Sands	This soil unit consists of sandier soils with a high gravel and cobble content with finer soil material having been removed via alluvial action. These soils are often deep and well drained with some occasional occurrence in shallower areas near rocky outcrops. The areas have a sparse ground cover vegetation associated with river red gums and other riverine species.
SMU2 – Cloncurry Box Drainage Terraces	This soil consists of loamy to clayey sands present along terraces adjacent to drainage depressions in relatively flat topography (1-2%). This soil type typically has lower fine gravel content but larger (20-+60mm) sub-rounded to coarse fragments. There is evidence of minor gully erosion within the ephemeral watercourses, but soil chemistry suggests there is no strong predisposition to dispersion or erosion.
SMU3 – Snappy Gum Slopes	This soil unit is comprised of clayey sands to sandy clay loams with moderate to high levels of gravel content. The topography is made up of mostly steep low hills with extensive areas of rocky outcrop and steeper slopes.

Field surveys found little evidence of soil erosion within the Study Area and soil physio-chemical properties do not indicate an increased predisposition to dispersion. With the exception of one isolated data point within SMU2, soil chemical properties were non-sodic (ESP <6%), had favourable calcium magnesium ratios (>2) and were non-saline.

3.0 PROJECT LAYOUT

The Project has a number of water management areas which are intended to cater for the types of activities occurring on site, and the locations in which they occur. In general, these can be categorised as mining -related areas and non-mining related areas as described following.

3.1 MINING AREAS

The Run of Mine (RoM) pad, the North pit and South Pit, as well as the WRD are the principal active mining areas associated with the Project. Runoff from these areas is defined as mine affected water (MAW) as outlined in Section 4.0.

Management of RoM Pad runoff is achieved via bunding with all runoff directed towards the South Pit. Excess water from the South Pit is able to be pumped to either the North Pit or WRD Dam to allow for the continuation of mining.

In addition to mining operations, the North Pit will operate as a storage and evaporative facility in the event of large volumes of MAW requiring containment. The North Pit is a regulated dam and is planned to be available for water storage from October 2019. Water levels within the North Pit will be controlled via pumping between the South Pit and WRD Dam.

In addition to being the primary mineral extraction point, the South Pit is also a regulated dam and is able to be used for water management and runoff containment for other MAW sources. The levels within the South Pit will be controlled via pumping between the North Pit and WRD Dam.

Stormwater runoff from the WRD drains will drain to WRD Sediment Dam which will allow for settlement of suspended sediment.

3.2 NON-MINING AREAS

The WRD Dam is the primary holding facility for storm water runoff from the WRD and, in concert with the North and South Pits, facilitates the storage of water for the Project during the wet season.

The Light Infrastructure Area housing the administration offices, workshop, fuel storage, and power facility is bunded to divert stormwater runoff from surrounding areas and reduce the possibility of sediment release into the receiving environment.

The Access Road and Haul Road have been constructed with the intention of causing minimal impact from clearing and both utilise causeways where they intersect natural drainage lines. Activity on these roads is monitored and restricted in wet weather to reduce the potential for disturbance.

Non-mining areas also include diversions, drainage lines, the sewage treatment facility, the explosives magazine and access roads.

4.0 PROJECT WATER MANAGEMENT

The current WMP was developed by ATCW in 2019 (Appendix A) with the objective as stated below:

> *To maintain the biological integrity of water (surface or ground) at the Barbara Copper Project, and to ensure quality of waters do not adversely affect environmental values or the health, welfare and amenity of people and land users by meeting statutory requirements and acceptable standards.*

The following water types have been identified for the purposes of the WMP:

- Mine Affected Water (MAW); water potentially impacted via exposure to mine waste and ore;
- Sediment Affected Water (SAW); water potentially impacted by elevated suspended sediments and associated water quality issues;
- Clean Water; water that has not been affected by mine site activities.

The principles of water management at the Project site are to:

- Separate MAW from non-impacted water streams, with non-impacted water diverted and able to flow to the downstream environment;
- Retain MAW in structures that are designed to minimise the risk of release off site and/or reusing this water on site where possible.

Potential sources for contamination were identified as the waste rock and ore generated in construction and mining operations. Both the North and South Pit have been configured to hold water inflow via surface and groundwater ingress with the North Pit utilised as the final site storage for waters transferred from the South Pit and WRD Dam. The WMP nominates the Northern Pit, Southern Pit and WRD Sediment Dam as regulated water management structures for the Project.

Water is able to be re-used for dust suppression and plant and vehicle washdown facilities.

4.1 STORMWATER CONTROL STRATEGIES

The following stormwater management control strategies apply for the Project:

- Uncontaminated stormwater will be diverted around all areas where mining activities occur, or where contaminants or wastes are stored or handled;
- Within mining activity areas, contamination of stormwater will be minimised or prevented by utilising drains, bunds, and sediment traps and dams as appropriate;
- All stormwater contaminated by mining activities (past or present) will be captured and reused, or treated and released in compliance with the conditions of the EA;
- For disturbed and rehabilitated areas, sediment and erosion control infrastructure will be installed, to minimise erosion and prevent the contamination of waters;
- All existing and future water management infrastructure shall be designed, constructed and operated in accordance with the requirements of the EA; and

- Monitoring of the receiving environment shall be undertaken in accordance with the Project's EA to ensure stormwater is being effectively managed on the Project.

5.0 EROSION AND SEDIMENT CONTROL APPROACH

This section outlines the methods of control that will be utilised on the Project site to manage soil erosion and reduce the risk of release of pollutants off site.

5.1 SOURCES OF EROSION AND SEDIMENT

Operations within the Project site have the potential to alter the quality of surface water flow and patterns following clearing and land disturbance. Mining activities with potential to affect these parameters include:

- The construction and maintenance of haul and access roads and tracks;
- The movement of equipment within around the site;
- Land clearance in preparation for construction or mining;
- The RoM and WRD stockpiles;
- Land rehabilitation activities and areas awaiting rehabilitation.

5.2 CONTROL APPROACH

The control of erosion and sediment at the Project site will be developed with regard to the following guidelines:

- EPA Best Practise Urban Stormwater Management – Erosion and Sediment Control (Queensland 2008);
- Stormwater and environmentally relevant activities (Queensland Government 2014);
- Best Practice Erosion and Sediment Control (IECA 2008); and
- Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (DES 2019).

ESC management will fall into three tiers with the first tier being the WMP as the basis for management of clean and mine affected water within the site. The control of erosion generating sources including rainfall and surface water runoff will form the second tier of control. Finally, the capture, treatment and reuse of MAW and SAW will limit impacts to downstream waters as defined in the EA.

5.3 OBJECTIVES AND TARGETS

The main objective of the ESCP is to reduce the potential for erosion and sediment discharge to maintain downstream environmental values and water quality objectives.

The objectives of this ESCP are defined in Table 2.

Table 2 ESCP objectives

Objectives	Targets	Indicators
Minimise erosion on site and in immediate surroundings	No reports of erosion incidents	Incident reports relating to instances of erosion
Minimise movement of sediment off-site	Retention of MAW and SAW on site	Incident reports of any uncontrolled releases from site
Ensure erosion and sediment controls are operating and maintained effectively	Regular checks of sediment control structures with accumulated sediment removed	Indicators for maximum allowable sediment storage and records of maintenance checks

6.0 EROSION RISK ASSESSMENT

This section of the report assesses the potential for soil loss on the Project site. This will assist in identifying appropriate control measures to reduce the potential for erosion and sediment loss across the site.

6.1 METHODOLOGY

The determination of potential soil loss for this project is based on the Revised Universal Soil Loss Equation (RUSLE) as described by the International Erosion Control Association (IECA). The RUSLE equation is::

$$A = R \times K \times LS \times C \times P, \text{ where:}$$

- A represents the soil loss rate in tonnes per hectare per year (t/ha/yr);
- R represents the rainfall erosivity potential of the area determined as a product of kinetic energy of storms;
- K is the soil erodibility factor as determined by soil studies determining the physical and chemical composition of soils present;
- LS is the estimation of the combined length and slope factor;
- C represents the vegetative ground cover and land management as per the equation

$$C = PLU \times CC \times SC \times SR; \text{ where:}$$

  - PLU is Prior Land Use;
  - CC is Crop Canopy;
  - SC is the surface or ground cover;
  - SR is the surface roughness;
- P represents the erosion control in place.

Through application of the RUSLE, soil loss rates have been determined and risk categories allocated in accordance with the IECA 2008 report as per Table 3.

Table 3 IECA erosion risk categories (2008)

Soil Loss (t/ha/year)	Risk Category
0 – 150	Very Low
150 – 225	Low
225 – 500	Moderate
500 – 1,500	High
>1,500	Extreme

6.1.1 Rainfall Erosivity

The R factor is calculated as a product of kinetic energy of a storm, times the maximum 30-minute storm depth as a sum of all storms in a year. This factor is representative of the driving inputs that cause sheet and rill erosion. The seasonal distribution of rainfall has an impact to the calculation of the R factor. Both the soil erodibility (K) and vegetative ground cover (C) change throughout seasons as the Project has defined wet and dry seasons. The Australian Soil Resource Information System (ASRIS) nominates an R factor for the site of 2701.8108.

6.1.2 Soil Erodibility

Soil erodibility is defined as the potential for soil to erode. Soils with high silt contents have a greater likelihood for erosion while higher sand and clay contents are more resistant to erosion. Erodibility factors are as described in Table 4. Based on the SLSA and data provided by ASRIS, the K factor for the site determined to be 0.0441.

Table 4 Soil erodibility (K)

Generalised Soil Characteristic	K	Description
High clay content	0.05 - 0.15	Resistant to detachment decreases erodibility
Course textured sandy soils	0.05 - 0.2	Though easily detached, these soils produce low runoff.
Medium textured silt loam soils	0.25 - 0.4	Moderately susceptible to detachment and produce moderate runoff.
High silt content	0.4-0.69	Highly erodible as easily detached while also prone to crusting surface which produces high runoff rates.

6.1.3 Length and Slope

From the ASRIS data, the L factor for the Project area has a maximum of 5.88, a minimum of 1.027 and a mean of 2.128. The S factor for the site has a maximum of 5.39, a minimum of 0.05 and a mean of 0.78. The S factor for the majority of the site rests between 0 and 1 with the higher values occurring in the northwest corner of the ML outside of active mining areas.

6.1.4 Ground Cover

The C factor ranges from 0.0001 where ground cover is dense and there is a canopy present such as within forests to 1 for unprotected bare earth. The ground cover factor at the site is determined from the data supplied by the State-Wide Landcover and Trees Study, the Normalised Difference Vegetation Index, Broad Vegetation Groups and satellite imagery. From this data, the C factor is estimated to fall between 0.25 for areas retaining the grazed low open woodland ecosystem (RE 1.11.2a) that was present onsite prior to mining operations and 1 for the heavily disturbed portions of bare earth present during mine operations.

6.1.5 Supporting Practises

Supporting practises are a measure of the effect of management practices on sediment loss control. Management controls may impact runoff velocity and flow paths. For the Project the P factor has been

assumed to be 1 as the Project has both disturbed areas that have erosion controls, and undisturbed areas that have no erosion control measures in place.

6.2 RESULTS

From the RUSLE factors determined above, risk ratings have been calculated for disturbed areas of the Project. When compared against IECA rates, the soil loss rate from site can be categorised as being of low risk.

Table 5 Risk assessment results

Description	Area (ha)	R	K	S (%)	L	P	C	A (t/ha/yr)	Risk Rating
North Pit Catchment	1.4	2701.8108	0.0441	0.78	2.128	1	1	197	Low
South Pit Catchment	14.7	2701.8108	0.0441	0.78	2.128	1	1	197	Low
WRD Dam	31	2701.8108	0.0441	0.78	2.128	1	1	197	Low
LIA	2.1	2701.8108	0.0441	0.78	2.128	1	1	197	Low

7.0 PROPOSED CONTROL MEASURES

7.1 CONSTRUCTION AND OPERATION PHASES

During the construction and operational stages of the Project, land clearing will be limited and progressive to ensure that disturbance areas at any point in time are minimised. Where possible, rehabilitation of disturbed areas will occur progressively to further reduce areas of disturbance.

7.1.1 Diversion of clean water

The South Pit east drain, North Pit east drain and WRD east drain are located upstream of disturbed sites and have been constructed to protect disturbed areas and reduce the total volume of MAW collected and requiring storage. These drains have been constructed in areas with a high composition of rock which will assist in retarding flow velocities and reducing erosion within the diversions. The drains have been designed to cater for the large flow events expected during the wet season.

In conjunction with upstream diversion drains existing clean water drainage lines throughout the site have been retained through the installation of under access roads and tracks. Figure 2 displays the location of diversion drains and culverts on site for separation of clean water and MAW.

7.1.2 Sediment Dam

The Sediment dam displayed in Figure 2 is proposed to be constructed to the North of the WRD with the purpose of receiving runoff from the WRD for settlement of suspended solids. Collected runoff water will either be evaporated or reused for dust suppression or other purposes. Water is able to be transferred to the South Pit and North Pit to balance the Projects water storage capacities and usage requirements.

The dam is proposed as an earthen fill embankment lined with a bituminous geomembrane liner. Dam sizing is such that a spillway release will only occur at less than a 1% annual exceedance probability.

7.1.3 Perimeter bunds

Perimeter bunding is implemented around all of the work areas and haul roads on the Project. These bunds direct surface water flow to storages on site and will contain any spills in work areas. Perimeter bunds play an additional safety role for areas adjacent to excavation sites and traffic control.

Bunding will be maintained to ensure integrity and non-impedance of natural drainage features.

7.1.4 Sediment fences & Coir logs

For short term disturbances sediment fences will be erected immediately downstream of land disturbances to capture sediment arising from storm events. Coir logs are an alternative that can be put in place downstream of worksites to capture disturbed sediment. Check dam traps are to be implemented in drains to supplement the major sedimentation controls and minimise erosion in drains.

During operation of the Project use of sediment fences will be reduced as they will be replaced with more permanent solutions such as bunding and diversion drains.

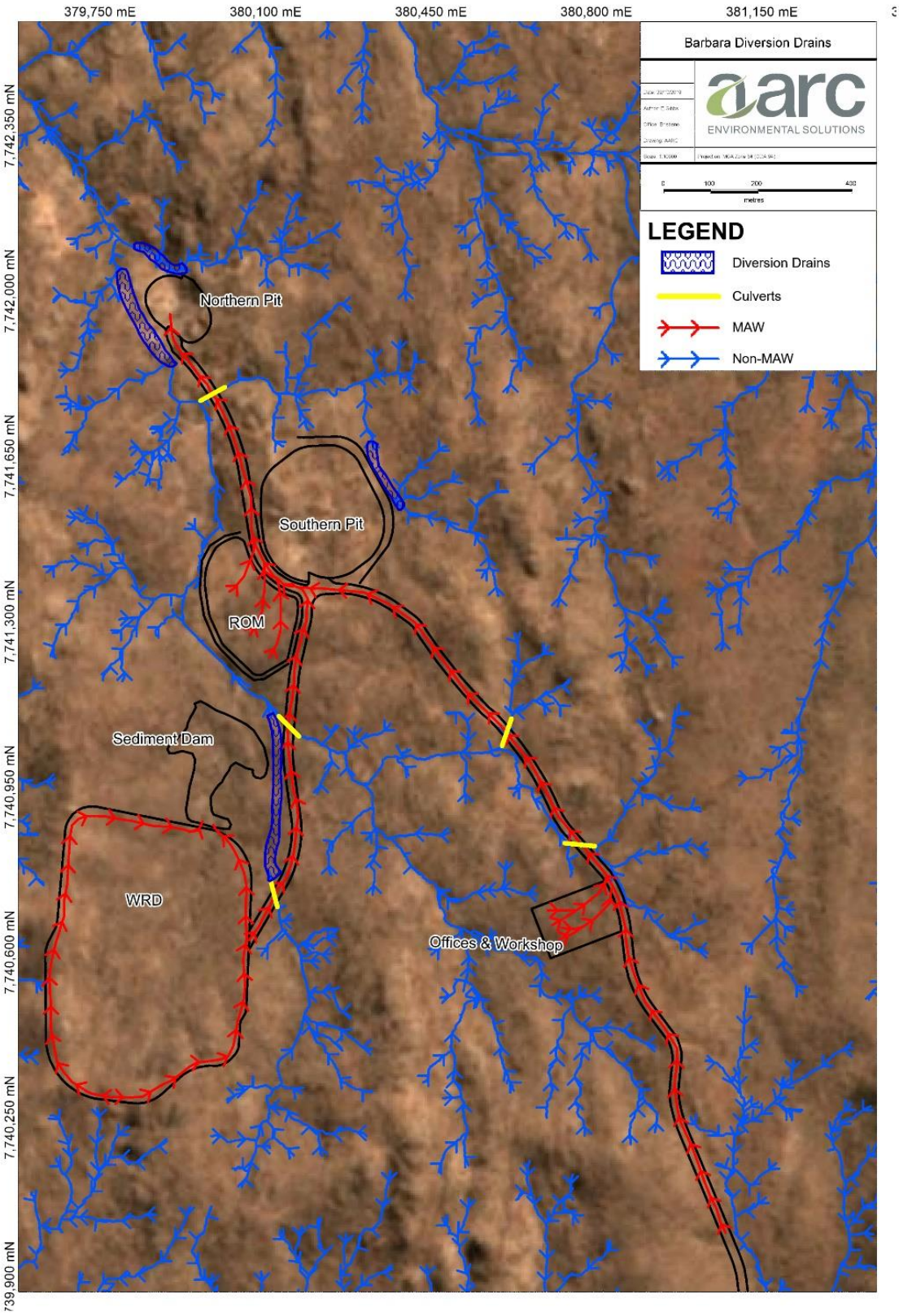

Figure 2 Project Water Separation

7.1.5 Traffic

Measures to minimise impacts from vehicle movement within the Project will include the following:

- Vehicles to be restricted to access tracks and designated haul roads;
- Erosion and sediment control measures installed on all haul roads, access tracks and roads with maintenance as required;
- Bunding alongside haul roads used by heavy vehicles on site;
- Speed limits to be observed by all machine operators;
- Cleaning and/or maintenance of vehicles or plant equipment to be undertaken within a work area that is able to capture and treat runoff.

7.2 REHABILITATION AND CLOSURE

The final landform design has as its objective the formation of a stable landform able to resist erosion caused by surface water runoff. Throughout the project progressive rehabilitation of areas will reduce the presence of bare earth areas. In accordance with condition G2 of the EA the Project will have in place a Post Mine Land-use Plan describing how rehabilitation objectives will be achieved.

Prior to germination of rehabilitated areas, activities to ensure maximum potential for revegetation of areas are to be undertaken. These measures include:

- Timing seeding activities to ensure best germination rates are achieved;
- Sediment fences and temporary perimeter banks for short term bare earth areas;
- Sediment and erosion control structures will not be removed until disturbed areas have been stabilised;
- Exposed surfaces will be ripped and left with sufficient surface roughness to minimise the potential for erosion;
- Bunds and check dams will be implemented across contours in order to capture and slow runoff; and
- Disturbed areas will be contoured to ensure all runoff is directed through erosion and sediment controls and onsite water management systems.
- Mulching and/or hydromulching, and/or temporary seeding of stockpiles will be utilised as appropriate for rehabilitation areas.

8.0 ADMINISTRATION

8.1 MONITORING AND MAINTENANCE

8.1.1 General

Regular monitoring of construction, operation and rehabilitation areas will be undertaken. Contractors conducting construction and rehabilitation works will be responsible for maintaining surface water diversion structures and erosion control measures.

Routine inspections of all Project areas will be undertaken until rehabilitation completion criteria have been satisfied. Inspection will be completed prior to expected rainfall events to ensure the performance of control measures.

Periodic inspections of site drainage systems will be undertaken, especially prior to the wet season and when any major change is implemented or planned. Amendments to the existing erosion and sediment controls and WMP will be undertaken as required.

8.2 CORRECTIVE ACTIONS

The following actions will be undertaken by ROM as required:

- Revision of construction, operation and rehabilitation activities as required;
- Maintenance and de-silting of erosion and sediment controls at a frequency determined by inspections undertaken monthly during the dry season and weekly during the wet season;
- Incident reports will be completed following any relevant non-compliance or erosion incidents;
- In the event of an environmental incident, appropriate responses to be implemented to minimise environmental harm;
- Close out any non-conformances as soon as practicable.

8.3 RECORDS

Records of inspections are to be stored in accordance with ROM document systems and physical copies of inspection checklists stored on site.

8.4 REPORTING

8.4.1 Internal

Incident reports will be utilised to inform of incidents and drive corrective actions. Incident reports are to be completed as soon as possible after becoming aware of an incident.

8.4.2 Regulatory Authority

The Mine Supervisor, or their delegate, will notify DES within 24 hours of becoming aware of an incident that has the potential to cause, or threaten to cause, material or serious environmental harm.

8.5 REVIEW

This document will be reviewed annually or earlier if required.

8.6 RESPONSIBILITIES

Roles and responsibilities are outlined below.

Table 6 Roles and responsibilities

Role	Responsibility
Site Supervisor or Delegate	Ensure resources are available to implement the contents of this plan Facilitate ESCP reviews Report incidents to DES
Senior Environmental Officer	Implement contents of this plan Train Staff in environmental awareness, issues and requirements of ESCP Facilitate monitoring of requirements in ESCP Report non-conformances to technical services Manage and ensure actions are closed out Advise on EA conditions Investigate environmental incidents and provide assistance with DES where necessary
Employees	Be familiar with contents of ESCP Undertake erosion and sediment control works Report visual degradation or apparent non-conformances with this ESCP within shifts as observed
Contractors	Undertake corrective actions as soon as practicable Report and non-conformance/environmental incidents within same shift as noticed Be familiar with contents of ESCP Prepare design and plan for construction,

9.0 REFERENCES

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Appendix A ATC William: Barbara Copper Project - Water Management Plan

A

Calibrated Erosion Modelling

Waste Rock Dump

Barbara Copper Project

Prepared for Round Oak Minerals Pty Ltd | December 2021

Round Oak MINERALS

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Calibrated Erosion Modelling

Waste Rock Dump

Barbara Copper Project

Prepared for Round Oak Minerals Pty Ltd | 15 December 2021

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Table of contents

1.0 Introduction 8
1.1 Background 8
1.2 Mine description 8
1.3 Scope 8
1.4 Link to the Progressive Rehabilitation and Closure Plan 9
2.0 Desktop review 11
2.1 Site conditions 11
2.1.1 Climate 11
2.1.2 Topography 11
2.1.3 Hydrology 11
2.2 Final landform design 11
2.3 Cover material 13
2.3.1 Geochemistry 13
2.3.2 Stability 13
2.4 Target erosion rate 13
3.0 Rainfall and overland flow simulations 15
3.1 Method 15
3.1.1 Equipment 15
3.1.2 Experiments 16
3.1.3 Calculations 16
3.2 Results and discussion 18
3.2.1 Rainfall simulation 18
3.2.2 Overland flow simulation 18
4.0 WEPP modelling 19
4.1 The WEPP model 19
4.2 Method 19
4.2.1 WEPP model parameters 19
4.3 Results 23
4.4 Discussion 23
4.4.1 Limitations 23
5.0 Conclusions 24
5.1 Rainfall and overland flow simulations 24
5.1.1 Rainfall simulation 24
5.1.2 Overland flow simulation 24
5.2 WEPP modelling 24
References 25
Appendix A ALS Laboratory Results 27

Figure

Figure 1	Mine location	10
Figure 2	WRD Landform	12
Figure 3	Average monthly rainfall comparison (CLIGEN and historical data)	20
Figure 4	Average recurrence interval comparison (CLIGEN and historical data)	20
Figure 5	Final Landform Representative Cross Sections	22

Table

Table 1	Material parameters	21
Table 2	Slope parameters	21
Table 3	Annual erosion rate	23

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1.0 Introduction

1.1 Background

SGM environmental Pty Limited (SGME) has been engaged by Round Oak Minerals Pty Limited (Round Oak) to complete a calibrated erosion model to assess the long-term stability of the final landform of the waste rock dump (WRD) (the final landform) at the Barbara Copper Project (the Mine).

1.2 Mine description

The Mine is a copper deposit located in north-western Queensland approximately (~) 65 kilometres (km) north-east of Mount Isa (Figure 1) and operates under environmental authority (EA) EPML02840015. Round Oak began operations in March 2019, incorporating conventional drill and blast / load and haul methods. The Mine operated until December 2020 and has now been placed in care and maintenance.

No processing of ore occurs at the Mine, with extracted ore being transported by road train to Glencore's Mount Isa processing facility for treatment. The Mine incorporates the following key infrastructure:

- north pit;
- south pit;
- WRD;
- WRD sediment dam;
- light infrastructure area;
- run-of-mine (ROM) pad;
- road train loading area; and
- magazine.

The final landform is located in the southern area of the Mine and was designed to store the waste rock produced from both the north and south pits. Waste rock is predominantly non-acid forming (NAF) and has low sulfur content. Post-closure, the runoff from the WRD will partially flow to the south pit via the haul road.

1.3 Scope

The reliability of an erosion model is based on a combination of the model's internal equations and the accuracy of the model's parameters. Using inaccurate erodibility parameters will result in inaccurate predictions which can lead to costly amendments due to a poorly designed landform.

The scope of this report is to complete rainfall and overland flow simulations to provide calibrated erodibility parameters for the cover material of the final landform. The calibrated parameters have been used for long-term erosion modelling of the final landform that meets the landform evolution modelling (LEM) requirements of the *Guideline: Progressive rehabilitation and closure plans (PRC plans)* (PRC plan guideline).

This report includes the following:

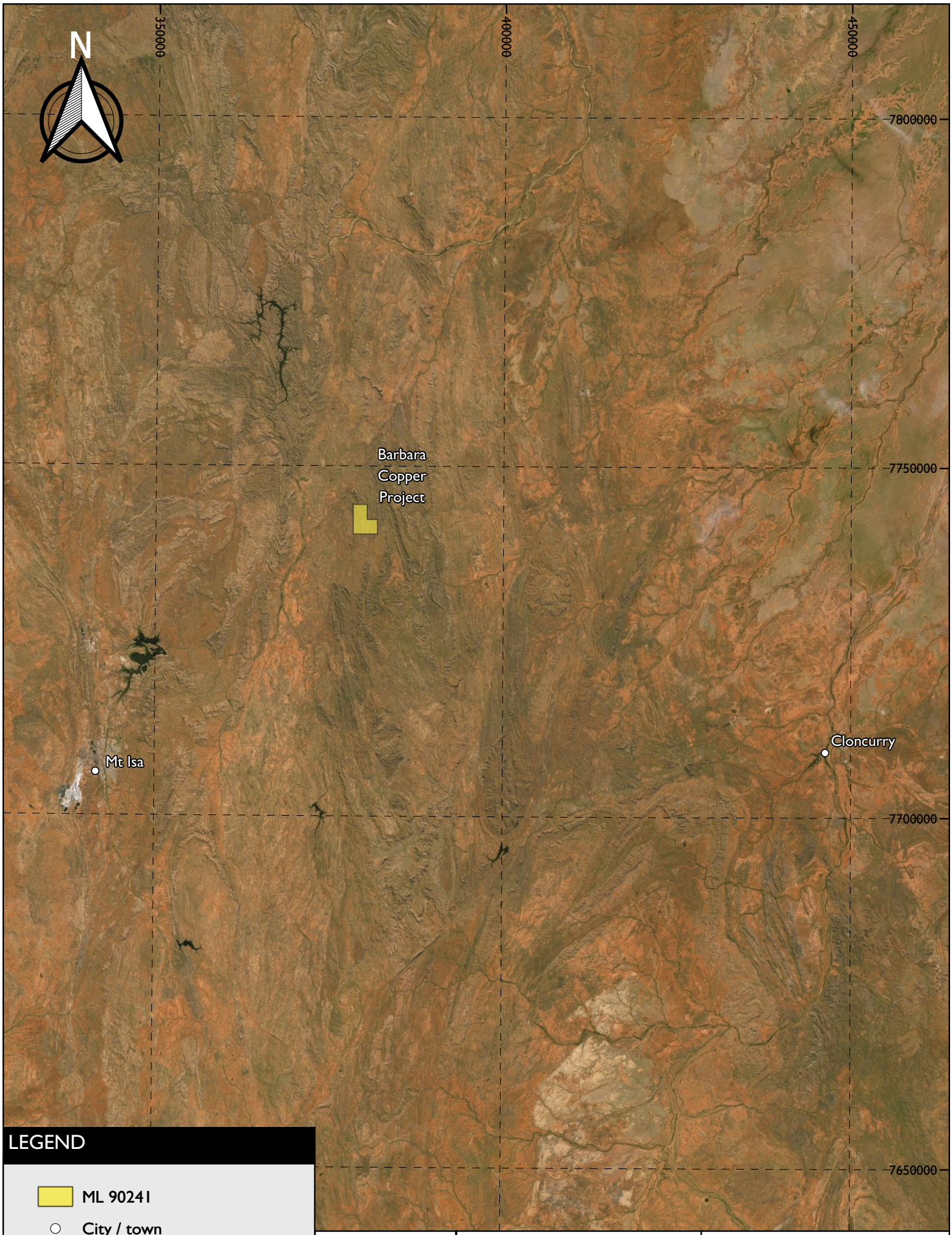
- desktop review of the landform design. including material properties (Section 2.0);
- rainfall and overland flow simulations to calibrate the erosion model (Section 3.0);
- calibrated erosion modelling to predict the long-term stability of the WRD (Section 4.0); and
- conclusions, limitations and assumptions of the rainfall simulation, overland flow simulation, erosion model and landform design (Section 5.0).

1.4 Link to the Progressive Rehabilitation and Closure Plan

The PRC plan guideline states that the *Progressive Rehabilitation and Closure Plan* (PRC plan) must include all supporting information required by the Department of Environment and Science (DES) to reach a decision on the 'soundness' of the rehabilitation strategies and delivery techniques to meet the approved land outcomes.

The objective of the final landform's design is to follow the Mine's rehabilitation objective outlined in EA EPML02840015. The post-closure objectives are to return the disturbed land to an agreed post-mining land use (PMLU) that is:

- safe (ie erosion gullies not presenting a danger to humans / animals);
- non-polluting (ie sediment runoff does not impede offsite assets);
- stable (ie stability does not compromise the PMLU or surrounding environment); and
- self-sustaining (ie the growth medium can support the PMLU).



LEGEND

ML 90241

City / town

Scale 1 : 750 000

0 10 20 30 km

Client: Round Oak Minerals Pty Ltd	Project: Calibrated Erosion Modelling	
Design: SGM Environmental Pty Ltd 05.11.2021 Scale: 1 : 750,000 CRS: GDA94 / MGA zone 55	Title: Mine Location	Figure: 1

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2.0 Desktop review

2.1 Site conditions

2.1.1 Climate

The climate of the region that the Mine is located in is referred to as a local steppe climate. The region is classified as hot semi-arid climate (BSh) according to the Köppen-Geiger climate classification. These climates tend to have hot sometimes extremely hot, summers and warm to cool winters, with some to minimal rainfall. High variability in rainfall, temperature and evaporation are common in north-west Queensland. The average annual temperature is 25.2 degrees Celsius (˚C) and the average rainfall is ~ 396 millimetres (mm) per year.

