



MOUNT RAWDON ENVIRONMENTAL EVALUATION

Stage 2: Geochemical Transport Model

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1 Executive Summary

Evolution Mining operates Mount Rawdon Operations (MRO), an open pit gold mine located 75 km southwest of Bundaberg in Queensland, Australia. The mine produces about 100,000 ounces of gold each year, and has produced 1.8 million ounces of gold since 2001. Projected production is estimated to be a further 24.65 Mt at 0.68 g/t of gold ore reserves until the anticipated end of mine life in 2027.

Mining excavates about 7 Mt of waste rock each year that requires onsite storage. The Waste Rock Management Plan used by MRO is based on acid-base accounting of total sulfur and carbon, and uses a block model to identify the different rock types across the mine to inform selective handling and placement of excavated rock. Excavated waste rock that is potentially acid-forming is either placed below the water blanket in the TSF where it is encapsulated by acid neutralising calcite, albite and chlorite silt (tailings), or placed in the Northern Waste Rock Dump (NWRD) under non-acid-forming (NAF) rock and a compacted clay cap. The NWRD has been designed to produce neutral drainage, with acid runoff formed in the centre of the dump passing through the cover of neutralising rock. The outer batter walls of the TSF as well as the West Waste Rock Dam (WWRD) are used to store NAF, which weathers more slowly than the potentially-acid-forming rock (PAF), and hence by design the outer batter walls of the TSF and the WWRD generate less neutral mine drainage than the NWRD.

Water egressing from the TSF and the NWRD consistently reports elevated concentrations of sulfate and nitrate, as well as occasionally reporting elevated concentrations of dissolved heavy metals. Stormwater and seepage water from the TSF and NWRD are captured by interception dams such as Waste Rock Dam 2 (WD2).

The Environmental Authority EPML00712113 (EA) at Conditions E18 – Schedule E27 states the operating conditions relevant to groundwater that MRO is required to comply with. The Notice to conduct an Environmental Evaluation requires an explanation of exceedances of the groundwater trigger values stated in the EA, noting that there is no indication of contamination based on seven years of AUSRIVAS monitoring performed in creeks as well as an investigation of aquifer stygofauna. In response this report (the Stage 2 investigation) provides detailed reviews of (a) the history of mining - affected water seeping below the TSF and waste rock dumps in the mining lease, (b) the geophysical structure of aquifers that impede and transmit seepage, and (c) the efficacy of mitigation at addressing the influence of mining on groundwater quality. Outputs of the report are a method for distinguishing mining-affected water from the local background, proposed groundwater trigger limits for the mining lease, and proposed improvements to stabilize and address mining influences on groundwater.

The Mine is comprised of several mining leases. These boundaries are not directly pertinent to the investigations described in this report and, accordingly, the Mine is referred to as a single premises throughout, with various features, attributes, or specific locations described as relevant.

The extent of mining influence, and transfer of Chemicals of Potential Concern in the mining lease

The current horizontal and vertical extents of mining related groundwater seepage, and the rates and directions of movement of Chemicals of Potential Concern (COPCs) in groundwater, were identified by interpreting trends observed in time series graphs of water quality data from monitoring bores. These trends were reproduced by predictive computer modelling of solute transport along flow-paths from mining infrastructure towards receiving environments. The proportions of mining-affected and native groundwater that were predicted by modelling are described below. The vertical extent of mining - affected groundwater was inferred, using geophysical images, to be predominantly in shallow weathered rock. The horizontal extents along the following pathways were:

1) Seepage west of the TSF: Mining-affected water has contacted the riparian zone of upper Swindon Creek. Based on a modelling estimate, in May 2018 the shallow aquifer in the

riparian zone reported 4.1% TSF fluid, 19.7% solutes generated in the outer batter wall of the TSF, and 76.1% native groundwater, whereas the deep aquifer in the riparian zone reported 3.5% TSF fluid, 2.1% solutes generated in the outer batter wall of the TSF and 94.5% native groundwater. Mitigation is proposed to stabilise the mining influence.

2) The Northern Seepage Zone: Mining-affected water has contacted the riparian zone of lower Swindon Creek, and penetrated along the landscape spur between Swindon Creek and the unnamed creek. In May 2018 the riparian zone in lower Swindon Creek at MRMB12 reported a mix of 1.4% TSF fluid, 44.8% solutes generated in the outer batter wall of the TSF and 53.7% native groundwater. Mitigation has delayed the effect of mining on groundwater, but more mitigation is needed.

3) Rawdon Creek: Mining-affected groundwater has penetrated along Rawdon Creek. Some of this movement could relate to historic overtopping of Sediment Dam 1 (SD1) in 2012, 2015 and 2017 and to temporary damage of the clay lining of SD1 in October 2011 (repaired in 2012). In May 2015 the shallow aquifer in Rawdon Creek below what is now the footprint of the dam wall of Sediment Dam 3 (SD3) reported a mix of 6.4 - 9.5% TSF fluid, 2.2 - 4.3% solutes generated in the outer batter wall of the TSF, and 88 - 89% native groundwater. In an adjacent paired bore that screened both the shallow and deep aquifers reported 10 - 42% TSF fluid, $\leq 3\%$ solutes generated in the outer batter wall of the TSF and 54 - 90% native groundwater. The mining influence on groundwater has stabilised since SD3 was commissioned in 2017, and more mitigation immediately downstream of SD3 is planned to further address the mining influence.

4) Twelve Mile Creek (including the landscape spur between Rawdon Creek and Twelve Mile Creek): Mining-affected water has been drawn into pump-back bores MRMB26 and MRMB27, and there is evidence that the mining-influence in MRMB63 has stabilised and reversed between 2014 and 2018. In May 2016 the shallow aquifer in Rawdon Creek reported a mix of 26% WD2 type water and 73% native groundwater, and

5) The southern drainage to Mingham Creek: Mining-affected water has penetrated the ground below South Dam and the processing plant. Seepage of mining-affected water has not progressed significantly past South Dam. In February 2013 the fractured rock aquifer in the southern drainage below the current footprint of the WWRD reported $<1\%$ TSF fluid, 1.8% solutes generated in the outer batter wall of the TSF, and 97% native groundwater.

Groundwater trigger limits and descriptions of groundwater in the mining lease

Groundwater trigger limits that verify the current and predicted extent of mining-affected groundwater seepage were calculated using a procedure that is particularly suitable for the compartmentalized and heterogenous groundwater system in the Mount Rawdon mine lease, as defined by the Queensland Water Quality Guidelines (2009) Section 4.3.5, 5(a). Since the Queensland Water Quality Guidelines (2009) are referenced by DSITI (2017), this approach is consistent with the requirements for the Environmental Evaluation.

The proposed groundwater trigger limits are tabled in this report as total concentrations. These trigger limits are not intended to be pass or fail criteria, and by definition do not necessarily signify contamination because 20% of high, but not contaminating background concentrations, will exceed the trigger limits. Rather the limits represent conservative values that trigger further investigation into whether the exceedance is mining related, and if mining related, the toxicological and biological significance to receptors. This approach is consistent with the precautionary principle applied by the Australian Water Quality Guidelines.

Descriptive water quality statistics for each groundwater monitoring bore were reported as boxplots, Piper diagrams, time-series graphs and summary tables to represent compositions for groundwater and for mining - affected water. These helped to describe groundwater in the mine lease area, and the extent of seepage from the TSF and waste rock dumps.

Chemical speciation modelling and potential for contamination

Chemical speciation modelling in *Visual MINTEQ* was used to identify the activities of dissolved solutes in groundwater, and the potential for some solutes to be transmitted through

aquifers during groundwater transport and/or be immobilised by coprecipitation with aquifer minerals. The speciation model identified significant modification of the activities of Al^{3+} and Cr^{3+} by about 80% relative to the total concentrations of these COPC measured in groundwater, and activities of Cd^{2+} , Cu^{2+} , Fe^{2+} , Mn^{2+} , Pb^{2+} and Zn^{2+} were modified by about 50% relative to total concentrations. Carbonate, hydroxyl and oxide complexes were identified by the speciation modelling as important components of the groundwater matrix. Modelling showed that several COPC (Cd^{2+} , Fe^{2+} , Mn^{2+} and Zn^{2+}) exist predominantly as free ions.

The predominance of secondary mineral precipitates in the aquifer, which include calcite, dolomite, pyrolusite and iron-oxides demonstrate that some solutes are removed from groundwater by co-precipitation as aquifer minerals. Because toxicity tests have not been performed, we have not established the exposure limits of aquatic organisms to mining - affected water from MRO, and it is unclear whether the complexes have converted solutes to forms that are less toxic, or less biologically available. However, it is possible to make general observations that a recent investigation of stygofauna reported low occurrence and limited taxa of subterranean fauna in groundwaters of the Mine, and seven years of AUSRIVAS monitoring between 2013 and 2020 has also consistently indicated a low probability that mining activities have influenced stream macroinvertebrate assemblages.

Inverse modelling and solute transport modelling

A source term for neutral mine drainage generated in the TSF was developed using NETPATH and PHREEQC modelling software, informed by measured solute concentrations in the decant, known mineral weathering processes in the TSF, and known mineral weathering processes affecting the waste rock used for the outer batter wall of the TSF. Inverse modelling mixed these mine-derived source terms to describe seepage from the TSF. The model source terms were compared with observed tailings seepage from Sediment Dam 1 and Seep 26 (a known tailings seep), and the comparison demonstrated reasonable fit for major ions. A source term for neutral mine drainage from the Northern Waste Rock Dump is also described in the report.

Inverse modelling in NETPATH and geochemical transport modelling in PHREEQC, were used to quantify the reactive transport of COPC's from the TSF and waste rock dumps towards ephemeral creek-lines in the mining lease. Solute movement was modelled along five flow-paths from the TSF and waste rock dumps, which identified the respective rates of COPC movement along these paths and allowed prediction of the potential for COPC migration to the creeks with no seepage mitigation as a base-case, as well as with seepage mitigation which is discussed below.

Agreement between modelled PHREEQC concentrations with measured groundwater data was done manually with an emphasis on matching the modelled sulfate concentrations with the observed sulfate concentrations in breakthrough curves in monitoring wells. A sequential order of processes was simulated, with the best match at each step being built on by the sequential step. The stepwise processes were (1) Darcian flow velocity controlled by adjusting the hydraulic conductivity of the aquifer across the measured range in the mining lease, followed by (2) exchange of cations between aquifer minerals and groundwater controlled by adjusting the cation exchange capacities for sodium, potassium, magnesium and calcium and adjusting the specific surface areas attributed to hydrous-ferric oxide (HFO), across the ranges of measured cation exchange capacities (CECs determined using 1M ammonium acetate extractions at pH 7) and estimated proportions of iron oxides (using Tamm's reagent) from representative aquifer samples, and (3) evaporation. These three processes were evaluated sequentially and in combination, using a progression of 4 or 5 steps representing low, middle, high and extreme concentrations across the measured data ranges. The models that agreed best with data observed in monitoring bores along the respective flow-paths, were used to represent the unmitigated or base-case models.

Recommended strategy for stabilising and reversing mining influences

A detailed investigation of seepage flow-paths below the TSF, NWRD and WWRD was performed using the most plausible models in predictive mode. The investigation simulated the expected effect of dewatering mining-affected groundwater to achieve a lower hydraulic head potential that would slow the seepage of mining-affected groundwater towards receiving environments. This report has identified potential improvements to seepage management that could result from extending the Seepage Interception Drain to capture seepage to the west of the TSF, as well as commissioning additional pump-back bores. Recommendations are:

1. Extend the Seepage Interception Drain, and install additional pump-back bore capacity, to improve interception of mining - affected groundwater potentially seeping into upper Swindon Creek. These mitigations should limit groundwater discharge from 7 m³/day to 4.9 m³/day, which would slow breakthrough after which mitigations associated with mine closure could be implemented.
2. Install additional pump-back capacity (e.g. two pump-back bore's and equip MRMB31) to intercept mining - affected groundwater seeping towards lower Swindon Creek. The combined effects of the Seepage Interception Drain and enhanced pump-back capacity could limit groundwater discharge along the B - B' flow-path from 2.5 m³/day to 0.3 m³/day. This would delay breakthrough to a time commensurate with mine closure.
3. Long term groundwater monitoring along Rawdon Creek indicates that trends of mine impact in this creek are stabilizing. The Seepage Interception Drain has slowed groundwater discharge along the C – C' pathway from about 3.5 m³/d to 3.2 m³/d. With additional pump-back capacity, groundwater flow along this pathway could slow even further to about 2 m³/d.
4. In Twelve Mile Creek existing mitigation includes pump-back bore MRMB27, which dewateres seepage from WD2 along the D - D' transect at about 1/3rd of the groundwater discharge along this flow-path (12.4 m³/day). This cone of depression might not intercept all seepage from WD2, and a geophysical survey was performed to investigate the extent of aquifer connections in this sub-catchment and where additional mitigation (a second pump-back bore) is needed.
5. In the southern drainage, modelling indicated that the risk of mining-affected water causing contamination in Mingham Creek was low. Based on this analysis, no additional mitigation along this drainage line is required.

A costed schedule and timeframe for implementation is provided in the report. This comprises an estimated \$600,000 to be implemented in FY21, with ongoing monitoring. It might be necessary to implement additional dewatering bores between FY21 and mine closure in 2026, which will be done if monitoring results indicate that further dewatering across seepage pathways is necessary. After 2026 the closure plan will update and supersede the seepage management plan proposed by this report.

2 Introduction

Mount Rawdon Operations is required to control and prevent seepage to groundwater and surface waters under the EA. In 2018 a Notice to commission an Environmental Evaluation (STAT 1254 EPML00712113) was issued to MRO by the Queensland Department of Environment and Science (DES). The Notice discusses exceedences of trigger values listed in the EA that had been observed in some groundwater monitoring bores, and seeks to better understand the natural and potential mine influences leading to these monitoring results. A Stage 1 report was submitted and presented to the DES in November 2019. Stage 2 of the Environmental Evaluation requires the following deliverables:

Stage 2: Mapping potential contaminant migration, assessment of various options for remediation and selection of appropriate options

- *Item 5. Identify and describe the pathways and mechanisms for the release and transport of contaminants to groundwater, due to activities conducted at the premises.*
- *Item 6. Determine the current horizontal and vertical hydrogeographical extents of contaminants released to groundwater due to activities conducted at the premises, as well as rates and directions of movement of contaminants in groundwater through undertaking transient solute transport modelling using appropriate contaminants.*
- *Item 7. Predict likely future extent of current contaminant migration and impact using the transient solute transport modelling outlined in Requirement 6.*
- *Item 8. Undertake calibration and sensitivity analysis of the transient solute transport model.*
- *Item 9. Submit to the department the calibrated transient solute transport model, including: a summary of the findings; visual representation of the current and future horizontal and vertical hydrogeographical extents of contaminants; assumptions relied upon; and uncertainties and exclusions.*
- *Item 10. Determine, and install any additional monitoring bores with sufficient geographical coverage to assist in quantifying the magnitude and extent of existing groundwater contamination caused by mining activities at the premises.*
- *Item 11. Determine, and install any additional monitoring bores with sufficient geographical coverage to assist in quantifying the magnitude and extent of modelled likely future extent groundwater contamination caused by mining activities at the premises.*
- *Item 12. Assess impacts and potential impacts to groundwater and surface waters. The assessment must include:*
 - *A) descriptive water quality statistics for each groundwater monitoring bore at the premises including date range, count, mean, minimum, median and 80th and 95th percentiles (and 5th and 20th percentiles for pH),*

- B) box plots for all groundwater monitoring bores at the premises for each identified groundwater contaminant showing the minimum, the median, 20th and 80th percentiles, and the maximum,
- C) spatial trends in groundwater contaminants at the premises,
- D) temporal trends in groundwater contaminants including time series plots for all groundwater monitoring bores at the premises for all contaminants

[Note: the method for assessing groundwater quality must be consistent with the guideline: Using monitoring data to assess groundwater quality and potential environmental impacts. Version 1. Department of Science, Information Technology and Innovation (DSITI) 2017, Queensland Government, Brisbane or a later version].

- *Item 13. Identify appropriate groundwater limits that will provide for verification of the current and predicted horizontal and vertical hydrogeographical extents of contaminants released to groundwater due to activities conducted at the premises.*
- *Item 14. Identify all potential options and estimate corresponding implementation timeframes and costs for:*
 - *A) the prevention of further contaminant releases from the premises to groundwaters, and*
 - *B) remedial measures to reduce contaminant concentrations in groundwaters*
- *Item 15. Nominate the preferred options from Requirement 14*

The studies described in this report employed the geochemical speciation model Visual MINTEQ 3.1, the inverse modelling software NETPATH, and geochemical transport modelling using PHREEQC to address these requirements.

Stage 1 of the Environmental Evaluation developed a conceptual hydrogeological flow model, and a steady-state groundwater flow model in MODFLOW-SURFACT. The results of the model simulations were used to identify the groundwater flow-paths in the Mount Rawdon Mining Lease area (the Mine). The modelling results, as outlined below, identify the locations of groundwater expression (and associated solutes) into drainage lines of the mine lease.

After the Environmental Evaluation has been completed, DES will be required to decide whether any further steps are necessary. This Report proposes alternative groundwater triggers which could be included in the EA to better reflect the existing environment and observed and expected/modelled developments in solute composition and fate.

2.1 Overview

A schematic of the main groundwater flow-paths in the Mine that illustrates the sources of solutes, groundwater flow-paths that transfer solutes through the landscape, and barriers / conduits to groundwater flow is provided in Figure 1. A conceptual model for regional salinity developed by Douglas and Cox (1994) is included with Figure 1. The schematic and conceptual model show the main aquifers (fractured rock, weathered rock, colluvium and alluvium) that facilitate groundwater movement, and flow barriers (dykes, lithological contacts) that direct groundwater to surface exfiltration points. Backflow of groundwater from the river towards the flanking landscape, through alluvium of creek-lines was identified by Douglas and Cox (1994). These images are not to scale.

A geological map (Figure 2) and geological cross sections (Figure 3) show the main lithologies and geological structures in the Mine. The map shows the locations of groundwater bores

and groundwater groups identified by multivariate statistical analysis of water chemistry. Group 1 represents predominantly tailings seepage affected groundwater, Group 2 represents predominantly waste - rock affected seepage and group 4 represents groundwater (some of which has been mining - affected) that is hosted in Curtis Island Group meta-sediments with dacite or granite intrusive rock (refer section 3.3.1 of the Stage 1 report).

Maps showing the locations of groundwater flow-paths, the potential for groundwater exfiltration to the surface, and the location of groundwater monitoring bores are reported in Section 2.3.

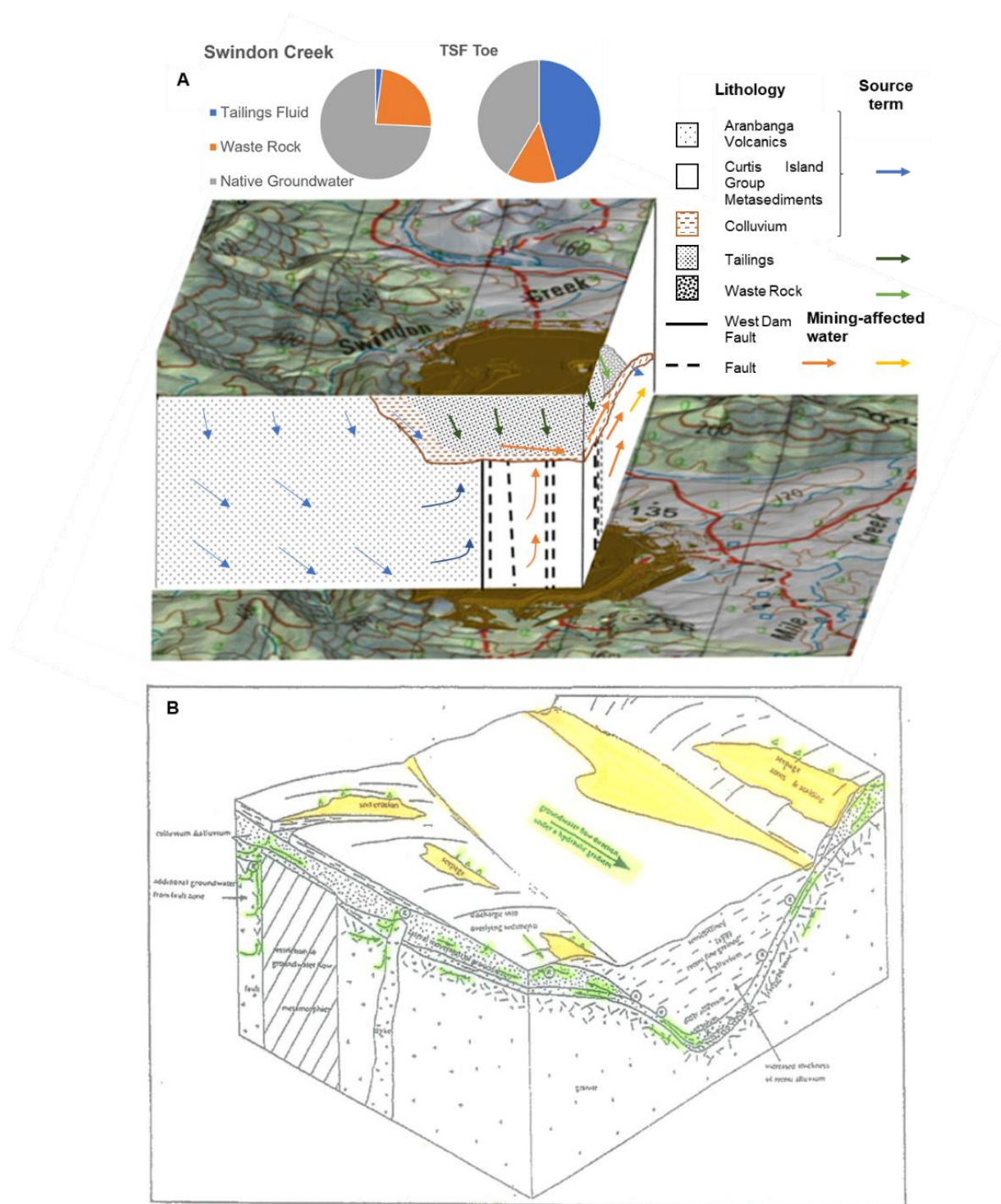


Figure 1: Overview of the main groundwater flow-paths in the Mount Rawdon mine lease ¹

¹ (A) Schematic showing the main lithologies in the Mine, groundwater flow-paths, and barriers / conduits to groundwater flow. Source terms represented are tailings fluid and waste rock seepage (both mining related) and native groundwater. These source terms form mixtures of mining-influenced groundwater that migrate slowly downslope towards ephemeral creek lines. The Pie charts show mixtures of mining affected water sampled in 2006 from MRMB9 (close to the toe of the TSF) and from MRMB12 (close to Swindon Creek). (B) Conceptual model for regional salinity developed by Douglas and Cox (1994).

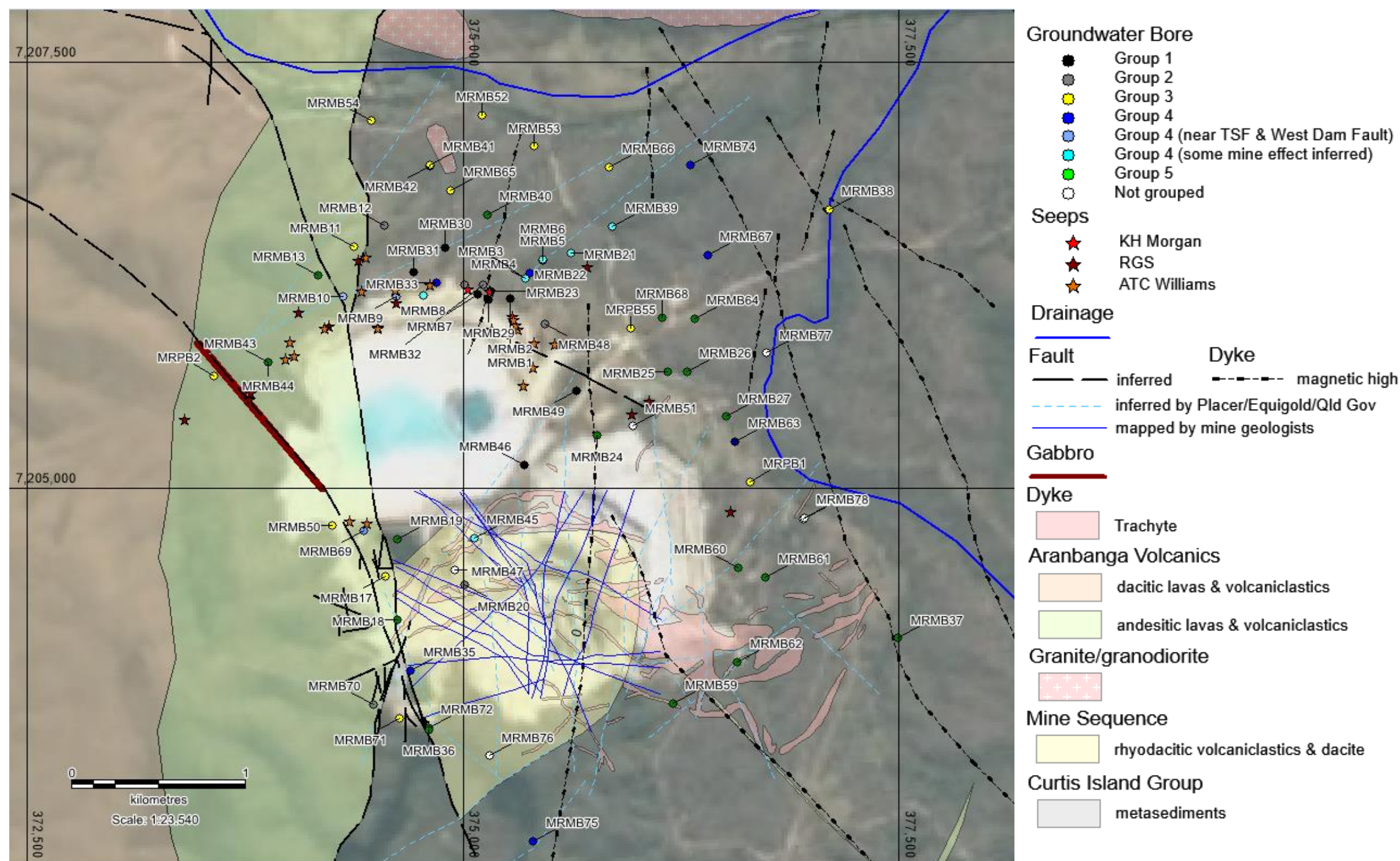


Figure 2: Spatial locations of groundwater classification groups in the Mount Rawdon Mine Lease ²

² Groundwater in Group 1 has been influenced by tailings seepage, in Group 2 by waste rock seepage (except for MRMB70 for reasons discussed in the Stage 1 report), and in Groups 3, 4 & 5 predominantly by geology and landscape. Mine influenced groundwater has affected Group 4 groundwater near the intersection of the TSF & West Dam fault, and along Rawdon Creek. Refer to section 3.3.1 of the Stage 1 report for information about the multivariate classification of groundwater types in the Mine.

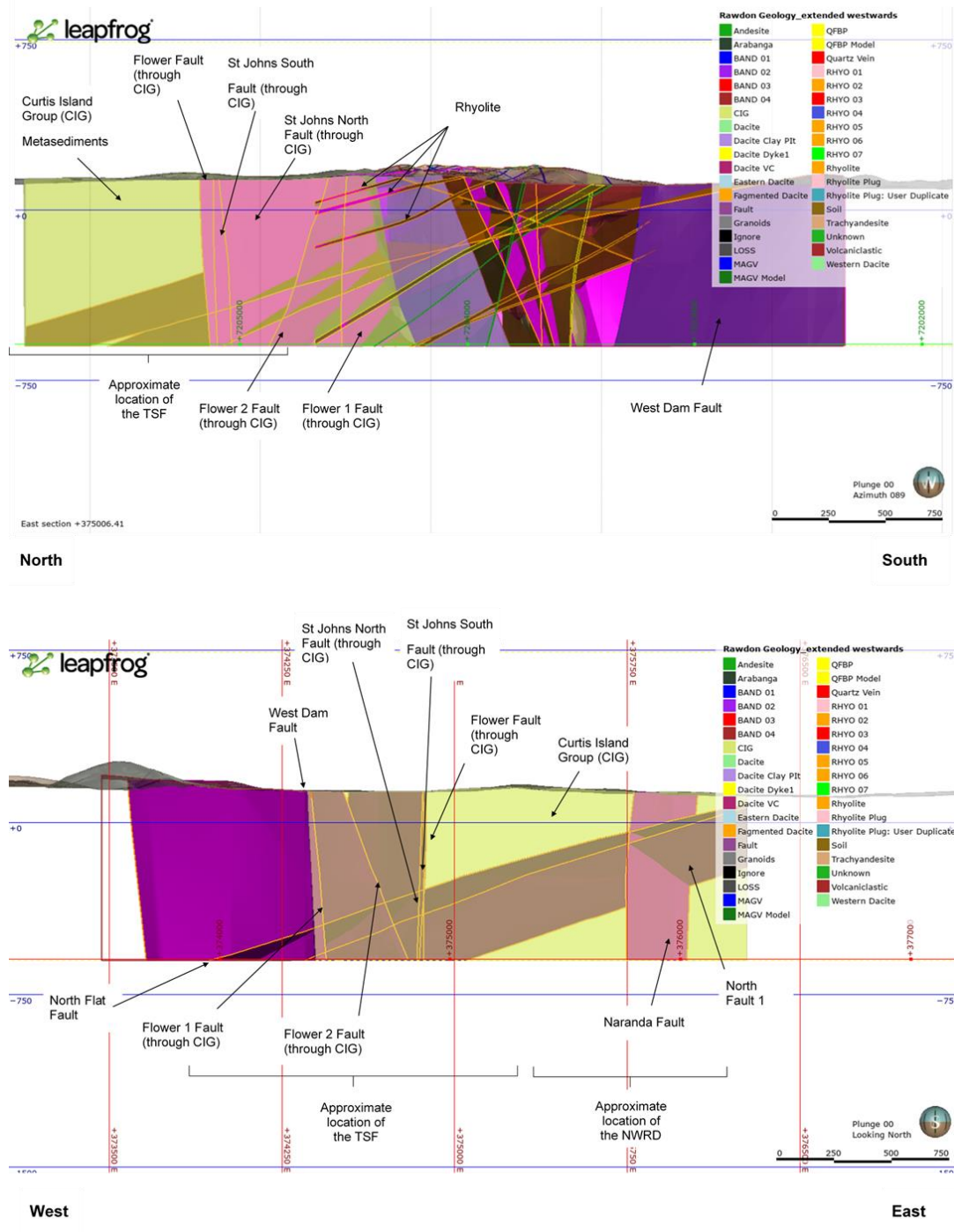


Figure 3: Geological cross sections³

³ Geological cross-sections north to south along easting 375000 (top image), and west to east along northing 7205200 (bottom image). The sections show the major faults, colour enhanced to represent their apparent strike and dip, which are at oblique angles to the cross-sections. The Curtis Island Group lithology, TSF and NWRD are shown. The cross-sections are located approximately along the edges of the raised block shown in Figure 1.

2.2 Conceptual Hydrogeological Model

Previously developed and well-established conceptual hydrogeological models of dryland salinity, which describe the generation and movement of solutes in catena soils of the Central Burnett, apply to the Mine (Douglas and Cox 1994, Queensland Government, 2003). These conceptual models describe the natural hydrological and hydrogeological process, as they occur unaffected by mining activities. Following these conceptual models, granite weathering in sloping terrain generates solutes that concentrate on lower slopes, and there is a moderate hazard of salt expression on the lower slopes of Mingham Creek south of the TSF and the WWRD, as well as moderate hazard of salt expression into Twelve Mile Creek east of the TSF and the NWRD, and into Rawdon Creek north east of the TSF.

After mining commenced, the TSF and later the NWRD became the highest hydraulic head features in the area leading to groundwater mounding below these post mining features. The pit became the lowest head feature in the area. The presence of flow barriers (faults between the pit, TSF and surrounding strata) has led to little inflow into the pit. Groundwater flow potentials across the Mine have been altered by mining-related water management activities.

The conceptual model described in the Stage 1 Environmental Evaluation report (the Stage 1 report) proposed that the principal components of the median ionic compositions of water in the Mine were consistent with:

1. Weathering of feldspar and carbonate in the natural landscape, represented by high concentrations of sodium and bicarbonate coupled with low concentrations of nitrate,
2. Solutes generated by the mining and processing of mineralized ore, represented by high concentrations of sulfate, nitrate, total cyanide and arsenic, and
3. Solutes generated from unmined mineralized sources, represented by high concentrations of arsenic and low concentrations of total cyanide.

The Stage 1 report identified the interactions of mining-affected waters with groundwater along flow-paths towards Swindon Creek, Rawdon Creek, Twelve Mile Creek and Mingham Creek. The solute transport behavior along these flow-paths has been simulated as part of the Stage 2 investigation (detailed in this report).

Further details of the conceptual model, and hydrogeological features of the Mine, are provided in the Stage 1 Environmental Evaluation report (refer sections 3 and 4 of the Stage 1 report).

2.3 Groundwater Flow-paths

The MODFLOW-SURFACT model in the Stage 1 report identified the contemporary movement of groundwater across the mine lease, which included groundwater exfiltration to the surface and into drainage lines, and hyporheic groundwater movement along the drainages. These groundwater flow and surface expression pathways are shown in Figures 4 – 6 (also refer to sections 3.4 – 3.5 of the Stage 1 report).

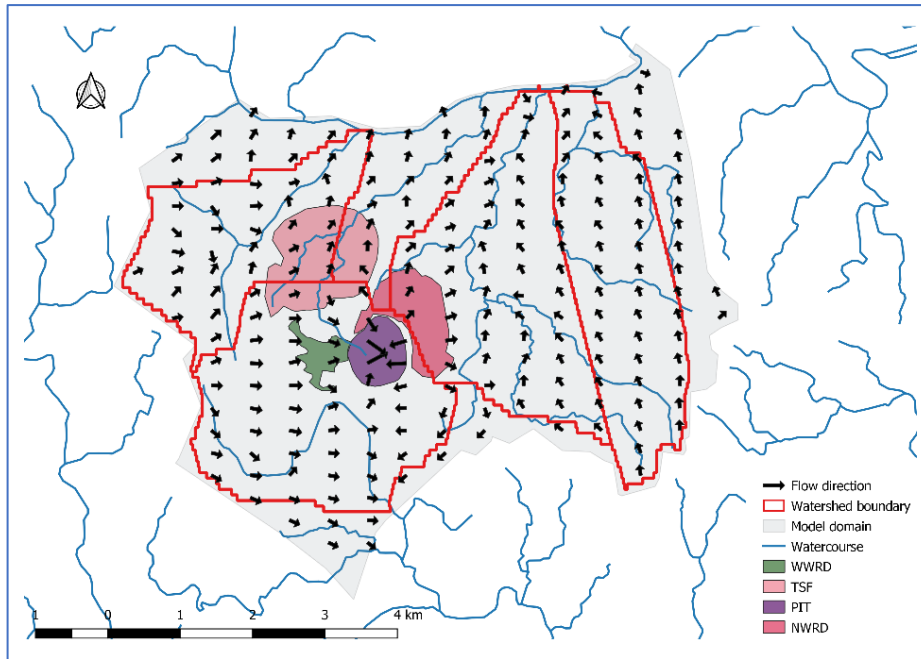


Figure 4: Groundwater movement in the mine lease (Source: Northern Resource Consultants, 2019)⁴

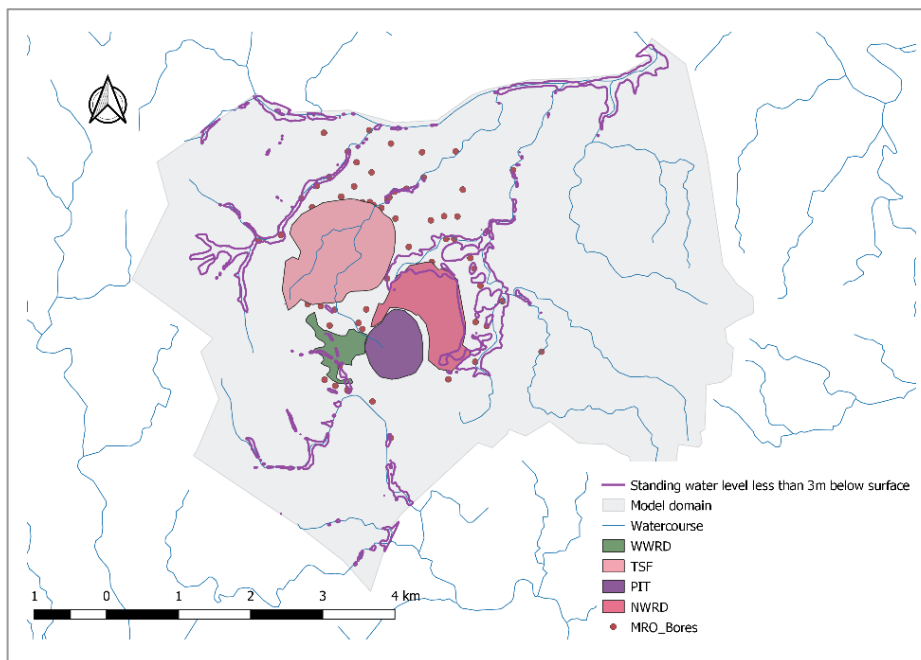


Figure 5: Hyporheic groundwater flow in the mine lease (Source: Northern Resource Consultants, 2019)⁵

⁴ The post-mining watershed boundaries include the TSF and Northern Waste Rock Dump, and do not conform to the pre-mining watershed boundaries.

⁵ Groundwater less than 3 metres below the ground surface.

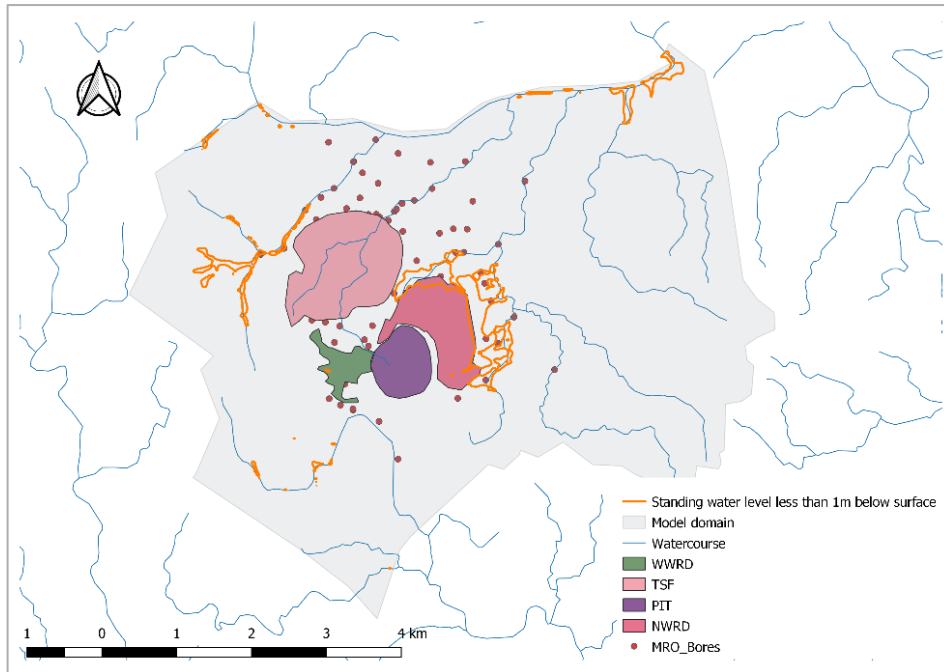


Figure 6: Groundwater exfiltration to the surface (Source: Northern Resource Consultants, 2019)⁶

This Stage 2 report describes the pathways and mechanisms for the release of mine-related solutes into groundwater, and the transport of solutes along the flow-paths shown in Figure 7. These flow-paths express into Swindon Creek (flow-paths A-A' and B-B'), Rawdon Creek (flow-path C-C'), Twelve Mile Creek (flow-path D-D') and Mingham Creek (flow-path E-E').

A brief summary of observed historic interactions between mining-affected water and groundwater along these flow-paths is provided in the Stage 1 report (refer section 3.6, pages 72 – 73), together with maps of (1) the groundwater surface and (2) the depth to groundwater in the mine lease (refer Stage 1 report, Figures 32 and 33). A useful visual representation of the depth to groundwater in catena soil of the Mine is shown in Figure 33 in the Stage 1 report.

⁶ Groundwater less than 1 metre below the ground surface, which is effectively surface expression.

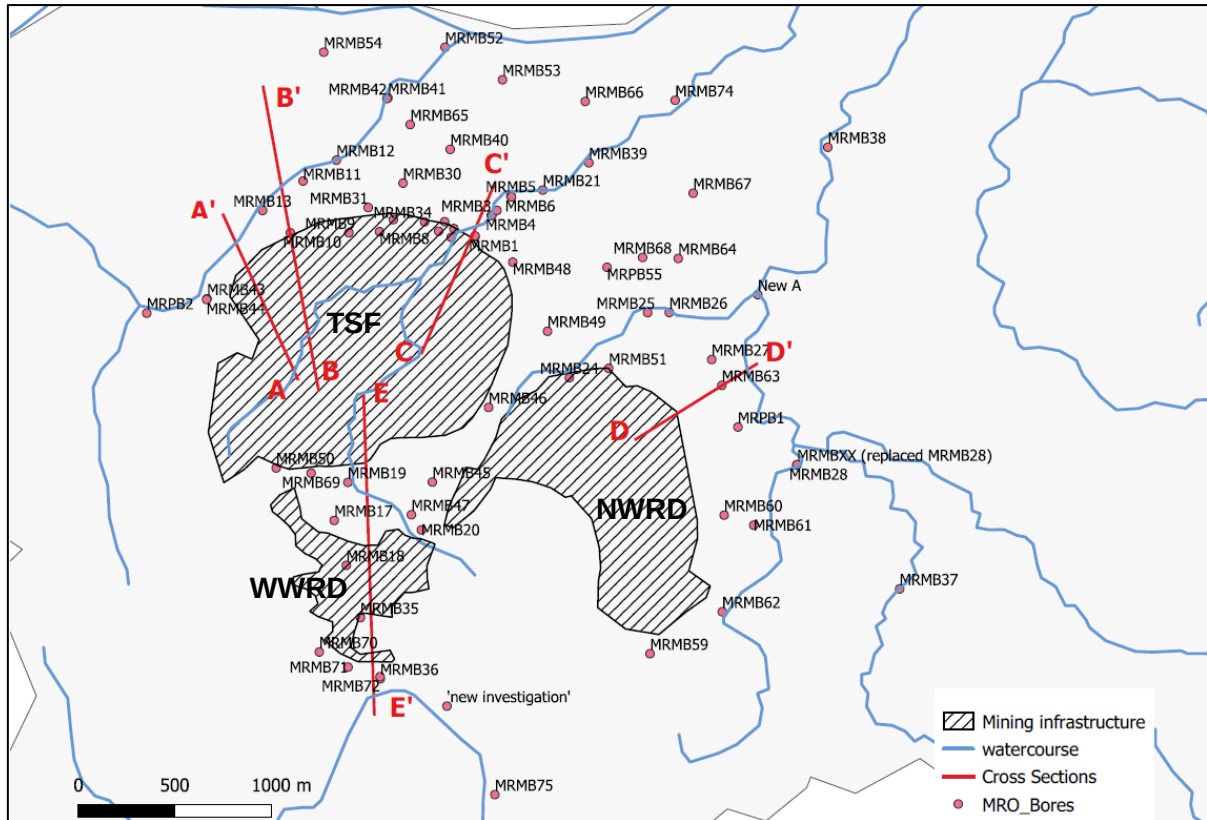


Figure 7: Sample location map showing transects of groundwater flow represented in the geochemical transport model (Source: Northern Resource Consultants, 2019)

2.4 Existing and Proposed Additional Mitigation of Groundwater Seepage

Existing mitigation of mining - affected seepage includes drains that intercept seepage from the TSF, waste rock dams that intercept seepage and stormwater from the NWRD and WWRD, and pump-back bores that intercept seepage below the TSF wall, drains and waste rock dams. These are:

1. The Toe Seepage Interception Drain that collects tailings fluid expressing below the northern wall of the TSF (Northern Seep), and intercepts flow-paths B-B' and C-C'. This was installed in 2006 and reconditioned in 2017. The drain is now buried below the outer batter wall of the TSF. Seepage modelling by ATC Williams indicates that this drain intercepts 49 m³/day;
2. The Seepage Interception Drain that also collects tailings fluid expression from the Northern Seep, which intercepts flow-paths B-B' and C-C' with proposed future extension to include flow-path A-A'. This interception drain was installed in 2017 and is downgradient of and more substantive than the Toe Seepage Interception Drain. The drain is at the toe of the outer batter wall of the TSF Stage 5 lift, and ATC Williams seepage modelling predicted that it intercepts 515 m³/day;
3. Waste Rock Dams. The four waste rock dams include West Dam that intercepts flow-path E-E'. Interception dams built across drainage lines from the NWRD and WWRD collect seepage and stormwater runoff from waste rock, with the water being reused in the processing circuit. Seepage below the dam structures are intercepted by enhanced drainage and sumps. Intercepted seepage includes about 2.5 m³/day from below West Dam, about 107 m³/day from below Waste Rock Dam 1 (WD1) and about 44 m³/day from below Waste Rock Dam 2 (WD2);

4. Pump-back Bores that include MRDB2 and MRDB3 along flow-path A-A', and MRMB27 along flow-path D-D'. Pump-back bores have been installed in groundwater bores that intercept deep drainage pathways. MRDB2 intercepts about 0.09 m³/d, MRDB3 intercepts about 0.7 m³/day and MRMB27 intercepts about 4 m³/day.

During the remaining mine operation, proposed additional seepage mitigations could include extending the Seepage Interception Drain across the A-A' flow-path, and installing additional pump-back bores to intercept seepages that bypass existing mitigation units. The intercepted seepage will be returned to the processing circuit for reuse.

During decommissioning of the mine, it is proposed that constructed wetlands in conjunction with synthetic hydrotalcite (*Virtual Curtain*) be considered as a possible water treatment unit concept that intercepts and remediates seepage pathways. The concept that is being investigated involves the application of constructed wetlands and synthetic hydrotalcite to remove large fractions of sulfate, nitrate, phosphate, cyanide, arsenic, cadmium, copper and zinc from mining - affected waters. This concept is being investigated by Evolution Mining in conjunction with the *CSIRO* and *Australian Wetlands Consulting*.

3 Methods

Synopsis: The Environmental Evaluation requires an evaluation of the nature and extent of COPC transfer through the Mine and requested predictive modelling of the geochemical transport of mining - generated solutes to receptors.

This section describes statistical methods by which a combination of solutes can be used to indicate where mining - affected groundwater possibly exists in a landscape influenced by dryland salinity and heterogenous water quality. The geochemical transport modelling approach used to describe solute transfer through the aquifer is also explained.

To address Items 5 – 9 of the Environmental Evaluation, geochemical transport modelling was performed to assess coupled solute transport and geochemical reactions between mining - affected areas and creek-lines.

Sections 3.1 – 3.3 describe the available data and the methods used to inform the models about aquifer and groundwater properties that might affect the release and transport of COPCs. These properties were obtained using historical groundwater data, as well as tests of the aquifers' mineralogical and physical properties that were performed to support the Environmental Evaluation. Section 3.2 describes the speciation and geochemical transport models that were used to describe the chemical behavior of COPCs, including interactions of solutes with solid mineral phases in the aquifer. Section 3.3 describes the waste rock and tailings fluid source terms, as well as solute concentrations in native groundwater, which were used in the model.

Sections 3.4 – 3.5 describe how sensitivity testing was used to reconcile modelled and measured data. This approach involved varying the assumed rates of groundwater flow, cation exchange capacity of the aquifer, and the surface site density associated with iron oxide minerals. The model simulations that best fitted measured data were used to identify the most plausible model. This model was subsequently used to test the efficacy of potential options to prevent mining - affected groundwater reporting to downstream receptors. The assumptions, uncertainties and limitations of the model are discussed in section 3.5.

Section 3.6 presents an integration of hydrogeological, geological and geophysical data into a 3-dimensional geological model, as implemented via *Leapfrog*[®] software, to illustrate the preferred groundwater flow-paths and associated geological structures that could transmit mining - affected water. Together with results of the geochemical transport model reporting to downstream receptors via these pathways (refer section 4 below), and the known present extent of mining - affected groundwater, it is possible to visually represent the current and future horizontal and vertical hydrogeographic extents of mining - affected groundwater seepage. This approach assumes that the 3-dimensional model of the aquifer represents the vertical and horizontal boundaries of flow-paths that would transmit mining - affected water, and the 1 – dimensional model represents the rate of geochemical transfer of solutes within these flow boundaries. This spatial representation was used to locate additional dewatering bores and/or the possible application of constructed wetlands to prevent further reporting of mining - affected seepage to downstream receptors (Item 14 of the Environmental Evaluation).

To address Items 12 – 13 of the Environmental Evaluation, statistical representation of groundwater quality associated with each groundwater monitoring bore in the mining lease was performed. The details of this work are outlined in sections 3.7 – 3.8.

Section 3.7 details the development of summary statistics of COPC concentrations from each groundwater bore: date range, count, mean, minimum, median and 80th and 95th percentiles (and 5th and 20th percentiles for pH), as well as graphical representation using boxplots and time - series graphs. Spatial trends for mining - affected groundwater in the mine lease were represented in a GIS generated map overlay using color coded symbols.

Section 3.8 details the development of groundwater limits suitable for verifying the current and predicted extents of mining - affected COPC's being released to groundwater. The output

was a decision tree to allow mining - affected water to be distinguished from native groundwater with high concentrations of COPC. The decision tree utilized groundwater limits for potentially mining related COPC's that were developed using the current government standard (*DSITI, 2017 Using monitoring data to assess groundwater quality and potential environmental impacts*). Two other references were used to develop the groundwater limits:

- *The Queensland Water Quality Guidelines 2009 (DEHP, 2009). refer Section 4.3.5 Deriving sub-regional water quality guidelines (SMD waters), pp. 92 – 96; and*
- *Statistical guidance for determining background groundwater quality and degradation (Idaho DEQ, 2014).*

A detailed description of the methods used in the Stage 2 Environmental Evaluation is provided below.

3.1 Hydrogeological and Geochemical Characterisation of the Aquifer

3.1.1 Aquifer Properties

Aquifer properties used in the model are described from soil and weathered rock samples collected from walls of the clay borrow pit and the Seepage Interception Drain north of the TSF, and from the properties of drill chips of fractured rock in pump-back bores MRDB2 and MRDB3 west of the TSF. The location of the soil and rock samples, and where mining - affected water has been observed in monitoring bores and surface seeps are shown in Figure 8.

Hydrogeological properties (hydraulic conductivity, bulk density, porosity and soil texture if applicable) of the soil, weathered rock and fractured rock have been described in the Stage 1 report (refer section 3.1.2 of the Stage 1 report). In Stage 2, further laboratory tests were performed by the Environmental Analytical Laboratory (Southern Cross University, Lismore) and SGS (Cairns) on the same soil, weathered rock and fractured rock samples described in Stage 1, to obtain a detailed geochemical characterization of the aquifer material namely:

1. Cation Exchange Capacity (CEC as meq/100g),
2. pH and exchangeable major elements (mg/kg dry weight),
3. Specific Surface Area (m^2/g BET Surface Area),
4. Iron, aluminium and heavy metals extracted by Shuman's Reagent and Tamm's Reagent, which extracted metals bound to crystalline and amorphous iron minerals, and metals bound to amorphous iron substrates, respectively. The crystalline (goethite hosted) metal fraction was calculated by subtracting the measured amorphous iron (hydrous-ferrous oxide) fraction in the Tamm's extract from the Shuman's extract,
5. Leaching in deionised water that simulated rainfall leaching through the aquifer mineral assemblage,
6. Toxicity Characteristic Leaching Procedure (TCLP), which extracted water soluble trace elements under conditions that simulated the presence of putrescible organic matter (i.e. possible future constructed wetland conditions), and
7. X ray diffraction (XRD)/Scanning Electron Microscopy (SEM) analysis of surface minerals.

The results of the characterization were used to define the input parameters for inverse modelling in NETPATH. This inverse modelling procedure identified a suite of feasible reaction pathways that may result in the generation or removal of solutes from groundwater via mineral dissolution or precipitation reactions, during solute movement across the aquifer. The cation exchange, specific surface area, and Schuman's and Tamm's extractable iron and manganese properties were also subsequently used to the define model input parameters for

forward geochemical transport modelling with PHREEQC. Specifically, the results were used to define the mineral surface properties controlling the extent of cation exchange (CEC) and of surface complexation reactions (Specific Surface Area) that are, for example, associated with the presence of goethite and pyrolusite within the mineral assemblage.

More details on the inferred release of solutes to groundwater by chemical weathering are provided in Appendix 1, which lists minerals known to exist at Mt Rawdon and the corresponding, inferred weathering pathways that naturally contribute to the generation of soluble salts in the landscape.



Figure 8: Locations of samples of soil, weathered rock and fractured rock aquifer ⁷

Prior to the Stage 2 work, mineralogical studies (RGS 2012, Esslemont 2019) associated with surface expressions of groundwater in the Mine area were used to describe aquifer minerals present in seepage pathways that potentially influence the release of solutes to groundwater. The results of previous mineralogical studies are tabled in Appendices 2 – 4, indicating consistency in the identified minerals in between the studies (Appendix 1).

3.2 Model Groundwater Properties

3.2.1 Speciation Modelling

To identify the possible role of toxicity in the definition of contamination assumed by Item 5 of the Environmental Evaluation, the chemical speciation of solutes in groundwater was modelled in Visual MINTEQ. The speciation model was informed by historic records of groundwater compositions, including pH and, where available, Eh or dissolved oxygen. Both redox potential (Eh) and dissolved oxygen (DO) have been reported since 2018. Groundwater records of these field parameters can be used as approximate indicators of the prevailing redox condition, and thus be considered in the aqueous speciation calculations.

Groundwater constituents and parameters considered in the Visual MINTEQ simulations were major and minor ions (Na, Ca, Mg, K, Cl, F, SO₄, HCO₃), field filtered trace elements

⁷ Refer to Table 1 of the Stage 1 report.

(Al, As, B, Cd, Cu, Pb, Zn, Cr, Fe, Mn, Mo), CN, NO₃_N and field measured pH. A temperature of 25°C was assumed for all simulations.

Silica (SiO₂) and phosphorus (P) concentrations in groundwater are useful for understanding the weathering of host rock along the flow-paths shown in Figure 7. Because SiO₂ and P concentrations have not been historically reported at MRO, SiO₂ and P groundwater concentrations measured in 2018 from across the Mine were used where feasible in this Stage 2 report. The 2018 investigation used low flow pumping technology to obtain minimally disturbed groundwater.

Chemical speciation is an important control of the activities of CPOC such as copper, lead, cadmium and zinc, and oxides of arsenic and chromium, which in turn influences their toxicity. As such the chemical species and activities identified by the speciation calculations describe the relative speciation of element concentrations measured in groundwater, which is key to the definition of “critical concentration” used in the Environmental Evaluation.

3.2.2 Inverse Modelling

To explore potential geochemical mechanisms affecting aqueous concentrations during solute migration (to be addressed under Items 5 and 6 of the Environmental Evaluation) solute concentrations in groundwater along the flow-paths, as shown in Figure 7, were modelled using the USGS code NETPATH (Plummer, Prestemon and Parkhurst, 1994).

NETPATH is inverse modelling software that was used to reconcile the stoichiometry of solutes measured in groundwater bores along a flow-path towards a receiving environment (i.e. Swindon Creek, Rawdon Creek, Twelve Mile Creek or Mingham Creek), where a source term of mining-affected water (fluids from the TSF or NWRD as described in section 3.3) mixes with native groundwater. The model accommodates for interactions between groundwater and the host aquifer, by enabling dissolution and precipitation of minerals associated with rock weathering and allows for evaporation and dilution. The model input for NETPATH simulations included:

- Components: major ions (Na, Ca, Mg, K, Cl, F, SO₄, HCO₃), a limited range of field filtered (nominally dissolved) trace elements (Al, B, Fe, Mn), NO₃_N, field measured pH, and where available field measured Eh and DO. The source terms for TSF fluid, Waste Rock fluid and groundwater from the monitoring bore before mine influence (described in Section 3.3) were entered for a sequence of monitoring bores along flow-paths A-A', B-B' ... E-E'. A temperature of 25°C was assumed.
- Mineral phases relevant to the weathering sequence (described in Section 3.3 and Appendices 1 – 4) were used in the model. The dominant weathering process (refer Appendix 1) relevant to the flow-path was considered, because the model is limited by number of phases and components. For groundwater bores near the toe of the TSF (e.g. MRMB9, MRMB10), weathering processes inside the TSF that generate neutral mine drainage (pyrite oxidation and dissolution of fresh calcite, feldspar and chlorite) were represented in the model. For groundwater bores further from the TSF (e.g. MRMB12), weathering processes expected to occur in saprolite (e.g. tropical weathering of feldspars and chlorite to clay, iron oxide and gibbsite) were represented in the model. Processes of evaporation, dilution and ion exchange of Ca/Na between charged mineral surfaces and solution, were also represented in the model.

As such NETPATH was used to represent transport of mining - affected groundwater, in the context of landscape processes associated with dryland salinity as identified by the conceptual model (refer section 4 of the Stage 1 report). Models that converged were investigated in more detail by geochemical transport modelling, as described in Section 3.2.3.

3.2.3 Geochemical Transport Modelling

To address Conditions 6 and 7, geochemical transport modelling was performed with PHREEQC. Because the NETPATH models indicated that rock weathering, surface reactions and evaporation processes were important, these processes were also represented in the PHREEQC models.

Source terms for the TSF and waste rock were mixed in proportions predicted by the NETPATH model. Aquifer transfer of these combined “mining” source terms towards surface water receptors in Swindon Creek, Rawdon Creek, Twelve Mile Creek and Mingham Creek were modelled. Refer to section 3.3.1 for descriptions of how the source terms were combined using PHREEQC. Refer to section 3.4.1 for how the mixed source term was compared with the observed seepage water quality in Seep 26 and the Northern Seep Zone.

Calculation of the Darcian movement of groundwater along flow-paths A-A' ... E-E' was based on the steady state hydraulic gradients calculated by the MODFLOW groundwater flow model (Northern Resource Consultants, 2019). The groundwater discharge (m^3/d), the annual seepage velocities (m/y) and the number of years for groundwater flow to reach the creeks as represented in the PHREEQC model were in line with the aquifer hydraulic conductivities and porosities described in section 3.1.2 of the Stage 1 report. Tables of these flow parameters and the cell inputs used for the PHREEQC model are listed in Appendix 5.

For aqueous solutions migrating across the shallow aquifer, geochemical equilibrium with quartz (SiO_2), goethite (FeOOH), pyrolusite (MnO_2) and atmospheric oxygen was assumed. This assumption was based on field observations that showed the presence of goethite, pyrolusite, silicification and seasonally variable standing water levels in groundwater bores that could add oxygen to the unsaturated aquifer in fresh rainfall recharge. In the saturated zone, however, there is no mechanism to replenish oxygen if groundwater becomes oxygen depleted by any redox reactions. Further to the field observations, speciation modeling indicated that silica precipitation would be commonly expected to occur in aquifers. Modelling predictions of iron and manganese mineral precipitation based on saturation indices in groundwater were reported where relevant.

The possibility of groundwater flowing through the deep, fractured rock aquifer was also investigated in some model scenarios. However, simulated concentrations could not be reconciled with the observed rates and directions of mining-affected groundwater movement. For further discussion of the identification of the most plausible models used to justify the modelling of groundwater flow through the shallow aquifer, refer to section 3.4.

Surface complexation reactions with hydrous-ferric oxide were modelled, and were equilibrated against the number of moles of iron extracted by Tamm's Reagent, an assumed porosity of 5.5% in saprolite, and mineral particle density of 2.7 kg/L . Details of the calculations are provided as annotated notes in the attached electronic versions of the PHREEQC models. In short, the PHREEQC model assumed surface adsorption to reactive iron sites according to Dzombak and Morel, 1990.

Cation exchange reactions associated with clays were also included in the model. This allowed for the adsorption of cations from groundwater to clay surfaces and the release of cations from the clay surfaces to solution. The cation exchange capacity assumed in the model was based on measured K, Mg, Na and Ca concentrations adsorbed to aquifer surfaces (refer to the laboratory tests performed on aquifer samples, as listed in section 3.1.1).

In summary PHREEQC was used to (1) assess and understand the historic migration of mine-affected solutes in groundwater due to activities conducted at the premises, and (2) predict the likely future extent of contaminant migration and impact.

3.3 Source Terms used in the Geochemical Transport Model

3.3.1 Waste Rock Secondary Minerals and Solute Generation

To identify and describe the pathways and mechanisms for the mining related solutes releasing to groundwater due to activities conducted at the premises (Item 5), the source terms representing fluids released from the tailings and waste rock were defined. This was achieved using a combination of known weathering pathways associated with tropical weathering (Ewington, 1996, Appendix 1), laboratory analyses of secondary minerals observed in waste rock trial leaching pads (Appendix 2), laboratory analyses of minerals associated with groundwater exfiltration sites (RGS, 2012, Appendix 3), laboratory analyses of leachate in shallow groundwater plumes associated with seepage from the Northern Waste Rock Dump (RGS, 2012, Appendix 4), as well as laboratory analysis of water in the decant and seeps (Seep 26, Sediment Dam 1).

Leaching of major cations and anions from the aquifer rocks was identified by the conceptual model (refer section 4.1 of the Stage 1 report) as is expected to occur in heavily weathered rock and soil. Weathering pathways (Appendix A) involve pyrite weathering that accelerate the decomposition of carbonate, and conversion of feldspar and chlorite to intermediate clays (smectite, illite) that subsequently convert to goethite and kaolinite. Late stage tropical weathering is expected to form gibbsite from kaolinite, and speciation modelling indicated that aluminium hydroxides are expected to form based on groundwater solution (refer section 3.2.1).

Mineralogical analysis by X-ray diffraction (XRD) were performed on secondary minerals and salts in the weathering rinds of waste rock (Appendix 2), as well as associated with groundwater exfiltration sites north of the TSF (Appendix 3) and in Twelve Mile Creek (Appendix 4). The XRD analysis reported gypsum in salt efflorescence near the toe of the NWRD (refer sample I3698/001:1 in Appendix 4).

Solutes generated by weathering of waste rock were measured at the toe of the NWRD, in shallow groundwater sampled from four seepage pathways using soil lysimeters that also allowed measuring of field pH and Eh in the collected samples. Thirty samples were collected over a year, and the sample chosen to represent the waste rock source term was a charge balanced result close to the median (50thile) solute composition, which was identified using *Excel* by firstly calculating the median water quality value, and then sorting the entire dataset and median concentrations by rank of chemical components represented in gypsum (Ca, SO₄), magnesium bicarbonate (Mg, HCO₃), halite (Na, Cl) and potassium (in the order listed). This method identified a representative (median) charge-balanced source term with respect to dissolved salts that during the dry season are temporarily immobilised by precipitation (of halite, gypsum and dolomite salts) and adsorption of cations and anions (to clay surfaces).

It was assumed that over the wet season, these elements subsequently re-dissolve during aquifer recharge following rainfall events, and the redissolved salts are then mobilised with flowing groundwater. These seasonal influences upon salt mobilisation through the landscape were identified by the conceptual model (refer section 4 of the Stage 1 report) but were not explicitly represented the PHREEQC geochemical transport model. It is possible that the poor fit for chloride in the PHREEQC model is a consequence of the model not representing differential re-dissolution of chloride and sulfate (refer to section 3.5 for discussion in relation to model uncertainties and limitations).

Solutes generated by weathering of tailings involved selecting the median composition of 86 samples of decant water (by the method described above). A decant water sample collected on the 3rd December 2012 was representative. In PHREEQC this median decant water sample was modelled to react with major minerals in the TSF (calcite, albite, muscovite, chlorite) via the weathering pathways listed in Appendix 1. For detail of these calculations that were used to derive the tailings fluid source term refer to PHREEQC worksheets.

The mine source terms for waste rock and tailings were mixed in ratios identified for the A-A', B-B' ... E-E' flow-paths by the NETPATH model, and this mixed source term was used to

represent mine solutes in seepage that enter the receiving environment. The mixed source term was compared with observed concentrations of mine solutes in Seep 26 (for the A-A' flow-path) and in Sediment Dam 1 (for the B-B' and C-C' flow-paths) to verify the modelled solute generation in the TSF and mixing with waste rock solutes. Refer to section 3.4.1 for discussion of this validation.

3.3.2 Native Groundwater

The native groundwater source terms were adopted from the chemical compositions measured in monitoring bores that represented the respective A-A', B-B' ... E-E' flow-paths preceding the influence of mine source terms. For example, in the A-A' flow-path groundwater in MRMB44 sampled during 2012 was used to represent native groundwater screened from the aquifer.

The modelling procedure allowed the mine source term to mix with the native groundwater source term, which represented seepage of mining - affected water during groundwater flow from the TSF or NWRD to the receiving creek line.

3.4 Sensitivity Testing and Calibration

Agreement between modelled PHREEQC outputs and measured groundwater data was done manually by matching modelled sulfate concentrations with observed sulfate concentrations in breakthrough curves in monitoring wells. Sulfate was chosen because it is a relatively conservative ion associated with mining, noting that some non-conservative behaviour in the form of gypsum precipitation and redissolution associated with rainfall patterns does occur in the Mine. A sequence of processes was simulated, with the best match at each step being built on from the sequential step. The stepwise processes were (1) Darcian flow velocity controlled by adjusting the hydraulic conductivity of the aquifer across the measured range in the mining lease, followed by (2) exchange of cations between aquifer minerals and groundwater controlled by adjusting the CEC for sodium, potassium, magnesium and calcium and adjusting the specific surface areas attributed to hydro-ferric oxide (HFO), across the ranges of measured CEC and measured iron oxides from representative aquifer samples, and (3) evaporation. These three processes were evaluated sequentially and in combination, using a progression of 4 or 5 steps representing low, middle, high and extreme values across the measured data ranges. The models that agreed best with data observed in monitoring bores along the respective flow-paths, were used to represent the unmitigated (base-case) models.

Specific descriptions of the sensitivity tests and calibration performed on each flow-path (A-A', B-B' ... E-E') are provided electronically with the PHREEQC models. The general approach to improve the accuracy and predictive capacities of the transport model is outlined below.

3.4.1 Mixing of TSF and Waste Rock Source Terms

Measured concentrations in monitoring bores or seepage interception dams in the seepage flow-paths provide reference values with which model outputs can be compared. Seep 26 is associated with flow-path A-A', and Sediment Dam 1 receives seepage associated with flow-paths B-B' and C-C' (from the Northern Seep zone).

NETPATH models reported mixing ratios of tailings fluid and waste rock, which were compared with data measured in Seep 26 and Sediment Dam 1. There were situations when several outputs were reported by a model, on the basis that all outputs successfully converged in NETPATH. The NETPATH output that best fitted observed data (i.e. Seep 26 and Sediment Dam 1 data) was selected for the PHREEQC model from the multiple options.

- Flow-path A-A': PHREEQC model predictions for Na, Cl and S were within 30% of observed values, and model predictions for Ca and K were within 70 % (Table 1). The

model overestimated Mg and HCO_3 (C) concentrations by less than 300%. Predicted concentrations of trace metals were reasonable for Al, Cd, Pb and Zn (70% or less), but initial prediction overestimated As, Cu, CN, Fe and Mn and underestimated NO_3 . The poor initial model predictions for Cu, Fe and Mn were explained by the substantial heterogeneity of source term concentrations in waste rock seepage: Fe (0.03 – 43.8 mg/l) and Mn (0.3 – 44.5 mg/l) as well as in decant water: Cu (0.6 – 19.7 mg/l). Using model inputs with lower concentrations for Fe and Mn in the waste rock source term, and a lower concentration for Cu in the decant water source term coupled with precipitation of copper carbonate minerals (malachite and azurite) as decant fluid flows through the tailings, and precipitation of goethite from waste rock seepage, it was possible to bring the modelled concentrations for Fe, Mn and Cu much closer to the observed concentrations in Seep 26. Even models that precisely match observations will potentially contain non-unique solutions and uncertainties, and the tabulated comparison between modelled and measured concentrations (Table 1) reflects that. Because the model did not account for decomposition of CN in the TSF, the measured value of CN at Seep 26 was used as a substitute for the CN source term value developed by the model.

- Flow-path B-B': model predictions were within the range of values observed in Sediment Dam 1, and thus resembled mining - affected groundwater expressed via the Northern Seep that reported to Sediment Dam 1 (Table 2). The model overestimated CN concentrations. The measured value of CN in flow-path B-B' was substituted for the model value.
- Flow-path C-C': model predictions were also within the range of values observed in Sediment Dam 1 (Table 3). However, the model overestimated K and CN concentrations. The measured value of CN was substituted for the model value.

In summary, the source terms used in the PHREEQC models to represent mining-affected groundwater entering flow-paths A-A', B-B' and C-C' and approximated observed solute concentrations in seepage water, except for CN that was overestimated by the model. Because decomposition of CN was not included in the model, this overestimation was accommodated for by substituting observed CN concentrations for model values.