2.1.2 Topography

The topography of the Mine is undulating hills with frequent outcropping of rocky ridgelines. The landforms surrounding the Mine include rugged hills and mountain ranges separated by undulating valleys to the east and the Leichardt River to the west. The surrounding mountain ranges typically rise to a maximum height of 400-500 metres (m) Australian Height Datum (AHD).

2.1.3 Hydrology

The Mine is located in the Leichardt River Basin. The Leichardt River Basin begins to the south of Mount Isa and drains via the Leichardt River to the Gulf of Carpentaria. The Mine contains several drainage lines and ephemeral tributaries that tend to drain north-west down the steeper hills into the Leichardt River.

2.2 Final landform design

A rainfall-shedding capping system (the capping) has been built over the final landform's footprint. A potentially acid forming (PAF) cell has been constructed to store all PAF waste rock in a stable and non-polluting manner. The capping contains a low permeability layer above and below the PAF waste rock, comprised of compacted NAF waste rock to prevent infiltration into the PAF cell and isolate it from the permeable NAF waste rock located beneath it. The overall performance objectives for the cover are to:

- promote a stable landform using vegetation growth where applicable;
- direct surface runoff to the WRD sediment dam via the exit ramp to the south pit; and
- prevent capillary rise of salt and other contaminants into the cap.

The final landform has a total disturbance footprint of ~ 23 hectares (ha). The side batters are at angle of repose (~ 37 degrees (°)) with a batter height of 10 m and a bench width of 12 m leading to an average batter slope of 1V:2.5H. The final landform is shown in Figure 2.

The natural rilling of the batters is expected to create natural rock armouring / outcropping that will provide potential habitat for the Purple-Necked Rock-Wallaby.

LEGEND

Contour (1 metre)

Cross section

Scale 1 : 3 000

0 50 100 m

Client: Round Oak Minerals Pty Ltd	Project: Calibrated Erosion Modelling	
Design: SGM Environmental Pty Ltd 05.11.2021 Scale: 1 : 3,000 CRS: GDA94 / MGA zone 55	Title: WRD Landform	Figure: 2

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2.3 Cover material

2.3.1 Geochemistry

The final landform is mostly NAF waste rock (the cover material) with low sulfur content. Geochemical static characterisation of the Mine's waste rock was done by Environmental Geochemistry International Pty Limited (EGi) in 2014. In 2019 a kinetic leach column testing program was also done. The Kinetic column testing found that apart from limited leaching of copper, there was no evidence of leaching of environmentally important elements such as arsenic, cadmium, mercury, lead and zinc from either the cover material or the PAF samples (EGi 2020).

2.3.2 Stability

The structural stability of waste rock is heavily influenced by a combination of physical and chemical properties (eg exchangeable cations, electrical conductivity (EC) and organic matter (OM)).

Sodicity is the presence of a high proportion of sodium ions relative to other exchangeable cations. Waste rock is considered sodic when the exchangeable sodium percentage (ESP) is greater than six and highly sodic when the ESP is greater than 15.

High salt content can prevent the dispersion caused by sodicity. If the salinity falls below the requirement for stability, even a small amount of sodium can produce significant dispersion. The electrochemical stability index (ESI) is the ratio of EC and the ESP and is used to describe this relationship.

The Emerson aggregate test measures the stability of the waste rock structure when immersed in water and is used to predict slaking and / or dispersive behaviour.

OM content is representative of the structural condition and stability of the material. A high (greater than (>)3) percent (%) of OM can reduce erosion by increasing water infiltration and forming stable aggregates.

Closure studies were done by SGME in 2021 which included physical and chemical characterisation of the cover material. The findings from this study, with regard to erosion and landform stability, can be summarised as:

- ESP indicates the cover material has low sodicity (less than (<)6) and negligible risk of dispersion;
- ESI indicates the cover material should be stable;
- Emerson aggregate tests indicate the cover material is potentially dispersive (Class 3) when remoulded at the plastic limit (heavily trafficked); and
- OM content indicates the cover material has very poor structural condition and very low structural stability.

2.4 Target erosion rate

There is currently no broad agreement on what constitutes an 'acceptable' rate of erosion on a rehabilitated landform. The *Prediction of Sheet and Rill Erosion Over the Australian Continent: Incorporating Monthly Soil Loss Distribution* (Lu et al 2001) has previously reported that:

- the average Australian soil erosion rate is 6.3 tonnes per hectare per year (t/ha/y);
- a low rate of erosion is defined as <0.5 t/ha/y; and
- a high erosion rate is defined as >10 t/ha/y.

Landloch (2013) have shown that rehabilitated mine slopes have a low tendency to rill with an average erosion rate of <5 t/ha/y. The elimination of rilling will largely reduce the potential of channelised flow which can result in gully erosion. Therefore, avoiding rill formation will ensure landform stability and reduce the likelihood of excessive erosion.

It is important to note that erosion rates can vary from year to year depending on climatic conditions. Therefore, the maximum annual erosion rate will also be used as a secondary performance indicator.

Target average and maximum erosion rates of <5 t/ha/y and <10 t/ha/y have therefore been adopted for the WRD landform.

3.0 Rainfall and overland flow simulations

The studying of hydrological processes such as runoff, erosion and infiltration usually require the use of field plots under natural rainfall or field scale rainfall simulators. Laboratory scale rainfall simulators are a convenient and cost-effective method that has been proven to be effective in predicting hillslope erosion rates and deriving site-specific erodibility parameters for mining landforms (Evans et al 1997; Sheridan et al 2000; Landloch 2010; So et al 2018). These calibrated parameters can be used in conjunction with erosion models to assess the long-term stability of mining landforms.

3.1 Method

3.1.1 Equipment

3.1.1.1 Rainfall simulator

Mhaske et al (2019) provides a detailed design of the rainfall simulator used in this report. The simulator can be divided into four key parts (XXXX):

1. Water supply system connected to a pressurised full cone nozzle to produce simulated rainfall.
2. Supporting steel frame to mount water supply system and canvas windshields.
3. Hydraulic jack attached to a tilting table for slope adjustment.
4. Perforated plot to hold the sample to be tested and provide a means to capture runoff and infiltration.

a Water supply system and full cone nozzle

Irrigation pipes made of polyvinyl chloride (PVC) are used for the water supply system. A flow meter placed between two control valves is used to monitor and control the flow rate.

Full-cone spray nozzles constructed by Spraytech Systems Pvt Limited (Spraytech) are used to simulate rainfall. The spray angle of the nozzles is 45˚. Spray nozzles of four different orifice sizes are used to simulate different rainfall intensities:

- DA13.250 — 1.9 mm;
- DA13.350 — 2.2 mm;
- DA13.650 — 3.1 mm; and
- DA23.100 — 3.8 mm.

b Steel frame

A supporting steel frame was constructed to attach the water supply system and canvas wind shields. The frame is 3.0 m long, 2.0 m wide and 3.5 m high. The spray nozzle is attached centrally at the top of the frame to ensure adequate coverage (~ 3 m diameter spray area).

c Tilting table with hydraulic jack

A 1.2 m high tilting table was constructed to hold the erosion plot / overland flow flume and allow the adjustment of the slope angle. A manual hydraulic jack is fixed at the bottom of the table to lift the plot / flume to the desired slope angle.

d Erosion plot

A 0.5 m wide and 1.0 m long erosion plot secured to the top of the tilting table is used to hold the cover material and collect runoff and infiltration samples. The plot is divided into two sections by a perforated sheet that allows

the infiltration of water. The upper section holds the cover material and allows for runoff generation and collection, the lower section allows for infiltration through the plot and sample collection. This allows for both runoff and infiltration to be collected simultaneously.

e Calibration

Rainfall intensity is an important factor in accurate rainfall simulations. The rainfall simulator was calibrated using a flow meter and tipping bucket rain gauges. Four full cone nozzles with differing orifice sizes (Section 3.1.1.1a) were calibrated to achieve a variety of possible rainfall intensities. The nozzles have a 45° spray angle resulting in a spray area of ~ 2.50-3.00 m in diameter. Rain gauges were positioned at various places within the target area (0.5 square metres (m^2)) and averaged to calculate the rainfall intensity applied to the erosion plot.

3.1.1.2 Overland flow simulation

A 0.75 m wide and 2.00 m long flume was used to simulate overland flow and assess rill erosion. A hose was attached to the rainfall simulator's water supply system (to make use of the flow meter) and was discharged into a feeder tank that is located at the top of the flume to ensure a steady and even flow across the flume.

3.1.2 Experiments

NAF waste rock was collected by Round Oak staff from the final landform and transported in an intermediate bulk container to the SGME laboratory to be assessed. The cover material was uniformly mixed and placed into an erosion plot and an overland flow flume achieving a bulk density that is representative of a trafficked WRD (~ 1.5 tonnes per cubic metre (t/m^3)).

3.1.2.1 Rainfall simulation

Interrill erosion is measured by applying a simulated storm (ie 100 millimetres per hour (mm/h)) to a plot 0.50 m wide and 1.00 m long. The plot is set to a gradient of 20% and the storm event is run for 30 minutes. Rainfall is applied until steady state runoff is reached; then timed runoff and infiltration samples are collected at 5 minute intervals. The runoff samples collected after steady state is achieved are dried and weighed to measure the interrill erosion rate. Rainfall is measured by rain gauges and accounted for in the calculation of interrill erosion.

3.1.2.2 Overland flow simulation

Rill erosion is measured by applying various rates of overland flow to a flume 0.75 m wide and 2.00 m long. The flume is set to a gradient of 20% and consecutive rates of overland flow (measured with the flow meter) are applied for 3 minute intervals. Flow rates are increased until the maximum possible flow is achieved or until rills cut to the base of the flume. For each applied flow rate, three runoff samples are collected at 1 minute intervals. The samples are dried and weighed with the mean used to measure the rill erosion rate. No rainfall is applied during the overland flow simulation.

3.1.3 Calculations

In the *Water Erosion Prediction Project* (WEPP) model (the WEPP model) the erosion process is divided into interrill and rill erosion. These two processes are calculated in the model via a number of erodibility parameters (the parameters):

- interrill erodibility (K_I);
- rill erodibility (K_r);
- critical shear stress (τ_c); and
- effective hydraulic conductivity (K_e).

The parameters are derived from data collected during the rainfall and overland flow simulations and equations sourced from Liebenow, Elliot, Laflen & Kohl 1990, Sheridan, Loch & So 2000, Franco, Cassol, Pauletto & Pinto 2010 and Reichert & Norton 2013:

- K_i is calculated using the runoff samples obtained from the rainfall simulation and Equations 1-5 (Section 3.1.3.1);
- K_r and τ_c are calculated using the runoff samples obtained from the overland flow simulation and Equations 6-8 (Section 3.1.3.2); and
- K_e is calculated using the infiltration rates measured from the rainfall simulation.

3.1.3.1 Interrill erodibility

a Interrill erosion rate

$$E_i = \frac{Mss}{AD} \quad (1)$$

Where, E_i = interrill erosion rate (kilograms per squared metre seconds (kg/m^2 s)); Mss = soil dry mass (kilograms (kg)); A = plot area (m^2); D = time of sampling (seconds (s)).

Adjusted interrill erosion rate

$$E_{Ai} = (\frac{I_D}{I_M})^2 \times E_i \quad (2)$$

Where, E_{Ai} = adjusted interrill erosion rate (kg/m^2 s); I_D = design rainfall intensity (metres per second (m/s)); I_M = measured rainfall intensity (m/s).

b Interrill erodibility factor

Slope steepness factor

$$S_f = 1.05 - 0.85e^{-4sin\theta} \quad (3)$$

Where, S_f = slope steepness factor; θ = slope angle (radians).

Cover factor

$$C_f = e^{-2.5C} \quad (4)$$

Where, C_f = cover factor; C = rock (greater than (>) 2 millimetre (mm)) fraction.

Interrill erodibility factor

$$K_i = \frac{E_i}{IQS_fC_f} \quad (5)$$

Where, K_i = interrill erodibility factor (kilogram seconds per quartic metre (kg s/m^4)); Q = steady-state runoff rate (m/s).

3.1.3.2 Rill erodibility

a Rill erosion rate

$$E_r = \frac{Mss}{A_rD} \quad (6)$$

Where, E_r = rill erosion rate (kg/m^2 s); A_r = rill bed area (m^2); D = time of sampling (s).

b Hydraulic shear stress

Open channel flow (no rilling)

$$\tau = yds \tag{7}$$

Where, τ = hydraulic shear stress (pascals (Pa)); y = specific weight of water (9,806 kilograms per squared metre seconds ($kg/m^2 s^2$)); d = average water depth (m); s = hydraulic gradient (≈ flume slope angle (radians)).

Flow in rills

$$\tau = yrs \tag{8}$$

Where, r = hydraulic radius (m); s = hydraulic gradient (≈ rill slope angle (radians)).

c Rill erodibility factor and critical shear stress

Rill erosion rates (Equation 6) for all of the simulated flows is plotted against their corresponding hydraulic shear values (Equation 7 or 8) and a regression line is calculated. The slope of the regression line is the rill erodibility factor (seconds per metre (s/m)) and the intercept with the horizontal axis is the material's critical shear stress (Pa).

3.2 Results and discussion

3.2.1 Rainfall simulation

Interrill erosion was assessed by applying rainfall at an initial intensity of 112 mm/h to the erosion plot. The plot was set to a gradient of 20% and rainfall was maintained for 30 minutes. Timed (10-30 second) infiltration samples were collected at 5 minute intervals during the simulation. No runoff was observed for the initial intensity, so the simulation was repeated at ~ 400 mm/h (the maximum achievable intensity). Timed infiltration samples were collected at 5 minute intervals during the 30 minute simulation. No runoff was observed for the maximum achievable intensity.

Once steady state infiltration was achieved, the subsequent infiltration rates were averaged to derive the cover material's effective hydraulic conductivity (422 mm/hr). Interrill erodibility was not able to be calibrated from the rainfall simulation because no runoff was generated by any of the simulated storm events.

3.2.2 Overland flow simulation

Rill erodibility and critical shear were not calibrated from the overland flow simulation because no rilling was observed during any of the simulated flows.

4.0 WEPP modelling

4.1 The WEPP model

The WEPP model is a continuous simulation erosion prediction model, initially developed for agricultural purposes by the United States Department of Agriculture (USDA). The WEPP model integrates hydrology, vegetation science, hydraulics and soil mechanics to simulate the erosion process (both detachment and transport) at a two-dimensional hillslope scale.

The WEPP model is a daily time step model that simulates daily runoff and erosion for a given slope shape, based on initial waste rock hydrological conditions, characteristics of the rain event and waste rock erodibility and infiltration parameters on each day. The WEPP model can also be used to assess the erosion potential for extreme rainfall events.

The WEPP model has been used in the design of landforms for mines across Australia. Howard and Roddy (2012) have shown that observed cumulative erosion rates for mined landforms in Western Australia show good agreement with the WEPP model's predictions.

4.2 Method

The WEPP model was used to simulate final landform stability predictions for a 100 year period including data for rainfall, runoff, and sediment loss for the final landform. The WEPP model was also used to determine reductions in erosion rates from increasing groundcover.

4.2.1 WEPP model parameters

WEPP model inputs can be broken up into four key components: climate, material properties, topography and surface conditions.

4.2.1.1 Climate

A 100 year synthetic climate file was generated using the CLIGEN stochastic weather generator. CLIGEN has been widely used and validated in Australia (Yu 2003). The following data was imported into CLIGEN to generate this file:

- 121 years of patched daily temperature (maximum and minimum), rainfall and solar radiation sourced from the Bureau of Meteorology (BoM) SILO data drill (the SILO data drill); and
- 24 years of pluviograph (6-minute rainfall intensity) data from the BoM's Mount Isa Aero weather station (029127), located ~ 47 km south-west of the Mine.

Various parameters were then adjusted in the generated climate file to match the inputted data more closely. These include average rainfall on a wet day, maximum 30 minute rainfall intensity and time to peak rainfall intensity.

a Validation

The CLIGEN climate file has been compared to the SILO data drill to verify the accuracy of the WEPP model. The CLIGEN climate file and the SILO data drill show a high level of consistency in terms of both monthly rainfall totals (Figure 3) and design storm events (Figure 4). Therefore, the CLIGEN climate data file is considered appropriate for use in the WEPP model.

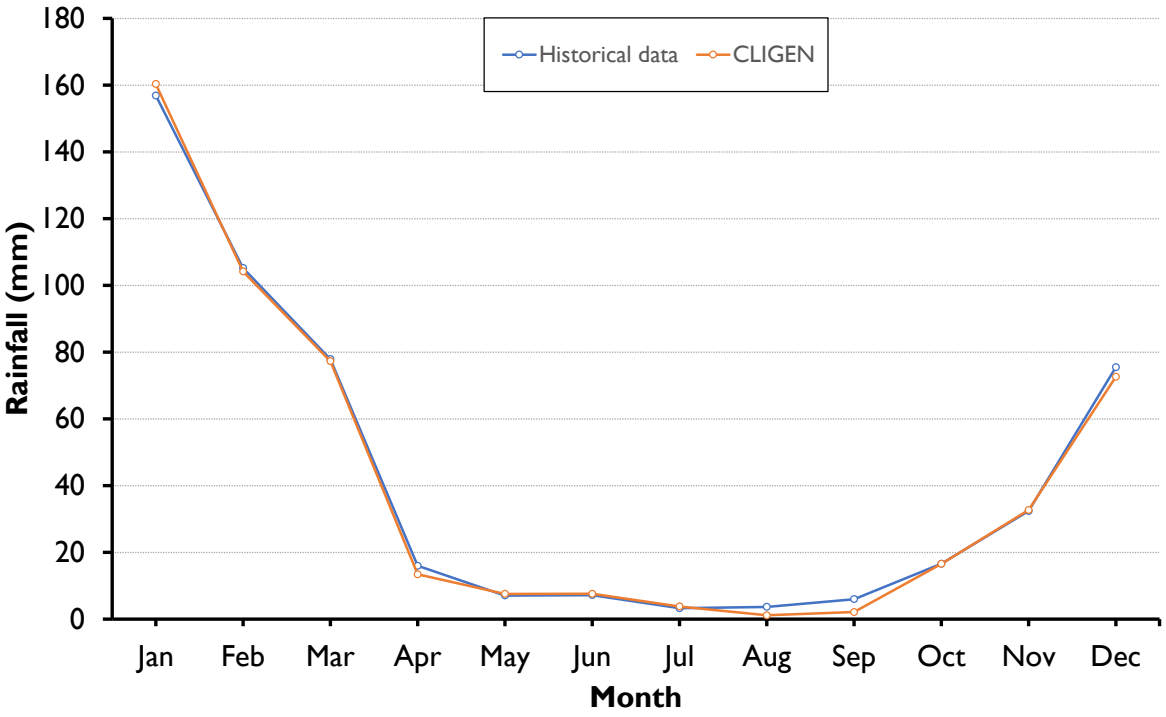


Figure 3 Average monthly rainfall comparison (CLIGEN and historical data)

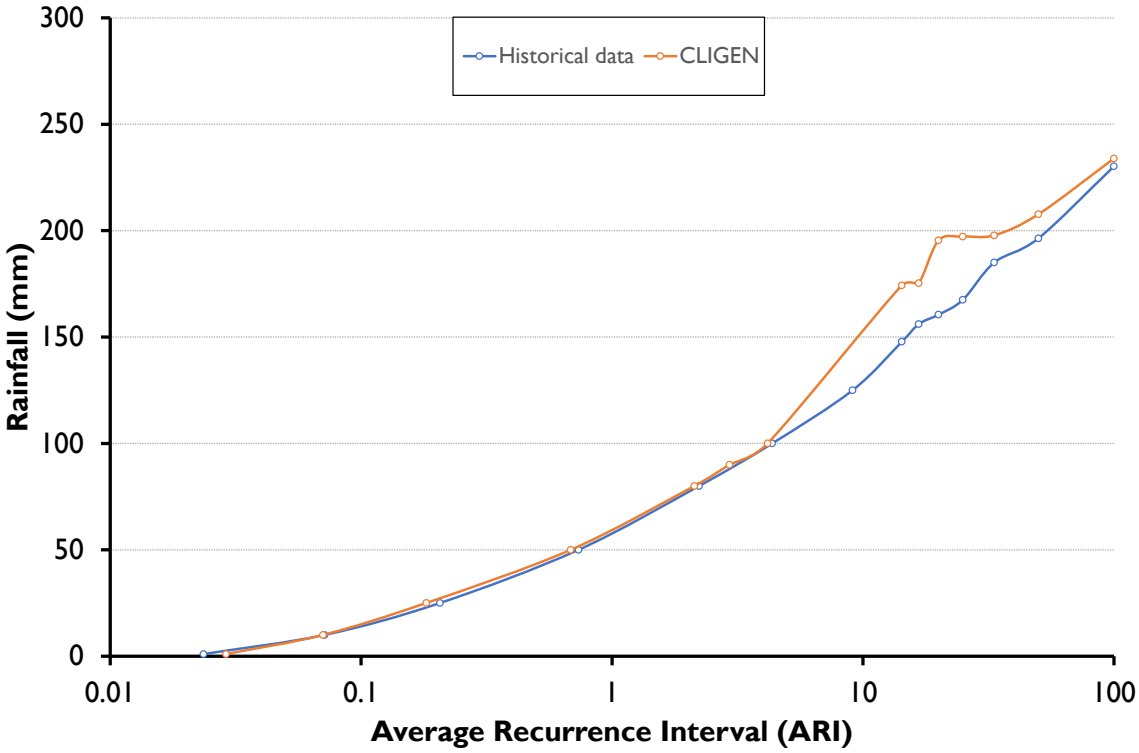


Figure 4 Average recurrence interval comparison (CLIGEN and historical data)

4.2.1.2 Material properties

The WEPP model has been run using median values derived from laboratory physical and chemical data (SGME 2021). The NAF waste rock parameters inputted into the WEPP model are given in Table 1.

Table 1 Material parameters

Material type	Depth	Sand	Clay	Rock	OM	Cation exchange capacity (CEC)
	m	%	%	%	%	milliequivalents per 100 grams (meq/100g)
NAF waste rock	2.0	9.8	0.2	88.0	0.31	7.4

Effective hydraulic conductivity was derived from the maximum infiltration achieved during the rainfall simulator (422 mm/h). Interrill erodibility, rill erodibility and critical shear were calculated via the WEPP model since the parameters were not able to be derived from the rainfall simulation (no runoff achieved) or overland flow simulation (no rilling observed) and therefore could not be calibrated.

4.2.1.3 Topography

Three cross-sections that are considered representative of the WRD final landform were modelled. Table 2 and Figure 5 summarise the slope parameters used in the WEPP model. The slope gradient varies slightly around the final landform and includes a bench with a gentler gradient ~ halfway down, breaking the slope into sections.

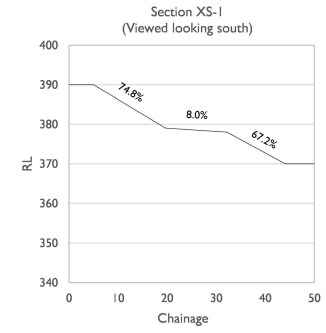
Table 2 Slope parameters

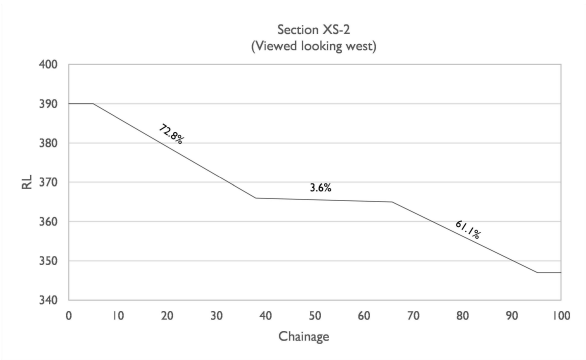
Slope ID	Height	Section 1		Section 2		Section 3	
	m	Length (m)	Slope (%)	Length (m)	Slope (%)	Length (m)	Slope (%)
XS-1	19.0	14.7	74.8	12.5	8.0	11.9	67.2
XS-2	42.0	33.0	72.8	27.7	3.6	29.5	61.1
XS-3	32.0	343.9	9.6	-	-	-	-

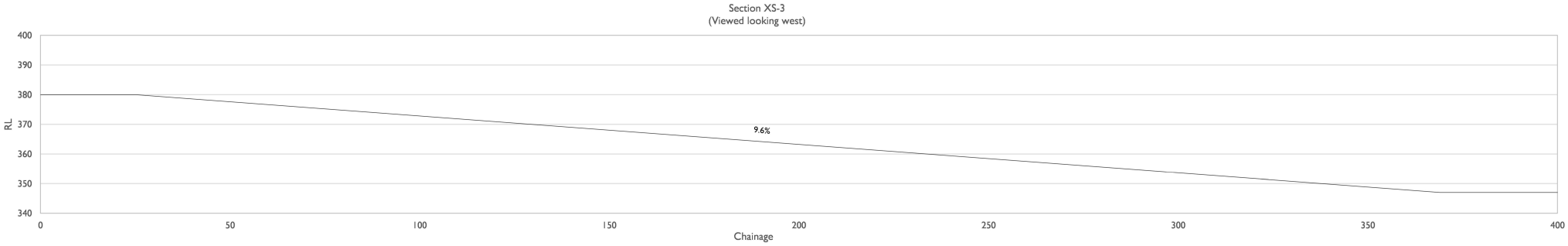
4.2.1.4 Surface conditions

The WEPP model was run for a no vegetative groundcover scenario (worst-case). Vegetation development was also restricted during the WEPP model because vegetation growth rates for the area are not currently known.

Rill spacing was set to 0.5 m and surface roughness was set to 0.03 m, which is typical of a smooth surface that would develop after many rainfall events.







0 200 400 m

(Aerial)

SGMenvironmental

Client: Round Oak Minerals Pty Ltd		Project: Calibrated Erosion Modelling	
Design: SGM Environmental Pty Ltd	23.11.2021	Title: WRD Cross Sections	Figure: 5
Scale: 1 : 5,500 (Aerial)			
CRS: GDA94 / MGA zone 54			

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4.3 Results

The average and maximum annual erosion rates are given in Table 3.

Table 3 Annual erosion rate

Slope ID	Average	Maximum
XS-1	nil	nil
XS-2	nil	nil
XS-3	0.06	0.37

1. Units are in t/ha/y

4.4 Discussion

Table 3 shows that the final landform will experience negligible erosion rates (<0.6 t/ha/y) with the modelled cover and can be considered stable (unlikely to develop significant rilling). Similarly, the maximum erosion rates modelled (<0.37 t/ha/y) indicate that the final landform will be stable in the event of extreme rainfall.

The very low erosion rates predicted by the WEPP model can be attributed to the high effective hydraulic conductivity of the cover material which was derived from the rainfall simulation (Section 3.0). While the high hydraulic conductivity of the cover material will limit the potential for sheet and rill erosion, sediment may be transported through minor forms of tunnel erosion.

4.4.1 Limitations

The following limitations apply to the WEPP model:

- it does not predict deposition patterns;
- it does not adjust hillslope elevation in response to erosion;
- it does not consider gully and tunnel erosion; and
- it does not account for weathering, surface armouring and pedogenesis.

The effects of climate change on future rainfall event intensities, durations and / or frequencies may also affect the predictions made by the WEPP model.

5.0 Conclusions

5.1 Rainfall and overland flow simulations

Rainfall and overland flow simulations were done on NAF waste rock collected from the final landform in order to derive calibrated erodibility parameters. A rainfall simulator was used to study the interrill erosion process and calibrate the interrill erodibility factor and the effective hydraulic conductivity. An overland flow simulator was used to study the rill erosion process and calibrate the rill erodibility factor and critical shear stress.

5.1.1 Rainfall simulation

The effective hydraulic conductivity was derived from the infiltration rates measured during the rainfall simulation. However, interrill erodibility was not able to be calibrated from the rainfall simulation as no runoff was observed for any of the simulated storm events.

5.1.2 Overland flow simulation

Rill erodibility and critical shear were not able to be calibrated from the overland flow simulation as no rilling was observed for any of the simulated flows.

5.2 WEPP modelling

The WEPP model was run using desktop data, calibrated erodibility parameters and current landform designs to estimate the potential annual erosion rate (t/ha/y) for a 100 year period.

The WEPP model indicated that, given current landform designs, the final landform will experience negligible erosion (<0.37 t/ha/y) and can be considered stable with regard to the average and maximum rates of erosion (<5 t/ha/y and <10 t/ha/y respectively).

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Appendix A
Laboratory Results

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Julie Byrd	Manager	Anthony Nilsson
Client	ROUND OAK MINERALS PTY LIMITED	Laboratory	SGS Cairns Environmental
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Project	**21B002**	SGS Reference	**CE153058 R0**
Order Number	(Not specified)	Date Received	02 Jun 2021
Samples	8	Date Reported	30 Jun 2021

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(3146/19038)

SIGNATORIES

Alyson BERGAMO
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Jon Dicker
Manager Northern QLD

Mitsuko BALDWIN
Metals Team Leader

Parameter	Units	LOR	CE153058.001 Soil BCO waste rock 1	CE153058.002 Soil BCO waste rock 2	CE153058.003 Soil BCO clay 1	CE153058.004 Soil BCO clay 2
Moisture Content Method: AN002 Tested: 3/6/2021						
% Moisture	%w/w	0.5	<0.5	<0.5	6.8	4.9
pH in soil (1:5) Method: AN101 Tested: 10/6/2021						
pH	pH Units	-	8.9	9.4	8.8	7.1
pH (CaCl2)*	pH Units	-	8.5	8.8	8.3	7.3
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 10/6/2021						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	1	170	120	110	8700
Total Dissolved Solids (by calculation)	mg/kg	5	510	350	330	26000
Chloride (water extractable) Method: AN274 Tested: 11/6/2021						
Chloride (water extractable 1:5)	mg/kg	5	50	22	22	14000
Colwell Phosphorus Method: AN015 Tested: 9/6/2021						
Colwell Phosphorus	mg/kg	1	1	1	7	25
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by Auto Analyser in Soil Method: AN248 Tested: 17/6/2021						
Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	0.05	3.5	1.2	2.5	210

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name	CE153058.001 Soil BCO waste rock 1	CE153058.002 Soil BCO waste rock 2	CE153058.003 Soil BCO clay 1	CE153058.004 Soil BCO clay 2
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 9/6/2021							
Total Organic Carbon	%w/w	0.05		0.17	0.19	0.33	0.54
Organic Matter	%w/w	0.1		0.29	0.33	0.57	0.94
Exchangeable Cations and Cation Exchange Capacity (CEC/ESP/SAR) Method: AN122 Tested: 16/6/2021							
Exchangeable Sodium, Na	mg/kg	2		96	76	42	6400
Exchangeable Sodium, Na	cmol (+)/kg	0.01		0.42	0.33	0.18	28
Exchangeable Sodium Percentage*	%	0.1		6.0	4.2	1.2	63.7
Exchangeable Potassium, K	mg/kg	2		84	82	110	160
Exchangeable Potassium, K	cmol (+)/kg	0.01		0.21	0.21	0.29	0.41
Exchangeable Potassium Percentage*	%	0.1		3.1	2.6	1.9	0.9
Exchangeable Calcium Percentage*	%	0.1		81.1	86.2	89.3	24.1
Exchangeable Calcium, Ca	cmol (+)/kg	0.01		5.6	6.9	14	11
	mg/kg	2		1100	1400	2700	2100
Exchangeable Magnesium, Mg	mg/kg	2		83	68	140	610
Exchangeable Magnesium, Mg	cmol (+)/kg	0.02		0.68	0.56	1.2	5.0
Exchangeable Magnesium Percentage*	%	0.1		9.9	7.0	7.6	11.4
Cation Exchange Capacity	cmol (+)/kg	0.02		6.9	8.0	15	44
Sodium Adsorption Ratio*	No unit	0.1		0.2	0.2	<0.1	10.0
Exchangeable Calcium/Exchangeable Magnesium Ratio*	No unit	0.1		8.2	12.3	11.7	2.1
Exchangeable Magnesium/Exchangeable Potassium	No unit	0.1		3.2	2.6	4.1	12.2
Soil - Aluminium (KCL Extraction) Method: AN046 Tested: 21/6/2021							
Exchangeable Aluminium*	mg/kg	1		-	-	-	-
Exchangeable Aluminium*	cmol (+)/kg	0.01		-	-	-	-
DTPA Extractable Metals in Soil Method: AN025/AN320 Tested: 15/6/2021							
Copper, Cu	mg/kg	0.05		54	24	1.6	3.7
Zinc, Zn	mg/kg	0.05		1.0	0.60	0.35	0.85
Manganese, Mn	mg/kg	0.5		7.5	9.8	11	53
Iron, Fe	mg/kg	0.5		14	21	20	15
HCl Extractable S, Ca and Mg in Soil ICP OES Method: AN014 Tested: 24/6/2021							
Acid Soluble Sulfur (SHCl)	%w/w	0.005		0.006	<0.005	-	-
Acid Neutralising Capacity or Neutralisation Potential(ANC/NP) Method: AN212 Tested: 22/6/2021							
ANC as % $CaCO_3$	% CaCO3	0.05		1.0	1.3	-	-
ANC as % $CaMg(CO_3)2$	%w/w	0.05		1.1	1.4	-	-
Acid Neutralisation Capacity/Neutralisation Potential	kg CaCO3/T	0.5		10	13	-	-
Acid Neutralisation Capacity/Neutralisation Potential kg	kg H2SO4/T	0.5		9.8	12	-	-

Parameter	Units	LOR	CE153058.001 Soil BCO waste rock 1	CE153058.002 Soil BCO waste rock 2	CE153058.003 Soil BCO clay 1	CE153058.004 Soil BCO clay 2
Net Acid Generation Potential (NAGP) Method: AN215 Tested: 24/6/2021						
Net Acid Production Potential (Tot S and ANC only)	kg H2SO4/T	-400	**-8.0**	**-11**	-	-
Maximum Potential Acidity (MPA)	kg H2SO4/T	0.2	**1.8**	**1.6**	-	-
Single Addition Net Acid Generation (NAG) Method: AN216 Tested: 24/6/2021						
ECox (NAG Conductivity)	µS/cm	1	**81**	**110**	-	-
pHox (NAG pH)	No unit	-	**8.6**	**8.2**	-	-
NAG as kg H_2SO_4/tonne to pH 4.5	kg H2SO4/T	0.5	<0.5	<0.5	-	-
NAG as kg H_2SO_4/tonne to pH 7	kg H2SO4/T	0.5	<0.5	<0.5	-	-
NAG as kg CaCO3/tonne to pH 4.5	kg CaCO3/T	0.5	<0.5	<0.5	-	-
NAG as kg CaCO3/tonne to pH 7	kg CaCO3/T	0.5	<0.5	<0.5	-	-
Total Sulfur Method: AN012/AN320 Tested: 24/6/2021						
Total Sulfur	%w/w	0.005	**0.058**	**0.052**	-	-

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name	CE153058.005 Soil BCO clay 3	CE153058.006 Soil BCO NAF 1	CE153058.007 Soil BCO NAF 2	CE153058.008 Soil BCO NAF 3
Moisture Content Method: AN002 Tested: 3/6/2021							
% Moisture	%w/w	0.5		4.1	<0.5	<0.5	<0.5
pH in soil (1:5) Method: AN101 Tested: 10/6/2021							
pH	pH Units	-		9.1	9.5	9.4	9.0
pH (CaCl2)*	pH Units	-		8.7	8.4	8.3	8.4
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 10/6/2021							
Conductivity of Extract (1:5 dry sample basis)	µS/cm	1		6500	140	140	150
Total Dissolved Solids (by calculation)	mg/kg	5		20000	420	430	460
Chloride (water extractable) Method: AN274 Tested: 11/6/2021							
Chloride (water extractable 1:5)	mg/kg	5		4600	13	16	10
Colwell Phosphorus Method: AN015 Tested: 9/6/2021							
Colwell Phosphorus	mg/kg	1		7	<1	<1	<1
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by Auto Analyser in Soil Method: AN248 Tested: 17/6/2021							
Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	0.05		28	11	7.7	13

Parameter	Units	LOR	CE153058.005 Soil BCO clay 3	CE153058.006 Soil BCO NAF 1	CE153058.007 Soil BCO NAF 2	CE153058.008 Soil BCO NAF 3
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 9/6/2021						
Total Organic Carbon	%w/w	0.05	0.30	0.40	0.32	0.30
Organic Matter	%w/w	0.1	0.52	0.69	0.55	0.52
Exchangeable Cations and Cation Exchange Capacity (CEC/ESP/SAR) Method: AN122 Tested: 16/6/2021						
Exchangeable Sodium, Na	mg/kg	2	8100	39	38	41
Exchangeable Sodium, Na	cmol (+)/kg	0.01	35	0.17	0.16	0.18
Exchangeable Sodium Percentage*	%	0.1	74.8	1.1	1.0	1.1
Exchangeable Potassium, K	mg/kg	2	120	110	110	100
Exchangeable Potassium, K	cmol (+)/kg	0.01	0.31	0.27	0.28	0.27
Exchangeable Potassium Percentage*	%	0.1	0.7	1.7	1.7	1.7
Exchangeable Calcium Percentage*	%	0.1	22.8	94.7	94.7	94.9
Exchangeable Calcium, Ca	cmol (+)/kg	0.01	11	15	16	15
	mg/kg	2	2100	2900	3100	3000
Exchangeable Magnesium, Mg	mg/kg	2	98	46	52	43
Exchangeable Magnesium, Mg	cmol (+)/kg	0.02	0.80	0.38	0.43	0.35
Exchangeable Magnesium Percentage*	%	0.1	1.7	2.4	2.6	2.2
Cation Exchange Capacity	cmol (+)/kg	0.02	47	15	17	16
Sodium Adsorption Ratio*	No unit	0.1	14.6	<0.1	<0.1	<0.1
Exchangeable Calcium/Exchangeable Magnesium Ratio*	No unit	0.1	13.3	38.8	36.6	42.2
Exchangeable Magnesium/Exchangeable Potassium	No unit	0.1	2.6	1.4	1.5	1.3
Soil - Aluminium (KCL Extraction) Method: AN046 Tested: 21/6/2021						
Exchangeable Aluminium*	mg/kg	1	-	-	-	-
Exchangeable Aluminium*	cmol (+)/kg	0.01	-	-	-	-
DTPA Extractable Metals in Soil Method: AN025/AN320 Tested: 15/6/2021						
Copper, Cu	mg/kg	0.05	1.7	5.0	5.5	13
Zinc, Zn	mg/kg	0.05	0.36	0.26	0.47	0.26
Manganese, Mn	mg/kg	0.5	6.1	5.2	4.4	4.9
Iron, Fe	mg/kg	0.5	13	35	26	29
HCl Extractable S, Ca and Mg in Soil ICP OES Method: AN014 Tested: 24/6/2021						
Acid Soluble Sulfur (SHCl)	%w/w	0.005	-	0.039	0.032	0.018
Acid Neutralising Capacity or Neutralisation Potential(ANC/NP) Method: AN212 Tested: 23/6/2021						
ANC as % $CaCO_3$	% CaCO3	0.05	-	2.9	2.9	3.3
ANC as % $CaMg(CO_3)2$	%w/w	0.05	-	3.1	3.1	3.5
Acid Neutralisation Capacity/Neutralisation Potential	kg CaCO3/T	0.5	-	29	29	33
Acid Neutralisation Capacity/Neutralisation Potential kg	kg H2SO4/T	0.5	-	28	28	32

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name	CE153058.005 Soil BCO clay 3	CE153058.006 Soil BCO NAF 1	CE153058.007 Soil BCO NAF 2	CE153058.008 Soil BCO NAF 3
Net Acid Generation Potential (NAGP) Method: AN215 Tested: 24/6/2021							
Net Acid Production Potential (Tot S and ANC only)	kg H2SO4/T	-400		-	**-21**	**-22**	**-23**
Maximum Potential Acidity (MPA)	kg H2SO4/T	0.2		-	**7.0**	**6.7**	**8.4**
Single Addition Net Acid Generation (NAG) Method: AN216 Tested: 24/6/2021							
ECox (NAG Conductivity)	µS/cm	1		-	**160**	**180**	**200**
pHox (NAG pH)	No unit	-		-	**9.1**	**9.3**	**8.6**
NAG as kg H_2SO_4/tonne to pH 4.5	kg H2SO4/T	0.5		-	<0.5	<0.5	<0.5
NAG as kg H_2SO_4/tonne to pH 7	kg H2SO4/T	0.5		-	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 4.5	kg CaCO3/T	0.5		-	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 7	kg CaCO3/T	0.5		-	<0.5	<0.5	<0.5
Total Sulfur Method: AN012/AN320 Tested: 24/6/2021							
Total Sulfur	%w/w	0.005		-	**0.23**	**0.22**	**0.27**

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Acid Neutralising Capacity or Neutralisation Potential(ANC/NP) Method: ME-(AU)-[ENV]AN212

Parameter	QC Reference	Units	LOR	DUP %RPD	LCS %Recovery
Acid Neutralisation Capacity/Neutralisation Potential	LB091324	kg CaCO3/T	0.5	0 - 6%	NA
Acid Neutralisation Capacity/Neutralisation Potential kg H_2SO_4/t	LB091324	kg H2SO4/T	0.5	0 - 6%	NA

Chloride (water extractable) Method: ME-(AU)-[ENV]AN274

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Chloride (water extractable 1:5)	LB090985	mg/kg	5	<5	0 - 1%	103 - 104%

Colwell Phosphorus Method: ME-(AU)-[ENV]AN015

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Colwell Phosphorus	LB090930	mg/kg	1	<1	0 - 2%	96%

DTPA Extractable Metals in Soil Method: ME-(AU)-[ENV]AN025/AN320

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Copper, Cu	LB091082	mg/kg	0.05	<0.05	2%	105%
Zinc, Zn	LB091082	mg/kg	0.05	<0.05	8%	111%
Manganese, Mn	LB091082	mg/kg	0.5	<0.5	1%	117%
Iron, Fe	LB091082	mg/kg	0.5	<0.5	0%	97%

Exchangeable Cations and Cation Exchange Capacity (CEC/ESP/SAR) Method: ME-(AU)-[ENV]AN122

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Exchangeable Sodium, Na	LB091147	mg/kg	2		2%	97%
Exchangeable Sodium, Na	LB091147	cmol (+)/kg	0.01	<0.01	2%	NA
Exchangeable Potassium, K	LB091147	mg/kg	2		2%	96%
Exchangeable Potassium, K	LB091147	cmol (+)/kg	0.01	<0.01	2%	NA
Exchangeable Calcium, Ca	LB091147	cmol (+)/kg	0.01	<0.01	2%	NA
		mg/kg	2		2%	100%
Exchangeable Magnesium, Mg	LB091147	mg/kg	2		1%	99%
Exchangeable Magnesium, Mg	LB091147	cmol (+)/kg	0.02	<0.02	1%	NA
Cation Exchange Capacity	LB091147	cmol (+)/kg	0.02	<0.02	2%	NA

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Nitrate Nitrogen and Nitrite Nitrogen (NOx) by Auto Analyser in Soil **Method: ME-(AU)-[ENV]AN248**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Nitrate/Nitrite Nitrogen, NOx as N	LB091190	mg/kg	0.05	<0.05	1%	104%

Single Addition Net Acid Generation (NAG) **Method: ME-(AU)-[ENV]AN216**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
ECox (NAG Conductivity)	LB091406	µS/cm	1	40	0 - 14%	97%
pHox (NAG pH)	LB091406	No unit	-	5.4	2 - 3%	92%
NAG as kg H_2SO_4/tonne to pH 4.5	LB091406	kg H2SO4/T	0.5	<0.5	0%	110%
NAG as kg H_2SO_4/tonne to pH 7	LB091406	kg H2SO4/T	0.5	<0.5	0 - 2%	106%
NAG as kg CaCO3/tonne to pH 4.5	LB091406	kg CaCO3/T	0.5	<0.5	0%	110%
NAG as kg CaCO3/tonne to pH 7	LB091406	kg CaCO3/T	0.5	<0.5	0 - 2%	106%

Total Organic Carbon by Heanes Oxidation **Method: ME-(AU)-[ENV]AN273**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Total Organic Carbon	LB090902	%w/w	0.05	<0.05	0%	99%	98%
Organic Matter	LB090902	%w/w	0.1		0%		

METHOD	METHODOLOGY SUMMARY
AN002	The test is carried out by drying (at either 40°C or 105°C) a known mass of sample in a weighed evaporating basin. After fully dry the sample is re-weighed. Samples such as sludge and sediment having high percentages of moisture will take some time in a drying oven for complete removal of water.
AN002/AN320/AN321	Soil sample is extracted in deionised water (1:2 or 1:5) and metals analysed by ICP OES, method AN320/AN321, with results reported on the dried sample basis.
AN012/AN320	Dried prepared soil is digested by oxidation with nitric acid and bromine followed by analysis of the digest by ICP OES.
AN014	This method is for the determination of soluble sulfate (SO4-S) by extraction with hydrochloric acid. Sulphides should not react and would normally be expelled. Sulfur is determined by ICP.
AN015	Soil sample is extracted in an end over end roller in 0.5 N sodium bicarbonate at pH 8.5 with the supernatant liquor analysed for Phosphorous. Orthophosphate anion (PO43-) is reacted with ammonium molybdate and potassium antimony tartrate in sulfuric acid solution. The resulting phospho-molybdate complex is reduced, using ascorbic acid, to an intense blue coloured complex Molybdenum Blue. The absorbance of this complex is measured at 880 nm by Discrete Analyser, and compared with calibration standards to obtain the concentration of orthophosphate in the sample. Based on Rayment & Higginson 9B1.
AN025/AN320	A chelating agent is used to complex metal ions in solution. The extracted elements are determined byICP OES.
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode and is calibrated against 3 buffers purchased commercially. For soils, sediments and sludges, an extract with water (or 0.01M CaCl2) is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN103	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode (glass plus reference electrode) and is calibrated against 3 buffers purchased commercially. For soils, an extract with water is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract of as received sample with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Salinity can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. Reference APHA 2510 B.
AN122	Exchangeable Cations, CEC and ESP: Soil sample is extracted in 1M Ammonium Acetate at pH=7 (or 1M Ammonium Chloride at pH=7) with cations (Na, K, Ca & Mg) then determined by ICP OES/ICP MS and reported as Exchangeable Cations. For saline soils, these results can be corrected for water soluble cations and reported as Exchangeable cations in meq/100g or soil can be pre-treated (aqueous ethanol/aqueous glycerol) prior to extraction. Cation Exchange Capacity (CEC) is the sum of the exchangeable cations in meq/100g.

METHOD	METHODOLOGY SUMMARY
AN122	The Exchangeable Sodium Percentage (ESP) is calculated as the exchangeable sodium divided by the CEC (all in meq/100g) times 100. ESP can be used to categorise the sodicity of the soil as below: ESP < 6% non-sodic ESP 6-15% sodic ESP >15% strongly sodic Method is referenced to Rayment and Lyons, 2011, sections 15D3 and 15N1.-
AN212	Samples are initially evaluated to determine the strength of reagents needed using a `'fizz' test. Samples are then subjected to an excess of hydrochloric acid followed by alkaline back titration to pH 7. Results are expressed in kg H2SO4/tonne or Kg CaCO3/tonne after correction for moisture content if applicable.
AN215	This is purely a calculation based on results obtained from Total Sulphur, Sulfate Method, and Acid Neutralisation Capacity Method (ME-AU-ENV-AN212). The negative value included as the LOR allows negative NAPP data to be reported in the LIMS, it is not the numerical LOR which would theoretically be 1kg H2SO4/tonne. The range of results is theoretically -980 to 1640kg H2SO4/Tonne.
AN216	Pulverised sub-sample of a waste rock or an as received sample of filter cake, soil or sludge is subjected to an oxidising digest with 15% hydrogen peroxide adjusted to pH 4.5. The pH and EC of the NAG suspension is recorded at various stages in the digest. The acid produced (if any) is titrated using standardised NaOH to pH 7.0. NAG results are reported to 0.5 kg H2SO4/tonne.
AN248	Nitrate / Nitrite in extract by Auto Analyser: In an acidic medium, nitrate is reduced quantitatively to nitrite by cadmium metal. This nitrite plus any original nitrite is determined as an intense red-pink azo dye at 540 nm following diazotisation with sulphanilamide and subsequent coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. Reference APHA 4500-NO3- F.
AN273	The sample is digested in Dichromate / Sulfuric Acid to oxidise the organic carbon. The determination is completed colourimetrically by Aquakem Discrete Analyser at 600 nm. Based on Rayment & Higginson 6B1.
AN274	Chloride by Aquakem DA following 1:5 or 1:2 DI water extraction: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Results reported on dry sample basis. Reference APHA 4500Cl-
AN277	Nitrite on the extract is determined as an intense red-pink azo dye at 540 nm following diazotisation with sulphanilamide and subsequent coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. The original nitrite is determined. Reference APHA 4500-NO2- B.
AN281	The sample is heated in the presence of Sulphuric acid, K2SO4 and CuSO4 for two and half hours using a temperature controlled digestion block. Amino Nitrogen of many organic materials is converted to ammonium ion. Free ammonia also is converted to ammonium. The digest is cooled and placed on the Aquakem 250 discrete analyser for Ammonia determination.
SOL061	Soil sample is extrcated 1:10 in 1MKCl with aluminium determined by ICP OES.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
		QFL	QC result is below the lower tolerance
**	Indicative data, theoretical holding time exceeded.	-	The sample was not analysed for this analyte
***	Indicates that both * and ** apply.	NVL	Not Validated

Unless it is reported that sampling has been performed by SGS, the samples have been analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC and MU criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here: www.sgs.com.au/en-gb/environment-health-and-safety.

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Our Ref: PSM2319-041L

20 November 2020

Senior Mine Geologist
Round Oak Minerals
Level 10/120 Edward Street,
Brisbane QLD 4000
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Attention: Sarah Traeger

Dear Sarah

RE: MINE CLOSURE GEOTECHNICAL STUDY, BARBARA COPPER PROJECT

1. Introduction

This report presents the geotechnical assessment undertaken by PSM to inform the mine closure requirements for the Barbara Copper Mine on behalf of Round Oak Minerals, as per the Queensland Government Progressive Rehabilitation and Closure Plan Guideline (ESR/2019/4964)[1] . The assessment has been undertaken at the request of Peter Brown via email to Mr Greg Kennedy of PSM[2], with the agreed work package detailed in PSM2319-040L[3].

To complete the assessment, PSM have utilised the extensive experience gained by providing geotechnical advice for the Barbara Copper Mine since 2013 including initial Feasibility Design Studies through to the current operational geotechnical support since mining began in 2019. This report documents the background information, geotechnical model, adopted criteria and stability analyses used for the geotechnical assessment to assess requirements for mine closure.

2. Overview of Mining Footprint

The existing development comprises two open pits with ore mined using a conventional truck and shovel operation with out of pit dumps for stockpiling of overburden. Mining in the North pit has ceased at approximately 295 mRL, with pit access currently bunded off.

Open pit mining continues in the South pit and, at the time of reporting, is at approximately 240 mRL. The final pit depth is planned to 205 mRL. Figure 1 presents the location of both pits and shows the existing shape of the North pit and the latest final design shape of the South pit.

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[1] Progressive Rehabilitation and Closure Plan Guideline (ESR/2019/4964), Queensland Government Department of Environment and Science

[2] RE: Address, email from Peter Brown of Round Oak to Greg Kennedy of PSM, received 18 September 2020

[3] PSM2319-040L Proposal for Closure Study, Barbara Copper Mine, issued 14 October 2020

3. Scope of Work

The scope of works for the Barbara closure study comprises:

1. Assessment of pit wall geotechnical stability, considering the effects of long-term erosion and weathering of the pit wall and the effects of significant hydrological events.
2. Proposed final slope angles of high wall, low wall and end walls of each final void, and used to determine the location of the abandonment bund beyond the final extent of potential failure.
3. Any mechanisms for achieving geotechnical stability to be detailed, and supervision, verification and auditing of engineering works carried out to achieve the post-closure void landform, to ensure construction is consistent with the geotechnical design.
4. Consideration of stability under rehabilitation goal of voids in Schedule G1 of the Environmental Authority (EA) for the mine[4].

The agreed work package to address items 1 to 4 above has been detailed in PSM2319-040L[5] and has been summarised in Section 4.

4. Approach

The geotechnical report requirements defined within the Queensland Government Progressive Rehabilitation and Closure Plans (PRC) for the void closure plan are set out within Section 3.6.3 of that document and include the following comments related to the required geotechnical report:

> *"A geotechnical report should focus on how the void will achieve post-closure slopes that will exhibit stability characteristics consistent with the planning and design of the post closure void"*

The long-term stability of the open pit void is dependent on several factors, the most important of which are:

- The presence and orientation of major geological structures (i.e. faults and shears) within the pit slopes
- The strength of the rock mass within the pit slope
- Variation in the strength of the rock mass with time (i.e. from stress relief and ongoing weathering)
- The depth and characteristics of soil or completely weathered rock in the upper pit walls, and their susceptibility to erosion over time
- The geometry of the pit wall
- The influence of groundwater and rainfall on slope stability
- The influence of seismic events.

The primary objective of the mine closure assessment is to identify the stable long-term crest location and nominate an exclusion zone around the perimeter of the final pit crest based on the predicted long-term slope stability. This is then used to plan the location of an abandonment bund to restrict access and manage public safety. To achieve this, PSM have taken the following approach, which has been illustrated schematically in Inset 1:

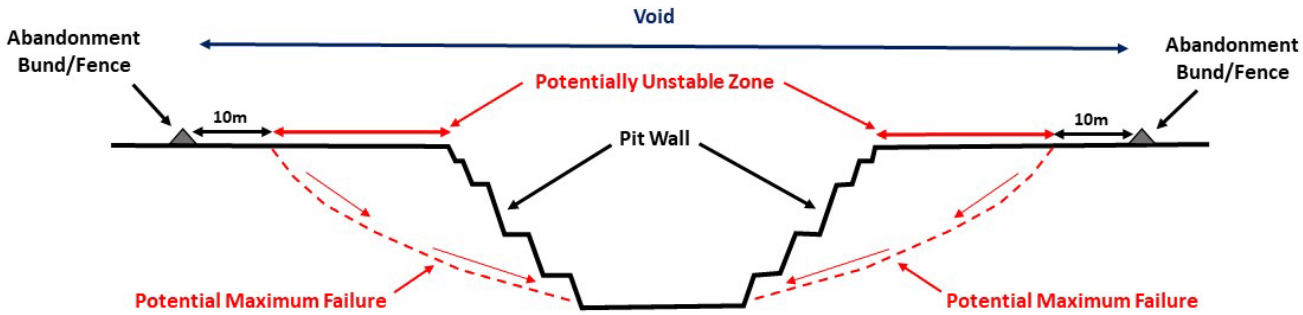
1. Identification of the long-term stable pit crest location by assessing the extent of the "potential maximum failure" using appropriate stability analyses methods, which in this case includes:
    a. Limit Equilibrium (LE) stability analyses, detailed in Section 7.1
    b. A geotechnical site inspection to identify potential structural failure mechanisms, detailed in Section 7.2

[4] Stable Rehabilitation Goal of Voids, Schedule G1 of Environmental Authority "*EPML02840015*"

[5] PSM2319-040L Proposal for Closure Study, Barbara Copper Mine, issued 14 October 2020

c. Use of approach as presented in the Western Australian guidelines for identification of a potentially unstable pit edge zone (DIR, 1997) – detailed in Section 7.3 but revised to take account of the long term landforms evident in weathered materials.

2. The "potential maximum failure" identifies the long-term post closure "potentially unstable zone" surrounding the void.
3. To ensure the long-term potentially unstable zone poses no risk to public safety, the zone is defined as an exclusion zone with a post closure abandonment bund/fence installed to restrict public access. An additional 10 m offset from the "potential maximum failure" boundary has been included for conservatism and that would allow maintenance of the bund if so required.



Inset 1: Schematic illustration highlighting long-term potential maximum failure, potentially unstable zone, abandonment bund and void.

The stable "void" is defined as the area within the abandonment bund/fence as illustrated in Inset 1. Long-term instability is not anticipated to impact areas outside of the recommended abandonment bund/fence location.

5. Data Sources

Existing data from previous work undertaken by PSM at the Barbara Operation was utilised for this study, and principally comprised data from the:

- Feasibility study undertaken for the open pits (PSM, 2014), and
- Quarterly geotechnical site inspections of the open pits (PSM, 2019a; 2019b; 2020a; 2020b).

Groundwater data was available from the preliminary groundwater assessment for the Barbara Operation conducted by Rob Lait and Associates (Pty) Ltd in 2013, which formed part of the feasibility study. Additionally, a hydrologic assessment of pit closure water levels is being undertaken by ATC Williams. A summary of their findings was provided to PSM via email[6].

The following three-dimensional (3D) surfaces (wireframes) were supplied by Round Oak Minerals (for this study as well as previous studies) and which included:

- Interpreted geological model (latest received - 03/08/2020)
- Digital elevation models (DEMs) of the North and South pit (22/10/2019), and the North pit only (18/10/2020), and
- South Pit Stage 2 Design V4B (20/08/2020).

[6] Email titled "*FW: Barbara Closure Water Balance for Voids*" from Gemma Brown, Round Oak Minerals to Greg Kennedy, Pells Sullivan Meynink (PSM), 23 October 2020.

6. Geotechnical Model

6.1 Rock Mass Units

The rock mass units (RMU's) are based on those adopted for the design of the open pits, with several RMU's having been defined for previous pit slope designs at the Barbara Operation (PSM, 2014). However, these can be simplified to three (3) RMU's as follows:

- Weathered rock (rhyodacite, amphibolite)
- Fresh rock (rhyodacite, amphibolite), and
- Mineralized zone (dolerite, schist, breccia), including the Barbara Fault Zone (BFZ).

Table 1 presents a simplified summary of the RMU's characteristics.

Table 1 – Summary of Typical Rock Mass Unit Characteristics

RMU	Field Strength	Weathering	RQD (%)	Defect Type	Defect Character
Weathered rock	R0 to R4/R5	Extremely to slightly weathered	10 - 100	Jointing	Closely to widely spaced, planar to irregular, smooth to rough, iron stained to chlorite or clay infill
Fresh rock	R5	Fresh	90 - 100	Jointing	Widely spaced, planar to irregular, smooth to rough, clean
Mineralised zone (BFZ)	R4 to R5	Fresh	90 - 100	Foliation and jointing	Widely spaced, planar to irregular, smooth to rough, clean or with chlorite veneer

The material properties adopted for the stability analyses for the rock mass units detailed in Table 1 are summarised in Table 2. The adopted material properties were based on those used by PSM in previous stability analyses for pit design purposes (e.g. PSM, 2014). However, lower bound Hoek-Brown parameter values were assigned to address long-term stability.

Groundwater levels for the analyses assumed that groundwater would be present at the pre-mining average level of 12 m below the surface and with hydrostatic conditions below the phreatic surface adopted in the analyses. Additionally, the pit closure water levels provided by ATC Williams were adopted for the study.

Table 2 - Adopted Rock Mass Shear Strengths

Rock Mass Unit	Hoek-Brown Parameters			
	UCS (MPa)	GSI	*mi*	*D*
Weathered Rock	25	35	25	0
Fresh Rock	80	55	25	0
Mineralised Zone (BFZ)	25	30	12	0

6.3 Structure

The structural model is based largely on the mapping completed by PSM and Round Oak within the South pit during the Quarterly Geotechnical Inspections. The existing structural database comprises data from field mapping undertaken by Round Oak, as well as field mapping and photogrammetric mapping undertaken by PSM.

The structural data shows:

- Major structures in the rock mass comprise foliation and faults / shears:
  - Foliation forms a predominant defect within the schist rock mass, comprising two splays of the BFZ, and is also present in localised zones of weakly foliated felsic volcanics adjacent to the schist
  - Sporadic faults and shears may also be present within the rock mass.
- Minor structures in the rock mass that are less continuous with jointing the main defect type.

Five (5) domains have been mapped over the south pit (PSM, 2020a; 2020b). The following summarises the structural model from the South pit:

- Domain 1 and Domain 2 (east wall of the South pit):
  - Most joint defects dip greater than 60° towards the west. Joints mapped in the north-east part of the East wall, Domain 2, are slightly rotated likely due to the proximity to the BFZ
  - Faults and shears are present in Domain 1 and Domain 2. These are generally moderately to steeply dipping (greater than 55°) but some moderately to shallow dipping faults and shears are also present.
- Domain 3, Domain 4, and Domain 5 (west wall of the South pit):
  - Most defects dip greater than 75° towards the east, except for a cluster of joints exposed in Domain 4 that dip between 30° and 50° towards north-northeast (NNE)
  - The shallow defect set dipping towards the NNE is evident within Domain 4, and typically have a persistence of less than 5 m.

Although the structural character is similar for the North pit, the following has been additionally noted (PSM, 2019a; 2019b):

- Joint sets form cubic blocks, resulting in a blocky to very blocky character
- Poorer structural conditions are associated with the BFZ, with dilation and poorer rock mass conditions occurring proximal to this zone.

6.4 Hydrogeology

Groundwater at the project site is primarily associated with the ore body. Groundwater exists in fractured rock aquifer systems in the rhyodacite, schist and amphibolite units. Monitoring in exploration holes in October 2013 (pre-mining) suggested a median depth to groundwater of approximately 12 m below the ground surface (Rob Lait & Associates, 2013).

It was noted at the pre-feasibility stage that the potentiometric surface is highly undulating suggesting there is variation in local permeability and compartmentalised by faults and shears. This compartmentalisation and variability in the level of saturation was observed during mining, whereby groundwater levels were noted as not being uniform across the pit floor (PSM, 2019a).

Pit lake water levels post-closure have been estimated by ATC Williams at approximately 303 mRL in the North pit and 290 mRL in the South pit.