3.4.2 Effect of Flow Variation

Sensitivity tests were performed to represent the timing of breakthrough curves reporting to monitoring wells at four levels of varied flow through the A-A', B-B' ... E-E' flow-paths, by varying the hydraulic conductivity through saprolite between $K = 12.1$ m/d, $K = 1.21$ m/d, $K = 0.121$ m/d (or a measured slug test/pump test value for the monitoring bore was used instead if available), $K = 0.0121$ m/d and $K = 0.00179$ m/d. The hydrogeological model developed for the Stage 1 report identified that the K for saprolite was 0.121 m/d and the K for fractured rock was 0.00179 m/d, which means that the range of hydraulic conductivities represented by the sensitivity test was within the expected range for the Mount Rawdon mining lease. The assumed width of the flow-path was 250m (i.e. 125 m either side of the flow-path). Input values for the varied flow scenarios are listed in Appendix 5.

The best fit relative to measured sulfate concentrations in the breakthrough curve reporting to the observation well was selected for further sensitivity tests of surface exchange properties on solute concentrations. These were sensitivity tests 1 – 4 in the results sections.

3.4.3 Effect of Solid-phase Surface properties

Sensitivity tests were performed to evaluate the effect of varying levels of the sorptive properties of the aquifer through the A-A', B-B' ... E-E' flow-paths. This was achieved by varying both the assumed surface areas of iron oxides and the CEC (Appendix 6). The levels used in the sensitivity tests were equivalent to:

- 1/10th of the lowest sorptive surface area and CEC measured in test samples indicated in Section 3.1.1,
- a low sorptive surface area equivalent to values measured in surface soil,
- moderate surface area equivalent to values measured in saprolite,
- moderately high surface area equivalent to values measured in fractured rock, and
- high surface area equivalent to 10x values measured in fractured rock.

The best fit relative to the observed data reporting to the monitoring bore was selected for further sensitivity tests of the effect of evaporation on solute concentrations. These were sensitivity tests 5 – 9 in the results sections.

Table 1: Comparison of the A-A' Source Term with Seep 26 Data

Element	Moles	At. Wt.	Modelled	Actual	% difference
Major Elements					
Ca	8.19E-03	40.08	328	204	-61
Cl	4.07E-03	35.453	144	197	27
K	4.70E-04	39.102	18	51	64
Mg	8.51E-03	24.312	207	76	-172
Na	2.18E-02	22.991	502	608	17
S	2.15E-02	96.06	2060	1780	-16
C	9.72E-03	61.016	593	157	-279
Trace elements					
Al	1.86E-07	26.982	0.005	0.006	9
As	4.25E-07	74.922	0.03	0.02	-112
Cd	4.92E-09	112.4	0.0006	0.001	62
Cu	1.74E-06	63.54	0.1	0.1	-11
Cyanide	3.30E-05	26.018	0.86	0.03	-3141
Fe	2.00E-08	55.847	0.001	0.043	97
Mn	5.53E-06	54.938	0.3	0.2	-39
N	7.17E-07	14.007	0.01	1.7	99
P	1.30E-06	30.974	0.040		
Pb	2.42E-09	207.19	0.001	0.001	60
Si	4.63E-04	28.086	13.004		
Zn	3.61E-07	65.37	0.02	0.08	70
Field Parameters					
pH			7.2	8.3	
pe			2.48		
T			24	25	

Table 2: Comparison of the B-B' Source Term (NETPATH Sequence 1, Model output 2) with Seep 26 data and SD1 data

Element	Moles	At. Wt.	Modelled	Seep 26 actual	Seep 26 % difference	SD1 Actual	SD1 % difference	Max	Min
Major Elements									
Ca	3.951E-03	40.08	158	204	22	148	-7	316	41
Cl	7.534E-03	35.453	267	197	-36	254	-5	926	0
K	1.799E-03	39.102	70	51	-39	34	-107	72	2
Mg	3.404E-03	24.312	83	76	-9	83	0	183	25
Na	2.606E-02	22.991	599	608	1	556	-8	845	53
S	1.517E-02	96.06	1457	1780	18	1510	3	2090	322
C	5.020E-03	61.016	306	157	-96	101	-203	464	0
Trace elements*									
Al	1.858E-07	26.982	0.005	0.006	9	0.035	86	4.98	0
As	1.733E-06	74.922	0.13	0.02	-766	0.01	-2064	0.26	0.001
Cd	1.912E-08	112.4	0.0021	0.001	-48	0.181	99	0.408	0.001
Cu	7.248E-06	63.54	0.5	0.1	-363	0.4	-21	1.72	0
Cyanide	1.379E-04	26.018	3.59	0.03	-13439	0.19	-1798	1.25	0.066
Fe	3.108E-11	55.847	0.00	0.043	100	0.090	100	3.5	0
Mn	5.671E-06	54.938	0.3	0.2	-43	11.4	97	18.3	1.35
N	7.160E-07	14.007	0.01	1.7	99	3.1	100	21.8	0.01
P	1.295E-06	30.974	0.040						
Pb	2.420E-09	207.19	0.0005	0.001	60	0.001	60	0.011	0
Si	2.768E-04	28.086	7.774						
Zn	8.742E-07	65.37	0.06	0.08	29	11.10	99	28.9	0.194
Field Parameters									
pH			7.4			6.8		7.69	4.21
pe			2.62						
T			25			25			

Assumes that the mixing ratio of tailings seepage: waste rock runoff mixing is 0.71:0.29.

Table 3: Comparison of the C-C' Source Term (NETPATH Model output 10) with Seep 26 data and SD1 data

Element	Moles	At. Wt.	Modelled	Seep 26 actual	Seep 26 % difference	SD1 Actual	SD1 % difference	Max	Min
Major Elements									
Ca	3.009E-03	40.08	121	204	41	148	18	316	41
Cl	8.303E-03	35.453	294	197	-49	254	-16	926	0
K	2.094E-03	39.102	82	51	-62	34	-141	72	2
Mg	2.269E-03	24.312	55	76	27	83	34	183	25
Na	2.700E-02	22.991	621	608	-2	555.5	-12	845	53
S	1.377E-02	96.06	1323	1780	26	1510	12	2090	322
C	3.976E-03	61.016	243	157	-55	101	-140	464	0
Trace elements*									
Al	1.858E-07	26.982	0.005	0.006	9	0.035	86	4.98	0
As	2.023E-06	74.922	0.15	0.02	-910	0.01	-2426	0.26	0.001
Cd	2.228E-08	112.4	0.0025	0.001	-73	0.181	99	0.408	0.001
Cu	8.472E-06	63.54	0.5	0.1	-441	0.4	-41	1.72	0
Cyanide	1.612E-04	26.018	4.19	0.03	-15727	0.19	-2119	1.25	0.066
Fe	2.976E-11	55.847	0.00	0.043	100	0.090	100	3.5	0
Mn	5.702E-06	54.938	0.3	0.2	-44	11.4	97	18.3	1.35
N	7.159E-07	14.007	0.01	1.7	99	3.1	100	21.8	0.01
P	1.295E-06	30.974	0.040						
Pb	2.420E-09	207.19	0.0005	0.001	60	0.001	60	0.011	0
Si	2.355E-04	28.086	6.614						
Zn	9.882E-07	65.37	0.06	0.08	19	11.10	99	28.9	0.194
Field Parameters									
pH			7.5			6.8		7.69	4.21
pe			2.56						
T			25			25			

Assumes that the mixing ratio of tailings seepage:waste rock runoff mixing is 0.83:0.17

3.4.4 Effect of Evaporation

Sensitivity tests were performed to represent evaporation on groundwater in flow-paths A-A', B-B' ... E-E'. The levels used in the sensitivity tests were between 1% and 10% evaporation.

The best model fit relative to observed data reporting to the monitoring bore was identified and used to represent the base-case and develop mitigation scenarios. Model scenarios were performed on the base case (unmitigated), and then the hydrogeological changes associated with installing (or extending) the TSF Seepage Interception Drain and installing pump-back bores. As such the effects of existing and new mitigations were calculated in *Excel* independently and in combination by subtracting the discharge removed by the mitigation(s) from the base-case groundwater flow (in m³/day), which correspondingly revised the seepage velocity along the respective flow-paths towards the monitoring bore. The revised seepage velocities associated with the mitigations were then used as revised input in the PHREEQC model, and results generated by the mitigations were compared with the unmitigated base-case.

3.5 Model Assumptions, Uncertainties and Exclusions

The geochemical transport model simulations performed for the selected flow-paths represent substantial simplifications of the natural system. Some of the key assumptions, uncertainties and exclusions were:

1. The conceptual hydrogeological model underpinning the geochemical transport model was based on an earlier developed model describing landscape processes associated with the Mount Rawdon Mine. It is assumed that this model can also apply to the post mining period if suitable modifications were made to represent the final landform after mine closure. The model addresses processes controlling dryland salinity on sloping landscapes, and groundwater mounding below the TSF / waste rock dumps. These assumptions are discussed in more detail in Section 4 of the Stage 1 report.
2. All considered chemical processes, i.e. cation exchange, surface complexation and mineral dissolution / precipitation were assumed as equilibrium reactions.
 - a. The PHREEQC model has assumed that primary and secondary minerals identified in the tailings dam and in the landscape represent weathering pathways, and that these weathering pathways have proceeded to equilibrium in the TSF. Note that equilibrium might not occur during weathering of some primary minerals in the TSF (particularly minerals that are slow to react such as albite), which is an uncertainty in the model.
 - b. The cation exchange capacity of the aquifer matrix represents the equilibrium state of cations adsorbed to aquifer clays at the time of sampling. As such the PHREEQC model has assumed that cation exchange of solutes with groundwater will be constrained by the charge balance and exchangeable quantity of cations at the time of sampling. This assumption is likely valid given the availability of bicarbonate present in the neutral mine drainage at Mt Rawdon as well as in background groundwater, which maintains the pH of the aquifer system and the cation exchange capacity of the aquifer matrix.
 - c. Chloride has not been well represented by the model. While chloride is usually a conservative (unreactive) element in groundwater, the likelihood that halite precipitates and redissolves seasonally in the variably saturated aquifer was not represented in the PHREEQC model (the PHREEQC model used here assumes steady-state, one-directional groundwater flow).
 - d. Organic Matter (dissolved organic carbon) mineralisation was not considered, which could have had some influence on the redox conditions. Neither the NETPATH or PHREEQC models have represented biogeochemical

processes that degrade cyanide and nitrogen in the TSF and the landscape, nor have they represented processes that add nitrogen to groundwater in the landscape (nitrogen fixation by wattles, hot bushfires). Some chemical processes relevant to cyanide and nitrogen are uncertainties that have been excluded from the model.

- e. There is a potentially a wide range of solute concentrations that can occur in leachates from waste rock and from tailings, as discussed in Section 3.4.1 for manganese and iron in waste rock leachate, and for copper in tailings fluid. By adjusting the model inputs for iron, manganese and copper from the median value to lower values within the known range of concentrations, it is possible to reconcile model outputs with observed concentrations in the seepage expression. However, it needs to be noted that even models that perfectly match observations will contain non-unique outcomes and uncertainties.
3. Uniform, steady-state groundwater (advective) flow through homogenous aquifers along the A-A', B-B' ... E-E' transects. This assumption might hold for saturated groundwater flow through soil and strongly weathered saprolite. However, it might not hold for aquifer recharge by rainfall in the variably saturated zone that seasonally precipitates then re-dissolves solutes during downslope movement towards valleys. This assumption might explain the poor reconciliation of model results for chloride, and for sulfate/chloride ratios, with observed data from the monitoring bores.
4. Fractured rock features compartments of stagnant groundwater in isolated or semi isolated pockets, which form against fault barriers and planes of weakness along lithological contacts, foliations and bedding planes. Groundwater in these compartments may not mix along the flow-paths as assumed by the employed advection - dispersion model, and bimodal flow through fractured rock has not been included in the model.
5. Faults were assumed by the earlier MODFLOW-SURFACT model to be impermeable boundaries to flow. As such the flow-paths and hydraulic-head potentials developed as output of the MODFLOW-SURFACT model groundwater flow model, and subsequently used as input for the 1-dimensional PHREEQC model, tacitly carry the assumption that faults represent flow barriers. Alternatively, the other extreme case some faults may act as preferred pathways for solute flow. However, the process of calibration of the MODFLOW-SURFACT groundwater model identified, and allowed for, some permeability of groundwater flow through faults.
6. The simplified one-dimensional solute transport in a three-dimensional landscape has not accommodated for converging flow-paths in the spur-valley landscape of the mine lease (e.g. the amphitheatre-shaped valley that converges slightly downstream of monitoring bores MRMB43 and MRMB44). The assumption of the model may be a limitation because it only represents one-directional groundwater flow from the TSF to the creek and does not represent aquifer recharge from the creek (i.e. backflow from the creek into the aquifer).
7. Changes in redox potential will have a strong influence of the precipitation of Fe and Mn in particular. These hydrous ferric oxyhydroxides have the potential to act as major sorbents for a range of metals and metalloids and hence regulate their concentration.

In summary, while solute transport of major cations and some trace elements are well represented by the model, the behaviors of chloride, nitrogen, and some trace elements are not well represented by the geochemical transport model. The discrepancies can mostly be attributed to the above-listed simplifying assumptions, uncertainties and some exclusions relevant to advective flow, weathering pathways, and solute interactions within the aquifer.

3.6 Current and Future Solute Movement

Items 6 and 9 require an understanding, and visual representation, of the present and possible future horizontal and vertical hydrogeographical extents of mining - affected groundwater. To achieve this, the best available hydrogeological, geological and geophysical data from the mining-lease were developed using 3-dimensional geological software (*Leapfrog®*) to map the 3-dimensional geometry of aquifer boundaries. These aquifer boundaries can be used in combination with the monitored extent of mining-affected groundwater, and the 1-dimensional PHREEQC model predictions of geochemical transfer of mining affected groundwater across selected flow-paths, to represent the current and future extents of mining - affected groundwater in the mining lease area. Data that have been included in the construction of the model are:

- The modelled steady state groundwater surface identified by groundwater modelling,
- Electrical Resistivity Imaging of low electrical resistivity (high electrical conductivity) sub-surface domains that might imply the presence of saline water, as well as showing vertical features that might represent fault boundaries,
- Rock-types as well as known and inferred geological faults identified from mine-lease scale geological mapping, and
- Detailed mapping of rock-types and geological faults along the Seepage Interception Drain north of the TSF. This is the same drain from which soil and rock samples were collected to represent the aquifer matrix in the solute transport model (refer Figure 8, section 3.1.1)

The 3-dimensional model output is a visual representation of inferred groundwater flow-paths and associated geological structures that could transmit mining - affected water. This model has assisted with the positioning of mitigation options such as pump-back bores to intercept mining - affected water along seepage pathways (required by Item 14).

3.7 Assessment of Mining Influence on Groundwater and Surface Water

Items 12 – 13 of the Environmental Evaluation require the representation of groundwater quality associated with each groundwater monitoring bore in the mining lease to be represented with summary statistics and graphs. For ease of interpretation and discussion, data were partitioned by sub-catchment, with results of the assessments shown in the appendix for each sub-catchment as follows:

- Swindon Creek (Appendix 13),
- The unnamed creek between Swindon Creek and Rawdon Creek (Appendix 14),
- Rawdon Creek (Appendix 15),
- The landscape spur between Rawdon Creek and Twelve Mile Creek (Appendix 16),
- Twelve Mile Creek (Appendix 17), and
- The southern drainage towards Mingham Creek (Appendix 18).

Data for each sub-catchment are represented in the appendix as tables of summary statistics, time series graphs (*Excel*), boxplots (*PASW Statistics 17.0*) and Piper diagrams (*GW_Chart, USGS*). Due to overlapping data the time series graphs were further partitioned within each sub-catchment into upstream, mid and downstream sections to allow for better visualization. The time series graphs were arranged to allow for visual representation of trends of groundwater quality alongside standing water levels and rainfall patterns, so that antecedent landscape influences upon groundwater quality are evident.

The proposed groundwater limits identified by this report (refer section 3.8) are indicated in the box and whisker plots (boxplots). The symbol codes used in the boxplots are:

- horizontal line through the centre of the box = 50th percentile also called the median value,
- box boundaries = 25th and 75th percentiles (the software did not report 80th and 20th percentiles as requested by the Environmental Evaluation requirements),
- whiskers = smallest and largest values of the distribution,

- circles = outlying values between 1.5 and 3 box lengths from the upper or lower edge of the box,
- stars = extreme values 3 or more box lengths from the upper or lower edge of the box,
- Concentration values beside the stars and circles.

GIS images of the plan-view extents of mining - affected groundwater seepage, as well as 3-D geophysical profiles of the horizontal and vertical extents of inferred groundwater seepage pathways (refer section 3.6) were included in the sub-catchment summaries to assist with the visual interpretation of solute movement in the mine lease.

3.8 Identification of Groundwater Limits to verify Mining Influence on Groundwater

Groundwater limits suitable for verifying the current and predicted extents of COPC's that are released to groundwater by mining activity, were developed according to DSITI (2017) *Using monitoring data to assess groundwater quality and potential environmental impacts*. Two other references were used to support development of the groundwater limits:

- *The Queensland Water Quality Guidelines 2009 (DEHP, 2009). Refer Section 4.3.5 Deriving sub-regional water quality guidelines (SMD waters), pp. 92 – 96; and*
- *Statistical guidance for determining background groundwater quality and degradation (Idaho DEQ, 2014).*

The *Statistical guidance for determining background groundwater quality and degradation* developed by the Idaho DEQ states three fundamental premises that underpin the statistical theory and practice supporting background determination:

1. The collection of measurements represents a random sample of the underlying population that is free of bias imposed by the measurement process (i.e. the individual who is conducting the sampling, or the analytical method used to make the measurements),
2. The statistics estimated for a population depend on the measurements used to make the estimate but bracket the true population statistics (i.e. the sample is representative), allowing the population to be inferred from any sample, and
3. Most importantly, the data are independent. That is, each measurement is randomly representative of the target population and its value is not influenced by any other measurement (i.e. each measurement is independent of every other). Dependent variables exhibit less variability (i.e. samples taken at five-minute intervals will be near identical), which leads to an underestimation of the population variance that in turn affects the prediction limit and tolerance limit. Every measurement in the physical world is somewhat autocorrelated with the previous measurement, and from a practical standpoint the Idaho DEQ recommend that samples at six monthly intervals can be assumed to be independent except for slowly flowing aquifers.

Over the last twenty years there has been substantial groundwater data collected at the Mine using a consistent sampling procedure (similar pumps, same purging times, same field protocols and the same field technician for the last 10 years). From a practical standpoint, twelve data sampled over a minimum of three years and four seasons were assumed to meet the minimum sampling requirements from a monitoring bore (Idaho DEQ, 2014 page 47). This philosophy achieves the Australian standard (DSITI, 2017 page 11) that indicates a minimum of eight samples collected over one year for surface waters, and two years for groundwater, as the minimum standard.

The ionic composition of groundwater bores was reviewed using multivariate statistics during the Stage 1 investigation, which showed that the ionic composition of groundwater data

allowed mining - affected groundwater to be distinguished from native groundwater using concentrations of arsenic, cyanide, nitrate and sulfate (the sulfate/chloride ratio), which were observed to increase over time in mining - affected groundwater. A preliminary guide to interpreting groundwater with high concentrations of Chemicals of Potential Concern in the Mount Rawdon mining lease was developed (Appendix 12), and used to identify fifteen groundwater bores with sufficient data that are free of mine influence, from which groundwater limits (background) could be identified:

- MRMB13 – The screen intersects weathered rock and fresh rock, but mostly weathered Aranbanga Volcanics (andesitic lavas and volcaniclastics).
- MRPB2 – As above.
- MRMB70 – As above. The screen intersects fresh rock and an oxidation zone (possible fault).
- MRMB36 – Weakly oxidised Curtis Island Metasediments / Mine Sequence (rhyodacitic volcaniclastics and dacite).
- MRMB40 – The bore screens both weathered rock and fresh rock, but mostly fractured Curtis Island Metasediments.
- MRMB62 – Fresh Curtis Island Metasediments / trachyte dyke.
- MRMB64 – Lightly weathered granite in fresh quartz / biotite schist (Curtis Island Metasediments).
- MRMB67 – Fresh granite in Curtis Island Metasediments.
- MRMB68 – Fresh dacite in Curtis Island Metasediments.
- MRMB37 – Weathered gneiss in Curtis Island Metasediments.
- MRMB48 – Fresh granite in Curtis Island Metasediments.
- MRMB38 – Fresh Curtis Island Metasediments (bore screens low in the landscape).
- MRMB52 – As above.
- MRMB53 – As above.
- MRMB54 – As above.

Groundwater data (twelve samples collected at six-monthly intervals over six years) from nine bores were compared using a nested ANOVA design to evaluate background groundwater quality at different scales - the landscape unit scale and the individual bore scale. This is a balanced statistical design that meets the minimum sampling requirements stated by DSITI (2017) and the Idaho DEQ (2014), with data evenly represented from each monitoring bore across three wet and dry seasons. Three bores from the Aranbanga Volcanics (MRPB2, MRMB13, MRMB70) with collar heights between 125 and 150 m AHD, three bores from the Curtis Island Metasediments screening in elevated parts of the landscape (MRMB48, MRMB64, MRMB68) with collar heights between 125 and 142 m AHD, and three bores from the Curtis Island Metasediments screening low in the landscape position (MRMB38, MRMB52, MRMB54) with collar heights between 104 and 125 m AHD) were compared using the following nested design:

$$[\text{COPC}] = \mu + A_i + B_{j(i)} + e_{i,j,k} \quad \text{where:}$$

- [COPC] is the groundwater concentration (mg/L) of chemicals of potential concern,
- μ is the mean groundwater concentration (mg/L) of chemicals of potential concern in the mine lease,
- A is the variation of groundwater concentration in a landscape unit identified by geological group and position on a landscape slope (2 degrees of freedom),
- B is the variation of groundwater concentration in the portion of aquifer screened by a monitoring bore (6 degrees of freedom), and
- e is the error term (99 degrees of freedom).

The outcome of the nested test was that there was insufficient evidence from the available data to justify partitioning of background water quality data by geology or position on a sloping

landscape, demonstrated by low statistical power (between 0.05 and 0.36) and low effect size (η_p^2 between 0.001 and 0.48) of the test at the landscape unit level. Box and whisker plots of reference data, as well as the proposed groundwater trigger limit developed below, are shown in Figure 9.

It is possible to use the fifteen groundwater bores that are free of mine influence to describe variation in groundwater quality at the Mine scale with high statistical power (between 0.68 and 1) and reasonable effect size (η_p^2 between 0.11 and 0.99). There is significant heterogeneity among the bores used to represent background. Because the Mine is a volcanic complex subjected to varying depths of weathering and featuring igneous sill and dyke intrusions within meta-sediments, the observed heterogeneity in background groundwater bore chemistry is expected. It was decided to develop guideline values to represent groundwater at the Mine scale.

Rather than partitioning data into a weathered rock aquifer and fractured rock aquifer, the background groundwater water quality at the Mine scale was described as a fractured rock aquifer that has been variably weathered. The justification for this approach was that several reference bores (refer above) have screens that intersect multiple lithologies of both weathered and fresh fractured rock and purging three bore-casing volumes of water potentially draws fresh groundwater from both the weathered and un-weathered portions of the aquifer.

The *Queensland Water Quality Guidelines (2009)* have an interim procedure for developing sub-regional guidelines where the 20th and 80th percentiles from the reference sites are naturally heterogenous. This approach involves obtaining data from as many reference sites as possible, then calculating confidence intervals around the average 80th and 20th percentiles. That is two standard errors above the 80th percentile (i.e. +2xSE) and two standard errors below the 20th percentile (i.e. -2xSE) around the average 80th and 20th percentiles respectively. This government-standard procedure was adopted for the Stage 2 Environmental Evaluation.

The procedure recommended by the Idaho DEQ (2014) was applied as a supplementary approach for the Stage 2 Environmental Evaluation (Figure 10), primarily because the procedure had already been committed to by the Operational Groundwater Management Plan (Evolution, 2018). This procedure tests data for normality (p-p plots as well as Kolmogorov-Smirnov tests) and independence (Ljung Box Test). Some data were transformed to make the sampled population more normally distributed (log 100 [Ca], log [K], square root [Mg]), non-independent data were removed and trigger values were identified that accommodated for non-parametric population data distributions (if normality was not achieved or if a significant portion of data were non-detects). The trigger values were then back transformed to concentration in mg/L.

Both the DSITI (2017) and Idaho DEQ (2014) procedures were used to identify 80th percentile trigger values, and some COPC concentrations (aluminum, arsenic, boron, total cyanide, lead and selenium) were below the default ANZECC toxicant guideline values. For toxicants, DSITI (2017) indicate that when the local groundwater quality is less than the ANZECC toxicant guideline, the ANZECC toxicant guideline value is a suitable groundwater limit for initiating an investigation into the possibility of environmental harm. On this basis, the ANZECC toxicant guideline is proposed as the groundwater limit for aluminum, arsenic, boron, total cyanide, lead and selenium.

The proposed groundwater limits are represented below in Figure 9, as horizontal reference lines together with data from the nine bores used for the nested ANOVA test discussed above. Concentration units for each water quality parameter are mg/L except for EC ($\mu\text{S}/\text{cm}$), pH (unitless) and SO_4/Cl ($\text{Mol.L}^{-1}/\text{Mol.L}^{-1}$), and data have been transformed in some graphs as indicated above. Groundwater concentrations of the water quality parameters vary across the natural landscape, as shown by the non-overlapping boxplots from different bores. Interesting features of this natural variation of the water quality parameters are:

- 1) Low natural variability for groundwater pH across the Mine,

2) Naturally occurring exceedances of the 80th percentile trigger values are shown for major ions in monitoring bore MRMB64 (for K, Mg, Na, Cl, F, total alkalinity), MRMB13 (for Mg) and MRMB68 (for total alkalinity and F). The Environmental Authority states that major ions are used for interpretation purposes only, and as such these elevated natural concentrations do not represent exceedances of groundwater limits. However, MRMB64 showed natural exceedances of the proposed groundwater limits for EC (6362 $\mu\text{S}/\text{cm}$), As (0.013 mg/L), Cd (0.0002 mg/L) and Cu (0.002 mg/L). As such there are natural exceedances of the 80th percentile trigger values and proposed groundwater limits,

3) Monitoring bore MRMB38 contains elevated SO_4/Cl ratios relative to the proposed 80th percentile trigger value of 0.17 ($\text{Mol.L}^{-1}/\text{Mol.L}^{-1}$). The main aquifer of this bore is 14 to 34 metre below ground, and the bore-log reported a water-containing fracture at 14 metres. Bulk rock assays indicate a possible intrusive granitic signature at the 8 - 10 metre interval (marked by molybdenum), and possible weak mineralization between 8 – 12 metres (marked by As, Zn, Pb, Au), between 14-16 metres (marked by Zn), between 24 – 26 m (marked by Ag, Zn, Pb) and between 34 – 36 m (marked by Zn, Pb). The elevated SO_4/Cl ratios in this bore may represent an oxidized zone hosting weak mineralization, and

4) There is inherent variation in the concentrations of iron and manganese in bores MRMB64 and MRMB68, as well as variations in the concentrations of nitrate in MRMB64 and MRMB70. Changes in redox conditions, and possible microbial processes, might regulate the composition of the background concentrations of these redox sensitive solutes on a local to minesite scale.

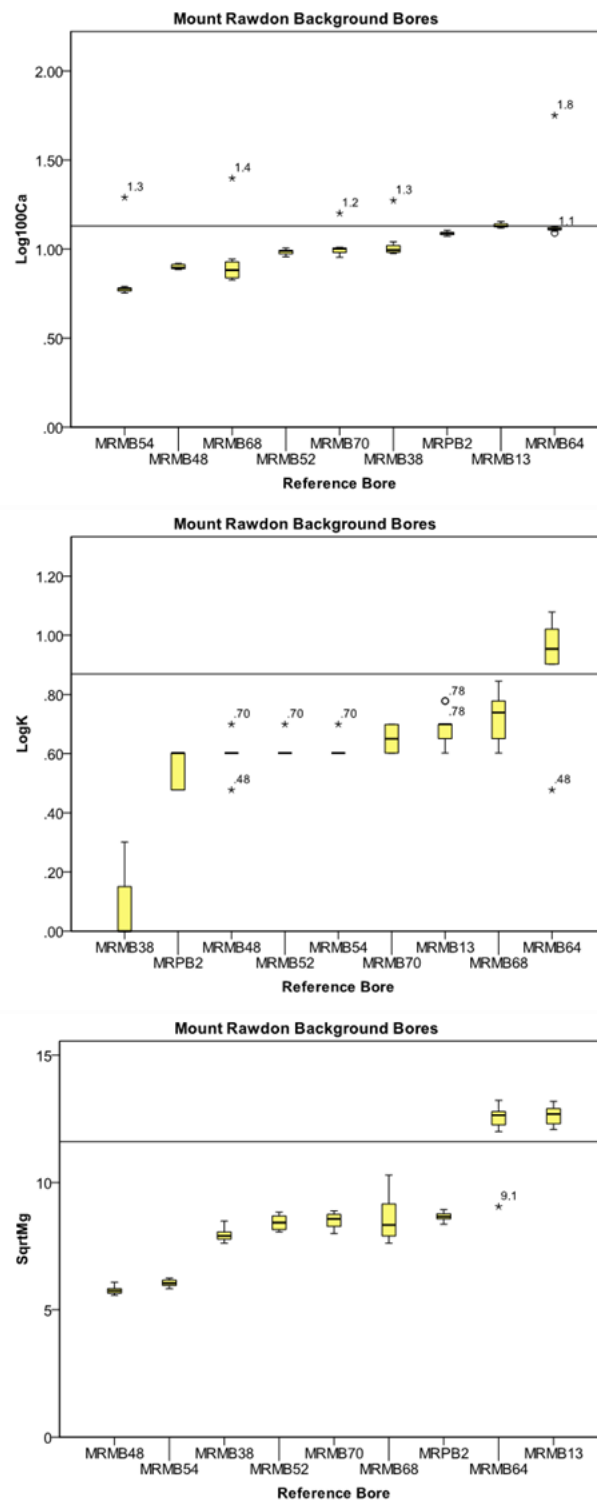
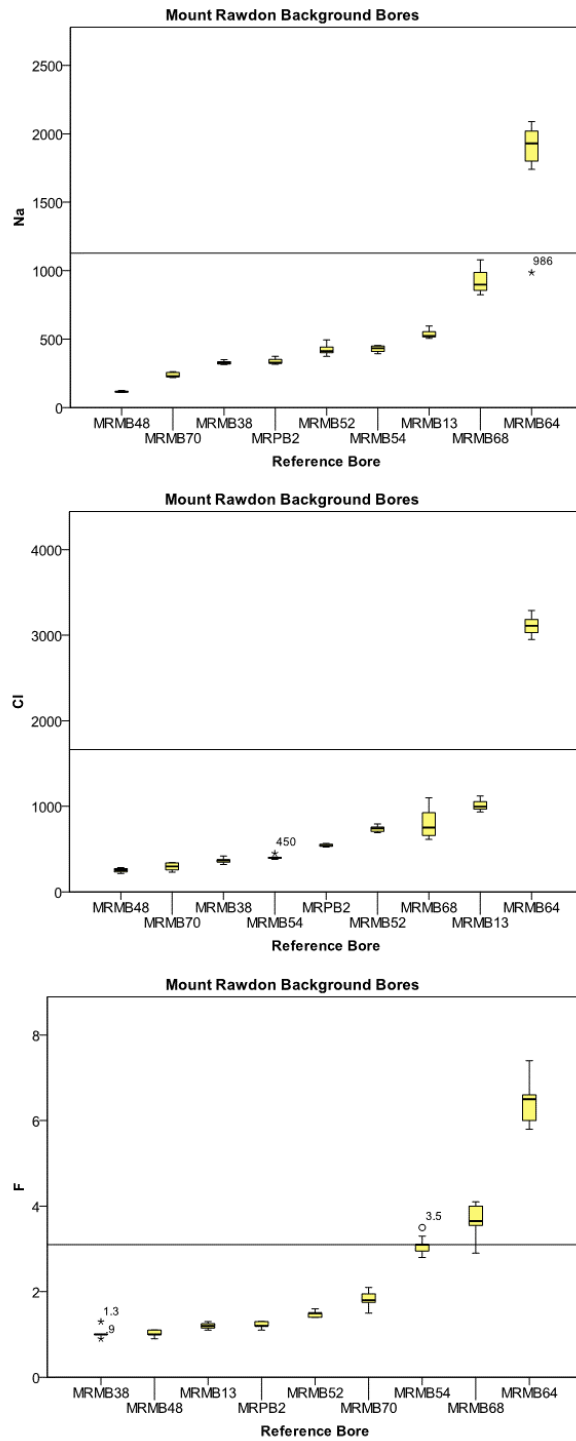
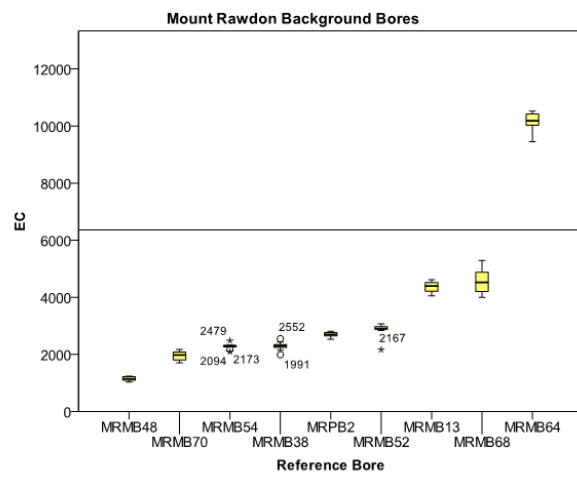
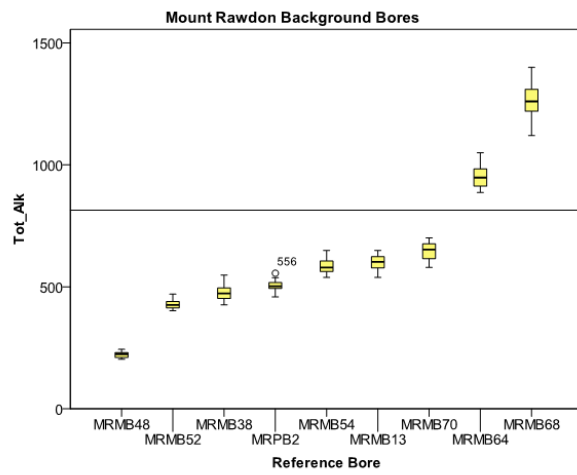
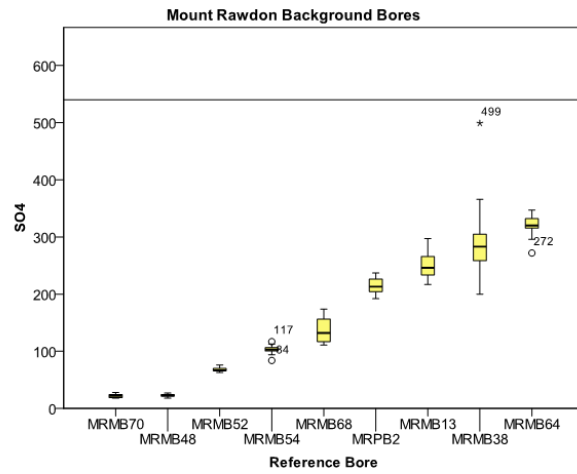


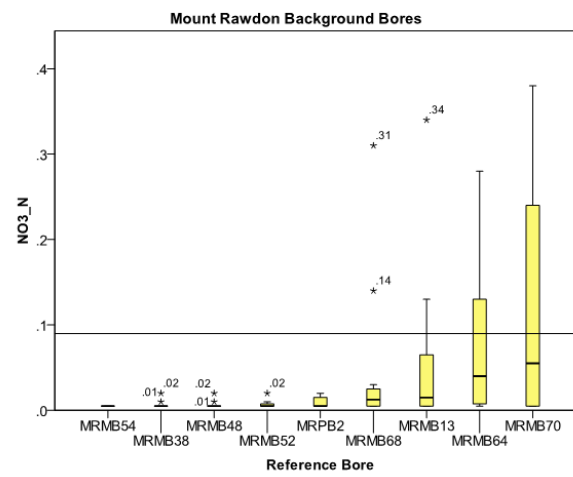
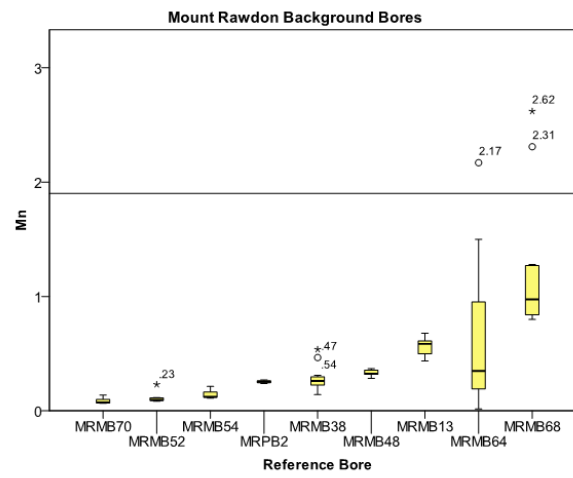
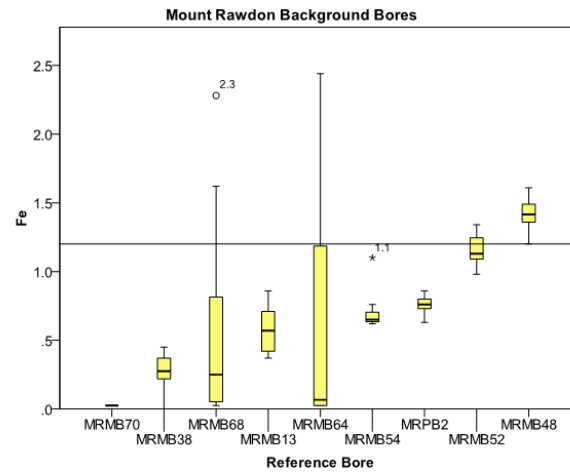
Figure 9: Box and whisker plots of reference groundwater bore data ⁸

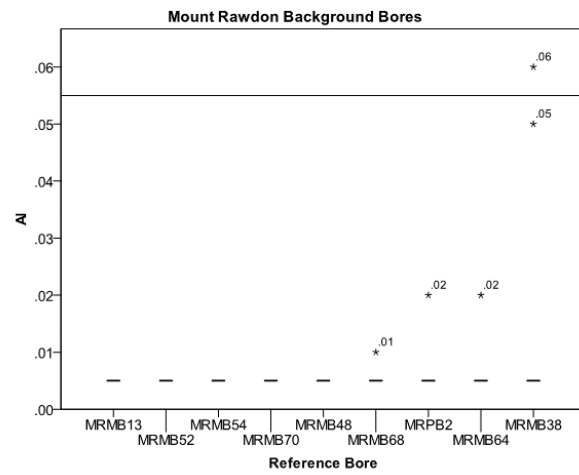
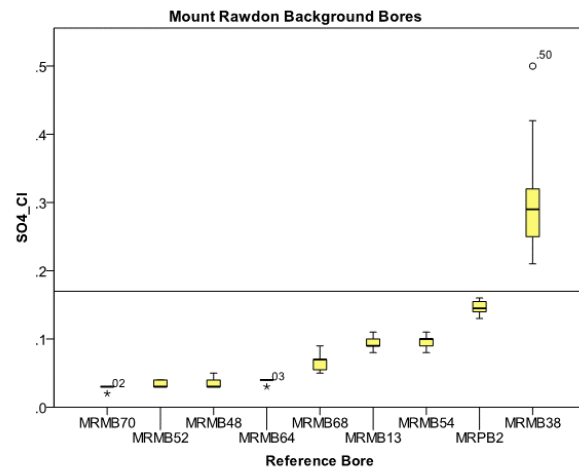
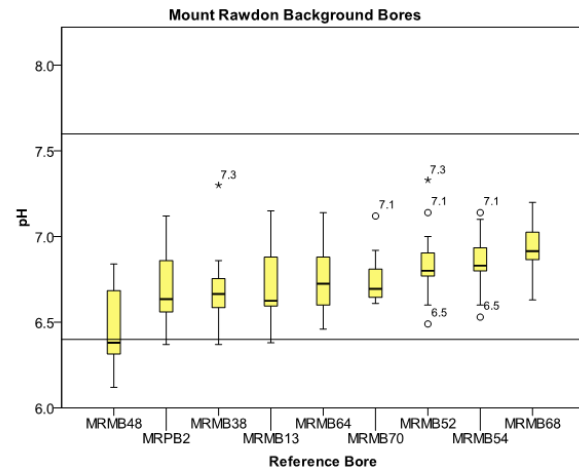
⁸ Data represented in the box-plots are from nine bores used for the nested ANOVA test. Units are mg/L except for EC ($\mu\text{S}/\text{cm}$), pH (unitless) and SO_4/Cl ($\text{Mol.L}^{-1}/\text{Mol.L}^{-1}$). For each groundwater bore, boxes show the median value, 25th percentile and 75th percentile, and whiskers show the smallest and largest values for each distribution. Circles show outlying values (1.5 – 3 box lengths from the edge of the box) and stars show extreme values (> 3

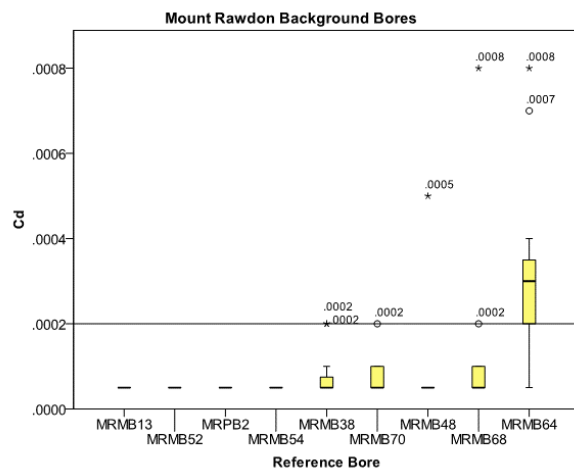
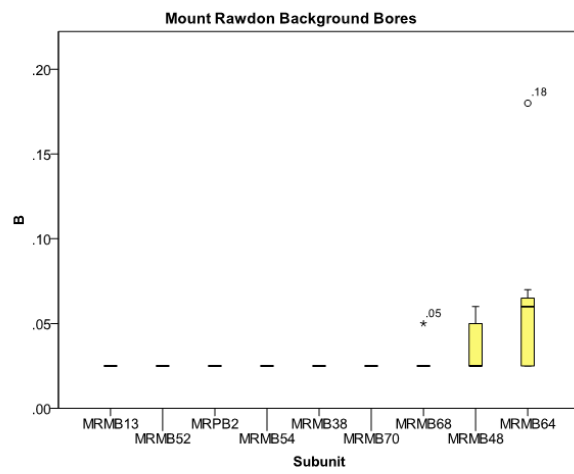
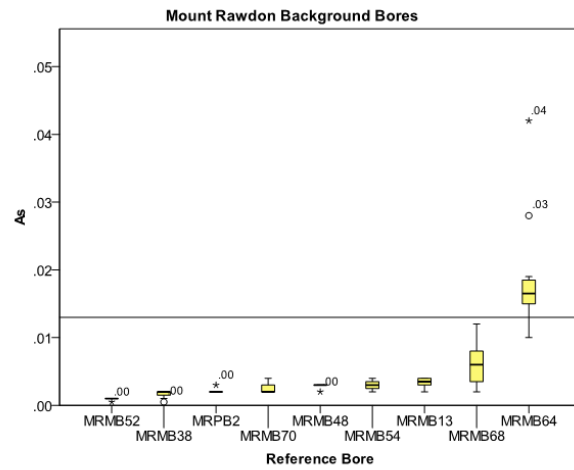


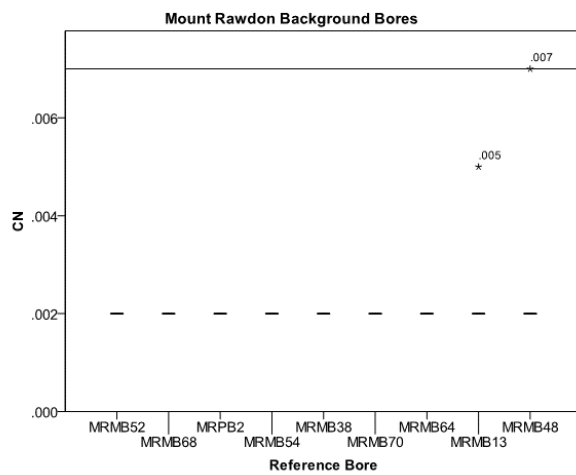
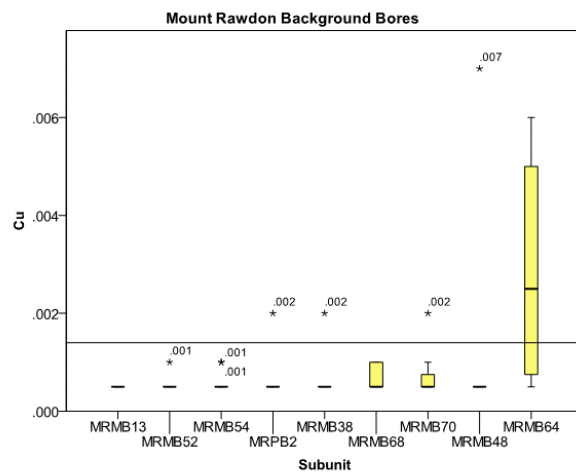
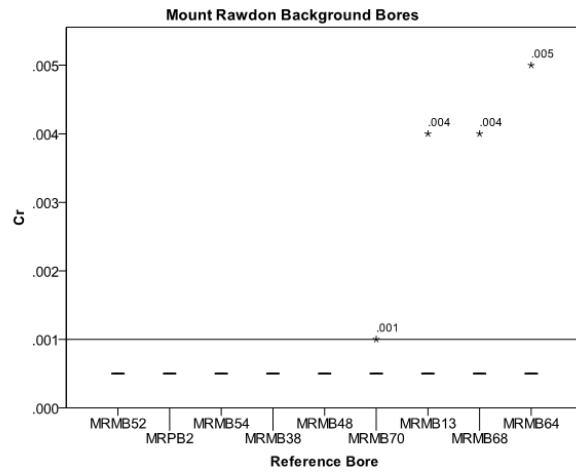
box lengths from the edge of the box) reported from each bore. The proposed groundwater limits are represented as horizontal reference lines. Data have been transformed to represent normality. The full dataset is represented (i.e. non-independent data have not been removed).

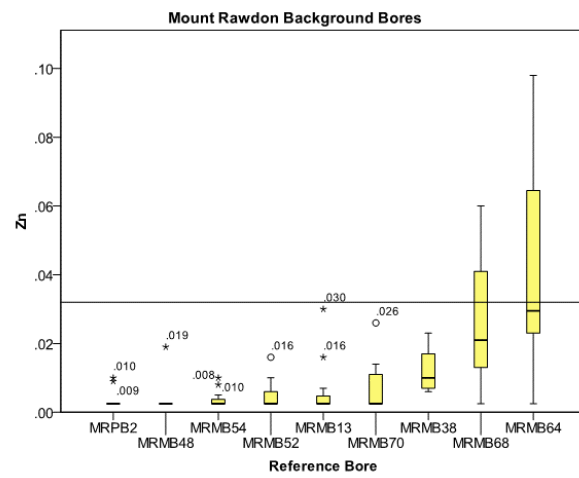
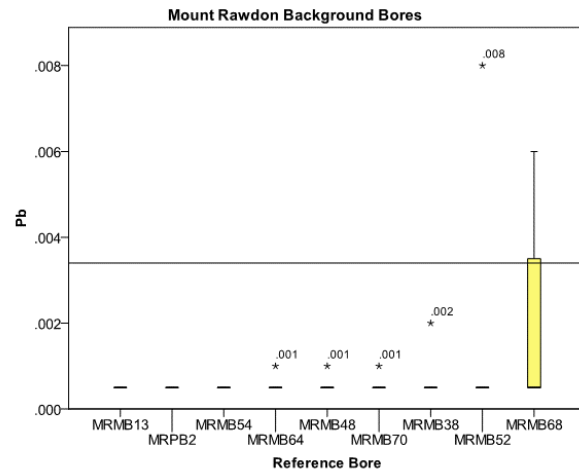












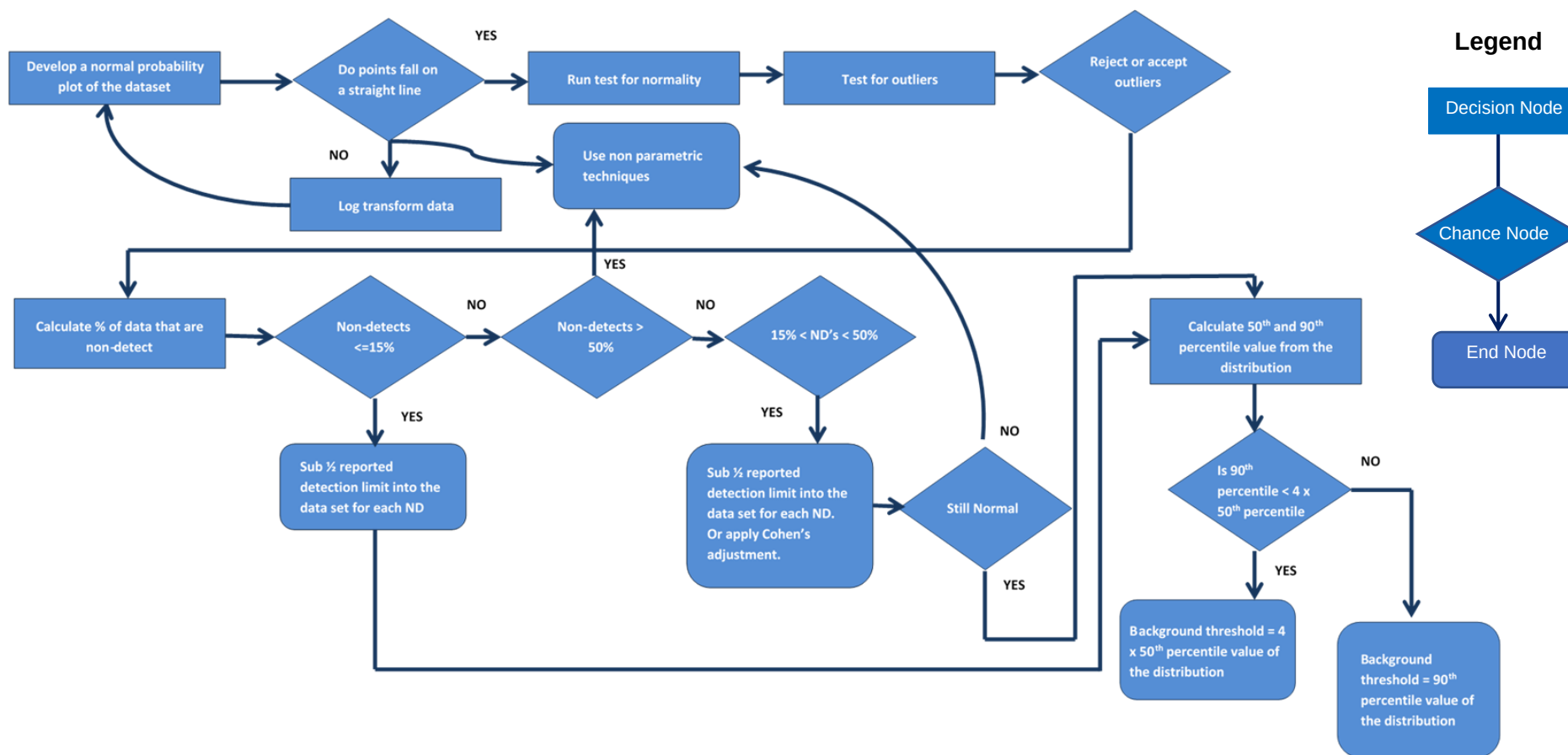


Figure 10: Statistical procedure for identifying background threshold values from groundwater data ⁹

⁹ The Idaho DEH recommend using the 90th percentile value. Evolution mining have used the 80th percentile value to be consistent with Australian criteria.

3.9 Identifying Mitigation Options

Water management units that have been commissioned to mitigate seepage up until now have been described in section 5.2 of the Stage 1 report. They include:

1. **Groundwater interception along the Northern Seepage Zone.** Seepage (pH 4.2 – 7.7, sulfate 322 – 2090 mg/L, nitrate N 0.01 – 21.8 mg/L, total cyanide 0.07 – 1.25 mg/L) is intercepted by the Seepage Interception Drain, as well as the reconditioned Toe Interception Seepage Drain that is now buried under the outer batter wall of the TSF. These water management units intercept seepage from the TSF that is returned to the processing circuit via Sediment Dam 1, and they limit the effective head potential of seepage from the TSF to downgradient receptors. The Seepage Interception Drain supersedes four pump-back wells and two pump-back bores,
2. **Groundwater interception downstream of the Western Saddle Embankment and the western side of the TSF.** Seep 26 (pH 7.9 – 8.0, sulfate 1650 – 1910 mg/L, nitrate N 1.54 – 1.87 mg/L, total cyanide 0.025 – 0.028 mg/L) has been intercepted and directed into the Seepage Interception Drain. Three pump-back bores have been commissioned, and two wells that intercept shallow groundwater seepage have had the reliability of their pump-back capability improved,
3. **Groundwater interception to the south and southeast of the TSF.** An interception drain connected to a sump (Stans Well) was installed along the southern wall of the TSF, which returns intercepted water (pH 7.6 – 8.6, sulfate 736 – 1770 mg/L, nitrate N $\leq$ 1.32 mg/L, total cyanide $\leq$ 1.28 mg/L) to the processing circuit via South Dam. Groundwater drawdown by Stans Well limits seepage expression below the eastern wall of the TSF, and
4. **Groundwater interception downstream of the Northern Waste Rock Dump and the West Waste Rock Dump.** Interception dams have been installed along drainage lines from the waste rock dumps. Sumps have been installed downstream of Waste Dam 1, Waste Dam 2 and West Dam to intercept mining - affected water (pH 6.3 – 8.9, sulfate 30 - 2710 mg/L, nitrate N $\leq$ 63.4 mg/L). Pump-back bores have been installed along the flow-paths from Waste Dam 1 and Waste Dam 2 to Twelve Mile Creek.

New mitigation options have been identified during Stage 2 to support the existing seepage management plan in the following areas:

1. **Along the western side of the TSF** to intercept seepage towards MRMB43 and MRMB44,
2. **Along the Northern Seepage Zone** to intercept seepage passing below the Seepage Interception Drain towards MRMB30, MRMB31, MRMB12 and MRMB65,
3. **In Rawdon Creek** to intercept seepage towards MRMB21 and MRMB39. Seepage along this creek appears to have stabilised already, and
4. **In the Twelve Mile Creek catchment** to intercept seepage towards MRMB63 and Twelve Mile Creek.

The justification for these locations were historical groundwater monitoring trends that show the extent of mining-affected groundwater in the Mine (refer Figure 21), geophysical images (ERI) that show likely flow-paths and possible bounding faults, and results of the solute transport model that indicated scenarios that might be achieved using the options listed below (model results are shown in section 4 and are discussed in section 5).

During the remaining life of mine operation to 2026 suggested mitigation options are:

1. **Extending the Seepage Interception Drain along the western side of the TSF** to intercept seepage towards MRMB43 and MRMB44. The design intent is to limit the effective head potential of seepage from the TSF to Swindon Creek, to the RL of the base of this drain, and
2. **Installing pump-back bores to intercept deep seepage pathways.** The design intent is to develop cones of depression that lower the standing water levels in the main seepage pathways (e.g. below the Seepage Interception Drain and near Seep 26) to match the invert level of the Mount Perry Weir, thereby removing the head potential of seepage via these pathways from the TSF to the Perry River. Geological interpretation based on geological mapping and ERI was used to locate these bores in priority areas where maximum effect is expected to be gained, and if required to position future pump-back wells in a staged approach that will be guided by the results of ongoing monitoring. The recovered seepage is to be returned to the processing circuit for reuse.

After mine closure, the commissioning of wetlands that intercept hyporheic flow and immobilise COPC's by sulfate reduction is being investigated by Evolution Mining, CSIRO and *Australian Wetlands Consulting*. Laboratory and field trials that are underway will be used to optimise the wetland design if this option progresses. This is a possible low-maintenance management option for intercepting and mitigating seepage that will be considered to support the closure plan.

4 Model Scenarios

The precautionary approach of adopting deliberately pessimistic mitigation predictions were adopted, to allow for redundancy in whichever mitigation approach is ultimately used. As such a relatively minor lowering of effective hydraulic head (by 0.75 m) resulting from the Seepage Interception Drain, and a relatively low rate of groundwater removal by pump-back bores (0.4 m³/d), were used in the mitigation scenarios.

4.1.1 Effect of the Seepage Interception Drain

The TSF Seepage Interception drain has been observed to lower the effective hydraulic head of seepage from the TSF by between 0.7 and 1.4 m during dry weather. The effect of lowering the effective head by 0.75 m was modelled.

4.1.2 Effect of Pump-back Bores

Pump back bores have been installed in the Mine. Pump-back bores MRDB2 and MRDB3, which were installed in flow-path A-A' remove about 0.09 m³/d and 0.7 m³/d of seepage respectively. Pump-back bore MRMB27, installed in flow-path D-D', removes about 4 m³/d of seepage.

The effects of the existing pump-back bores on seepage mitigation, and the effect of adding an additional pump-back bore, were modelled.

5 Results

For ease of description, the Mine has been partitioned into sub-catchments. The conditions that need to be met for the Environmental Evaluation are presented and discussed for each sub-catchment. First the groundwater limits, which have been developed for use at the Mine scale, will be described.

5.1 Guide to interpreting groundwater with high concentrations of Chemicals of Potential Concern

MRO extracts gold from pyrite (FeS_2). Heavy metals (As, Cd, Pb, Cu, Zn) are also hosted by sulfides in mineralized zones and are Chemicals of Potential Concern (COPC) that can migrate into groundwater because of mining activity.

Sulfate (SO_4), total cyanide (Tot. CN) and nitrate_N ($\text{NO}_3\text{-N}$) in groundwater are the best indicators of mining related activity at Mount Rawdon (Stage 1 Environmental Evaluation). In combination, these parameters indicate whether groundwater is being impacted by mining.

Because there are satellite ore bodies in the Mine, it is plausible that some of the high concentrations of SO_4 , As, Cd, Cu, Pb and Zn in groundwater are expressions of unmined ore bodies or mineralisation haloes. There are other enriched sources of $\text{NO}_3\text{-N}$ in the landscape (wetland processes, nitrogen fixing plants, bushfires), so it is plausible that sources other than explosive residues contribute to high nitrogen concentrations in groundwater.

The flow chart in Appendix 12 outlines a strategy to determine if groundwater with high concentrations of COPC is being affected by mining activity.

5.2 Swindon Creek headwaters

Synopsis: Results for the Swindon Creek headwater area, to address Items 5 – 9, 12 and 14 of the Environmental Evaluation (listed in section 2), are presented as follows:

- The role of chemical speciation on the release and transport of COPC in groundwater,
- Aquifer boundaries defined by geophysical evidence,
- The rates of COPC movement from the TSF to the riparian zone of Swindon Creek
- Statistical evaluations of COPC in groundwater within the headwater sub-catchment,
- Existing and future mitigations to intercept downstream movement of mining-affected water from the TSF to Swindon Creek

5.2.1 Pathways and mechanisms for the release and transport of mining related solutes to groundwater in the headwater zone of the Swindon Creek sub-catchment

In Upper Swindon Creek (bores MRMB43 and MRMB44) the activities of Al^{3+} and Cr^{3+} were lowered by about 80% relative to the total dissolved concentrations of these metals, and activities of Cd^{2+} , Cu^{2+} , Fe^{2+} , Mn^{2+} , Pb^{2+} and Zn^{2+} were lowered by about 50% relative to total concentrations. Several dissolved metals (Cd^{2+} , Fe^{2+} , Mn^{2+} and Zn^{2+}) exist dominantly as free ions, with bicarbonate and carbonate species of these metals being present in lesser amounts. Carbonate complexes are the dominant dissolved forms of Cu^{2+} and Pb^{2+} . Hydroxyl complexes form with Al^{3+} and Cr^{3+} . Boron and arsenic occur as boric acid (H_3BO_3) and arsenous acid (H_3AsO_3). As such, carbonate, hydroxyl and oxide complexes are important components of the groundwater matrix that moderate the release and transport of solutes in groundwater. The toxicity of metal species and metal complexes in part relate to the solubility of the metal, the valence state of the metal and whether the metal is in an inorganic form or complexed with an organic ligand.

Aluminium (Al^{3+}) and Mn^{2+} occur at concentrations that allow the formation of mineral precipitates (e.g. gibbsite, pyrolusite and potentially other minerals), which immobilise Al^{3+} and Mn^{2+} and limit their transport in groundwater. Coprecipitation of clay and carbonate (e.g. kaolinite, calcite and other minerals) generate fracture minerals with charged surfaces that adsorb Pb^{2+} and Cu^{2+} , thereby assisting the aquifers capacity to attenuate these COPCs.

Beyond the prediction of metal speciation based on major ions and trace metals using Visual MINTEQ, we have not measured for dissolved humic or fulvic substances that might complex metals such as cadmium, copper and zinc in receiving surface water or groundwater

environments. Nor have we progressed with more detailed interpretation of the possible role that metal speciation, might have on toxicity. The reasons for not progressing with a toxicity investigation was because there is no evidence for contamination of waterways based on seven years of AUSRIVAS monitoring of aquatic macroinvertebrates in local streams, as well as a recent investigation of stygofauna that reported low occurrence and limited range of taxa in groundwaters of the Mine.

In summary dissolved complexes lower the activities of Al^{3+} , Cr^{3+} , Cd^{2+} , Cu^{2+} , Fe^{2+} , Mn^{2+} , Pb^{2+} and Zn^{2+} in groundwater solution, which moderates their behaviour in groundwater. A proportion of these COPC's are expected to be transiently to permanently immobilised by coprecipitation and/or adsorption to fracture minerals such as gibbsite, pyrolusite, clay and carbonate depending on the prevailing physico-chemical conditions.

5.2.1.1 Geophysical evidence for groundwater pathways to the headwater zone of the Swindon Creek sub-catchment

Electrical Resistivity Imaging (ERI) was performed to evaluate subsurface conditions that might indicate seepage pathways. The resistivity sections showed a highly variable weathering profile and deeper weathering profiles likely to translate to increased fracturing and associated increases in permeability.

The method showed a distinct boundary between clays/weathered bedrock (see cyan – green coloured areas representing ERI contour values 2 – 2.5 Ohm.m logarithmic). At depth, vertical features in the ERI images might indicate possible faults. However, the method does not discriminate well between near surface clay soil and highly weathered bedrock (blue – purple colours) because both lithologies are conductive and have similar resistivity values.

The geophysical transects were used to identify three deep pathways for seepage mitigation using pump-back bores (MRDB1, MRDB2 and MRDB3), with the ERI <1.75 Ohm.m logarithmic contour being used to infer the presence of weathered strata through which seepage was inferred. The hydraulic cross-sectional areas of the seepage pathways (aquifer) were inferred from the ERI <1.75 Ohm.m logarithmic contour.

A pump-back bore MRDB3 (formerly called TS06) was commissioned in line 5 (Figure 11), and another pump-back bore MRDB1 (formerly called TS02) was commissioned in line 3 (Figure 12), where deep pathways were identified. A third pump-back bore (MRDB2) could not be installed at the preferred location (TS07 in line 1) because of the planned extension of the TSF batter wall during the Stage 5 lift, but instead was installed approximately where AS4L2 in line 5 was located (Figure 13). These bores create localized cones of depression in the deep fracture zone that match the level of the stream bed in Swindon Creek. The design intent of this strategy is to lower the effective hydraulic heads of groundwater flows through these seepage pathways.

The ERI contours were represented in 3 dimensions using *Leapfrog*® geological software, which indicated a shallow, high conductivity zone in the Swindon Creek upper catchment that extended across Swindon Creek from the TSF on the right bank to the left bank (Figure 14a). Monitoring bores MRMB43 and MRMB44 are in the riparian zone adjacent to the creek. MRMB44 screens 10 – 13m below ground in weathered rock in the 1.6 – 1.8 Ohm.m logarithmic interval, and MRMB43 screens 24 – 37.5 m below ground in weathered fractured rock in the 2.2 – 2.4 Ohm.m logarithmic zone. The shallow, conductive zone could be a groundwater pathway from the TSF to the upper section of Swindon Creek (Figure 14b).

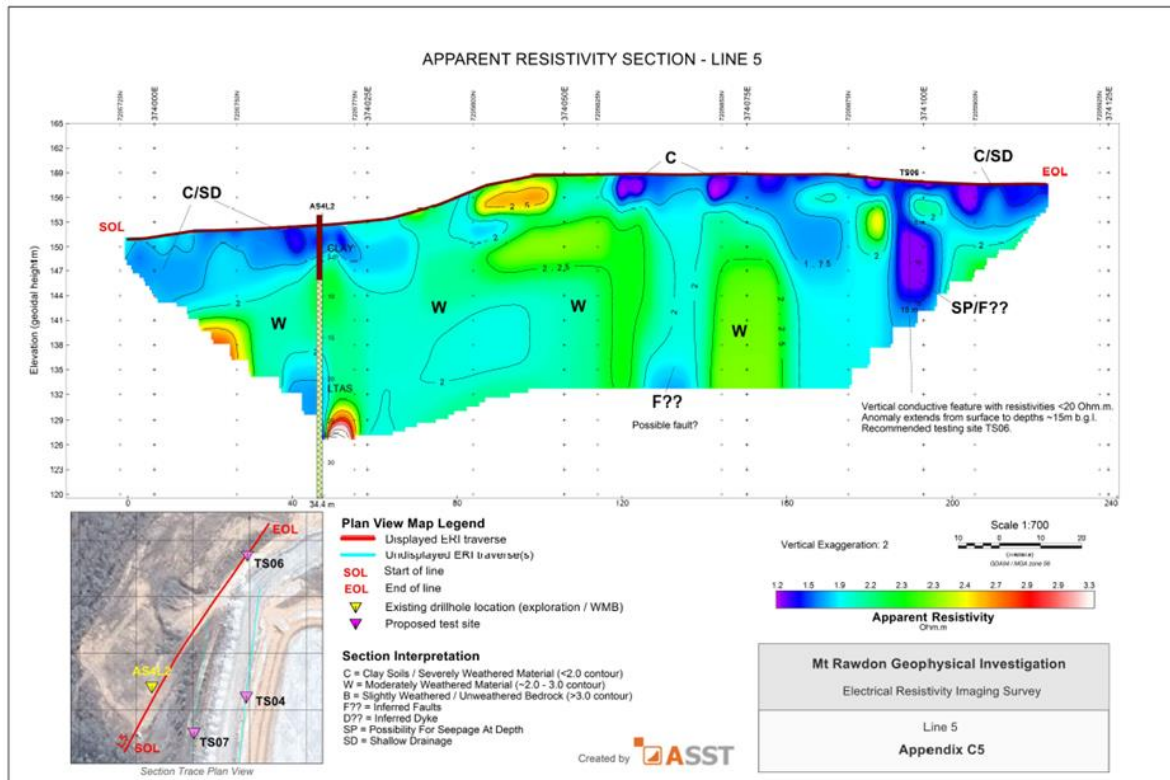


Figure 11: ERI image for line 5 that hosts pump-back bore MRDB3 (formerly TS06)

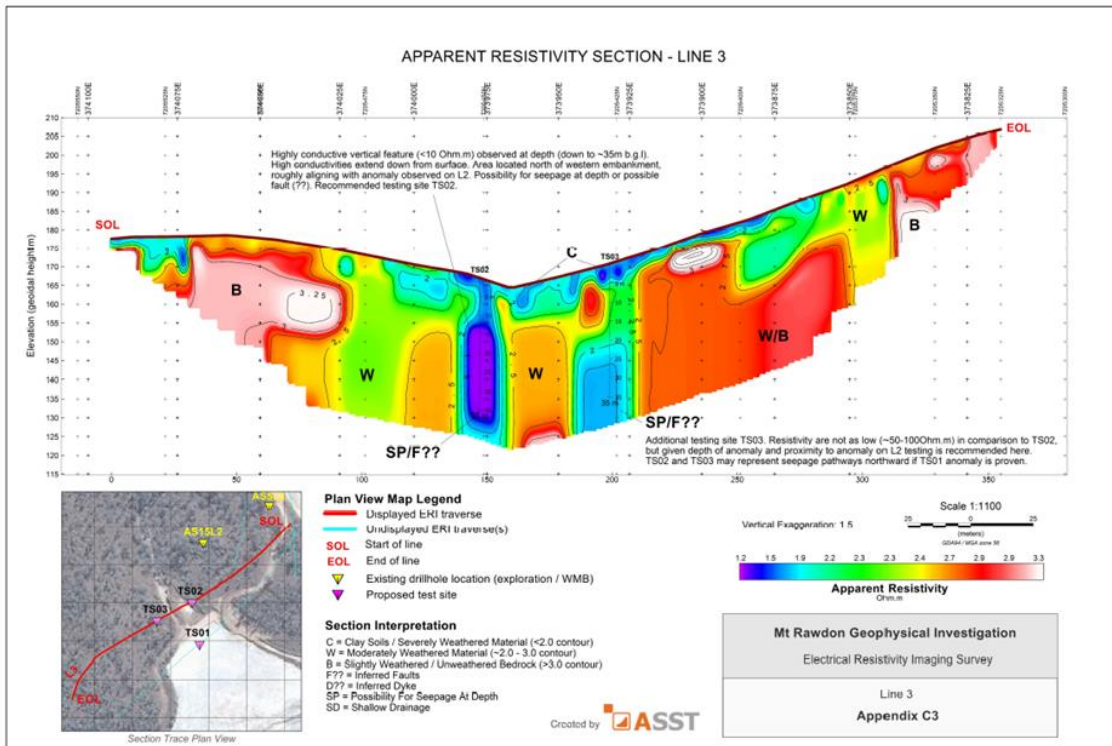


Figure 12: ERI image for line 3 that hosts pump-back bore MRDB1 (formerly TS02)

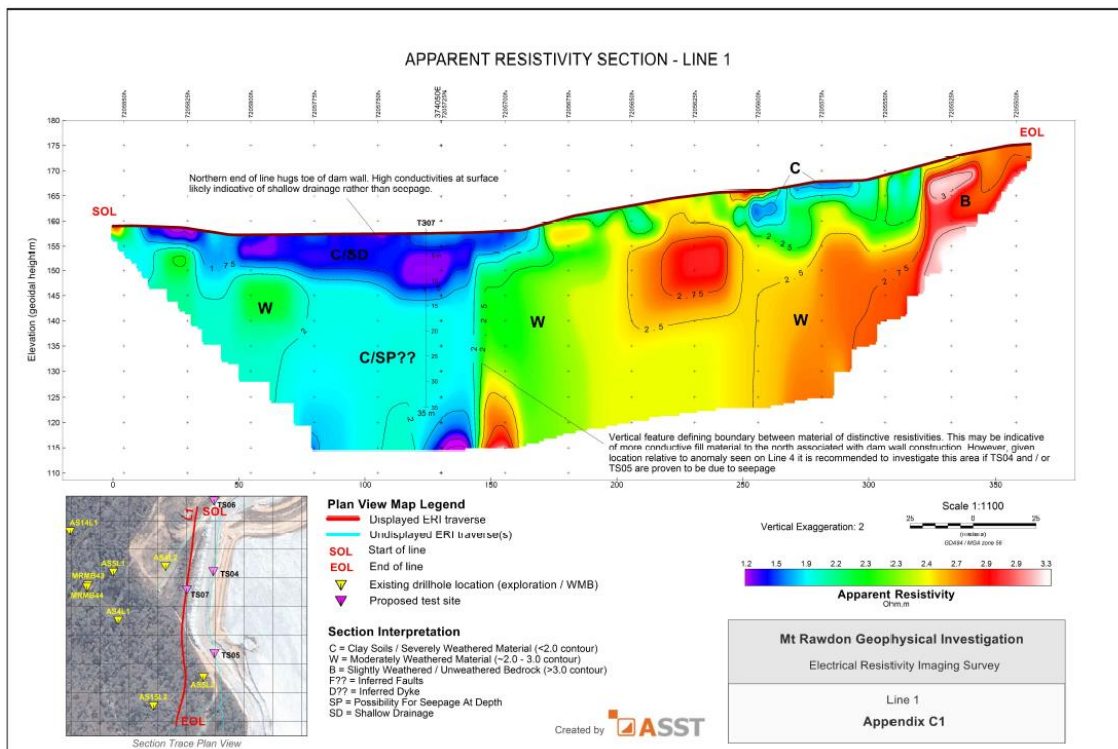


Figure 13: ERI image for line 1 that hosts pump-back bore MRDB2 (formerly TS07)

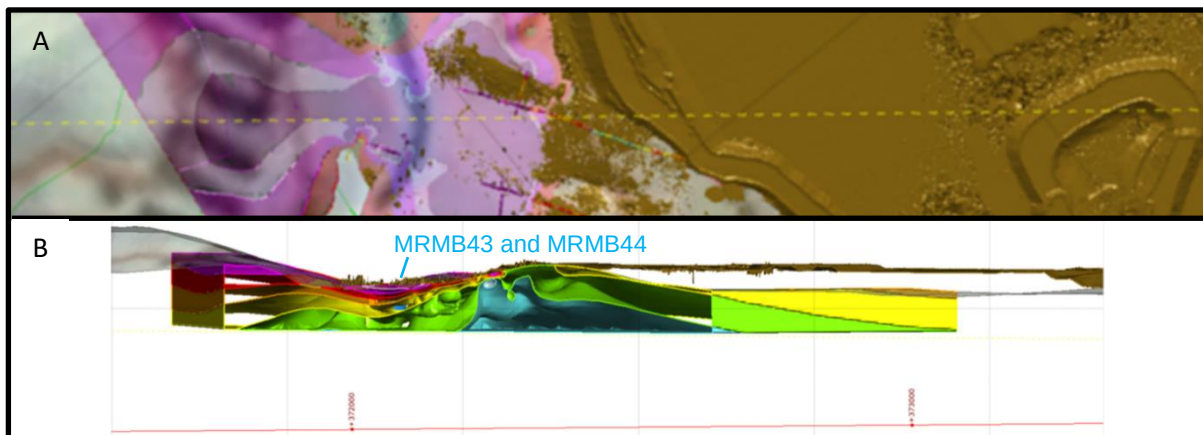


Figure 14: Planview and profile of western side of the Tailings Storage Facility

5.2.2 Rates and direction of solute movement in groundwater

Calculation of groundwater movement assuming Darcian flow (and the aquifer parameters reported in Stage 1) indicates that solutes travel from the TSF outer batter wall towards the upper section of Swindon Creek at a seepage velocity of about 21 m/year through saprolite, taking 9.7 years to reach the riparian zone of the creek where a monitoring bore that screens 10 - 13 metres below ground is located (MRMB44). In deeper fractured rock the seepage velocity is slower, at about 5.3 m/year, and seepage would take 39 years to reach the riparian zone where a deeper monitoring bore that screens 24 – 37.5 metres below ground is located (MRMB43). MRMB43 and MRMB44 are paired monitoring bores.

Field observations of the increase in the SO_4/Cl concentration ratio over time correspond with solute movement through saprolite. While the deep bore (MRMB43) also shows an increase in SO_4/Cl concentration ratio over time, the increase in the deeper fractured rock can be explained by bore purging causing groundwater from the shallow aquifer to be drawn into the deep aquifer.

As such it was concluded that the movement of mine-affected groundwater towards the upper section of Swindon Creek is through saprolite, at rates consistent with Darcian flow based on the aquifer parameters reported earlier during Stage 1.

5.2.3 Statistical Evaluation of Groundwater Quality in the headwater zone of the Swindon Creek sub-catchment

A Piper diagram showing 50th percentile values for major elements in groundwater monitoring bores in Swindon Creek, and for major elements in seepage expression from Seep 26 and in Sediment Dam 1, is provided in Appendix 13. For comparison the 20th, 50th and 80th percentile values of major elements in TSF decant water as well as in waste rock seepage (measured in seepage from the NWRD) are included in the Piper diagram.

The Piper diagram showed that the waste rock source term was a calcium chloride type water, whereas the decant water as well as Seep 26 water and Sediment Dam 1 water were sodium chloride type water. In terms of anions all the mining related source terms were sulfate type water. In terms of cations the source term for the decant, Seep 26 and Sediment Dam 1 was sodium and potassium type water, while the source term for waste rock was either calcium type water or no dominant type.

In comparison water from MRPB2 was mixed calcium chloride, sodium chloride and magnesium bicarbonate water, while water from MRMB43 and MRMB44 was mixed sodium bicarbonate, magnesium bicarbonate and sodium chloride water. In terms of cations the

monitoring bores were sodium and potassium type water, and in terms of anions monitoring bores MRMB43 and MRMB44 were bicarbonate type water, while MRPB2 was chloride type water. Importantly no monitoring bore was the predominant sulfate water type of the mining related source terms, therefore the median water type was predominantly not seepage.

An additional Piper diagram showing representative ranges of groundwater quality over time were also developed for MRMB43 and MRMB44, as well as for the reference bore MRPB2. The Piper diagrams shows that the bores are not sulfate type water, although MRMB44 does shows some shift in anion composition from bicarbonate type water to no dominant type.

Correlations for SO_4/Cl vs Na/Cl show the relative contributions of sulfate and sodium to groundwater solutes (Appendix 13). Monitoring bores MRMB43 and MRMB44 show a slight shift along the SO_4/Cl axis, negligible change along the Na/Cl axis, and weak correlations among these ions that indicate that the contribution of sulfate enriched (mining – affected) groundwater reporting to these monitoring bores is relatively low.

Boxplots of mining related COPC's for MRMB44 reported a median ratio of SO_4/Cl that exceeded the proposed groundwater trigger limit of 0.17 M/M, and time series graphs show an increasing trend for this element ratio over time. Since March 2018 the concentration of sulfate in MRMB44 has exceeded the proposed trigger limit of 540 mg/L. The time series graphs for MRMB44 show that the SO_4/Cl ratio and EC trends stabilised during 2019 and started to reverse after June 2019. MRMB43 reports a slowing but still increasing trend for SO_4/Cl .

Groundwater concentrations of total cyanide for MRMB44 and MRMB43 also reported increasing trends over time, with total CN in MRMB44 exceeding 0.007 mg/L in August 2019, and total CN in MRMB43 equalling 0.007 mg/L in February 2019. The median groundwater concentration during 2019 however remained below the proposed trigger limit of 0.007 mg/L.

In summary, some mining influence on the SO_4/Cl ratio and total cyanide concentration in groundwater has reported to the riparian zone of the upper section of Swindon Creek screened by monitoring bores MRMN44 and MRMB43. The monitoring data show that during 2019 the installation of pump-back bores that intercept deep seepage pathways, and improved reliability of water management units, have demonstrated initial success at stabilising the seepage of mining - affected water towards the upper section of Swindon Creek.

5.2.4 Solute movement

The NETPATH model was used to evaluate the processes of rock weathering, and formation of secondary minerals in the weathering profile, which were identified by the conceptual model (discussed in section 2.2 and tabled in Appendix 1). The following models converged, which indicate that they are stoichiometrically plausible descriptions of the release and transport of solutes in groundwater moving from the TSF to the upper section of Swindon Creek.

On 17/5/2018 the shallow aquifer (MRMB44) was consistent with 4.1% TSF fluid, 19.7% solutes generated in the outer batter wall of the TSF, and 76.1% native groundwater. Reactions of groundwater with the aquifer, which were associated with solute concentrations ($\mu\text{M}/\text{kg}$ water) moving along the flow-path were:

3.7 Pyrite - 28.1 Rhodochrosite – 932 Calcite – 107 Goethite – 5446 Gibbsite + 933 Exchange - 9277 Illite + 5463 K mica + 4462 Mg Montmorillonite.

A positive symbol indicates dissolution of a mineral phase (i.e. pyrite releasing iron and sulfur into groundwater) and a negative symbol indicates precipitation of a mineral phase (i.e. rhodochrosite removing manganese and carbonate from groundwater).

On 11/5/2018 the deep aquifer (MRMB43) was consistent with 3.5% TSF fluid, 2.1% solutes generated in the outer batter wall of the TSF and 94.5% native groundwater. Reactions of groundwater with the aquifer associated with solute concentrations (mM/kg water) were:

4.4 Pyrite – 0.9 Rhodochrosite – 2090 Calcite + 17 Goethite - 2075 Exchange - 189 Illite - 75 Mg Montmorillonite – 1306 Quartz + 610 Albite.

Purging of the deep bore could have drawn mining - affected water from the shallow aquifer, and it is possible that the mine effect is in the surface aquifer and the deep aquifer is unaffected.

As such the inverse model was consistent with the presence of a small amount of mining - affected water in the riparian zone of upper Swindon Creek, which included both a tailings fluid component and a waste rock component (representing solutes washed off the outer batter wall). The mining - affected water had reacted with the aquifer during groundwater movement from the TSF to the monitoring bores. The inverse model did not converge for evaluations of water quality done at earlier dates.

The PHREEQC solute transport model results are shown Appendix 7 as follows:

1. Sensitivity testing results that show graphical responses to varying amounts of evaporation for major ion concentrations in mg/L (Ca, Mg, SO₄, K, Na, Cl, SO₄/Cl, N and CN), which was the line of best fit when flow, CEC and HFO adsorption parameters had been adjusted.
2. The graphs show how modelled data for the breakthrough curve responded to varying amounts of evaporation/ evapotranspiration during downslope flow of groundwater, with modelled results being compared with measured data in the MRMB44 monitoring bore. Results indicate reasonable fit for some ions and poor fit for other ions (the outcome of the sensitivity tests and calibration are discussed below),
3. Graphical PHREEQC output for unmitigated seepage, which indicates the projected long-term reporting of mining - affected water to MRMB44. This graph shows that sulfate, cyanide and arsenic (anions) are mobilized faster than copper and lead in the seepage plume. Monitoring has confirmed breakthrough of sulfate and cyanide, but arsenic has not yet been observed in monitoring bore MRMB44, and
4. The effects at slowing the breakthrough of mining - affected water to MRMB44, by four mitigations:
 - a. Mitigation 1. Lowering the effective head from the base-case (A-A' Saprolite + 2.5% Evaporation), by 0.75 m by extending the northern seepage drain to include seepage from the Seep 26. This would lower the rate of groundwater flow from the TSF from 7 m³/d to 6 m³/day,
 - b. Mitigation 2. Lowering the effective head from the base-case (A-A' Saprolite + 2.5% Evaporation) by installing MRDB2 and MRDB3 to intercept seepage from the Seep 26 (this has already been done). This lowered the rate of groundwater flow from the TSF from 7 m³/d to 6 m³/day,
 - c. Mitigation 3. Combined effects of mitigations 1 and 2. This would lower the rate of groundwater flow from the TSF from 7 m³/d to 5.3 m³/day, and
 - d. Mitigation 4. Mitigation 3 plus installing an extra dewatering well. This would lower the rate of groundwater flow from the TSF from 7 m³/d to 4.9 m³/day

Sensitivity testing and calibration of the solute transport model (PHREEQC) indicated that the best model fit was for groundwater flow through saprolite with the hydraulic conductivity measured in MRMB44 (K = 0.079 m/d), a low CEC capacity, low availability of hydro-ferrous oxide surfaces, and a small amount of evaporation (2.5%). This model provided the best possible fit for SO₄, Ca, Mg, Na and K (Appendix 7). However, the fit for some other elements was poor (N, Cl), possibly because processes responsible for groundwater concentrations of these elements are not represented by the PHREEQC model (refer discussion in section 3.5).

5.2.5 Effect of mitigation on solute movement

Estimates of Darcian groundwater flow rates through hydraulic cross sectional areas were identified using the ERI <1.75 Ohm.m logarithmic contour, as well as recharge rates measured during a pumping test when the bores were pumped to dryness then allowed to recharge, and the long - term seepage recovery between the 1st November 2019 and the 1st June 2020 are shown in Table 4.

Table 4: Pump-back bore recovery of seepage from the Western Cell and western side of the TSF

Dewatering Bore	Estimated groundwater discharge (m ³ /day)	Measured recharge of groundwater bore (m ³ /day)	Measured long – term seepage recovery (m ³ /day)
MRDB1	0.72 – 1.87	< 2.16 (0.72 median)	Data not logged
MRDB2	8.64 – 12.96	< 2.59 (1.44 median)	< 0.31 (0.10 median)
MRDB3	1.15 – 1.30	<3.89 (1.15 median)	0.21 - 1.77 (0.57 median)

Existing mitigation includes two pump-back bores (MRDB2 and MRDB3) in the flow-path of Seep 26, which have slowed the modelled groundwater discharge along the flow-path from 7 m³/d (refer table in Appendix 5 listing groundwater flow through saprolite assuming K_{sat} of 0.079 m/d) to about 6 m³/d. Two additional mitigation are proposed that involve (1) extending the Seepage Interception Drain and (2) installing an additional dewatering well. Individually the mitigations will limit groundwater discharge by about 1 m³/d, and in combination the existing pump-back bores, the extended drain and an additional dewatering well is expected to limit groundwater discharge from 7 m³/d to 4.9 m³/d. Slowing seepage from the TSF will delay breakthrough of mine solutes to the creek by about 3 years, which is a period that approaches completion of mine life after which mitigations associated with the mine closure plan can be considered for implementation (Appendix 7).

It is anticipated that the mine closure plan will involve decommissioning and capping the TSF, and possibly installing constructed wetlands to intercept and mitigate seepage of mining - affected groundwater.

5.3 Swindon Creek lower reaches

Synopsis: Results for the Northern Seepage Zone, describing groundwater movement towards the lower section of Swindon Creek and the adjacent unnamed creek, to address Items 5 – 9, 12 and 14 of the Environmental Evaluation (listed in section 2), are as follows:

- The role of chemical speciation on the release and transport of COPC in groundwater,
- Aquifer boundaries defined by geophysical evidence,
- The rates of COPC movement from the TSF to the riparian zone of Swindon Creek
- Statistical evaluations of COPC in groundwater within the sub-catchment,
- Existing and future mitigations to intercept downstream movement of mining-affected water from the TSF to Swindon Creek

5.3.1 Pathways and mechanisms for the release and transport of mining related solutes to groundwater

In lower Swindon Creek (bores MRMB9 and MRMB10) the activities of free Al³⁺ and Cr³⁺ ions were lowered by about 90% relative to the total dissolved concentrations of these metals, and activities of Cd²⁺, Cu²⁺, Fe²⁺, Mn²⁺, Pb²⁺ and Zn²⁺ were lowered by about 60% relative to total concentrations due to complexation with anions.

Solute modelling indicated that dolomite, gibbsite and possibly calcite and other aluminium hydroxides may precipitate as secondary minerals. In the riparian zone of lower Swindon Creek (MRMB12), precipitation of clay (kaolinite), silica (chalcedony, quartz) and apatite is plausible based on solute modelling.

In summary dissolved complexes lower the activities of some COPCs (Al^{3+} , Cr^{3+} , Cd^{2+} , Cu^{2+} , Fe^{2+} , Mn^{2+} , Pb^{2+} and Zn^{2+}) in groundwater solution, and moderate their release and transport in groundwater. Some COPC's are expected to be immobilised by coprecipitation and/or adsorption to fracture minerals such as gibbsite, clay and dolomite. This process of complexation, precipitation and release of solutes into groundwater is included in the solute transport model.

5.3.1.1 Geological evidence for groundwater pathways in the Northern Seepage Zone

A three-dimensional representation of possible groundwater pathways was developed using *Leapfrog*® software, based on the following data:

- 1) Electrical Resistivity Imaging,
- 2) Lithologies and faults mapped along the Seepage Interception Drain,
- 3) The surface geology of the mining lease,
- 4) The topographic surface of the mining lease,
- 5) The topographic surface of the Tailings Storage Facility,
- 6) The groundwater surface developed by the MODFLOW groundwater model (Northern Resource Consultants, 2019) that represents contours from which the direction of steady state groundwater flow can be inferred,
- 7) Groundwater bores showing depth of the screen zone.

Geological contacts between volcanics, metasediments and faults mapped along the Seepage Interception Drain, the screened zone of the groundwater bores, 10 metre contours of the groundwater surface, and the ERI transects are shown by Figure 15. Of note are vertical features in the ERI transects that coincide with the geological contact between volcanics and metasediments, and with faults in that part of the Seepage Interception Drain.

The TSF topography and ERI resistivity contours in planview are shown in Figure 16, and indicate shallow, high conductivity zones that are potential groundwater flow-paths. The high conductivity near-surface clays (ERI contour values < 1.5 Ohm.m logarithmic) downgradient of MRMB9 are superimposed above slightly less conductive weathered rock (ERI contour values 1.6 – 1.9 Ohm.m logarithmic) at depth. The insert in Figure 16 shows extensions of a mapped fault and lithological contacts that may influence groundwater flow. These geological extensions were identified by surface mapping of structures and lithologies associated with salt efflorescence on exposed rock in the Seepage Interception Drain as well as along Swindon Creek and the unnamed creek, and are considered to represent potential groundwater flow-paths associated with the Northern Seepage Zone. This field identification has been used to coordinate the installation of dewatering bores that will connect with deep flow-paths that penetrate below the Seepage Interception Drain, and the bores will be used to create cones of depression that intercept seepage from the TSF via the Northern Seepage Zone (refer section 6.8).

The vertical and horizontal extents of the groundwater pathway through the northern seep are shown in Figure 17, which extends north from MRMB09 through the Seepage Interception Drain past MRMB30 towards MRMB65. Bore MRMB09 screens in a strongly oxidised zone at 12 – 16m, a moderately oxidised zone at 16 – 18m, and weakly oxidised to fresh rock between 18 – 24m (1.7 Ohm.m logarithmic interval). Bore MRMB30 was deliberately positioned on interpreted geological structures down-gradient from MRMB09 and screens in the 1.8 – 2.2 Ohm.m logarithmic interval. Bore MRMB65 screens a contact between fresh granite and fresh Curtis Island Metasediments between 27.3 and 30m in the 2.2 – 2.5 Ohm.m logarithmic interval.

A deep vertical ERI feature that indicates deep weathering associated with a bifurcation in the West Dam Fault contact between the Curtis Island Metasediments and Aranbanga Andesite Volcanics is shown in Figure 18. The West Dam Fault is argillized, silicified and weakly carbonatized gouge material that is several metres wide at the surface and less than 1 m wide at 220 m depth, which was represented as a flow barrier in the MODFLOW SURFACT groundwater model. There is no geological evidence of oxidation at depth associated with this fault, and hence no evidence of transfer of oxygenated water from the surface to depth, which supports the inference that the fault does not transmit fluids.

The West Dam Fault is shown as being a barrier to groundwater flow in Figure 15 by the curved 140 m AHD groundwater contour. Bore MRMB10 screens 18 to 36 m below ground in the 2.0 – 2.2 Ohm.m logarithmic interval, with the lithology ranging between clay and highly oxidised diorite/granodiorite above 19 metres to slightly oxidised trachyte or dacite at 36 metres. MRMB 13 screens 18 to 30 metres below ground also in the 2.0 – 2.2 Ohm.m logarithmic interval, with the lithology being predominantly lightly weathered, fractured andesite to rhyolite with disseminated pyrite.

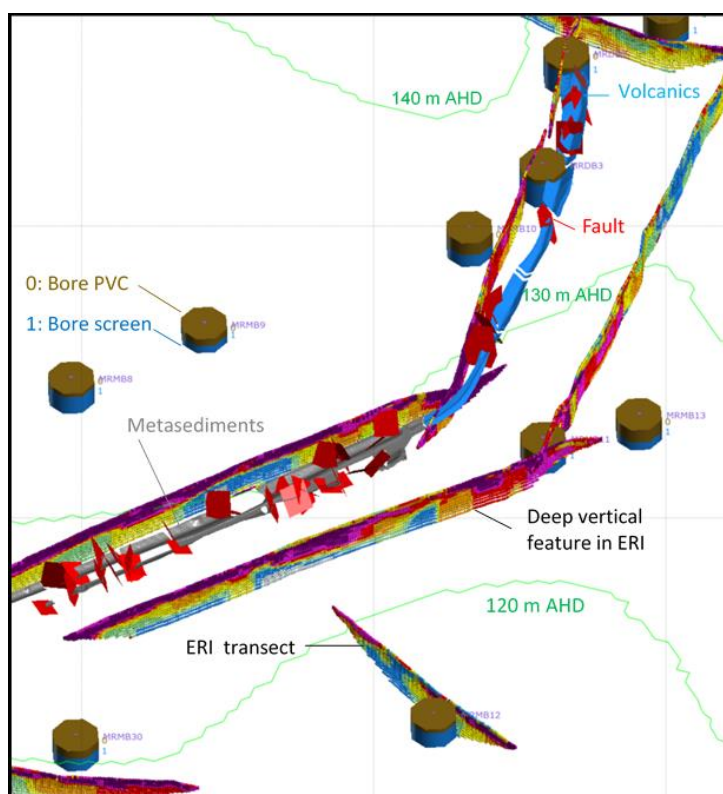


Figure 15: ERI transects and geological map of the Seepage Interception Drain ¹⁰

¹⁰ Features shown are lithology (labelled along the Seepage Interception Drain), groundwater bores (the PVC pipe is brown and screen zone is blue), 10m contour intervals of the groundwater surface (green) and ERI transects. The groundwater flow direction is perpendicular to the groundwater contour intervals. Definition of the ERI intervals are shown in the legend of Figure 16. ERI intervals that represent strata that have weathered to clay are purple - red, whereas the intervals of least weathered rock are blue - grey. Refer Appendix 13 (pp. 158-160) for supporting figures.

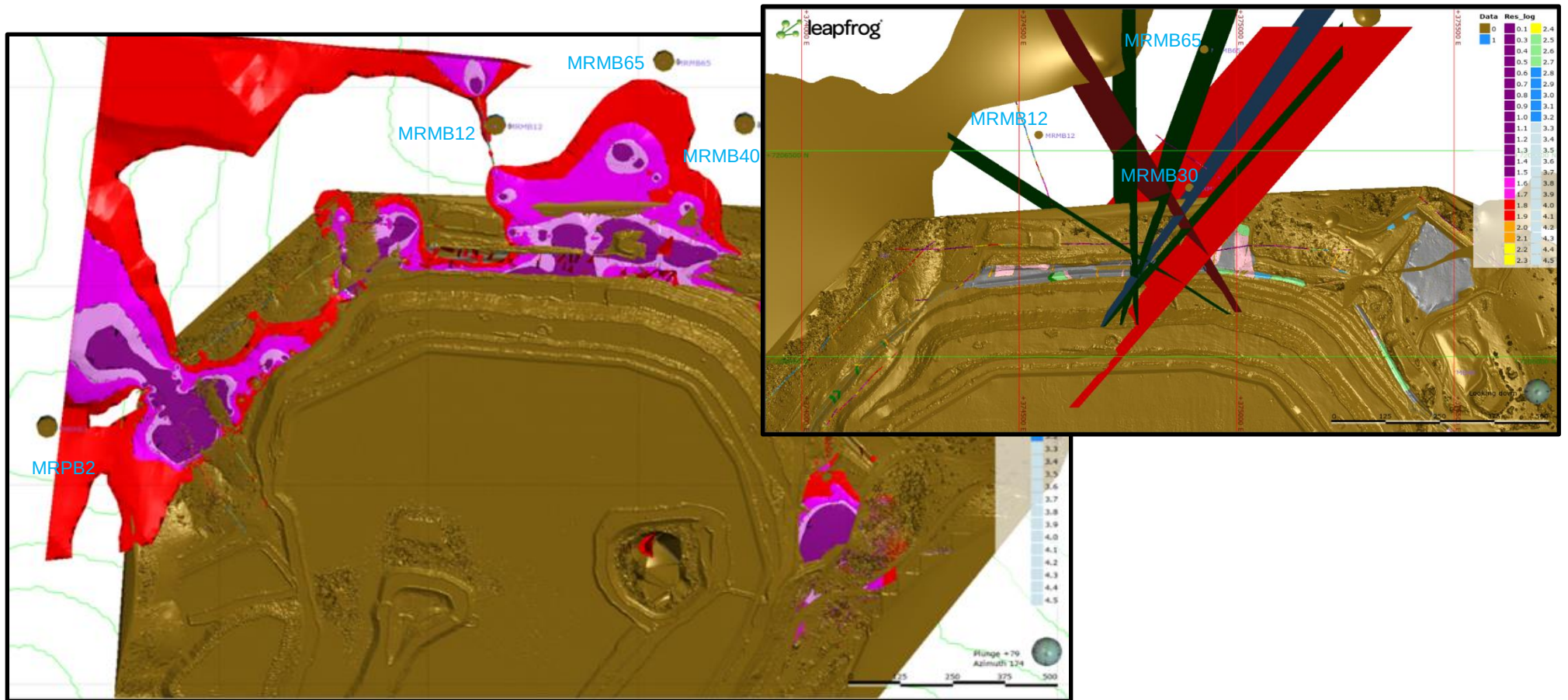


Figure 16: Planview of the TSF topography and ERI contours ¹¹

¹¹ Figure 16 shows the topography on and near the TSF (bronze surface), as well as ERI contours representing resistivity intervals ≤ 1.5 Ohm.m logarithmic in heavily weathered strata (purple) that are superimposed over the less weathered 1.6 – 1.9 Ohm.m logarithmic interval (red). Also shown are 10-metre groundwater contours (green) and groundwater bores downslope of the TSF. The insert shows the extension of a mapped fault (red) that might provide a flow barrier between MRMB30 and MRMB40 (shielded from view in the insert by the fault), as well as extensions of mapped lithological contacts (black) that are possible flow conduits that transmit mining - affected groundwater. Mining - affected groundwater has reported to MRMB12, MRMB30 and MRMB65, but not to MRMB40. Refer Appendix 13 (pp. 158 – 160) for supporting figures.

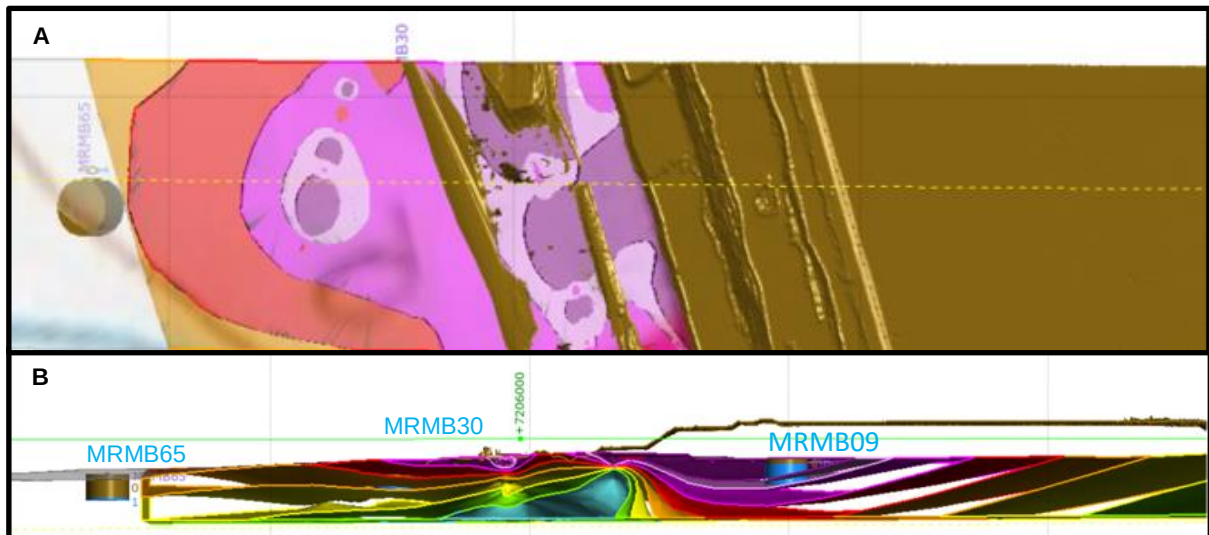


Figure 17: Planview (A) and profile (B) of resistivity contours through the northern seep

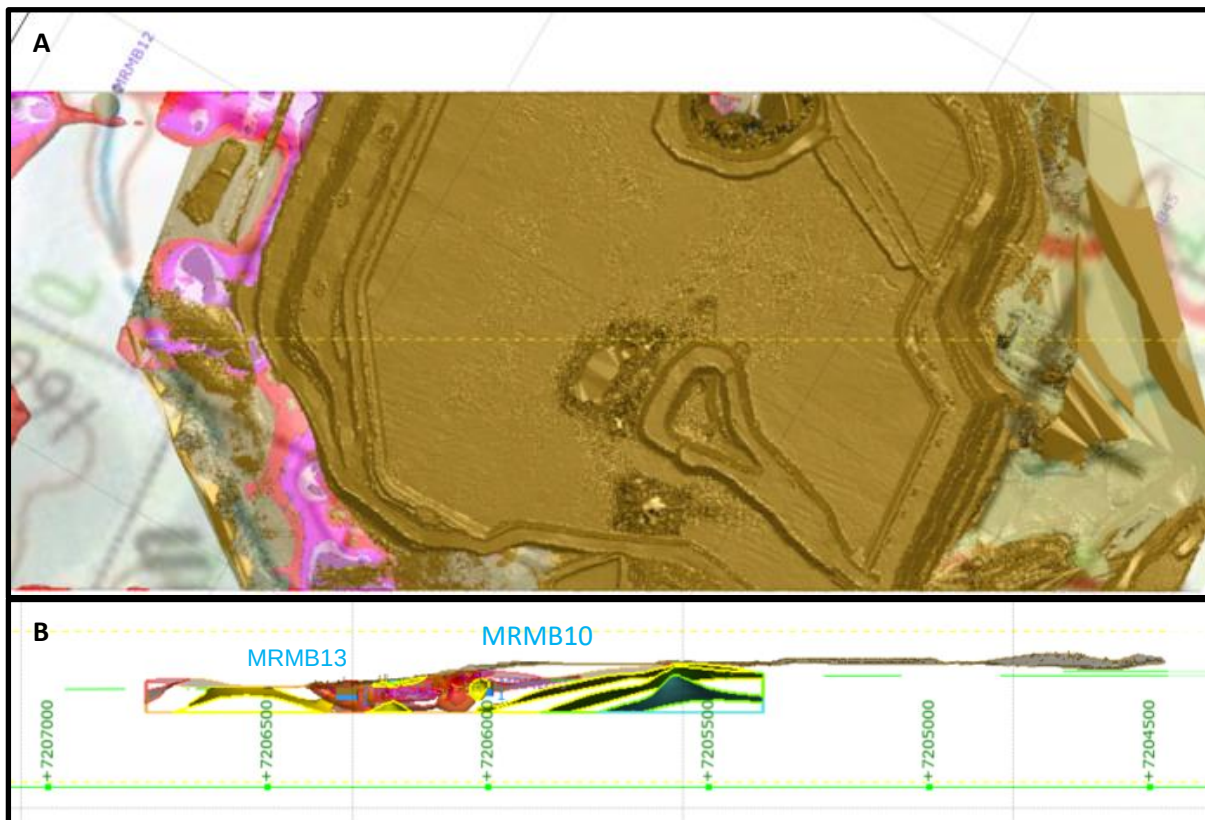


Figure 18: Planview (A) and profile (B) of resistivity contours through a deep vertical ERI feature

5.3.2 Rates and direction of solute movement in groundwater

Predictions of groundwater movement, assuming Darcian flow and the aquifer parameters reported in Stage 1, indicate that solute travels from the TSF outer batter wall towards the lower section of Swindon Creek at a seepage velocity of about 20 m/year through saprolite. Based on this prediction it would take 16 years for breakthrough of the solute front into the riparian zone of Swindon Creek where MRMB12 screens 5 - 27 metres below ground. In deeper fractured rock the seepage velocity is slower, at about 4.8 m/year, and seepage would take 64 years to reach the riparian zone.

Field observations of the increase in the concentrations of total cyanide and SO_4/Cl over time in MRMB12 indicate breakthrough after about 10 years, which is in the same order as the rate of solute movement through saprolite identified by the model. It was concluded that the movement of mine-affected solute in groundwater towards lower Swindon Creek is through saprolite.

5.3.2.1 Hydraulic gradients in the Swindon Creek sub-catchment

A detailed time series graph of standing water levels in groundwater bores in Swindon Creek is provided in Appendix 13 (page 150), which shows daily rainfall along the same temporal scale as standing water levels in groundwater bores. The graph documents the standing water level response to aquifer recharge, as well as the response of standing water levels in groundwater bores to the change in hydraulic head associated with the building of the TSF.

The sub-catchment scale groundwater gradient across Swindon Creek between MRPB2 upstream of the TSF to the compliance bore MRMB52 is 0.016 m/m, with a hydraulic head difference of 35 m over 2.18 km (refer Appendix 13).

A 19 m change in topography in this sub-catchment occurred during the first ten years of TSF development that commenced in 2001 with Stage 1 and continued through to 2010 with completion of Stage 3B. During this period the TSF crest level changed from 137 m to 156 m. At the toe of the TSF northern wall there was a coincident 18 m change in standing water level reporting to MRMB8 and MRMB9, and a 31 m change in standing water level reporting to MRMB10 (this unusually large change in standing water level is explained below).

Between 2001 and 2014 there were recorded changes in the hydraulic gradient between the toe of the TSF northern wall (MRMB9, MRMB10) and a downgradient bore near Swindon Creek (MRMB12) as follows:

- MRMB10 to MRMB12 was -0.017 m/m in 2001, which changed to 0.04 m/m in 2014. The flow potential apparently reversed during this time; and
- MRMB09 to MRMB12 was 0.015 m/m in 2001, which changed to 0.05 in 2014. There was a 3x increase in hydraulic head potential during this time.

In 2014 the hydraulic head potential across the middle section of the sub-catchment between the toe of the TSF northern wall at MRMB9, and downstream monitoring bores that have received some mining - affected groundwater (MRMB31, MRMB30¹² and MRMB65) was 0.04

¹² Groundwater movement through the Northern Seepage Zone flows towards both Swindon Creek and the unnamed creek. Refer to Appendix 14 page 176 for the time series graphs of standing water levels in groundwater bores MRMB30 and MRMB31 in the unnamed creek.

m/m. As such the hydraulic head potential for TSF seepage reporting via the Northern Seepage Zone across the middle section of the sub-catchment is 0.04 m/m.

In the Upper Swindon Creek riparian zone, a groundwater bore that screens in shallow weathered rock is paired with another bore that screens in deeper fractured rock, (MRMB43, MRMB44). There is a second pair of shallow and deep bores in the lower Swindon Creek riparian zone (MRMB41, MRMB42). The bore pairs indicate the vertical head potential between the upper weathered rock aquifer and the lower fractured rock aquifer.

In upper Swindon Creek the MRMB43 and MRMB44 bore pair indicated slight upward head potentials from the deeper fractured rock aquifer to the weathered rock aquifer of up to 31 cm about 68 percent of the time, which indicated upward movement of groundwater. However, at other times the MRMB43 and MRMB44 bore pair indicated slight downward head potentials from the weathered rock aquifer to the deeper fractured rock aquifer of up to 82 cm about 32 percent of the time, which indicated downward movement of groundwater near the stream.

This pattern was observed also in lower Swindon Creek. The MRMB41 and MRMB42 bore pair indicated slight upward head potentials from the deeper fractured rock aquifer to the weathered rock aquifer of up to 11 cm about 65 percent of the time, therefore at these times the potential for groundwater movement is upwards. However, at other times the MRMB41 and MRMB42 bore pair indicated slight downward head potentials from the weathered rock aquifer to the deeper fractured rock aquifer of up to 45 cm about 35 percent of the time, which indicated downward movement of groundwater.

In summary, there is potential for groundwater movement to move away from the toe of the TSF towards downgradient receptors in the Swindon Creek sub-catchment, and there is also potential for reversal of vertical groundwater movement between aquifers in the riparian zone of Swindon Creek.

5.3.2.2 Hydraulic gradients in the Unnamed sub-catchment

The present sub-catchment scale groundwater gradient across the unnamed sub-catchment between MRMB8 (now decommissioned and buried by the TSF northern wall) to the compliance bore MRMB53 is 0.027 m/m, with a hydraulic head difference of 29 m over 1.08 km (Appendix 14, page 176).

Between 2001 and 2014 the change in standing water levels measured in MRMB8 at the then toe of the TSF northern wall was 18 metres, similar to the change observed in MRMB9 also located along the northern wall.

5.3.3 Statistical Evaluation of Groundwater Quality in the Northern Seepage Zone

5.3.3.1 Piper Diagrams and Correlations

Piper diagrams for Swindon Creek and the unnamed sub-catchment are respectively provided in Appendix 13 (page 147) and Appendix 14 (page 174). They show the 50 percentile values for major elements reporting to groundwater monitoring bores in Swindon Creek and the unnamed sub-catchment, as well as in seepage expressions reporting to Seep 26 and Sediment Dam 1. For comparative purpose the 20th, 50th and 80th percentile values of major elements in waste rock seepage (measured in seepage from the Northern Waste Rock Dump) and in TSF decant water are included in the Piper diagrams.

The Piper diagrams showed that the median waste rock source term was a calcium chloride type water, whereas the decant water, Seep 26 water and Sediment Dam 1 water were sodium chloride type waters. In terms of anions all these mining related source terms were sulfate type water. In terms of cations the source term for the decant, Seep 26 and Sediment Dam 1 was sodium and potassium type water, while the source term for waste rock was either calcium type water or no dominant type.

In comparison median values for waters in Swindon Creek from MRMB13, MRMB41 and MRMB42 were mixed calcium chloride, sodium chloride and magnesium bicarbonate water,

while waters from MRMB11 was mixed sodium bicarbonate, magnesium bicarbonate and sodium chloride type waters. MRMB12 was like the waste rock source term, which was calcium chloride type water. Waters in MRMB9, MRMB10, MRMB52, MRMB65 and MRMB54 were the sodium chloride type.

Waters in the unnamed sub-catchment from MRMB8, MRMB31, MRMB30 MRMB40 and MRMB53 were also sodium chloride type water.

In terms of cations the monitoring bores in Swindon Creek were either sodium and potassium type water, or no dominant type. In terms of anions monitoring bore MRMB11 was bicarbonate type water, MRMB9 and MRMB54 were no dominant type, and the other monitoring bores were chloride type water.

In the unnamed sub-catchment cations were sodium and potassium type water and anions were chloride type water. Importantly none of the monitoring bores were predominantly of the sulfate type composition of the mining-related source terms.

Additional Piper diagrams showing representative ranges of groundwater quality over time were also developed for selected groundwater bores that have reported some mining influence over time in Swindon Creek (MRMB12, MRMB9, MRMB10, MRMB65) and in the unnamed sub-catchment (MRMB9, MRMB30, MRMB31), as well as for groundwater bores with no mining influence in Swindon Creek (MRMB52, MRMB54) and in the unnamed sub-catchment (MRMB53). Refer Appendix 13 (page 147) and Appendix 14 (page 174). The Piper diagrams shows that while MRMB9, located close to the TSF in the Northern Seepage Zone, has reported some sulfate type water the remaining bores are not sulfate type water. MRMB12 is a calcium chloride or mixed type water, and in terms of cations is either a calcium type or no dominant type. MRMB30 and MRMB31 are sodium chloride type waters, which in terms of cations and anions are sodium / potassium type and chloride type waters.

Correlations between SO_4/Cl vs Na/Cl show the relative contributions of sulfate and sodium to groundwater solutes in Swindon Creek (Appendix 13, pages 148 - 149) and the unnamed sub-catchment (Appendix 14, page 175). Mining - affected water shows higher contributions of SO_4/Cl (from pyrite weathering) while naturally occurring saline groundwater shows higher concentrations of Na/Cl (e.g. in landscape sumps), and strong correlations of SO_4/Cl vs Na/Cl might indicate neutral mine drainage. Seepage from the NWRD shows high contributions of both SO_4/Cl and Na/Cl , and high correlations among these ions, which is consistent with neutral mine drainage. Decant water has lower contributions of SO_4/Cl and Na/Cl , and weak correlation among these ions, indicating frequent replenishment of decant water with river water or recycled water (including stormwater). Monitoring bores MRMB9, MRMB10, MRMB30 and MRMB31 report ratios of SO_4/Cl and Na/Cl more similar to decant water than to waste rock seepage and show strong correlation among these ions that is consistent with neutral mine drainage.

5.3.3.2 Boxplots and Time Series Interpretation

Data summaries in the form of boxplots representing Swindon Creek water and the unnamed sub-catchment are presented in Appendix 13 and Appendix 14 respectively. The boxplots show the historical distributions of measured data together with the proposed groundwater limits for triggering further investigation. When the median historical water quality values exceeded the proposed limits, the trends of water quality reporting to these bores were reviewed and are discussed below.

Electrical conductivity: The median electrical conductivity measurements for MRMB8, MRMB9, MRMB10, MRMB31 and MRMB30 were greater than the proposed groundwater trigger limit of 6362 $\mu S/cm$. MRMB8, MRMB9 and MRMB10 showed declining long-term trends for EC, noting that MRMB10 had two interim increases in EV values that peaked in 2006 and 2010. Electrical Conductivity measurements in MRMB30 and MRMB31 peaked in 2006.

Total cyanide: The median total cyanide measurements for MRMB8, MRMB9, MRMB31 and MRMB30 were greater than the proposed groundwater trigger limit of 0.007 mg/L. In early

2012 a sudden increase in total cyanide concentrations reporting to MRMB8, MRMB9, and MRMB30 coincided with removal of clay from the borrow pit near the toe of the TSF northern wall and continued to increase over the next two years. The increasing cyanide trend that reported to MRMB30 flattened and stabilised after 2013 after commissioning of Marty's Trench and an upgrade of the Toe Seepage Interception Drain, which indicated improved seepage mitigation. After 2012 increasing concentrations of total cyanide also reported to MRMB12 and MRMB65, with evidence of strong wet and dry season influences on the total cyanide concentrations reporting to MRMB12.

Sulfate: The median sulfate concentrations for MRMB9, MRMB10 and MRMB31 exceeded the proposed groundwater trigger limit of 540 mg/L, and the median SO_4/Cl ratio for MRMB9, MRMB10 and MRMB31 exceeded the proposed groundwater trigger limit of 0.17 (unitless ratio). The sulfate concentrations in MRMB9 and MRMB10 continued to increase until 2008 – 09 when the Toe Seepage Interception Drain was commissioned to mitigate the seepage. The sulfate concentrations in MRMB31 continued to increase until 2010. After commissioning of the Toe Seepage Interception Drain, the trends in MRMB9, MRMB10 and MRMB31 bores either flattened and stabilised or reversed. The SO_4/Cl ratio increased most significantly in MRMB8, MRMB9 and MRMB31, which was interpreted to signify a greater proportion of seepage of mining - affected water reporting to these three bores. The significance of increased reporting of mining - affected water to MRMB8, MRMB9 and MRMB31 concomitant with declining long-term trends in EC is a result of partial success in dewatering of mining - affected water by the Toe Seepage Interception Drain, Marty's Trench and associated mitigations.

Nitrate: The median dissolved nitrate concentrations for MRMB12, MRMB31 and MRMB30 exceeded the proposed groundwater trigger limit of 0.09 mg/L.

Cadmium: The median dissolved cadmium concentration for MRMB30 exceeded the proposed groundwater trigger limit of 0.0002 mg/L. Cadmium concentrations reporting to MRMB30 over time peaked between 2008 and 2013 and stabilised thereafter.

Iron: The median dissolved iron concentrations for MRMB41 and MRMB65 exceeded the proposed groundwater trigger limit of 1.2 mg/L.

Manganese: The median dissolved manganese concentrations for MRMB42 exceeded the proposed groundwater trigger limit of 1.9 mg/L.

Collectively the boxplots and time series graphs show evidence of mining - affected water reporting to monitoring bores in seepage pathways downslope of the TSF northern wall, as well as successes over time at mitigating the seepage.

5.3.4 Solute movement

NETPATH was used to develop an inverse model of groundwater concentrations observed at MRMB9, MRMB10 and MRMB12 as follows:

On 19/07/2006, mine-affected groundwater reported to the shallow aquifer near the former toe of the TSF (MRMB9 screened 12 – 24 m below ground). Models that converged indicated that the groundwater quality in this aquifer could be explained by a mix of 19 - 69% TSF fluid, 2 - 24% solutes generated in the outer batter wall of the TSF and 7 – 72 % native groundwater. This mining - affected solute expression was identified at the time and was subsequently mitigated by the commissioning of interception drains and a pump-back bore, as discussed above in section 5.3.3.2.

On 23/04/2015, mine-affected groundwater reported further downstream of the TSF (MRMB10 screened 18 – 36 m below ground). Models that converged indicated that water quality in this aquifer could be explained by a possible mix of 6 - 28% TSF fluid, $\leq$ 32% solutes generated in the outer batter wall of the TSF, and 60 – 88% native groundwater. Mitigation of shallow groundwater seepage involved an engineered cut off wall that forces groundwater into an interception drain, which was commissioned in 2017.

On 18/07/2006, mine-affected groundwater reported to MRMB12 in the lower Swindon Creek riparian zone (MRMB12 screens 5 – 27 m below ground). Several possible models converged, which indicated that groundwater quality could be explained by a mix of 0.5 – 10% (mostly < 4%) TSF fluid, 3 – 48% solutes generated in the outer batter wall of the TSF, and 48 - 96% native groundwater. Tailings fluid was a very minor constituent in the mining - affected water.

On 18/05/2018, mine-affected groundwater reported to MRMB12. One model converged, which indicated that groundwater quality could be explained by a mix of 1.4% TSF fluid, 44.8% solutes generated in the outer batter wall of the TSF, and 53.7% native groundwater. Again, tailings fluid was a very minor constituent in the mining - affected water. This inverse model of groundwater movement through the aquifer indicated the following groundwater – aquifer mineral interactions may have occurred during groundwater transfer ($\mu\text{M/kg}$ water):

56 Pyrolusite + 72 Mg Montmorillonite + 17348 Halite – 2530 Calcite – 8916 Gypsum - 228 Goethite – 168 Gibbsite - 1237 Exchange.

As such the inverse model was consistent with the presence of mining - affected water in the riparian zone of lower Swindon Creek that had been substantially modified by solute interactions with the aquifer, of which TSF fluid was a minor component.

The PHREEQC solute transport model results for the B – B' groundwater pathway is shown in Appendix 8 as follows:

1. Sensitivity testing results that show graphical responses for sensitivity tests 6 and 7 while assuming 4% evaporation/evapotranspiration in mg/L (Ca, Mg, SO_4 , K, Na, Cl, SO_4/Cl N and CN), which were the lines of best fit when flow, CEC and HFO adsorption parameters had been adjusted.
 - a. Sensitivity Test 6 represented a hydraulic conductivity of 0.08 m/day, and assumed a low amount of surface HFO and CEC capacity (equivalent to what was measured in surface soil in the Northern Seep Zone),
 - b. Sensitivity Test 7 represented the same hydraulic conductivity as sensitivity test 6 and assumed a moderate surface HFO precipitate and CEC capacity (equivalent to BET and CEC observed in saprolite from the Northern Seep).

The graphs show how modelled data for the breakthrough curve reporting to MRMB12 in the riparian zone of Swindon Creek tracked against observed data. Note that observed data is heavily flushed each wet season by creek flow, which lowers the concentrations of solutes in the groundwater seepage expression to the concentrations of solutes in the sand and gravel of Swindon Creek. By contrast modelled data is not seasonally flushed, so does not represent these wet season and dry season variations. Model results indicate reasonable fits for sulfate (scenario 7), calcium and cyanide (scenarios 6 and 7), but overestimated magnesium, potassium, sodium and chloride. Nitrogen concentrations were not well represented by the model.

2. Graphical PHREEQC output for unmitigated seepage, which indicates the projected long-term reporting of mining - affected water to MRMB12. This graph shows that sulfate, cyanide and arsenic (anions) are mobilized in the seepage plume. Monitoring has confirmed breakthrough of sulfate and cyanide, but arsenic has not yet been observed in monitoring bore MRMB12 possibly because of adsorption to iron oxyhydroxides and clay in the aquifer.
3. Scenario testing results for mitigating a 250m wide B – B' steady-state seepage pathway invoking 4 possible mitigations:
 - a. Mitigation 1: The Seepage Interception Drain (current case) lowers the effective head potential of the seepage pathway by 0.75 m (from 11.3 m to 10.5 m). This changed groundwater discharge along the flow-path from 2.5 m^3/d to 2.3 m^3/d and the seepage velocity from 20 m/year to 18 m/year,

- b. Mitigation 2: Installing a pump-back bore capable of extracting 1.2 m³/day. This is predicted to limit groundwater discharge from 2.5 m³/d to 1.3 m³/d and the seepage velocity to 13 m/year along the identified flow-path,
- c. Mitigation 3: Combining mitigation 1 and mitigation 2 is predicted to limit groundwater discharge to 1.1 m³/d and the seepage velocity to 9 m/year along the flow-path, and
- d. Mitigation 4: Mitigation 3 plus additional pump-back capacity of 0.8 m³/day (totalling 2 m³/day) is predicted to limit groundwater discharge to 0.3 m³/d and the seepage velocity to 3 m/year along the identified flow-path.

Sensitivity testing and calibration of the solute transport model (PHREEQC) indicated that the best model fit for groundwater flow was through saprolite with hydraulic conductivity (K) = 0.08 m/d, a moderate CEC, moderate availability of hydro-ferric oxide surfaces and a small amount of evaporation (4%). This model provided the best fit for SO₄ at MRMB10, and the best fit for Ca, SO₄ and CN in MRMB12. Model fits for the other elements (N, Cl, Mg, K, Na) were poor (Appendix 8).

5.3.5 Effect of mitigation on solute movement

Historically mitigations in the Northern Seepage Zone have included the Toe Seepage Interception Drain, TSF wells installed at intervals along the drain that were equipped with pumps to improve flow, cutoff walls between the Toe Seepage Interception Drain and Marty's Trench, Marty's Trench and a pump-back bore. The Toe Seepage Interception Drain was reconditioned in 2017, and Marty's Trench now transfers seepage into the Seepage Interception Drain.

All these mitigations were buried under the outer batter wall of the TSF during the Stage 5 lift, when the TSF wells and pump-back bore were decommissioned. Current mitigation of the Northern Seepage Zone is the Seepage Interception Drain, which superseded and replaced the earlier mitigation works. The Seepage Interception Drain lowers the effective groundwater head by about 0.75m relative to the steady state groundwater level (based on the RL of salt efflorescence observed on the side of the drain closest to the TSF, during dry periods when the only seepage intercepted is steady flow below the TSF). During ephemeral rainfall events, pulses of salt held by the cation exchange capacity of soil below the outer batter wall are flushed into the drain. ATC Williams (2018) predicted that the Seepage Interception Drain, in conjunction with the reconditioned Toe Seepage Interception Drain, intercepts 564 m³/day along its entire length.

Results of the four mitigation options (refer 5.3.4) section indicate that breakthrough of mine solutes to the creek would be delayed by supplementing the Seepage Interception Drain with one or more pump-back bores (Appendix 8). These additional mitigations should suffice during the remaining operational mine life, after which time the mine closure plan will be implemented.

It is anticipated that the mine closure plan will decommission and cap the TSF, as well as possibly using constructed wetland remediation to intercept future seepage of COPC's from the decommissioned TSF.

5.4 Rawdon Creek sub-catchment

Synopsis: Results for the Rawdon Creek sub-catchment, describing groundwater movement towards the riparian zone of Rawdon Creek, to address Items 5 – 9, 12 and 14 of the Environmental Evaluation (listed in section 2), are as follows:

- The role of chemical speciation on the release and transport of COPC in groundwater,
- Aquifer boundaries defined by geophysical evidence,
- The rates of COPC movement from the TSF to the riparian zone of Rawdon Creek,
- Statistical evaluations of COPC in groundwater within the sub-catchment,
- Existing and future mitigations to intercept downstream movement of mining-affected water from the TSF to Rawdon Creek.

5.4.1 Pathways and mechanisms for the release and transport of mining related solutes to groundwater

Solute modelling of groundwater in Rawdon Creek using Visual MINTEQ, indicated that gibbsite and other aluminium hydroxides potentially precipitate as secondary minerals. Other secondary minerals forming in the weathering profile may include clay (e.g. kaolinite, halloysite), silica (chalcedony, quartz) and apatite. Some of these minerals contribute to the CEC of the aquifer and provide, armouring minerals that limit re-dissolution of mining related solutes that coprecipitate within the aquifer wall rock. As such, these secondary minerals provide a mechanism for attenuating some COPCs during groundwater flow through the aquifer.

The inverse model and solute transport model invoked solute interactions with secondary minerals, and aquifer exchange reactions involving CEC of clay minerals and SSA of hydro-ferrous oxide minerals (refer section 5.4.2).

In MRMB1, MRMB5 and MRMB21 calcite and dolomite might precipitate as secondary minerals, but these secondary minerals were not identified as being plausible secondary minerals in other groundwater bores along this flow-path because of different water chemistries.

5.4.1.1 Geological evidence for groundwater pathways in the Rawdon Creek sub-catchment

A three-dimensional representation of possible groundwater pathways was developed using *Leapfrog*[®] software, based on data described in section 5.3.1.1. There appears to be geometric correspondence of the Rawdon Creek drainage line with low resistivity contours (purple and red) in the ERI image that are being assumed to represent weathered rock (Figure 19). More detailed representation of low resistivity contours down the Rawdon Creek drainage is shown in planview (Figure 20a) and profile (Figure 20b), and indicate apparent shallowing of the low resistivity contours with downstream distance from the outer batter wall of the TSF.

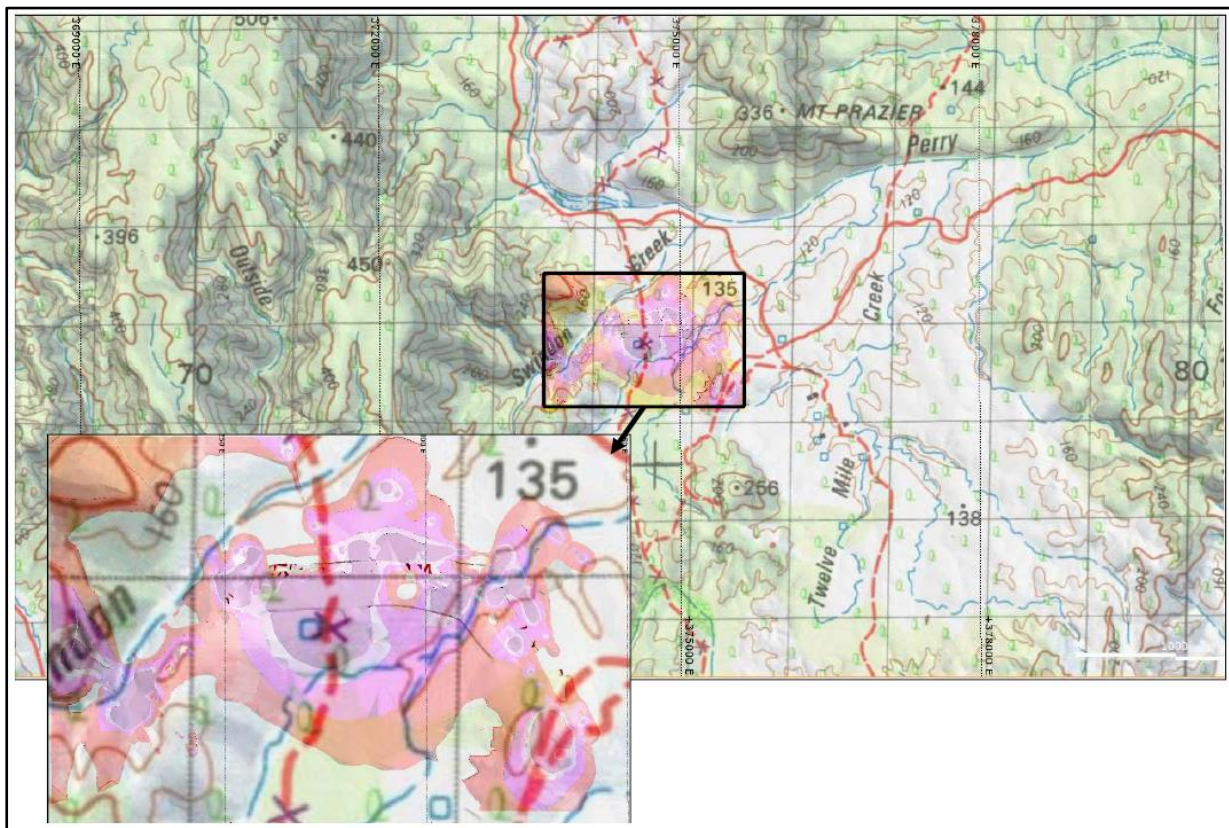


Figure 19: Topographic map of Rawdon Creek showing correspondence with low resistivity contours (purple and red) in the ERI image

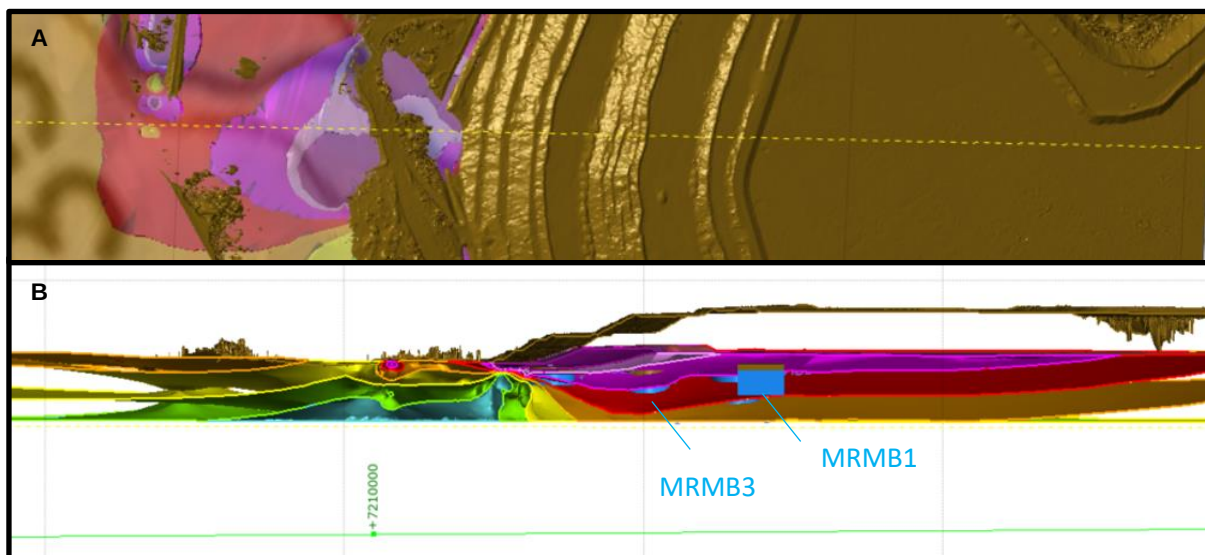


Figure 20: Planview (A) and profile (B) of resistivity contours along Rawdon Creek

5.4.2 Rates and direction of solute movement in groundwater

Predictions of groundwater movement from the TSF outer batter wall to the upper section of Rawdon Creek (near the TSF toe), indicated a seepage velocity of about 22 m/year through saprolite, taking 4.1 years to reach the riparian zone of the upper section of Rawdon Creek near where MRMB2 screened 6 - 12 metres below ground. MRMB2 is now decommissioned and buried below the TSF.

NETPATH modelling of water quality reporting to MRMB2 on 14/05/2015 identified four models that converged, which included possible mixtures of mining - affected water with native groundwater within the following ranges: 7 - 18% TSF fluid, 3 - 11% solutes generated in the outer batter wall of the TSF and 78 - 81% native groundwater. These models indicated that groundwater – aquifer mineral interactions may have occurred, with results being reported in $\mu\text{M/kg}$ water:

(1248 – 1697) Pyrite + (10 - 2123) Albite + (99 - 181) Chlorite + 301 Calcite + (415 - 640) Kaolinite – (2021 – 2392) CO_2 gas – (365 - 806) Illite – (1308 - 1715) Goethite – (5 – 10) Pyrolusite – (291 – 350) Exchange.

As such the inverse model was consistent with pyrite oxidation, dissolution of albite, chlorite, calcite and kaolinite, and precipitation of illite, goethite and pyrolusite. The models also invoked degassing of CO_2 , exchange reactions between groundwater and aquifer minerals, and evaporation. These reactions were constant with geochemical processes described by the conceptual model (refer Appendix 1).

The PHREEQC solute transport model results for the C – C' groundwater pathway are shown in Appendix 9 as follows:

1. Graphical results for sensitivity test 6 when evaporation/evapotranspiration varied between 1 and 7.5%. Sensitivity test 6 represented a hydraulic conductivity of 0.025 m/day and assumed a low amount of surface HFO precipitate and CEC capacity (equivalent to what was measured in surface soil in the Northern Seep Zone). Model results were reported in mg/L for calcium, magnesium, sulfate, potassium, sodium, chloride, SO_4/Cl , N and cyanide.

The graphs show how modelled data for the breakthrough curves reporting to MRMB1 and MRMB2 in the riparian zone of Rawdon Creek tracked against observed data. It needs to be noted that measured results for the first five years represent unmitigated seepage, after which mitigation strategies that included equipping MRMB1 with a pump-back bore, were implemented. Model results indicate reasonable fits for all solutes relative to the first five years of data measured in MRMB1 and MRMB2 except for chloride, nitrogen, SO_4/Cl and cyanide. The best model fits were observed with between 1 and 2.5% evaporation/evapotranspiration.

4. Graphical PHREEQC output for unmitigated seepage, which indicates the projected long-term reporting of mining - affected water to MRMB2. This graph shows that sulfate, cyanide and arsenic (anions) are mobilized in the seepage plume. Monitoring has confirmed breakthrough of all these anions.
5. Scenario testing results for mitigating a 250m wide C – C' steady-state seepage pathway invoking 4 possible mitigations:
 - a. Mitigation 1: The Seepage Interception Drain (current case);
 - b. Mitigation 2: Installing a pump-back bore capable of extracting 0.8 m^3/day ;
 - c. Mitigation 3: Combining mitigation 1 and mitigation 2; and
 - d. Mitigation 4: Mitigation 3 plus additional pump-back capacity of 1.2 m^3/day .

Sensitivity testing and calibration of the solute transport model (PHREEQC) indicated that the best model fit for groundwater flow was through saprolite with a hydraulic conductivity of ($K = 0.025$ m/d), low CEC capacity, low availability of hydro-ferrous oxide surfaces, and a small amount of evaporation (2.5%). This model provided reasonable fits for Ca, SO_4 , Mg, Na and K (Appendix 9).

5.4.2.1 Hydraulic gradients in the Rawdon Creek sub-catchment

A detailed time series graph of standing water levels in groundwater bores in Rawdon Creek is provided in Appendix 15 (page 192), which shows daily rainfall along the same temporal scale as standing water levels in groundwater bores. The graph shows the standing water level responses to aquifer recharge, as well as the standing water level responses to the change in hydraulic head associated with the building of the TSF. The sub-catchment scale groundwater gradient across Rawdon Creek between MRMB1 to the compliance bore MRMB74 is 0.013 m/m, with a hydraulic head difference of about 18 m over 1.41 km.

In Rawdon Creek, a line of three paired groundwater monitoring bores (six bores in total) were installed to investigate aquifer properties in the near surface (6 – 12 metres below ground) as well as in the deeper aquifer (up to 48 metres below ground). They provide information about the vertical hydraulic head potentials between these groundwater compartments. These now decommissioned bores were installed downstream of the TSF, near where Sediment Dam 1 and Sediment Dam 3 are now located, and results that are relevant to hydraulic head potential are described below.

Groundwater bores (MRMB2 and MRMB1) were installed in Rawdon Creek upstream of Sediment Dam 1 and closest to the TSF. These respective bores screen in oxidised quartz-muscovite gneiss between 6 and 12 metres below ground, and in the same oxidised rock as well as fresh pegmatite and quartz muscovite gneiss between 6 and 48 metres below ground. The shallower bore (MRMB2) had a measured transmissivity of 175.8 m²/d, which was much more transmissive than the deeper bore (MRMB1) that measured 5.65 m²/d. The bore pair indicated upward head potentials of up to 77 cm more than 94 percent of the time from the deep aquifer to the shallow aquifer.

A second pair of groundwater bores (MRMB4 and MRMB3) were commissioned 151 m downgradient from the MRMB1 and MRMB2 bore pair in the Rawdon Creek drainage, and downgradient of Sediment Dam 1. MRMB4 and MRMB3 respectively screen in weakly oxidised gneiss between 6 and 12 metres below ground, and in pegmatite and quartz muscovite gneiss between 6 and 48 metres below ground. The shallower bore (MRMB4) had a measured transmissivity of 5.56 m²/d, which was more transmissive than the deeper bore (MRMB3) that measured 1.36 m²/d. This bore pair indicated upward head potentials of up to 2.09 m more than 98 percent of the time from the deeper aquifer (screening 6 - 48 metres below ground) into the shallower aquifer (screening 6 – 12 metres below ground). The large maximum 2.09 m upward head potential measured on the 15th April 2014, and another large upward head potential of 1.06 m measured on the 25th December 2007 were anomalous and if these two values were excluded the upward head potential from the deeper aquifer to the shallower aquifer was 36 cm more than 98 percent of time. The maximum value of 36 cm upward head potential for the MRMB 3 and MRMB4 bore pair is reasonable.

The third pair of groundwater bores (MRMB5 and MRMB6), installed 300m downstream of the MRMB 1 and MRMB2 bore pair, recorded standing water levels in Rawdon Creek between 2001 and 2015. These now decommissioned bores were in the footprint of the dam wall of Sediment Dam 3, and the main aquifers intercepted by these bores screened between 12 and 16 metres below ground in MRMB6, and 12 and 38 metres below ground in MRMB5. The bore pair indicated upward head potentials of up to 53 cm more than 99 percent of the time from slightly oxidised to fresh rock in MRMB5 (the deeper aquifer screening 24 - 48 metres below ground) into strongly weathered rock in MRMB6 (the shallower aquifer screening 8 – 14 metres below ground).

A 4-metre change in standing water level in MRMB1 and MRMB2 occurred during the first ten years of TSF development that commenced in 2001 with Stage 1 and continued through to 2010 with completion of Stage 3B. A parallel 2-metre change in standing water level in MRMB3 and MRMB4 occurred during the same period, downstream of Sediment Dam 1 and further away from the TSF. The most distant bore pair from the TSF, MRMB 5 and MRMB6, were slower to respond than the upstream MRMB1 / MRMB 2 and MRMB 3 / MRMB 4 bore pairs, showed greater seasonal fluctuations in standing water levels, and reported a larger

change in standing water level of 7 metres (Appendix 15). These three bore pairs have responded to increased hydraulic loading associated with building of the TSF.