7. Stable Long-Term Pit Slope Stability Assessment

7.1 Limit Equilibrium (LE) Analyses

Limit Equilibrium (LE) stability analyses have been completed using the Rocscience software program *Slide2* on representative cross sections through the North and South pits in the most geotechnically adverse location. These locations typically comprise the highest/steepest part of pit wall and where the lowest Factor of Safety (FoS) would be expected. The analyses provide the lowest FoS of the pit wall and the path of the surface for which the FoS is applicable (i.e. if failure where to occur it would be anticipated to occur along the path). The software also allows the user to query where alternative paths may form and for either a given FoS or range of FoS's. Based on experience the FoS increases with distance from the pit crest.

The analyses have been used to identify the location where a FoS of 1.5 is achieved beyond the pit crest and which defines the location of the stable long-term pit crest. A FoS of 1.5 is recommended as an appropriate value for defining long term stability as referenced within the Guidelines for Open Pit Slope Design[7].

The analyses have been completed using both non-circular and circular failure mechanisms with the rock mass strength parameters detailed in Section 6.1 and using the GLE-Morgenstern Price method.

Stability analyses were completed for Section A for the North Pit, and Section B and Section C for the South pit, with the respective locations shown in Figure 1. The results of the analyses are presented in Appendix A, with global Factor of Safety (FoS) summarised in Table 3.

Table 3 – Summary of the Global Factor of Safety (FoS) Obtained Per Failure Mechanism for Each Section

Section	FoS - Circular	FoS - Non-Circular
Section A	2.20	2.31
Section B	4.28	4.31
Section C	3.89	4.13

The results in Table 3 imply that a low risk of global instability impacting outside the final pit crests.

The results indicate that the current pit crests have a FoS of greater than 1.5 when considering only rock mass failure. As the majority of the rock mass within the Barbara open pits is high to very strength rock, global pit stability is controlled by geological structure (i.e. failure will occur along adverse defects), which has been assessed in Section 7.2.

7.2 Structural Failure and Current Pit Slope Performance

Structurally controlled failure mechanisms are the critical control for global pit slope stability for the majority of pit walls within the North and South pits.

Importantly, no global scale kinematically unstable structures or potential intersections of structures have been mapped or identified during mining. No signs of potential global instability, such as tension cracking beyond the pit crest, have been observed.

A prism pit slope monitoring system has been utilised since June 2020 with prisms installed along berms between 340 mRL and 280 mRL, with manual prism readings taken at regular intervals. To date, these prisms have shown no signs of pit slope movements which would indicate potential global pit slope failure.

Bench scale instability has been observed during mining with the following smaller-scale failures observed within the South pit:

[7] APA (6th ed.) Read, J., Stacey, P., & CSIRO (Australia). (2009). Guidelines for open pit slope design. Collingwood, Vic: CSIRO Publishing.

- North and East wall – bench-scale shallow wedge failures in the northeast, and planar failures in the east wall. Below the access ramp at 290 mRL and above the current mining floor at 240 mRL in the north wall, a south west dipping fault on the eastern margin of the BFZ has caused a shallow, multiple bench scale wedge failure. This structure has been mined out above 290 mRL and therefore does not pose risk of global pit slope instability beyond the current pit crest
- South wall – half-bench to bench-scale planar and wedge failures and zones of ravelling within the poorer rock mass associated with the Western Fault and Barbara Fault Zone
- West wall – bench-scale steep planar and one-sided wedge failures in the north-western area.

None of the failure mechanisms related to bench scale instability detailed above are expected to impact global pit slope stability beyond the current pit crest.

Unravelling of the very blocky rock mass proximal to the Barbara Fault Zone and progressive erosion of weak and weathered slope material may also occur due to water flow over time and has therefore been assessed using the approach as set out in WA guidelines detailed in Section 7.3 below.

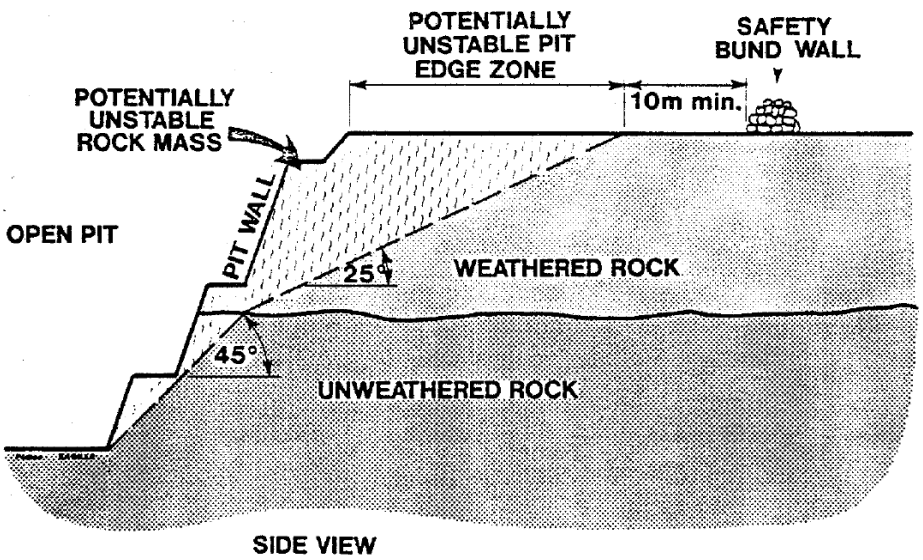
7.3 WA Guidelines - Assessment of Maximum Area of Potentially Unstable Rock Mass

The Western Australian guidelines (DIR, 1997) provide a methodology for assessing the long-term slope stability following mine closure and identify an exclusion zone for the placement of an abandonment bund around the perimeter of the pits. This guideline has been developed primarily for pit slopes within deeply weathered profiles (primarily saprolite deposits) and is therefore considered to be conservative for the Barbara deposit.

The WA guidelines recommend the identification of a potentially unstable pit edge zone, with the abandonment bund location thereafter nominated 10 m (at minimum) outside of this zone to restrict access. The overall angle defining the maximum potentially unstable rock mass, is primarily dependant on whether the pit wall consist of weathered rock or unweathered (i.e. fresh) rock. The maximum potentially unstable pit edge zone for failure through each class of rock is defined by two separate design angles as follows:

- 25° for weathered rock, and
- 45° for unweathered (or fresh) rock.

Inset 2: presents a schematic section from DIR (1997) showing the placement of an abandonment bund 10 m beyond the potentially unstable pit edge zone.



Inset 2: Schematic cross-section presenting the recommended Western Australia guidelines for the placement of abandonment bunds from DIR (1997).

As the WA guidelines have been developed primarily from case studies of mine sites within saprolite, the recommended design angles in weathered and fresh rock may therefore be less appropriate for the rock mass at the Barbara as the rock mass is not significantly decomposed and has not undergone considerable weathering. As such, whilst the approach provided in Inset 2 was utilised, the adopted design angles for the bund location assessment were revised as follows:

- 25° in the Barbara Fault Zone – based on pit slope performance and observations within and proximal to the BFZ (i.e. ravelling)
- 30° in weathered rock – based on measured in-situ slope morphology angles from topographic features adjacent to the pits, Inset 3:
- 45° in unweathered (fresh) rock – unchanged from the Western Australian guidelines.

Inset 3: *In-situ* slope angles in weathered rock mass proximal to the North pit.

7.4 North Pit

The assessed potentially unstable pit edge zone for Section A is shown in Figure 2 and is located within 26 m behind the crest of the pit wall at this location. The minimum location of the abandonment bund at this location should therefore be 36 m behind the pit crest.

The assessed minimum location of the abandonment bund around the entire perimeter of the North pit is shown in Figure 3. The bund location typically varies from 15 m to 20 m around the perimeter, except in the south-east (Section A), where it is 36 m from the crest , due to a deeper weathering profile exposed in the pit walls.

The bund location behind the north-east pit crest traverses a diversion drain and the following options are recommended for the construction of the bund in this area:

- Follow the assessed bund location through the diversion drain and over the hill, but with the bund comprising a fence or highly permeable rock fill when located within the diversion drain. This will ensure that drainage can occur through the bund, whilst restricting access
- Alternatively, a waste rock buttress can be dumped below the regulated structure (on the access ramp, up to the nominal height of the regulated structure). This would ensure that the location of the required abandonment bund would coincide with the position of the regulated structure, and the existing regulated structure can therefore act as the abandonment bund.

7.5 South Pit

The assessed potentially unstable pit edge zone for Section B and Section C is shown in Figure 4 and Figure 5, respectively. The assessed potentially unstable pit edge zone is located within 4 m and 22 m behind the crest of the pit wall at these respective locations. The minimum location of the abandonment bund at these locations should therefore be 14 m and 32 m behind the pit crest, respectively.

The assessed minimum location of the abandonment bund around the entire perimeter of the South Pit is shown in Figure 6 and varies between 14 m to 32 m around the perimeter. The localised larger distances in the eastern and northern wall are due to a deeper weathering profile and presence of the Barbara Fault Zone, which are exposed in the pit walls at these locations.

7.6 Bund Location

For completeness the bund location for both pits was provided to Round Oak Minerals in electronic format, email of 20 November as a dxf file. Appendix B provides a figure of the dxf for completeness.

7.7 Bundwall Construction

The abandonment bund should be constructed as follows (DIR, 1997):

- Minimum dimensions of 2 m height and 5 m base width
- Where possible, from unweathered, freely draining, end dumped rockfill.

Should weathered rock only be available for the construction of the abandonment bund, the least weathered or hardest material should be used.

Suitable signs, clearly stating the risk to public safety and prohibiting public access, should be erected at appropriate locations around the safety bund wall. Shrub and/or tree planting at the outside edge of the bund wall should be implemented where practicable, to lessen the visual impact of the wall.

Where possible, it is recommended to utilise existing bunds and partially disturbed ground so long as the recommended minimum bund location is achieved.

8. Closure

We trust this report meets your immediate requirements. Please contact the undersigned if you have any queries or wish to discuss or clarify any aspect of the report.

For and on behalf of
PELLS SULLIVAN MEYNINK

GREG KENNEDY
ASSOCIATE

ALEX DURAN
PRINCIPAL

Encl.	Figures	1 to 6
	Appendix A	Limit Equilibrium Stability Analyses
	Appendix B	Abandonment Bund Location (provided electronically in dxf format)

References

1. [DIR] Department of Industry and Resources (1997). *Safety Bund Walls Around Abandoned Open Pit Mines*, Government of Western Australia, Department of Industry and Resources, Perth.
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8. Read, J. and Stacey, P. (2009). *Guidelines for Open Pit Slope Design*, CSIRO Publishing, Victoria, Australia.
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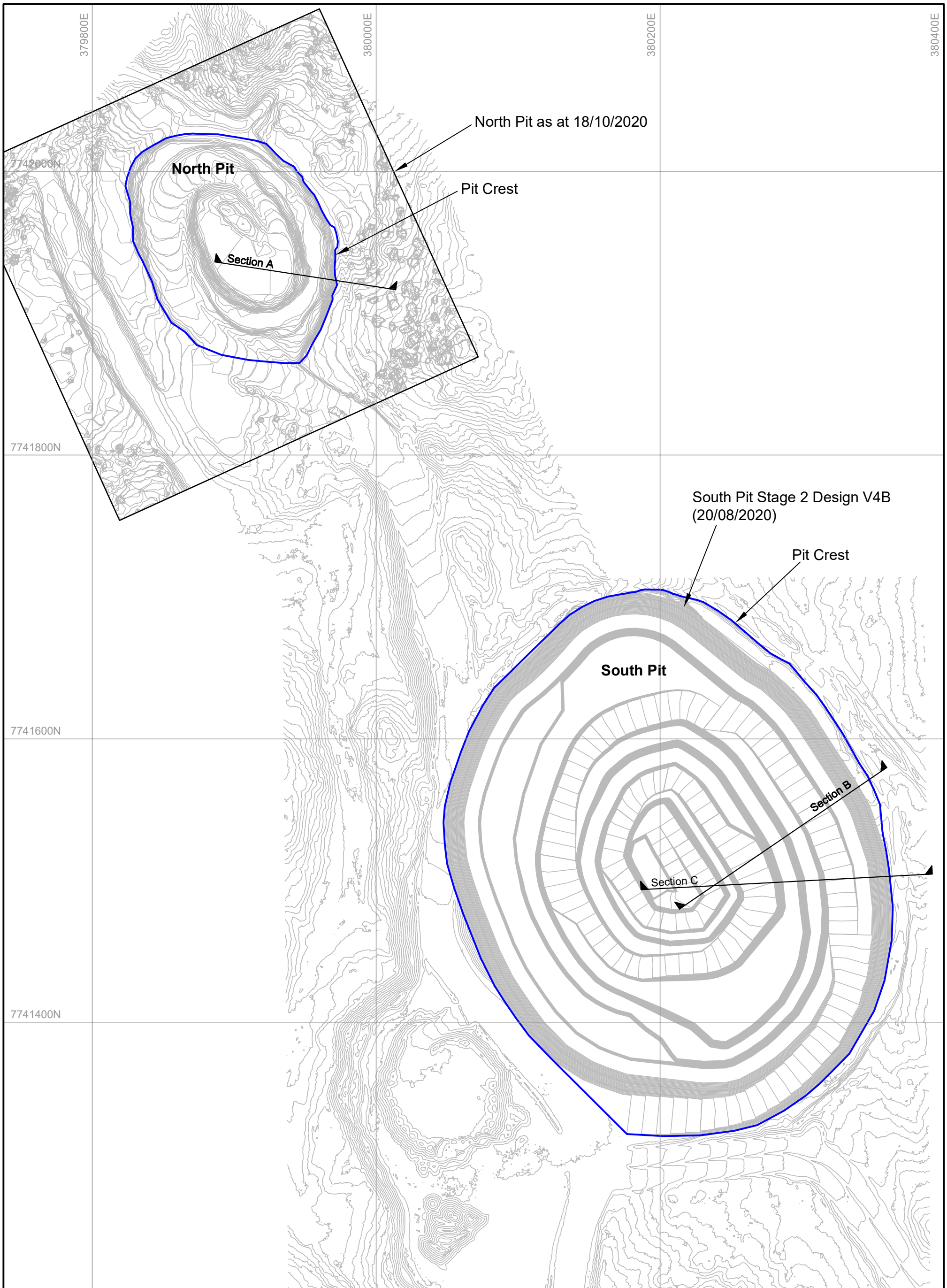
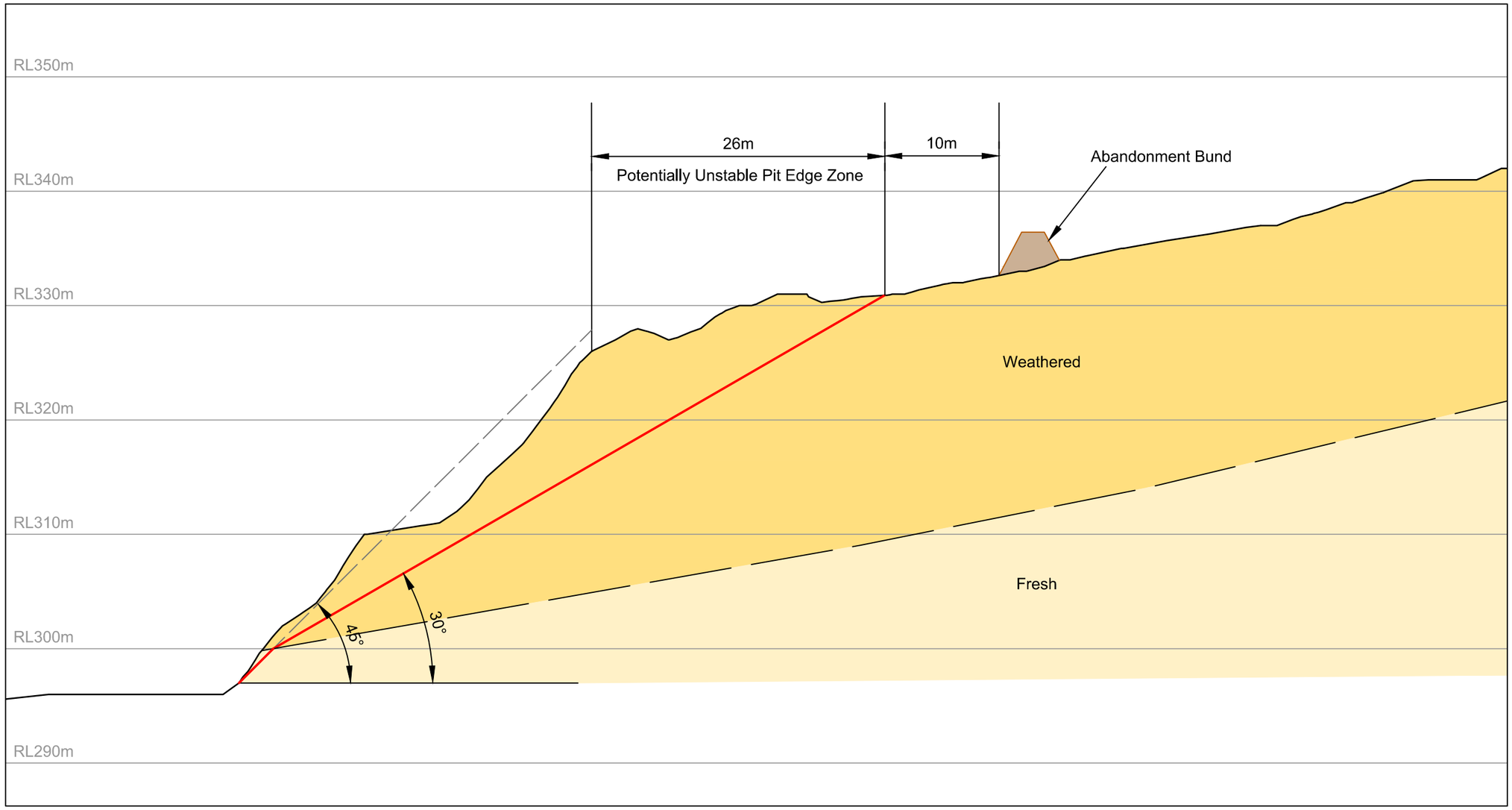


0 50 100
Scale (m)

Round Oak Minerals
Barbara Copper Project
Mine Closure Geotechnical Study

LOCATION PLAN

PSM2319-041L | Figure 1



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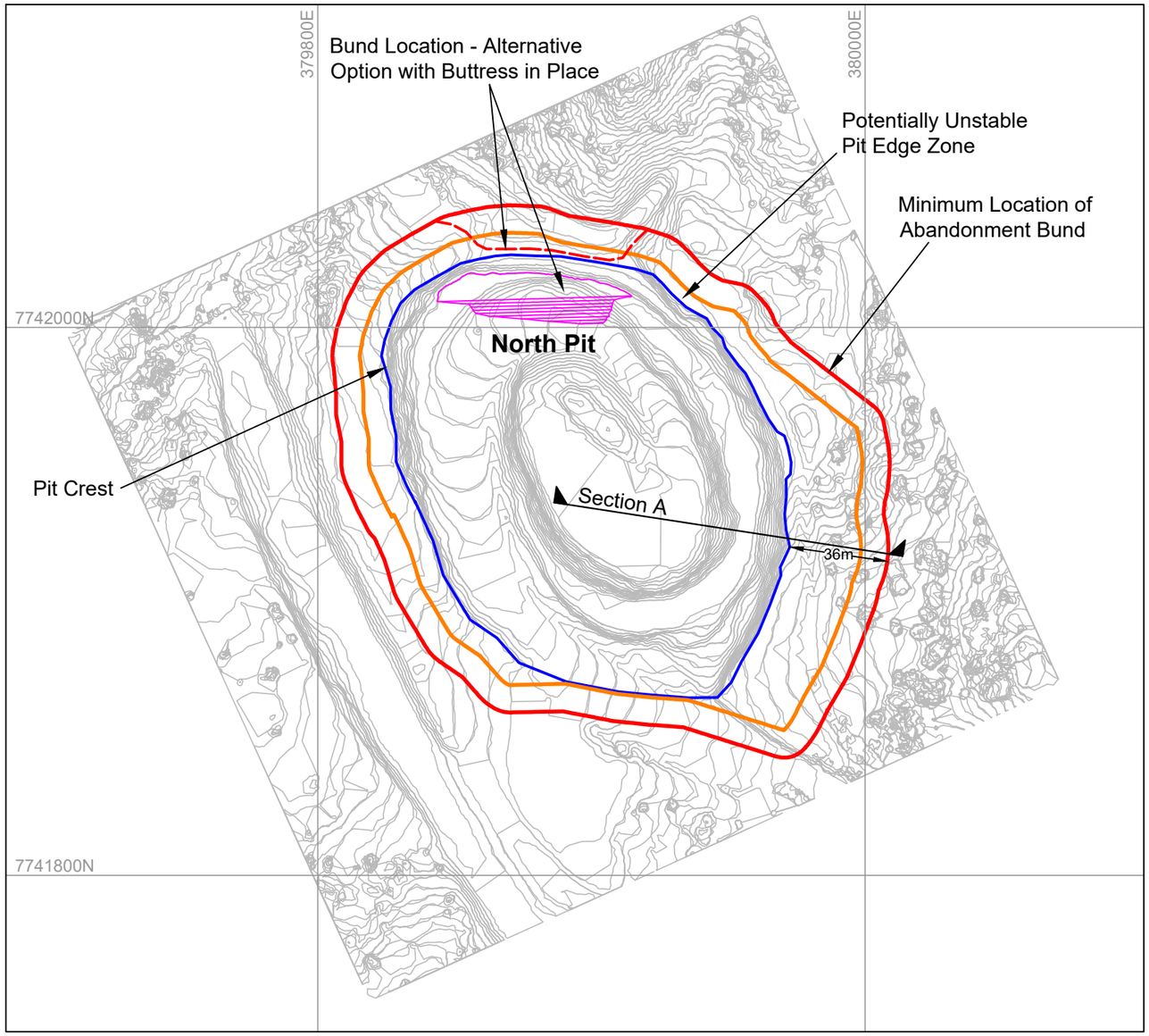
Scale (m)

Round Oak Minerals
Barbara Copper Project
Mine Closure Geotechnical Study

SECTION A - NORTH PIT

PSM2319-041L | Figure 2



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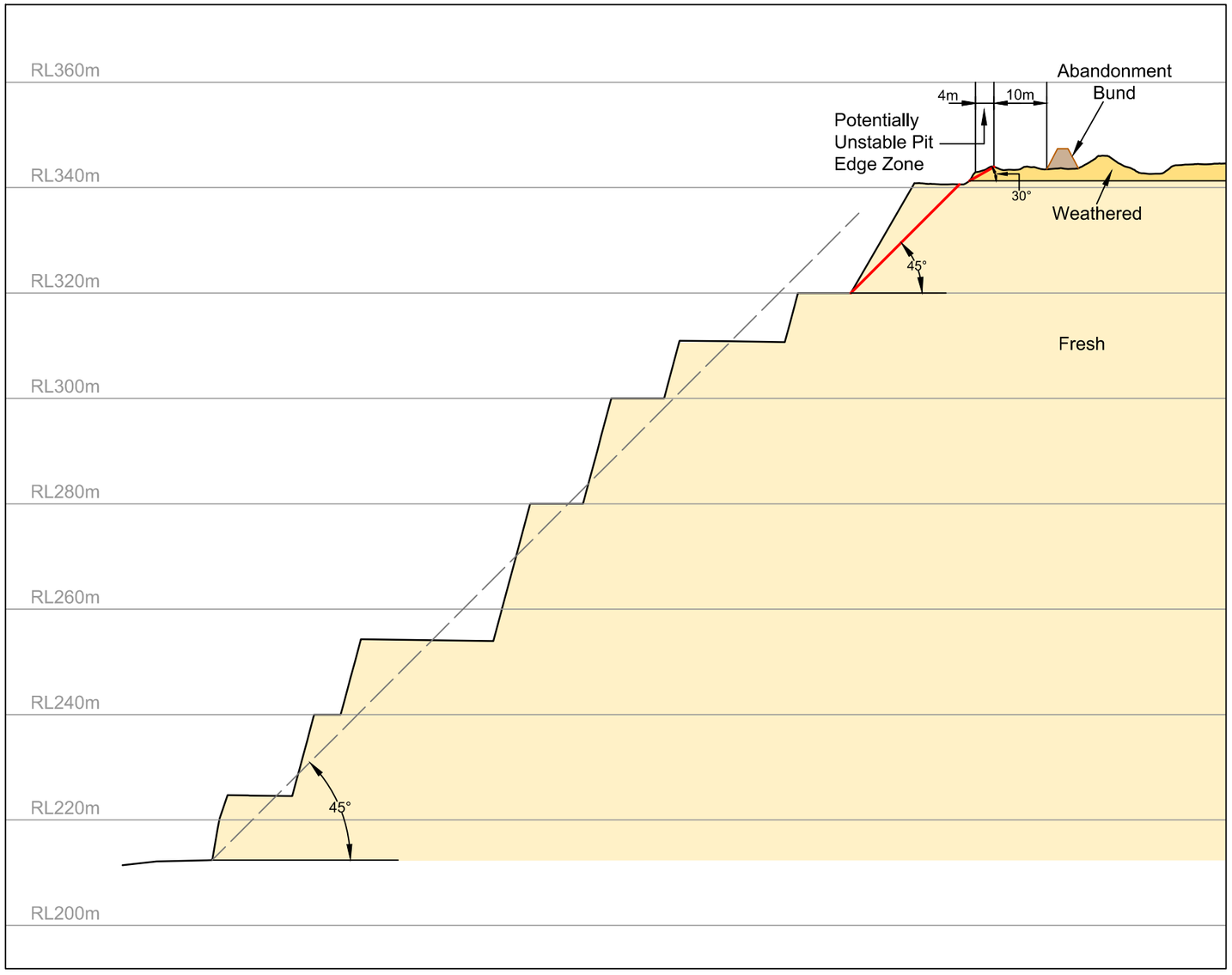
Scale (m)

Round Oak Minerals
Barbara Copper Project
Mine Closure Geotechnical Study

NORTH PIT BUND LOCATION

PSM2319-041L	Figure 3



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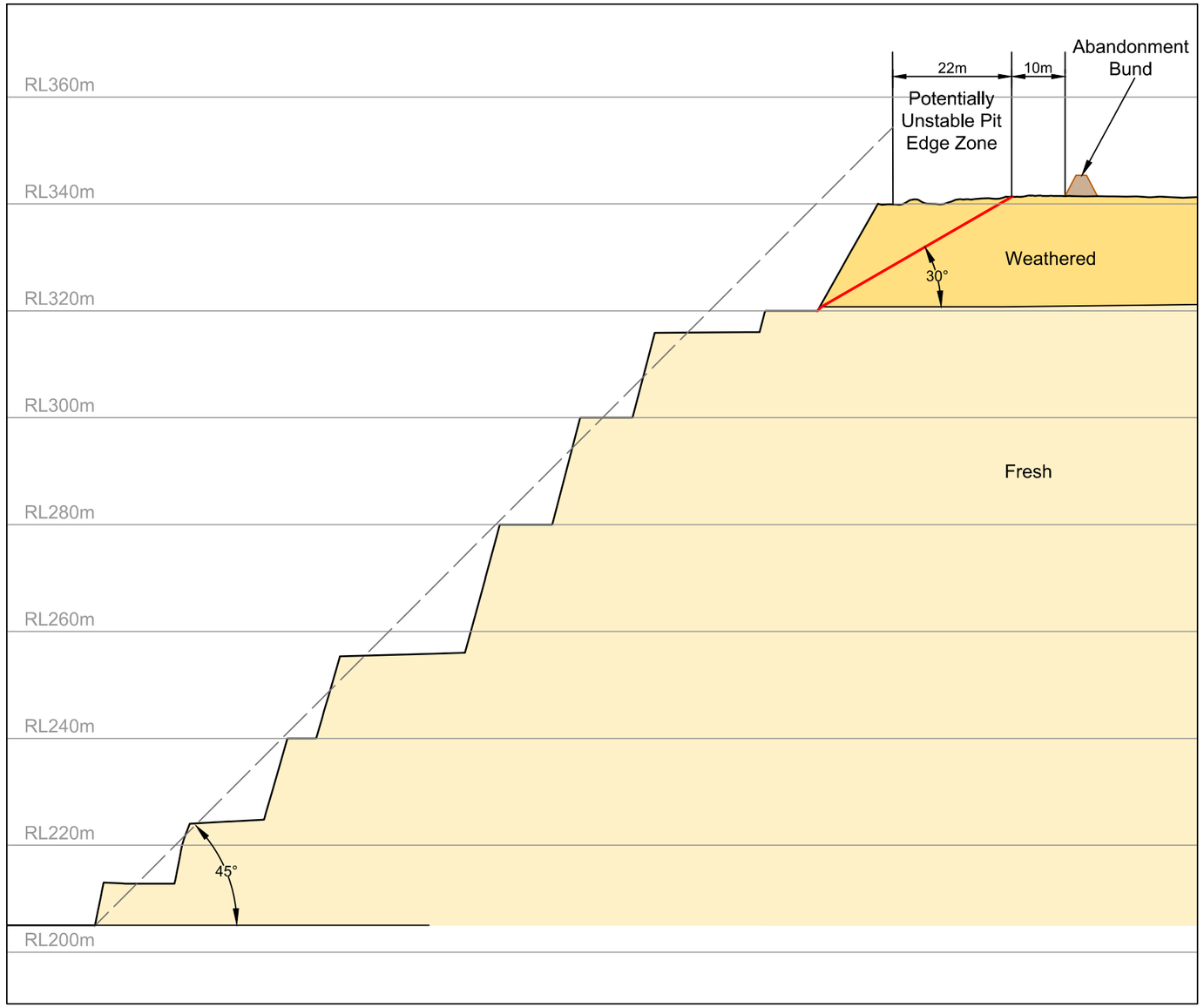
Scale(m)