A cluster of four groundwater bores in a localised area in the north east side of the TSF have reported standing water levels higher than the standing water level of 119 m AHD observed in MRMB1. Monitoring bores MRMB7, MRMB23, MRMB32 and MRMB34 reported standing water levels in m AHD respectively of 119 - 124m, 118 - 120m, 120 – 124 m and 123 – 129 m. These bores are interpreted as screening a groundwater compartment, with the rise in standing water level representing resistance to lateral groundwater flow through aquifer media.

5.4.3 Statistical Evaluation of Groundwater Quality in the Rawdon Creek Sub-catchment

5.4.3.1 Piper Diagrams and Correlations

A Piper diagram with 50 percentile values for major elements reporting to groundwater monitoring bores in Rawdon Creek and to Sediment Dam 1 is shown in Appendix 15. For comparative purpose the 20th, 50th and 80th percentile values of major elements in waste rock seepage (measured in seepage from the NWRD) and in TSF decant water are shown in the Piper diagram.

The Piper diagram showed that the waste rock source term was a calcium chloride type water, whereas decant water and Sediment Dam 1 waters were sodium chloride type. The monitoring bores were also sodium chloride type water, except for MRMB48, MRMB21 and MRMB39 that were mixed sodium chlorite type and calcium chloride type waters.

In terms of anions, all the mining related source terms were sulfate type water. Bores MRMB74, MRMB34, MRMB29, MRMB39, MRMB21 and MRMB48 were chloride type water, and MRMB66 and MRMB32 were bicarbonate type water. Bores MRMB1, MRMB2, MRMB4, MRMB7, MRMB23 were no dominant type, and MRMB3 was borderline chloride type with no dominant type. The anion plot indicated that mine-affected sulfate type water had mixed with and changed groundwater in MRMB1, MRMB2, MRMB3, MRMB4, MRMB7 and MRMB23 from chloride type water to no dominant type water.

In terms of cations, monitoring bores reported either sodium and potassium type water or no dominant water type.

Additional Piper diagrams showing representative ranges of groundwater quality over time were also developed for selected groundwater bores (refer Appendix 15, page 189). The Piper diagrams shows that supported the observation that mine-affected sulfate type water had mixed with and modified groundwater in MRMB1, MRMB2, MRMB3 and MRMB4 from chloride type water to no dominant type water.

Correlations between SO_4/Cl vs Na/Cl show the relative contributions of sulfate and sodium to groundwater solutes in Rawdon Creek (Appendix 15, pages 190 - 191). Results from Sediment Dam 1 and monitoring bores MRMB1, MRMB2 and MRMB4 reported concentration ratios of SO_4/Cl and Na/Cl more similar to decant water than to waste rock seepage and showed strong correlation among these ions (consistent with neutral mine drainage). Of note the correlations for SO_4/Cl vs Na/Cl for MRMB5, MRMB6 and MRMN21 were weaker than for the upgradient bores (MRMB1, MRMB2 and MRMB4), which was interpreted as a waning influence of neutral mine drainage with distance from the toe of the TSF.

5.4.3.2 Boxplots and Time Series Interpretation

Boxplots are presented in Appendix 15. The boxplots summarise the historical distributions of measured data together with the proposed groundwater limits for triggering further investigation. When the median historical water quality values exceeded the proposed limits, the trends of water quality reporting to these bores were reviewed and are discussed below.

pH: The median pH in MRMB34 was below the proposed lower trigger limit of 6.4. RGS Environmental (2015) identified that this lower pH was caused by changes in manganese speciation after increased elevation of the groundwater table and considered that the pH change was not of concern.

Electrical conductivity: The median electrical conductivity measurements for MRMB29, and MRMB74 were greater than the proposed groundwater trigger limit of 6362 $\mu\text{S}/\text{cm}$. The electrical conductivity in MRMB29 increased between 2006 and 2011, stabilised after 2011 and reversed after 2014. The compliance bore, MRMB74, has shown consistently elevated electrical conductivity values since monitoring commenced in 2017, and because these values were much higher than in the upstream monitoring bores MRMB21 and MRMB39 there was no evidence of that a concentration gradient of salt expression has progressed from the TSF. Furthermore, MRMB74 was shown by the site-scale groundwater model to belong to a separate groundwater compartment than the Mine scale groundwater model (Northern Resource Consultants, 2019). Because the standing water level in MRMB74 (98 m AHD) coincides with the overflow of the Perry River Weir (98 m AHD), it was concluded that backflow of groundwater from the weir has generated a marsh-like environment that acts as a sump for salt washing in from adjacent landscape spurs (Appendix 15, 199).

Total cyanide: The median total cyanide concentrations for MRMB1, MRMB2, MRMB3, MRMB4, MRMB7, MRMB23, MRMB29, MRMB21 and MRMB39 were greater than the proposed groundwater trigger limit of 0.007 mg/L.

Periods of increasing cyanide concentrations in MRMB1, MRMB2, MRMB3 and MRMB4 coincided with the initial TSF build in 2001, desludging of Sediment Dam 1 in 2011 (the first time this dam had been de-sludged, which damaged its clay lining) and working of the clay borrow pit at the toe of the TSF north wall in 2012 that collectively promoted the release of cyanide laden tailings seepage into Sediment Dam 1. Successful management actions to mitigate tailings seepage were shown to have effect by declining concentrations of cyanide in MRMB1, MRMB2, MRMB3 and MRMB4. Low cyanide concentrations in these four bores between 2008 and 2009 coincided with the commissioning of pumps in MRMB1 and MRMB23 and commissioning of the Toe Seepage Interception Drain. Declining cyanide concentrations observed in these four bores after 2012 coincided with repair of the clay lining in Sediment Dam 1, improved dewatering along the Northern Seepage Zone, and changed dewatering practices to avoid overloading drains.

Periods of elevated cyanide concentrations in MRMB7 and MRMB23 also coincided with the initial TSF build in 2001 and subsequent working of the clay borrow pit at the toe of the TSF north wall in 2012. The initial response of MRMB7 to seepage from the TSF was pronounced in comparison to MRMB1, MRMB2, MRMB3 and MRMB4, but the improved dewatering along the Northern Seepage Zone mentioned above was effective at reversing TSF seepage through this flow-path (Appendix 15).

Progressive increases each year of about 4 $\mu\text{g}/\text{L}$ cyanide reporting to MRMB29 have been observed. This slowly increasing trend has not responded to efforts to improve dewatering along the Northern Seepage Zone. This may also signify a delay between mitigation and effects observed at MRMB29.

A period of increasing cyanide concentrations in MRMB21 and MRMB39 along Rawdon Creek commenced with desludging of Sediment Dam 1 in 2011 and working of the clay borrow pit at the toe of the TSF north wall in 2012, which collectively promoted the release of tailings seepage into Sediment Dam 1. After commissioning the Seepage Interception Drain and Sediment Dam 3 in 2017, cyanide concentrations reporting to MRMB21 and MRMB39 stopped increasing and have stabilised at 0.08 mg/L.

Sulfate: The median sulfate concentrations for MRMB1, MRMB2, MRMB4, MRMB7 and MRMB23 exceeded the proposed groundwater trigger limit of 540 mg/L. The sulfate concentrations in these five monitoring bores began to increase when the initial TSF build commenced in 2001, and there was evidence that the sulfate trends either slowed, stabilised, or reversed after 2008 and 2013 when effective seepage mitigation strategies were

implemented. The median SO_4/Cl ratios for MRMB1, MRMB2, MRMB3, MRMB7, MRMB23 and MRMB32 exceeded the proposed groundwater trigger limit of 0.17 (unitless ratio). However, the SO_4/Cl ratios in MRMB1, MRMB2, MRMB3, MRMB7 and MRMB32 show evidence of stabilised or reversed mine influence in groundwater reporting to these bores. The SO_4/Cl ratios in MRMB66 also exceeded the proposed groundwater trigger limit and declined over time, but the elevated ratio in this monitoring bore is not caused by tailings seepage because sulfate and cyanide concentrations were too low to trigger an investigation (refer Appendix 12 *Guide to interpreting groundwater with high concentrations of chemicals of potential concern*).

The SO_4/Cl ratio in MRMB23 briefly stabilised between 2010 and 2015 and has continued to increase over time. Because MRMB23 was equipped with a pump, it has continued to draw mining-affected groundwater that is subsequently returned to the processing circuit via Sediment Dam 1.

Nitrate: The median dissolved nitrate concentrations for MRMB23, MRMB29, MRMB32 and MRMB34 exceeded the proposed groundwater trigger limit of 0.09 mg/L. These four groundwater bores are in a localised area of 0.64 ha, and immediately downgradient of the north east toe of the TSF.

Aluminium: The median dissolved aluminium concentrations for MRMB34 exceeded the proposed groundwater trigger limit of 0.055 mg/L. There were exceedances between 2005 and 2014, but no long-term trend evident in aluminium concentrations reporting to this groundwater bore.

Iron: The median dissolved iron concentrations for MRMB34 and MRMB48 exceeded the proposed groundwater trigger limit of 1.2 mg/L.

Consistent with other sections of the Northern Seepage Zone, there is evidence that mining - affected water has historically reported to monitoring bores in seepage pathways, and that seepage mitigations have had demonstrated successes.

5.4.4 Effect of mitigation on solute movement

Four mitigation options were considered for the Rawdon Creek Seepage Pathway:

1. **Mitigation 1:** Existing mitigation includes the Seepage Interception Drain (the current case), which lowers the effective hydraulic head by 0.75m and slows groundwater discharge along the C-C' transect from 3.45 m³/d to 3.23 m³/d and the seepage velocity from 22 m/year to 20 m/year,
2. **Mitigation 2:** The addition of a pump-back bore dewatering at 0.8 m³/d, which would limit groundwater discharge from 3.45 m³/d to 2.65 m³/d and the seepage velocity from 22 m/year to 17 m/year,
3. **Mitigation 3:** Combining mitigation 1 and mitigation 2, which would limit groundwater discharge from 3.45 m³/d to 2.43 m³/d and the seepage velocity from 22 m/year to 15 m/year, and
4. **Mitigation 4:** Combining mitigation 1 and a second pump-back bore dewatering at 1.2 m³/d, which would limit groundwater discharge from 3.45 m³/d to 2.03 m³/d and the seepage velocity from 22 m/year to 13 m/year.

Operational monitoring suggests that the current strategy (Mitigation 1) is stabilising the trends of mining related solutes (total cyanide and the SO_4/Cl ratio) reporting to MRMB21 and MRMB39 in Rawdon Creek. Slowing seepage from the TSF even more (Mitigation 4) will delay further breakthrough of mine solutes to the creek by about 3 years, closer to the anticipated mine closure date in 2026.

The mine closure plan may ultimately involve the commissioning of constructed wetlands, which would be designed to attenuate cyanide, sulfur and other COPCs. This mitigation option is the subject of on-going evaluation.

5.5 Twelve Mile Creek sub-catchment

Synopsis: Results for the Twelve Mile Creek sub-catchment, describing groundwater movement towards the riparian zone of Twelve Mile Creek, to address Items 5 – 9, 12 and 14 of the Environmental Evaluation (listed in section 2), are as follows:

- The role of chemical speciation on the release and transport of COPC in groundwater,
- Aquifer boundaries defined by geophysical evidence,
- The rates of COPC movement from the NWRD to Twelve Mile Creek
- Statistical evaluations of COPC in groundwater within the sub-catchment,
- Existing and future mitigations to intercept downstream movement of mining-affected water from the NWRD to Twelve Mile Creek

5.5.1 Pathways and mechanisms for the release and transport of mining related solutes to groundwater

Sulfate is the dominant ligand for Cd^{2+} , Fe^{2+} and Mn^{2+} in WD2 (mining - affected surface water), with carbonate being the dominant ligand for Pb^{2+} and Cu^{2+} . The dominance of these ligands might change as a function of pH. In groundwater (bores MRMB27, MRMB63 and MRPB1) dissolved metals (Cd^{2+} , Fe^{2+} , Mn^{2+} and Zn^{2+}) exist dominantly as free ions with metal complexes forming with bicarbonate and carbonate (particularly Pb^{2+} and Cu^{2+}), hydroxyl and oxide. These complexes moderate the speciation of solutes in groundwater. The activities of Al^{3+} and Cr^{3+} were lowered by 73 - 86% relative to the total dissolved concentrations of these metals, and activities of Cd^{2+} , Cu^{2+} , Fe^{2+} , Mn^{2+} , Pb^{2+} and Zn^{2+} were lowered by 44 - 59% relative to total concentrations. Element speciation influences the potential toxicity as discussed in section 5.2.1. Because stream health assessments have not reported stream contamination at Mount Rawdon, we have not progressed with a toxicological investigation.

Secondary minerals that could form in Twelve Mile Creek are those that could form elsewhere on the Mine (refer sections 5.2.1, 5.3.1 and 5.4.1).

5.5.1.1 Geological evidence for groundwater pathways in the Twelve Mile Creek sub-catchment

A total of twelve geophysical (ERI) transects were investigated in the Twelve Mile Creek catchment, to intercept five potential groundwater flow pathways that included:

1. A transect between the TSF and the NWRD, across the groundwater flow pathway intercepted by Stan's Well, and monitored by groundwater bores MRMB46 and MRMB49.
2. Transects upgradient and downgradient of Waste Rock Dam 1 (WD1), across a groundwater flow pathway intercepted by WD1, a sump downstream of WD1 and pumpback bore MRMB26.
3. Transects upgradient and downgradient of Waste Rock Dam 2 (WD2), across a groundwater flow pathway intercepted by WD2, a sump downstream of WD2 and pumpback bore MRMB27.
4. Transects flanking Waste Rock Dam 3 (WD3), and
5. Transects downgradient of Waste Rock Dam 4 (WD4).

These transects are described by ASST (2020) and summarized below:

1. This was an extended low-resistivity zone extending from the topographic high at the start of the transect (near Stans Well) and intercepting surface water expression downslope of the mechanical workshop. There is a possibility of five faults along this transect, which may impede or transmit groundwater flow. Stan's Well and WD1 intercept and contain mining affected groundwater, which is transferred to South Dam for reuse in the processing water circuit.

2. The transect upgradient of WD1 indicated the possibility of three deep faults, one of which is in a wet area with water flowing at the surface into WD1. The transect immediately downgradient of WD1 indicated possible seepage through clayey soil, and three possible faults that may impede or transmit seepage at depth. The groundwater sump immediately downgradient of WD1 intercepts the shallow groundwater flow path. Downstream of this transect (further away from WD1), a groundwater seepage pathway below the creek line was suggested by another geophysical transect. Located on this downstream transect is MRMB26, a pumpback bore well positioned to intercept shallow groundwater seepage in the soil zone below the creek line and potentially also deeper seepage from a nearby deeply weathered zone (about 30 metres northwest of MRMB26).
3. The transect upgradient of WD2 indicated deeply weathered zones and three possible faults, with suggestion of three or more seepage pathways less than 10 metres below ground and a possible seepage pathway 20 – 35 metres below ground. Transects along the WD2 dam wall and north-west of WD2 show wet soil below the dam wall (intercepted by the sump immediately downgradient of the WD2 dam wall) and a weathered area at depth that may facilitate seepage to the west of WD2. This deep zone will be targeted for dewatering. The long transect downstream of WD2, which extends parallel to Twelve Mile Creek and beside the homestead, indicates that dewatering bore MRMB27 is well positioned to intercept shallow seepage from soil and shallow weathered rock. There are five possible faults along this transect, and several zones of deep weathering (possible aquifers) are indicated near the old homestead.
4. A long transect parallel to the western flank of the NWRD and upgradient of WD3, indicated four possible faults, with suggestion of a seepage pathway less than 10 metres below ground associated with a creek line intercepted by WD3 (situated about 50 metres south of monitoring bore MRMB60). Another transect that intersected the creek line downstream of WD3 also indicated a 10 metre deep, low-resistivity, heavily-weathered zone flanked on both sides by possible deep faults.
5. The transect immediately downgradient of WD4 intersected a clayey creek line associated with the WD4 drainage, which suggested weathering at depth (a possible fault). The sloping landscape on the southern flank of WD4 identified low-resistivity clayey soils (consistent with the sodic soils observed in this area), and three possible faults.

5.5.2 Rates and direction of solute movement in groundwater

Predictions of groundwater movement from the Northern Waste Rock Dump towards Twelve Mile Creek (along the D-D' transect) indicated a seepage velocity of about 39 m/year through saprolite, taking 11 years to reach the creek (Appendix 5).

NETPATH modelling of water quality in MRMB63 on 23/06/2016 identified one model that converged, which was an apparent mix of 27% WD2 water and 73% native groundwater. Some groundwater – aquifer interaction was indicated by the model with results being reported in $\mu\text{M/kg}$ water as follows:

144 Halite + 950 Exchange + 106 Kaolinite + 351 Dolomite + 1724 CO_2 - 22 Illite – 0.4 Pyrolusite – 995 Calcite – 161 Gibbsite – 0.1 Goethite.

Some evaporation was accommodated for by the model.

The inverse model was consistent with release of salt and exchangeable ions from chemical weathering of the landscape, as described by the conceptual model (refer Section 2.1). The significance of the halite and exchange sites is important because of dryland salinity processes known to occur in the landscape.

The PHREEQC solute transport model results for the D – D' groundwater pathway to MRMB27 are shown in Appendix 9 as follows:

1. Graphical results for sensitivity test 6 when evaporation/evapotranspiration varied between 1 and 10%. Sensitivity Test 6 represented a hydraulic conductivity of 0.121 m/day and assumed a low amount of surface HFO precipitate and CEC capacity (equivalent to what was measured in surface soil). Model results were reported in mg/L for calcium, magnesium, sulfate, potassium, sodium, chloride, SO₄/Cl, N and cyanide.

The graphs show how modelled data for the breakthrough curves reporting to MRMB27 downgradient of WD2 tracked against observed data. It needs to be noted that measured results for the first eleven years are representative of unmitigated seepage, after which mitigation strategies were implemented. Model results indicate reasonable fits for all solutes up to the time that mitigation commenced, except for chloride, nitrogen and SO₄/Cl. Cyanide was not modelled because there is no cyanide in seepage from the Northern Waste Rock Dump. The best model fits were observed with between 5 and 7.5% evaporation/evapotranspiration.

2. Graphical PHREEQC output for unmitigated seepage, which indicates the projected long-term reporting of mining - affected water to MRMB27. This graph shows that sulfate and nitrate (anions) are mobilized in the seepage plume. Monitoring has confirmed breakthrough of these anions, although the model has marginally overstated concentrations of nitrate and sulfate because the model did not represent processes of denitrification and sulfate reduction that likely occurred in the permanently wet soil prior to mitigation.
3. Scenario testing result for mitigating a 250m wide D – D' steady-state seepage pathway. This simply involved comparing the unmitigated base case model with observed data for the reason explained below.

The existing mitigation downgradient of WD2 is an interception zone immediately downgradient of the dam wall that pumps at 44 m³/day, and a pump-back in MRMB27 that has a daily pump-back rate of 4 m³/d. Groundwater monitoring records show that nitrate and sulfate concentrations reporting to MRMB63 promptly reversed after mitigation commenced. On this basis Appendix 10 (page 136) shows only the unmitigated base case (with seepage) and observed data that demonstrates the reversal and stabilisation of mine effects reporting to MRMB27.

In summary sensitivity testing and calibration of the solute transport model (PHREEQC) indicated that the best model fit for groundwater flow from the NWRD to Twelve Mile Creek was through saprolite with a hydraulic conductivity of $K = 0.121$ m/d, low CEC capacity, low availability of hydro-ferrous oxide surfaces and 5 – 7.5% evaporation (refer Appendix 10). This model reproduced groundwater concentrations of Ca, Mg, Na and K observed in groundwater reporting to MRMB27. The model underestimated N and SO₄ concentrations, although overall trends of increasing concentrations over time were represented by the model. The model did not predict groundwater concentrations of Cl well, and it is possible that processes that contribute to Cl concentrations to groundwater (rainfall patterns) were not represented by the model either. The existing dewatering infrastructure may be adequate at intercepting groundwater flow along the 250m wide flowpath towards MRMB63. A geophysical investigation is underway to facilitate better understanding of the groundwater flowpaths and seepage pathways from mining infrastructures in Twelve Mile Creek. The geophysical survey will identify the dimensions of the aquifer screened by MRMB63.

If required, a third pump-back bore in Twelve Mile Creek will be commissioned based on the result of the geophysical survey.

5.5.2.1 Hydraulic gradients in the Twelve Mile Creek sub-catchment

The MODFLOW SURFACT groundwater model identified groundwater compartments in the Twelve Mile Creek sub-catchment, in the landscape spur between Rawdon Creek and Twelve Mile Creek, as well as in the headwater section of Twelve Mile Creek. These groundwater compartments have unusual hydrogeological features that do not conform to the Mine scale model of downslope groundwater flow towards Perry River or Mingham Creek and will be

addressed first before the hydrogeological gradient along Twelve Mile Creek is described. This initial discussion will also describe groundwater bores that are influenced by lateral displacement of groundwater by the Mount Perry Weir.

Groundwater monitoring bores MRMB38 and MRMB67 have standing water levels that coincide with the Mount Perry Weir crest height (98 m AHD), which is the downslope flow control (Appendix 16, page 215). As such backflow of groundwater from the weir impoundment has created landscape sumps that are screened by these bores.

The landscape spur between Rawdon Creek and Twelve Mile Creek contains bores MRMB64 and MRMB67. The standing water level in MRMB67 periodically recharges in response to rainfall (Appendix 16, page 214), but as mentioned above the standing water in this bore subsequently stabilises at the weir crest height. The standing water level in MRMB64 is usually lower than the weir crest height but is highly variable and rainfall recharge of the aquifer can result in standing water levels that are occasionally higher than the weir crest. As such MRMB67 is influenced by the weir impoundment, and MRMB64 is a semi-isolated groundwater compartment that is recharged by rainfall.

Bores MRM37 and MRMB61 also screen in groundwater compartments that do not conform to the groundwater model. Despite being at the headwater of Twelve Mile Creek, the standing water level in MRMB37 is often below the Perry River weir crest level further downstream (Appendix 17, page 230).

The sub-catchment scale groundwater gradient across Twelve Mile Creek between MRMB59 and the compliance bore MRMB38 is 0.016 m/m, with a hydraulic head difference of about 49 m over 3.02 km (Appendix 17, page 230).

5.5.3 Statistical Evaluation of Groundwater Quality in the Twelve Mile Creek sub-catchment

5.5.3.1 Piper diagrams and Correlations

Piper diagrams for the landscape spur between Rawdon Creek and Twelve Mile Creek, as well as for Twelve Mile Creek itself, are appended (refer page 213 in Appendix 16 and page 228 in Appendix 17). These Piper diagrams show 50 percentile values for major elements reporting to groundwater monitoring bores in the landscape spur, and in seepage expressions reporting to Sediment Dam 1 or Seep 26. For comparative purpose the 20th, 50th and 80th percentile values of major elements in waste rock seepage (measured in seepage from the Northern Waste Rock Dump) and in TSF decant water are included in the Piper diagrams.

The Piper diagrams showed that the waste rock source term was a calcium chloride type water, whereas the decant water and Sediment Dam 1 water were sodium chloride type waters. In terms of anions all these mining related source terms were sulfate type water. In terms of cations the source term for the decant, Seep 26 and Sediment Dam 1 was sodium and potassium type water, while the source term for waste rock was either calcium type water or no dominant type.

In the landscape spur groundwaters from MRMB64 and MRMB67 were sodium chloride water, while MRMB55 reported a mixed sodium bicarbonate, magnesium bicarbonate and sodium chloride type water. MRMB68 was a marginally sodium chloride water, but its position on the piper plot was close to a mixed water type.

In terms of cations, the monitoring bores in the landscape spur were sodium and potassium type water. In terms of anions, MRMB55 was bicarbonate type water, MRMB68 was no dominant water type, while MRMB64 and MRMB67 were chloride type water.

In Twelve Mile Creek groundwaters were sodium chloride water, except for MRMB24 and MRMB26 that were a mixed sodium bicarbonate, magnesium bicarbonate and sodium chloride type water, and MRMB28 that was magnesium bicarbonate water.

In terms of cations the monitoring bores in Twelve Mile Creek were sodium and potassium type water, except for MRMB24, MRMB26 and MRMB28 that were no dominant water type. Anions were chloride type water except for MRMB28 that was bicarbonate type water, MRMB27 and MRMB38 that were no dominant water type, and MRMB60 and MRMB63 that were borderline sulfate type water.

Additional Piper diagrams showing representative ranges of groundwater quality over time were also developed for selected groundwater bores (MRMB25, MRMB27, MRMB37, MRMB38 and MRMB63) in Twelve Mile Creek (refer Appendix 17, page 228). The additional Piper diagrams supported the observations that the groundwaters were sodium chloride type water. Cations were sodium and potassium type water. Anions were chloride type water except for MRMB38 and some MRMB27 samples that were no dominant water type, and MRMB63 that was a borderline sulfate water type.

Correlations between SO_4/Cl vs Na/Cl show the contributions of sulfate and sodium relative to chloride in groundwater from the Twelve Mile Creek sub-catchment (Appendix 17, page 229). Results from Waste Rock Dam 1 and Waste Rock Dam 2 reported concentration ratios of SO_4/Cl and Na/Cl that resembled waste-rock seepage measured at the toe of the NWRD and showed strong correlation among these ions (consistent with neutral mine drainage). The concentration ratios for SO_4/Cl vs Na/Cl for MRMB25 and MRMB27 varied along the SO_4/Cl axis more than along the Na/Cl axis, and the SO_4/Cl concentration ratios exceeded 0.17 (the proposed groundwater trigger value) which indicated some contribution of sulfate enriched (mining – affected) groundwater reporting as neutral mine drainage to these monitoring bores. However, the correlations were weak indicating that the neutral mine drainage was diluted by native groundwater.

The reference bores for the Twelve Mile Creek sub-catchment, MRMB37 (upstream) and MRMB38 (downstream) also indicated weak correlations, and hence lack of evidence of neutral mine drainage. Bore MRMB38 screens in an oxidised zone hosting weak mineralisation, which due to probable sulfide weathering is in accord the exceedance of the SO_4/Cl proposed trigger value as well as the variation along the SO_4/Cl axis (refer discussion in section 3.8, page 38).

The significance of the sulfate type water classification for monitoring bores MRMB60 and MRMB63 will be discussed in section 5.5.3.2.

5.5.3.2 Boxplots and Time Series Interpretation

Boxplots representing the landscape spur between Rawdon Creek and Twelve Mile Creek, as well as Twelve Mile Creek, are presented in Appendix 16 and Appendix 17 respectively. The landscape spur will be discussed first followed by Twelve Mile Creek.

Electrical conductivity in the landscape spur: The median electrical conductivity measurements for MRMB64 and MRMB67 were greater than the proposed groundwater trigger limit of 6362 $\mu\text{S}/\text{cm}$. The electrical conductivity in both bores have remained consistent over time.

Arsenic in the landscape spur: The median arsenic concentration for MRMB64 exceeded the proposed groundwater trigger limit of 0.013 mg/L. Arsenic concentrations have decreased substantially after establishment of the bore.

Iron in the landscape spur: The median dissolved iron concentrations for MRMB67 exceeded the proposed groundwater trigger limit of 1.2 mg/L.

There is no evidence of ingress of mining - affected groundwater into the aquifers under the landscape spur.

Electrical conductivity in Twelve Mile Creek: The median electrical conductivity measurements for MRMB24, MRMB46 and MRMB37 were greater than the proposed groundwater trigger limit of 6362 $\mu\text{S}/\text{cm}$. The elevated electrical conductivity measurements in MRMB37 are not mining related and have remained stable during the period of monitoring between 2012 and 2019. These concentrations represent a groundwater compartment in the

headwater of Twelve Mile Creek. The electrical conductivities in MRMB24 had increased between 2004 and 2009, after which the trend stabilised. The electrical conductivity in MRMB46 has steadily decreased since monitoring of this bore commenced in 2014. The Southern Embankment seepage collection system, which includes Stans well, is a major seepage interception system that was installed in 2008. The stabilised electrical conductivity measurements in MRMB24, and the decreasing trend of electrical conductivity in MRMB46 since 2014, demonstrate the success of vastly improved seepage capture from the Southern Embankment.

Total cyanide in Twelve Mile Creek: The median total cyanide concentration for MRMB46 exceeded the proposed groundwater trigger limit of 0.007 mg/L. The median total cyanide concentration for MRMB49 was on the proposed groundwater trigger limit. Concentrations of total cyanide in MRMB46 have declined since 2014 as a result of improved seepage capture from the Southern Embankment. However, concentrations of total cyanide reporting to MRMB49 have slowly increased since measurement commenced in 2012. Groundwater seepage pathways in this area are being investigated using geophysics, as discussed in section 5.5.1.1.

Sulfate in Twelve Mile Creek: The median sulfate concentrations for MRMB24, MRMB46, MRMB63 and MRMB60 exceeded the proposed groundwater trigger limit of 540 mg/L. Sulfate concentrations reporting to MRMB24 began to increase in 2006, then the trend flattened and stabilised after 2009. In MRMB63 sulfate concentrations increased until 2015, then the trend also flattened and stabilised. The sulfate concentrations in MRMB60 and MRMB46 have steadily increased between 2013 and 2018. The median SO_4/Cl ratios for MRMB38, MRMB24, MRMB26, MRMB63, MRMB27, MRMB60 and MRMB28 exceeded the proposed groundwater trigger limit of 0.17 (unitless ratio). The exceedance of the SO_4/Cl ratio in MRMB38 (the compliance bore) is not mining related for reasons identified in the conceptual model (refer section 3.3.1.4 and section 4 of the Stage 1 report), recognition of an oxidised, weakly mineralized zone intersected by the screen of this bore (refer section 3.8, page 38), and because the sulfate concentration was below the trigger limit that would warrant further investigation of a COPC (refer Appendix 12). The SO_4/Cl ratios for MRMB26 and MRMB63 have increased over time, but subsequently the ratios have flattened and stabilised, or in some cases, reversed.

The SO_4/Cl ratios for MRMB27, MRMB28 and MRMB60 have varied over time. These time series trends' have already been interpreted and reported (refer section 3.3.1.4 in the Stage 1 report). MRMB27 has been equipped with a pump, so on this basis draws mining - affected groundwater seeping below the base of Waste Rock Dam 2. MRMB28 has received mining - affected water during wet season overtopping of waste dams, but the aquifer recovered after the overtopping was brought under control. MRMB60 reports increasing sulfate concentrations over time being driven by increased groundwater flow caused by mounding below the NWRD that mobilises sulfate salts in the soil, possibly in combination with inferred nearby sulfide mineralization.

The sulfate:chloride ratio in MRMB38 has remained stable between 2009 and 2019, indicating that mining - affected water has not reported to this monitoring bore (refer section 3.3.1.4 in the Stage 1 report).

Nitrate in Twelve Mile Creek: The median dissolved nitrate concentrations for MRMB49, MRMB46, MRMB24, MRMB26, MRMB25 and MRMB27 exceeded the proposed groundwater trigger limit of 0.09 mg/L. Refer section 3.3.1.4 in the Stage 1 report for a comprehensive discussion of plausible mining and non-mining related reasons for these high nitrate concentrations.

Arsenic in Twelve Mile Creek: The median dissolved arsenic concentration for MRMB61 was on the proposed groundwater trigger limit of 0.013 mg/L. Arsenic concentrations declined after monitoring began in 2013 and have remained stable since 2014.

Cadmium in Twelve Mile Creek: The median dissolved cadmium concentration for MRMB24 exceeded the proposed groundwater trigger limit of 0.0002 mg/L.

Iron in Twelve Mile Creek: The median dissolved iron concentrations for MRPB1 exceeded the proposed groundwater trigger limit of 1.2 mg/L. Iron concentrations reporting to this bore have progressively increased since 2005.

Lead in Twelve Mile Creek: The median dissolved lead concentration for MRMB24 exceeded the proposed groundwater trigger limit of 0.034 mg/L.

Zinc in Twelve Mile Creek: The median dissolved zinc concentration for MRMB24 exceeded the proposed groundwater trigger limit of 0.032 mg/L.

The boxplots and time series plot show that mining-affected water has previously reported to monitoring bores (MRMB46, MRMB49) in seepage through the southern embankment of the TSF, however subsequent implementation of the Southern Embankment seepage collection system has partially captured seepage from the TSF. The time series plots also show that pump-back bore MRMB26 has captured seepage bypassing WD1, and pump-back bore MRMB27 has captured seepage bypassing WD2, as indicated by stabilisation and/or decline of electrical conductivity values reporting to these bores over time, coupled with increasing sulfate:chloride ratios that signify more effective capture of dissolved sulfate in the water.

The boxplots and time series plots show that there is slow seepage reporting past MRMB49 that may need further mitigation. However, WD1 will capture seepage that bypasses the Southern Embankment seepage collection system, with the captured water being returned to the processing circuit. Planned geophysical work will assist with guiding the possible location of wetland remediation and/or pump-back capacity in Twelve Mile Creek.

5.5.4 Effect of mitigation on solute movement

Existing mitigation includes MRMB27, which is a deep pump-back bore screening 5 – 52 metres below ground level that provides a localised cone of depression (and therefore acts as terminal sink) for mining-affected water seeping from WD2 along the D - D' transect. This groundwater bore dewateres 4 m³/day, which is about 1/3rd of the groundwater discharged along the D-D' transect (12.4 m³/day) (refer Appendix 5). As such MRMB27 intercepts seepage from WD2 along this flow-path, but it is possible that this cone of depression does not intercept all the seepage from WD2. A geophysical survey has been performed to investigate whether additional flow-paths exist between WD2 and Twelve Mile Creek, or between WD2 and the aquifer that supplies the homestead (which may also connect with Twelve Mile Creek), as discussed earlier in section 5.5.1.1.. A second pumpback bore will be installed to intercept possible seepage along this potential groundwater flow path.

The mine closure plan may commission constructed wetlands to optimise removal of nitrogen, sulfur and other COPC by in-situ, enhanced biogeochemical processes. The design concept of the wetland would be to promote sulfate reduction and denitrification to generate a permanently water-saturated pseudo acid sulfate soil.

5.6 Mingham Creek sub-catchment

Synopsis: Results for southern drainage line to Mingham Creek, describing groundwater movement towards the riparian zone of Mingham Creek, to address Items 5 – 9, 12 and 14 of the Environmental Evaluation (listed in section 2), are as follows:

- The role of chemical speciation on the release and transport of COPC in groundwater,
- The rates of COPC movement from the TSF to the riparian zone of Mingham Creek
- Statistical evaluations of COPC in groundwater within the sub-catchment,
- Existing and future mitigations to intercept downstream movement of mining-affected water from the TSF to Mingham Creek

5.6.1 Pathways and mechanisms for the release and transport of mining related solutes to groundwater

Sulfate is the dominant ligand for Zn^{2+} , Cd^{2+} , Fe^{2+} , Mn^{2+} in mining - affected surface water in West Dam and South Dam, with carbonate being the dominant ligand for Pb^{2+} and Cu^{2+} . As discussed in section 5.2.1 ligands will influence the activities and the potential toxicities of these metals, but because stream health assessments have demonstrated that contamination has not occurred in receiving environments we have not progressed with toxicological investigation.

In groundwater dissolved metals (Cd^{2+} , Fe^{2+} , Mn^{2+} and Zn^{2+}) exist dominantly as free ions. Metal complexes form with bicarbonate and carbonate (particularly Pb^{2+} and Cu^{2+} carbonate complexes), hydroxyl and oxide as minor dissolved species. In groundwater bores MRMB35 and MRMB36, Cd^{2+} , Fe^{2+} , Mn^{2+} and Zn^{2+} complexes with sulfate were also represented as minor dissolved species. Secondary minerals that could form in the southern drainage towards Mingham Creek include aluminium hydroxides (gibbsite, boehmite and others), calcite, dolomite and rhodochrosite. These secondary precipitates potentially immobilise COPC in mining - affected groundwater moving through the aquifer system at Mt Rawdon.

5.6.2 Rates and direction of solute movement in groundwater

Predictions of groundwater movement from the TSF outer batter wall, via the southern drainage, indicated a seepage velocity of about 12 m/year through saprolite potentially taking 102 years to reach Mingham Creek. In the southern drainage area, the weathering profile is thin, meaning that fractured rock is the more common aquifer medium. In fractured rock a seepage velocity of about 2 m/year means that solutes moving from the TSF would take 624 years to reach Mingham Creek (Appendix 5). As such, the distance of the TSF from Mingham Creek coupled with the impermeable rock type means that seepage from the TSF is unlikely to connect with Mingham Creek during the operational life of the mine.

NETPATH modelling of groundwater quality in MRMB19 (the monitoring bore closest to the TSF) identified that groundwater screened by this bore had been mine influenced on 02/09/2003. Three model results converged that indicated 10 – 38% TSF fluid, 52 – 80% rock wall source term and 6 – 10% native groundwater. MRMB19 screens weathered and fractured rock that is 24 – 48 metres below ground level. Because this bore is in the footprint of South Dam and has been overtopped by the water level in South Dam, mining - affected water has flowed down the bore casing into the aquifer screened by this bore.

Monitoring bore MRMB17 downslope of MRMB19 screens weathered and fractured rock, 14 – 44 metres below ground level, and time series trends for SO_4/Cl and total cyanide do not indicate that mining-affected water had significantly entered the aquifer. The inverse model estimate of the groundwater quality record on 06/02/2014 indicated 2 - 5% TSF fluid, <1% rock wall source term and 94 - 97% native groundwater.

Monitoring bore MRMB35, downslope of MRMB17 and in the footprint of West Dam, screens in fractured rock 19 - 49 metres below ground level. Time series trends for SO_4/Cl and total cyanide do not indicate that mining - affected water had significantly entered the aquifer. The inverse model estimate of the groundwater quality record on 21/02/2013 indicated <1% TSF fluid, 2% rock wall source term and 97% native groundwater.

Monitoring bore MRMB36, downslope of MRMB35 and West Dam, screens in fractured rock 13 - 49 metres below ground level. Time series trends for SO_4/Cl and total cyanide indicate that mining-affected water had not significantly entered the aquifer. The inverse model estimate based on the groundwater quality measurement made on 26/11/2019 indicated 6% West Dam fluid and 94% native groundwater.

Sensitivity testing and calibration of the solute transport model (PHREEQC) performed against MRMB19 indicated that the best fitting model was through rock with a hydraulic conductivity (K_{sat}) of 0.097 m/d, low CEC, low availability of hydro-ferrous oxide surfaces and minimal evaporation (2.5%). It was identified after the modelling was done that mining

affected surface water from South Dam has periodically reported to MRMB19 via the downpipe, and as such this bore is poor for calibration. There were no alternative bores in the southern drainage that show a diagnostic breakthrough curve for mining affected water, as indicated by an increasing SO_4/Cl ratio, therefore the MRMB19 data have been used in the absence of better data. On this basis the poor fit between modelled results and measured data may indicate the compromised quality of the field data.

This model identified consistent concentrations over time for calcium, magnesium, sodium and nitrogen (Appendix 11). These concentrations were within the range observed in the monitoring bore was used for calibration (MRMB19), but the observed data showed much more variation in solute concentrations than was predicted by the model (because additions of South Dam water when the MRMB19 standpipe was overtopped by the South Dam water level has confounded the comparison). The model identified an increasing trend in SO_4 concentrations over time, with the overall trend corresponding with data observed in MRMB19, although finer scale variations of SO_4 over time in observed data were not represented by the model. The model tended to overestimate groundwater concentrations of K, and model predictions for Cl trends and for total cyanide trends over time were not supported by observed data in MRMB19.

Because the base case of mining - affected groundwater entering Mingham Creek via the southern drainage pathway indicated minimal risk to receiving waters during the operational life of the mine, mitigation options were not modelled for the southern drainage pathway.

5.6.2.1 Hydraulic gradients in the southern drainage to Mingham Creek

A detailed time series graph of standing water levels in groundwater bores in the Southern Drainage and in the Mingham Creek sub-catchment is provided in Appendix 18 (page 253). The graph shows the standing water level responses to aquifer recharge following rainfall events, as well as the standing water level responses to the changes in hydraulic head associated with the building of the TSF, South Dam and West Dam.

The sub-catchment scale groundwater gradient across the Southern Drainage into Mingham Creek, between MRPB50 at the south eastern toe of the TSF and the compliance bore MRMB75 at the southern boundary of the mine, is 0.029 m/m with a hydraulic head difference of 63 m over 2.20 km. This direct flowpath to the south from the TSF to Mingham Creek cross-cuts the mining-lease scale groundwater flowpath to the east from the hill flanking West Dam into the pit (Figure 4).

The 19 m change in topography in this sub-catchment during TSF construction, when the TSF crest level rose from 137 m AHD to 156 m AHD between 2001 and 2010, coincided with an 11 m change in standing water level reporting to MRMB19 and MRMB17 downslope of the southern toe of the TSF. The three groundwater bores in the footprint of South Dam near the toe of the TSF (MRMB69, MRMB19 and MRMB17) have standing water levels close to 135 m AHD, which corresponds with the water level in South Dam that is between 134 and 137 m AHD. This indicates that the water level in South Dam provides a localised hydraulic head that reports to nearby groundwater bores.

Bore MRMB20 that screens between South Dam and the open cut pit has reported standing water levels that have varied between 130 and 133 m AHD (approximately the standing water level in South Dam) and 122 m AHD. Between 2001 and 2004 the standing water level in MRMB20 steadily rose from 140 to 145 m AHD, and then declined to 125 m AHD in 2010 while reporting intermittent recharge in the 2007/08 and the 2009/10 wet seasons. The possible reasons for these changes are discussed below.

Bore MRMB45 initially reported a standing water level of 130 m AHD in 2011 and 2014, followed by a sudden drop in standing water level to 123 m AHD between May and November 2015, which has remained at this level apart from brief wet season recharge responses.

Bore MRMB70 reported increasing standing water levels from 119 m AHD in February 2014 to 125 m AHD in February 2015, after which time standing water levels in MRMB70 have remained constant apart from brief wet season recharge responses.

As such bores MRMB20, MRMB45 and MRMB70 appear to be influenced by a feature at 125 m AHD, which limits recharge of these aquifers. It is possible that a joint or fracture at 125 m AHD provides a drain that connects these aquifer compartments to the pit. This group of bores will be discussed further in section 5.6.3, when water quality trends associated with these bores are addressed.

Several monitoring bores in and around West Dam, which was commissioned in 2014, indicate responses to localised hydraulic loading imposed by this dam and groundwater mounding below the West Waste Rock Dump. The onsets of responses have varied in timing and magnitude, with MRMB18 and MRMB71 appearing to be more responsive to the change in standing water level in West Dam and closely matched the water level in this dam (discussed further below). Bores MRMB35, MRMB72 and MRMB36 were less responsive to the change in hydraulic loading caused by West Dam. They showed individual differences in standing water levels among these three bores and reported slower increases in standing water level than were observed in MRMB18 and MRMB71.

Monitoring bore MRMB18 (decommissioned in 2014) was located downslope of the present West Waste Rock Dump and upslope of West Dam. The standing water level in MRMB18 increased from 105 m AHD in 2011 to 114 m AHD in 2013, coinciding with West Dam construction. Measured water levels in West Dam are between 107 and 112 m AHD.

Monitoring bore MRMB71 (commissioned in 2014) is located south east of West Dam, and reports standing water levels between 107 m AHD and 115 m AHD (close to the standing water levels in West Dam). The standing water level in MRMB71 has subsequently increased to 116 m in 2018.

In summary, observations of standing water levels in monitoring bores influenced by hydraulic loading from West Dam have shown varying responses that are consistent with weakly connected groundwater compartments in a fractured rock aquifer.

5.6.3 Statistical Evaluation of Groundwater Quality in the southern drainage to Mingham Creek

5.6.3.1 Piper diagram

A Piper diagram for the southern drainage to Mingham Creek is contained in Appendix 18, page 251. It shows 50 percentile values for major elements reporting to groundwater monitoring bores in the drainage line, South Dam and Seep 26. For comparative purpose the 20th, 50th and 80th percentile values of major elements in waste rock seepage (measured in seepage from the Northern Waste Rock Dump) and in TSF decant water are included in the Piper diagrams.

The Piper diagrams showed that the waste rock and South Dam source terms were calcium chloride type water, whereas the decant water and Seep 26 water were sodium chloride type water. In terms of anions all these mining related source terms were sulfate type water. In terms of cations the source terms for the decant and Seep 26 were sodium and potassium type water, while the source terms for waste rock and South Dam were either calcium type water or no dominant type.

Groundwaters from bores MRMB20 and MRMB45 were calcium chloride type water. Groundwaters from bores MRMB76, MRMB71 and MRMB70 were magnesium bicarbonate type water. The remaining groundwater bore samples were sodium chloride type water.

In terms of cations all groundwaters were sodium and potassium type water, except for MRMB20, MRMB45, MRMB70, MRMB71 and MRMB76 that were no dominant type. In terms of anions MRMB69 was sulfate type water, MRMB20, MRMB72 and MRMB36 were no dominant water type, MRMB76, MRMB70 and MRMB71 were bicarbonate type water, while all other groundwaters were chloride type water. The significance of the sulfate type water classification for monitoring bore MRMB69 will be discussed in section 5.6.3.2.

Additional Piper diagrams showing representative ranges of groundwater quality over time were also developed for selected groundwater bores (MRMB17, MRMB19, MRMB36, MRMB72 and MRMB75) in Mingham Creek (refer Appendix 18, page 251). The West Waste Rock Dump Dam (West Dam) indicated some mixed water types as well as calcium chloride type water, with no dominant cations and anions that were sulfate type or bicarbonate type. The additional Piper diagrams supported the observations that the groundwaters were sodium chloride type water, with MRMB19 also reporting as mixed type water or calcium chloride type water because of ingress of water from South Dam into this bore. Cations were sodium and potassium type water, or in MRMB19 were no dominant type because of the ingress of South Dam water. Anions were chloride type water except for MRMB36 and MRMB72 that were also no dominant type. MRMB19 reported no dominant water type, or sulfate water type as expected because of the South Dam influence.

Correlations between SO_4/Cl vs Na/Cl show the contributions of sulfate and sodium relative to chloride in groundwater from the southern drainage and the Mingham Creek sub-catchment (Appendix 18, page 252). Results from South Dam, West Dam and MRMB19 reported concentration ratios of SO_4/Cl and Na/Cl across the range measured in decant water and showed strong correlation among these ions (consistent with neutral mine drainage). The concentration ratios for SO_4/Cl for MRMB36 exceeded 0.17 (the proposed groundwater trigger value) and had moderate correlation with Na/Cl , but these features might be a consequence of known mineralisation under West Dam and as such do not necessarily signify mining-affected groundwater, rather reporting as neutral mine drainage. The concentration ratios for SO_4/Cl vs Na/Cl in groundwater from MRMB75 are consistent with no mining influence.

5.6.3.2 Boxplots and Time Series Interpretation

Boxplots are presented in Appendix 18, and values that exceeded the proposed groundwater trigger limits are discussed below:

pH: The median pH values for MRMB45 and MRMB19 were marginally below the lower proposed pH limit of 6.4.

Total cyanide: The median total cyanide concentrations for MRMB45 and MRMB69 were above the proposed groundwater trigger limit of 0.007 mg/L.

Electrical conductivity: The median electrical conductivity measurements for MRMB75, MRMB36, MRMB72, MRMB18, MRMB17 and MRMB69 were greater than the proposed groundwater trigger limit of 6362 $\mu\text{S}/\text{cm}$. These five bores were classified as “group 1” type water in the Stage 1 groundwater report, which identified groundwater with elevated salts (sodium, bicarbonate, and occasional sulfate).

Electrical conductivities reporting to MRMB36 have increased since 2012 (although the increase has slowed since 2015), which could be a hydrostatic displacement of salt in the aquifer associated with the construction and commissioning of West Dam. Electrical conductivities in MRMB18 also reported an increase between 2012 and 2013 in response to West Dam construction, although electrical conductivities had previously varied by a factor of 10 between 2001 and 2012. Electrical conductivities in MRMB17 had varied by a factor of 3 between 2001 and 2005, but after 2005 remained steady. Electrical conductivities in MRMB69 have steadily declined since 2013.

Nitrate – N: The median dissolved nitrate concentrations for MRMB20 and MRMB19 located near the processing area exceeded the proposed groundwater trigger limit of 0.09 mg/L. Nitrate-N concentrations in these bores have varied substantially over time but do not show steadily increasing trends.

Arsenic: The median arsenic concentrations exceeded the proposed trigger limit of 0.013 mg/L in groundwater reporting to MRMB59, MRMB76, MRMB72, MRMB71, MRMB20, MRMB45 and MRMB69. Arsenic concentrations in MRMB71 are lower than historical values, but since late 2017 there has been an increasing trend of arsenic reporting to this bore.

Cadmium: The median dissolved cadmium concentration for exceeded the proposed trigger limit of 0.0002 mg/L in groundwater reporting to MRMB20 and MRMB19 between 2001 and 2014.

Copper: The median dissolved copper concentration for MRMB20 and MRMB19 exceeded the proposed groundwater trigger limit of 0.002 mg/L between 2001 and 2014.

Iron: The median dissolved iron concentrations for MRMB75 and MRMB45 exceeded the proposed groundwater trigger limit of 1.2 mg/L. Concentrations in MRMB45 reported an increasing trend in dissolved iron concentrations between 2014 and 2016, which has largely remained stable near 2.8 mg/L between 2016 and 2018. Concentrations in MRMB75 have been variable, with no evidence of a trend.

Manganese: The median dissolved manganese concentrations for MRMB59, MRMB72 and MRMB20 exceeded the proposed groundwater trigger limit of 1.9 mg/L.

Sulfate: The median dissolved sulfate concentrations for MRMB59, MRMB75, MRMB36, MRMB72, MRMB18, MRMB20, MRMB19 and MRMB69 exceeded the proposed groundwater trigger limit of 540 mg/L. The median SO_4/Cl concentration ratios exceeded the proposed groundwater trigger limit of 0.17 (unitless ratio) for MRMB59, MRMB36, MRMB72, MRMB19, MRMB20, MRMB76 and MRMB35. Monitoring bores MRMB19 and MRMB20 reported mining affected groundwater based on multiple lines of evidence: known ingress of South Dam water into MRMB19, high median SO_4 concentrations as well as high median SO_4/Cl ratios (and increasing SO_4/Cl ratios over time in MRMB20).

Bore MRMB69, between the TSF and South Dam, reported a median SO_4 concentration that exceeded the proposed trigger value, but because the median SO_4/Cl ratio was below the proposed trigger value it was inferred that evapo-concentration of solutes might be influencing the solute concentrations reporting to this groundwater bore. Enhanced evaporation of surplus process water on the TSF and evaporation of standing water in South Dam, are likely to have influenced this result. The rising trend for SO_4/Cl over time (coupled with increasing concentrations of total cyanide) indicated ingress of some mining affected water to MRMB69.

Bore MRMB35, upstream of West Dam and within this dam's zone of influence, reported a median SO_4/Cl ratio above the proposed trigger value, although the median SO_4 concentration was below the proposed trigger value. Two monitoring bores (MRMB36 and MRMB72) downgradient of West Dam reported elevated median concentrations of SO_4 and elevated median SO_4/Cl ratios. The sulfate results for MRMB35, MRMB36 and MRMB72 could relate to hydrostatic displacement of known mineralisation below West Dam via weakly connected groundwater compartments.

Bore MRMB59 is usually a dry bore that reported an elevated median SO_4 concentration and elevated median SO_4/Cl ratios relative to the proposed trigger values. This bore typically contains insufficient water to obtain a sample for water quality testing. Based on the existing small data set there is no evidence for increasing trends in SO_4 concentrations, or increasing trends in SO_4/Cl ratios, which is suggestive of no mining influence. However, there is insufficient data (6 samples) to make a strong evidence-based conclusion in relation to the possibility of mining influence on groundwater reporting to this bore, and it is necessary to obtain a statistically valid number of samples to prove this suggestion.

Bore MRMB75 reported a high median SO_4 concentration, but the median SO_4/Cl ratio was below the proposed trigger value. The position of this groundwater bore on a lower slope position in an area of moderate salinity hazard attributes this result to dryland salinity (refer to section 4.1 of the Stage 1 report).

Zinc: The median dissolved zinc concentration for MRMB20 and MRMB19 exceeded the proposed groundwater trigger limit of 0.032 mg/L. Dissolved zinc concentrations in MRMB20 increased until 2012, after which the trend reversed. In MRMB19 there has been an overall declining trend of dissolved zinc concentrations since 2005.

Analysis of boxplots and time series plots (Appendix 18) support the following interpretations:

1) Sulfur, arsenic, cadmium, copper, zinc and nitrate-N concentrations reporting to MRMB19 in the footprint of South Dam, and reporting to MRMB20 under the ore processing area, likely represent the reporting of groundwater influenced by ore processing and NAF waste rock. At times impounded water in South Dam has overtopped MRMB19 and flowed downward through the bore casing into the aquifer, which explains the substantial and rapid changes in concentrations of these elements in MRMB19. The SO_4/Cl ratio in MRMB20 increased between 2009 and 2014, which indicated increased breakthrough of mining - affected groundwater reporting to MRMB20 during this time. The changes in standing water levels in MRMB20 discussed above in section 5.6.2.1 suggest that a joint or fracture at RL125 m AHD may have been opened by mining activity after 2009 and created a hydraulic connection with the open pit.

2) Arsenic and total cyanide concentrations in MRMB45 and MRMB69 indicate that seepage of mining affected water from the TSF and/or South Dam has influenced groundwater in these two bores.

3) The proposed reason for elevated concentrations of arsenic in MRMB71 and MRMB72 is the influence of the West Dam impoundment on unmined sulfide mineralization known to occur under West Dam. The direction of groundwater flow is from the flanking hillside towards West Dam and ultimately the open pit (refer Figure 1), however West Dam has impounded water on a previously free draining slope. Since 2014 the standing water level in MRMB71 has increased from 113 m AHD to 116 m AHD, which has increased the depth of the water blanket in this groundwater compartment (i.e. promoted groundwater mounding). This slowly recharging bore is routinely purged to dryness for water quality sampling and often has not completely recharged before the next round of sampling, indicating that the aquitard that MRMB71 screens has poor capacity to store or transmit water. As a result, there has been in 6 – 8 metres of variation in standing water level recorded in MRMB71 after 2014. It is possible that these rapid changes in standing water levels, followed by prolonged exposure to air, facilitates in situ oxidation with associated release of arsenic from sulfide minerals.

4) Groundwater bore MRMB59 is on the headwater of the bordering Twelve Mile Creek and Mingham Creek catchments, so is on a high landscape position. This usually dry bore does not recharge effectively when purged. The high, and highly variable, concentrations of alkalinity, arsenic and manganese reporting to MRMB59 appear not to be mining related, based on suggestive results from six samples (with more samples need to be collected to make a statistically valid conclusion). The reason for this interpretation is the lack of trends in total alkalinity, arsenic and manganese concentrations, and the highly variable concentrations of redox sensitive elements (arsenic and manganese) that are inconsistent with observations of steadily increasing breakthrough plumes of mining-affected seepage observed elsewhere in the mine lease (e.g. manganese concentrations in MRMB8). Furthermore, because the open pit is located between the TSF and MRMB59, it is not hydrogeologically possible for TSF seepage to report to MRMB59.

5) MRMB76 and MRMB75 screen aquifers adjacent to Mingham Creek. MRMB76 screens in shallow fractured rock that is adjacent to, but not substantially below, the adjacent gravel creek bed and reports ambient water quality. MRMB75 screens in fractured rock adjacent to and below Mingham Creek but penetrates deeper into the aquifer, and reports elevated EC, sodium and chloride concentrations relative to proposed groundwater trigger limits. Both bores screen groundwater in a low landscape position that receives salt from the surrounding landscape (refer section 4 of the Stage 1 report). The proposed reason for the ambient solute concentrations in MRMB76 and the above normal solute concentrations in MRMB75 is that the former bore screens only in an aquifer that is regularly recharged by creek flow (the creek bed), whereas the latter bore screens groundwater compartment from a landscape sump that accumulates salt.

6 Discussion

Items that need to be addressed in the report are listed in the introduction (Section 2), and a brief outline of the Items and responses to each Item are included at the start of each section in this report. How the Items have been addressed are discussed in sequence below.

6.1 Item 5 - Identification and description of the pathways and mechanisms for the release and transport of contaminants to groundwater

Item 5 of the Environmental Evaluation requires identification and description of the pathways and mechanisms for the release and transport of contaminants to groundwater, due to activities conducted at the premises. Mining infrastructure that could cause contamination include the TSF and the waste rock dumps, from which weathering and seepage could result in mining - affected groundwater entering receiving environments.

Pathways and mechanisms for the release and transport of COPCs were described using speciation modelling. Modelling identified the activities of dissolved solutes in groundwater, and the potential for some solutes to be removed during groundwater transport either directly by precipitation of mineral phases (e.g. Mn^{2+} into pyrolusite), or indirectly by coprecipitation of minerals (e.g. clay, carbonate) that adsorb the solutes or provide armouring minerals (e.g. chalcedony, gibbsite) that limit release of adsorbed ions from clay surfaces into groundwater. The speciation model identified dissolved complexes that significantly lower the active concentrations (activities) of Al^{3+} and Cr^{3+} by about 80% relative to the total concentrations of these COPC measured in groundwater, and activities of Cd^{2+} , Cu^{2+} , Fe^{2+} , Mn^{2+} , Pb^{2+} and Zn^{2+} were lowered by about 50% relative to total concentrations. However, beyond the prediction of metal speciation based on major ions and trace metals, we have not measured for dissolved humic or fulvic substances that might complex metals such as Cd^{2+} , Cu^{2+} and Zn^{2+} in receiving surface water or groundwater environments. Nor have we progressed with more detailed interpretation of the possible role that metal speciation (e.g. arsenic III or V, or chromium III or VI) might have on toxicity. The reasons for not progressing with a toxicity investigation was because there is no evidence for contamination of waterways based on seven years of AUSRIVAS monitoring of aquatic macroinvertebrates in local streams, as well as a recent investigation of stygofauna that reported low occurrence and limited range of taxa in groundwaters of the Mine.

Speciation modelling also showed that several COPC (Cd^{2+} , Fe^{2+} , Mn^{2+} and Zn^{2+}) exist dominantly as free ions (usually the biologically most relevant fraction), with bicarbonate and carbonate complexes of these metals manifesting as minor species. Carbonate, hydroxyl and oxide complexes were identified by the speciation model as important components of the groundwater matrix that moderate the transport of COPC in groundwater along with release of COPC associated with adsorption/desorption reactions to minerals or ion-exchange reactions in response to changes in pH or solute composition.

An inverse model (NETPATH) and a solute transport model (PHREEQC) was used to represent source terms for neutral mine drainage generated in the TSF, using known solute concentrations in the decant, known minerals in the TSF and mineral weathering processes that had been identified from observed mineral phases in the TSF. NETPATH was initially used to reconcile the solute mass balance observed in groundwater exposed to TSF seepage. The NETPATH model mixed decant water with a waste rock source term (discussed below) and allowed dissolution or precipitation of minerals known to occur in the TSF, waste rock and aquifer. This generated results that reconciled the stoichiometry of the groundwater chemistry of a seepage affected bore in the flow-path of contributing fluids from tailings and waste rock (refer Figure 4 for relevant flow-paths from the TSF). Subsequent application of PHREEQC adopted the parameters identified by the NETPATH model (dissolved components, mineral phases and the mixing ratio of tailings fluid with waste rock). As such PHREEQC modelled decant water flowing through tailings, and allowed weathering of tailings minerals (pyrite to goethite, chlorite to smectite, albite to illite, equilibration of calcite,

rhodochrosite and malachite, and other weathering reactions), which was allowed to mix with the waste rock source term.

The source term for neutral mine drainage was described from seepage from the NWRD, based on field parameters and solute chemistries of 24 shallow groundwater samples collected over a year using soil lysimeters from 3 seepage pathways. To ensure a charge balanced source term, and a representative sample close to the median of the 24 samples was used. This waste rock source term was mixed with tailings seepage in ratios identified by the NETPATH model (described above), to develop source terms for mining - affected water egressing from the toe of the TSF towards creeks along the flow-paths shown in Figure 4. Flow-path D-D' from the NWRD to Twelve Mile Creek used the waste rock source term only.

As such Item 5 has been addressed by developing source terms appropriate for five seepage pathways (A-A', B-B' ... E-E') from mining - affected areas, which used a modelling approach informed by available water quality and representative mineralogical data. Where possible, the modelled source terms were verified against the best available seepage data representative of the five flow-paths. Inverse modelling invoked mixing of the tailing's fluid and waste rock source terms to describe leaching from the TSF tailings and batter wall. The reactive transport of the mixed source terms through the Mine is described under Items 6 and 7 below.

6.2 Item 6 - Determination of the horizontal and vertical extents of mining related groundwater seepage, and the rates and directions of movement of Chemicals of Potential Concern in groundwater

Item 6 requires determination of the current horizontal and vertical extents of mining related groundwater seepage, and an understanding of the rates and directions of movement of COPC in groundwater by undertaking transient solute transport modelling. The Stage 1 report had identified flow-paths using a three-dimensional finite difference groundwater flow simulation model in MODFLOW-SURFACT and developed a conceptual model of the influence of landscape processes (regional dryland salinity) on groundwater quality using multivariate statistics in PCORD software. The outcomes of Stage 1 were:

- 1) identification of the principal components of mine-affected water (sulfate, total cyanide, nitrate-N and arsenic) that show the measured extent of mining related groundwater seepage, and potential for contamination if flora and fauna in seepage pathways have been harmed by the mine-affected water; and
- 2) determination of steady state groundwater flow through a simplified aquifer system at the mine-lease scale, from which critical aquifer properties were identified (hydraulic heads, transmissivities and hydraulic conductivities of various aquifers).

During Stage 2 this understanding was enhanced using one-dimensional inverse modelling in NETPATH followed by one dimensional solute transport modelling in PHREEQC, for groundwater flow along the five seepage pathways (A-A', B-B' ... E-E'). The NETPATH model and PHREEQC model were informed as described above for Condition 5. As such the NETPATH and PHREEQC models described the rates and directions of movement of COPC in groundwater towards the nearest creek.

The aquifer dimensions relevant to soil and fractured fresh rock that transmit groundwater, were measured using Electrical Resistivity Images (ERI) to show the horizontal and vertical extents of groundwater pathways. Vertical and angled features with sharp contacts between resistivity contours representing heavily weathered rock and fresher rock in the ERI transects were inferred to be fault boundaries that could either transmit groundwater flow, or else provide impermeable barriers to groundwater flow that define aquifer boundaries. Detailed geological mapping along the Seepage Interception Drain and along creeks downslope of the Northern Seep Zone were used to corroborate these inferences. To better represent the depths and extents of aquifers in seepage pathways from the TSF, the ERI images were projected in three dimensions using geological software and interpreted using the extents of

permeable rock fabrics known from monitoring bore data to be transmitting mining - affected groundwater, as well as mapped faults and lithological contacts that were demonstrated by field observation to be aquifer boundaries. These interpretations of aquifer boundaries were used to identify suitable locations for dewatering bores to stabilise and reverse trends of mining-affected water entering the receiving environment.

The vertical extent of mining-affected groundwater appears to be predominantly shallow weathered rock, based on the ERI images mentioned above, the depths of the main aquifer identified from the bore logs of mining-affected monitoring bores, and reconciliation of the breakthrough curves for sulfate and total cyanide concentrations in measured data used to calibrate the solute transport model. The extents of mining-affected groundwater are as follows:

1) Seepage to the west of the TSF. The main weathered rock aquifer is between 3 and 13 metres below ground, which was identified from bore logs of two monitoring bores and three dewatering bores. There was evidence of possible deeper ingress of mining-affected water in partially weathered or fresh fractured rock between 18 and 32 metres below ground, noting that purging for water sampling could have drawn groundwater from the shallow aquifer into the deeper bore. The lateral extent of mining-affected groundwater is the MRMB43/MRMB44 bore pair in the riparian zone of upper Swindon Creek.

The geological profile between the TSF and the MRMB43/MRMB44 bore pair in the Swindon Creek riparian zone showed that the steady-state groundwater level identified by the MODFLOW – SURFACT groundwater flow model matched the ERI interval of 1.8 Ohm.m in the geophysical image. The solute breakthrough curve reporting to bores MRMB43 and MRMB44 identified by solute transport modelling matched the flow rate expected through weathered rock and was faster than the flow rate expected through fractured rock, as understood by Darcian groundwater flow calculations. The Darcian flow calculations used hydraulic conductivity and hydraulic head parameters developed from the MODFLOW – SURFACT groundwater flow model as well as aquifer measurements of hydraulic conductivity performed on bores MRMB43 and MRMB44.

NETPATH modelling identified results that were stoichiometrically possible mixtures of mining - affected water with groundwater as follows:

- Shallow aquifer (MRMB44) on 17/04/19: 4.1% TSF fluid, 19.7 % waste rock runoff, 76.1 % native groundwater, involving dissolution and precipitation of tailings and aquifer minerals as well as contributions from exchange sites,
- Deep aquifer (MRMB43) on 11/05/18: 3.5 – 4.9 % TSF fluid, 1.4 - 2.1 % waste rock runoff, 93.7 - 94.4 % native groundwater, involving aquifer interactions as described above. It is possible that purging of the bore for sampling has drawn mining - affected water from the shallow aquifer into the deeper aquifer.

Recent monitoring data from MRMB43 and MRMB44 beside upper Swindon Creek indicates that the extent of mine seepage is starting to stabilize. This may be a response to improved capture and diversion of seepage after 2018 by diversion of seep 26 into the Seepage Interception Drain, improved reliability of pumping infrastructure associated with Well 1 and Well 5, and installation of three pump-back bores in seepage pathways.

The alluvial sand and gravel of Swindon Creek is a strip aquifer, in which surface water mixes with and dilutes groundwater. In upper Swindon Creek upward head potentials of up to 31 cm from the deeper fractured rock aquifer to shallow weathered rock aquifer occurs about 68 percent of the time. The hydraulic head potential reverses about 32 percent of the time, when there are downward head potentials of up to 82 cm from the weathered rock aquifer to the deeper aquifer.

2) The Northern Seepage Zone. Mining - affected water has penetrated shallow weathered rock (12 - 26 metres below ground) under the northern toe of the TSF (MRMB8, MRMB9),

along the sloping landscape between lower Swindon Creek and the unnamed creek (MRMB31, MRMB30) and in Swindon Creek at MRMB12. There is evidence of some ingress of mining-affected water into deeper fresh rock between 25 and 30 metres below ground in MRMB65. The lateral extent of mining-affected groundwater is in the riparian zone of lower Swindon Creek (reporting to MRMB12) and below the sloping landscape between Swindon Creek and the unnamed creek (reporting to MRMB31, MRMB30 and MRMB65).

The Electrical Resistivity Image indicated that the ERI interval of 1.8 Ohm.m was 10 to 25 metres below the ground surface along two transects parallel to the Northern Seepage Zone, when the geophysical survey was performed in 2017. There were some instances of deeper weathering in the ERI images, which may represent faults (e.g. West Dam Fault and others), though it needs to be noted that the West Dam Fault appears to be a barrier to groundwater flow.

The time taken for the solute breakthrough curve to report to MRMB12 in transect B-B' corresponded more closely with the flow rate expected through weathered rock than with the flow rate expected through fractured rock, as understood by Darcian groundwater flow calculations informed by the groundwater flow model and by aquifer measurement of hydraulic conductivity performed on bore MRMB12.

NETPATH modelling identified stoichiometrically feasible results of mining - affected water mixing with groundwater, where mine influence diminishes with increasing distance from the TSF. Several models converged, with possible model outcomes listed below:

- MRMB09 on 11/02/14: 19 - 69 % TSF fluid, < 24 % waste rock runoff, 7 – 58% native groundwater,
- MRMB10 on 23/04/15: 6.8 – 10.3 % TSF fluid, 1.2 - 32.3 % waste rock runoff, 53.7 – 88.5 % native groundwater,
- Sediment Dam 1 (average): 67 - 88 % TSF fluid, < 11 - 31 % waste rock runoff, 1 – 3 % native groundwater. This represents mining-affected groundwater that was intercepted and redirected to processing via Sediment Dam 1,
- MRMB31 on 11/03/15: 1 - 43 % TSF fluid, 12 - 37 % waste rock runoff, 47 - 61 % native groundwater,
- MRMB30 on 06/02/19: 7 - 8 % TSF fluid, 24 - 25 % waste rock runoff, 47 - 68 % native groundwater, and
- MRMB12 on 18/05/18: 1.4 % TSF fluid, 44.8 % waste rock runoff, 53.7 % native groundwater.

While mitigation strategies (the Seepage Interception Drain and previous infrastructure) have intercepted some seepage, additional dewatering infrastructure is necessary to intercept deeper seepage continuing to report to MRMB12, MRMB31, MRMB30 and MRMB65.

Standing water levels in paired shallow and deep groundwater bores (MRMB41, MRMB42) in the riparian zone of lower Swindon Creek show head potentials of up to 11 cm from deeper fractured rock to weathered rock, which occur about 65% of the time when the stream is gaining water from the surrounding landscape. The head potential reverses about 35 % of the time, with downward head potentials of 45 cm occurring when the stream loses water to groundwater. As shown by time-series electrical conductivity measurements in MRMB12, groundwater in the Swindon Creek riparian zone is heavily diluted during wet season flows.

3) Rawdon Creek

Mining-affected water has penetrated below the northern eastern toe of the TSF (9 - 38 metres below ground) and has reported to paired groundwater bores in Rawdon Creek upstream of Sediment Dam 3 (pair MRMB1 and MRMB2, pair MRMB3 and MRMB4, pair MRMB5 and MRMB6) at depths of 9 – 32 metres below ground. These bore pairs indicate hydraulic head potentials from deeper fractured rock to shallow weathered rock of up to 77 cm in the upper section of Rawdon Creek below Sediment Dam 1 and Sediment Dam 3.

NETPATH modelling of mining - affected water reporting upstream of Sediment Dam 1 (i.e. to the shallow, weathered aquifer screened by MRMB2) on 14/05/2015 identified four models that converged, and the following possible mixes of mining - affected water with native groundwater: 7 - 18% TSF fluid, 3 - 11% solutes generated in the outer batter wall of the TSF and 78 - 81% native groundwater. The inverse model invoked weathering processes developed by the conceptual model (refer Appendix 1) and described for Item 5 of the EE. The solute transport model (PHREEQC) indicated that the best model fit for groundwater flow reporting to Rawdon Creek (bores MRMB1 and MRMB2) was through weathered rock, and provided reasonable fits for Ca, SO₄, Mg, Na and K (Appendix 9).

The main aquifer below Sediment Dam 3 is 9 – 16 metres below ground, based on evidence from bore logs for MRMB5 and MRMB6 (these decommissioned bores were buried below the dam wall of Sediment Dam 3) and geophysical evidence (the 1.8 Ohm.m ERI contour in geophysical transects below the dam wall of Sediment Dam 3, and upstream of Sediment Dam 3).

Mining-affected groundwater has reported downstream of Sediment Dam 3 to MRMB21 and MRMB39, a distance of 730 m down Rawdon Creek from the toe of the TSF. Some of the mining - affected water in MRMB21 and MRMB39 is likely to be residual contamination from overtopping of Sediment Dam1 and Sediment Dam 2 in December 2011, between January and February 2012, in November 2015 and between March and April 2017 that has previously been reported by Evolution Mining to the Queensland Government. Importantly, the trend of mining - affected water reporting to the downstream bores MRMB21 and MRMB39 in Rawdon Creek appears to have stabilised since Sediment Dam 3 was commissioned in 2017.

4) Landscape Spur and Twelve Mile Creek

Mining - affected water has reported between 5 and 27 metres below ground east of the TSF to MRMB46, and between 15 and 32 metres below ground to MRMB49. Both these bores are flanked by Waste Rock Dam 1, which captures mining - affected water. The Electrical Resistivity Image interval of 1.8 Ohm.m was 10 to 50 metres below the ground surface along three transects on the eastern flank of the TSF. Some of the deeper weathering may indicate the presence of faults (refer section 5.5.1.1).

Mining-affected water has historically reported downstream from Waste Rock Dam 1, between 2 and 8 metres below ground into the shallow aquifer (refer bore logs for MRMB25 and MRMB26), and between 30 and 48 metres below ground into the deep aquifer intersected by MRMB26. Remedial works to Waste Rock Dam 1 performed in 2014 included reconstructing the clay core and cut off key to better intercept shallow seepage below the waste dam wall, and equipping MRMB26 with a pump-back bore. Accordingly, the seepage is now captured.

Mining-affected water has also historically reported downstream from Waste Rock Dam 2, between 2 and 6 metres below ground into the shallow aquifer (refer bore log) for MRMB27, as well as into two intervals in the deeper aquifer screened by MRMB27 between 8 and 20, and between 31 and 33 metres below ground. Bore MRMB63 screens between 18 and 23 metres below ground. Remedial works to Waste Rock Dam 2 performed in 2014 have stabilized and reversed the reporting of mining-affected water to MRMB63 (refer Appendix 10). These remedial works included a reconstructed clay core and cut off key, a 5-metre-deep interception trench and pump back well immediately downstream of Waste Rock Dam 2, and equipping MRMB27 with a pump-back bore.

Both MRMB26 and MRMB27 have pump-back bores, and hence are drawing mining - affected water from the groundwater flow-paths downstream of Waste Rock Dam 1 and Waste Rock Dam 2 respectively. Because the base of the bore screen in MRMB26 (56 m AHD) and the base of the bore screen in MRMB27 (59 m AHD) are below the spillway height of the Perry River weir (98 m AHD), these dewatering bores generate localized sumps that remove mining - affected groundwater intercepted by their cones of depression.

NETPATH modelling of mining - affected water reporting downstream of Waste Rock Dam 2 to MRMB63 on 23/06/16 indicated 26% WD2 type water and 73 % native groundwater.

However, monitoring records show that the mine influence has stabilized and reversed since that date.

The solute transport model (PHREEQC) indicated that the best model fit for groundwater flow to MRMB27 is through weathered rock. This model reproduced groundwater concentrations of Ca, Mg, Na and K reporting to MRMB27 prior to the remediation works in 2014. The model overestimated groundwater concentrations of sulfate and nitrate_N reporting to MRMB27 prior to remediation, which might be a consequence of denitrification and sulfate reduction processes that occur in the aquifer but are not being modelled. Current work being performed by CSIRO, Australian Wetlands Consulting and Evolution Mining is identifying denitrification and sulfate reduction processes relevant to this aquifer, so that Mine closure planning can consider the possible application of constructed wetlands to address neutral mine drainage of sulfate, nitrate and heavy metals.

5) Southern Drainage to Mingham Creek

Mining - affected water has egressed to South Dam and ground below the processing plant. Mining - affected water has reported to the fractured rock aquifer screened by MRMB69 (28 - 36 metres below ground), to MRMB19 through two fracture intervals (30 - 32, and 32 - 36 metres below ground), and to MRMB45 screening 31 - 39 metres below ground. While mining - affected water has penetrated up to 39 metres into the aquifer below South Dam and the processing plant, this has been caused in part by water from South Dam flowing downward through the MRMB19 bore casing into the aquifer.

Modelling of groundwater quality in MRMB19 that is mining affected versus MRMB17 that is only marginally (< 6%) mining affected corroborated the observation that mining - affected water has penetrated the aquifer in and near South Dam, but there is no evidence that TSF seepage has penetrated significantly downgradient of South Dam.

Further down the southern drainage the aquifer screened by MRMB18 has two fracture intervals, which are 13 metres below ground and 47 - 48 metres below ground. Standing water levels in MRMB18 rose after 2012 until West Dam completion in 2014. The water level in West Dam has ranged between 107 and 112 m AHD, which compares with standing water levels observed in MRMB18 in 2012 (107 m AHD) and in 2014 (114 m AHD). Slow changes to standing water levels in and near West Dam (MRMB35, MRMB71 and MRMB72) were also observed during and after dam construction. Standing water levels in MRMB71 slowly rose by 3 metres from 113 m AHD in 2014 to 116 m AHD in 2019 (with substantial variation of about 8 m in this bore). The impervious rock intersected by MRMB71 (refer Table A2 in the Stage 1 report) means that the true standing water level does not always recover after purging between sampling intervals, which has caused the 8-metre standing water level variation in MRMB71. Standing water levels in MRMB72 also slowly rose between 107 m AHD in 2014 to 109 m AHD in 2019 at a similar rate to the slow rise in MRMB71. The standing water levels in MRMB36 reported differently to the standing water levels in other groundwater bores in and around West Dam. There are periodic drawdowns in standing water levels that are not understood. In summary, the groundwater responses observed several bores in and near West Dam are interpreted as screening weakly connected groundwater compartments in semi-pervious to impervious rock.

6.3 Items 7 and 8 - Prediction of the likely future migration and impact of Chemicals of Potential Concern using the solute transport model, and calibration and sensitivity analysis of the solute transport model

Item 7 requires prediction of the likely future extent of COPC migration and impact using the geochemical (solute) transport model, and Item 8 requires calibration and sensitivity analysis of the geochemical (solute) transport model. The Stage 2 report varied model parameters to evaluate the effect of variations in (1) groundwater flow, (2) aquifer capacities to attenuate COPCs and (3) evaporation, on geochemical transport as described in section 3.4. The models that fitted best with observed data along flow-paths were used as the calibrated

models, thereby addressing the requirement of Condition 8. The calibrated models represented the unmitigated (base-case) situations.

Predictions of how the base-case situations along each flow-path could be improved by mitigation involving modelling the effects of improved drainage and/or pump-back bores, on the breakthrough curves of COPCs entering the respective drainage lines. In the Northern Seepage Zone, a combination of the Seepage Interception Drain and pump-back bores should delay groundwater transfer of COPCs to receiving waters during the remaining Mine life after which time water management actions associated with mine closure are expected to commence. The adequacy of existing mitigation in Twelve Mile Creek needs to be confirmed by a geophysical survey that is evaluating the extent and connectedness of aquifers in this sub-catchment. The risk of COPCs generated by mining activity entering Mingham Creek is low, based on observed groundwater flow rates and inverse modelling. As such, additional mitigation in the southern drainage is not considered to be necessary.

6.4 Item 9 – Summary of findings and visual representation of the present and future vertical and horizontal extents of mining - affected groundwater

Item 9 requires a summary of findings, and visual representation of the present and future vertical and horizontal extents of mining - affected groundwater. It also required a discussion of the assumptions relied on, as well as uncertainties and exclusions associated with the model. To address this the Environmental Evaluation reviewed historical data and performed the inverse and solute transport models described for Conditions 5 and 6.

The visual representation of the lateral extent of mining-affected water across the Mine is shown in Figure 21. In this figure the red points show the present extent of mining-affected water, with yellow points showing the past extent of mining-affected water where trends have stabilized or reversed. Some bores will require a longer monitoring period to develop statistically valid data from which trends analysis can be done.

How the extents of mining - affected groundwater have changed over time at the sub-catchment scale in response to mining activity and historical mitigation of seepage from the TSF and WRDs, were identified using:

1. Bore logs that showed the depth of the main aquifer (or screen zone) intersected by monitoring bores,
2. Long-term records (2001 - 2020) of groundwater chemistry from which descriptive water quality statistics were developed. Efforts to mitigate mining-affected water manifested as changes to the EC values, SO_4/Cl concentration ratios, and concentrations of $\text{NO}_3\text{-N}$ and total cyanide in monitoring records,
3. Long term records of standing water levels in groundwater bores. These records allowed calculation of (a) hydraulic head potentials across the sub-catchments, (b) the increases in hydraulic head potentials associated with groundwater mounding under mining infrastructure, and (c) calculation of the vertical hydraulic head potentials. Importantly the records showed that the downstream flow control provided by the Perry River Weir has influenced the standing water level in several downstream monitoring and compliance bores.

Representation of the potential physical extents of mining - affected water seepage also relied on geophysical mapping of aquifer dimensions using ERI, which showed the likely geographical extents of saprolite (through which groundwater flow appears to predominate) and deep groundwater compartments in the fractured rock aquifer. As such these ERI images show the vertical and lateral extents of aquifers under the TSF relevant to the Northern Seepage Zone, which in conjunction with geological mapping of faults and lithological contacts that potentially transmit or impede groundwater flow, allows elucidation of potential groundwater flow-paths. The planned installation of dewatering bores will intercept these pathways (to be discussed for Item 10).

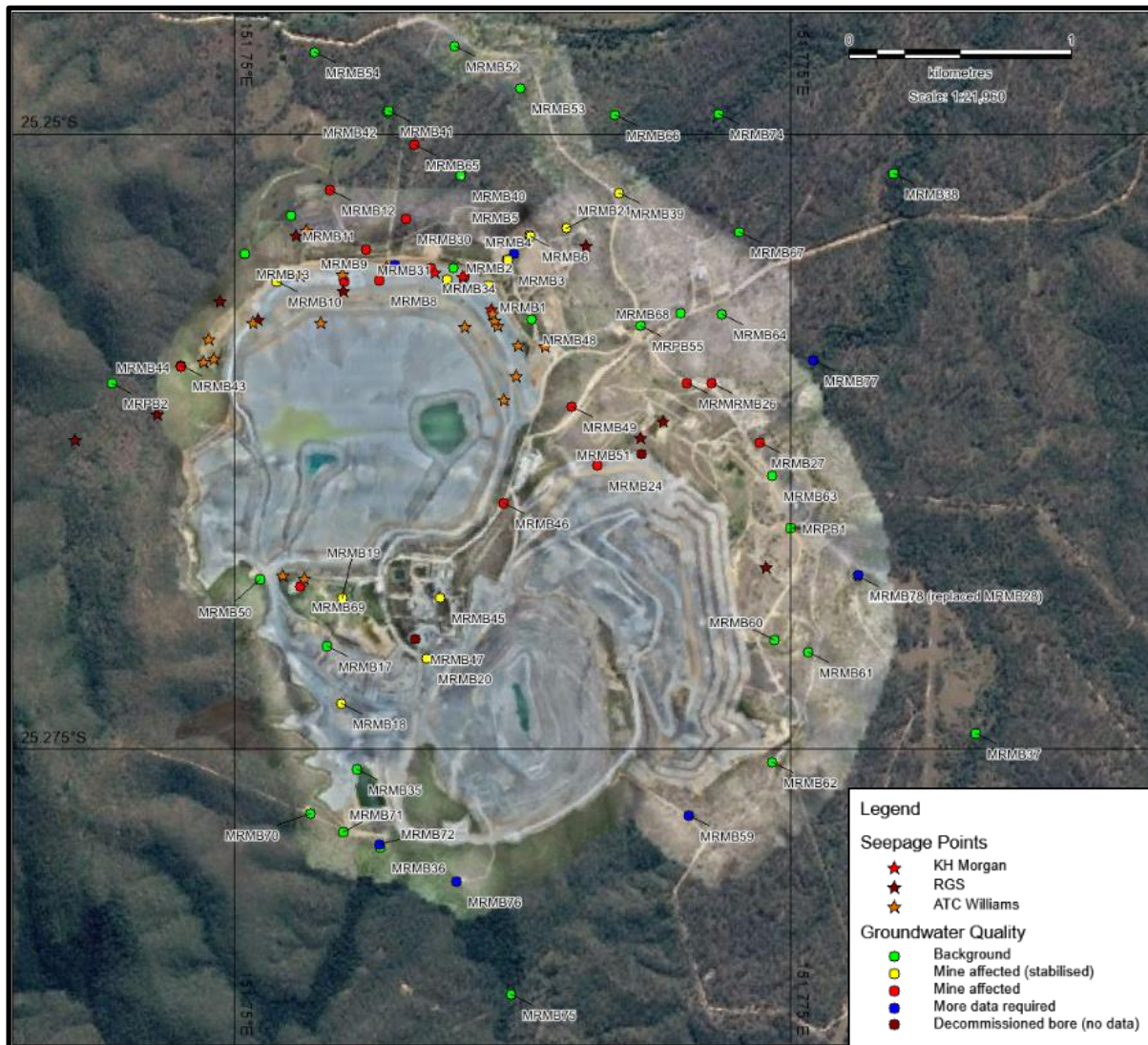


Figure 21: The lateral extent of mining - affected water across the mine lease

The review of standing water levels verified inferences made in the Stage 1 report that groundwater compartments occur in Twelve Mile Creek, below the landscape spur between Twelve Mile Creek and Rawdon Creek, in the headwater of Rawdon Creek, in the northwest corner of the TSF near the West Dam Fault, and in the southern drainage line towards Mingham Creek (near West Dam).

The review of historical data showed how the horizontal and vertical extent of mine influence has changed over time. It showed how mitigation has stabilized and reversed the egress of mining-affected water from the TSF and WRDs to the receiving environment.

The geochemical (solute) transport model developed source terms representative of tailings fluid, waste rock and mixtures of these source terms. It also represented the capacity of the aquifer through which these source terms flow to react with and modify mining-affected water. The model was calibrated by adjusting flow, aquifer matrix and evaporation parameters to obtain the best fit between observed and modelled data. The solute transport model has by necessity simplified the observed situation at the Mine scale by adopting assumptions, uncertainties and exclusions relevant to advective flow, weathering pathways and solute interactions with aquifer minerals. These are discussed in section 3.5 and include:

1. The conceptual hydrogeological model, which describes landscape processes in the Mount Rawdon mine lease as well as post mining hydrogeological processes,

2. Chemical processes that include cation exchange, surface complexation, biogeochemical decay or assimilation, and equilibrium,
3. Uniform, steady state groundwater (advective) flow through homogenous aquifers along the A-A', B-B' ... E-E' transects. Bimodal groundwater flow is not represented,
4. Faults have been assumed to be semi-permeable boundaries to flow, which is supported by field observations. Refer section 5.3.2.1 of this report, and sections 3.1.3 and 3.2 of the Stage 1 report, and
5. The simplified one-dimensional solute transport in a three-dimensional landscape has not accommodated for converging flow-paths in the spur-valley landscape of the mine lease, or the addition of rainfall recharge to groundwater during downslope solute movement towards valleys.

The effects of mitigation strategies to stabilize and reverse the reporting of mining - affected water to the receiving environment, were predicted as model scenarios. Possible mitigation measures include the Seepage Interception Drain and dewatering bores. These mitigations are additive so allow for progressively more removal of seepage water during the remaining operating mine life. After this, a closure plan will update and supersede the dewatering strategies proposed here. The closure strategy might include capping the TSF, commissioning of constructed wetlands and other concepts.

6.5 Items 10 and 11 - Review of the need for additional monitoring bores

Item 10 requires a review of the need for additional monitoring bores to quantify existing groundwater characteristics. Item 11 is in very similar terms but refers to additional bores to monitor the likely future extent of groundwater characteristics (assuming this is different). The existing geographical coverage is enough to quantify the magnitude and extent of mining - affected water reporting to the receiving environment, both existing and predicted, because the proposed mitigations are close to mining infrastructure and upgradient of the existing monitoring bore network. The established statistical trends of COPC in the existing bore network discussed below for Item 12 and shown in the appendix, will allow quantitative demonstration of the efficacy of the proposed mitigations.

6.6 Item 12 - Assessment of the impacts, and potential impacts, of mining to groundwaters and surface waters

Item 12 requires an assessment of the impacts, and potential impacts, of mining to groundwaters and surface waters. Relevant groundwater guidelines were referenced to develop a procedure that distinguished mining-affected water from background in the context of a landscape with dryland salinity and sulfide mineralization. These references were the *Queensland Water Quality Guidelines* (Department of Environment and Heritage Protection, 2009), *Using monitoring data to assess groundwater quality and potential environmental impacts* (DSITI, 2017), and *Statistical guidance for determining background groundwater quality and degradation* (Idaho DEQ, 2014). This built on work done during Stage 1 of the Environmental Evaluation, which demonstrated that the principal components for distinguishing native groundwater from mining - affected water were total cyanide, sulfur, nitrogen, arsenic, sodium and bicarbonate. A control chart was developed that used high threshold concentrations of chemicals of potential concern and a high threshold SO_4/Cl ratio, coupled with trends of increasing SO_4/Cl ratios, total cyanide and nitrate-N to distinguish possible mining-affected water from non-mining related exceedances of trigger values. The high threshold concentrations adopted in the control chart were the proposed guideline trigger limits developed for Item 13.

Because of the large amount of data collected between 2001 and 2020, data were partitioned and analyzed on a sub-catchment basis. This allowed for easier interpretation of possible mining effects in different parts of the mining lease.

Item 12a requires descriptive water quality statistics for each groundwater monitoring bore in the Mine. The statistics are tabled for Swindon Creek (Appendix 13), the unnamed creek between Swindon Creek and Rawdon Creek (Appendix 14), Rawdon Creek (Appendix 15),

the landscape spur between Rawdon Creek and Twelve Mile Creek (Appendix 16), Twelve Mile Creek (Appendix 17) and Mingham Creek (Appendix 18).

Item 12b requires boxplots for each groundwater monitoring bore in the Mine, which showed the minimum value, box (25th percentile, median and 75th percentile), maximum value, outlying values between 1.5 and 3 box lengths from the upper or lower edge of the box, and extreme values 3 or more box lengths from the upper or lower edge of the box. When a median exceeded the proposed guideline trigger limit, the exceedance was discussed. Boxplots were discussed for the Northern Seepage Zone in Section 5.3.3.2, for Rawdon Creek in Section 5.4.3.2, for the landscape spur between Rawdon Creek and Twelve Mile Creek in Section 5.5.3.2 and for Mingham Creek in Section 5.6.3.2. Boxplots were shown for Swindon Creek (Appendix 13), the unnamed creek between Swindon Creek and Rawdon Creek (Appendix 14), Rawdon Creek (Appendix 15), the landscape spur between Rawdon Creek and Twelve Mile Creek (Appendix 16), Twelve Mile Creek (Appendix 17) and Mingham Creek (Appendix 18).

In addition to the boxplots, Piper diagrams were used to represent major ion compositions for groundwater and for mining-affected water. These diagrams helped to describe groundwater in the Mine, and Piper diagrams were developed for Swindon Creek (Appendix 13), the unnamed creek between Swindon Creek and Rawdon Creek (Appendix 14), Rawdon Creek (Appendix 15), the landscape spur between Rawdon Creek and Twelve Mile Creek (Appendix 16), Twelve Mile Creek (Appendix 17) and Mingham Creek (Appendix 18).

Item 12c requires a description of spatial trends for mining - affected groundwater in the mine lease. Seepage paths from the west of the TSF towards the Swindon Creek riparian zone, as well as north from the TSF through the Northern Seepage Zone, are shown in Figure 18 to require further mitigation to stabilize seepage from the TSF. Historical seepage from the northeast of the TSF along Rawdon Creek has stabilized in response to existing mitigation (Figure 18).

Item 12d requires descriptions of temporal trends involving time series plots for all chemicals of potential concern in the mine lease. Temporal trends were provided for Swindon Creek (Appendix 13), the unnamed creek between Swindon Creek and Rawdon Creek (Appendix 14), Rawdon Creek (Appendix 15), the landscape spur between Rawdon Creek and Twelve Mile Creek (Appendix 16), Twelve Mile Creek (Appendix 17) and Mingham Creek (Appendix 18).

In summary, the Environmental Evaluation developed and applied a control chart to distinguish background groundwater quality from mining-affected water, and proposed groundwater trigger limits (discussed below) to review and analyze historical monitoring data. Exceedances of COPCs that were above the proposed limits were discussed. There were instances where exceedances were attributed to non-mining related phenomena such as lateral displacement of groundwater from the Perry River Weir, and unmined sulfide mineralization in the Mine. There were other instances where mining related exceedances were identified, most of which have been promptly brought under control during the history of Mine operations as discussed in the Stage 1 report (refer appendix 8.5 of the Stage 1 report). Further mitigation involving deep pump-back bores need to be implemented during the remaining operational life of the Mine, to stabilize and reverse some mining-related seepage that has continued to pass below the Seepage Interception Drain, and possibly in Twelve Mile Creek as well. These management options are discussed under Item 14.

6.7 Item 13 - Groundwater limits that verify the current and predicted extent of mining - affected groundwater seepage

Item 13 requires groundwater limits that will verify the current and predicted extent of mining - affected groundwater seepage. A procedure developed by the *Queensland Water Quality Guidelines (2009) Section 4.3.5, 5(a)* was identified as being suitable for the compartmentalized and heterogenous aquifer system in the Mine. This procedure develops trigger limits based on confidence intervals around the 20th and 80th percentile values of background water, and is recommended by DEHP 2009 as an interim procedure suitable for

naturally heterogenous systems. Since the *Queensland Water Quality Guidelines (2009)* are referenced by the Queensland groundwater guideline *Using monitoring data to assess groundwater quality and potential environmental impacts* (DSITI, 2017), this approach is consistent with the guideline required by the Environmental Evaluation.

The Groundwater Management and Monitoring Plan (Evolution, 2018) has previously proposed the Idaho DEQ procedure for developing groundwater limits, which was performed in parallel with the DSITI (2017) procedure because of this prior commitment. The Idaho DEQ and DSITI procedures were both run with the 80th percentile from same dataset but the Idaho DEQ procedure excluded some data that did not pass a test for independence (Idaho DEQ, 2014). The Idaho DEQ procedure is more conservative than the DSITI (2017) procedure for several COPCs relevant to the Environmental Authority (SO₄, Fe, Mn, NO₃_N, pH, As, B, Cd, Cu, Mo).

The DSITI and Idaho DEQ procedures define COPC concentration limits as being higher than 80% of the background groundwater concentrations in the Mine, which means that 20% of the time there will be naturally occurring exceedances of the proposed limits. The 80th percentile background concentrations for Mn, Al, As, B, CN and Pb in groundwater were lower than the ANZECC default guidelines, which are conservative limits for toxicants. Therefore, to represent a guideline trigger limit of toxicological significance it is feasible to use the ANZECC default guideline instead of the 80th percentile background groundwater concentration for these metals. The groundwater trigger limits proposed by this report are listed in underlined, bold font in Table 5. These trigger limits are not intended to be pass or fail criteria, but rather represent conservative values that trigger further investigation into whether the exceedance is mining related, and if so, what the potential toxicological and biological significance is to receptors.

This approach is consistent with the precautionary principle applied by the Australian Water Quality Guideline, which recommend applying conservative trigger limits that are lower than concentration exposures that would be of biological significance.

Current groundwater limits in the Environmental Authority, as well as the ANZECC water quality guideline limits, and local guideline limits developed using the 80th percentile background water quality values from the Mine following DSITI (2017) and Idaho DEQ (2014) procedures are listed in Table 5.

6.8 Item 14 - Identification of options to prevent further releases of mining - affected water from the premises to groundwater, and remedial measures to reduce contaminant concentrations in groundwaters

Item 14 requires the identification of all potential options to prevent further releases of mining-affected water from the premises to groundwater, and remedial measures to reduce contaminant concentrations in groundwaters. Item 14 also requires an estimation of corresponding implementation timeframes and costs for these seepage mitigation actions.

The current seepage management plan has demonstrated prevention of AMD at the source through effective measurement of carbon and sulfur in mined rock, separation of NAF from potentially acid-forming rock, and disposal of PAF either below the water blanket in the TSF (where water limits diffusion of oxygen into the disposal environment, and carbonate, albite and chlorite minerals neutralize acid generation), or encapsulated within non-acid-forming rock in a capped waste rock dump. This grade control and selective waste rock management strategy has been proven to prevent contaminant release from the Mine.

The current seepage management plan captures and reuses or evaporates NMD from the TSF and WRD through a combination of dams, drains, sumps and dewatering bores. These mitigation strategies have been progressively developed during the history of the Mine, and management responses have demonstrated the stabilization or reversal of mining - affected water entering aquifers into Rawdon Creek, Upper Swindon Creek and Twelve Mile Creek. Despite capture of 564 m³/day by the Seepage Interception Drain, mining - affected water

has continued to report to downgradient monitoring bores MRMB12, MRMB31, MRMB30 and MRMB65.

A strategy to improve dewatering in seepage zones (discussed below) will be implemented by MRO. These additional mitigation measures will support the interception of seepage pathways in Rawdon Creek and the western side of the TSF, which appear to have started to stabilize as a result of existing mitigations. The additional dewatering capacity is expected to further delay breakthrough of mining-affected groundwater seepage into upper Swindon Creek and Rawdon Creek.

The proposed mitigation will also equip bore MRMB31 with a pump and install two additional dewatering bores in the Northern Seepage Zone, to target deep seepage pathways that pass below the Seepage Interception Drain and report to MRMB31, MRMB30, MRMB12 and MRMB65. Electrical resistivity imaging transects parallel to the northern wall of the TSF and geological mapping in Swindon Creek, the unnamed creek and along the Seepage Interception Drain, were used to optimize the location of the two new dewatering bores. MRMB31 had already been deliberately positioned to capture underflow from the TSF once breakthrough had been established.

The design intent is to install pump-back bores that will draw down the groundwater level inside a cone of depression either to the level of the downstream flow control (the crest of the Perry River Weir), or to slightly above a fault that is inferred to pass between MRMB30 and MRMB40. This fault appears to be a flow barrier because of the lack of seepage of mining - affected water from MRMB30 and MRMB40. This strategy will remove the hydraulic head potential that drives seepage from the TSF, with the zone of influence of groundwater capture being the cone of depression developed by the three dewatering bores. Trends of increasing total cyanide concentrations and SO_4/Cl ratios bores reporting to MRMB12, MRMB30, MRMB65 are expected to stabilize and slowly reverse. If monitoring during the 2021 – 2024 financial years do not demonstrate the required stabilization and trend-reversal of the total cyanide concentrations and SO_4/Cl ratios then it will be necessary to widen the cones of depression by installing more pump-back bores in the seepage pathway.

The anticipated diameter of each cone of depression is between 26 and 188 metres, which was calculated using the Sichardt formula for unconfined aquifers, assuming a 30 – 40m drawdown and the hydraulic conductivities assumed for saprolite ($K = 0.0537 \text{ m/d}$) and fractured rock ($K = 0.00179 \text{ m/d}$). The actual diameters of the cones of depression will be calculated based on pumping tests to be performed in the field after the bores are commissioned.

The proposed implementation schedule and associated costs are included in Table 6. Figure 22 show the location of the existing and proposed water management units in the Northern Seepage Zone and Twelve Mile Creek.

Table 5: Proposed groundwater trigger values for the Mount Rawdon Mine Lease ¹³

Chemical of Potential Concern	EA Table E8		ANZECC (default)	DSITI, 2017	Idaho DEQ, 2014
	Limit A	Limit B		80%ile	80%ile
Calcium Dissolved (mg/L)				183	210
K Diss (mg/L)				7.4	7.0
Magnesium Dissolved (mg/L)				135	156
Sodium Dissolved (mg/L)				1127	1266
Chloride Dissolved (mg/L)				1664	1710
Fluoride (mg/L)				3.1	3.1
Sulphate (mg/L)	69 - 306	76 - 433		<u>540</u>	343
Alk Tot as CaCO ₃ (mg/L)				814	775
EC (µS/cm)	1382 - 4500	1403 - 4570	1244	<u>6362</u>	6920
Iron Dissolved (mg/L)	0.7 - 1.27	0.7 - 1.4	ID	<u>1.2</u>	0.76
Manganese Dissolved (mg/L)	<u>1.9</u>	<u>1.9</u>	<u>1.9</u>	0.7	0.4
Nitrate as N (mg/L)	2.1	2.1	0.015	<u>0.09</u>	0.02
pH	6.0 - 7.5	6.0 - 7.6	6.5 - 7.5	<u>6.4 - 7.6</u>	6.4 - 7.2
NH ₃ as N (mg/L)			0.01	0.22	0.07
SO ₄ /Cl (M/M)				<u>0.17</u>	0.13
Aluminium Dissolved (mg/L)	<u>0.055</u>	<u>0.055</u>	<u>0.055</u>	0.01*	*0.01
Arsenic Dissolved (mg/L)	<u>0.013</u>	<u>0.013</u>	<u>0.013</u>	0.008	0.004
Boron Dissolved (mg/L)			<u>0.37</u>	0.07	*0.05
Cadmium Dissolved (mg/L)	<u>0.0002</u>	<u>0.0002</u>	<u>0.0002</u>	0.0002	*0.0001
Chromium Dissolved (mg/L)	<u>0.001</u>	<u>0.001</u>	<u>0.001</u>	0.001*	*0.001
Copper Dissolved (mg/L)	<u>0.002</u>	0.0064	0.0014	<u>0.002</u>	*0.001
Cyanide Total (mg/L)	<u>0.007</u>	<u>0.007</u>	<u>0.007</u>	0.004*	*0.004
Lead Dissolved (mg/L)	<u>0.0034</u>	<u>0.0034</u>	<u>0.0034</u>	0.001	*0.001
Molybdenum Dissolved (mg/L)			ID	0.025	0.013
Zinc Dissolved (mg/L)	0.0142	0.0253	0.008	<u>0.032</u>	0.02
Se Diss (mg/L)	<u>0.011</u>	<u>0.011</u>	<u>0.011</u>	0.01*	*0.01

Source:

Idaho DEQ (2014) Statistical Guidance for determining background groundwater quality and degradation. Idaho Department of Environmental Quality. Technical Report (May 2009), 78 pp.

DSITI (2017) Using monitoring data to assess groundwater quality and potential environmental impacts. Version 1. Department of Science, Information Technology and Innovation (DSITI). Queensland Government, Brisbane.

Department of Environment and Heritage Protection (2009) Queensland Water Quality Guidelines, Version 3, ISBN 978-0-9806986-0-2

Department of Environment and Heritage Protection (2009) Queensland Water Quality Guidelines, Version 3, ISBN 978-0-9806986-0-3. Section 4.3.5 Deriving sub-regional water quality guidelines (SMD waters) Section 5a Calculate 20th and 80th percentiles for each reference site and compare with regional guidelines (if available)

¹³ The proposed groundwater trigger values are emboldened and underlined.

Table 6: Implementation Schedule – Preferred options

Catchment Zone	Issue / area of concern		Strategy	Intended outcome	Budgeted Cost (\$) approx.	Target completion date
A – A’ TSF Upper Swindon Creek	Seepage mitigation between the TSF and Upper Swindon Creek	I.	Install solar pump-back bore near MRMB43/44	Generate cone of depression and limit the effective hydraulic head to slow groundwater flow towards upper Swindon Creek riparian area.	\$32,000	1 st January 2020
		II.	TSF seepage interception and stormwater drainage improvements		\$400,000	1 st November 2021
B – B’ TSF Lower Swindon Creek	Seepage mitigation between the TSF and Lower Swindon Creek	I.	Install solar pump-back bore in MRMB31	Generate cones of depression that slow groundwater flow towards lower Swindon Creek riparian area.	\$64,000	1 st January 2020
		II.	Install solar pump-back bore downgradient of seepage pathway between MRMB8 and MRMB9			
		III.	Install solar pump-back bore upgradient of MRMB12			
C – C’ TSF Rawdon Creek	Seepage mitigation between the TSF and Rawdon Creek	I.	Install solar pump-back bore near toe of SD3, upstream of MRMB21 (Rawdon Creek C – C flow-path)	Generate cone of depression that slows groundwater flow towards lower Rawdon Creek riparian area.	\$32,000	1 st January 2020
D – D’ Twelve Mile Creek	Seepage mitigation between the NWRD and Twelve Mile Creek	I.	Geophysical survey to investigate the extent of aquifer connections	Generate cone of depression that slows groundwater flow towards Twelve Mile Creek (MRMB27).	\$40,000	Completed
		II.	Install solar pump-back bore north west of WD2 (near cattle yards)		\$32,000	1 st January 2020

7 Conclusion and Recommendations

Stage 2 of the Environmental Evaluation requires an investigation into and explanation of exceedances of the trigger values stated in Environmental Authority, noting that there is no indication of contamination based on AUSRIVAS monitoring and an investigation of stygofauna in groundwater. In response, this report (the Stage 2 investigation) provides detailed reviews of (a) the history of mining-affected water exfiltrating from the TSF, NWRD and WWRD towards receiving waters in the Mine; (b) the geophysical structure of aquifers that impede and transmit seepage; and (c) the efficacy of mitigation at stabilizing and reversing the influence of mining on groundwater quality. The outputs of the report are a method for distinguishing mining-affected water from background, groundwater trigger limits for the mining lease, and proposed improvements to stabilize and reverse mining influences on groundwater.

Groundwater trigger limits that verify the current and predicted extent of mining-affected groundwater seepage were calculated using a procedure suitable for the compartmentalized and heterogenous groundwater system in the Mount Rawdon mine lease, which was developed and recommended by the *Queensland Water Quality Guidelines (2009) Section 4.3.5, 5(a)*. Since the *Queensland Water Quality Guidelines (2009)* are referenced by DSITI (2017), this approach is consistent with the guideline required by the Environmental Evaluation.

The *Groundwater Management and Monitoring Plan* (Evolution, 2018) had proposed the Idaho DEQ (2014) procedure for developing groundwater limits, which was performed in parallel with the DSITI (2017) procedure because of this prior commitment. The Idaho DEQ procedure was more conservative than the Queensland Government procedure for several COPC's (SO₄, Fe, Mn, NO₃_N, pH, As, B, Cd, Cu, Mo).

The groundwater trigger limits proposed by this report (Table 5) are not intended to be pass or fail criteria, and do not necessarily signify contamination because by definition 20% of high background concentrations that are not contaminated will exceed the trigger limits. Rather the limits represent conservative values that trigger further investigation into whether the exceedance is mining related, including any toxicological and biological significance to receptors. This approach is consistent with the precautionary principle applied by the Australian Water Quality Guideline, which recommend applying conservative trigger limits that are lower than exposures to COPC concentrations of local biological significance.

Descriptive water quality statistics for each groundwater monitoring bore were reported as boxplots, Piper diagrams, SO₄/Cl vs Na/Cl graphs, time-series graphs and summary tables to represent major ion compositions for groundwater and for mining-affected water. These helped to describe groundwater in the Mine, and to identify possible seepage from TSF and waste rock.

Source terms appropriate for the five seepage pathways from mining infrastructure to creeks, were generated by a modelling approach informed by available water quality and representative mineral data. This approach modelled seepage of decant water through tailings and invoked weathering of tailings minerals along the flow-path to the toe of the TSF. The modelled source terms were verified against monitoring data. Inverse modelling invoked mixing of the tailings fluid and waste rock source terms and was used to describe blends of leachate from the TSF tailings and batter wall. Solute transport modelling was used to describe the reactive transport of the mixed source terms during groundwater flow through the mining lease.

The current horizontal and vertical extents of mining related groundwater seepage, and the rates and directions of COPC movement in groundwater, were reproduced by solute transport modelling. The vertical extent of mining - affected groundwater was shown, using geophysical

images, to be predominantly in shallow weathered rock. The horizontal extents along the following pathways were:

1. Seepage west of the TSF: Mining - affected water has contacted the riparian zone of upper Swindon Creek, but mitigation has started to stabilise the mining influence,
2. The Northern Seepage Zone: Mining - affected water has contacted the riparian zone of lower Swindon Creek, and penetrated along the landscape spur between Swindon Creek and the unnamed creek. Mitigation has delayed the mining effect, but more mitigation is needed,
3. Rawdon Creek: Mining - affected groundwater has penetrated along Rawdon Creek. Some of the mining effect relates to historical overtopping of SD1. The mining influence on groundwater has stabilised since Sediment Dam 3 was commissioned,
4. Twelve Mile Creek, including the landscape spur between Twelve Mile Creek and Rawdon Creek: Mining - affected water has extended to pump-back bores MRMB26 and MRMB27, with evidence that the mining-influence in MRMB63 has stabilised and reversed. There is no evidence that mining-influence has extended to the landscape spur between Twelve Mile Creek and Rawdon Creek, and
5. The southern drainage to Mingham Creek: Mining - affected water has penetrated the ground below South Dam and the processing plant. Seepage of mining - affected water has not progressed significantly past South Dam. There is evidence for groundwater mounding below West Dam, but no evidence for seepage of mining - affected water.

One-dimensional inverse modelling in NETPATH followed by one dimensional solute transport modelling in PHREEQC, of groundwater flow along the five seepage pathways was performed to represent seepage transfer of solutes from mining infrastructure towards the ephemeral creek lines. The solute transport model developed in PHREEQC was calibrated by adjusting model inputs for flow, exchange properties with the aquifer, and evapo-concentration so that model outputs matched measured breakthrough curves of mining-affected water reporting to monitoring bores. The calibrated model was used to predict the effects of intercepting and removing mining-affected groundwater along targeted pathways. Recommendations from the model predictions are:

1. Extend the Seepage Interception Drain, and increase pump-back bore capacity, to improve interception of mining - affected groundwater potentially seeping into upper Swindon Creek. These mitigations should limit groundwater discharge along the A – A' flow-path from 7 m³/day to 4.9 m³/day, which is expected to slow breakthrough by about 3 years after which water management units associated with mine closure would start to be commissioned,
2. Install additional pump-back capacity (pump-back bores and/or equip MRMB31 that is no longer being used as a monitoring bore) to intercept mining - affected groundwater seeping towards lower Swindon Creek. The combined effects of the Seepage Interception Drain and enhanced pump-back capacity could limit groundwater discharge along the B - B' flow-path from 2.5 m³/day to 0.3 m³/day. This is expected to delay breakthrough to a time commensurate with mine closure,
3. Long term groundwater monitoring along Rawdon Creek indicates that trends of mine impact in the creek line are stabilizing, which indicates that the existing mitigation is working. Improved capture of seepage water has slowed groundwater discharge along the C – C' pathway from 3.5 m³/d to 3.2 m³/d. With additional pump-back capacity, groundwater discharge along this pathway is expected to slow even further to 2 m³/d,
4. In Twelve Mile Creek existing mitigation includes pump-back bore MRMB27, which dewater seepage from WD2 along the D - D' transect at a rate about 1/3rd of groundwater discharge (12.4 m³/day) along this flow-path. It is possible that this cone of depression does not intercept all seepage from WD2, so a geophysical survey has been performed to investigate the extent of aquifer connections in this sub-catchment

and justify additional mitigation (commissioning a second pump-back bore near the cattle yards to the west of WD2),

5. In the southern drainage, modelling indicated that the risk of mining - affected water causing contamination in Mingham Creek was low. No additional mitigation along this drainage line is required based on this analysis.

A costed schedule and timeframe for implementation is provided in Table 6 and Figure 22.

Because these water management units will likely be superseded after mine closure in 2026, by lower maintenance water management units (possibly constructed wetlands), there is merit in commenting on the predicted long-term trends of solute transport from mining areas into groundwater. Cations such as cadmium, lead and zinc are attenuated by iron-hydroxide and clay minerals in the aquifer matrix, while anions such as cyanide, sulfate, nitrate and arsenic are more mobile in groundwater and have already reported to several investigation bores as shown in Figure 21 (and are, or will be, mitigated as discussed above). These longer-term, unmitigated, trends are shown by results of the solute transport model that extended beyond the expected 6 years of remaining mine operation (refer appendices 7 – 11), for example up to 130 years along the southern drainage line.

The operational phase of the Mine that has been modelled represents the current situation. After closure it is expected that the mining areas will be stabilised, decant water from the TSF will be removed, the TSF and the NWRD will be capped, and the water management strategy updated to possibly include exfiltrating mining - affected water through constructed wetlands. It is recommended that the MODFLOW SURFACT model developed for the Stage 1 report, and the PHREEQC solute transport model developed for the stage 2 report (this report) are updated as data becomes available and used to represent the groundwater heads, compositions and associated solute transport in the post-closure landscape. Long-term projections should be developed to demonstrate proof-of-concept of the post-closure mining landscape.

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9 Glossary

Abbreviation	Meaning
ABCC	Acid Buffering Characteristic Curve of the rock or tailings sample being tested for AMD potential, which is developed by slow titration of the sample while measuring pH to show the portion of the ANC that is immediately available for neutralising.
AMD	Acid Mine Drainage.
ANC	Acid Neutralising Capacity of the rock or tailings sample being tested for AMD potential. An acid (HCl) that will not react with pyrite is reacted with the sample, which consumes some of the HCl in proportion to the neutralising capacity of the sample. The solution is back titrated with NaOH to determine the amount of unreacted HCl. As such the acid consumed by reaction with the rock is calculated, and expressed in terms of kg H ₂ SO ₄ /t.
Andesite	Volcanic rock with fine hornblende and plagioclase crystals, which gives the rock a dark green to black colour. At Mount Rawdon andesite was associated with late stage brittle fracturing, where they formed narrow dykes common throughout the deposit area.
Argillization	Weathering of primary minerals in a rock to clay (e.g. feldspar to kaolinite).
Arsenopyrite	FeAsS. An arsenic mineral common in metallic sulfide ores. At Mount Rawdon it is an occasional trace accessory to pyrite.
ASST	Applied Scientific Services and Technology: Geophysical consultants (www.asstgroup.com) based in Perth, W.A.
Carbonate	Common minerals that contain carbonate at the Mount Rawdon Mine are calcite (CaCO ₃) and minor manganoan calcite (CaMn[CO ₃] ₂), which are minerals that occur in both unweathered and metamorphic rock fabrics, and possibly also in weathered rock and soil. They are important for the capacity of waste rock and soil on the lease to neutralise potential acid mine drainage and immobilise some constituents of potential concern by controlling groundwater pH. In circum neutral groundwater dissolved carbonate predominantly occurs as bicarbonate ion (HCO ₃ ⁻) but when groundwater is near to or above 8.2 pH the bicarbonate ion (CO ₃ ²⁻) occurs as well. In these situations total alkalinity represents the sum of bicarbonate and carbonate ions.
Catena	A repeatable sequence of distinct soils down a slope that occur in the same climate and from the same underlying parent material.
Chalcopyrite	CuFeS ₂ . A copper mineral present in metallic sulfide ores. In the Mount Rawdon deposit, it occurs in narrow (< 5 mm wide) discontinuous veinlets as a trace accessory to pyrite.
CEC	Cation-exchange capacity (CEC) is a measure of how many cations can be retained on soil particle surfaces. Negative charges on the surfaces of soil particles bind positively-charged atoms or molecules, but allow these to exchange with other positively charged particles in the surrounding soil water. This is one of the ways that solid materials in soil alter the chemistry of the soil. CEC affects many aspects of soil chemistry and is used as a measure of the capacity to retain pollutant cations (e.g. Pb ²⁺).
Chlorite	[Mg,Fe] ₃ [Si,Al] ₄ O ₁₀ [OH] ₂ . A green mineral associated with early metamorphic alteration at Mount Rawdon, which replaced iron-rich (mafic) minerals in the primary rock. Chloritization pre-dated and was partly overprinted by later sericite alteration. In the context of moderating possible acid mine drainage potential, chlorite contributes to the neutralizing capacity of the parent rock and forms part of the crystalline rock fabric that shields disseminated pyrite from oxidation.
Contamination	Environmental harm to humans, plants or animals that is caused by a chemical, biological or physical agent.
COPC	Chemical of Potential Concern are chemicals that have been shown through analysis to be those that are likely to be causing risk to humans, plants and animals at a site.

Dacite	A silica oversaturated lava intermediate between andesite and rhyolite. It is pale cream to dark green in colour, contains crystals of plagioclase, amphibole, biotite, Fe-Ti oxide and disseminated pyrite in a fine-grained siliceous groundmass, and occurs as both lavas and welded volcanic tuff formed by explosive reaction (pyroclastic's).
Dermosol	Soil that lacks strong texture contrast and has a well-structured B2 horizon with low levels of free iron. It is a high agricultural potential soil with good structure, moderate to high chemical fertility and water holding capacity.
Effect Size	See Statistical Effect Size.
Epidote	$\text{Ca}_2[\text{Al,Fe}]\text{Al}_2[\text{SiO}_4][\text{SiO}_7][\text{O,OH}]_2$. An apple green, calcium aluminosilicate mineral.
ERI	Electrical Resistivity Imaging measures the flow of direct current in the subsurface. The method delivers high resolution images of the electrical structure of soil and rock.
Exfiltration	Surface expression of groundwater, particularly into creek lines.
Galena	PbS. A lead mineral common in metallic sulfide ores. In the Mount Rawdon Mine it is an occasional trace accessory to pyrite.
Gangue	The commercially valueless material in which ore is found.
Gouge Material	When the two sides of a fault move along each other, the grinding and milling results in loosely fragmented material. First a fault breccia will form, but if grinding continues the rock becomes fault gouge.
Guideline Trigger Value	Concentrations that if exceeded will indicate a potential environmental problem, and so "trigger" further investigation. The investigation aims to both assess whether exceedance of a trigger value will result in environmental harm and refine a guideline value by accounting for environmental factors that can modify the effect of a chemical.
Hyporheic Zone	The region of sediment and porous space beneath and alongside a stream bed, where shallow groundwater mixes with surface water. The flow dynamics and behavior in this zone is important for surface water/groundwater interactions
Illite	$\text{K}_{1.5}\text{Al}_2[\text{Al}_{1.5}\text{Si}_{2.5}\text{O}_{10}][\text{OH}]_2$. A common potassium clay formed by weathering of feldspar and other aluminosilicate minerals.
Kaolinite	$\text{Al}_2[\text{Si}_2\text{O}_5][\text{OH}]_4$. A common clay formed by weathering or hydrothermal alteration of feldspar and other aluminosilicate minerals.
Mine	The mining lease owned and operated by Mount Rawdon Operations Pty Ltd.
Mining - affected water	In the Mount Rawdon mining lease, mining - affected water refers to solutes released from the Tailings Storage Facility and from waste rock. These solutes contain chemicals of potential concern that include sulfate, nitrate, cyanide and some heavy metals.
MODFLOW - SURFACT	MODFLOW-SURFACT Flow and Transport groundwater simulation software describes complex saturated/unsaturated subsurface flow and transport processes. It is based on the USGS modular groundwater flow model, MODFLOW.
MPA	The Maximum Potential Acidity determined from the %S in a rock or tailings sample being tested for AMD. $\text{MPA (kg H}_2\text{SO}_4/\text{t) = (Total \%S)*30.6}$, assumed as pyrite.
MRO	Mount Rawdon Operations Pty Ltd.
Muscovite	$\text{KAl}_2[\text{AlSi}_3\text{O}_{10}][\text{F,OH}]_2$. A common mineral in metamorphic and igneous rocks.
NAG	The Net Acid Generating potential of a rock or tailings sample being tested for AMD. The result is expressed in $\text{kg H}_2\text{SO}_4/\text{t}$ units.
NAF	Non-acid-forming rock or tailings sample being tested for AMD.
NETPATH for Windows	NETPATH is an interactive computer program used to interpret net geochemical mass-balance reactions between an initial and final water along a groundwater flow-path. NETPATH computes the mixing proportions of two to five initial waters and net

	geochemical reactions that can account for the observed composition of a final water. The calculations are useful for interpreting geochemical reactions, mixing proportions, evaporation and (or) dilution of waters, and mineral mass transfer in the chemical evolution of natural and environmental waters.
NWRD	Northern Waste Rock Dump located south east of the TSF in the Mount Rawdon Mine Lease. The waste rock dump has been designed to mitigate the generation of acid mine drainage, by encapsulation of PAF with NAF, and clay capping.
PAF	Potentially acid-forming rock or tailings sample being tested for AMD.
PC SWMM	A version of the industry standard USEPA Storm Water Management Model, which has enhanced GIS capability that has been developed by Computational Hydraulics International.
PHREEQC	PHREEQC is a computer program designed to perform a wide variety of hydrogeochemical calculations. It performs chemical speciation and inverse modelling calculations, with enhanced capacity to customize the C++ programming language to specific groundwater situations.
Phyllite	Low grade, fine-grained metamorphic rock with grained chlorite, quartz, and sericite.
Plagioclase	A series of feldspars ranging from albite ($\text{NaAlSi}_3\text{O}_8$) to anorthite ($\text{CaAl}_2\text{Si}_2\text{O}_8$). At Mount Rawdon, albite contributes to the neutralising capacity of the parent rock and to the crystalline rock fabric that shields disseminated pyrite from oxidation.
Porphyry	Quartz-feldspar-biotite porphyry is a rock-type at Mount Rawdon characterised by large crystals of quartz (3-5%), plagioclase (5-10%) & biotite (3-5%) in a fine-grained rock matrix of mainly k-feldspar with plagioclase (30-35%).
Propylitic alteration	Hydrothermal alteration of a volcanic rock, caused by iron and magnesium bearing fluids that alter biotite or amphibole in the rock groundmass to epidote, chlorite and albite.
Pyrite	FeS_2 . A common iron sulfide mineral that contributes to the acid mine drainage potential associated with weathering in the presence of water and oxygen. At Mount Rawdon it occurs as a minor mineral (1-2% by volume of rock) associated with the ore, either within the crystalline matrix of the rock where it is shielded from weathering, or as a late mineral formed along curvilinear shears, faults, joints and veins that are potentially exposed to weathering.
Quartz	SiO_2 . The most common silica mineral.
Riparian Zone	The riparian zone is an transition zone between two biological communities at the land and river interface. It is a zone where vegetation is controlled by water.
Rudosol	Poorly developed young soil, shallow and stony with a B2 horizon (>15% clay), potentially low fertility and low water holding capacity. Minimal development of an A1 horizon and presence of weathered rock or <10% clay/iron oxide precipitate in fissures of the parent rock.
Saprolite	Chemically weathered rock that occurs at the base of the soil profile and represents deep weathering of the bedrock surface.
Schist	Intermediate grade, coarse-grained, metamorphic rock with foliated layers of dark and light coloured minerals such as quartz, feldspar, biotite.
Sericitic alteration	Wall-rock alteration with products that are predominantly fine-grained muscovite (sericite) and quartz. At Mount Rawdon the main dacite is pervasively sericite altered, with sericite being accompanied by lesser amounts of illite-smectite, kaolinite, quartz and pyrite alteration products.
SD	Sediment Dam 1 (SD) and Sediment Dam 3 (SD3) receive stormwater and seepage that egresses from the TSF via the Northern Seepage Zone. The water is intercepted by the Downstream Seepage Interception Drain and diverted to SD1.
Smectite	The bentonite group of swelling clays that include montmorillonite $[\text{Al,Mg}]_8[\text{Si}_4\text{O}_{10}]_3[\text{OH}]_{10} \cdot 12[\text{H}_2\text{O}]$.
Sphalerite	A zinc mineral common in metallic sulfide ores. In the Mount Rawdon Mine it is a minor accessory to pyrite.
SSA	Specific surface area (SSA) is a property of solids defined as the total surface area of a material per unit of mass (with units of m^2/kg or m^2/g). The value can be used to represent the type and properties of an aquifer material (e.g. hydro-ferrous oxide) that has particular importance for adsorption and reactions on surfaces.
Statistical Effect Size	The proportion of data that contribute to a measured difference in a statistical comparison.

Statistical Power	The likelihood that a study will detect an effect. If statistical power is high (close to 1) the probability of concluding there is no difference when in fact, there is one is minimized. If statistical power is low (close to 0) there is a high risk that the real difference will be missed. A statistical power of 0.5 is like tossing a coin.
Steady state groundwater flow	Groundwater behavior when the wellhead or bottomhole pressure and flow rates are constant, which has been described at the Mount Rawdon mine lease scale using a MODFLOW-SURFACT model. The Mount Rawdon model was calibrated against 31 water level targets to simulate the groundwater flow, and the calibrated model result had a scaled root mean square error of 7.8%.
Tailings Fluid	Fluid expression from the TSF, which contains neutral mine drainage and chemicals of potential concern.
Tenosol	As for Rudosol with more developed A1 horizon or less developed B horizon.
Trachyandesite	A volcanic rock with lower Na ₂ O + K ₂ O content than trachyte and no large crystals (phenocrysts) of plagioclase feldspar.
Tremolite	Ca ₂ Mg ₅ Si ₈ O ₂₂ [OH] ₂ . An amphibole mineral associating with actinolite. It forms part of the Mount Rawdon hydrothermal alteration assemblage.
Trigger Value	See Guideline Trigger Value.
TSF	Tailings Storage Facility: The Mount Rawdon TSF commenced in 2001 as a valley type storage, formed by a primary embankment (Northern Embankment), an embankment on the southern end that extends around the eastern perimeter (Southern Embankment) and a saddle embankment to the west (Western Saddle Embankment). The TSF has subsequently been built in 3-metre lifts to form a turkeys-nest style containment, and maintain freeboard requirements where on the 1 st November of each year it can capture a 1:200 AEP 4 month wet season plus process inputs for the 4 month wet season as required by the Environmental Authority.
Virtual Curtain	VCL has worked with CSIRO to provide long term solutions for the remediation and neutralisation of geochemically complex wastewaters to a quality suitable for reuse or for discharge into the natural environment. The licenced product, <i>Virtual Curtain</i> , involves the synthesis and application of hydrotalcite (a magnesium clay).
VISUAL MINTEQ	Visual MINTEQ is a chemical equilibrium model for the calculation of metal speciation, solubility equilibria, sorption and other processes for natural waters.
WD	Waste Rock Dam. Four Waste Rock Dams (WD1, WD2, WD3 and WD4) were built across natural drainage lines to intercept stormwater and seepage from the NWRD. The captured water is either reused in the processing circuit, or removed by enhanced evaporation.
WWRD	West Waste Rock Dump located south of the TSF and South Dam and west of the pit. West Dam captures seepage and stormwater from this waste rock dump.

10 Appendices

Appendix 1: Weathering pathways in the Mount Rawdon Mine Lease

Parent rock	Waste rock dump and Saprolite	Soil
Pyrite ¹	Goethite ^{1, 3, 4, 6}	Solution: Remobilised SO ₄ ²⁻ , Ca ²⁺ , HCO ₃ ³⁻ , Fe ²⁺ (1, 2, 3, 4, 6)
Calcite ²	Gypsum ²	
Chlorite ³	Unresolved clay (possible vermiculite and smectite) ³	
Epidote ⁴		Kaolinite ^{3, 4, 5, 6, 7}
Albite ⁵	Possible halloysite ⁵	
Biotite ⁶		Solution: Mobilised K ⁺ , Na ⁺ (5, 6, 7)
Orthoclase ⁵	Unresolved clay (possible illite) ^{5, 7}	
Muscovite ⁷		
Quartz ⁸	Solution: Silicic acid ^{3, 4, 5, 8}	

Weathering of known mineral phases at MRO in parent rock, partially weathered rock (saprolite), mined rock and soil are tabled above in order of susceptibility to weathering. The left column lists the minerals most prone to weathering at the top of the column and the minerals most resistant to weathering at the bottom of the column. The central column lists secondary and intermediate minerals and solutes known to occur at MRO, which develop from the weathering of parent rock. The right column lists solutes and secondary minerals known to occur at MRO, which develop in the soil profile from the weathering of parent rock and partially weathered rock.

Textbook chemical reactions describing these weathering processes are listed below, numbered in order of the superscript. Reactions 1 and 2, and probably reactions 3 – 7, are expected to generate neutral mine drainage in the TSF and waste rock dumps. Reactions 3 – 8 are expected to dominate in the natural landscape, particularly involving rock types that do not involve the carbonate-bearing mine-sequence volcanics.

These minerals have been observed at MRO, either in hand specimen or in mineralogical descriptions. Where a mineral is suspected to be present but not observed at MRO (e.g. unresolved clay, unresolved halloysite), this is indicated.

1. Pyrite Weathering

Pyrite → Goethite + solution (containing sulfuric acid), probably with accompanying oxidation of Fe²⁺ to Fe³⁺
 $4\text{FeS}_2\text{(s)} + 15\text{O}_2\text{(g)} + 10\text{H}_2\text{O(l)} \rightarrow 4\text{FeOOH(s)} + 8\text{H}_2\text{SO}_4\text{(aq)}$

2. Weathering of Calcite and Pyrite

Solution (containing sulfuric acid) + Calcite → Gypsum + Carbon Dioxide
 $\text{H}_2\text{O(l)} + \text{H}_2\text{SO}_4\text{(aq)} + \text{CaCO}_3\text{(s)} \rightarrow \text{CaSO}_4 \cdot 2\text{H}_2\text{O(aq)} + \text{CO}_2\text{(g)}$

3. Chlorite Weathering

Chlorite → Kaolinite + Goethite + solution (containing silicic acid and magnesium bicarbonate). Possibly with vermiculite and smectite as intermediate phases during argillization
 $(\text{Mg,Fe})_5\text{Al}_2\text{Si}_3\text{O}_{10}(\text{OH})_2$

4. Epidote Weathering

Epidote → Kaolin + Goethite + solution (containing silicic acid and calcium bicarbonate)
 $\text{Ca}_2(\text{Al}_2\text{Fe})\text{Si}_3\text{O}_{12}(\text{OH})\text{(s)} + 6\text{H}_2\text{O(l)} + 4\text{CO}_2\text{(g)} \rightarrow \text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4\text{(s)} + \text{FeOOH(s)} + \text{H}_4\text{SiO}_4\text{(aq)} + 2\text{Ca}(\text{HCO}_3)_2\text{(aq)}$

5. Feldspar Weathering (PHREEQC has weathering rates for K-feldspar, Albite, Calcite, Pyrite, Pyrolusite)

Albite + solution (containing carbon dioxide) → Kaolinite + Solution (containing silicic acid and caustic soda). Possibly with halloysite as an intermediate mineral phase (not resolved)
 $4\text{NaAlSi}_3\text{O}_8\text{(s)} + 4\text{CO}_2\text{(aq)} + 22\text{H}_2\text{O(l)} \rightarrow 2\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4\text{(s)} + 8\text{H}_4\text{SiO}_4\text{(aq)} + 4\text{NaHCO}_3\text{(aq)}$

Orthoclase + solution (containing carbon dioxide) → Kaolinite + Solution (containing silicic acid and caustic potash). Possibly with illite as an intermediate mineral phase (not resolved)
 $4\text{KAlSi}_3\text{O}_8\text{(s)} + 4\text{CO}_2\text{(aq)} + 22\text{H}_2\text{O(l)} \rightarrow 2\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4\text{(s)} + 8\text{H}_4\text{SiO}_4\text{(aq)} + 4\text{KHCO}_3\text{(aq)}$

6. Biotite Weathering

Biotite → Kaolinite + Goethite + solution

7. Muscovite Weathering

Muscovite → Kaolinite + solution. Possibly with halloysite as an intermediate mineral phase (not resolved)

8. Quartz Weathering

Quartz → Silicic acid
 $\text{SiO}_2\text{(s)} + 2\text{H}_2\text{O(l)} \rightarrow \text{H}_4\text{SiO}_4\text{(aq)}$

Appendix 2: X Ray Diffraction analyses of weathering surfaces from the waste rock leachate trial

Waste Rock	Major	Minor	Trace
T1R1	Quartz	Muscovite	Pyrite
		Albite	Chlorite (Magnesium Iron Aluminium Silicate Hydroxide)
		Magnesian calcite	Sericite
T1R2	Quartz	Albite	Gypsum
		Muscovite	Pyrite
			Chlorite (Magnesium Iron Aluminium Silicate Hydroxide)
			Sericite
T1R3	Quartz	Muscovite	Gypsum
		Albite	Chlorite (Magnesium Iron Aluminium Silicate Hydroxide)
		Pyrite	Sericite
CHR1		Chlorite (Magnesium Iron Aluminium Silicate Hydroxide)	Gypsum
		Muscovite	Quartz
		Pyrite	Gypsum
		Albite	
		Magnesian calcite	
CHR2	Quartz	Iron Sulfide	Chlorite (Magnesium Iron Aluminium Silicate Hydroxide)
		Magnesium calcite	Albite
		Muscovite	Sericite
CHR3	Quartz	Muscovite	Chlorite (Magnesium Iron Aluminium Silicate Hydroxide)
		Chlorite-serpentine	Sericite
			Pyrite
			Gypsum
CNR1	Quartz	Muscovite	Chlorite (Magnesium Iron Aluminium Silicate Hydroxide)
		Albite	Pyrite
		Magnesian calcite	Calcite

Waste Rock	Major	Minor	Trace
			Sericite
			Halite
CNR2	Quartz	Muscovite	Chlorite (Magnesium Iron Aluminium Silicate Hydroxide)
	Calcite	Albite	Sericite
			Pyrite
			Gypsum
CNR3	Quartz	Albite	Pyrite
		Magnesian calcite	Sericite
		Muscovite	
		Chlorite (Magnesium Iron Aluminium Silicate Hydroxide)	
CMR1	Quartz	Magnesian calcite	Gypsum
		Pyrite	Sericite
		Muscovite	
		Albite	
		Chlorite (Magnesium Iron Aluminium Silicate Hydroxide)	
		Plagioclase	
CMR2	Quartz	Albite	Magnesium calcite
		Muscovite	Pyrite
		Chlorite (Magnesium Iron Aluminium Silicate Hydroxide)	Dehydroxylated muscovite
			Muscovite
			Gypsum
			Sericite
CMR3	Quartz	Albite	Pyrite
		Muscovite	Muscovite
		Chlorite (Magnesium Iron Aluminium Silicate Hydroxide)	Sericite
		Magnesium calcite	Gypsum

Waste Rock refers to the name of a leaching pad. Primary minerals include quartz, minor feldspar (albite, less plagioclase, orthoclase), chlorite, muscovite, calcite, pyrite. These weather to gypsum, sericite and halite.

Appendix 3: X Ray Diffraction analyses of groundwater exfiltration sites north of the Tailings Storage Facility

Source: Esslemont (2019)

Sample No.	Date Collected	Datum	Eastings	Northings	m AHD	Major	Minor	Trace
MRMB30 Seep B	13/09/2019	56J	375013	7206527		Quartz	Halite	Biotite
							Albite	
							Orthoclase	
MRMB30 Seep D	56J	56J	375006	7206506	129	Quartz	Halite	N.A.
							Orthoclase	
						Albite	Biotite	
MRMB30 Seep F	56J	56J	375029	7206523	132	Quartz	Halite	Biotite
							Albite	
							Orthoclase	
Swindon Creek Salt 1	27/09/2019	56J	374626	7206549	126	Quartz	Halite	N.A.
							Albite	
							Orthoclase	
							Biotite	
Swindon Creek Salt 2	27/09/2019	56J	374279	7206344	125	Quartz	Albite	Muscovite
							Chamosite	Biotite

Source: RGS (2012)

Sample No.	Date Collected	Datum	Eastings	Northings	m AHD	Location	Minerals (XRD)
27793	18/07/2011	56J	375709	7206296	N.A	Rawdon Creek downstream of SD2	Quartz, Albite, Chlinochlore, Muscovite
27794	18/07/2011	56J	374613	7206084	N.A	Rock pad adjacent to MRMB31	Quartz, Albite, Ca-albite, Orthoclase, Chlinochlore
27795	18/07/2011	56J	374396	7206333	N.A	Swindon Creek vicinity of MRMB12	Quartz, Anorthite, Orthoclase, Muscovite, Goethite
27796	18/07/2011	56J	374053	7206032	N.A	Swindon Creek vicinity of MRMB13	Quartz, Ca-albite, Orthoclase, Muscovite
27797	18/07/2011	56J	374226	7205952	N.A	Seep adjacent to MRMB10	Quartz, Ca-albite, Orthoclase, Chlinochlore, Muscovite
27798	18/07/2011	56J	373773	7205521	N.A	Swindon Creek tributary, NW of TSF	Quartz, Ca-albite, Orthoclase, Chlinochlore, Muscovite
27799	18/07/2011	56J	373780	7205559	N.A	Scrapings from MRMB43 casing	Quartz, Ca-albite, Anorthite, Orthoclase, Biotite, Mg-Calcite
27800	18/07/2011	56J	373402	7205404	N.A	Swindon Creek, upstream of MRM	N.A.

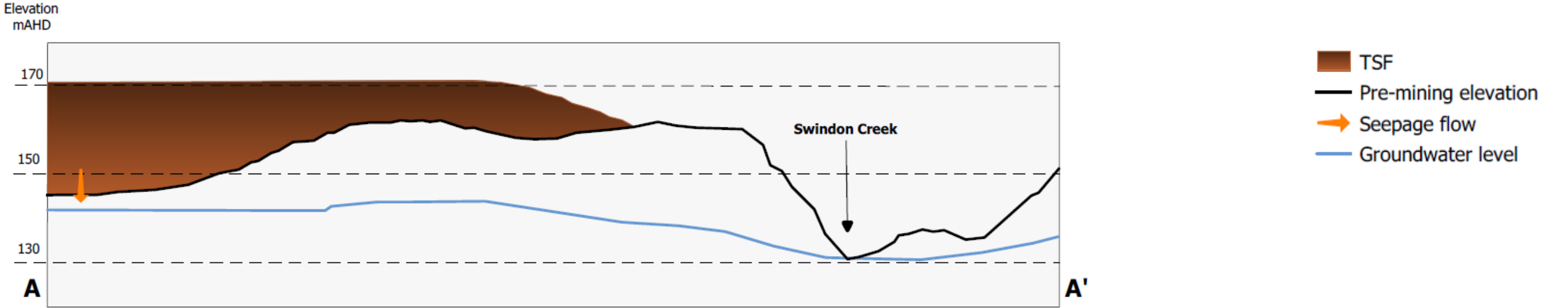
Appendix 4: X Ray Diffraction analyses of groundwater exfiltration sites in Twelve Mile Creek

Sample No.	Date Collected	Datum	Eastings	Northings	m AHD	Comment	Major minerals (XRD Mineral)	Minor Minerals (XRD)	Trace Minerals (XRD)
I3698/001:1	14/05/2019	56J	376335	7205140	N.A	Salt efflorescence near NWRD3	Quartz	Gypsum, Albite, Muscovite	Orthoclase

Source: RGS (2012)

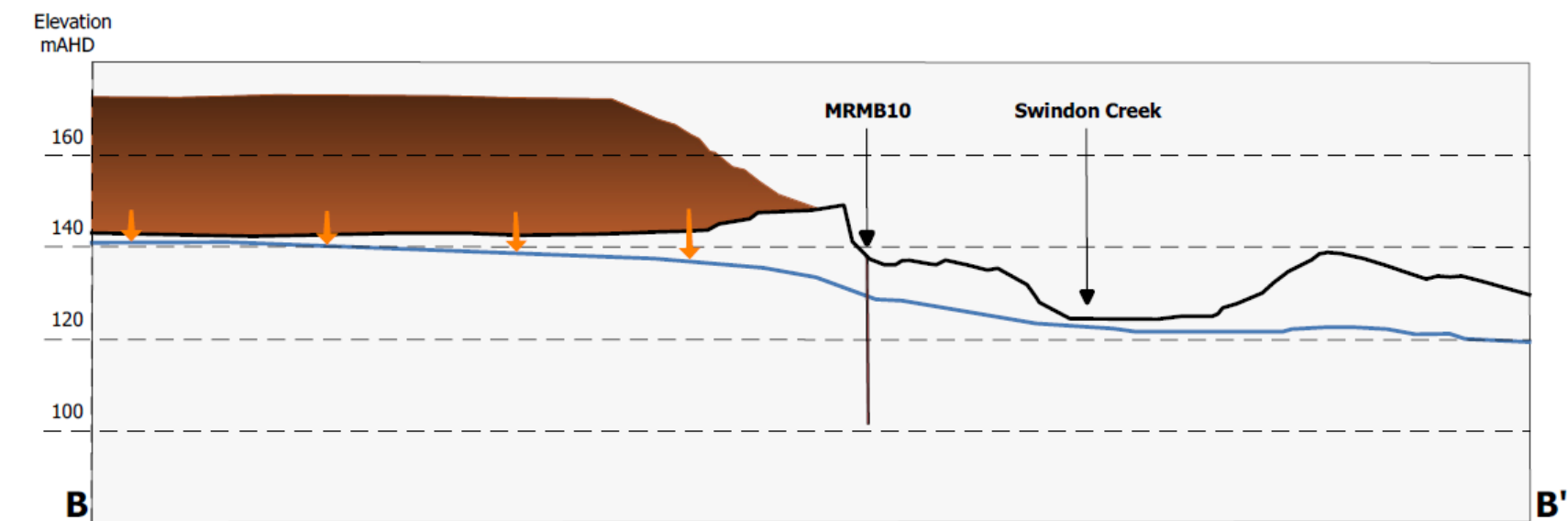
Sample No.	Date Collected	Datum	Eastings	Northings	m AHD	Comment	Minerals (XRD)
27801	18/07/2011	56J	376535	7204858	N.A	Ground at base of MRPB1	Quartz, Albite, Orthoclase, Clinocllore, Phlogophite, Calcite
27803	18/07/2011	56J	376063	7205508	N.A	Spring from below WD1 (below bore 25)	Quartz, Albite, Ca-albite, Anorthite, Muscovite
27804	18/07/2011	56J	375965	7205435	N.A	Banks of dam below WD1	Quartz, Albite, Anorthite, Orthoclase, Clinocllore

Appendix 5: Hydraulic Cross Sections representing flow-paths A-A', B-B' E-E'.