Round Oak Minerals
Barbara Copper Project
Mine Closure Geotechnical Study

SECTION B - SOUTH PIT

PSM2319-041L | Figure 4



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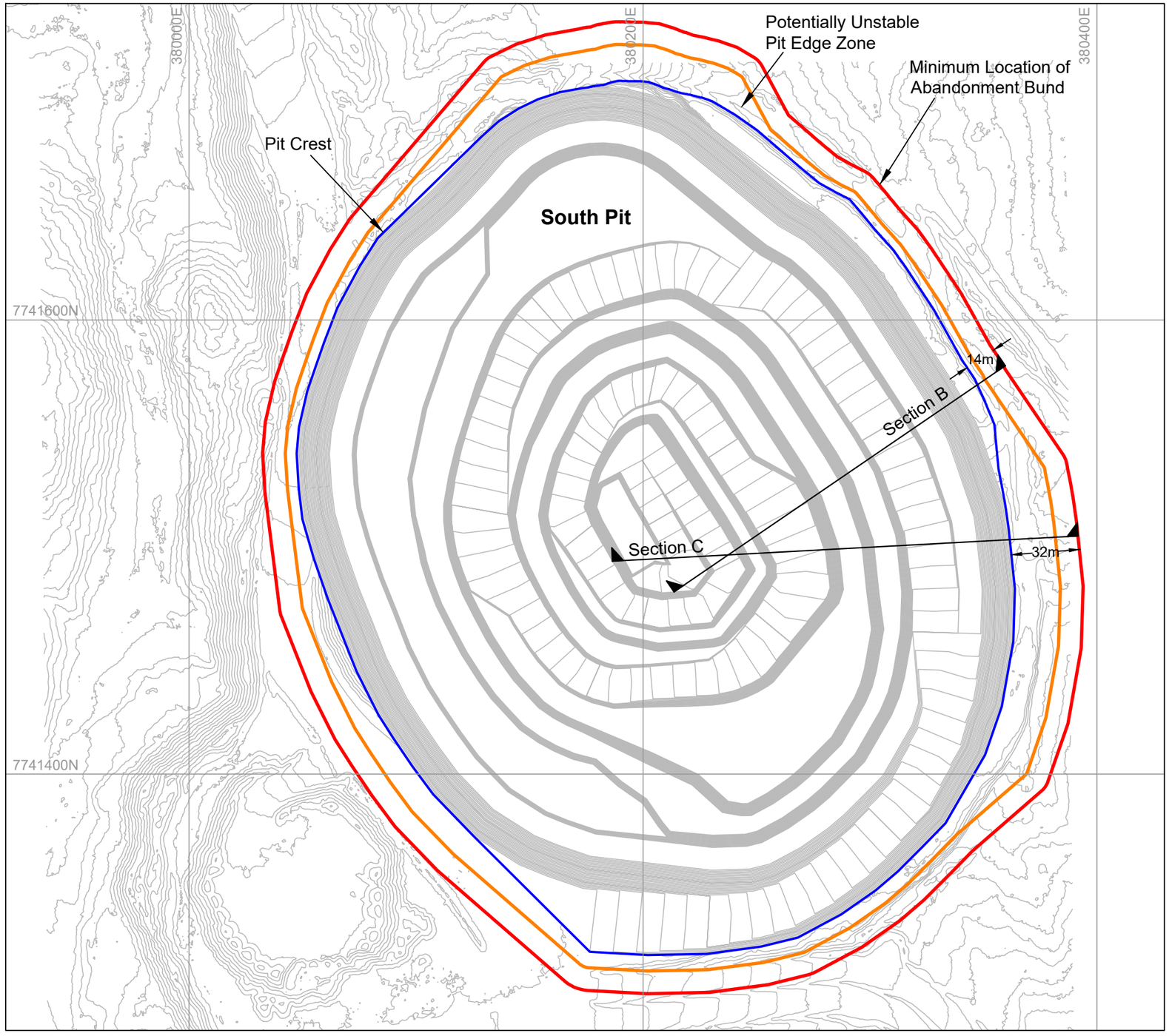
Scale(m)

Round Oak Minerals
Barbara Copper Project
Mine Closure Geotechnical Study

SECTION C - SOUTH PIT

PSM2319-041L | Figure 5



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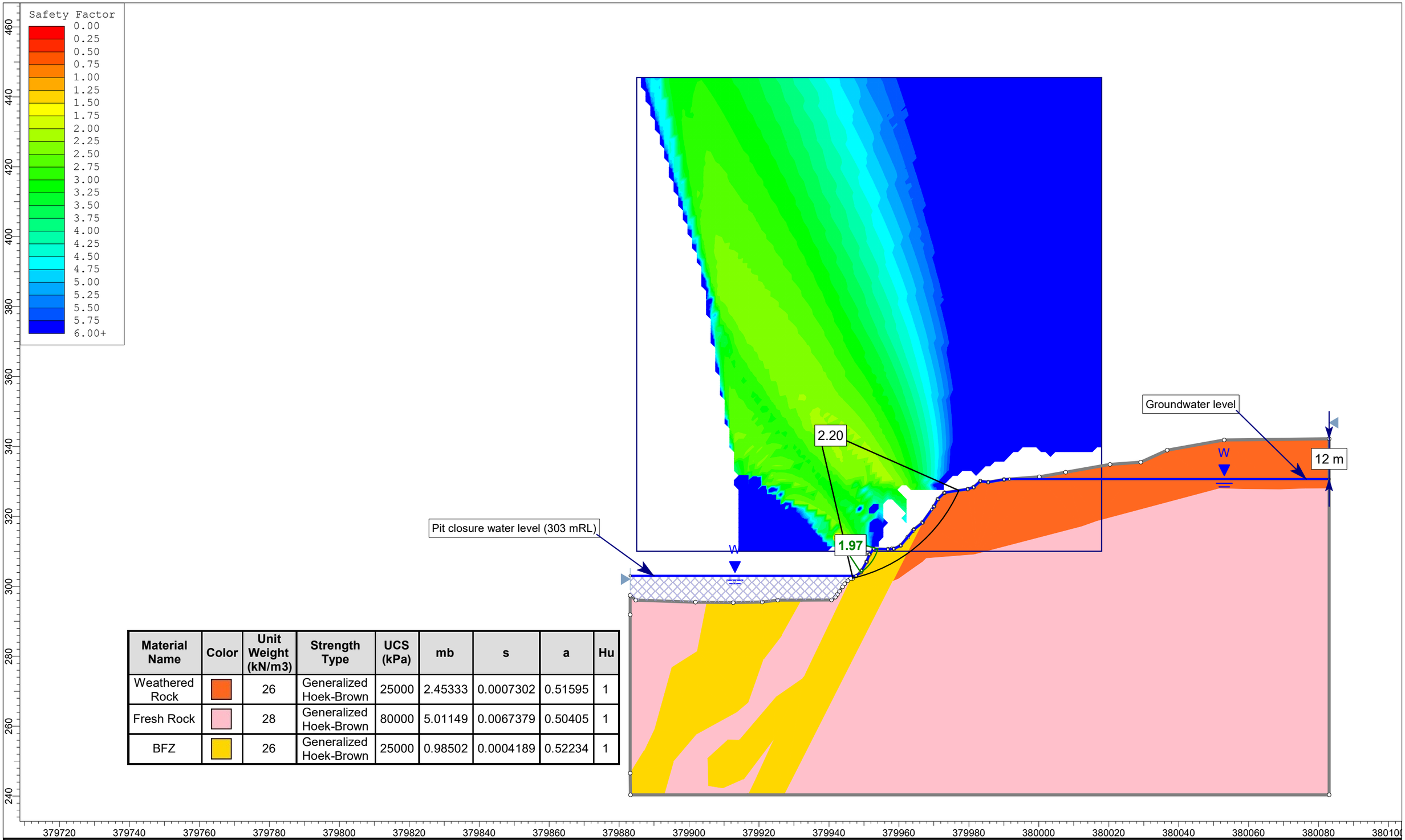
Scale (m)

Round Oak Minerals
Barbara Copper Project
Mine Closure Geotechnical Study

SOUTH PIT BUND LOCATION

PSM2319-041L | Figure 6

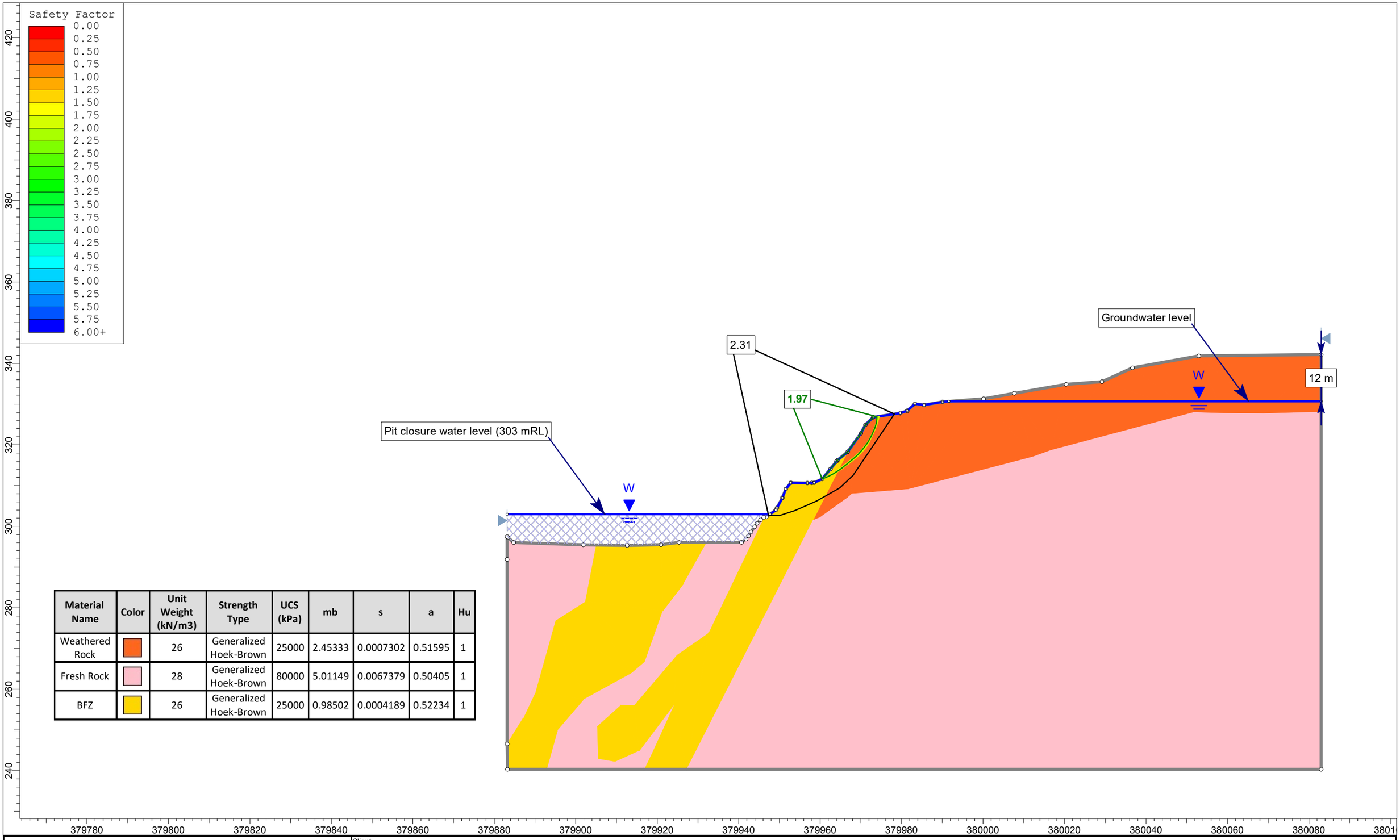
Appendix A
Limit Equilibrium Stability Analyses



Material Name	Color	Unit Weight (kN/m3)	Strength Type	UCS (kPa)	mb	s	a	Hu
Weathered Rock		26	Generalized Hoek-Brown	25000	2.45333	0.0007302	0.51595	1
Fresh Rock		28	Generalized Hoek-Brown	80000	5.01149	0.0067379	0.50405	1
BFZ		26	Generalized Hoek-Brown	25000	0.98502	0.0004189	0.52234	1

SLIDEINTERPRET 9.010

Client:	Round Oak Minerals				
Project:	Barbara Copper - Closure Study				
Location:	Section A (North Pit, SE Wall)				
Analysis description:	Static Limit Equilibrium Method (LEM) Analysis				
Job No: PSM2319	By: B. Jones	Date: 2/11/2020	Scale: 1:1000	Run ID: Master Scenario	



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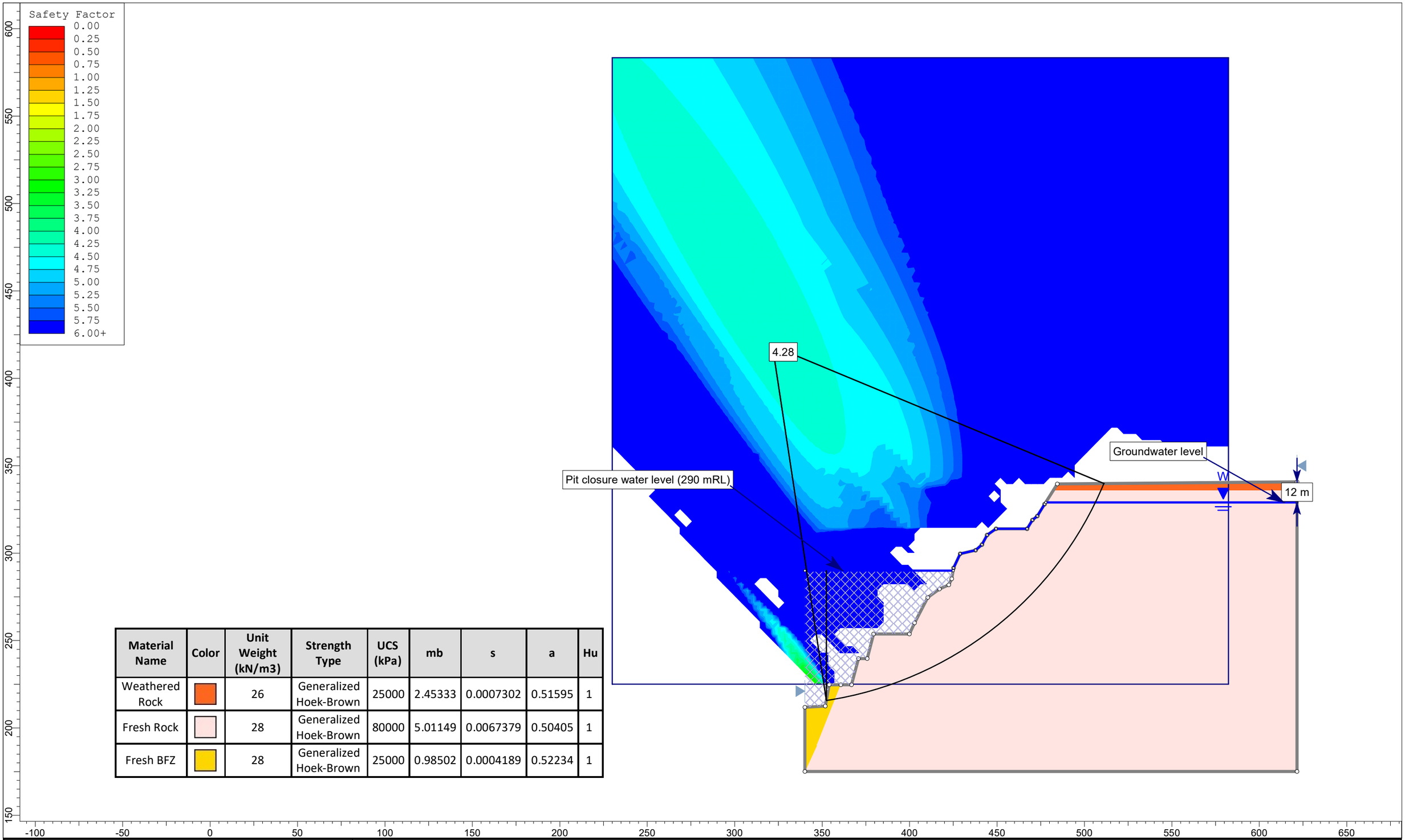
Fresh Rock		28	Generalized Hoek-Brown	80000	5.01149	0.0067379	0.50405	1
BFZ		26	Generalized Hoek-Brown	25000	0.98502	0.0004189	0.52234	1

SLIDEINTERPRET 9.010

Client:	Round Oak Minerals				
Project:	Barbara Copper - Closure Study				
Location:	Section A (North Pit, SE Wall)				
Analysis description:	Static Limit Equilibrium Method (LEM) Analysis				
Job No: PSM2319	By: B. Jones	Date: 18/11/2020	Scale: 1:856	Run ID: Master Scenario	



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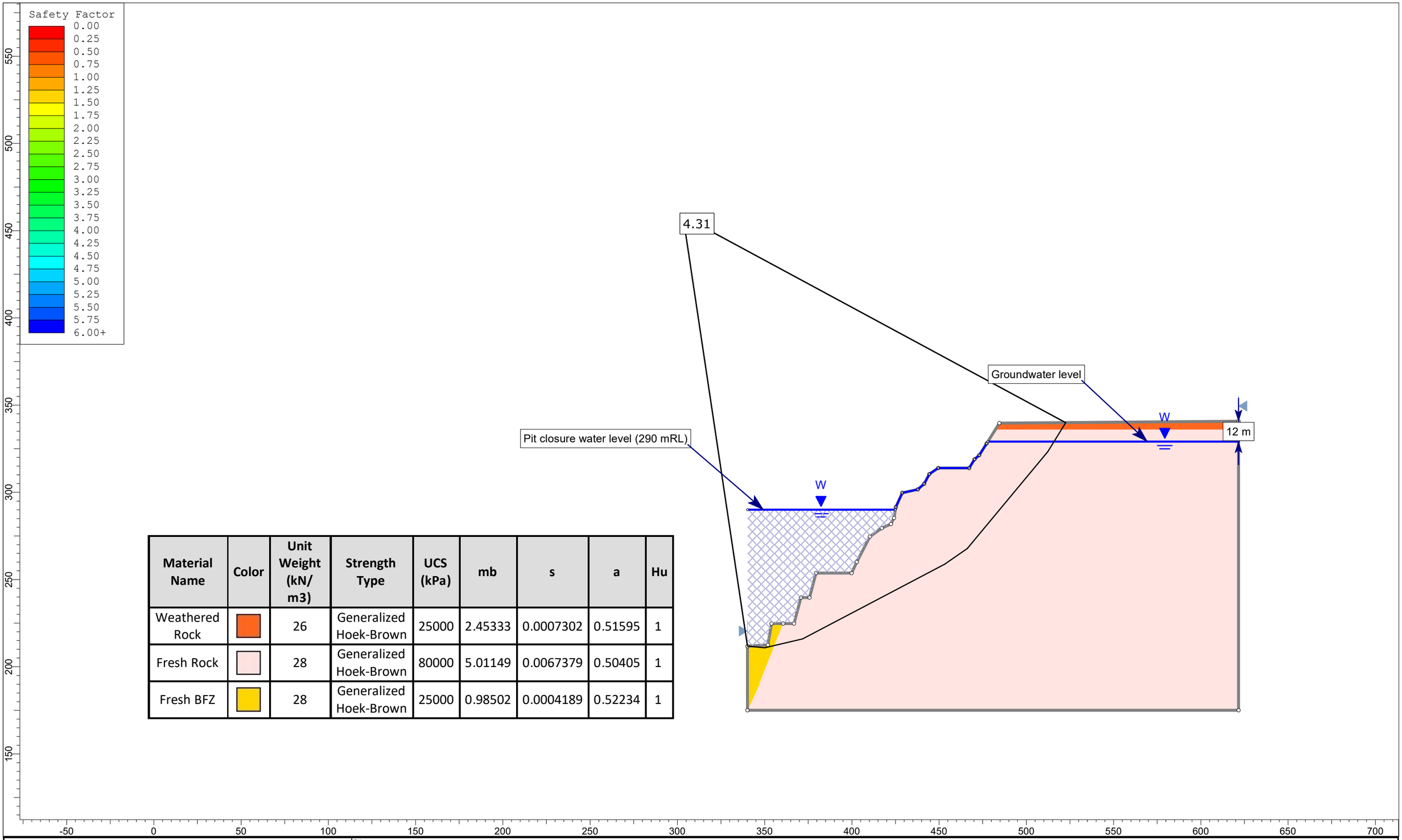
Fresh Rock		28	Generalized Hoek-Brown	80000	5.01149	0.0067379	0.50405	1
Fresh BFZ		28	Generalized Hoek-Brown	25000	0.98502	0.0004189	0.52234	1

SLIDEINTERPRET 9.010

Client:	Round Oak Minerals
Project:	Barbara Copper - Closure Study
Location:	Section B (South Pit, East Wall)
Analysis description:	Static Limit Equilibrium Method (LEM) Analysis

Job No:	PSM2319	By:	B. Jones	Date:	17/11/2020	Scale:	1:2000	Run ID:	Master Scenario



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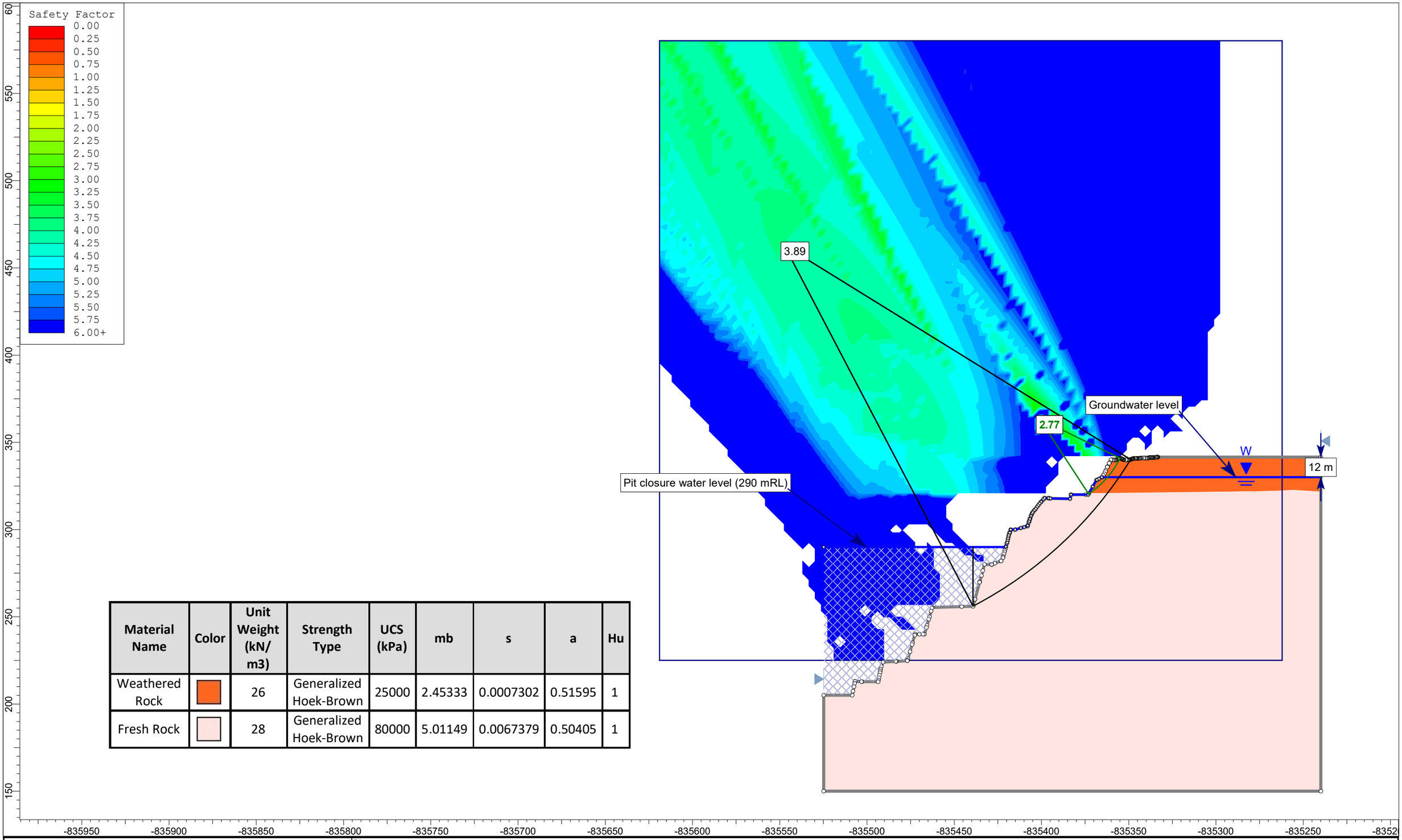
Fresh Rock		28	Generalized Hoek-Brown	80000	5.01149	0.0067379	0.50405	1
Fresh BFZ		28	Generalized Hoek-Brown	25000	0.98502	0.0004189	0.52234	1

SLIDEINTERPRET 9.010

Client:	Round Oak Minerals
Project:	Barbara Copper - Closure Study
Location:	Section B (South Pit, East Wall)
Analysis description:	Static Limit Equilibrium Method (LEM) Analysis

Job No:	PSM2319	By:	B. Jones	Date:	18/11/2020	Scale:	1:2000	Run ID:	Master Scenario



Material Name	Color	Unit Weight (kN/m3)	Strength Type	UCS (kPa)	mb	s	a	Hu
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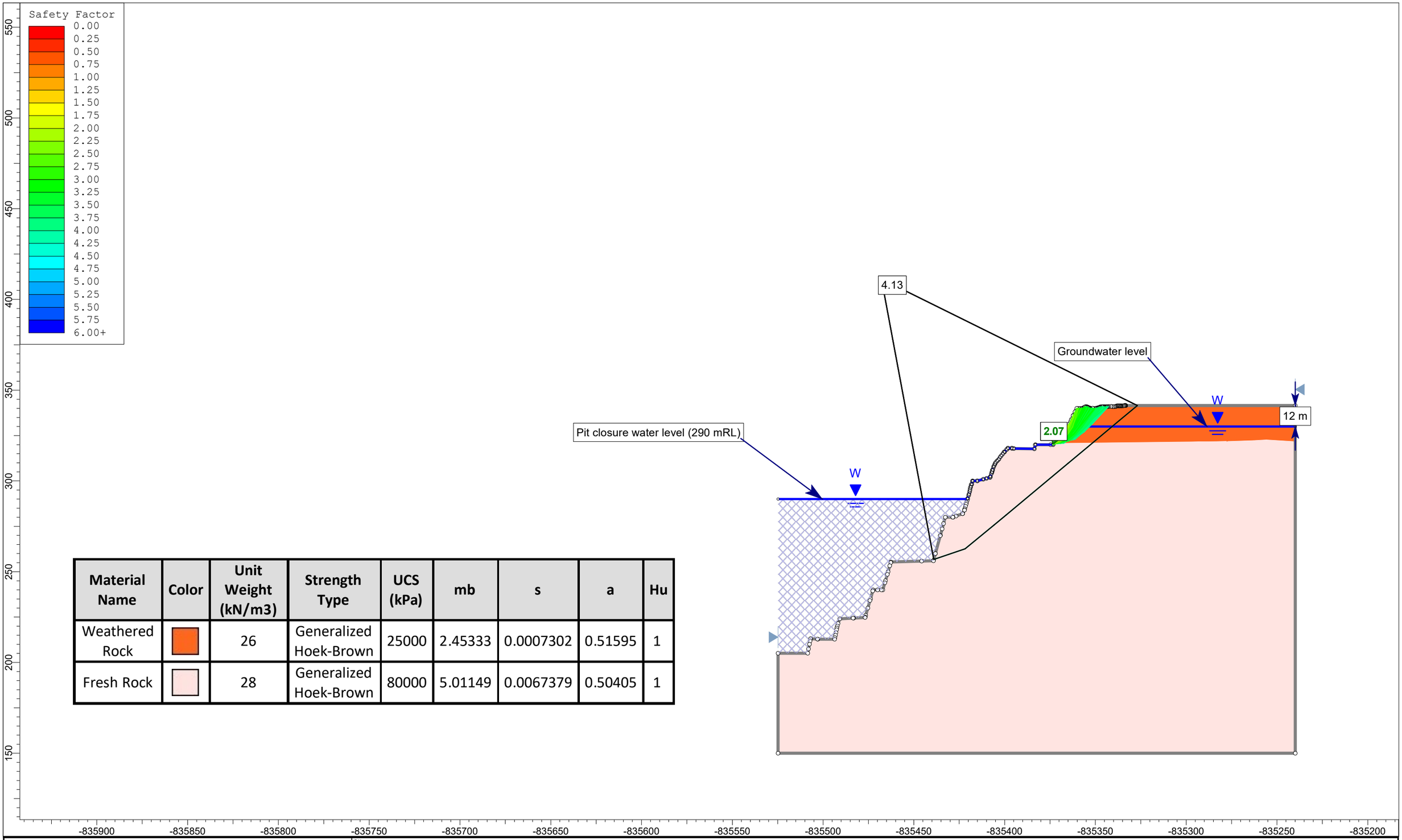
Fresh Rock		28	Generalized Hoek-Brown	80000	5.01149	0.0067379	0.50405	1

SLIDEINTERPRET 9.010

Client:	Round Oak Minerals
Project:	Barbara Copper - Closure Study
Location:	Section C (South Pit, East Wall)
Analysis description:	Static Limit Equilibrium Method (LEM) Analysis

Job No:	By:	Date:	Scale:	Run ID:
PSM2319	B. Jones	17/11/2020	1:2000	Master Scenario



Material Name	Color	Unit Weight (kN/m3)	Strength Type	UCS (kPa)	mb	s	a	Hu
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Fresh Rock		28	Generalized Hoek-Brown	80000	5.01149	0.0067379	0.50405	1

SLIDEINTERPRET 9.010

Client:	Round Oak Minerals
Project:	Barbara Copper - Closure Study
Location:	Section C (South Pit, East Wall)
Analysis description:	Static Limit Equilibrium Method (LEM) Analysis

Job No:	By:	Date:	Scale:	Run ID:
PSM2319	B. Jones	18/11/2020	1:1922	Master Scenario

Appendix B
Abandonment Bund Location (provided electronically)

REPORT

AERIS RESOURCES PTY LTD

Barbara Copper Project Progressive Rehabilitation and Closure Planning – Water Management Plan and Water Balance Model

118131.12
MARCH 2023

TAILINGS.WATER.WASTE.