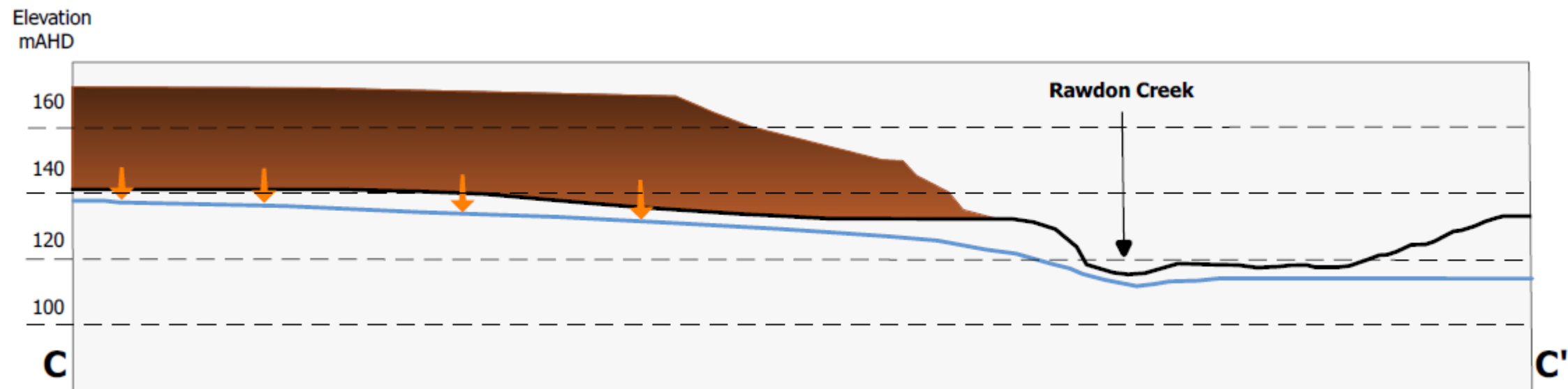
Subcatchment identifier		Darcian Flow Parameters											Parameters used in PHREEQC for WINDOWS					
PROFILE	Sub-catchment	Flow Medium		Groundwater Q (m³/d)	Darcy velocity (m/d)	K (m/d)	B1 (m)	B2 (m)	H (m)	b (m)	W (m)	L (m)	Annual seepage velocity (m/y)	No Years to flow-through into creek line	Cell Length (m)	Annual flow through cell (y)	Annual flow through cell (s)	No. Cells
A - A'	Swindon Upstream	Weathered Rock	Saprolite	1080	0.4910	12.1	13.0	4.6	8.4	8.8	250	207	3261	0.06	5.2	0.0016	50083	40
A - A'	Swindon Upstream	Weathered Rock	Saprolite	108	0.0491	1.21	13.0	4.6	8.4	8.8	250	207	326	0.6	5.2	0.02	500832	40
A - A'	Swindon Upstream	Weathered Rock	Saprolite	7	0.0032	0.079	13.0	4.6	8.4	8.8	250	207	21	9.7	5.2	0.2	7670978	40
A - A'	Swindon Upstream	Weathered Rock	Saprolite	1	0.0005	0.0121	13.0	4.6	8.4	8.8	250	207	3.26	63.5	5.2	1.6	50083247	40
A - A'	Swindon Upstream	Weathered Rock	Saprolite	0	0.0000	0.00121	13.0	4.6	8.4	8.8	250	207	0	635	5.2	15.9	500832468	40

Subcatchment identifier		Darcian Flow Parameters											Parameters used in PHREEQC for WINDOWS					
PROFILE	Sub-catchment	Flow Medium	Groundwater Q (m³/d)	Darcy velocity (m/d)	K (m/d)	B1 (m)	B2 (m)	H (m)	b (m)	W (m)	L (m)	Annual seepage velocity (m/y)	No Years to flow towards or into creek	Cell Length (m)	Annual flow through cell (y)	Annual flow through cell (s)	No. Cells	
A - A'	Swindon Upstream	Fractured Rock	Fractured Rock	15.98	0.00726	0.179	13	4.6	8.4	8.8	250	207	530.6	0.4	5.2	0.01	307774	40.0
A - A'	Swindon Upstream	Fractured Rock	Fractured Rock	1.60	0.00073	0.0179	13	4.6	8.4	8.8	250	207	53.1	4	5.2	0.1	3077741	40.0
A - A'	Swindon Upstream	Fractured Rock	Fractured Rock	0.16	0.00007	0.00179	13	4.6	8.4	8.8	250	207	5.3	39	5.2	1.0	30777414	40.0
A - A'	Swindon Upstream	Fractured Rock	Fractured Rock	0.02	0.00001	0.00026	13	4.6	8.4	8.8	250	207	0.8	269	5.2	7	211890659	40.0
A - A'	Swindon Upstream	Fractured Rock	Fractured Rock	0.00	0.00000	0.0000179	13	4.6	8.4	8.8	250	207	0.05	3901	5.2	98	3077741421	40.0



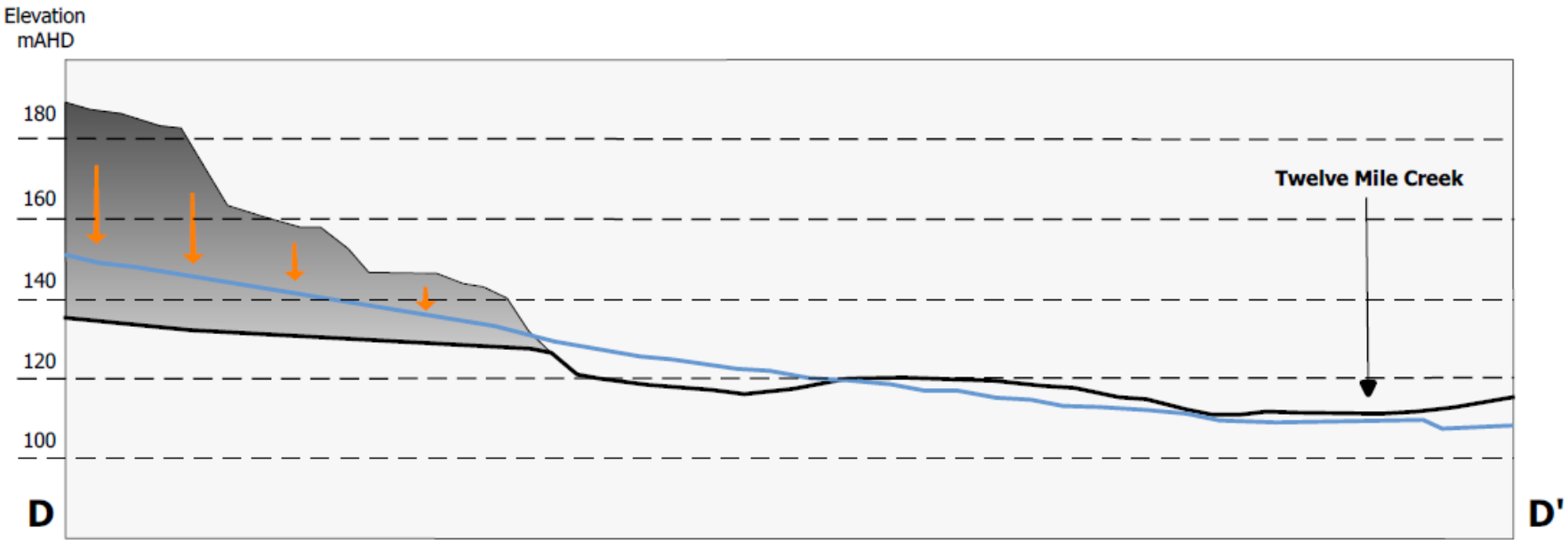
Subcatchment identifier				Darcian Flow Parameters									Parameters used in PHREEQC for WINDOWS					
PROFILE	Sub-catchment	Flow Medium		Groundwater Q (m³/d)	Darcy velocity (m/d)	K (m/d)	B1 (m)	B2 (m)	H (m)	b (m)	W (m)	L (m)	Annual seepage velocity (m/y)	No Years to flow-through into creek line	Cell Length (m)	Annual flow through cell (y)	Annual flow through cell (s)	No. Cells
B - B'	Swindon Downstream	Weathered Rock	Saprolite	378.1	0.4449	12.1	15	3.75	11.3	3.4	250	306	2954	0.1	7.65	0.00	81719	40
B - B'	Swindon Downstream	Weathered Rock	Saprolite	37.8	0.0445	1.21	15	3.75	11.3	3.4	250	306	295	1.0	7.65	0.03	817187	40
B - B'	Swindon Downstream	Weathered Rock	Saprolite	2.5	0.0029	0.08	15	3.75	11.3	3.4	250	306	20	16	7.65	0.39	12359952	40
B - B'	Swindon Downstream	Weathered Rock	Saprolite	0.4	0.0004	0.0121	15	3.75	11.3	3.4	250	306	2.95	104	7.65	2.6	81718691	40
B - B'	Swindon Downstream	Weathered Rock	Saprolite	0.0	0.0000	0.00121	15	3.75	11.3	3.4	250	306	0.3	1036	7.65	25.9	817186909	40

Subcatchment identifier				Darcian Flow Parameters									Parameters used in PHREEQC for WINDOWS					
PROFILE	Sub-catchment	Flow Medium		Groundwater Q (m³/d)	Darcy velocity (m/d)	K (m/d)	B1 (m)	B2 (m)	H (m)	b (m)	W (m)	L (m)	Annual seepage velocity (m/y)	No Years to flow towards or into creek	Cell Length (m)	Annual flow through cell (y)	Annual flow through cell (s)	No. Cells
B - B'	Swindon Downstream	Fractured Rock	Fractured Rock	7.40	0.00658	0.179	15	3.75	11.3	4.5	250	306	480.7	0.6	7.65	0.02	502182	40
B - B'	Swindon Downstream	Fractured Rock	Fractured Rock	0.74	0.00066	0.0179	15	3.75	11.3	4.5	250	306	48.1	6	7.65	0.16	5021819	40
B - B'	Swindon Downstream	Fractured Rock	Fractured Rock	0.07	0.00007	0.00179	15	3.75	11.3	4.5	250	306	4.8	64	7.65	1.6	50218190	40
B - B'	Swindon Downstream	Fractured Rock	Fractured Rock	0.01	0.00001	0.000179	15	3.75	11.3	4.5	250	306	0.5	637	7.65	16	502181899	40
B - B'	Swindon Downstream	Fractured Rock	Fractured Rock	0.00	0.00000	0.0000179	15	3.75	11.3	4.5	250	306	0.0	6365	7.65	159	5021818994	40



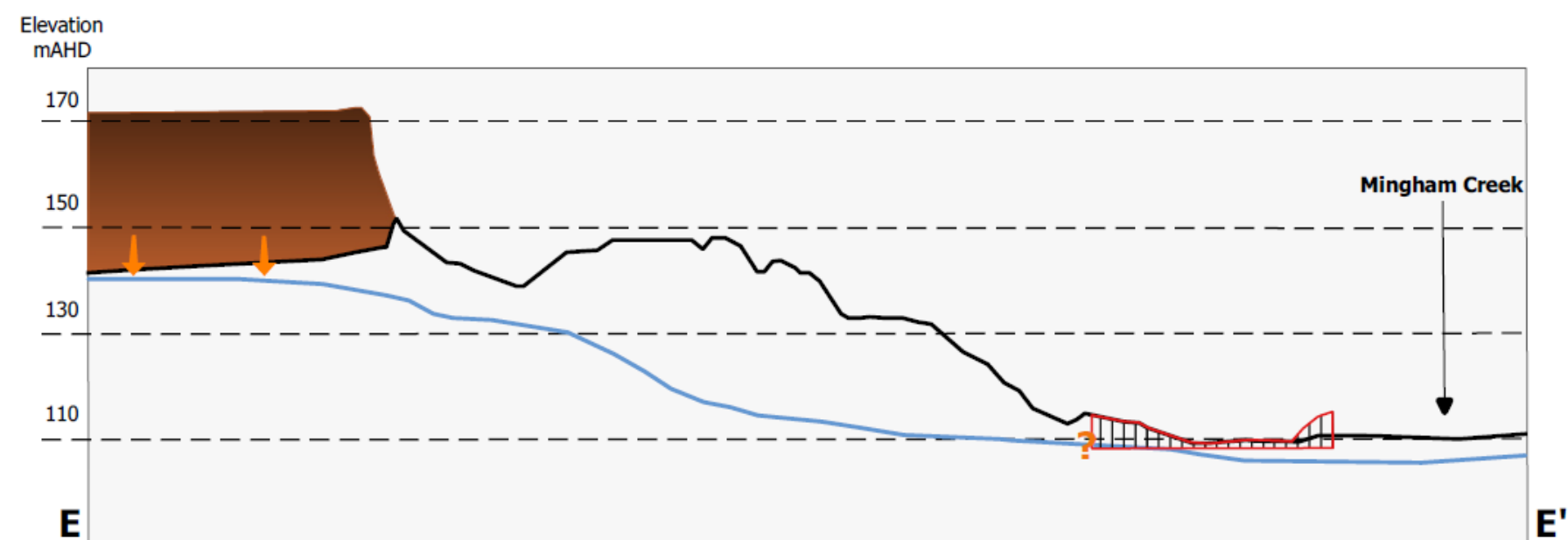
Subcatchment identifier		Darcian Flow Parameters											Parameters used in PHREEQC for WINDOWS					
PROFILE	Sub-catchment	Flow Medium	Groundwater Q (m³/d)	Darcy velocity (m/d)	K (m/d)	B1 (m)	B2 (m)	H (m)	b (m)	W (m)	L (m)	Annual seepage velocity (m/y)	No Years to flow-through into creek line	Cell Length (m)	Annual flow through cell (y)	Annual flow through cell (s)	No. Cells	
C - C'	Rawdon Upstream	Weathered Rock	Saprolite	1670	1.5907	12.1	13.5	1.8	11.7	4.2	250	89	10564	0.01	4.5	0.000	13294	20
C - C'	Rawdon Upstream	Weathered Rock	Saprolite	167	0.1591	1.21	13.5	1.8	11.7	4.2	250	89	1056	0.1	4.5	0.00	132940	20
C - C'	Rawdon Upstream	Weathered Rock	Saprolite	3.5	0.0033	0.025	12.8	1.8	11.7	4.2	250	89	22	4.1	4.5	0.20	6434289	20
C - C'	Rawdon Upstream	Weathered Rock	Saprolite	2	0.0016	0.0121	13.5	1.8	11.7	4.2	250	89	11	8.4	4.5	0.4	13293986	20
C - C'	Rawdon Upstream	Weathered Rock	Saprolite	0	0.0002	0.00121	13.5	1.8	11.7	4.2	250	89	1	84.3	4.5	4.2	132939860	20

Subcatchment identifier				Darcian Flow Parameters									Parameters used in PHREEQC for WINDOWS					
PROFILE	Sub-catchment	Flow Medium		Groundwater Q (m³/d)	Darcy velocity (m/d)	K (m/d)	B1 (m)	B2 (m)	H (m)	b (m)	W (m)	L (m)	Annual seepage velocity (m/y)	No Years to flow towards or into creek	Cell Length (m)	Annual flow through cell (y)	Annual flow through cell (s)	No. Cells
C - C'	Rawdon Upstream	Fractured Rock	Fractured Rock	22.06	0.02353	0.179	13.5	1.8	11.7	3.75	250	89	1719	0.1	4.5	0.00	81695	20
C - C'	Rawdon Upstream	Fractured Rock	Fractured Rock	2.21	0.00235	0.0179	13.5	1.8	11.7	3.75	250	89	172	1	4.5	0.03	816949	20
C - C'	Rawdon Upstream	Fractured Rock	Fractured Rock	0.22	0.00024	0.00179	13.5	1.8	11.7	3.75	250	89	17	5	4.5	0.26	8169489	20
C - C'	Rawdon Upstream	Fractured Rock	Fractured Rock	0.02	0.00002	0.000179	13.5	1.8	11.7	3.75	250	89	2	52	4.5	2.59	81694886	20
C - C'	Rawdon Upstream	Fractured Rock	Fractured Rock	0.00	0.00000	0.0000179	13.5	1.8	11.7	3.75	250	89	0	518	4.5	26	816948861	20



Subcatchment identifier				Darcian Flow Parameters									Parameters used in PHREEQC for WINDOWS					
PROFILE	Sub-catchment	Flow Medium		Groundwater Q (m³/d)	Darcy velocity (m/d)	K (m/d)	B1 (m)	B2 (m)	H (m)	b (m)	W (m)	L (m)	Annual seepage velocity (m/y)	No Years to flow-through into creek line	Cell Length (m)	Annual flow through cell (y)	Annual flow through cell (s)	No. Cells
D - D'	12 Mile Creek	Weathered Rock	Saprolite	1241.0	0.5909	12.1	24	3	21.0	8.4	250	430	3924	0.11	4.3	0.001	34579	100
D - D'	12 Mile Creek	Weathered Rock	Saprolite	124.1	0.0591	1.21	24	3	21.0	8.4	250	430	392	1.1	4.3	0.01	345787	100
D - D'	12 Mile Creek	Weathered Rock	Saprolite	12.4	0.0059	0.121	24	3	21.0	8.4	250	430	39	11	4.3	0.1	3457870	100
D - D'	12 Mile Creek	Weathered Rock	Saprolite	1.2	0.0006	0.0121	24	3	21.0	8.4	250	430	4	110	4.3	1.1	34578701	100
D - D'	12 Mile Creek	Weathered Rock	Saprolite	0.1	0.0001	0.00121	24	3	21.0	8.4	250	430	0	1096	4.3	11.0	345787013	100

Subcatchment identifier				Darcian Flow Parameters									Parameters used in PHREEQC for WINDOWS					
PROFILE	Sub-catchment	Flow Medium		Groundwater Q (m³/d)	Darcy velocity (m/d)	K (m/d)	B1 (m)	B2 (m)	H (m)	b (m)	W (m)	L (m)	Annual seepage velocity (m/y)	No Years to flow towards or into creek	Cell Length (m)	Annual flow through cell (y)	Annual flow through cell (s)	No. Cells
D - D'	12 Mile Creek	Fractured Rock	Fractured Rock	1.31	0.00874	0.179	24	3	21.0	0.6	250	430	638.6	0.7	4.3	0.0067	212495	100.0
D - D'	12 Mile Creek	Fractured Rock	Fractured Rock	0.13	0.00087	0.0179	24	3	21.0	0.6	250	430	63.9	6.7	4.3	0	2124948	100.0
D - D'	12 Mile Creek	Fractured Rock	Fractured Rock	0.01	0.00009	0.00179	24	3	21.0	0.6	250	430	6.4	67.3	4.3	0.7	21249481	100.0
D - D'	12 Mile Creek	Fractured Rock	Fractured Rock	0.00	0.00001	0.000179	24	3	21.0	0.6	250	430	0.6	673.4	4.3	7	212494812	100.0
D - D'	12 Mile Creek	Fractured Rock	Fractured Rock	0.00	0.00000	0.0000179	24	3	21.0	0.6	250	430	0.1	6733.6	4.3	67	2124948125	100.0



Subcatchment identifier				Darcian Flow Parameters									Parameters used in PHREEQC for WINDOWS					
PROFILE	Sub-catchment	Flow Medium		Groundwater Q (m³/d)	Darcy velocity (m/d)	K (m/d)	B1 (m)	B2 (m)	H (m)	b (m)	W (m)	L (m)	Annual seepage velocity (m/y)	No Years to flow-through into creek line	Cell Length (m)	Annual flow through cell (y)	Annual flow through cell (s)	No. Cells
E - E'	Mingham Creek	Weathered Rock	Saprolite	55.02	0.1834	12.1	23	4.25	18.8	1.2	250	1237	1218	1.0	24.3	0.02	629602	51
E - E'	Mingham Creek	Weathered Rock	Saprolite	5.50	0.0183	1.21	23	4.25	18.8	1.2	250	1237	122	10	24.3	0.2	6296015	51
E - E'	Mingham Creek	Weathered Rock	Saprolite	0.55	0.0018	0.121	23	4.25	18.8	1.2	250	1237	12	102	24.3	2.0	62960151	51
E - E'	Mingham Creek	Weathered Rock	Saprolite	0.06	0.0002	0.0121	23	4.25	18.8	1.2	250	1237	1	1016	24.3	20.0	629601513	51
E - E'	Mingham Creek	Weathered Rock	Saprolite	0.01	0.0000	0.00121	23	4.25	18.8	1.2	250	1237	0	10156	24.3	199.5	6296015127	51

Subcatchment identifier				Darcian Flow Parameters									Parameters used in PHREEQC for WINDOWS					
PROFILE	Sub-catchment	Flow Medium		Groundwater Q (m³/d)	Darcy velocity (m/d)	K (m/d)	B1 (m)	B2 (m)	H (m)	b (m)	W (m)	L (m)	Annual seepage velocity (m/y)	No Years to flow towards or into creek	Cell Length (m)	Annual flow through cell (y)	Annual flow through cell (s)	No. Cells
E - E'	Mingham Creek	Fractured Rock	Fractured Rock	4.34	0.00271	0.179	23	4.25	18.8	6.4	250	1237	198.2	6.2	24.3	0.1	3861879	51
E - E'	Mingham Creek	Fractured Rock	Fractured Rock	0.43	0.00027	0.0179	23	4.25	18.8	6.4	250	1237	19.8	62	24.3	1	38618790	51
E - E'	Mingham Creek	Fractured Rock	Fractured Rock	0.04	0.00003	0.00179	23	4.25	18.8	6.4	250	1237	2.0	624	24.3	12	386187904	51
E - E'	Mingham Creek	Fractured Rock	Fractured Rock	0.004	0.00000	0.000179	23	4.25	18.8	6.4	250	1237	0.2	6241	24.3	122	3861879040	51
E - E'	Mingham Creek	Fractured Rock	Fractured Rock	0.0004	0.00000	0.0000179	23	4.25	18.8	6.4	250	1237	0.0	62412	24.3	1224	38618790404	51

Appendix 6: Specific Surface Area values used to represent exchange sites on hydro-ferrous oxide (HFO), and Cation Exchange Capacity (CEC) associated with aquifers

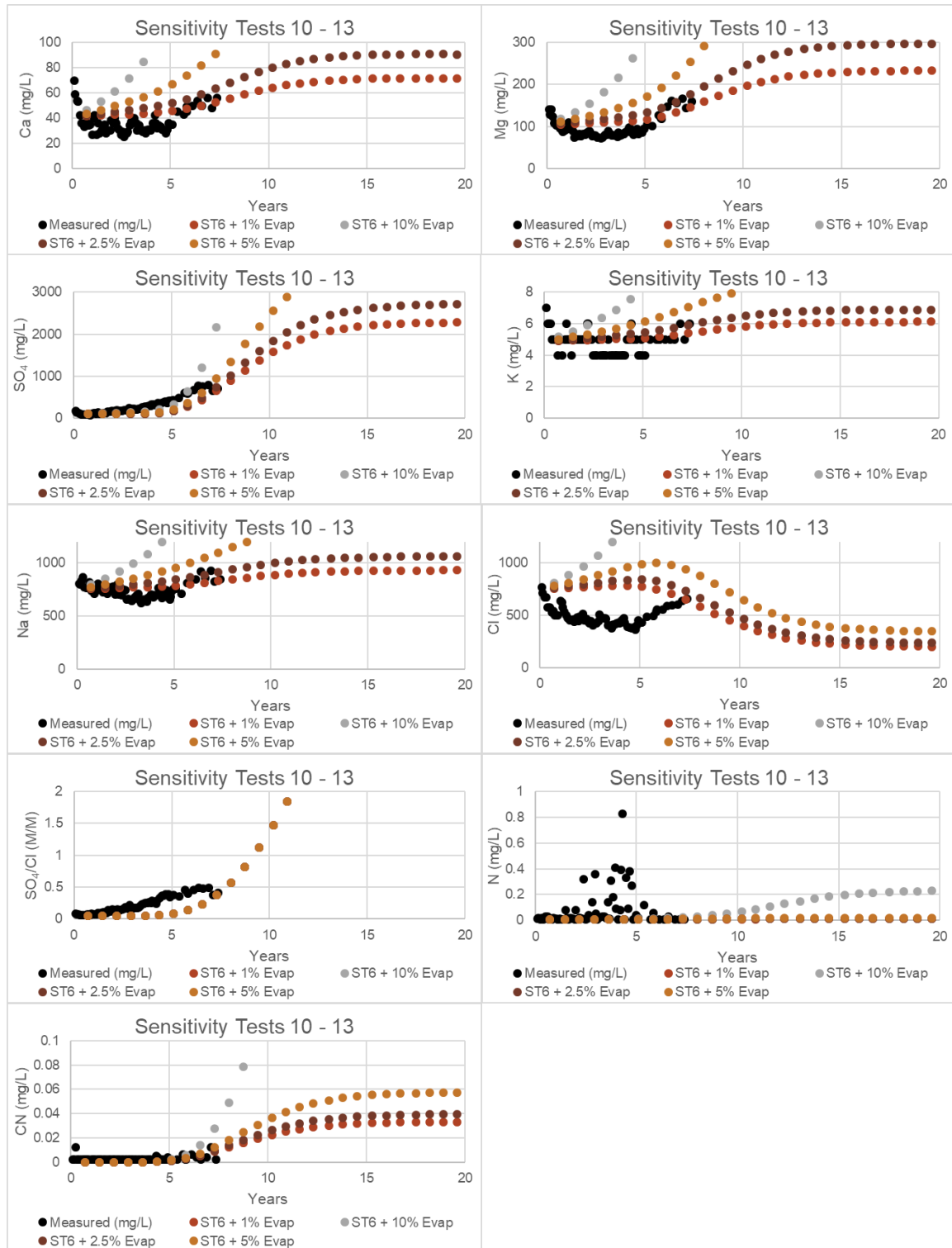
Aquifer substrate	mol Fe/kg rock	Proportion of solid: void in media	Particle Density (kg/L)	Mol Fe/L	Mol HFO/L	Mol HFO weak sites/L	SSA	Mass HFO	Mol HFO strong sites/L
Surface Soil	0.0148	1.56	2.7	0.062	0.062	0.012	67	5.6	0.00031
Subsoil	0.0430	1.22	2.7	0.142	0.142	0.03	151	12.6	0.00071
Saprolite - low K	0.0125	2.92	2.7	0.099	0.099	0.02	105	8.8	0.00049
Saprolite - Variable K	0.0166	17.2	2.7	0.771	0.771	0.15	822	68.6	0.00385
Fr. Rock	0.0184	199	2.7	9.902	9.902	1.98	10556	881	0.04951

(a) Mol Fe/kg = ((mg/L/1000)/55.845); (b) proportion of solid: void in media = (1-porosity)/porosity; (c) particle density = 2.7 kg/L; (d) Mol Fe/L = (a * b * c), (e) Mol HFO/L = (d); (f) Mol HFO weak sites/L = (e * 0.2); (g) SSA = (5330 * f); (h) Mass HFO = (89 * g); (i) Mol HFO strong sites / L = (0.005 * h).

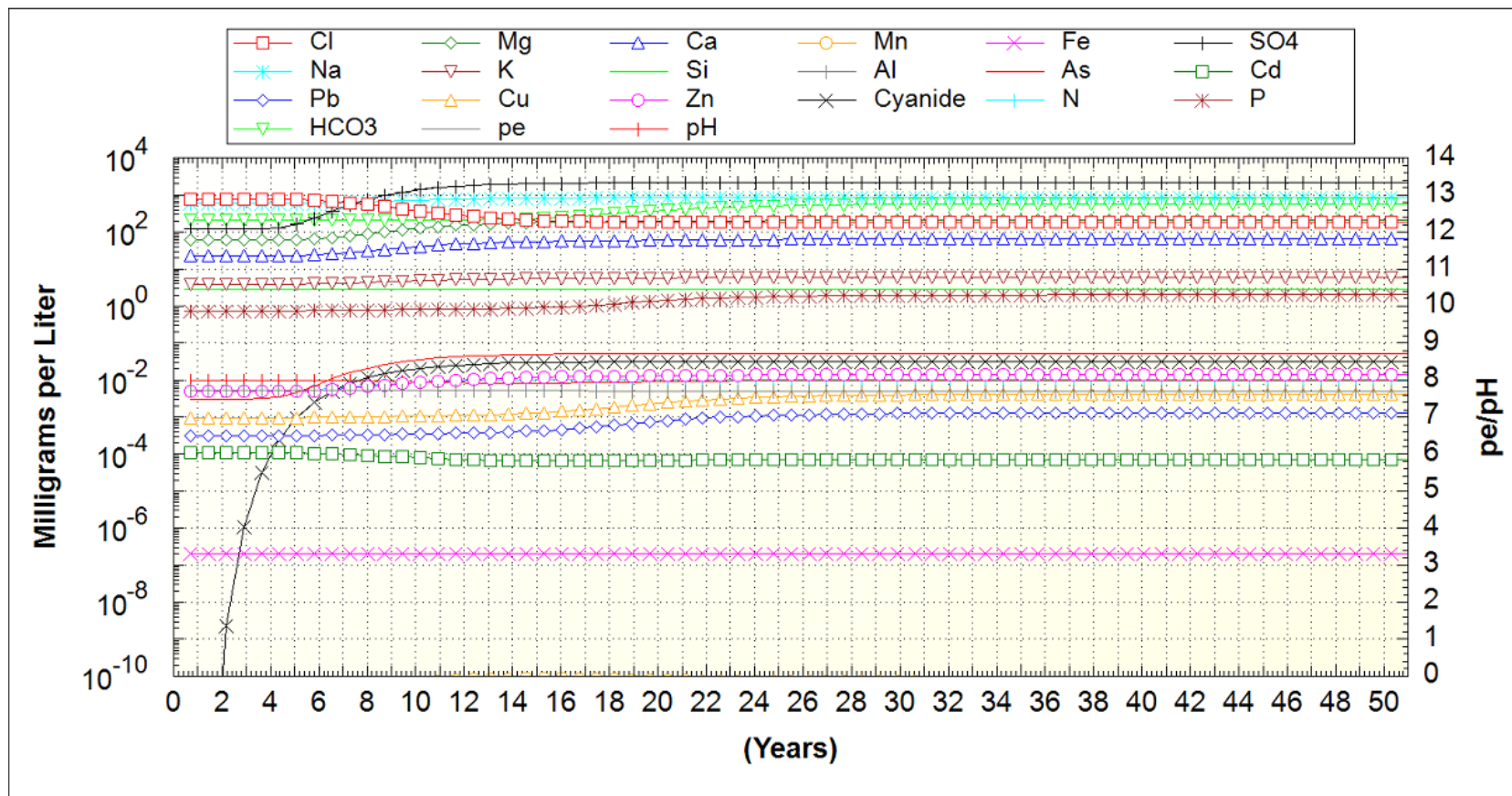
Aquifer substrate		X	NaX	KX	CaX ₂	MgX ₂
CEC Low	a	0.0006	0.0001	0.0001	0.0001	0.0002
	b	0.028	0.006	0.006	0.007	0.008
CEC Surface Soil	a	0.0068	0.002	0.001	0.002	0.002
	b	0.31	0.08	0.07	0.08	0.09
CEC Saprolite	a	0.1284	0.107	0.002	0.002	0.018
	b	5.96	4.96	0.09	0.09	0.82
CEC Fractured rock	a	0.1556	0.020	0.002	0.106	0.027
	b	83.61	10.59	1.31	57.20	14.51
CEC High	a	2.4723	0.478	0.038	1.297	0.658
	b	1328.38	257.07	20.61	697.10	353.60

1: X = Na, K, Ca and Mg (moles) extracted in 1M ammonium acetate at pH 7. The Total Exchange Sites (X) represents the sum of the 4 exchangeable cations (NaX, KX, CaX₂, MgX₂). 2: Conversion of (1) to moles per kilogram of aquifer rock as follows: (moles extracted)*((1-porosity)/porosity)* Particle Density. Water-filled porosity = 0.5% for fractured rock or 5.5% for soil or saprolite and Particle Density = 2.7 kg/L.

Appendix 7: Model Outputs for Flow-path A-A'¹⁴

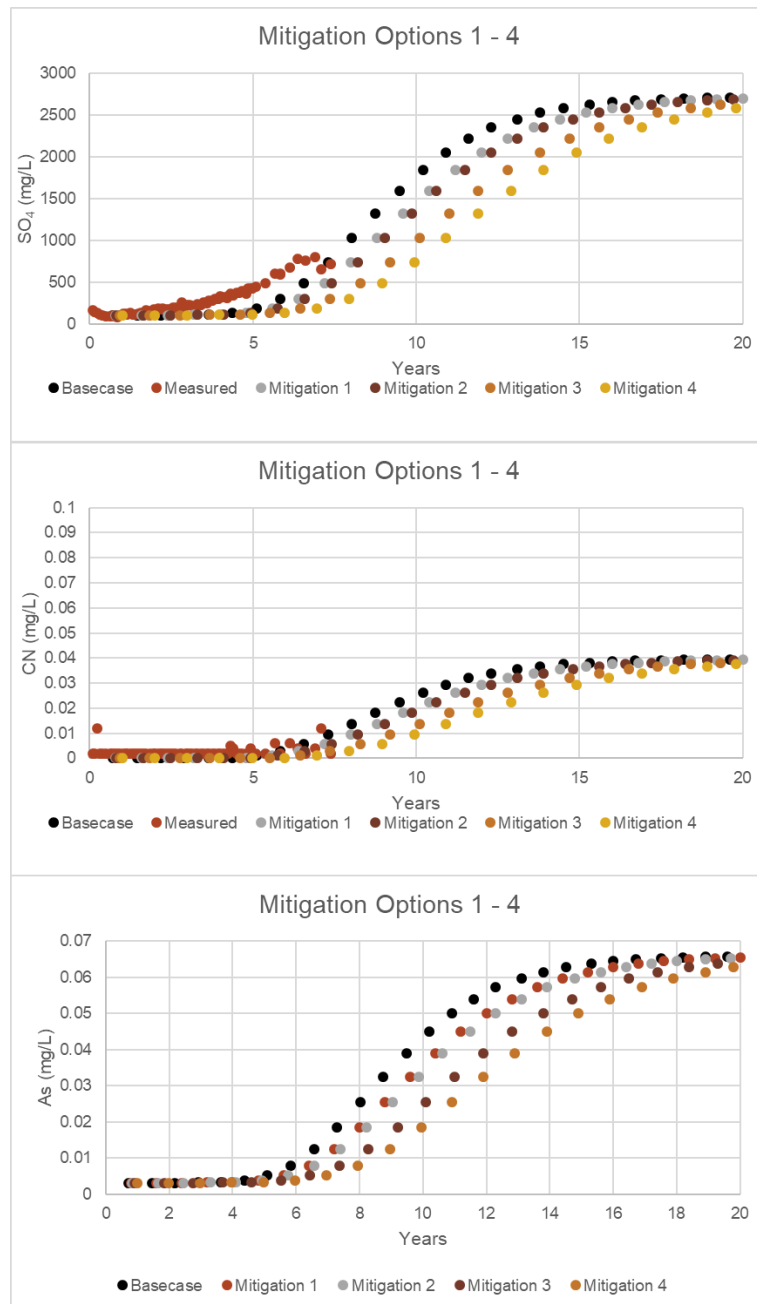


¹⁴ Measured data from MRMB44.



¹⁵ Footnote

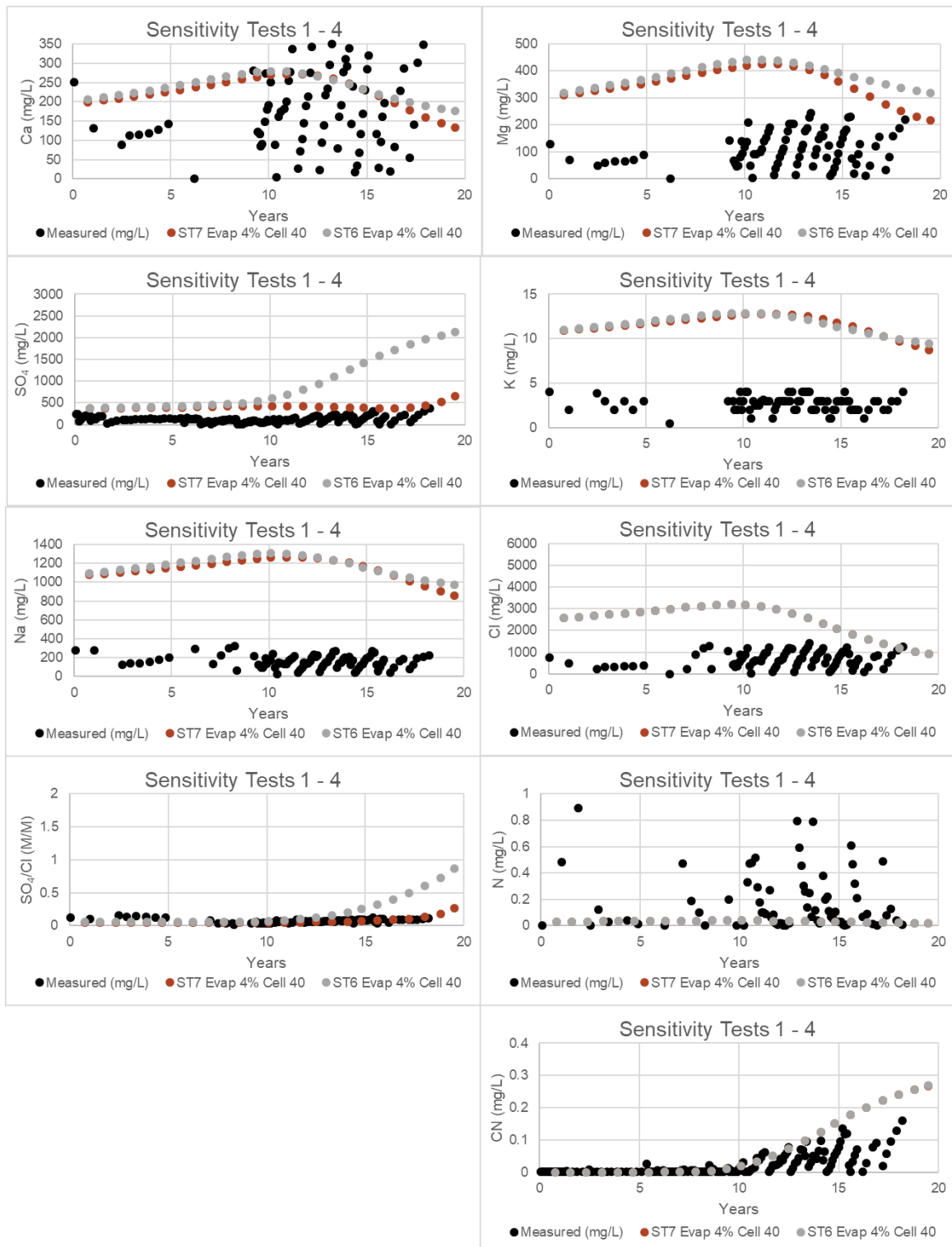
¹⁵ PHREEQC results for unmitigated geochemical transport of COPC to the riparian zone in the Swindon Creek headwaters near MRMB44 and MRMB43.



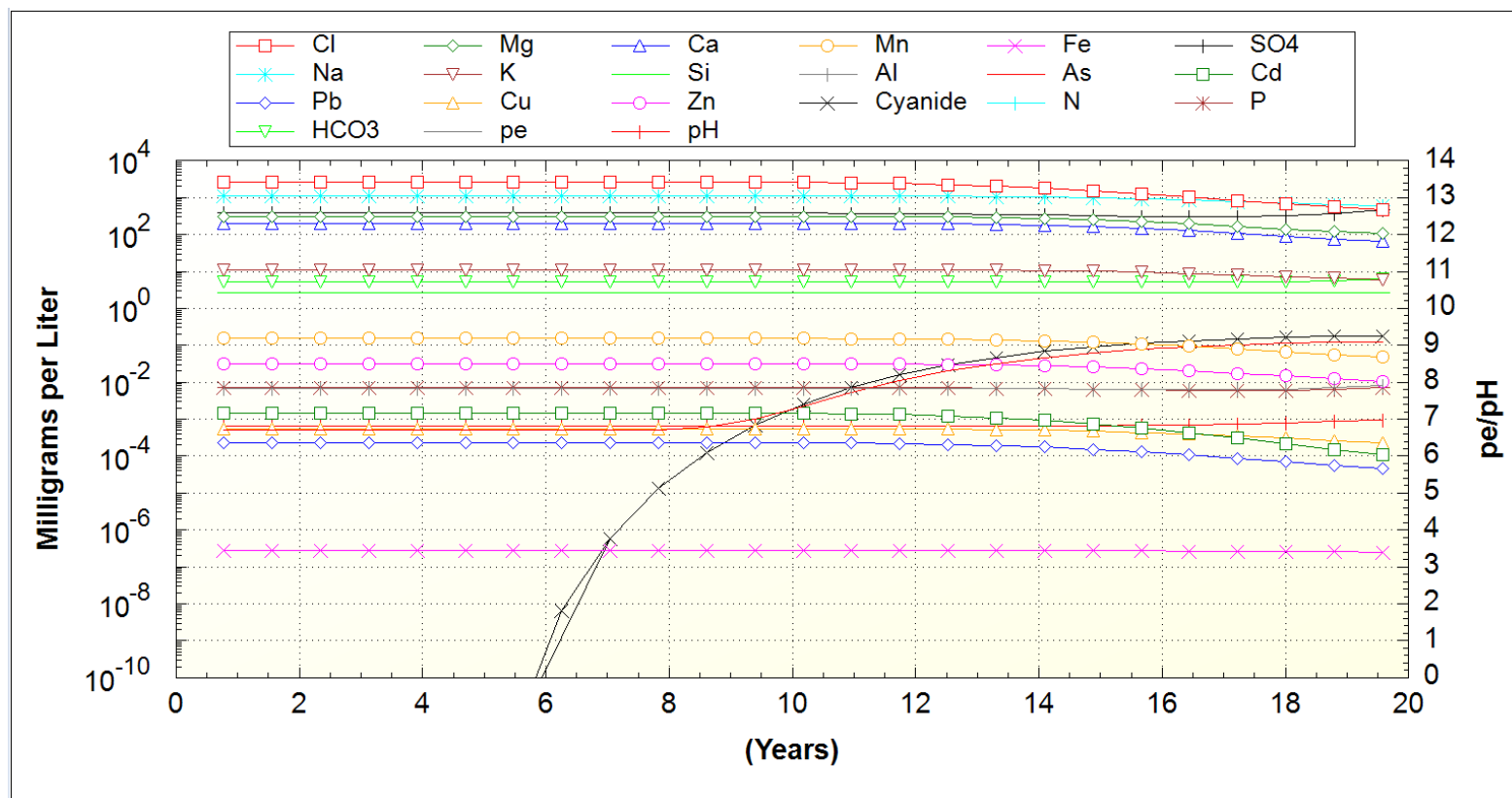
¹⁶ Footnote

¹⁶ Measured data from MRMB44.

Appendix 8: Model Outputs for Flow-path B-B'¹⁷

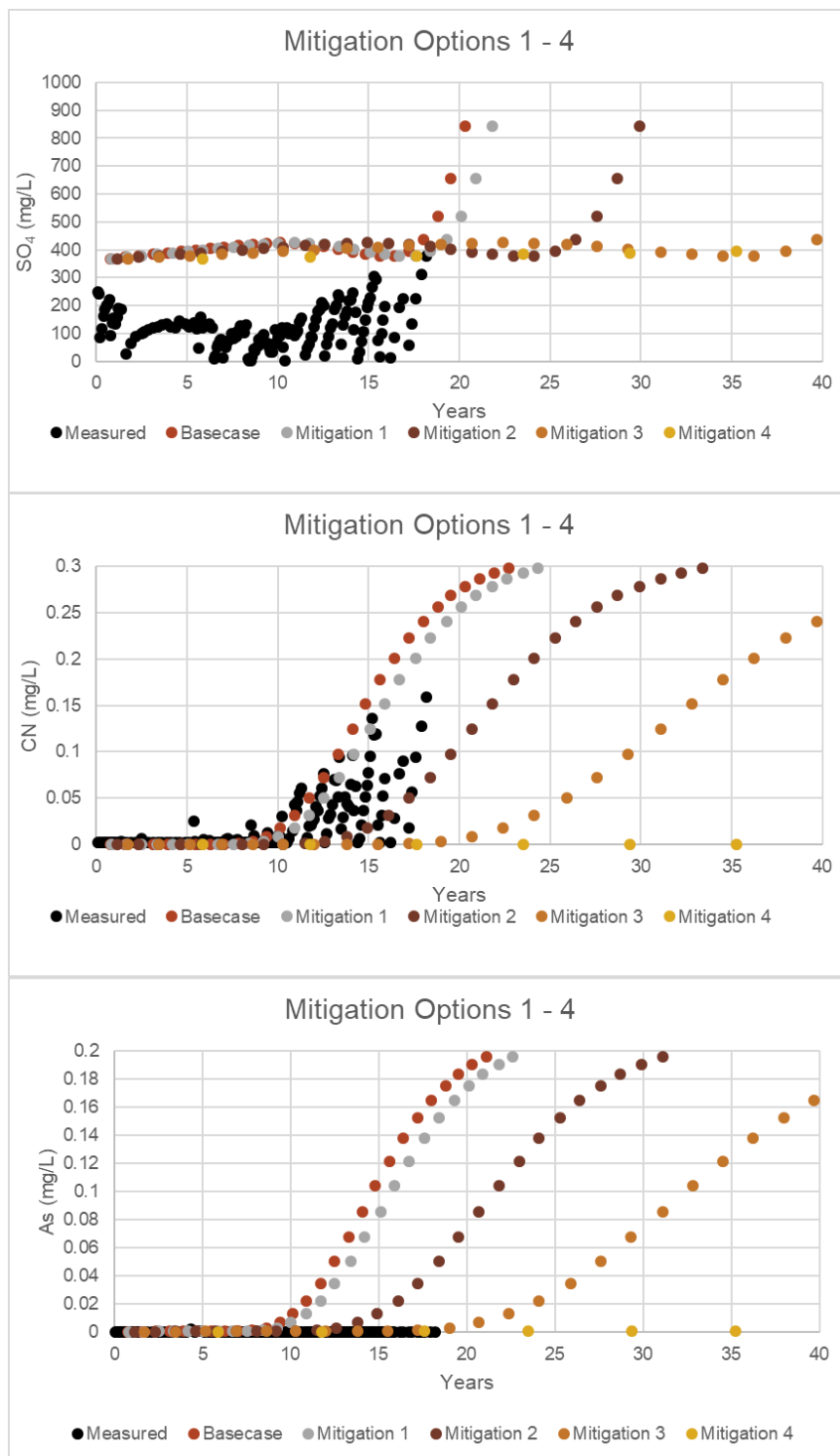


¹⁷ Measured data from MRMB12.



¹⁸ Footnote

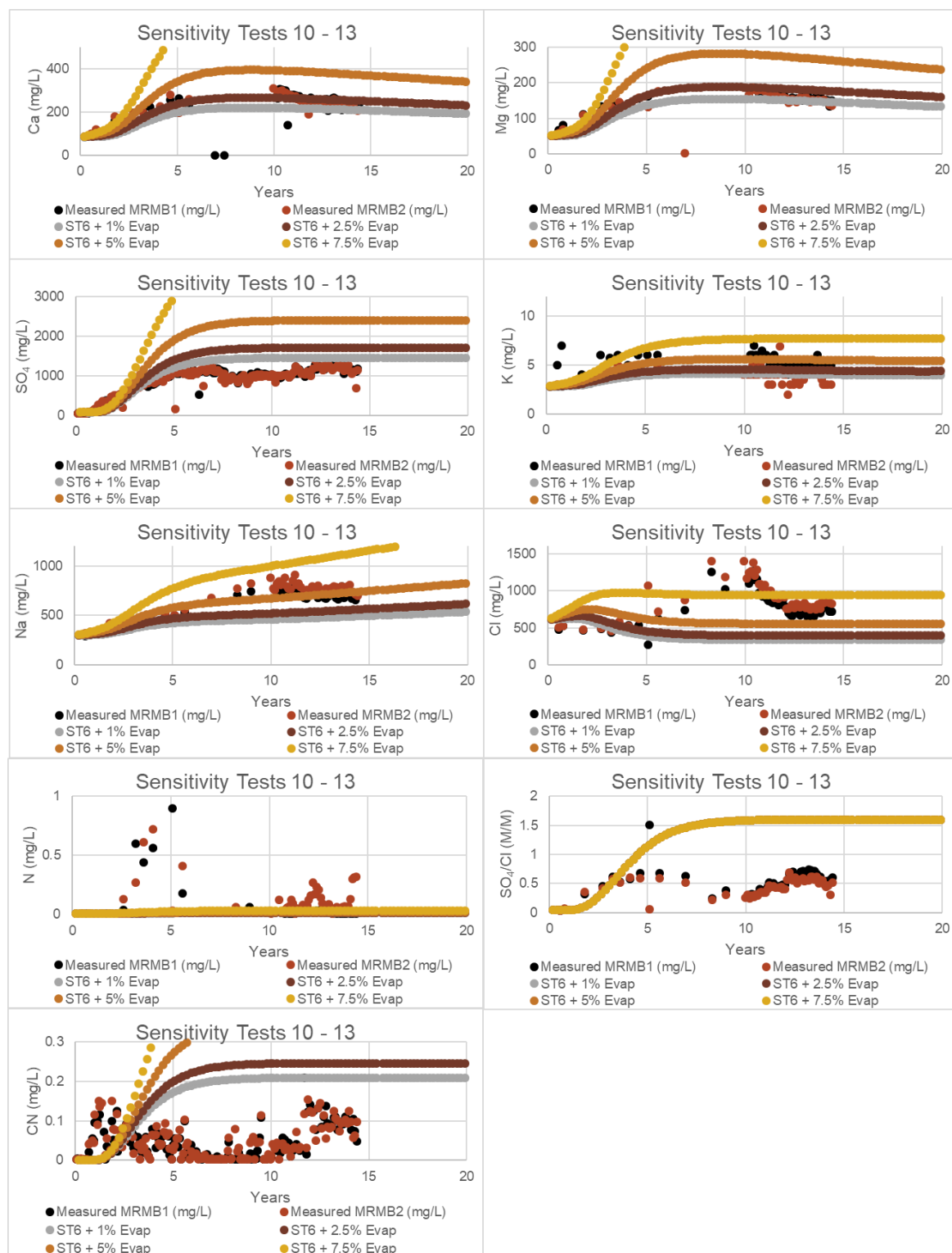
¹⁸ PHREEQC results for unmitigated geochemical transport of COPC to the riparian zone in Swindon Creek near MRMB12.



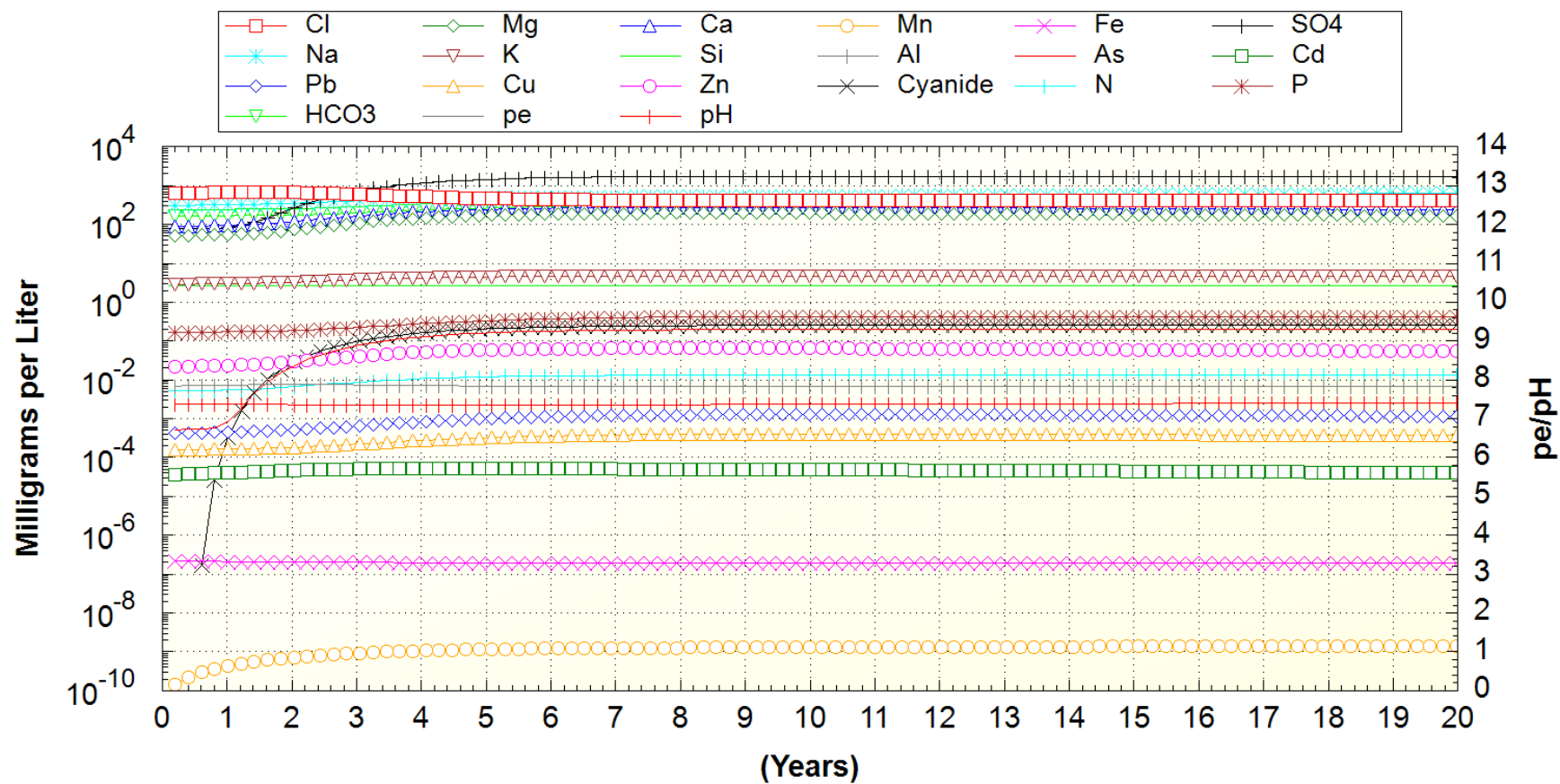
¹⁹ Footnote

¹⁹ Measured data from MRMB12.

Appendix 9: Model Outputs for Flow-path C-C'²⁰

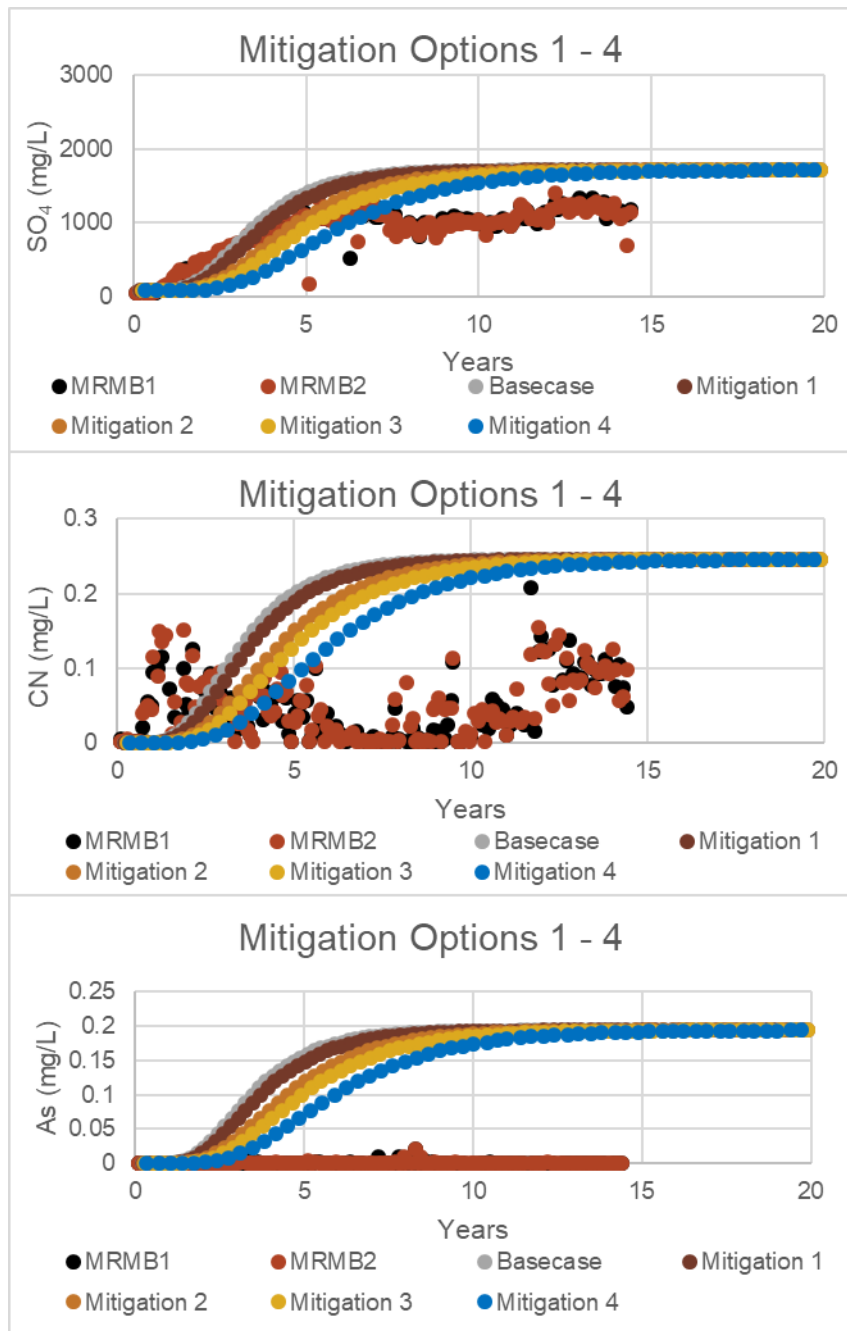


²⁰ Measured data from MRMB1 and MRMB2.



²¹ Footnote

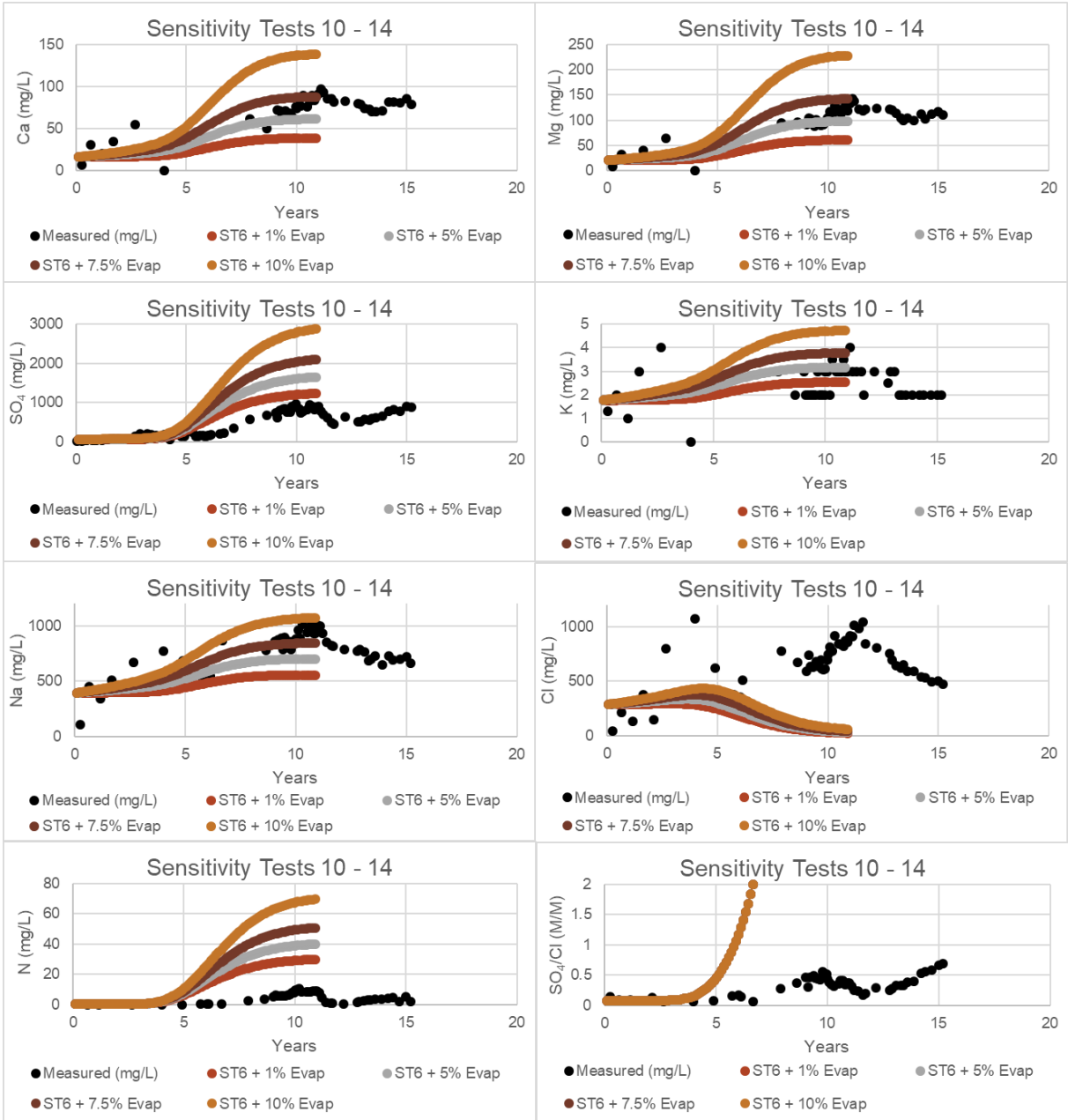
²¹ PHREEQC results for unmitigated geochemical transport of COPC to the riparian zone in Rawdon Creek near MRMB1 and MRMB2.



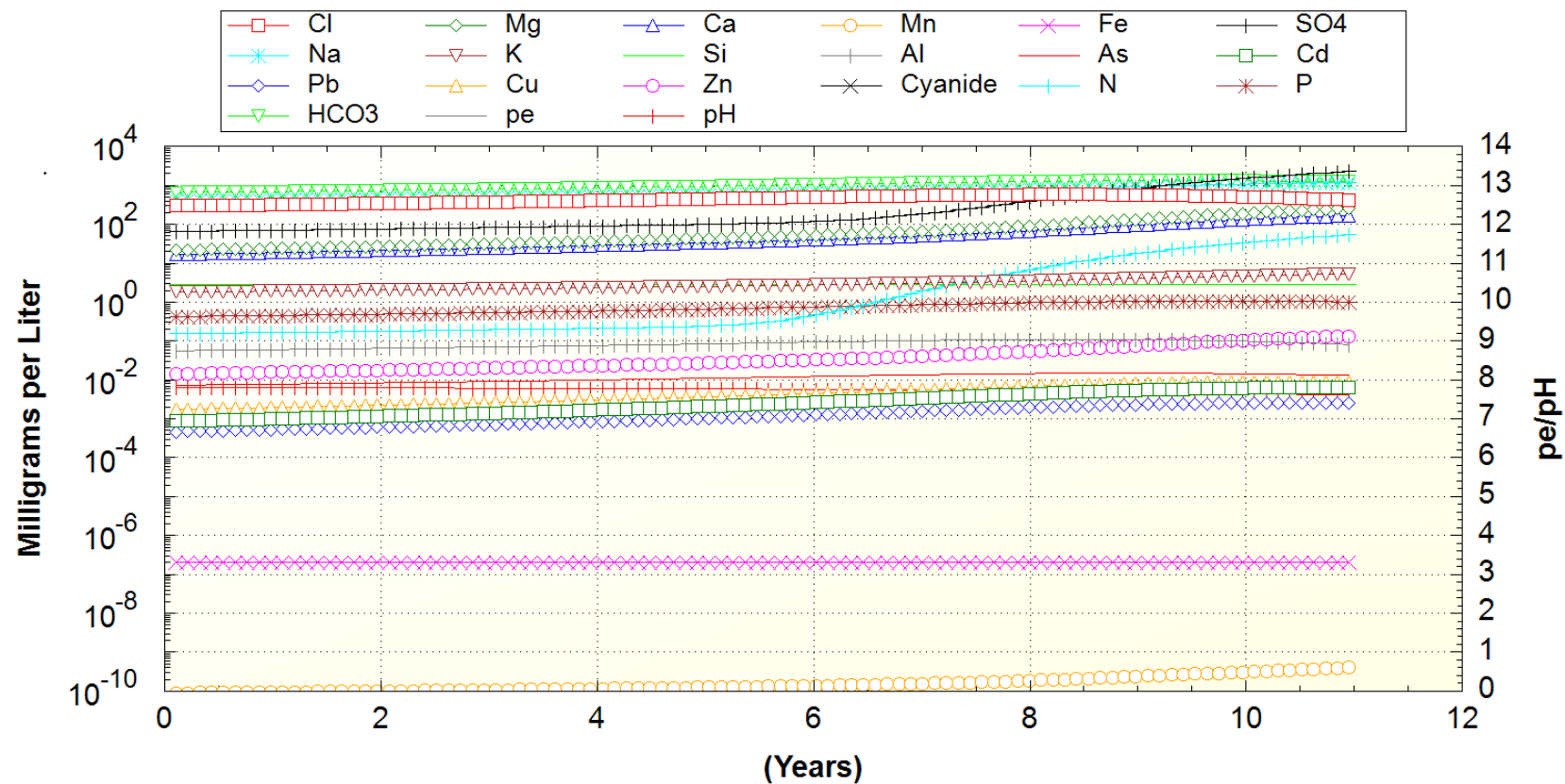
²² Footnote

²² Measured data from MRMB1 and MRMB2.

Appendix10: Model Outputs for Flow-path D-D' ²³

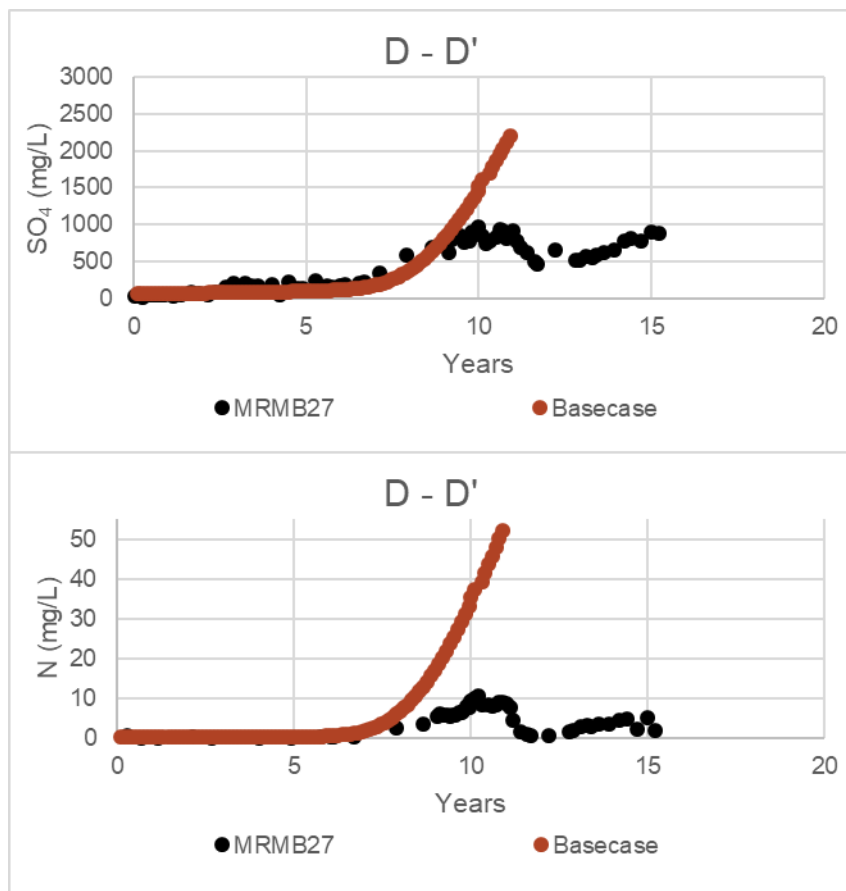


²³ Measured data from MRMB27.



²⁴ Footnote

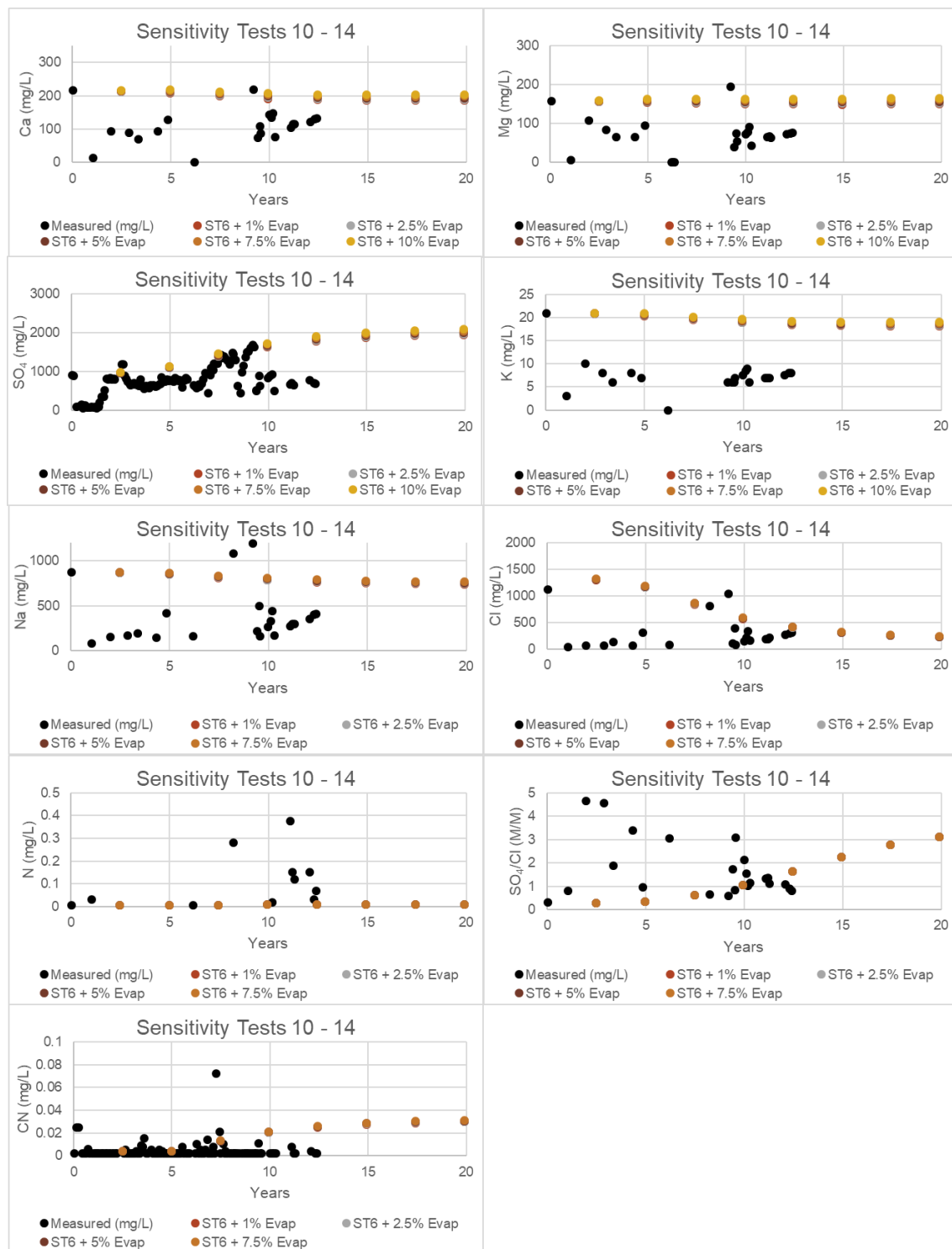
²⁴ PHREEQC results for unmitigated geochemical transport of COPC to the riparian zone in Twelve Mile Creek downstream of MRMB27.



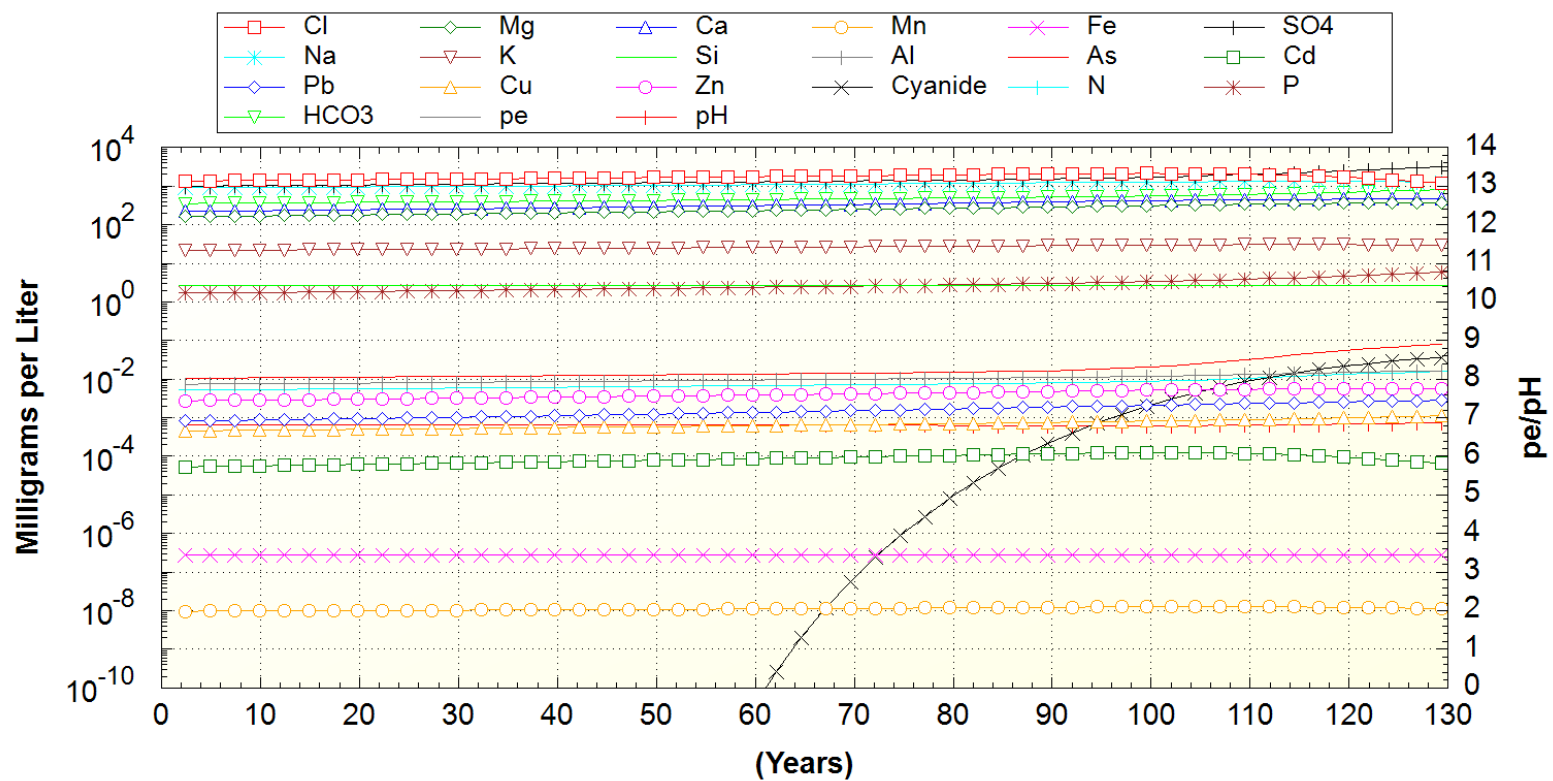
²⁵ Footnote

²⁵ Measured data from MRMB27.

Appendix 11: Model Outputs for Flow-path E-E' ²⁶

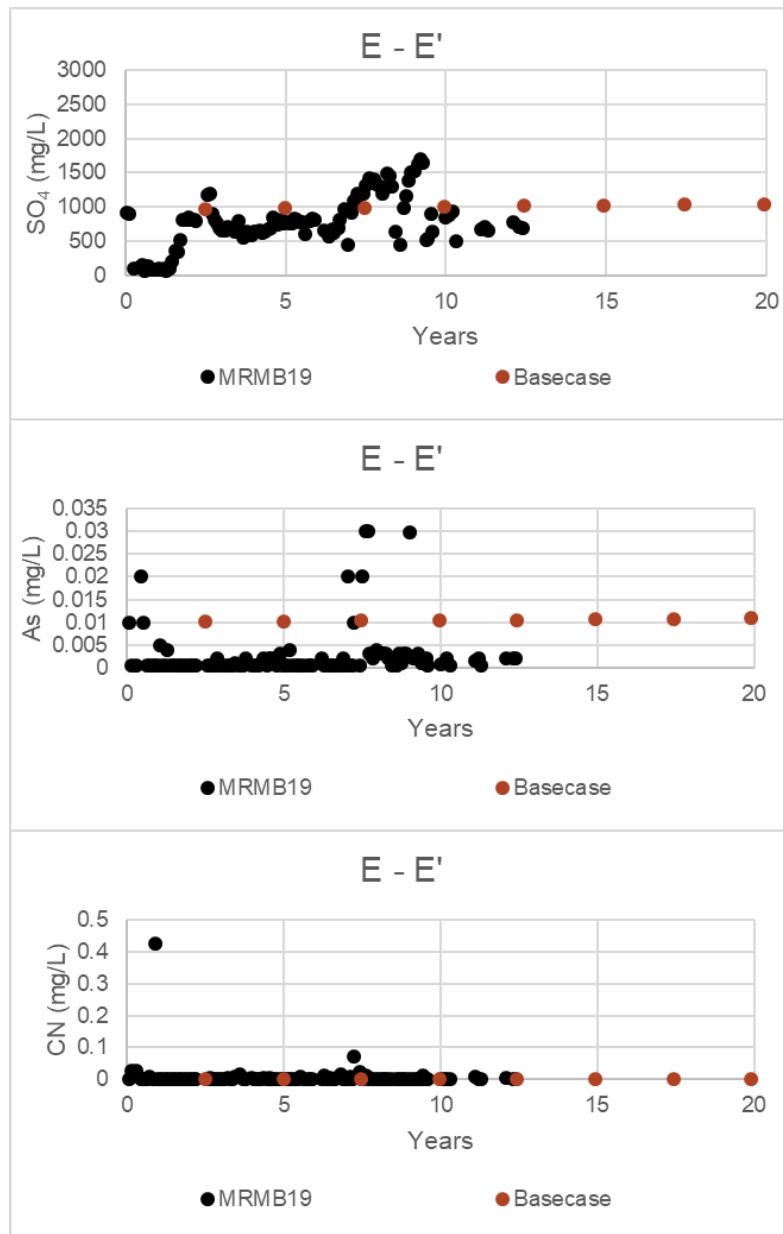


²⁶ Measured data from MRMB19.



²⁷ Footnote

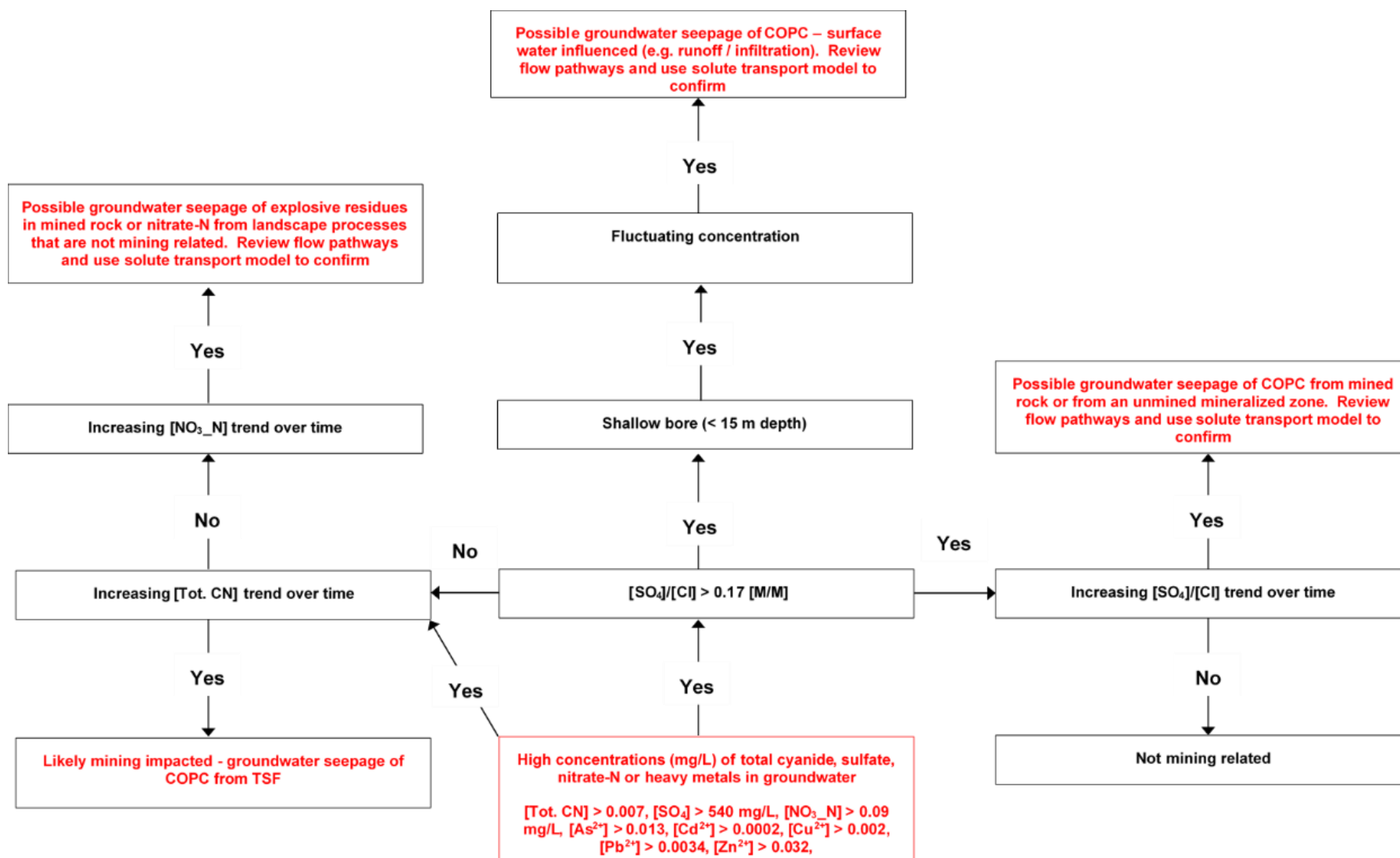
²⁷ PHREEQC results for unmitigated geochemical transport of COPC to the riparian zone in Mingham Creek downstream of West Dam.



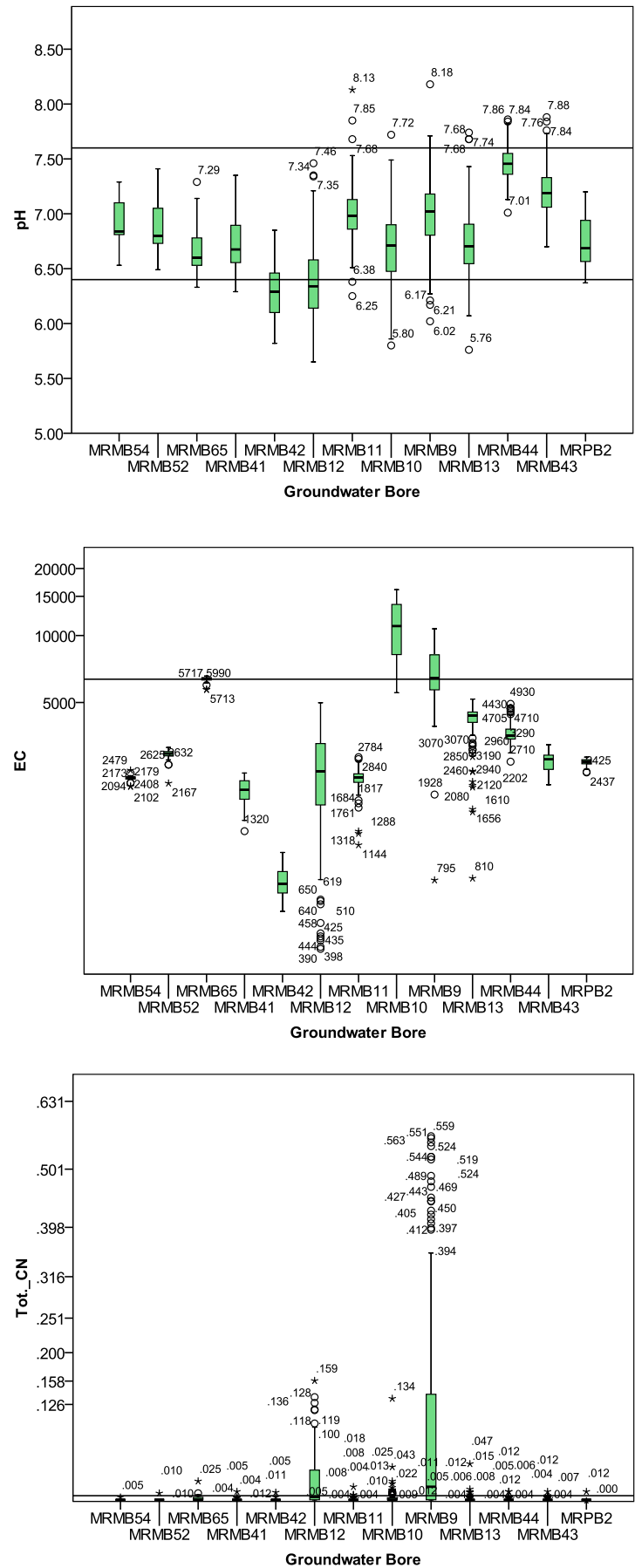
²⁸ Footnote

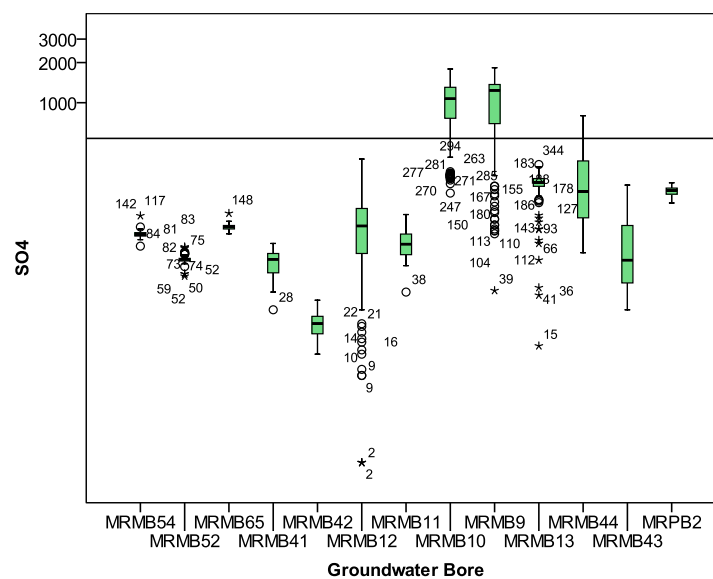
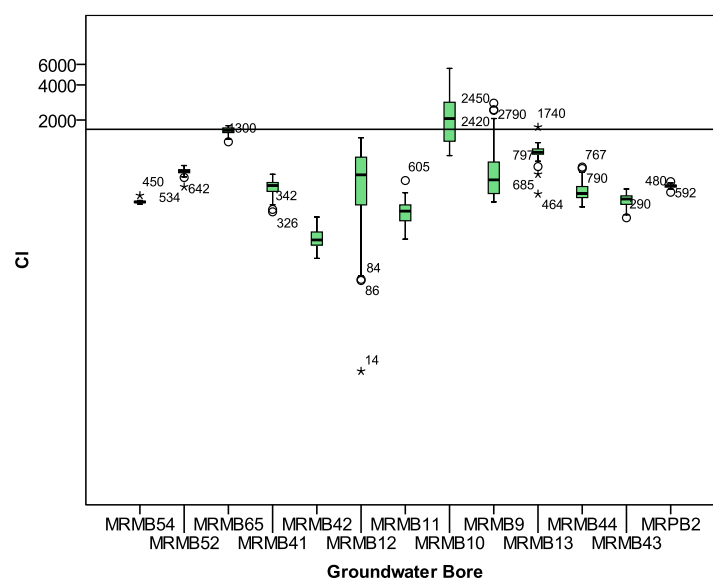
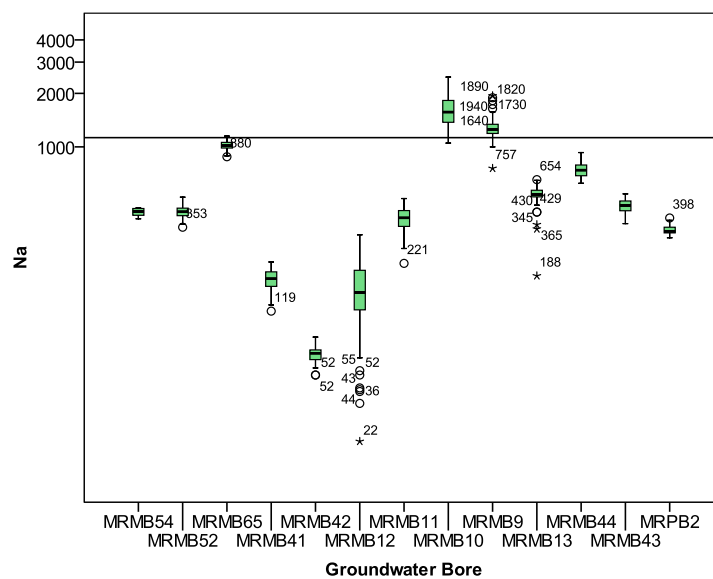
²⁸ Measured data from MRMB19.

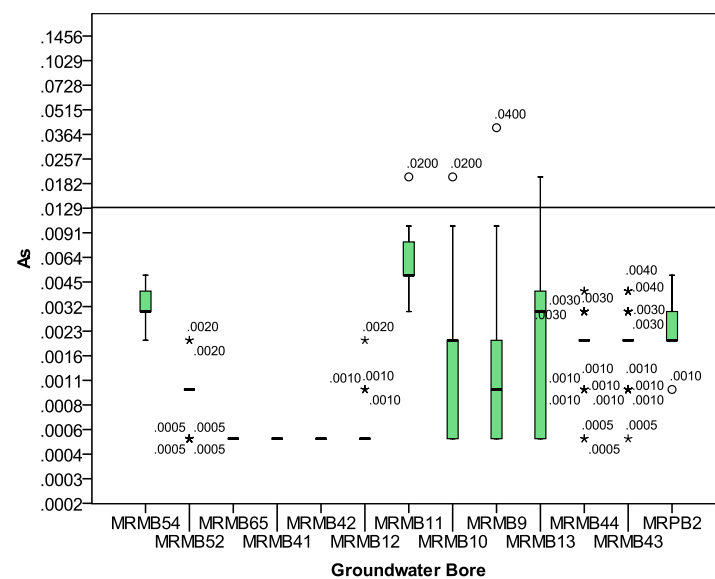
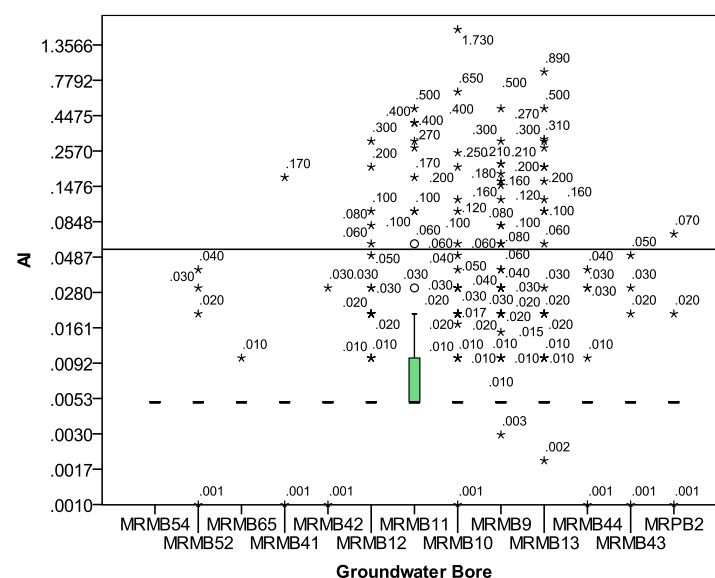
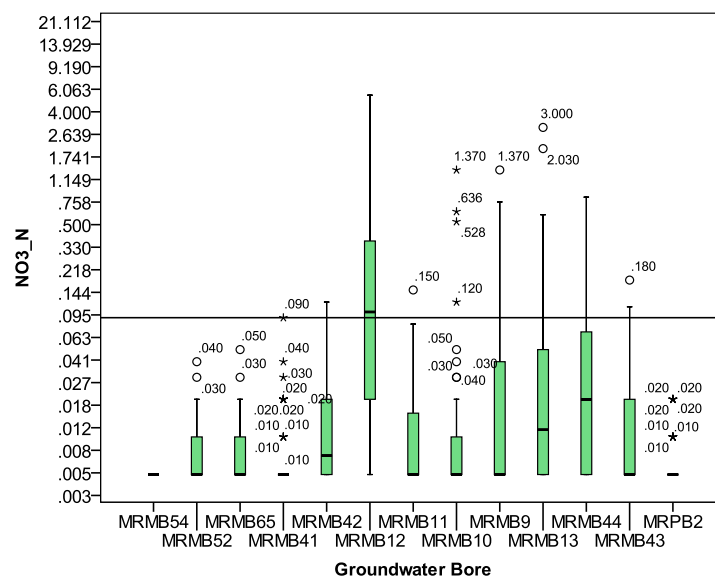
Appendix 12: Guide to interpreting groundwater with high concentrations of Chemicals of Potential Concern

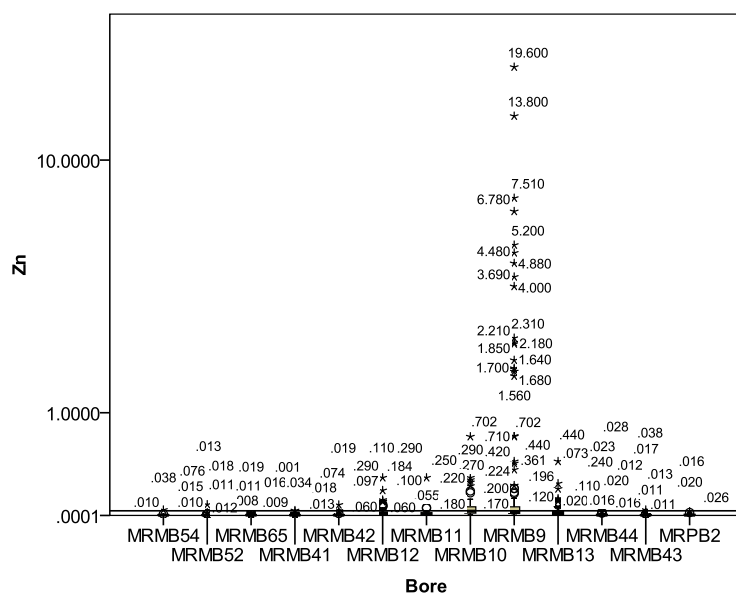
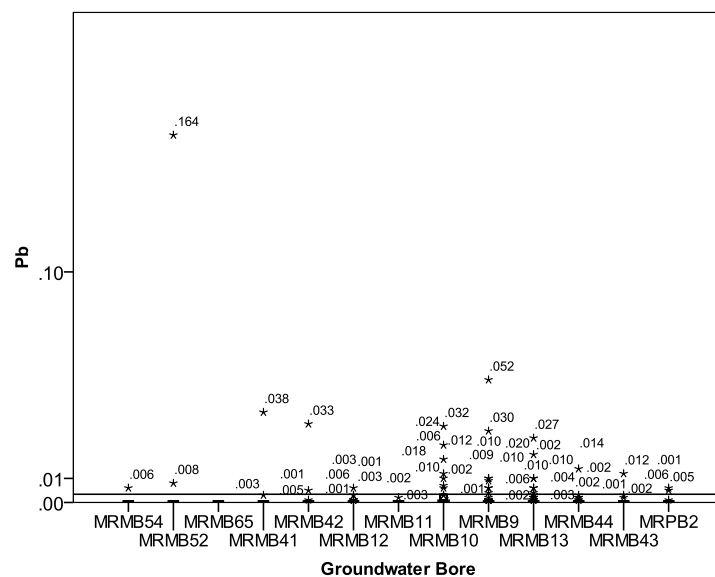
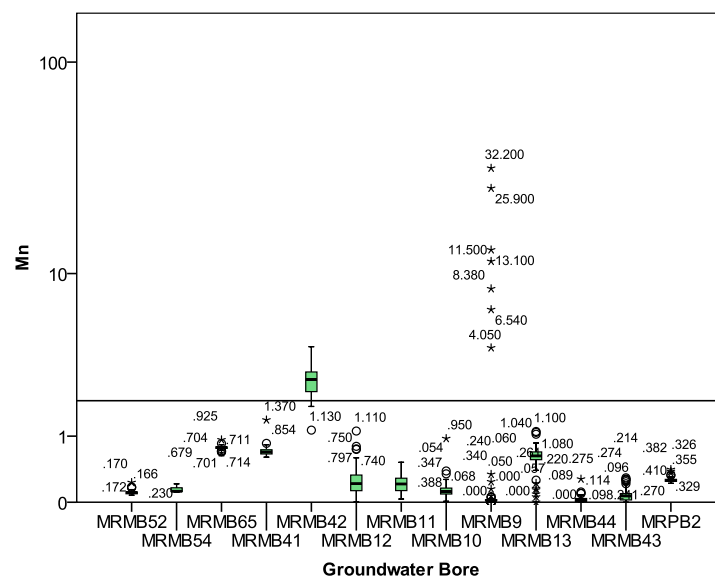


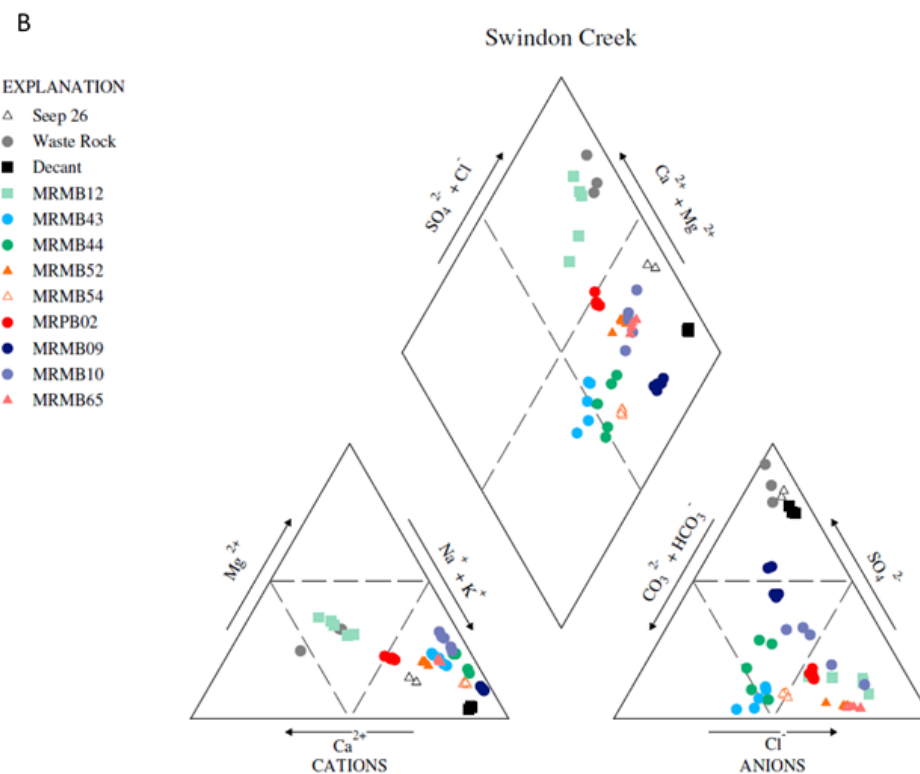
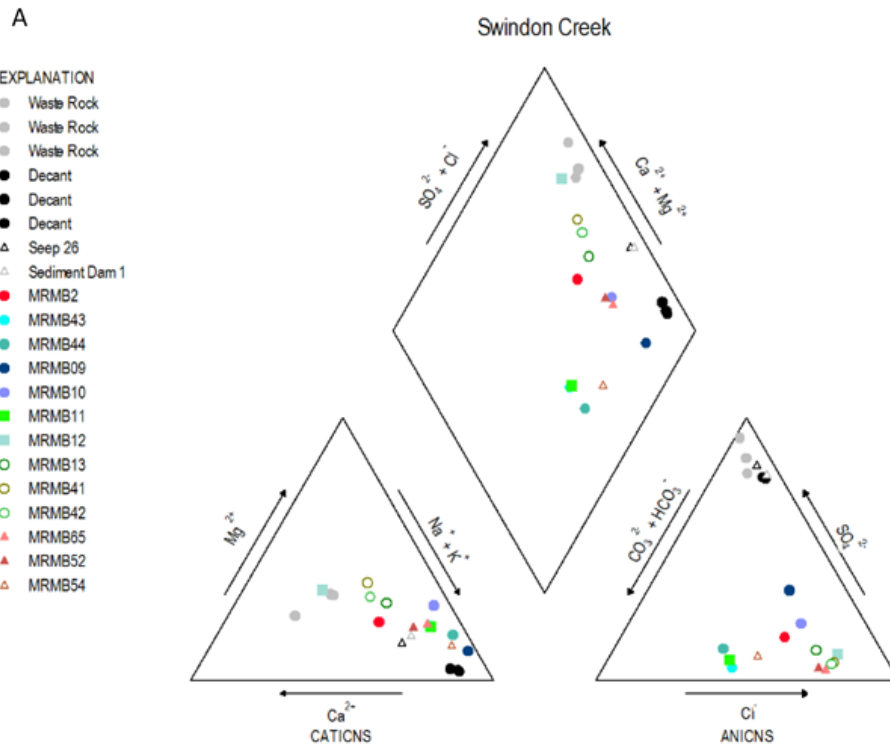
Appendix 13: Data Summaries for Swindon Creek





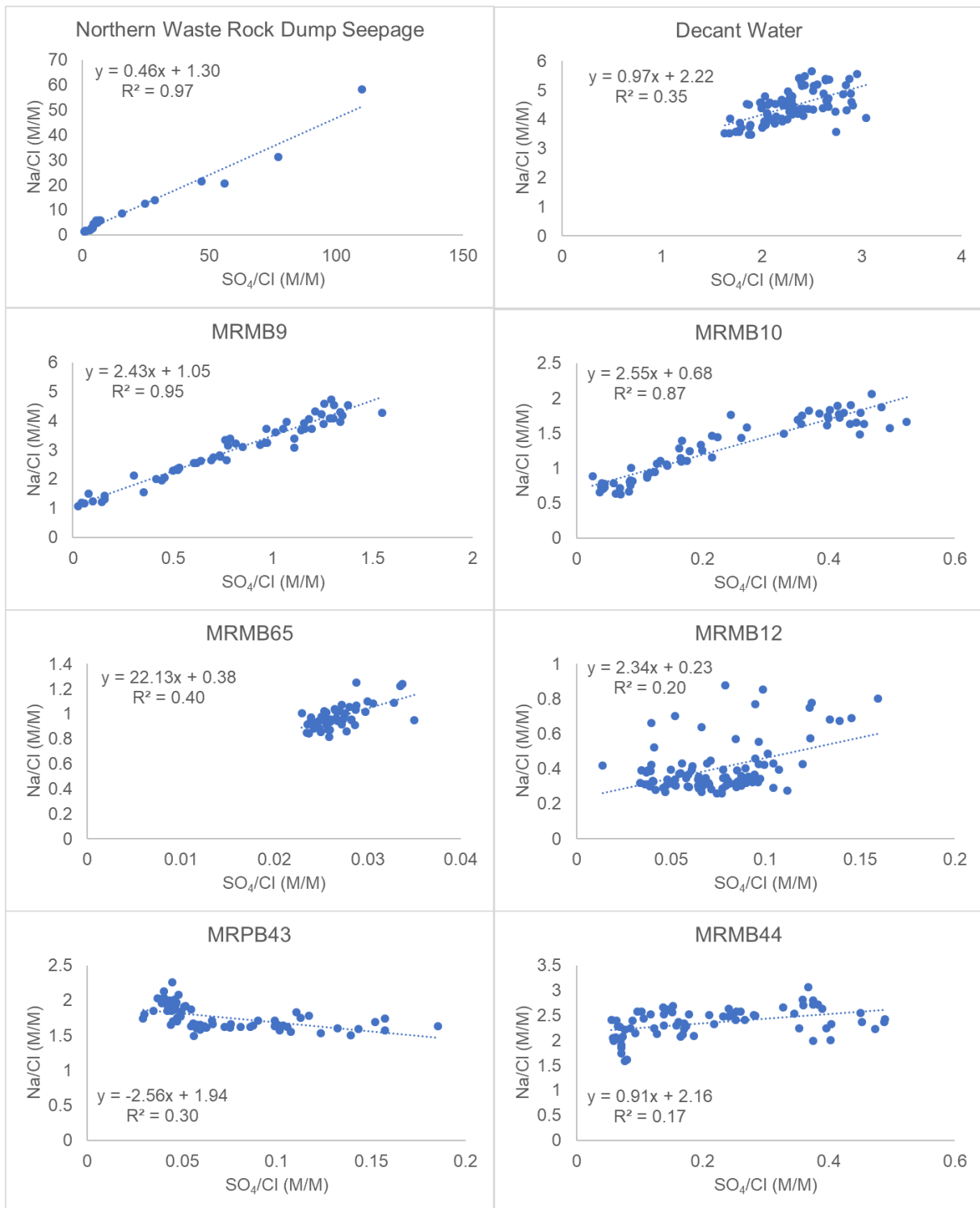






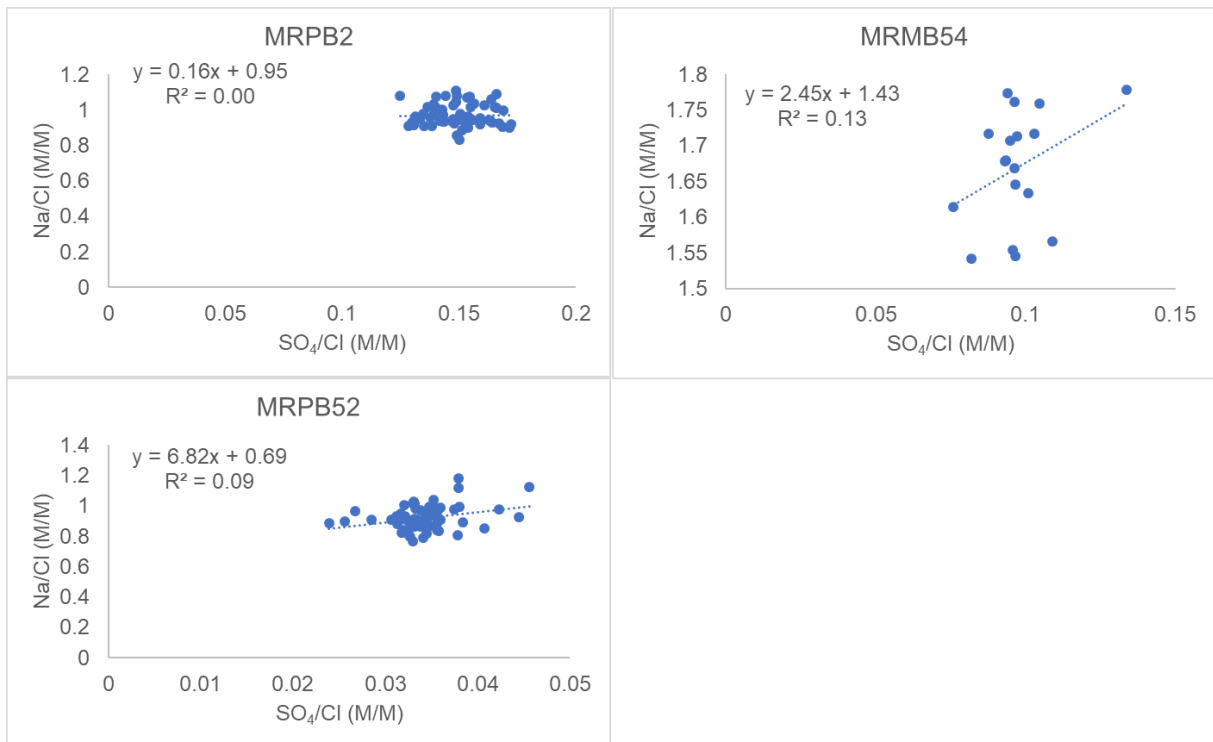
²⁹ Footnote

²⁹ A represents median cation and anion concentrations in groundwater monitoring bores, and representative cation and anion concentrations in waste - rock seepage and decant water. B shows representative cation and anion concentrations in selected groundwater monitoring bores, waste – rock seepage and decant water.



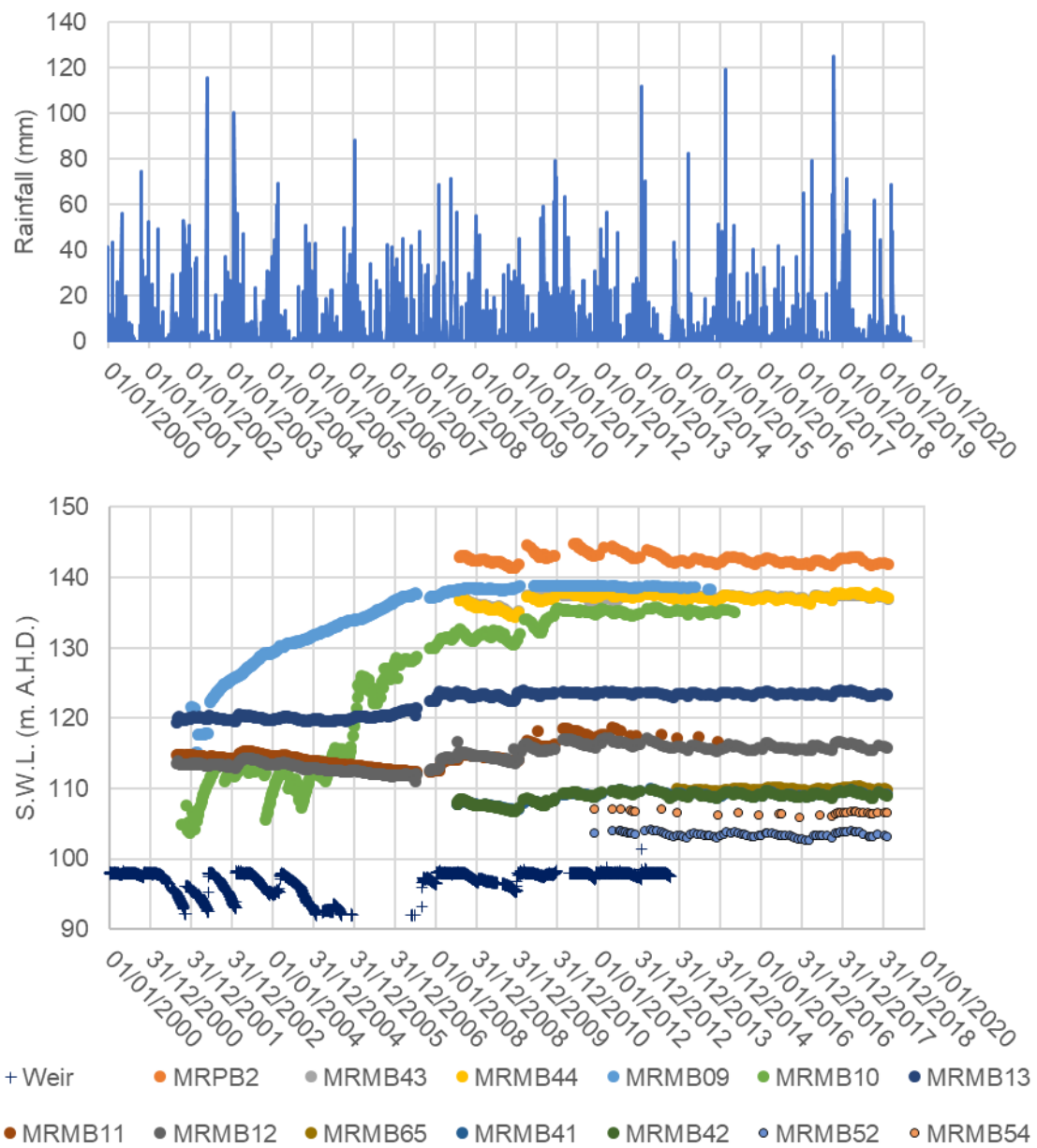
³⁰ Footnote

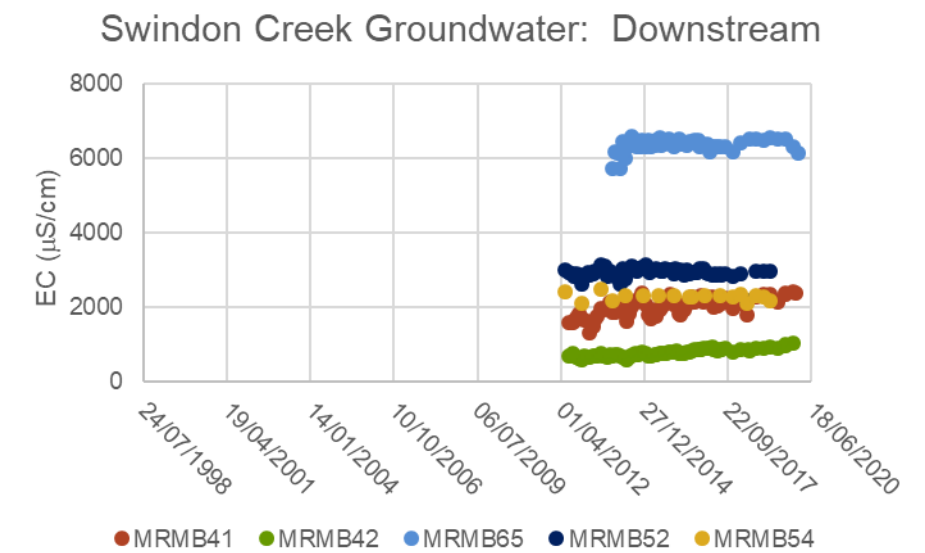
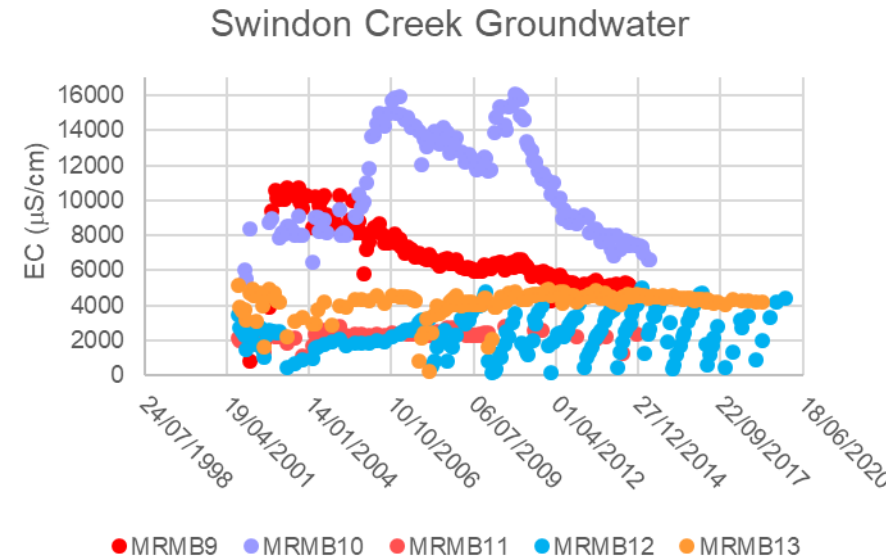
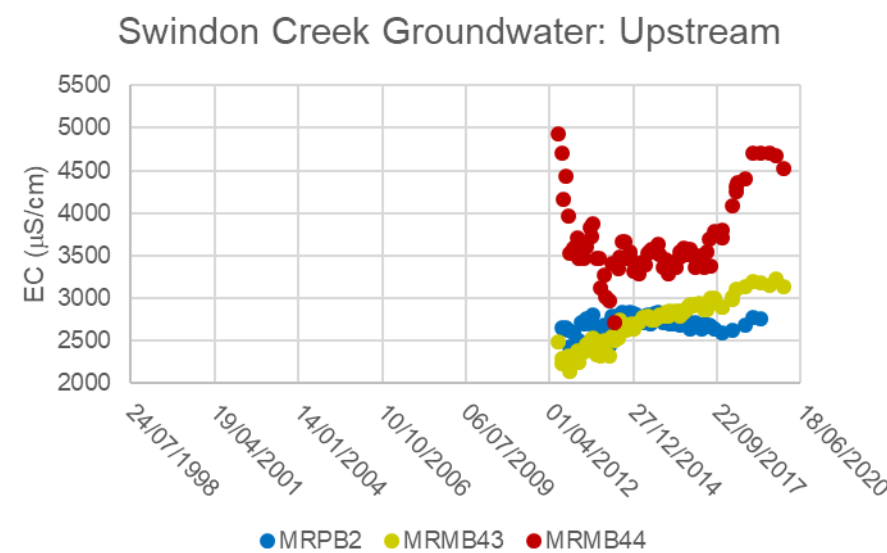
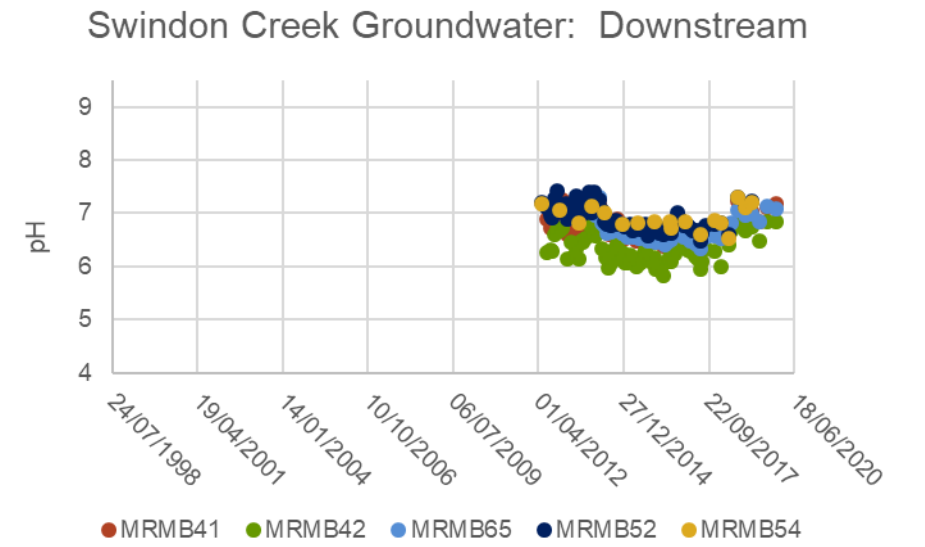
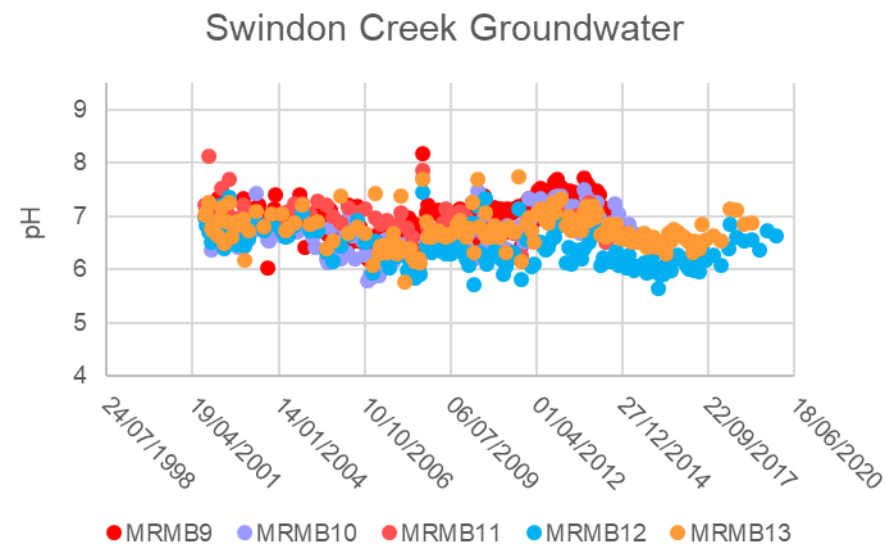
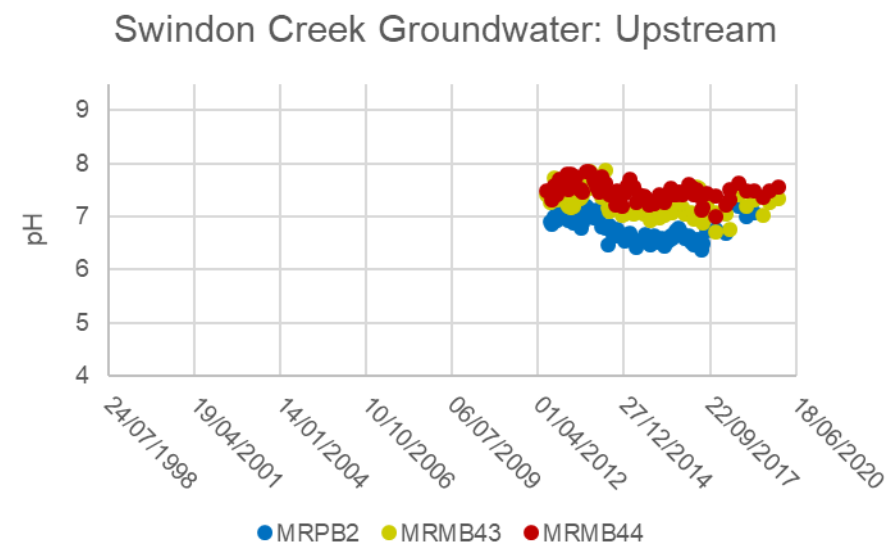
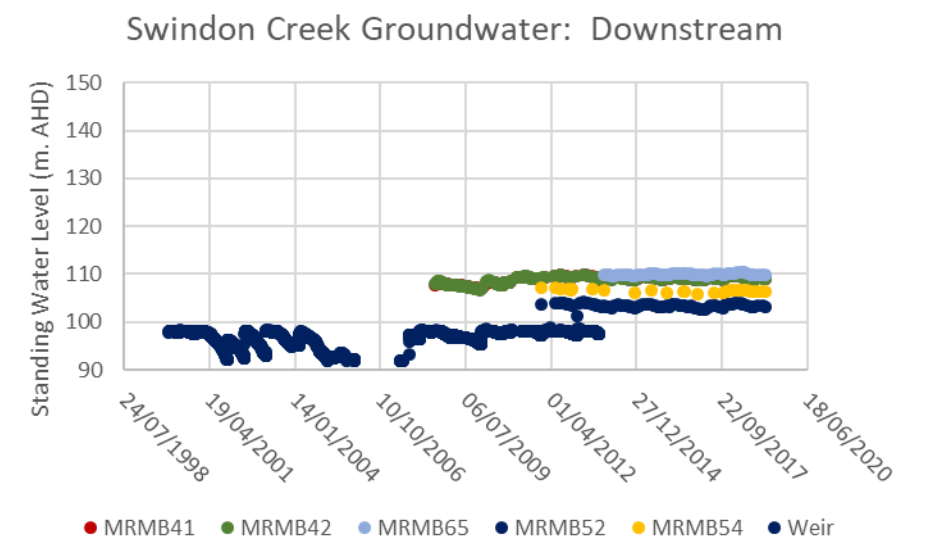
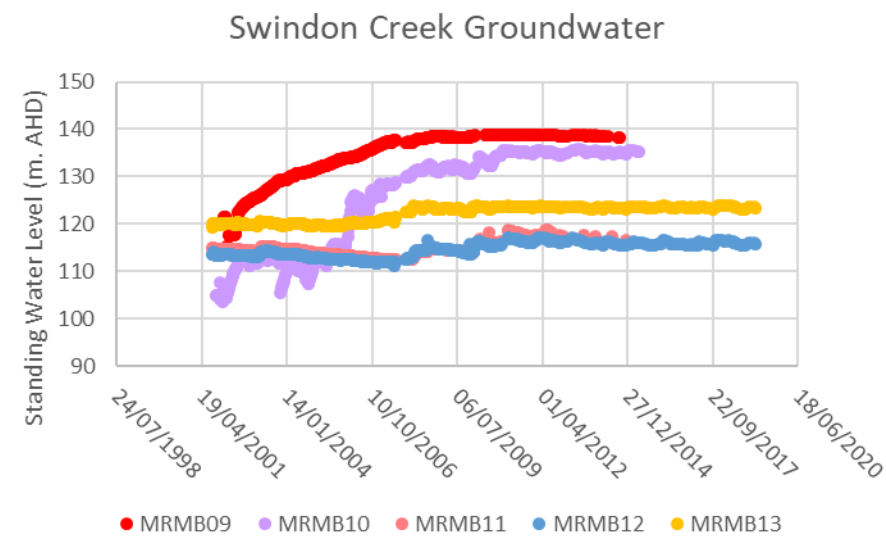
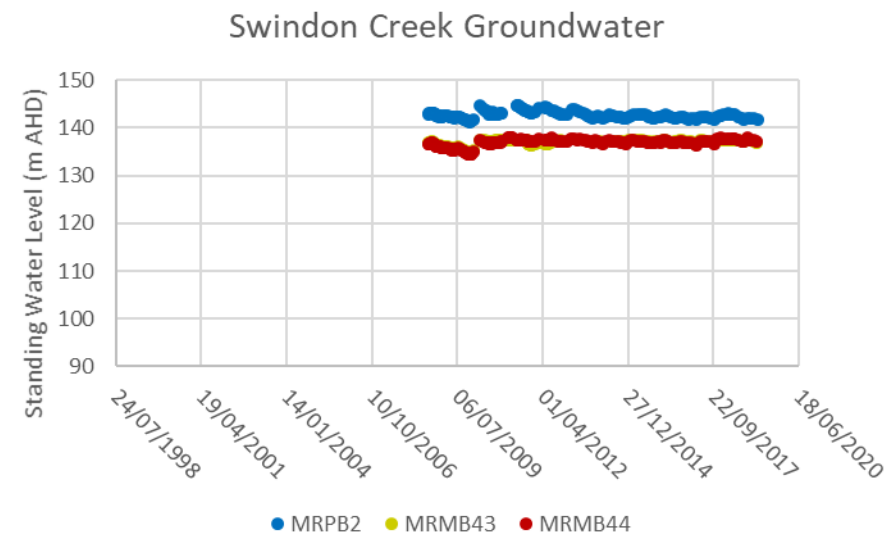
³⁰ Na/Cl (M/M) vs SO₄/Cl (M/M) concentration ratios in the source term (waste rock seepage, decant water) and in selected groundwater samples from Swindon Creek showing correlations associated with neutral mine drainage in mining affected water (MRMB9, MRMB10, MRMB12). Mining affected water has reported to monitoring bores MRMB43 and MRMB44, which show variation among SO₄/Cl concentration ratios but not among Na/Cl concentration ratios. An outlier is excluded in MRMB12 (Na/Cl 2.42 M/M, SO₄/Cl 0.05 M/M).