Document Control

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Document Title:	Progressive Rehabilitation and Closure Planning – Water Management Plan and Water Balance Model
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Project Number:	118131.12
Revision Status:	Draft Issue

Revision History

Revision	Issue	Prepared by	Reviewed by
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0	Final Issue	James Parker	Gideon Steyl

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CONTENTS

1. INTRODUCTION 5

1.1 Background 5

1.2 Scope 6

1.3 Methodology 6

1.4 Guidelines and Available Site Data 6

1.5 Structure of Report 7

2. SITE LAYOUT AND REGIONAL SETTING 8

2.1 Site Layout and Drainage Features 8

2.2 Regional Watercourses 9

3. POST CLOSURE PASSIVE WATER MANAGEMENT INFRASTRUCTURE 10

3.1 Decommissioned or Remediated Infrastructure 10

3.2 Retained Infrastructure 11

3.3 Abandonment Bunds and Fences 13

4 WATER BALANCE MODEL 15

4.1 Water Balance Model Development 15

4.2 Model Structure and Inputs 15

4.3 Model Development 20

4.4 Results 21

4.4.1 North Pit 21

4.4.2 South Pit 24

4.4.3 WRD Sediment Dam 25

5 SUMMARY 28

REFERENCES 29

TABLES

TABLE 1: NORTH PIT CONFIGURATION 12

TABLE 2: SOUTH PIT CONFIGURATION 12

TABLE 3: WRD SEDIMENT DAM CONFIGURATION 13

TABLE 4: ABANDONMENT BUND – TYPICAL GEOMETRY 13

TABLE 5: SITE WATER BALANCE – RAINFALL AND EVAPORATION INPUT DATA 16

TABLE 6: PIT AND WRD SEDIMENT DAM CATCHMENT DETAILS 16

TABLE 7: GROUNDWATER INFLOW ESTIMATES 18

TABLE 8: INITIAL STORAGE INPUTS 18

TABLE 9: AWBM MODEL PARAMETERS 21

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DIAGRAMS

DIAGRAM 1: SITE LOCATION 5
DIAGRAM 2: SITE LAYOUT 8
DIAGRAM 3: REGIONAL WATERCOURSES 9
DIAGRAM 4: DIVERSION DRAINS TO BE RETAINED AND REMOVED 11
DIAGRAM 5: ABANDONMENT BUND ALIGNMENT 14
DIAGRAM 6: WATER BALANCE MODEL 15
DIAGRAM 7: CATCHMENT EXTENTS 17
DIAGRAM 8: GROUNDWATER INFLOW CONCEPTUAL MODEL* 18
DIAGRAM 9: NORTH PIT STORAGE CURVE 19
DIAGRAM 10: SOUTH PIT STORAGE CURVE 19
DIAGRAM 11: WRD SEDIMENT DAM STORAGE CURVE 20
DIAGRAM 12: AWBM FOR RUNOFF CALCULATIONS 21
DIAGRAM 13: NORTH PIT WATER SURFACE ELEVATION 22
DIAGRAM 14: NORTH PIT ACCUMULATED GROUNDWATER INFLOWS 23
DIAGRAM 15: NORTH PIT ACCUMULATED GROUNDWATER OUTFLOWS TO THE SOUTH PIT 23
DIAGRAM 16: SOUTH PIT WATER SURFACE ELEVATION 24
DIAGRAM 17: SOUTH PIT ACCUMULATED GROUNDWATER INFLOWS 25
DIAGRAM 18: WRD SEDIMENT DAM WATER SURFACE ELEVATION 27

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1. INTRODUCTION

1.1 Background

Aeris Resources (Aeris) owns and operates the Barbara Copper Project (BCP), located on mining lease ML90241 within the Mt Isa City Council. The BCP is located approximately 49 km northeast of Mt Isa and is accessed via Lake Julie Road from the Barkly Highway. The BCP is located at the upstream extents of an unnamed tributary of the Leichardt River. The unnamed tributary of Leichardt River and the Leichardt River are located in the Gulf Rivers Basin which discharges into the Gulf of Carpentaria. The location of the BCP relative to Mt Isa and Cloncurry is shown on **Diagram 1**.

DIAGRAM 1: SITE LOCATION

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1.2 Scope

The purpose of this report is to present findings of the post closure water management plan and water balance model (WBM) to assist in determining in the long term water levels within the North Pit, South Pit and Waste Rock Dump (WRD) Sediment Dam. This report should be read in conjunction with ATCW (2023) **[1]** detailing the outcomes of the geochemical assessment. Additional interpretive documents will be prepared by others to support the geochemical assessment. The BCP is currently in care and maintenance, with some preliminary remediation and rehabilitation works underway.

1.3 Methodology

The methodology adopted to achieve the scope of works for the PRCP inputs consists of the following tasks.

- Post Closure Water Management Plan and Water Balance Model (WBM). This will include:
  - Identification of water management infrastructure that is to be retained;
  - Calculate the spill risk from the North Pit, South Pit and WRD Sediment Dam.

1.4 Guidelines and Available Site Data

This assessment was undertaken against the following reference guidelines:

- Department of Environment and Science (2021), 'Guideline Progressive rehabilitation and closure plans (PRC plans)', ESR/2019/4964, March 2021, version 2.00. **[2]**

The following inputs were used in the preparation of this assessment:

- Department of the Environment and Science (2020), Environmental Authority EPML00715513 (Effective Date 3 February 2020), Queensland Government. **[3]**
- Surveyed Water Levels in the North Pit, South Pit and WRD Sediment. **[4]**
- PSM (2020), 'Mine Closure Geotechnical Study, Barbara Copper Project', Ref: PSM2319-041L Rev1, dated 14 December 2020. **[5]**
- Department of Industry and Resources, (1997), 'Safety Bund Walls Around Abandoned Open Pit Mines Guideline', Document Number ZMA048HA, Version 1.0. **[6]**
- The Long Paddock (2021), SILO Data Drill for Cell -20.40, 139.85, accessed 29 April 2022, https://www.longpaddock.qld.gov.au/silo/gridded-data/, Queensland Government. **[7]**
- Rob Lait & Associates (2014), 'Barbara Copper Project Hydrogeological Report Copperchem Pty Ltd and Syndicated Metals Pty Ltd Joint Venture', Ref Project No 220, October 2014. **[8]**
- Aeris Resources /Diverse Survey (2021). '210501_Barbara_Points_Filtered_1m_mga94_z54_ahd.dwg', 13 September 2021. **[9]**
- Boughton, W.C. (2004). 'The Australian Water Balance Model. Environmental Modelling & Software', Vol. 19, pp943-956. **[10]**
- ATCW (2020), 'Barbara Copper Project – Water Balance Model for 2020/2021 Wet Season and Care and Maintenance Period', Ref: 118131-09-L001-Rev0', dated 25 November 2020. **[11]**

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1.5 Structure of Report

The structure of the report, to address the above scope of works, is as follows.

Section 2 Details the site layout and regional setting.

Section 3 Outlines the post closure passive management structures to be retained.

Section 4 Presents the inputs, assumptions, parameters and results on the post closure water balance model to determine the long-term water levels in the North Pit, South Pit and WRD Sediment Dam, as well as groundwater inflows and outflows.

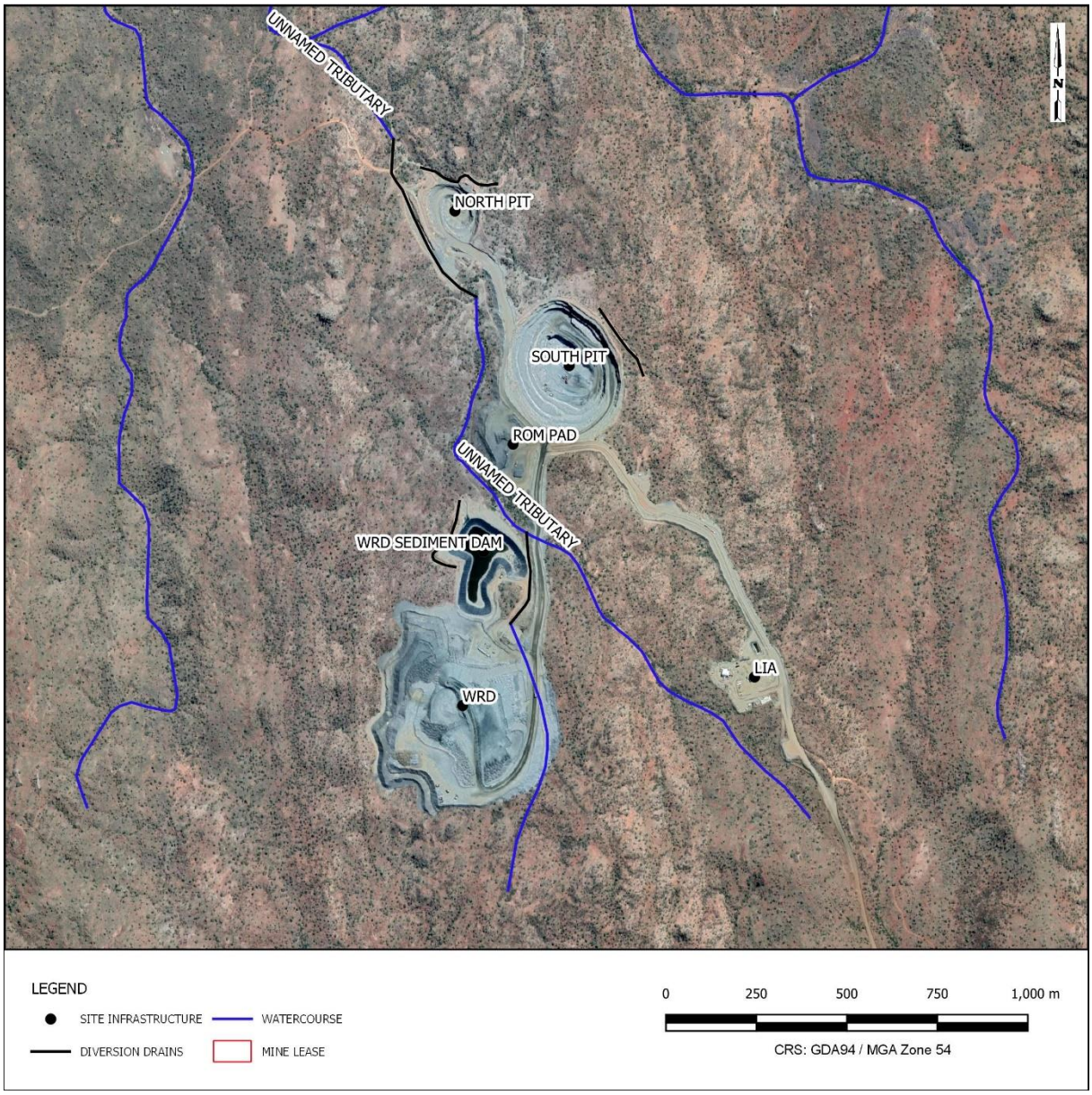
Section 5 Provides a summary of the WBM and conclusions drawn from the results.

2. SITE LAYOUT AND REGIONAL SETTING

2.1 Site Layout and Drainage Features

The locations of the exiting site features (including diversion drains) are depicted on **DIAGRAM 2**.

DIAGRAM 2: SITE LAYOUT



The BCP is located on the western and eastern banks of the unnamed tributary of the Leichardt River, which runs in an approximate southeast to northwest direction. The route of this unnamed tributary was formalised by the construction of two permanent diversion drains. The most upstream (southerly) diversion is to the east of the WRD Sediment Dam and the most downstream (northerly) diversion is to the west of the North Pit. The two diversion drains and an associated levee at the North Pit were sized to convey flows up to and including the 1:1,000 AEP (0.1% AEP) design storm event.

The North Pit, South Pit, Run of Mine (ROM) Pad, Light Infrastructure Area (LIA) (including site offices and workshop area) are located on the eastern bank of the unnamed tributary of the Leichardt River. The WRD and WRD Sediment Dam are located on the western bank of the unnamed tributary of the Leichardt River. The WRD is to be capped with material from the rehabilitated ROM Pad, LIA area and excess access road material. The WRD Sediment Dam is to be retained for stockwater use by the landowner.

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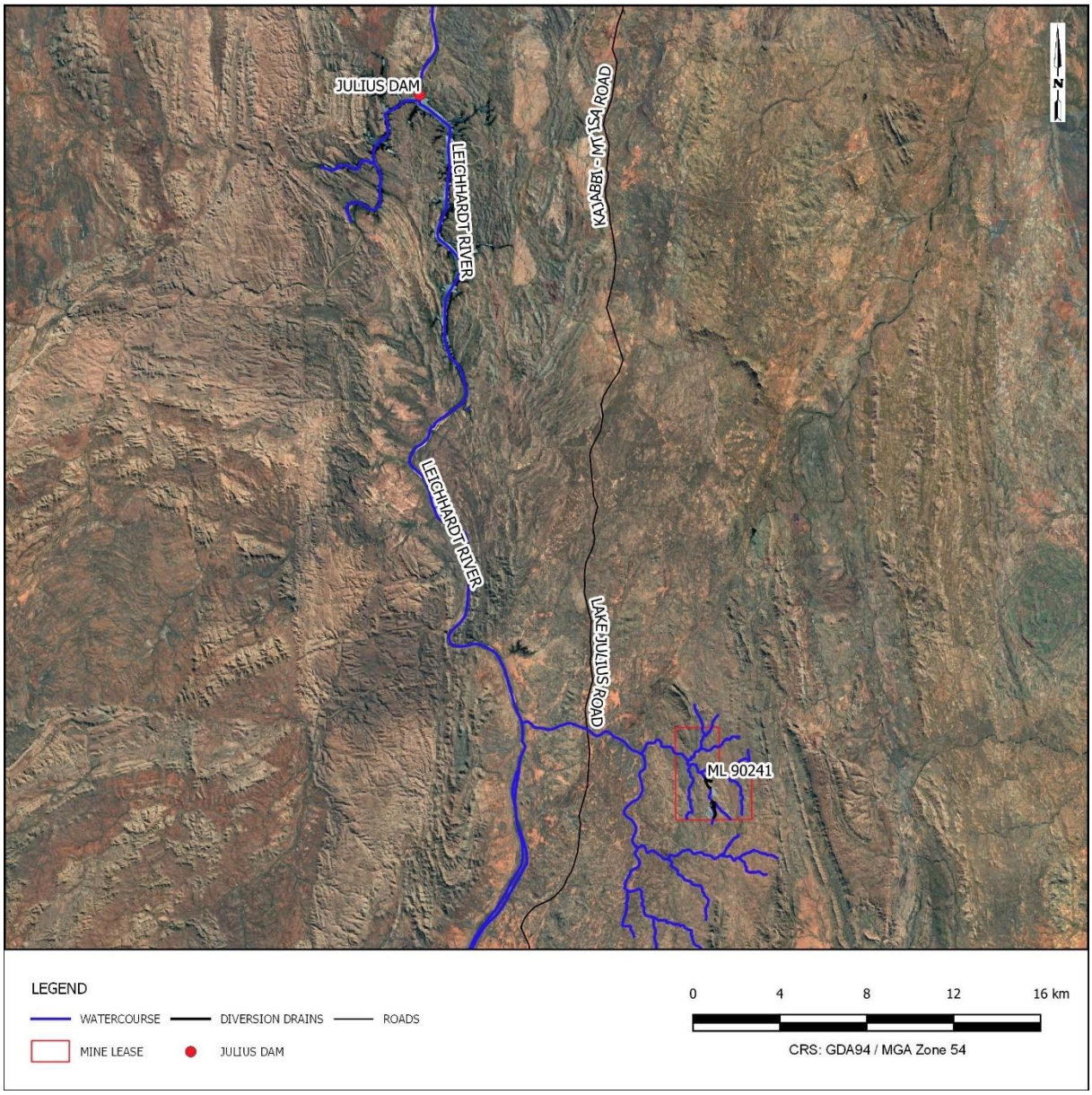
2.2 Regional Watercourses

The unnamed tributary of the Leichardt River conveys flows to the Leichardt River approximately 9.5 km to the west-northwest of the BCP. All tributaries to the east of the Leichardt River within mine lease (ML) 90241 are unnamed. As such, when the unnamed tributary of the Leichardt River is henceforth referred to, it refers to the flow path through the BCP site and its continuing flow path to the Leichardt River.

Excluding the BCP, there are no dams or engineered structures on the unnamed tributary of the Leichardt River which might impact the characteristics of surface water runoff or flood behaviour. Approximately 35 km north of the confluence of the unnamed tributary with the Leichardt River, the Leichardt River is impounded by the Julius Dam. The location of the unnamed tributary, the Leichardt River, Julius Dam and the BCP mining lease are depicted on **DIAGRAM 3**.

DIAGRAM 3: REGIONAL WATERCOURSES



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3. POST CLOSURE PASSIVE WATER MANAGEMENT INFRASTRUCTURE

As part of the PRCP, Aeris propose to cease all active pumping between the North Pit, South Pit and WRD Sediment Dam which are currently included in the Care and Maintenance management measures **[11]**. As such, all drainage elements and water management on the site will be passive. A summary of the infrastructure that is to be decommissioned or retained are summarised in the following sections.

3.1 Decommissioned or Remediated Infrastructure

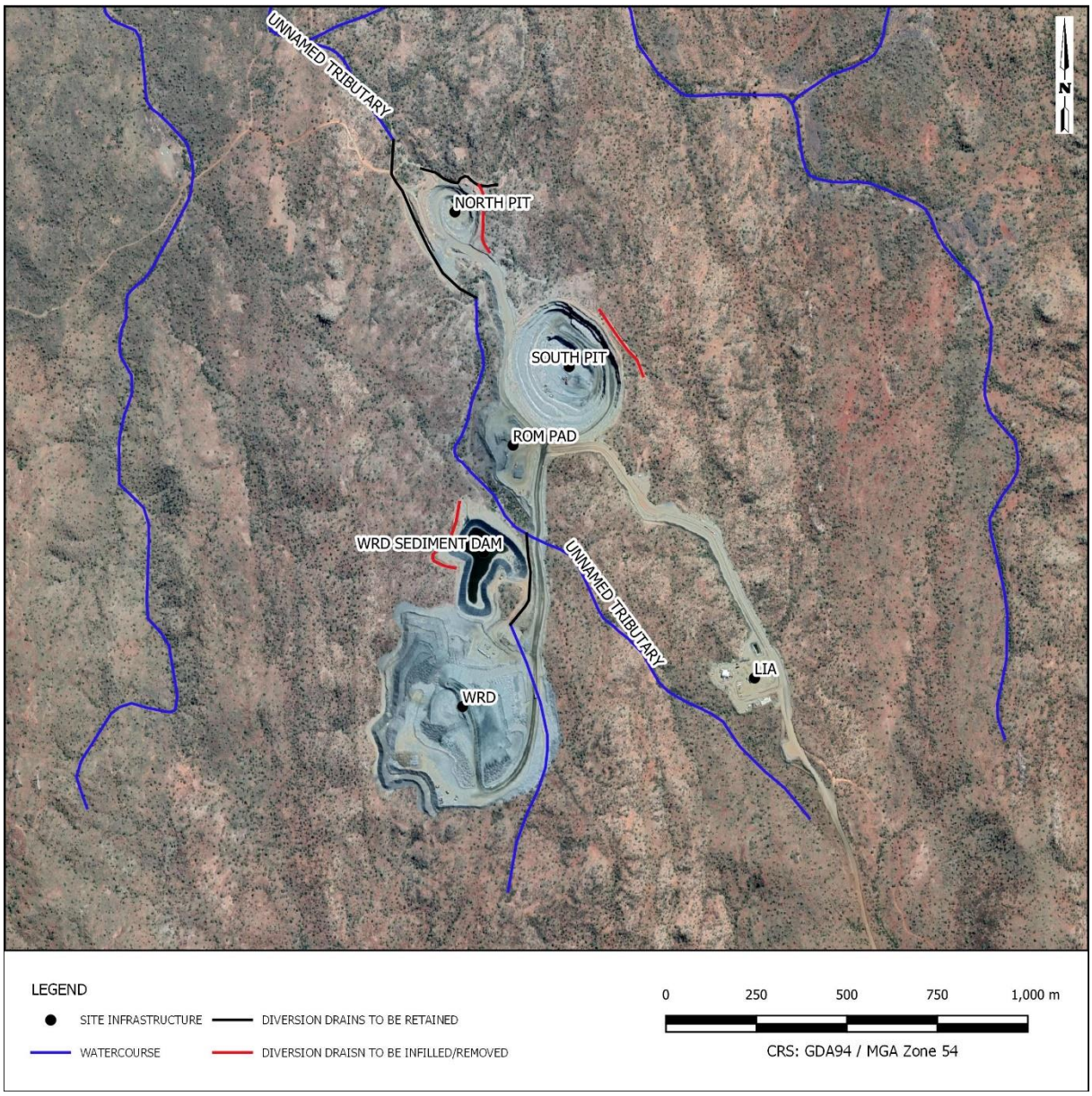
As part of the PRCP works, the following infrastructure is to be remediated or decommissioned:

- ROM Pad
- LIA
- Diversion drain to the west of the WRD Sediment Dam
- Diversion drain to the east of South Pit

The diversion drains to be retained (black lines) and decommissioned (red lines) are shown on **DIAGRAM 4**.

TAILINGS.WATER.WASTE.

DIAGRAM 4: DIVERSION DRAINS TO BE RETAINED AND REMOVED



The construction of the abandonment bunds, and the removal of the diversion drain west of the WRD Sediment Dam will impact the long-term water levels in the North Pit, South Pit and WRD Sediment Dam. Details of the catchments and WBM are included in **Section 4**.

3.2 Retained Infrastructure

As part of the PRCP works, the following infrastructure is to be retained:

- North Pit Residual Void (including an abandonment bund and fence) – The north wall of the North Pit is to be reduced from RL 316 m to RL 313 m to allow fresh water inputs to the North Pit for the catchment to the east.
- South Pit Residual Void (including an abandonment bund and fence)
- Diversion Drain (and Levee) to the west of the North Pit
- Rehabilitated WRD
- WRD Sediment Dam

TAILINGS.WATER.WASTE.

- Diversion Drain to the east of the WRD Sediment Dam

The configuration of the North Pit, South Pit and WRD Sediment Dam are detailed in **Table 1, Table 2** and **Table 3** respectively.

TABLE 1: NORTH PIT CONFIGURATION

Feature	Value
Pit Rim Elevation	RL 313.0 m
Pit Base Elevation	RL 295.0 m
Total Pit Capacity to Rim	112.7 ML
Approximate Pit Depth	18 m
Pit Water Level*	RL 304.53 m
Volume of stored water*	39.8 ML
Pit Extents	3.3 ha

*As at 16th September 2022 **[4]**

TABLE 2: SOUTH PIT CONFIGURATION

Feature	Value
Pit Rim Elevation	RL 334.0 m
Pit Base Elevation	RL 211.5 m
Total Pit Capacity to Rim	3,272 ML
Approximate Pit Depth	122.5 m
Pit Water Level*	RL 232.30 m
Volume of stored water*	44.4 ML
Pit Extents	10.2 ha

*As at 16th September 2022 **[4]**

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TABLE 3: WRD SEDIMENT DAM CONFIGURATION

Feature	Value
Embankment Crest Elevation	RL 338.0 m
Base Elevation	RL 329.3 m
Full Supply Level	RL 336.8 m
Depth to Spillway	7.5 m
Maximum Storage Capacity	131.9 ML
Dam Water Level*	RL 332.24 m
Volume of stored water*	23.5 ML
WRD Sediment Dam Extents	3.0 ha

*As at 16th September 2022 **[4]**

3.3 Abandonment Bunds and Fences

In 2020, PSM **[5]** proposed the location of the abandonment bunds around the North Pit and South Pit (shown in green on **DIAGRAM 5**).

Due to the long term assessed instability of the northern wall of the North Pit, it was concluded that the most suitable solution was to remove the northern wall of the North Pit to allow fresh water to enter the North Pit. In lieu of a circumferential bund, in area of steep terrain a fence is to be installed, as the topography will not allow for the access of construction machinery.

Additionally, the proposed abandonment bund was modified at the southwest corner of the North Pit to incorporate the existing levee. This will require a raise of an additional 2.5 m to at least 322.5 m AHD. The originally proposed and alternate bund alignments are shown on **DIAGRAM 5**.

The alignment of the South Pit bund proposed by PSM **[5]** is largely retained. A portion of the proposed bund is to be replaced by a fence to allow surface waters flows to enter the South Pit as detailed in **Section 4.2.2 below**The extents of the proposed bunds and fencing is depicted on **DIAGRAM 5**.

A small portion of the bund that intersects the Haul Road will be replaced by a fence to allow the landowner access to the North Pit. The alignments of the abandonment bunds are located outside the identified zones of instability identified by PSM **[5]**.

Where bunds are to be constructed. the geometry is to be in accordance with Western Australian Department of Industry and Resources **[6]**. This typical geometry is summarised in **Table 4**.

TABLE 4: ABANDONMENT BUND – TYPICAL GEOMETRY

Feature	Value
Bund Height	2 m (minimum)
Base Width	5 m (minimum)
Crest Width	0.5 m (minimum)
Side Slopes	1(H):0.5(V)

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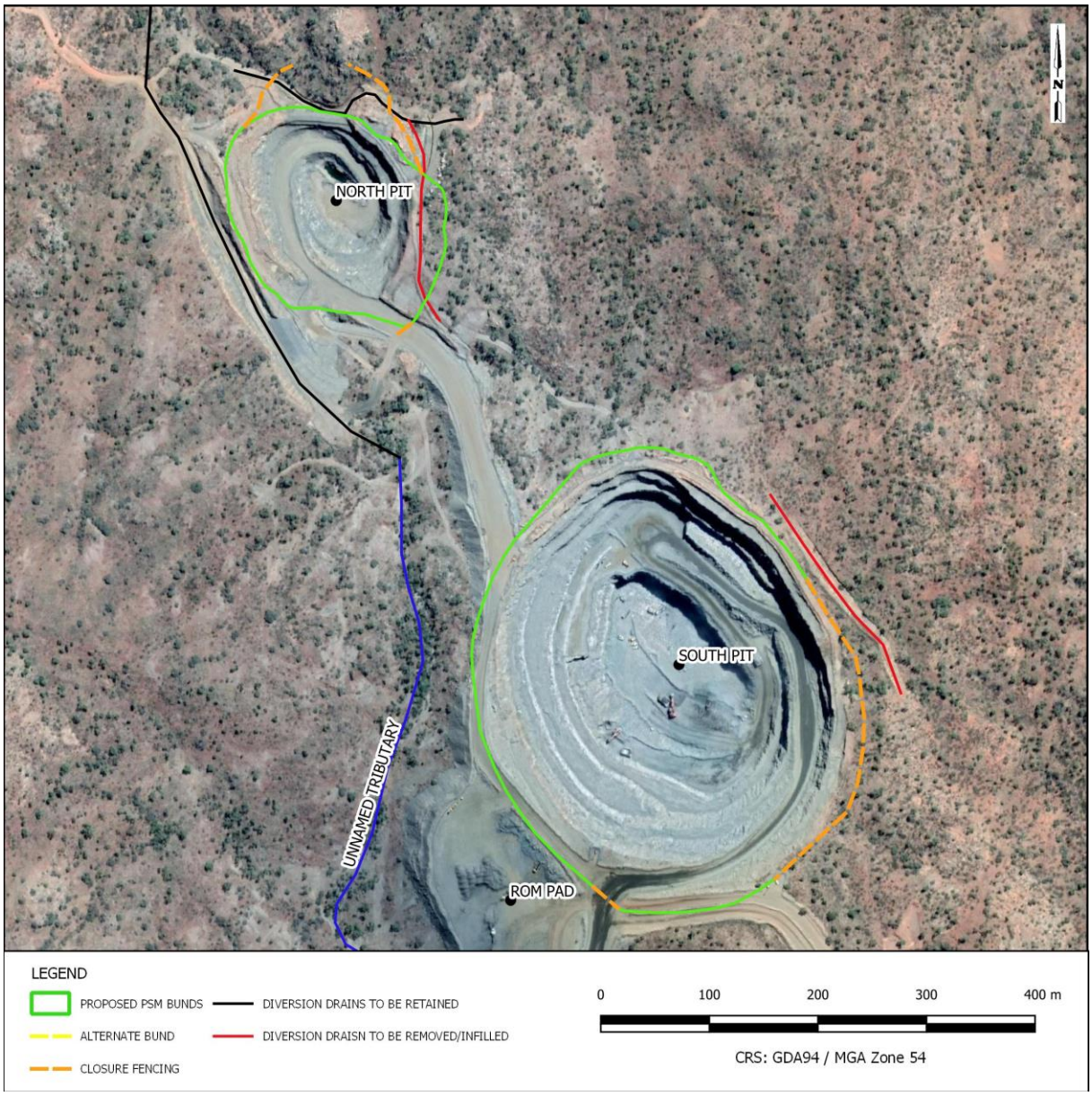
DIAGRAM 5: ABANDONMENT BUND ALIGNMENT



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4 POST CLOSURE WATER BALANCE MODEL

4.1 Closure Water Balance Model Development

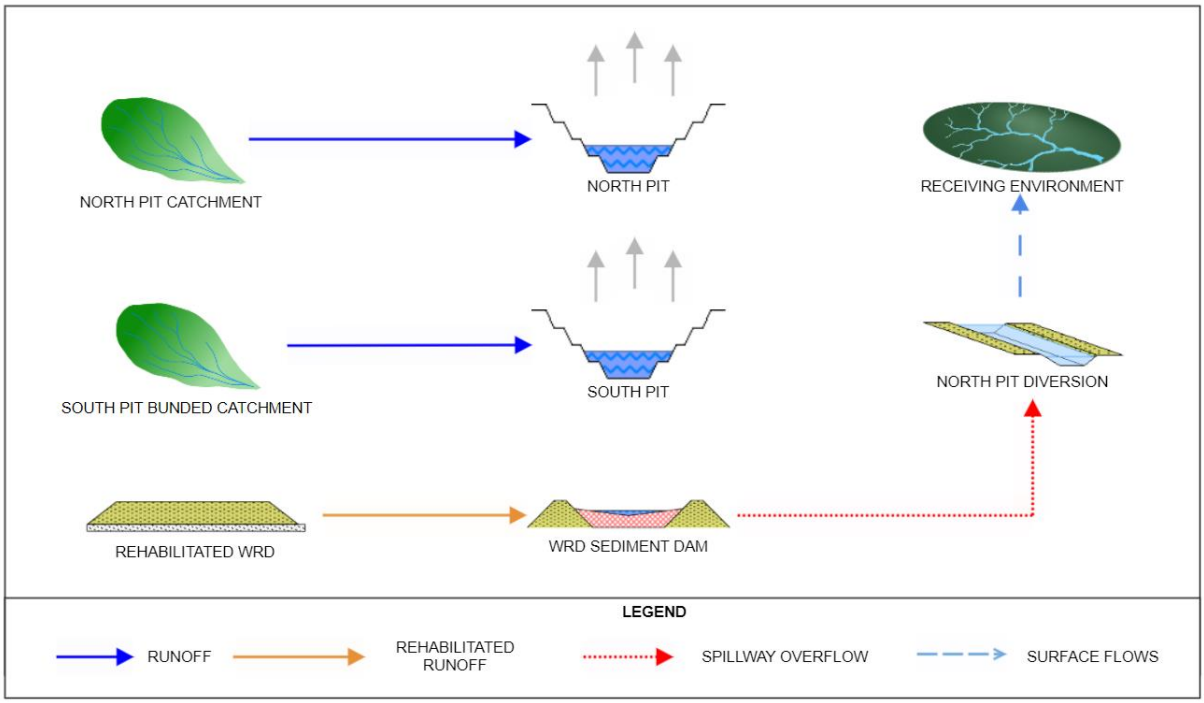
To assess the impact of surface water runoff, (both mine impacted and non-impacted), evaporation and groundwater inflows to the North Pit, South Pit and WRD Sediment Dam, a water balance model was developed using Goldsim Pro (Goldsim V12.1).

Goldsim is a dynamic probabilistic simulation program, which uses a range of parameters to represent the catchment surface water system, being routed through a time series of daily rainfall data for an estimated daily runoff. The water balance model reflects the effects of stormwater runoff, evaporation, and groundwater inflows/outflows at the site.

4.2 Model Structure and Inputs

The process flow chart for the Barbara site is depicted in **Diagram 6**. Primary water balance inputs applying to each of the elements in the model development are described the following sub-sections.

DIAGRAM 6: WATER BALANCE MODEL AT CLOSURE



4.2.1 Climatic Data

Climate data was obtained from SILO Data-drill specific to the site **[7]**, and brief details about the data parameters are provided in **Table 5**.

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TABLE 5: SITE WATER BALANCE – RAINFALL AND EVAPORATION INPUT DATA

Climate Data	Data Source	Comments
Daily Rainfall Rate (mm/day)	Rainfall data obtained from the SILO Data Drill Program for the Site Location (1889 - 2023)	Applied over dam surface areas, and as an input parameter for the estimation of surface runoff (AWBM).
Daily Evaporation Rate (mm/day)	Continuous record from SILO Data Drill formed by conjoining: CLIMARC estimates (1889 – 1957) and Class A Evaporation Data from proximate weather stations within the region (1889 – 2023).	Evaporation Data is scaled by evaporation factors for each site storage to reflect water storage conditions and expected water quality.
Daily Evapo-Transpiration Rate (mm/day)	As calculated by the FAO short crop reference methodology, assuming a wind speed of 2 m/s.	PET is calculated based on temperature, vapour pressure and solar global exposure parameters derived from climatic data and is adopted as a reasonable estimate of potential evapotranspiration losses from ground surfaces within the model.

4.2.2 Closure Catchment Delineation

Catchment delineation and estimation for the closure conditions was performed using survey and aerial photography. The catchments are depicted in **Diagram 7**. **Table 6** summaries the catchment delineation which was used to inform the AWBM Surface Runoff Volumes reporting. Two (2) scenarios were run for the South Pit to determine the best configuration of the bund/fence arrangement surrounding the South Pit. The impacts upon water quality are discussed in **[1]**.

TABLE 6: PIT AND WRD SEDIMENT DAM CATCHMENT DETAILS

Surface Runoff Type	Catchments (ha)		
	North Pit	South Pit	WRD Sediment Dam
Natural (Undisturbed)	10.1	-	7.8
Rehabilitated	-	-	20.3
Hardstand	0.5	3.2	4.6
Open Cut	3.1	8.2	-
Total Catchment Area	**10.2**	**Scenario 1 – 14.1** **Scenario 2 – 21.7**	**35.7**
Surface Water Area (at full supply)	1.5	8.2	3.0

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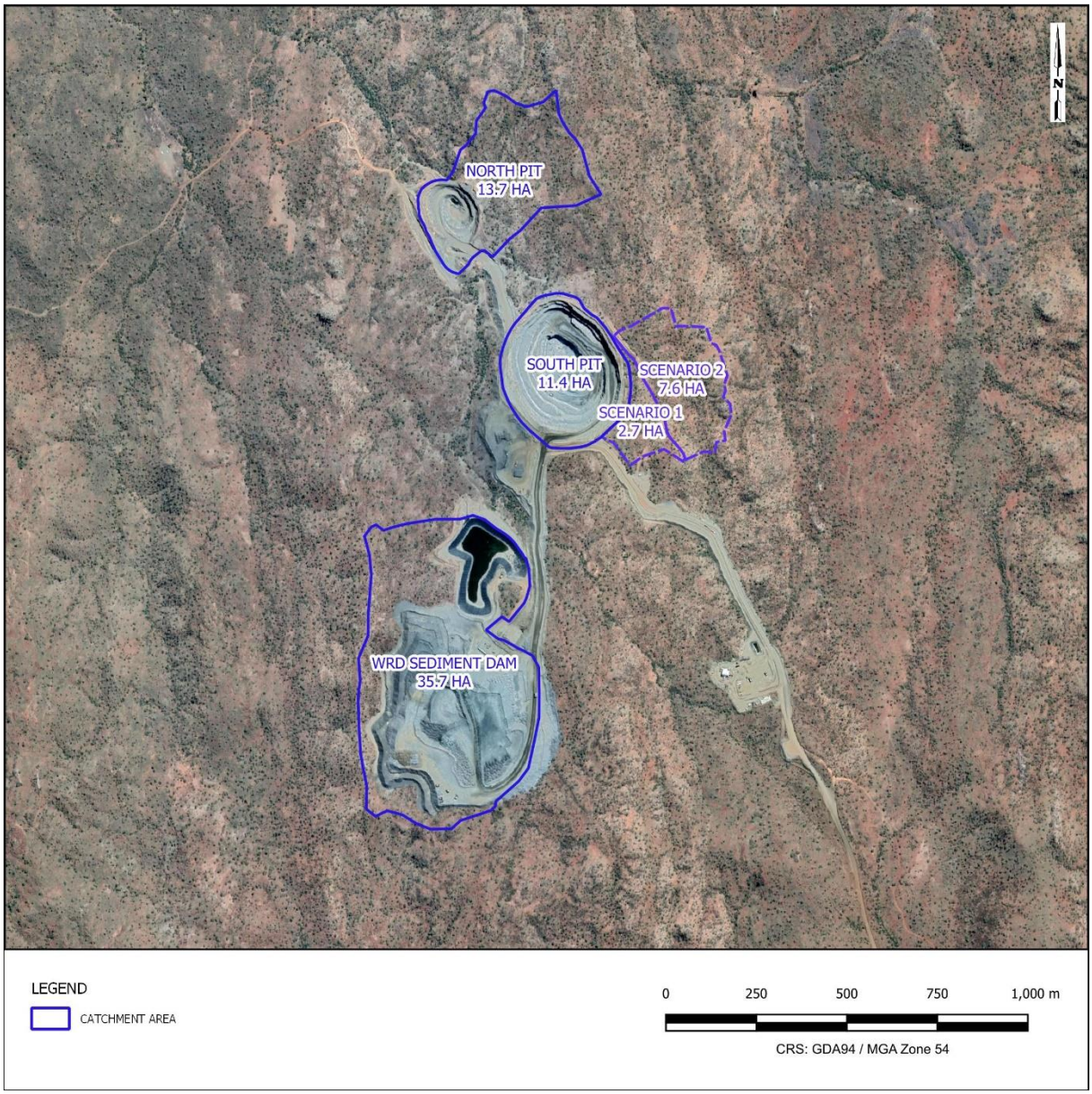
DIAGRAM 7: CATCHMENT EXTENTS



4.2.3 Groundwater Inflows

Groundwater interaction is likely to occur between the voids (from the North Pit to the South Pit due to base elevation differences). Additionally, both the North Pit and South Pit will receive groundwater flows from the surrounding area. Therefore, it is considered that inflows (and potential outflows) from the voids to the surrounding groundwater systems occur, with the direction of flow determined by the pit water level compared to the aquifer phreatic head. Reduced elevation of surface water levels within the pit are likely to cause inflows from the surrounding aquifer systems. Based on details of the groundwater monitoring bores outlined in Rob Lait & Associates **[8]**, groundwater inflow rates have been calculated using the Dupuit-Forchheimer approximation and outflows to the pit voids have been estimated through '*Darcy's Law for Flow in Confined Aquifers*'.

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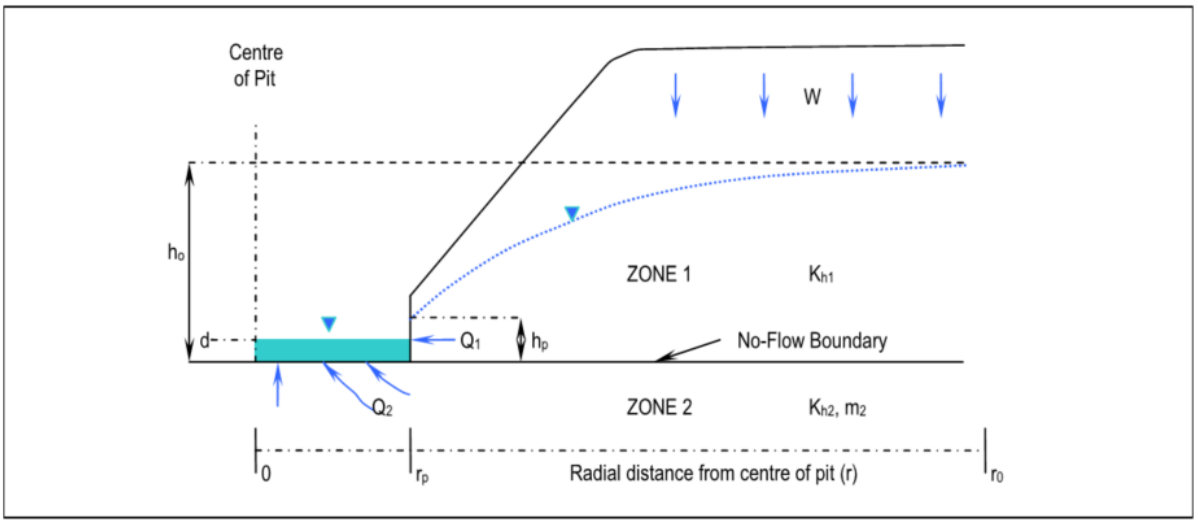
DIAGRAM 8: GROUNDWATER INFLOW CONCEPTUAL MODEL*



*Reproduced from Figure 9 **[8]**

The groundwater inflow rates for each pit as calculated by Rob Lait **[8]** are reproduced in **Table 7**.

TABLE 7: GROUNDWATER INFLOW ESTIMATES

Pit	Groundwater Inflow (L/s)
North	0.05
South	0.54

As noted by Rob Lait **[8],** these estimates of groundwater represent the groundwater that resided in the orebody prior to mining, with long term natural recharge expected to be much slower. As such, the inflows estimates are considered to be conservative and are summarised in **Section 4.4**.

Groundwater outflows from the North Pit to the South Pit have been estimates to be approximately 0.0028 L/s based upon the guidance of Woessner and Poeter **[13]**.

4.2.4 Storage Curve Data and Initial Conditions

Storage curves were derived for both site pits from the provided survey file. The resulting storage curve is depicted in **Diagram 9** and **Diagram 10**. The site survey was used for the water balance assessment and to derive storage curves in the pit void. Initial water storages were provided by Aeris from values surveyed on 7 June 2022 Error! Reference source not found. and are illustrated in **Table 8**.

TABLE 8: INITIAL STORAGE INPUTS

Parameter	North Pit	South Pit	WRD Sediment Dam
Initial Volume* (ML)	39.8 (RL 304.53 m)	44.4 (RL 232.30 m)	23.5 (RL 332.24)
Total Capacity (ML)	112.7	3,296.4	131.9
Overflow Level (m)	RL 313.0 m	RL 334.3 m	RL 337.0 m

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DIAGRAM 9: NORTH PIT STORAGE CURVE

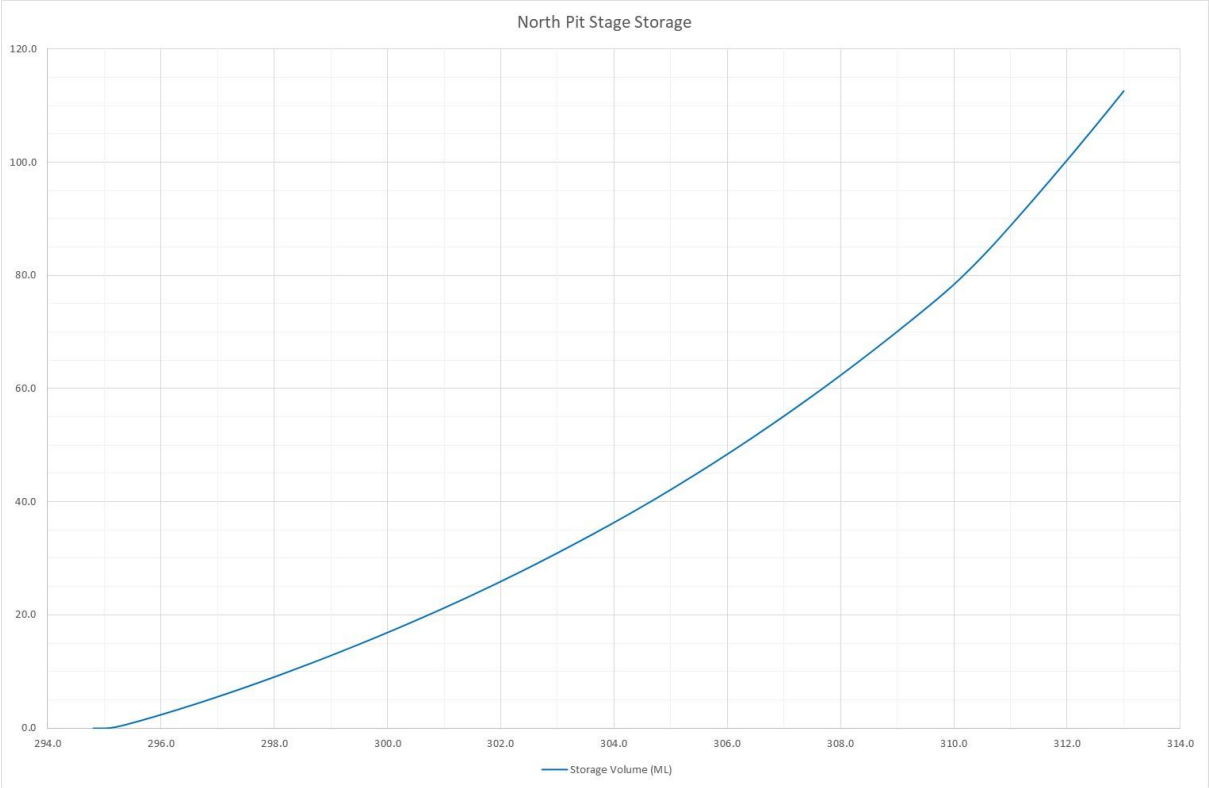

DIAGRAM 10: SOUTH PIT STORAGE CURVE

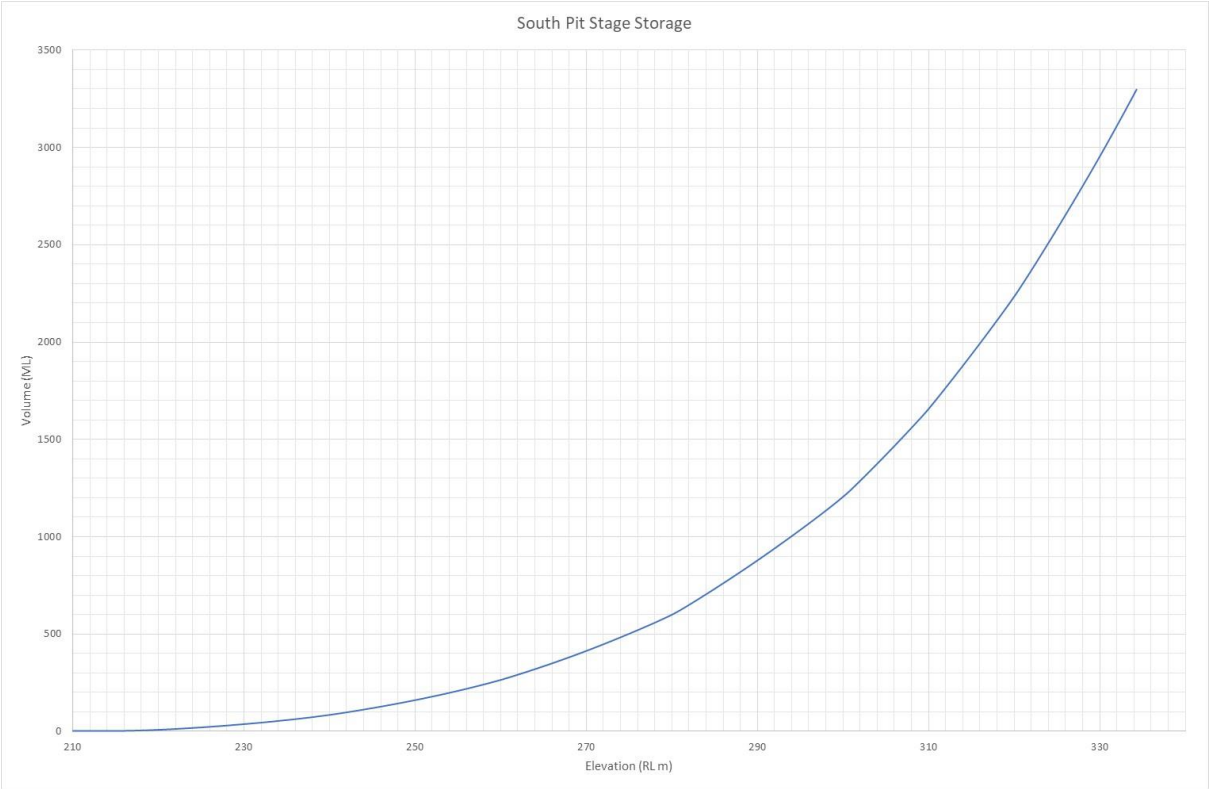

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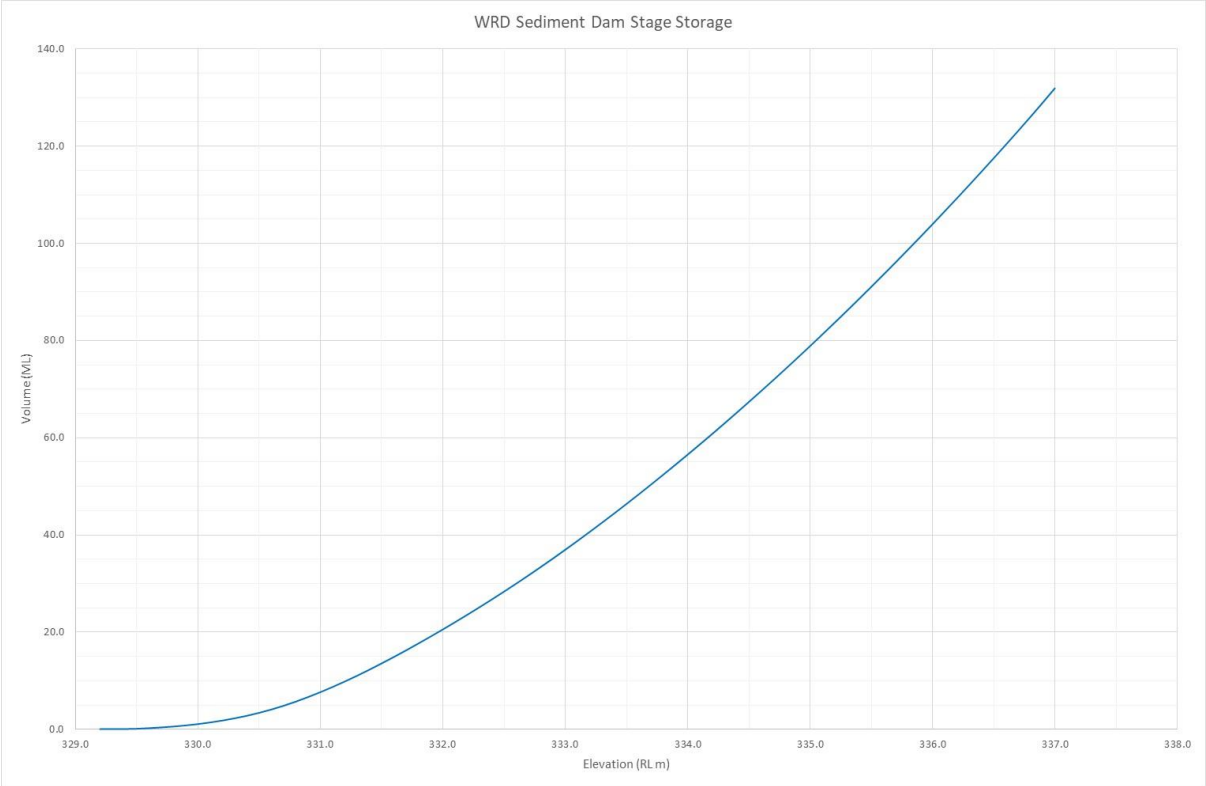
DIAGRAM 11: WRD SEDIMENT DAM STORAGE CURVE



4.3 Model Development

The Australian Water Balance Model (AWBM) was incorporated to simulate daily runoff from rainfall generated within the various sub-catchment types that are present on the project site. **Diagram 12** represents a schematic of the AWBM model, reproduced from Boughton (2004) **[10]**.

The catchment types and AWBM model parameters used to simulate these different catchment types and the average yields from these catchment areas are summarised in **Table 9**. Model parameters have been selected based on experience with similar water balance model studies and are considered to be conservative in the context of an uncalibrated model.

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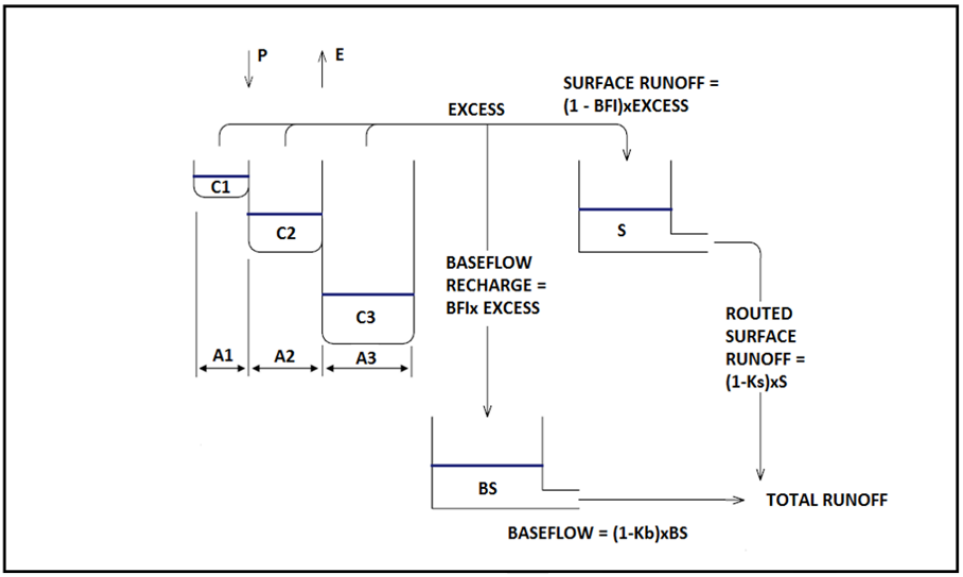
DIAGRAM 12: AWBM FOR RUNOFF CALCULATIONS



Where:
C1 - C3 = Surface Storage Capacities
A1 - A3 = Partial Areas Represented by Surface Storages
BFI = Baseflow Index
K_b = Daily Baseflow Recession Constant
BS = Current Volume in Baseflow Store
K_s = Daily Surface Flow Recession Constant
S = Current Volume in Surface Store Routing

TABLE 9: AWBM MODEL PARAMETERS

AWBM Parameters	Split Areas (sum=1.0)			Storage Capacities (mm)			Ks (day^{-1})	BFI	Kb (day^{-1})
	A1	A2	A3	C1	C2	C3			
Natural	0.13	0.43	0.43	12	120	250	0	0	1
Hardstand	1.00	0.00	0.00	3	0	0	0	0	1
Waste	0.20	0.80	0.00	10	300	300	0	0	1
Open Cut	0.10	0.90	0.00	5	20	20	0	0	1
Rehab waste	0.10	0.30	0.60	20	55	100	0	0	1
Stockpiles	0.10	0.90	0.00	5	50	50	0	0	1

4.4 Results

4.4.1 North Pit

The following conclusions can be drawn from **Diagram 13**:

- The North Pit rapidly accumulates water to 2033/2035, whereupon it reaches a state of 'dynamic equilibrium'. The 'dynamic equilibrium' has small variations throughout the year to account for periods of rainfall and evaporation.
- The mean (average) water level in the North Pit reaches a level of approximately RL 308.5 m to RL 309.5 m, with variations through the calendar year during periods of rainfall and evaporation.

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- The water level in the North Pit reaches the spill level of RL 313 m in years where the rainfall exceeds the 85th percentile.
- In any given year, the spill risk from the North Pit is approximately 9%.

The maximum modelled water level is approximately RL 313 m. The minimum modelled water level is approximately RL 303 m. These values represent the historically 'wettest' and 'driest' years occurring consecutively through the simulation.

DIAGRAM 13: NORTH PIT WATER SURFACE ELEVATION

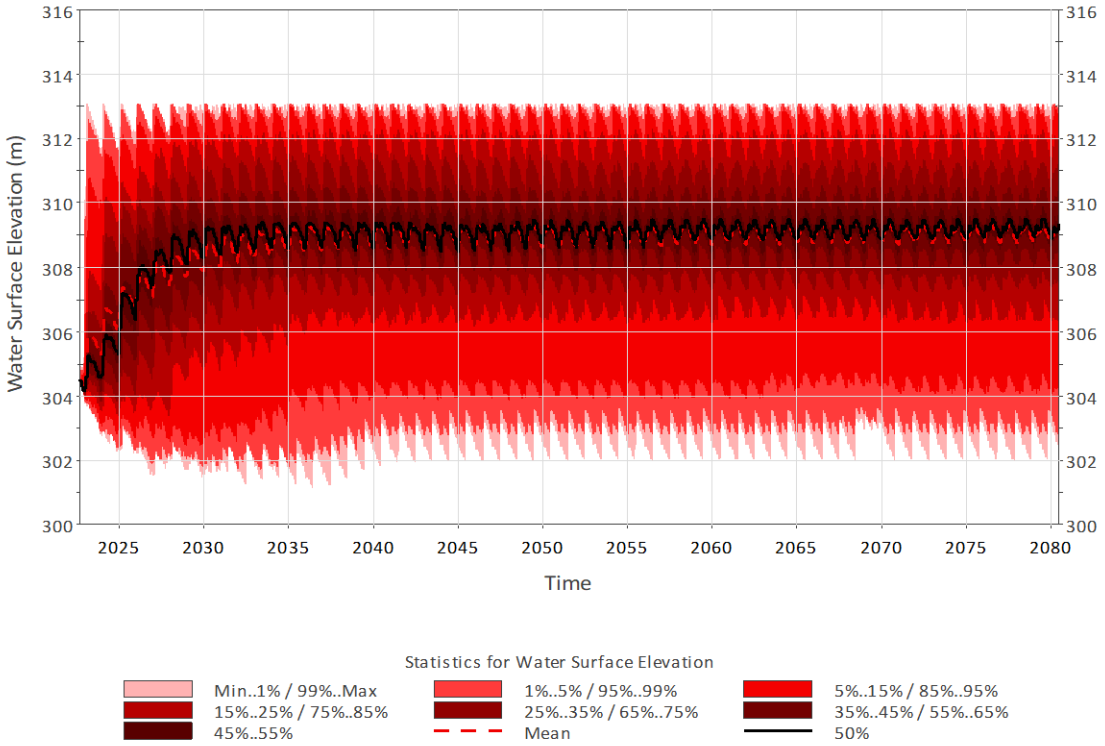

Diagram 14 illustrates the mean accumulated groundwater inflows into the North Pit over a period of sixty-five (65) years is approximately 100 ML, or approximately 1.5 ML/year throughout the simulation period from 2022-2087.

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DIAGRAM 14: NORTH PIT ACCUMULATED GROUNDWATER INFLOWS

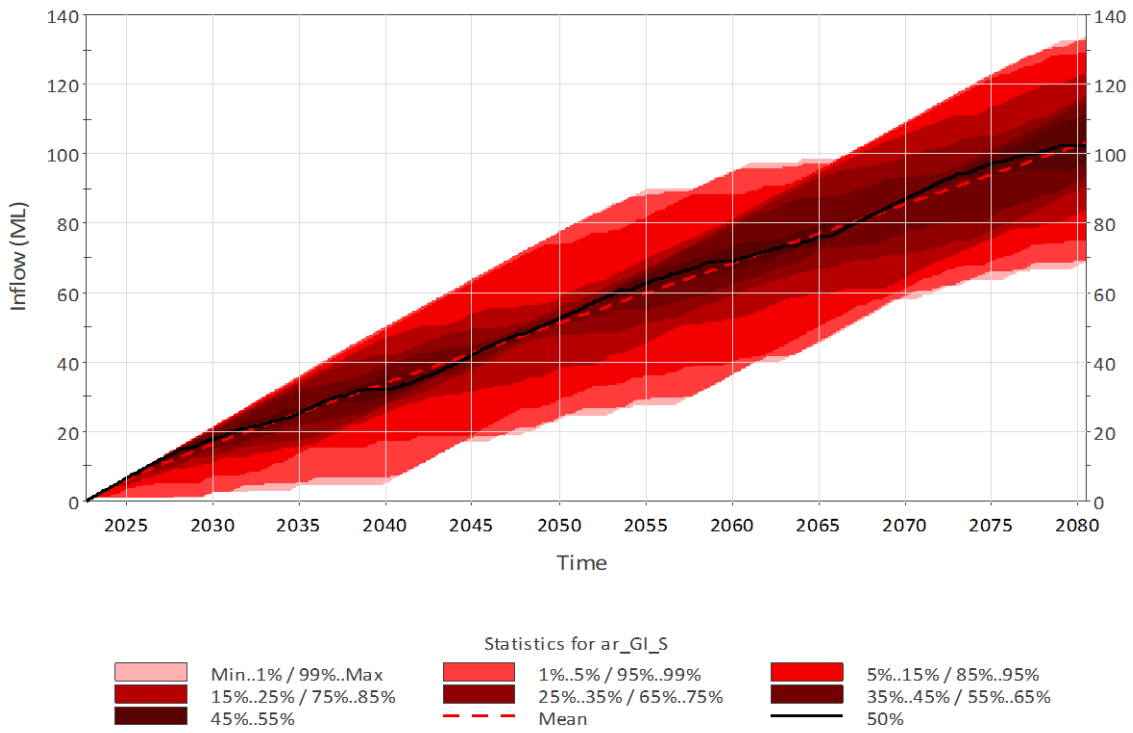
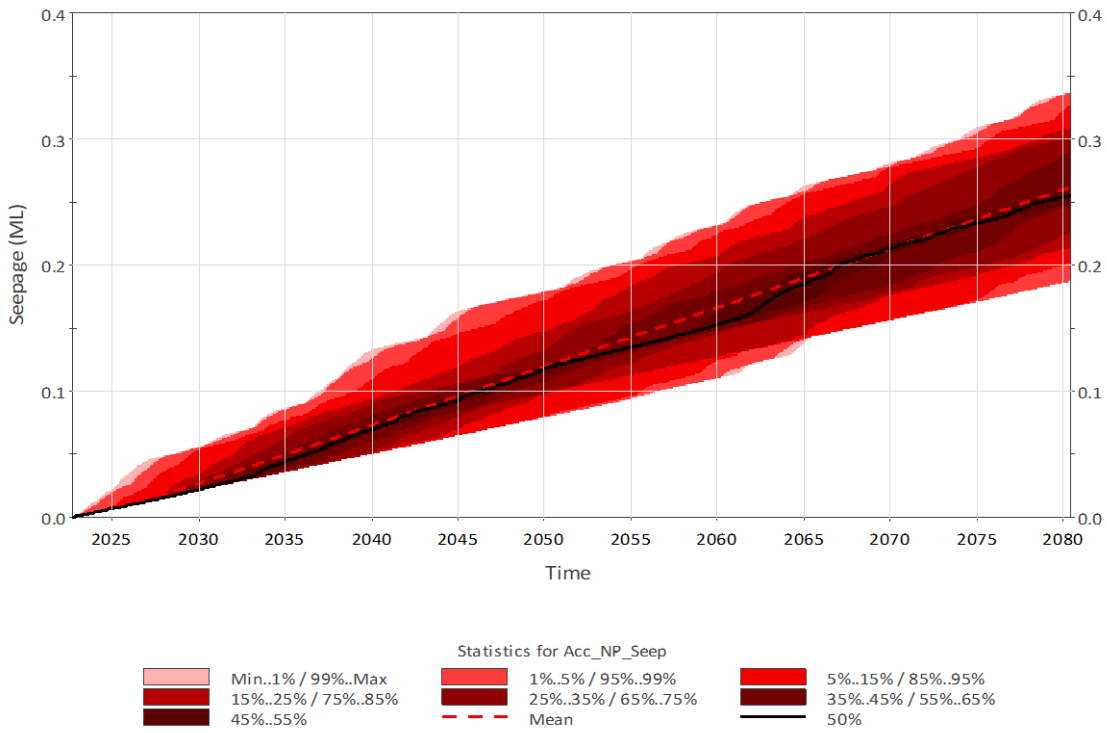


Diagram 15 illustrates the mean accumulated groundwater outflows from the North Pit towards the South Pit over a period of fifty-eight (58) years is approximately 0.26 ML, or approximately 0.0044 ML/year (4.4 kl/year) throughout the simulation period from 2023-2081. Based on the mean groundwater inflow rate of approximately 1.5 ML/year, the North Pit is a net groundwater sink.

DIAGRAM 15: NORTH PIT ACCUMULATED GROUNDWATER OUTFLOWS (INCLUDING TO THE SOUTH PIT



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4.4.2 South Pit – Scenario 1

The following conclusions can be drawn from **Diagram 16**:

- The South Pit rapidly accumulates water to the year 2040, with the rate of accumulation reducing by 2060. Whereupon the pit reaches a state of 'dynamic equilibrium'. The 'dynamic equilibrium' has small variations throughout the year to account for periods of rainfall and evaporation.
- The mean (average) water level in the South Pit reaches a level of approximately RL 286.5 m to RL 287.5 m.
- The water level in the South Pit never reaches the rim level of RL 334 m. As such, there are no modelled spills or overtopping events. This indicates the South Pit achieves long term containment.
- The maximum modelled water level is approximately RL 295 m. The minimum modelled water level is approximately RL 280 m. These values represent the historically 'wettest' and 'driest' years occurring consecutively through the simulation.

DIAGRAM 16: SOUTH PIT WATER SURFACE ELEVATION – SCENARIO 1

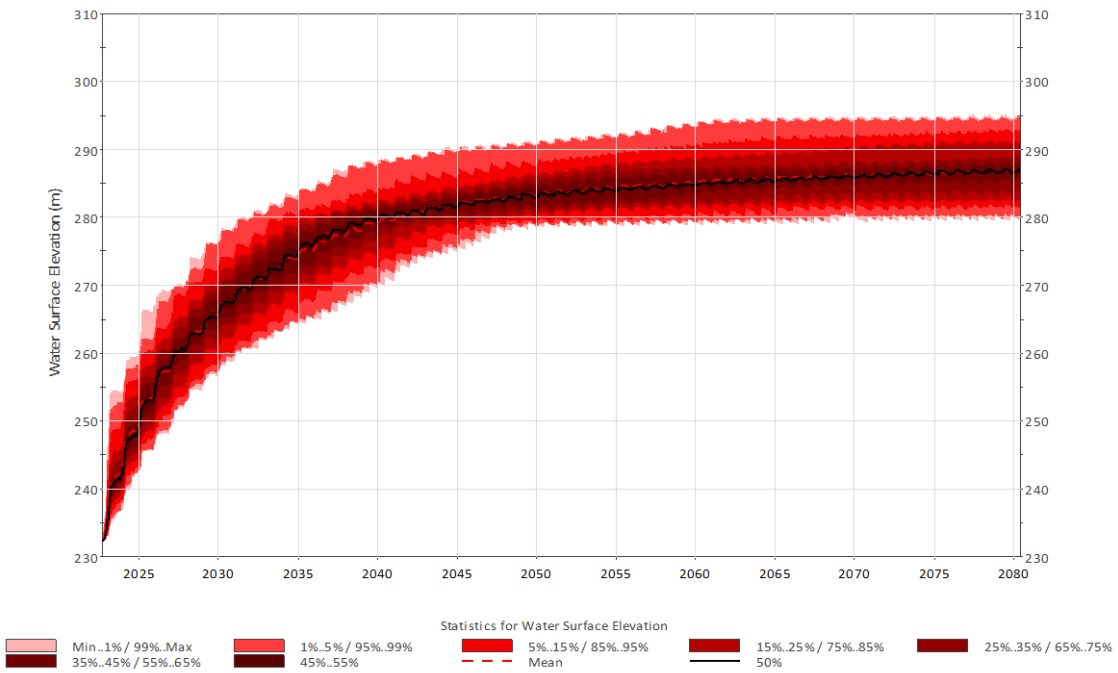

Diagram 17 illustrates the mean accumulated groundwater inflows into the South Pit over a period of fifty-eight (58) years is approximately 775 ML, or approximately 13.4 ML/year throughout the simulation period from 2023-2081.

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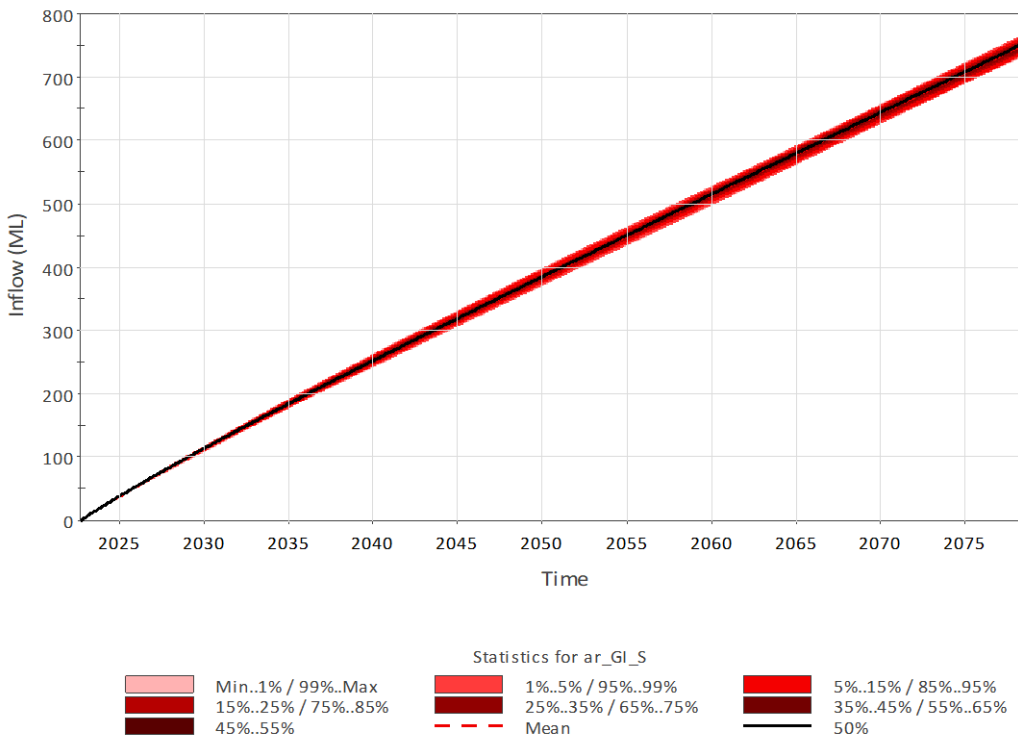
DIAGRAM 17: SOUTH PIT ACCUMULATED GROUNDWATER INFLOWS – SCENARIO 1



There were no modelled groundwater outflows from the South Pit, i.e., groundwater sink.

4.4.3 South Pit – Scenario 2

The following conclusions can be drawn from **Diagram 18**:

- The South Pit rapidly accumulates water to the year 2040, with the rate of accumulation reducing to 2065. Whereupon the pit reaches a state of 'dynamic equilibrium'. The 'dynamic equilibrium' has small variations throughout the year to account for periods of rainfall and evaporation.
- The mean (average) water level in the South Pit reaches a level of approximately RL 290 m to RL 291 m.
- The water level in the South Pit never reaches the rim level of RL 334 m. As such, there are no modelled spills or overtopping events. This indicates the South Pit achieves long term containment.
- The maximum modelled water level is approximately RL 300 m. The minimum modelled water level is approximately RL 282 m. These values represent the historically 'wettest' and 'driest' years occurring consecutively through the simulation.

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DIAGRAM 18: SOUTH PIT WATER SURFACE ELEVATION – SCENARIO 2

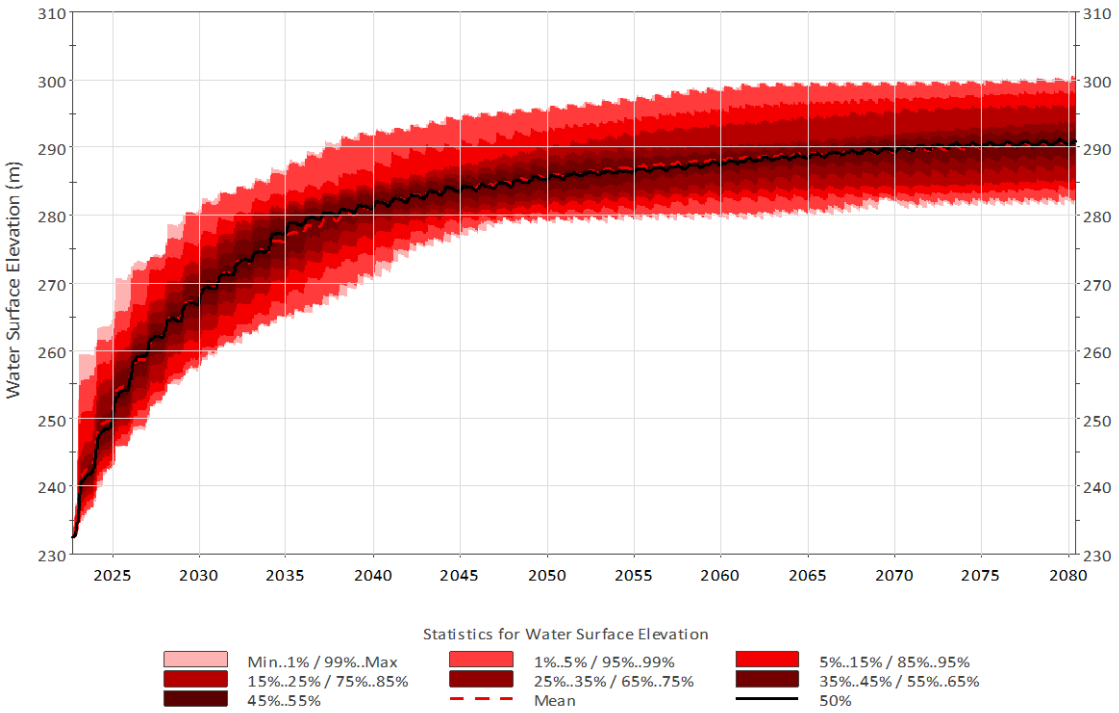
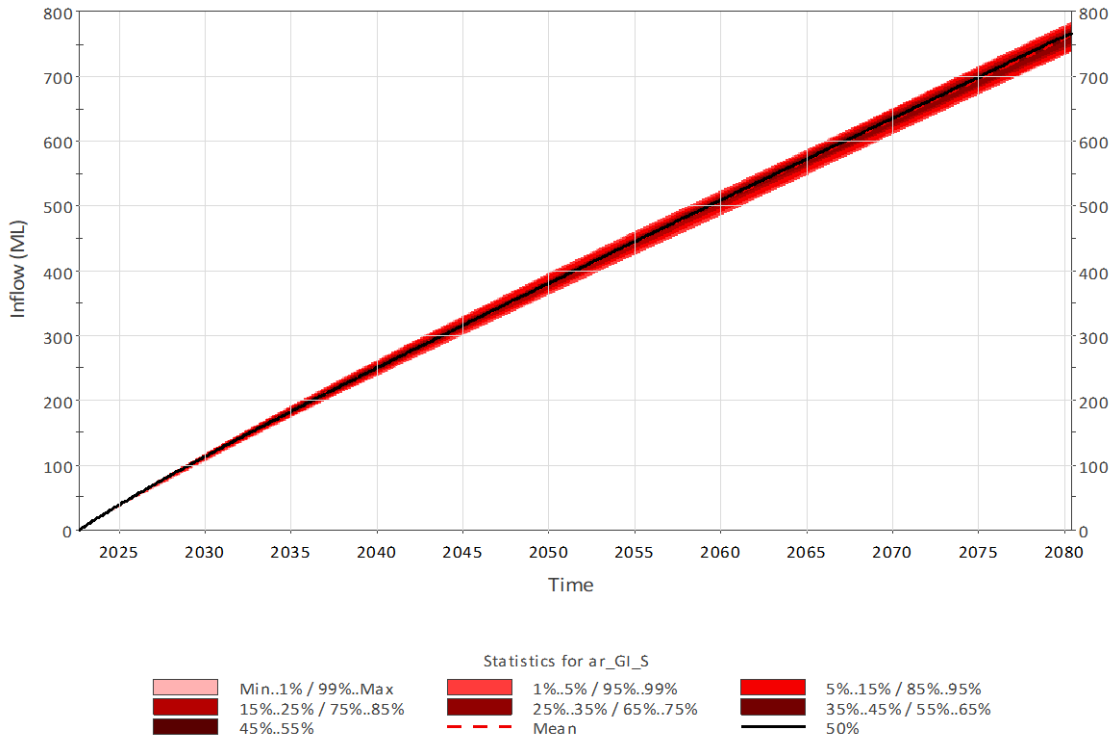


Diagram 19 illustrates the mean accumulated groundwater inflows into the South Pit over a period of fifty-eight (58) years is approximately 775 ML, or approximately 13.4 ML/year throughout the simulation period from 2023-2081.

DIAGRAM 19: SOUTH PIT ACCUMULATED GROUNDWATER INFLOWS – SCENARIO 2



There were no modelled groundwater outflows from the South Pit, i.e., groundwater sink.

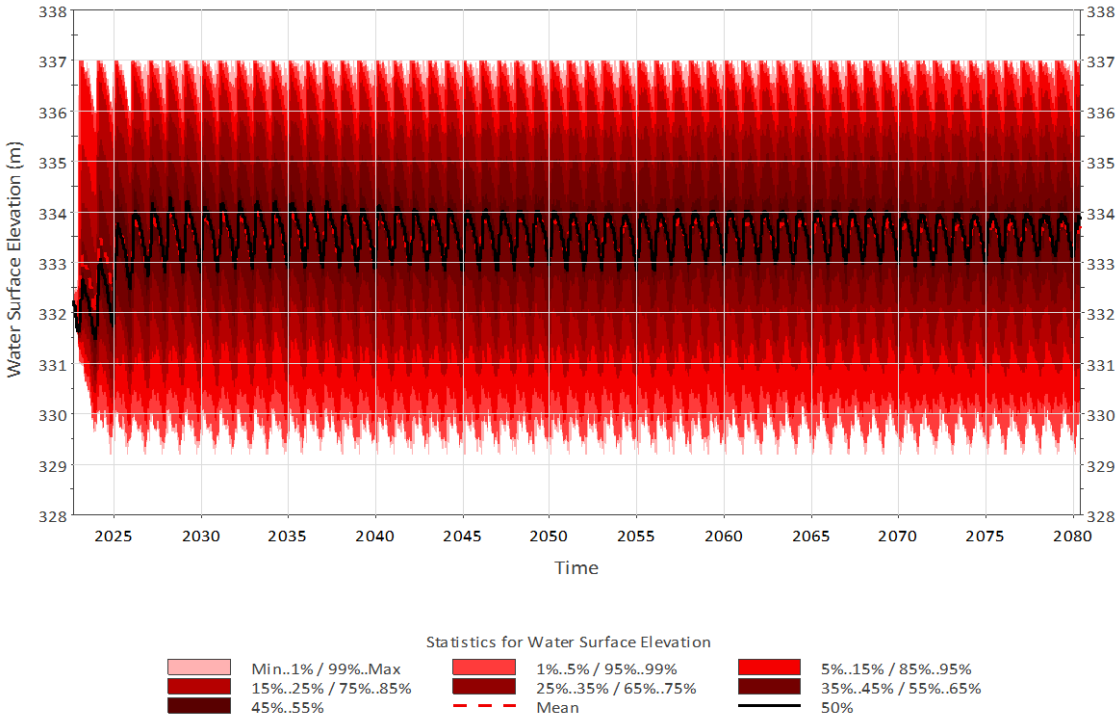
4.4.4 WRD Sediment Dam

The following conclusions can be drawn from **Diagram 20**:

- The WRD Sediment Dam rapidly accumulates water to the year 2027, whereupon it reaches a state of 'dynamic equilibrium'. The 'dynamic equilibrium' has small variations throughout the year to account for periods of rainfall and evaporation.
- The mean (average) water level in the WRD Sediment Dam reaches a level of approximately RL 333 m to RL 334 m.
- The water level in the WRD Sediment Dam reaches the spillway level of RL 337 m each year, which is equivalent to the rainfall exceeding the 95th percentile.

Due to the presence of the HDPE liner on the WRD Sediment Dam, no groundwater inflows or outflows were included or modelled.

DIAGRAM 20: WRD SEDIMENT DAM WATER SURFACE ELEVATION



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5 SUMMARY

At closure, the North Pit residual void has a long term lake level of between RL 308.5 m and RL 309.5 m. The mean groundwater inflow in any year is approximately 1.5 ML/year. The mean groundwater outflow in any given year is approximately 0.0038 ML/year. As such, the North Pit is a net groundwater sink. The North Pit overtops in events greater than the 85th percentile rainfall conditions. An estimated 0.1 ML/yr of groundwater outflows from the North Pit enters the South Pit.

At closure, the South Pit (under Scenario 1) has a long term lake level of between RL 286.5 m and RL 287.5 m. The maximum lake level reaches approximately RL 295 m, which equates to an impounded volume of 1,033 ML. The mean groundwater inflows in any given year is approximately 13.4 ML/year. There were no modelled groundwater outflows. As such, the South Pit is a groundwater sink. The South Pit never overtops, with maximum water level of RL 293 m being lower that the pit crest elevation of RL 334 m.

At closure, the South Pit (under Scenario 2) has a long term mean lake level of between RL 290 m and RL 291 m. The maximum lake level reaches approximately RL 300 m, which equates to an impounded volume of 1,203 ML. The mean groundwater inflows in any given year is approximately 13.4 ML/year. There were no modelled groundwater outflows. As such, the South Pit is a groundwater sink. The South Pit never overtops, with maximum water level of RL 293 m being lower that the pit crest elevation of RL 334 m.

It is recommended that the Scenario 2 fencing arrangement be adopted to provide a higher potential yield in the South Pit. Refer to ATCW **[1]** for further discussion regarding water quality impacts.

The North Pit and South Pit will fill via rainfall over their respective extents, as well as groundwater inflows. Both the North Pit and South Pit reach a level of long term equilibrium just below the surrounding groundwater level.

The WRD Sediment Dam has a long term water level of between RL 333 m and RL 334 m. The WRD Sediment overtops via the spillway in events exceeding the 95th percentile. The WRD Sediment is HDPE lined and is therefore not subject to groundwater inflows or outflows.

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[1] ATC Williams (2023), 'Memorandum - Barbara Copper Project - Geochemical assessment of the North Pit, South Pit and the WRD Sediment Dam', Ref: 118131.12.M02 – dated 17 March 2023.

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[3] Department of the Environment and Science (2020), Environmental Authority EPML00715513 (Effective Date 3 February 2020), Queensland Government.

[4] Eason, D. (2022), 'Aeris Resources, Mt Colin and Barbara - water level data, September 2022', Email, 18th September 2022.

[5] PSM (2020), 'Mine Closure Geotechnical Study, Barbara Copper Project', Ref: PSM2319-041L Rev1, dated 14 December 2020.

[6] Department of Industry and Resources, (1997), 'Safety Bund Walls Around Abandoned Open Pit Mines Guideline', Document Number ZMA048HA, Version 1.0.

[7] The Long Paddock (2021), SILO Data Drill for Cell -20.40, 139.85, accessed 29 April 2022, https://www.longpaddock.qld.gov.au/silo/gridded-data/, Queensland Government

[8] Rob Lait & Associates (2014), 'Barbara Copper Project Hydrogeological Report Copperchem Pty Ltd and Syndicated Metals Pty Ltd Joint Venture', Ref Project No 220, October 2014.

[9] Aeris Resources/Diverse Survey (2021). '210501_Barbara_Points_Filtered_1m_mga94_z54_ahd.dwg', 13 September 2021.

[10] Boughton, W.C. (2004). 'The Australian Water Balance Model. Environmental Modelling & Software', Vol. 19, pp943-956.

[11] ATCW (2020), 'Barbara Copper Project – Water Balance Model for 2020/2021 Wet Season and Care and Maintenance Period', Ref: 118131-09-L001-Rev0', dated 25 November 2020.

[12] Rob Lait & Associates (2013), 'Preliminary Groundwater Assessment Barbara Project Copperchem Pty Ltd', Ref Project No 220, October 2013.

[13] Woessner and Poeter (2020), 'Hydrogeologic Properties of Earth Materials and Principles of Groundwater Flow', 2020.

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COMMUNITY CONSULTATION PLAN

VERSION	DESCRIPTION	POSITION	REVIEWER	DATE
1.0	Initial Plan	Senior Environmental Advisor	Environment and Community Coordinator	January 2022

TABLE OF CONTENTS

1 OVERVIEW 3
1.1 Purpose 3
1.2 Scope 3
1.3 Objectives for Community Consultation 3
1.4 Principles of Community Engagement 3
2 BARBARA COPPER PROJECT COMMUNITY STAKEHOLDERS 4
2.1 Key community groups 5
3 COMMUNITY ENGAGEMENT TOOLS AND INFORMATION PROVIDED 5
3.1 Tools to inform 5
3.2 Tools to consult 6
3.3 Tools to collaborate 6
4 PROPOSED CONSULTATION FREQUENCY 6
5 FEEDBACK 6
5.1 Communication channels 6
5.2 Record keeping 6
5.3 Reporting escalation 7
6 REFERENCES 7

1 OVERVIEW

1.1 PURPOSE

Round Oak understands that effective consultation with the communities within which it operates is central to its social licence to operate. The purpose of this Community Consultation Plan (the Plan) is to set out how Round Oak identifies and engages with the community stakeholders relevant to site specific Post Mine Land Uses (PMLU), as part of the Progressive Rehabilitation and Closure Plan (PRC Plan). It is also designed to ensure that Round Oak achieves compliance with the intent of its Social Responsibility Policy.

The Plan is site specific for the Barbara Copper Project, which is authorised under Environmental Authority (EA) EPML02840015.

1.2 SCOPE

This Plan applies to all Round Oak operations, projects, and exploration activities. Furthermore, this Plan applies to all Round Oak employees, as well as all persons who work for, with, act on behalf of, or represent Round Oak, including subsidiary employees, contractors, visitors, volunteers and anyone working on a Round Oak site, office or other location requested by the company.

1.3 OBJECTIVES FOR COMMUNITY CONSULTATION

Round Oak sets the following objective for its community consultation plan:

- Comply with all legal obligations and company commitments in effect for the Barbara Copper Project, as outlined in the Department of Environment and Science (DES) *Guideline Progressive Rehabilitation and Closure Plans*, ESR2019/4964, dated March 2021. This includes, but is not limited to:
    - Objectives for community consultation;
    - Community engagement tools;
    - Proposed consultation frequency;
    - Information provided as part of community consultation; and
    - How feedback will be considered.

1.4 PRINCIPLES OF COMMUNITY ENGAGEMENT

Round Oak agrees with the standards set by the Minerals Council of Australia through their Enduring Value Framework (MCA, 2015), as they relate to community engagement, specifically Principles Nine and Ten.

Principle Nine

Contribute to the social, economic and institutional development of the communities in which we operate.

Principle Ten

Implement effective and transparent engagement, communications and independently verified reporting arrangements with stakeholders.

These Principles were designed to be consistent with the International Council on Mining and Metals' (ICMM) Mining Principles, including Principles Nine and Ten.

Principle 9 – Social performance

Pursue continual improvement in social performance and contribute to the social, economic and institutional development of host countries and communities.

Principle 10 – Stakeholder Engagement

Proactively engage key stakeholders on sustainable development challenges and opportunities in an open and transparent manner, effectively report and independently verify progress and performance.

To achieve the intent of the Principles, Round Oak is committed undertake its community engagement in accordance with the Foundation Principles for effective community and stakeholder engagement as set out by the South Australian Chamber of Mines and Energy (SACOME, 2012). These are set out in Figure 1.

Inclusive

The engagement process identifies, reaches out to and includes participants who clearly represent all stakeholder groups from community (including Aboriginal and Torres Strait Islanders), government and industry.

Transparent and accountable

The engagement process is transparent and it is clear who is responsible and accountable for its implementation and management of any outcomes.

Clear and informed

The engagement process provides timely, balanced and objective information and promotes shared understanding between and within stakeholder groups. Issues on which stakeholder groups are to be engaged are clearly scoped and the factors that may or may not be influenced by their input are clear. In addition to outlining the key economic and social impacts that a proposal may bring to community and stakeholder groups, a framework for ensuring that the benefits of such a proposal are realised should be clearly articulated.

Accessible and timely

The engagement process is accessible to stakeholder groups. Time to deliberate is provided and an appropriate tone is created to encourage deliberation and the development of informed opinion.

Meaningful

The engagement process and outcomes are considered by regulatory and industry decision-makers and can influence decisions made. The engagement process provides feedback to stakeholder groups on how their input influenced the decision(s) and outcomes.

Figure 1: Foundation principles of effective community engagement (SACOME, 2012)

2 BARBARA COPPER PROJECT COMMUNITY STAKEHOLDERS

A successful community consultation program relies upon the identification of all community stakeholders, understanding the issues of interest or concern for each stakeholder, determining the appropriate level of engagement for each stakeholders, and utilising appropriate communication tools to engage with each stakeholder. These considerations (both opportunities and threats) should be captured through Round Oak's risk assessment process.

2.1 KEY COMMUNITY GROUPS

There is the potential for only a few or many community stakeholders to have an interest in the activities associated with a project or operation. These can include, but are not limited to:

- Affected landowners;
- Landowners necessary to access of land to which the PRC Plan relates;
- Traditional Owner groups (and associated Trustees);
- Local Government; and
- Local community groups.

Table 1: Key community stakeholders for the Barbara Copper Project

Stakeholder	Contact details
Adjoining landholder	Ron and Joan Croft – West Leichardt Station (07) 4743 8947 Lot 1 on AA29 West Leichardt Holdings Mt Isa, QLD 4825
Shire Council	Mount Isa City Council (all enquiries) (07) 4747 3200
Native Title claimant group	Kalkadoon Native Title Aboriginal Corporation 109 Barkly Highway (07) 4749 2766

3 COMMUNITY ENGAGEMENT TOOLS AND INFORMATION PROVIDED

There is a wide range of community engagement tools that can be, and are, employed by Round Oak to engage with the communities within which it operates. Selecting the right engagement tool that reflects the nature of the engagement is an important aspect of ensuring the engagement process is successful.

The types of community engagement tools utilised as part of the PRC Plan process are as follows:

1. Tools to inform;
2. Tools to consult; and
3. Tools to collaborate.

3.1 TOOLS TO INFORM

The first tier of community members is those who should be 'informed'. These community members are typically local individuals / landowners with general interest in the future of the Project. These community members only want to know 'what is going on', with direct communication to each landowner being undertaken. If available, newsletters and updates are also suitable communications media. Round Oak will provide objective and balanced information to inform community members on what is planned, and the progress being made with these plans.

3.2 TOOLS TO CONSULT

The second tier of community members is those who should be 'consulted'. They will have a direct interest and will want to both be informed and to provide feedback. This tier includes selected neighbouring operators and most government agencies (including DES and Mount Isa City Council). Meetings or forums will be held with these community members so that concerns and issues can be identified, and practical solutions or actions imposed. Targeted supplementary email updates may also be used.

3.3 TOOLS TO COLLABORATE

The third tier is community members who need to be 'engaged' and who have the potential to be directly impacted. This tier is those who have a direct and influential role in Local government, key State government agencies, cultural heritage groups, landholders and landholders on the land necessary for access to the land to which the proposed PRC Plan relates to. The best method of consultation for this tier is regular, face to face meetings enabling candid discussions to occur. Some of the things that can contribute to the success of these groups include:

- A clear terms of reference for the group;
- Continuity of representatives from both the company and stakeholders;
- Advanced scheduling of regular meetings;
- Notification of an agenda for each meeting prior to the meeting;
- Documented and distributed minutes that include the tracking of actions raised; and,
- Provision of supporting materials for items covered in meetings, where appropriate.

4 PROPOSED CONSULTATION FREQUENCY

Consultation should occur prior to any PRC plan schedule amendments that are likely to impact the community and the register should be updated when this consultation is finished.

Ongoing community consultation will continue throughout completion of proposed milestones so that progressive rehabilitation and the socio-economic and environmental impacts related to mine closure can be discussed with the community.

5 FEEDBACK

5.1 COMMUNICATION CHANNELS

Round Oak will maintain a range of channels by which stakeholders associated with the Project can communicate with the business to make inquiries, raise complaints, or to express grievances. These channels will include sufficient options so that community members are not restricted in their ability to provide feedback due to technological or other limitations.

As a minimum, Round Oak will make available contact details that allow communication by post, email, and telephone.

5.2 RECORD KEEPING

All complaints and grievances will be recorded as HSEC events in the InControl® event management system. If requested, a complaint or grievance can be made anonymously. General inquiries may be recorded as an InControl® event where it is felt that a record of the inquiry might be appropriate, or where any follow up actions will take some time to complete, and their progress needs to be tracked.

A community consultation register has been formulated to electronically track the following:

- Consultation date;

- Identification of each community member;
- Description of consultation type;
- Information provided;
- Issued raised;
- How issues have been considered;
- Decisions and outcomes of the engagement; and
- Any commitments made by Round Oak.

5.3 REPORTING ESCALATION

Any feedback received in relation to potential criminal activity will be managed in accordance with relevant local laws and regulations, as well as applicable Round Oak procedures.

Any report of potentially inappropriate behaviour by a Round Oak employee, contractor, visitor, or volunteer will be directed to the Round Oak Human Resources team for investigation and management.

Escalation of feedback from the community within the Round Oak organisation will occur in accordance with the timeframes set out in **Table 2**. Escalation is to be based upon a risk assessment of the issue that has been raised. (Risk assessment occurs as part of the standard process for entering a HSEC event into InControl®.)

Table 2 Internal escalation of community feedback based upon risk

Risk level	E&C Coordinator	HSEC Manager	General Manager	COO and CEO
Low	Within 2 days			
Medium	By the end of shift	Within 2 days	Within 2 days	
High	Within 2hrs	By the end of shift	By the end of shift	Within 2 days
Critical	Immediately	Within 2hrs	Within 2hrs	By the end of shift

6 REFERENCES

Department of Environment and Science (DES) (2019), 'Guideline – Progressive Rehabilitation and Closure Plans', ESR/2019/4964, March 2021, version 2.00, Queensland Government

International Council on Mining and Metals (2020), Mining Principles – Performance Expectations

Minerals Council of Australia (MCA) (2015), Enduring Value – The Australian minerals industry framework for sustainable development

SACOME (South Australia Chamber of Mines and Energy), 2012, Code of Practice for Community and Stakeholder Engagement