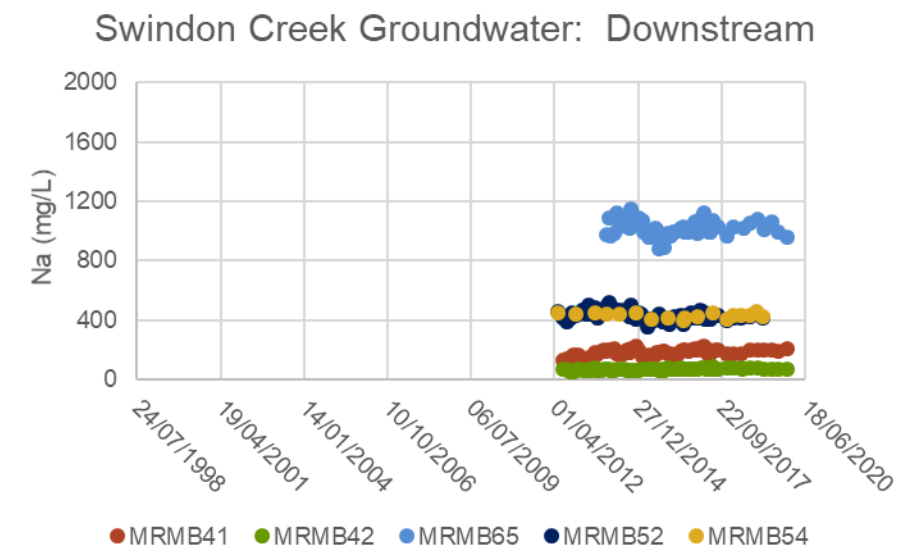
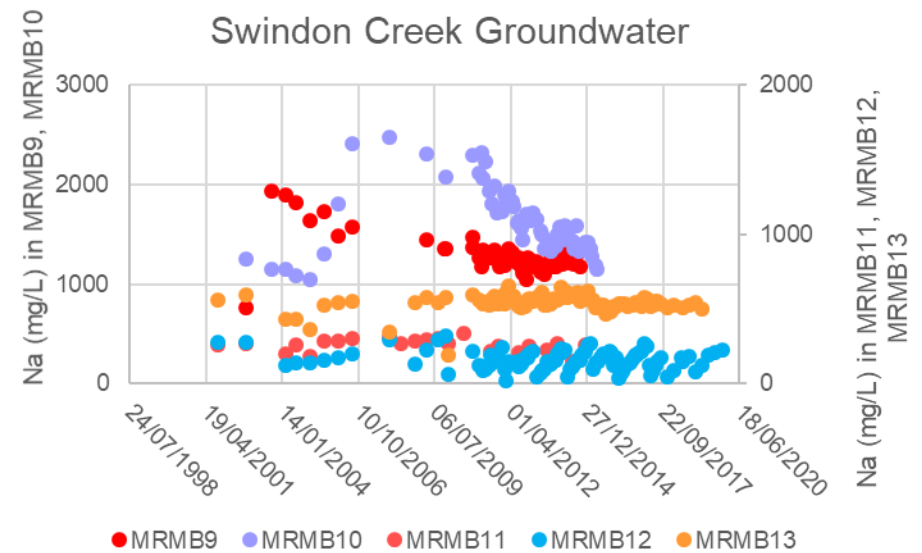
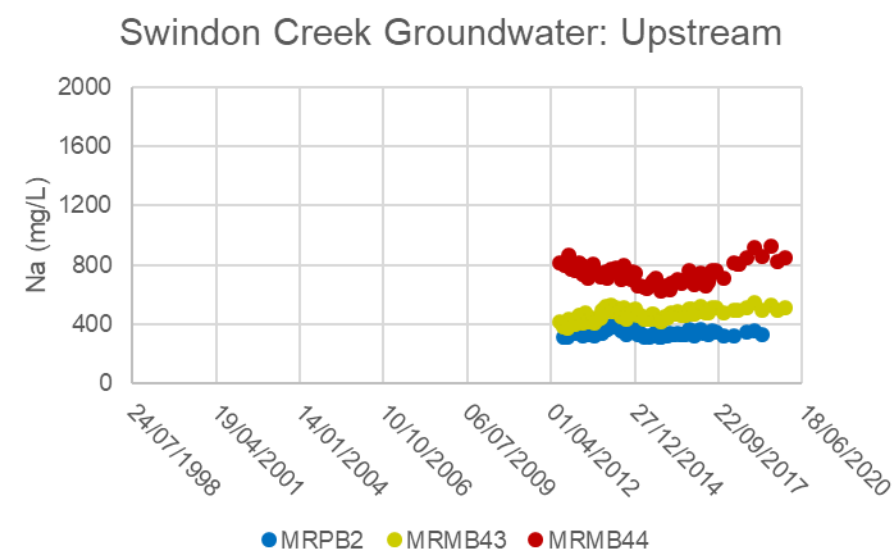
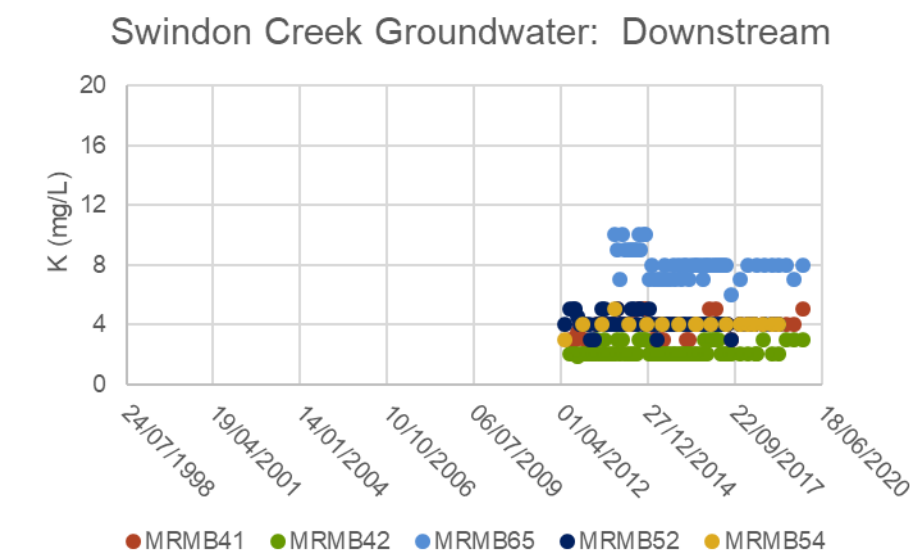
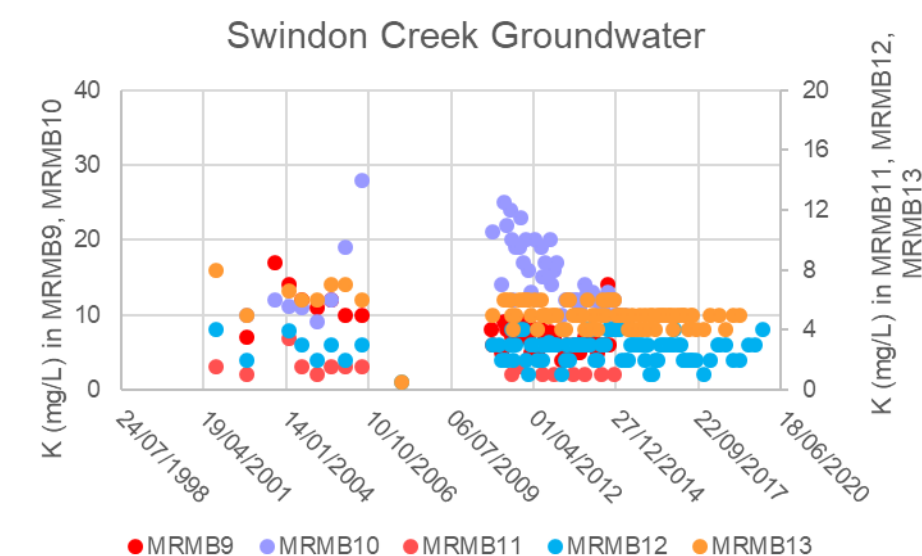
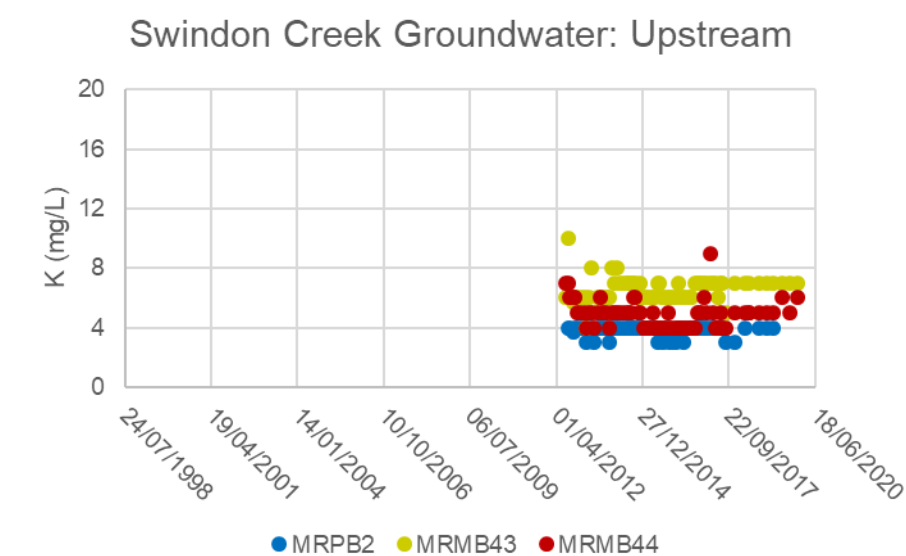
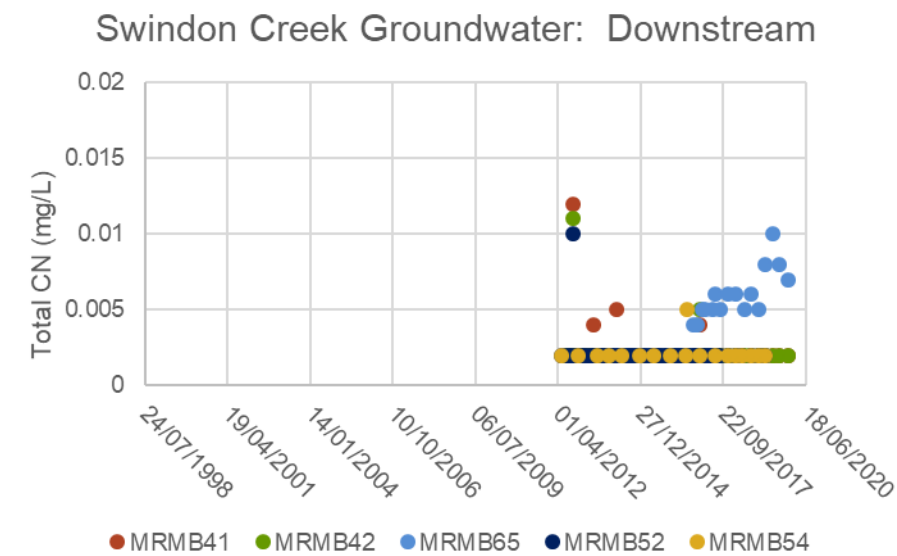
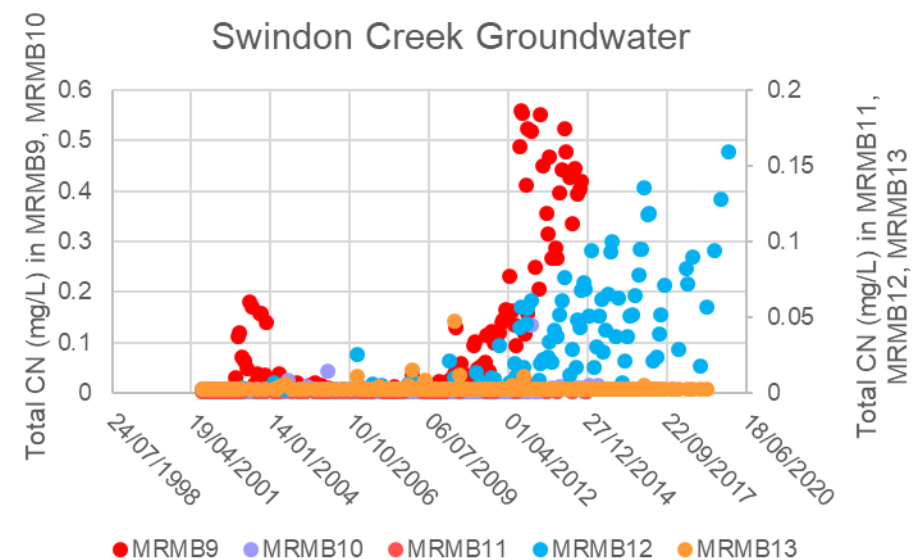
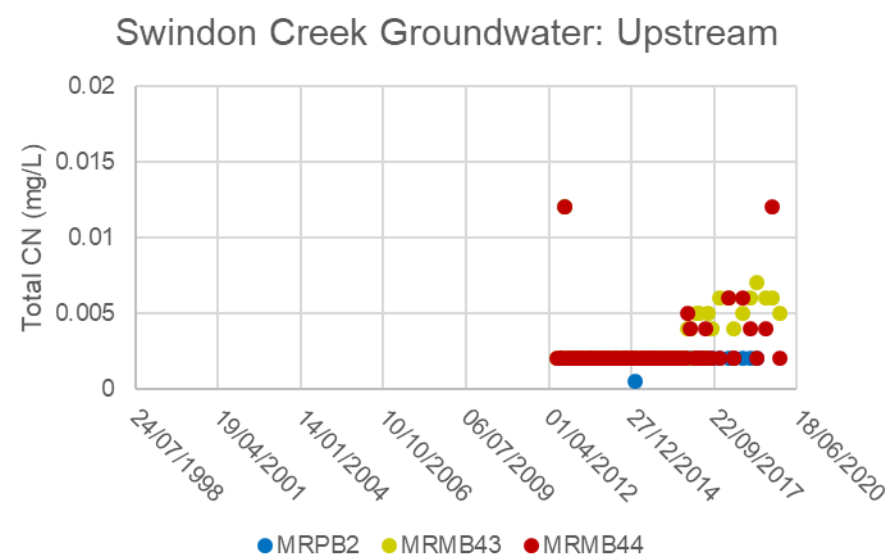


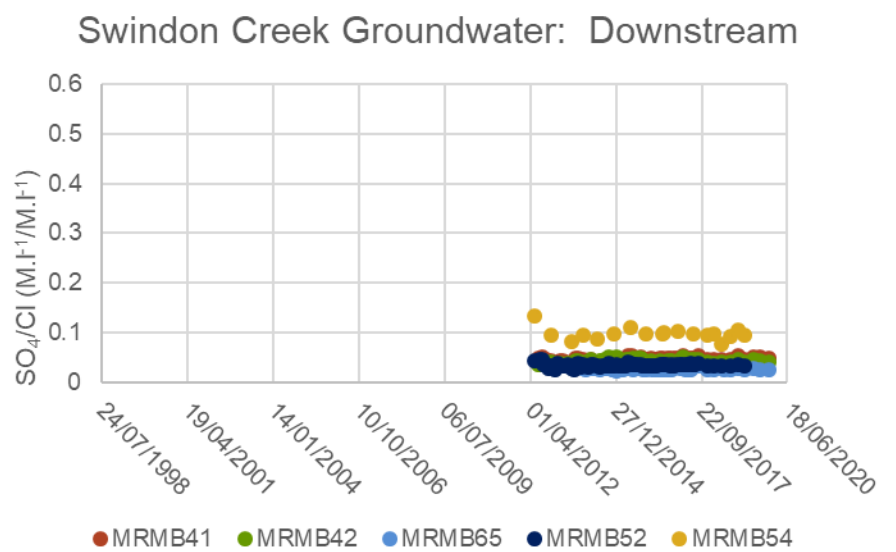
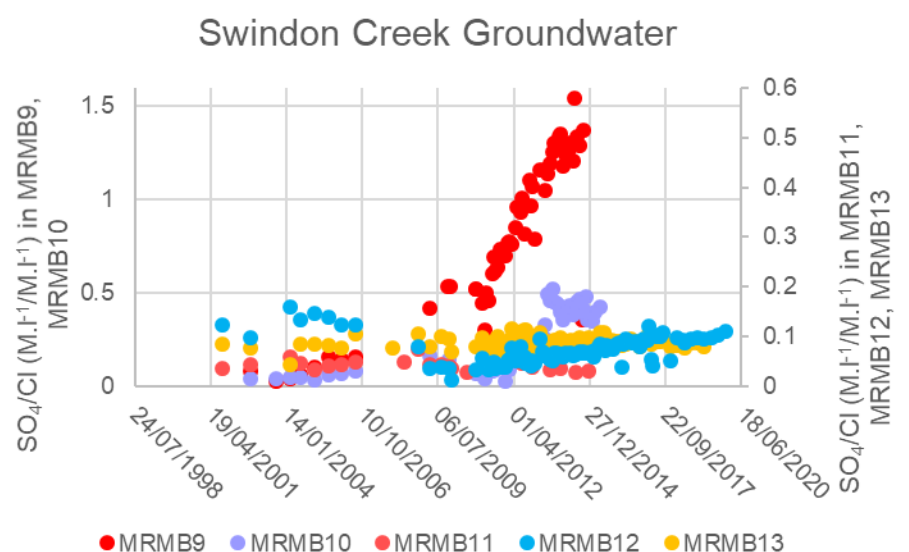
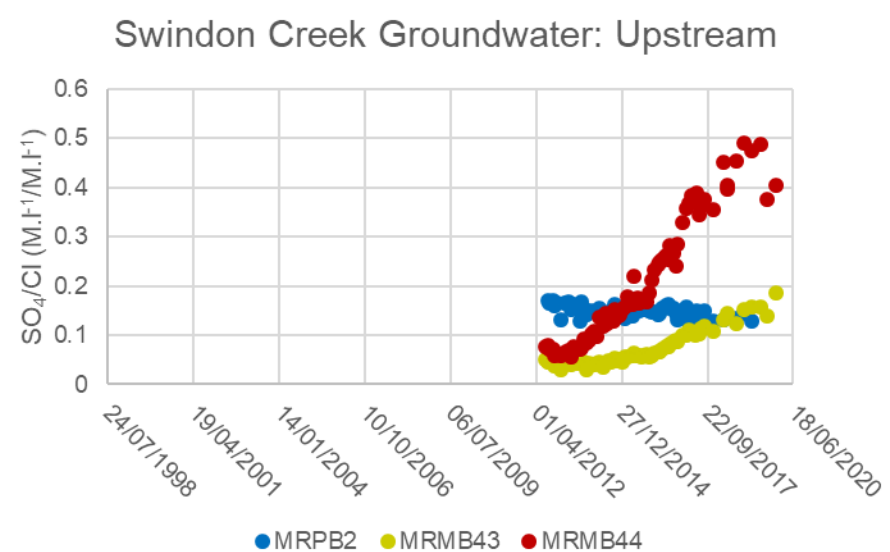
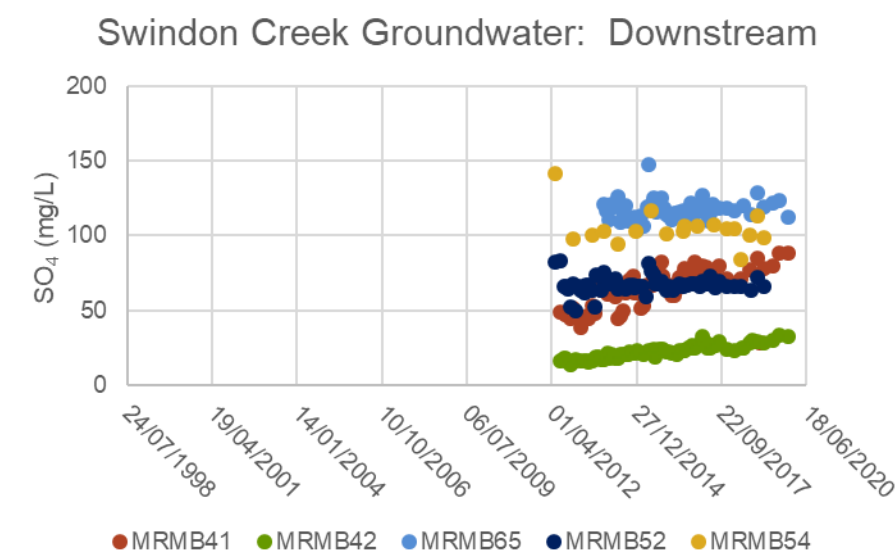
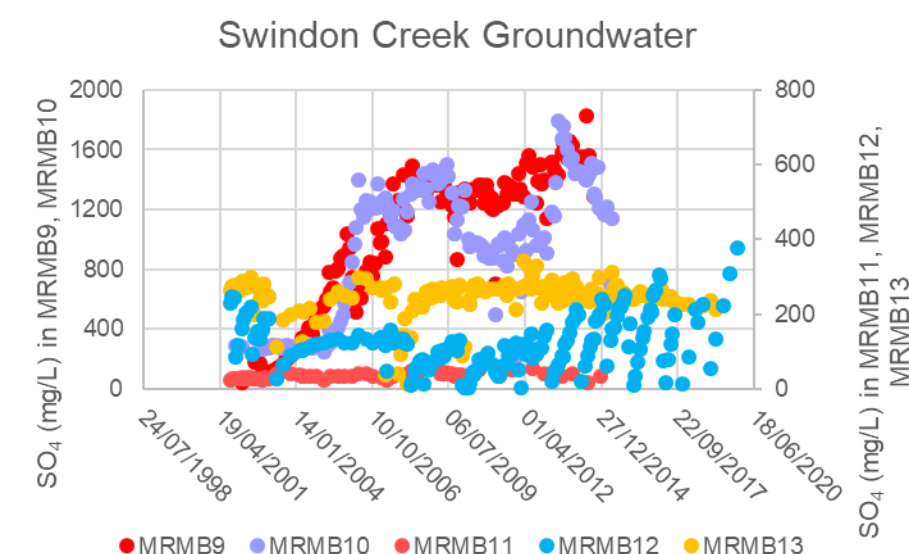
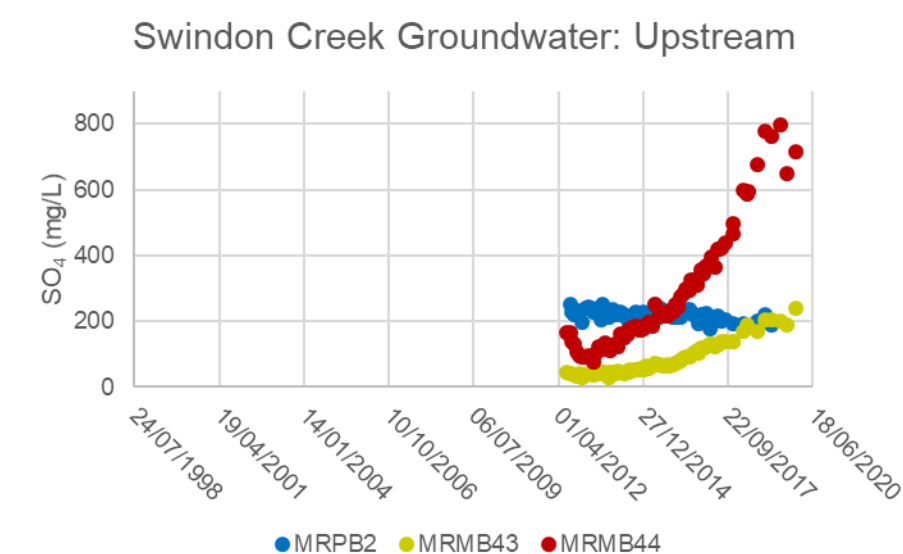
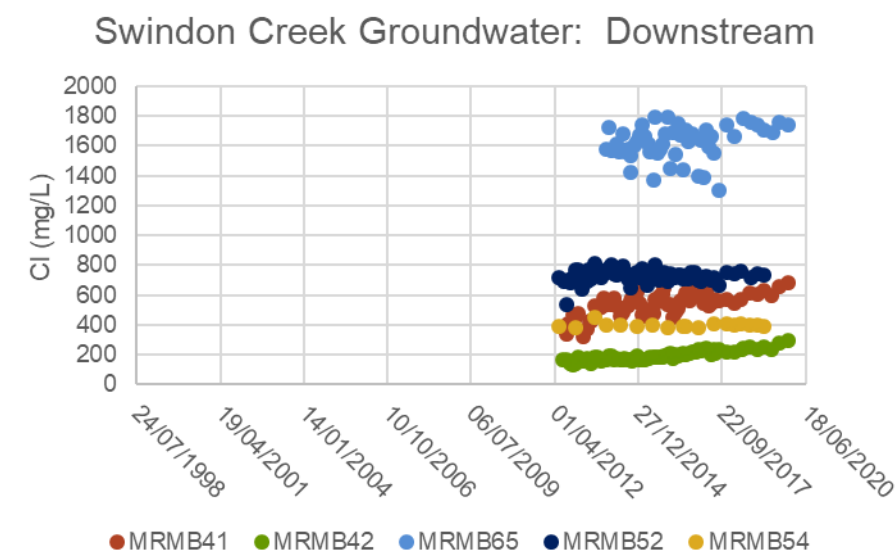
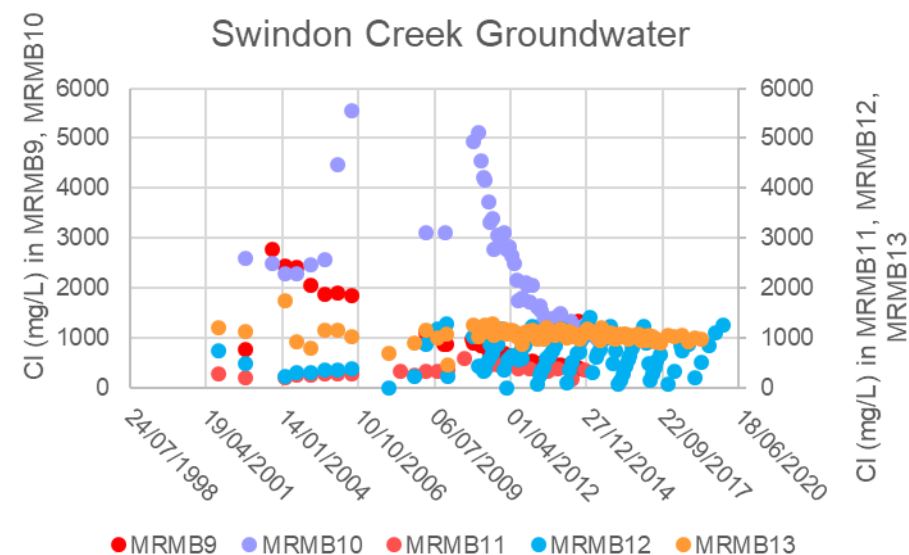
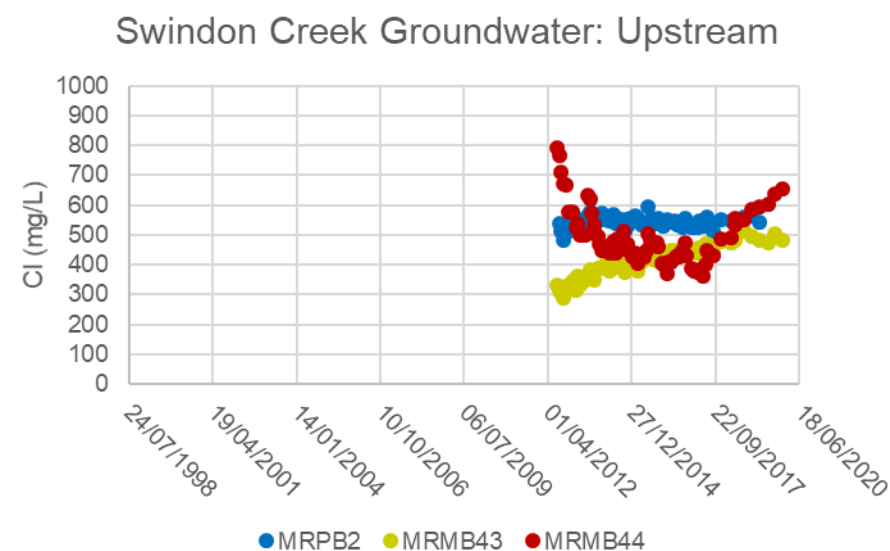
³¹ Footnote

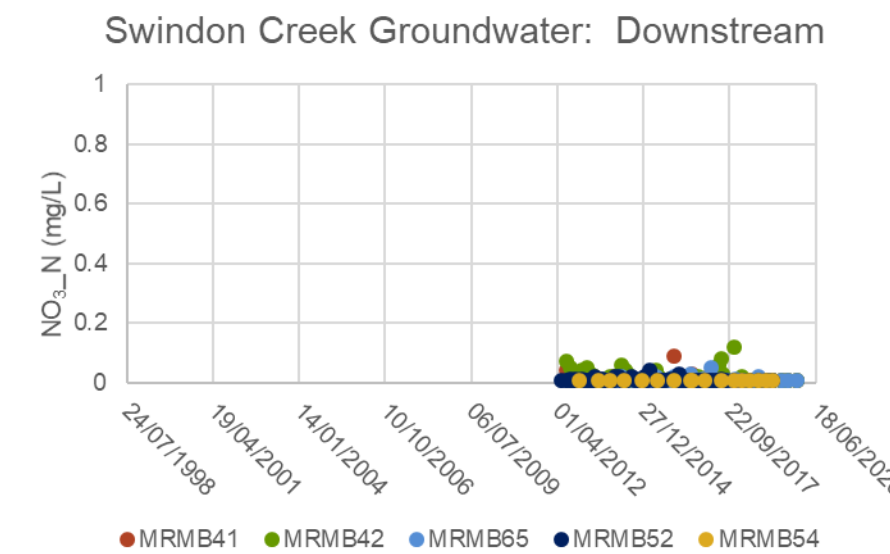
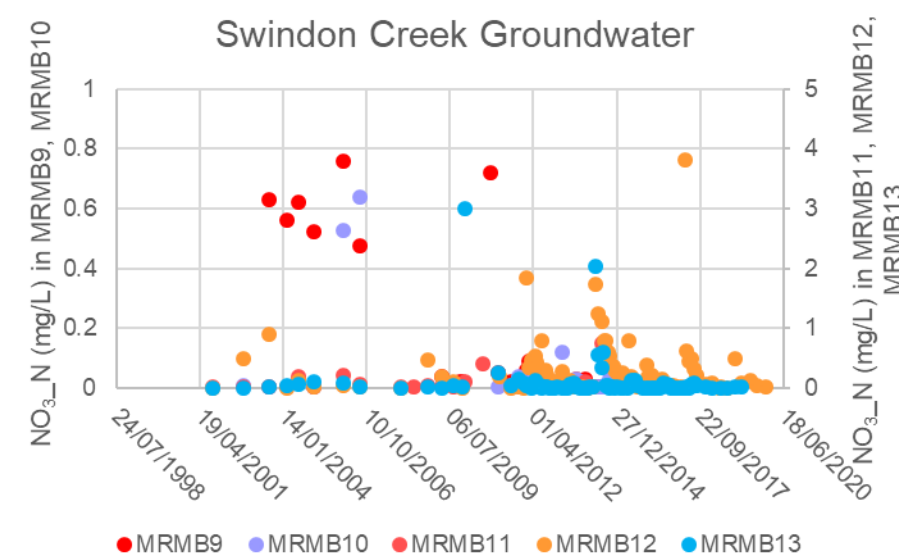
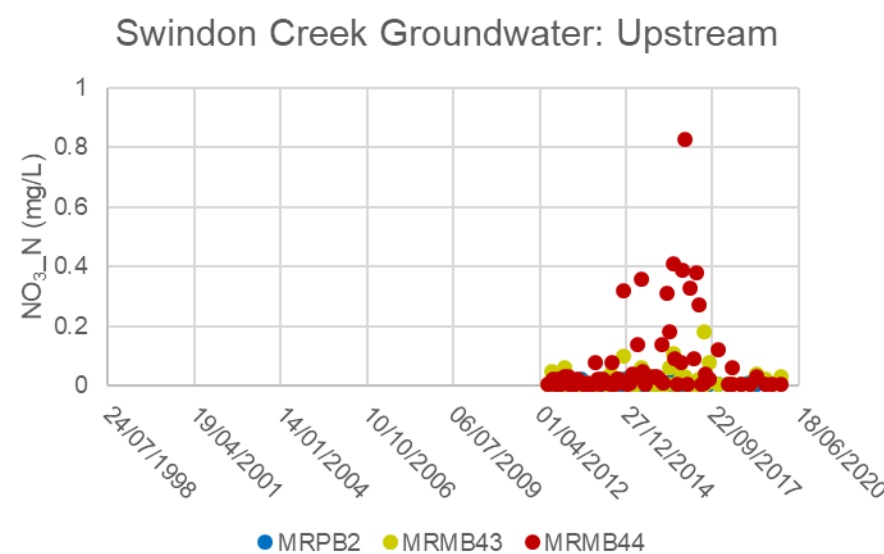
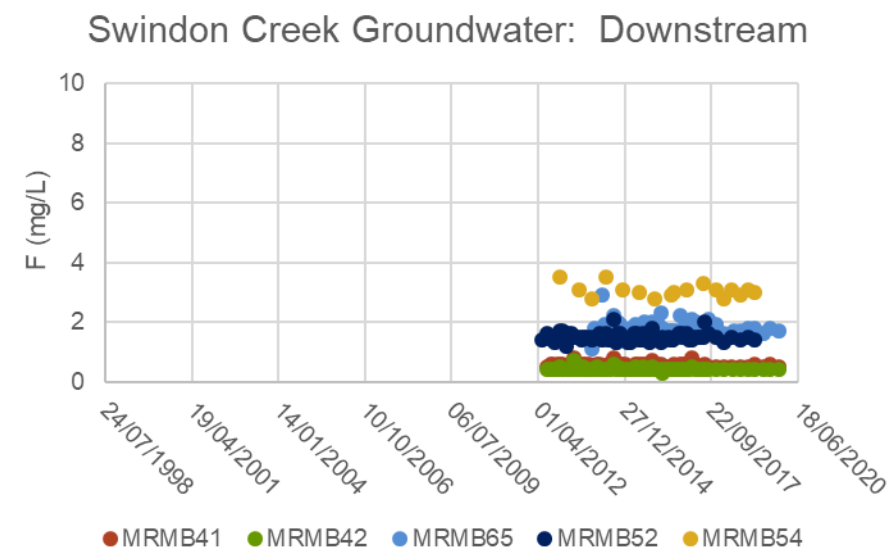
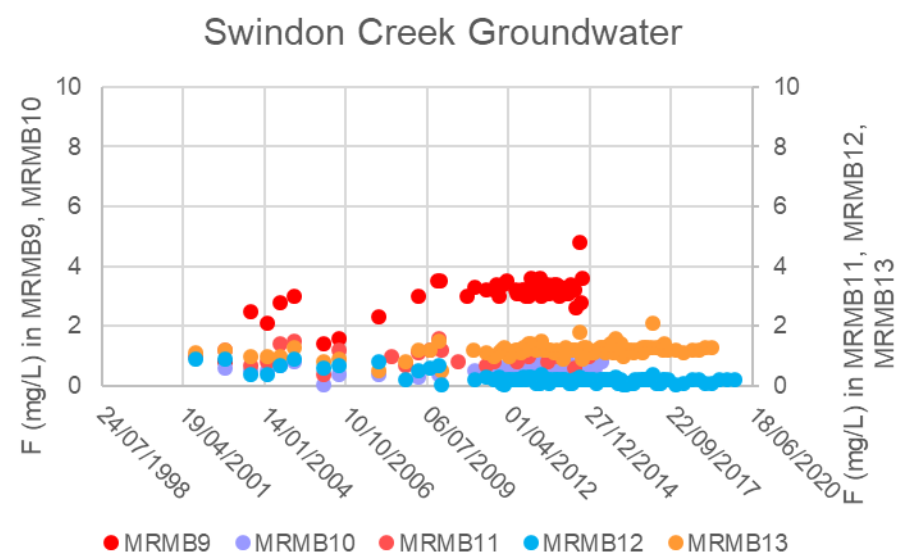
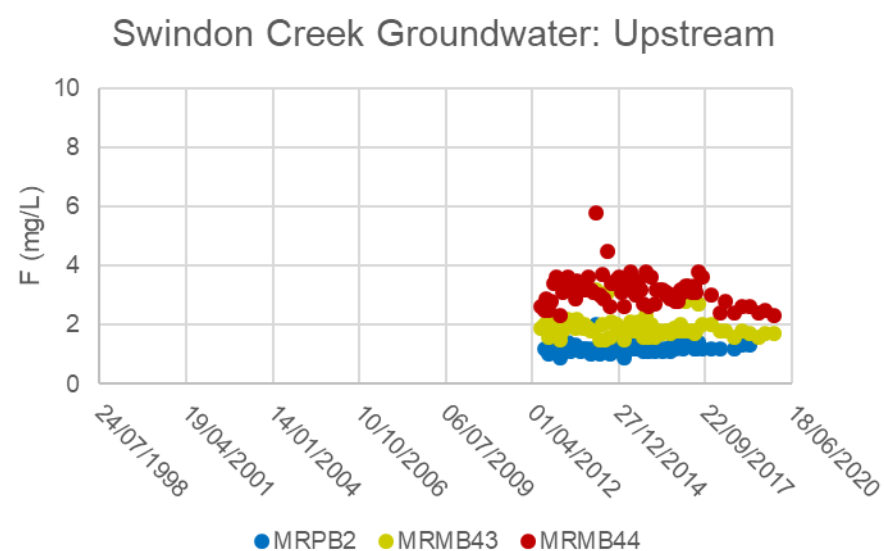
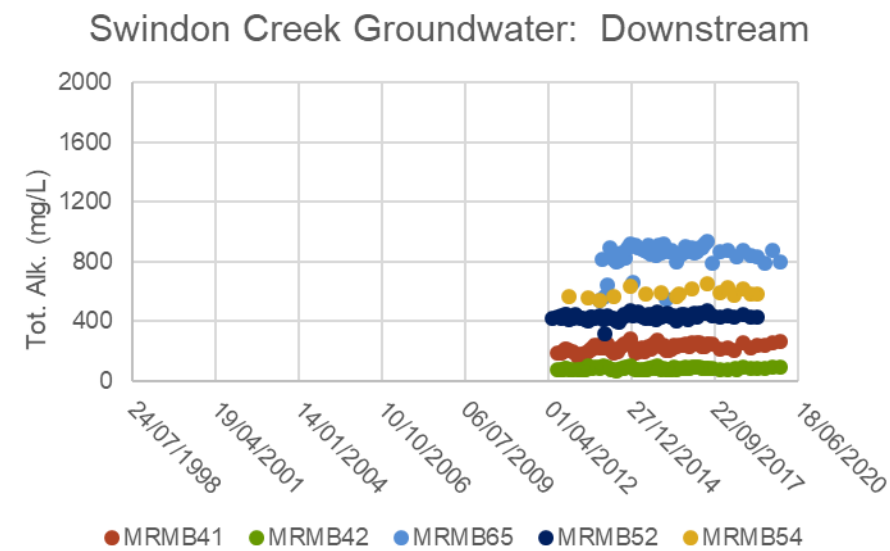
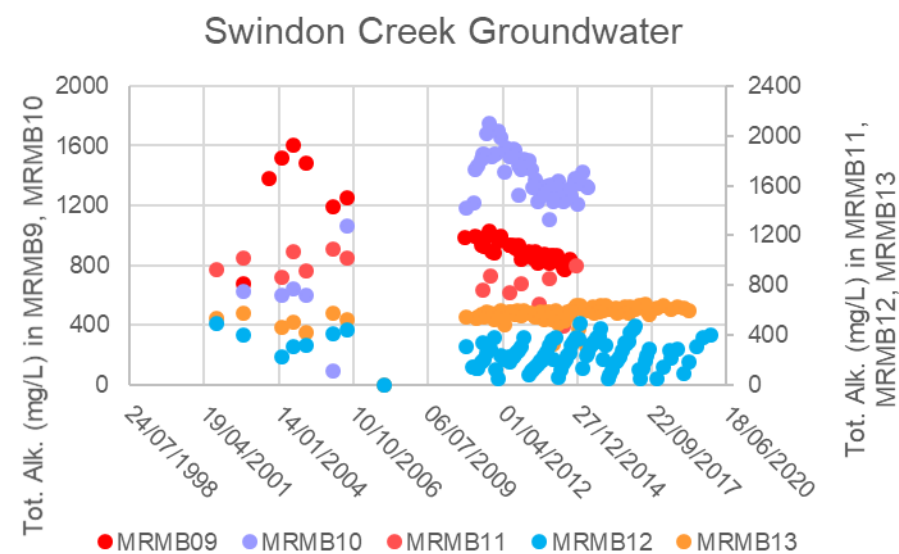
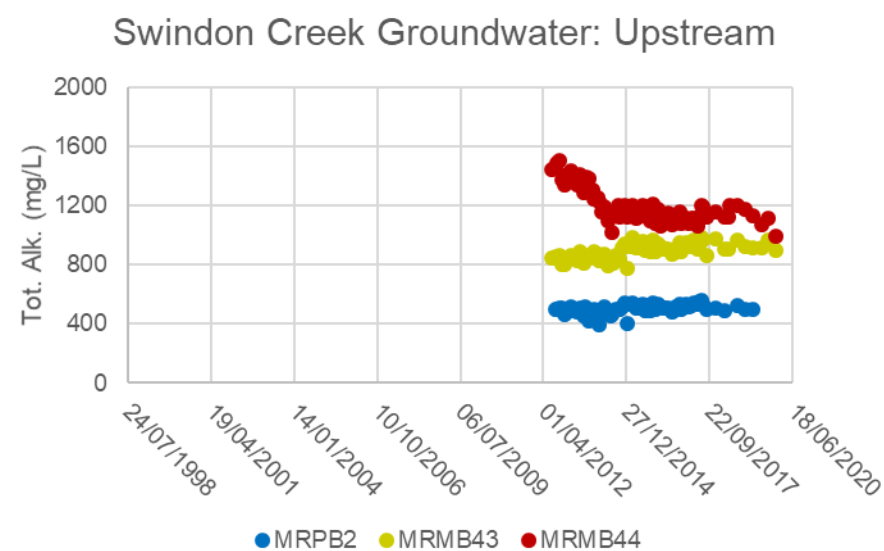
³¹ Na/Cl (M/M) vs SO₄/Cl (M/M) concentration ratios reported from Swindon Creek from a reference bore (MRPB2,) and two compliance bores (MRMB54, MRMB52).

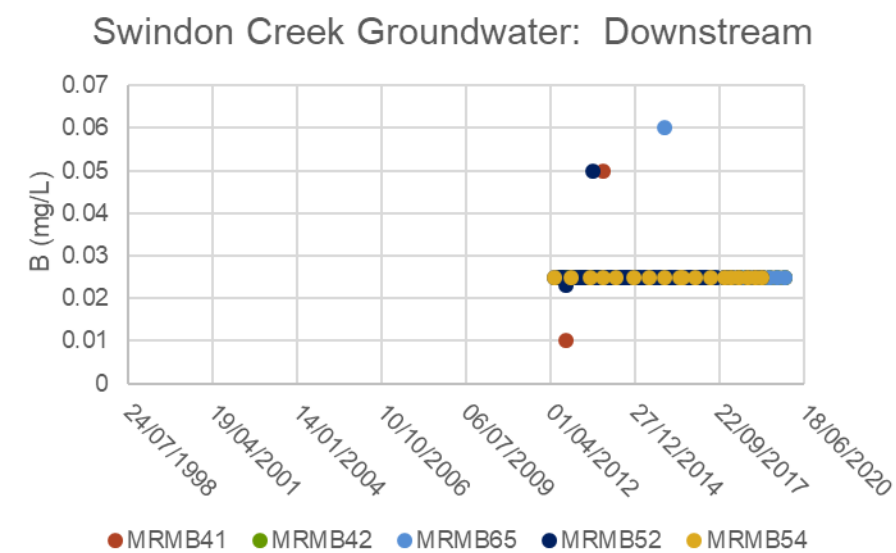
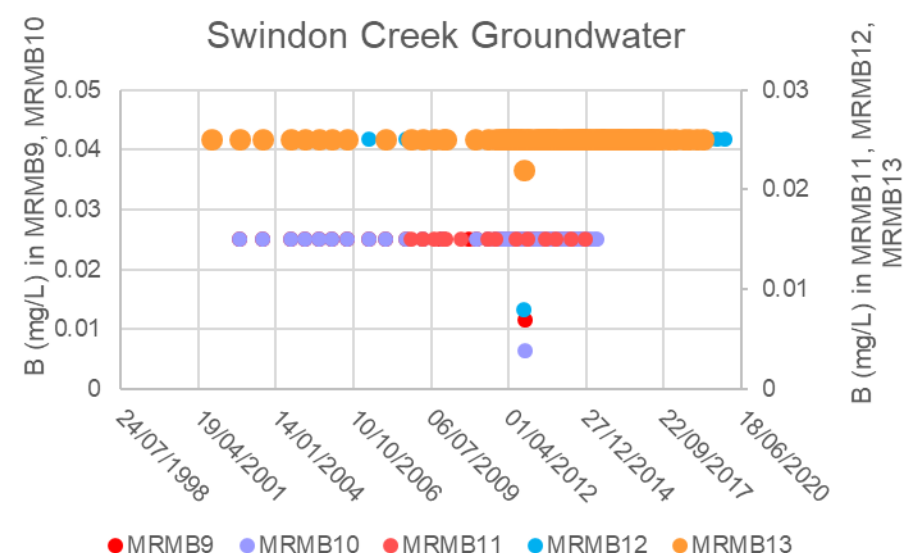
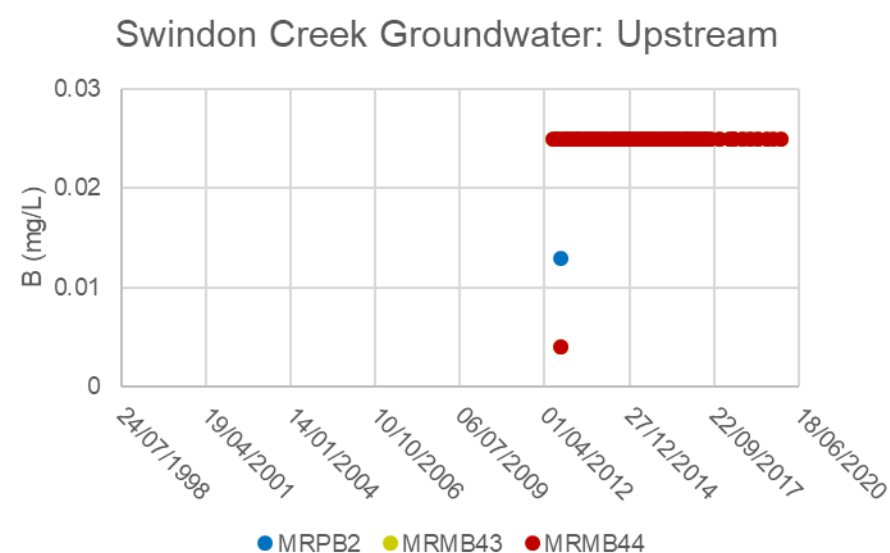
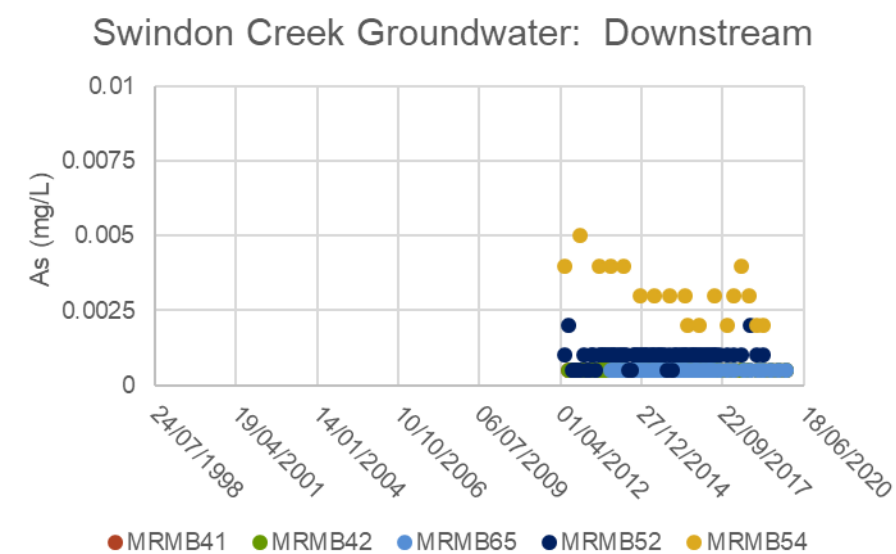
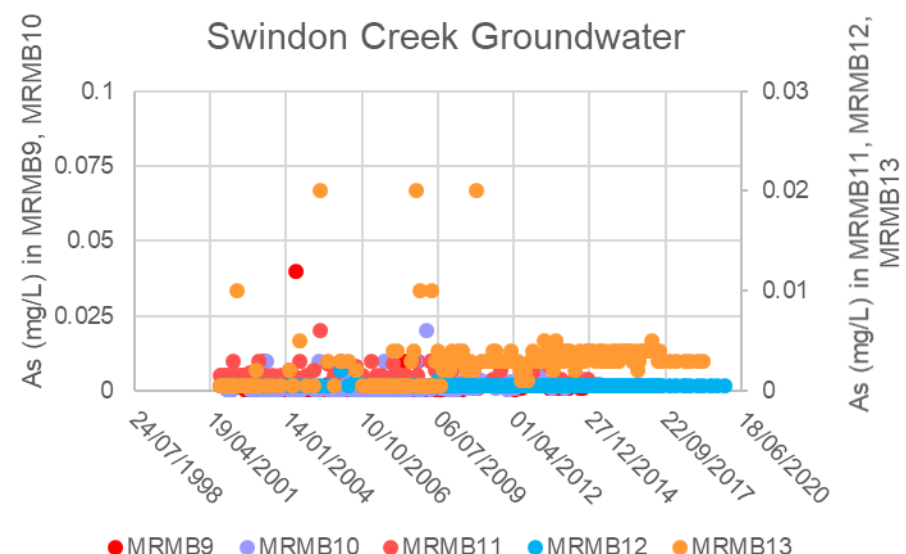
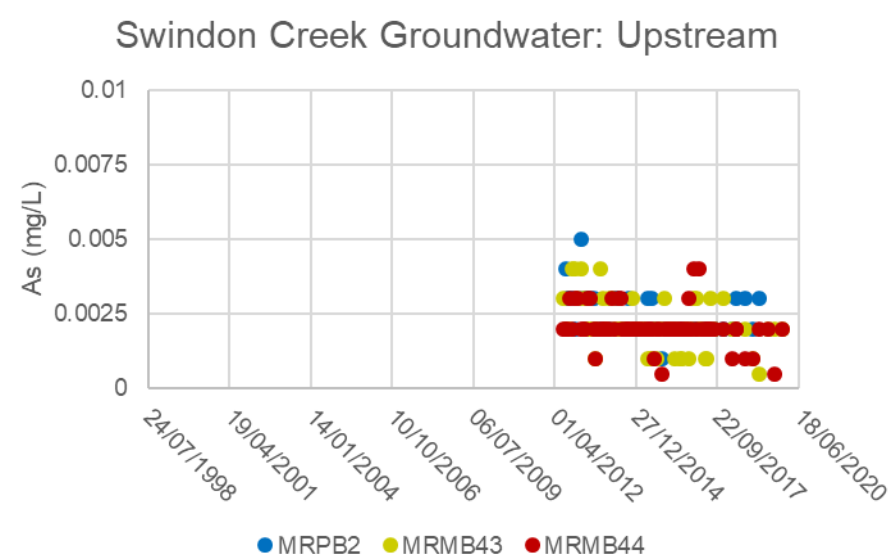
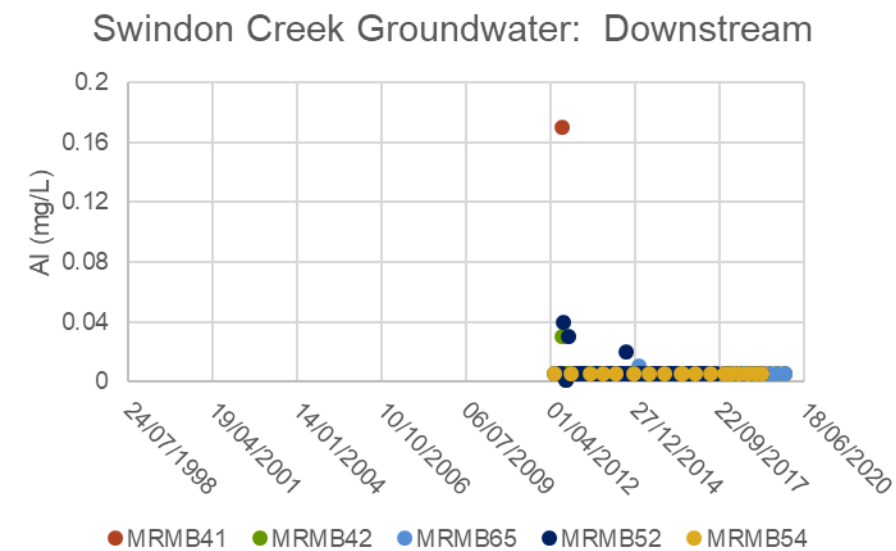
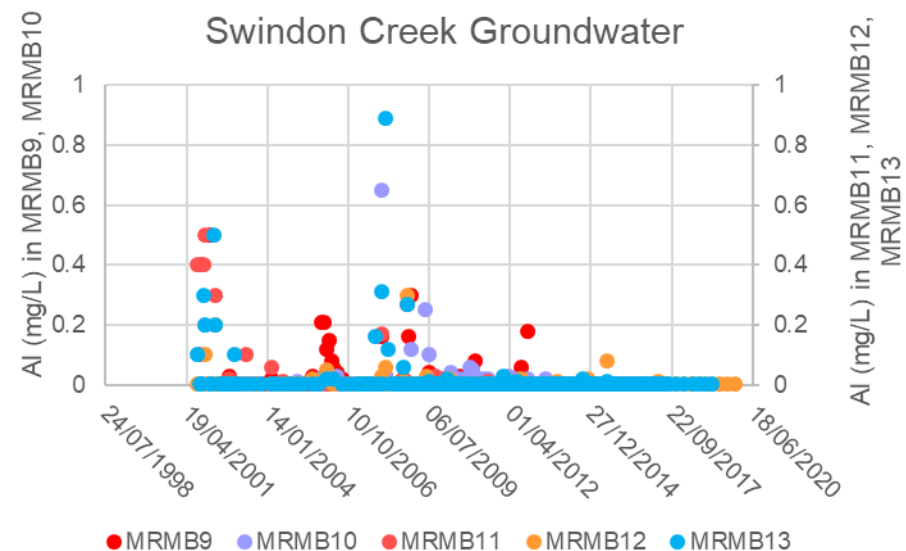
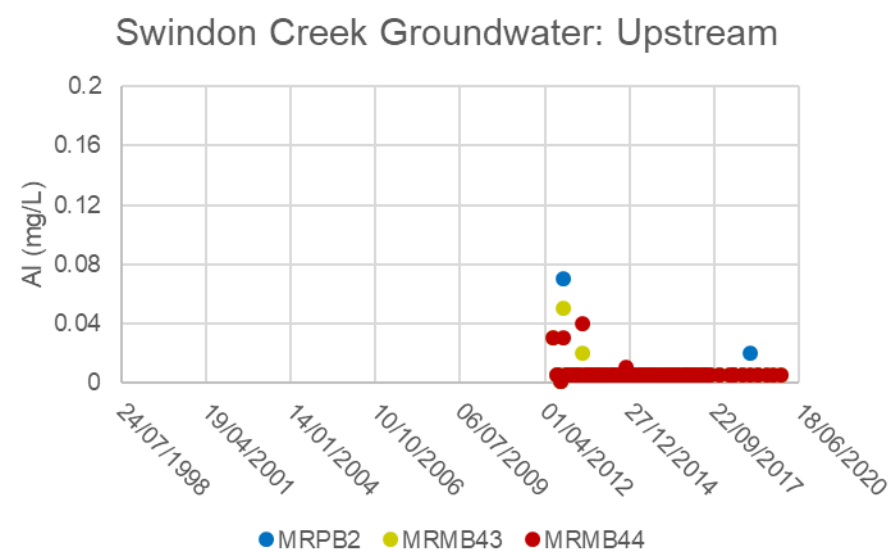


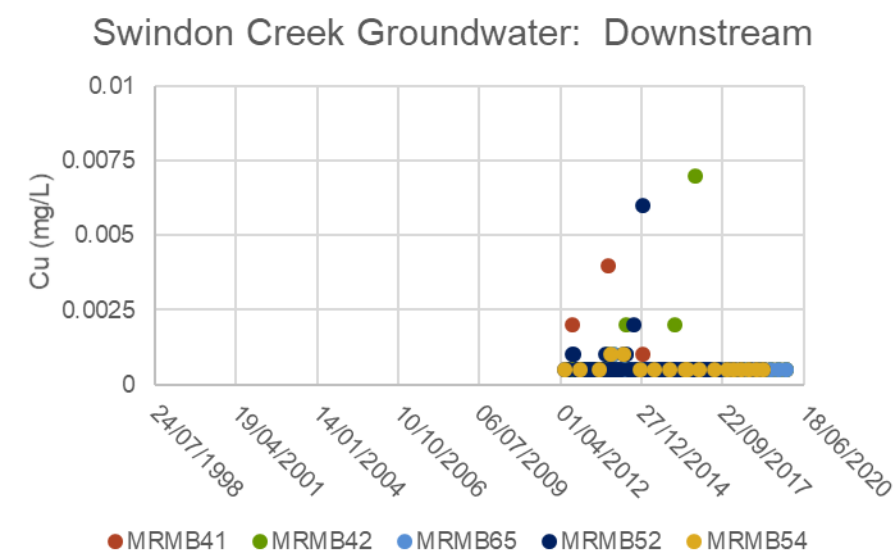
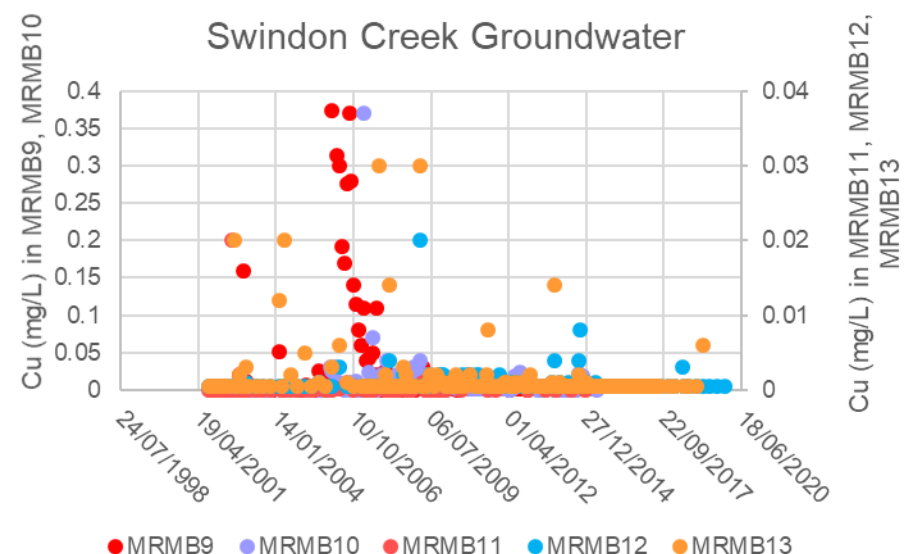
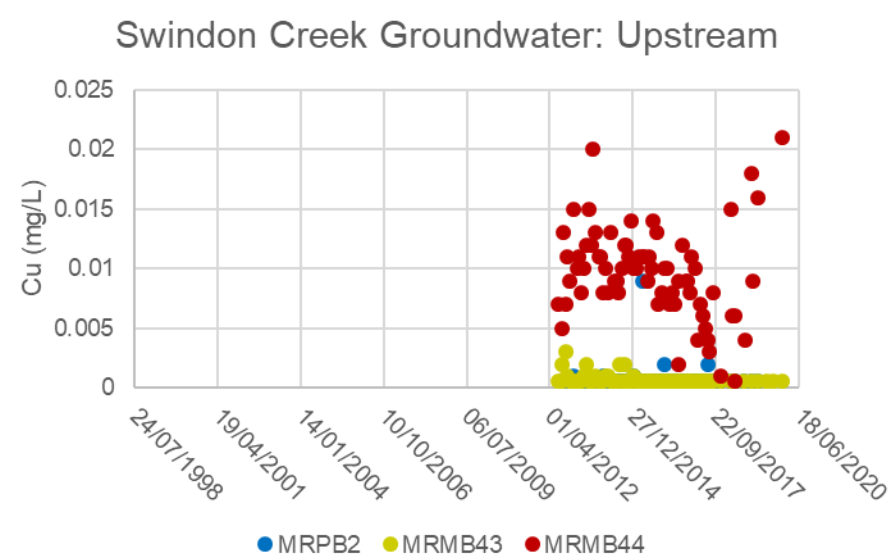
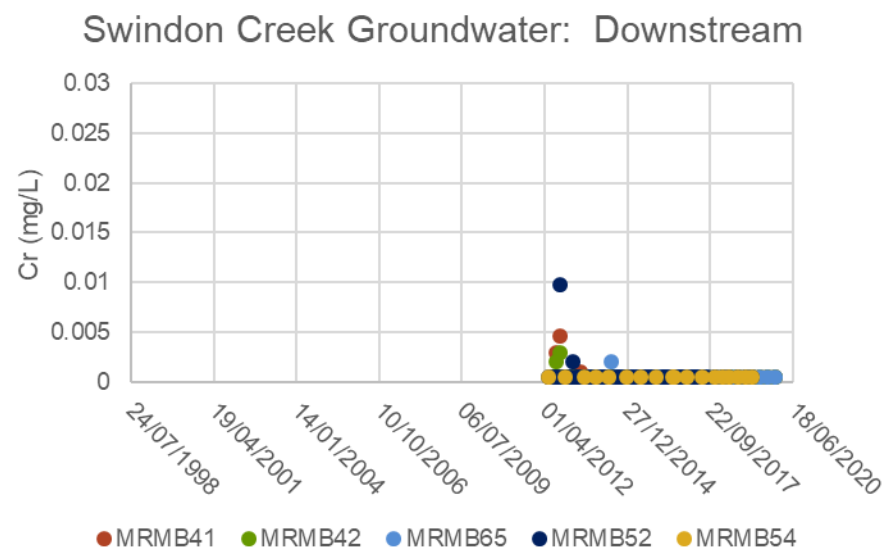
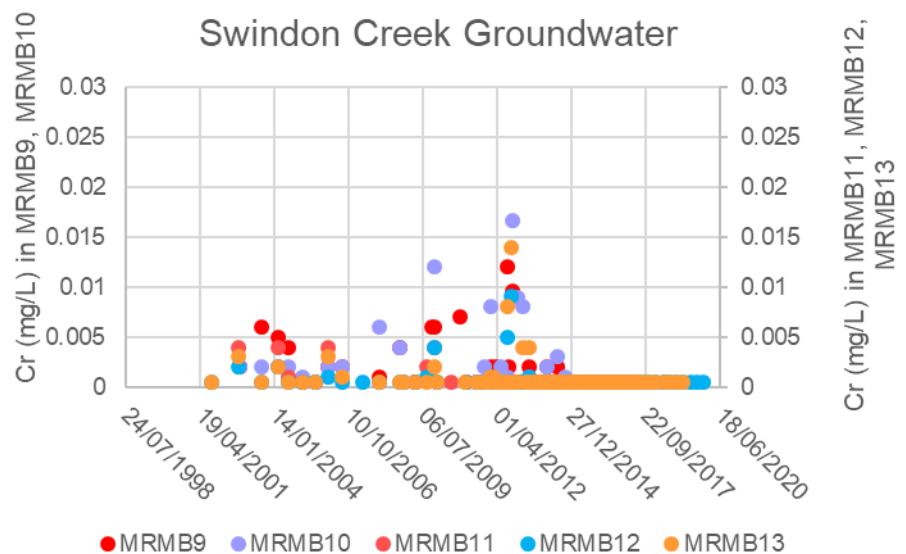
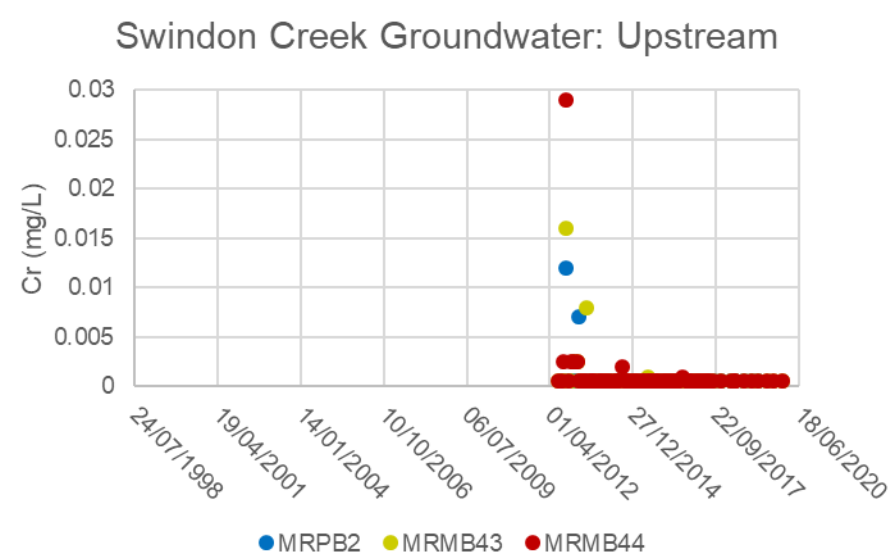
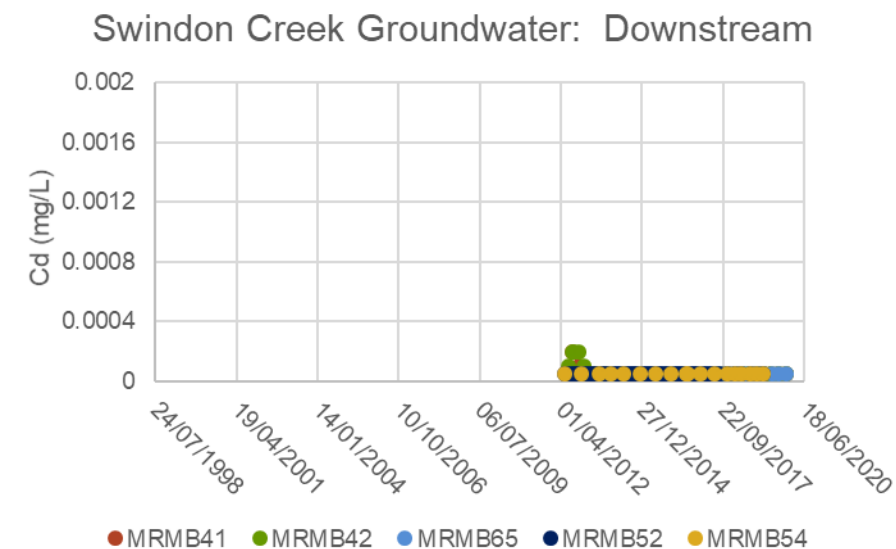
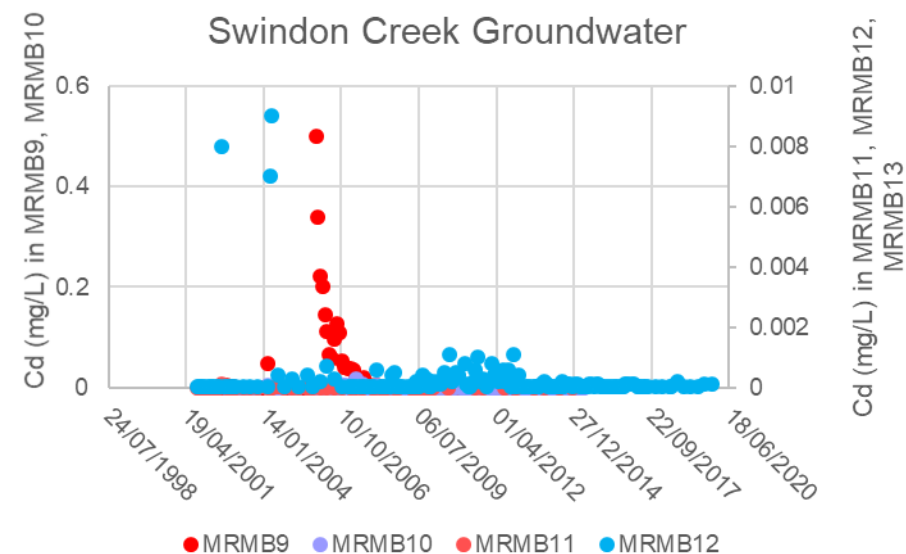
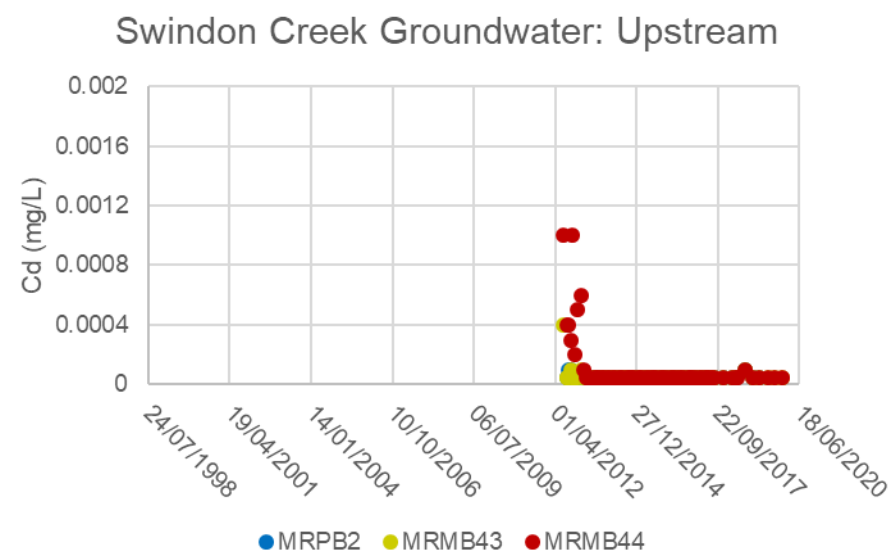


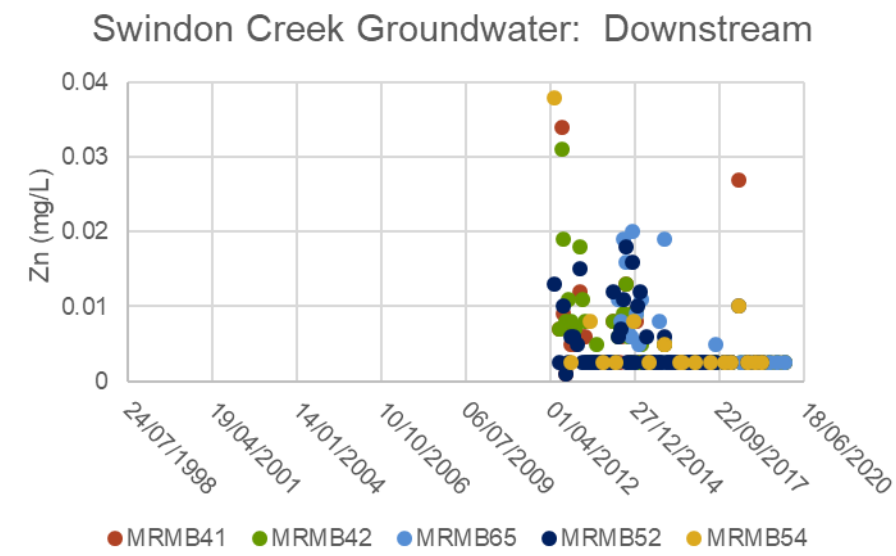
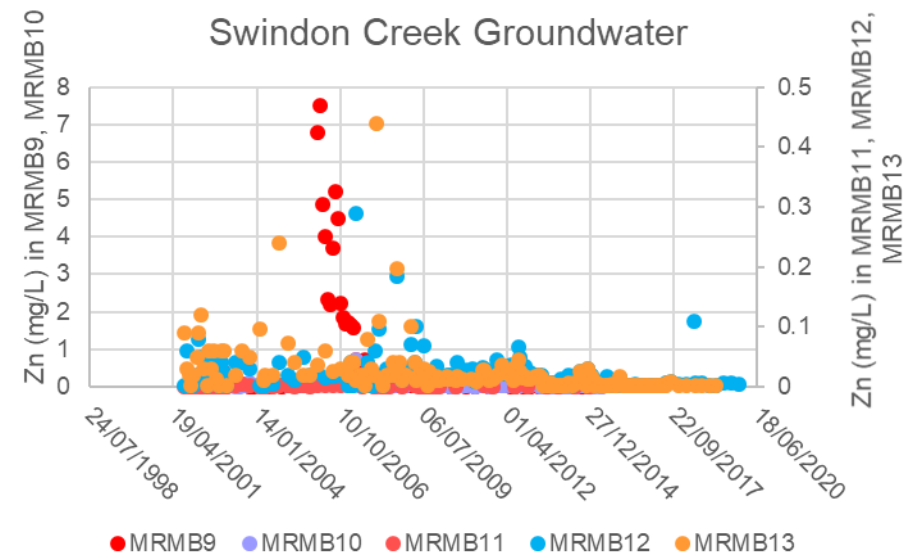
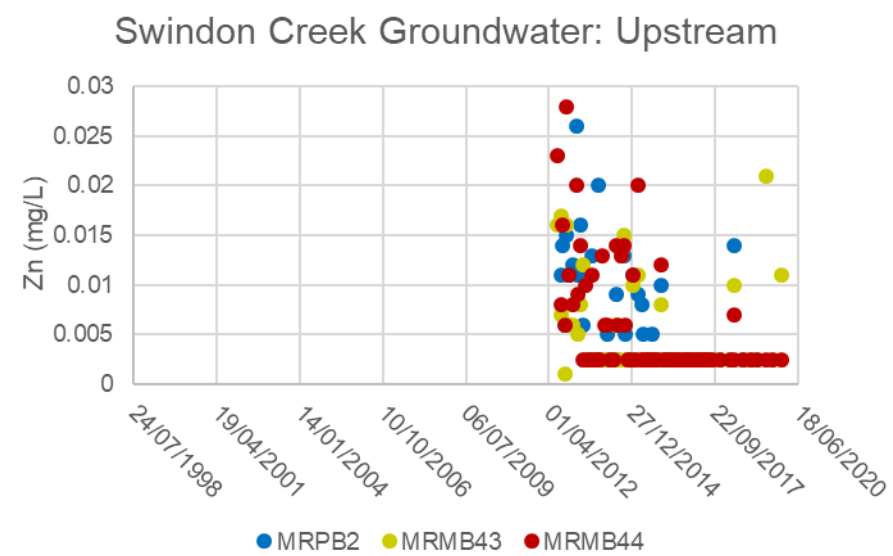


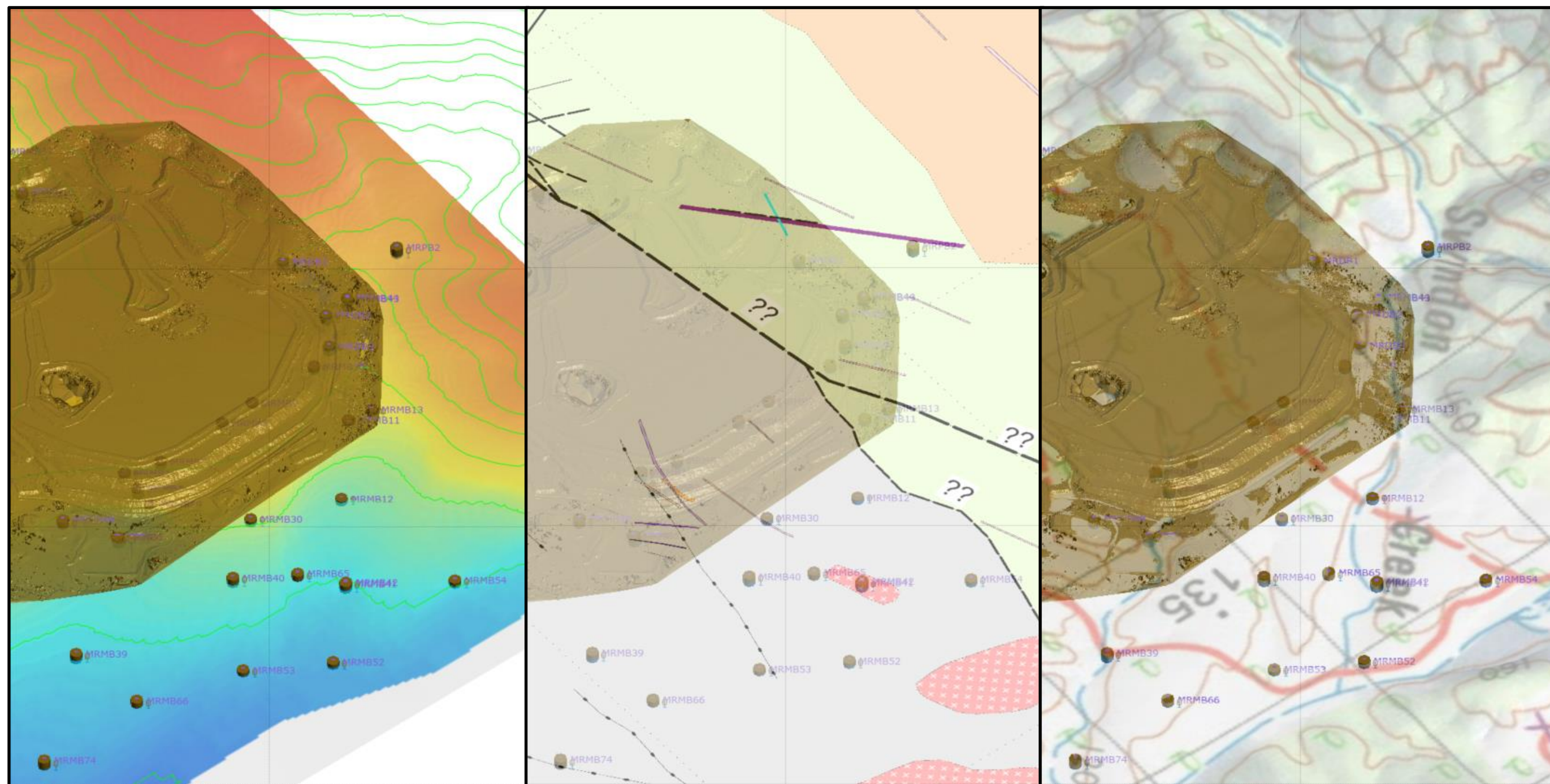






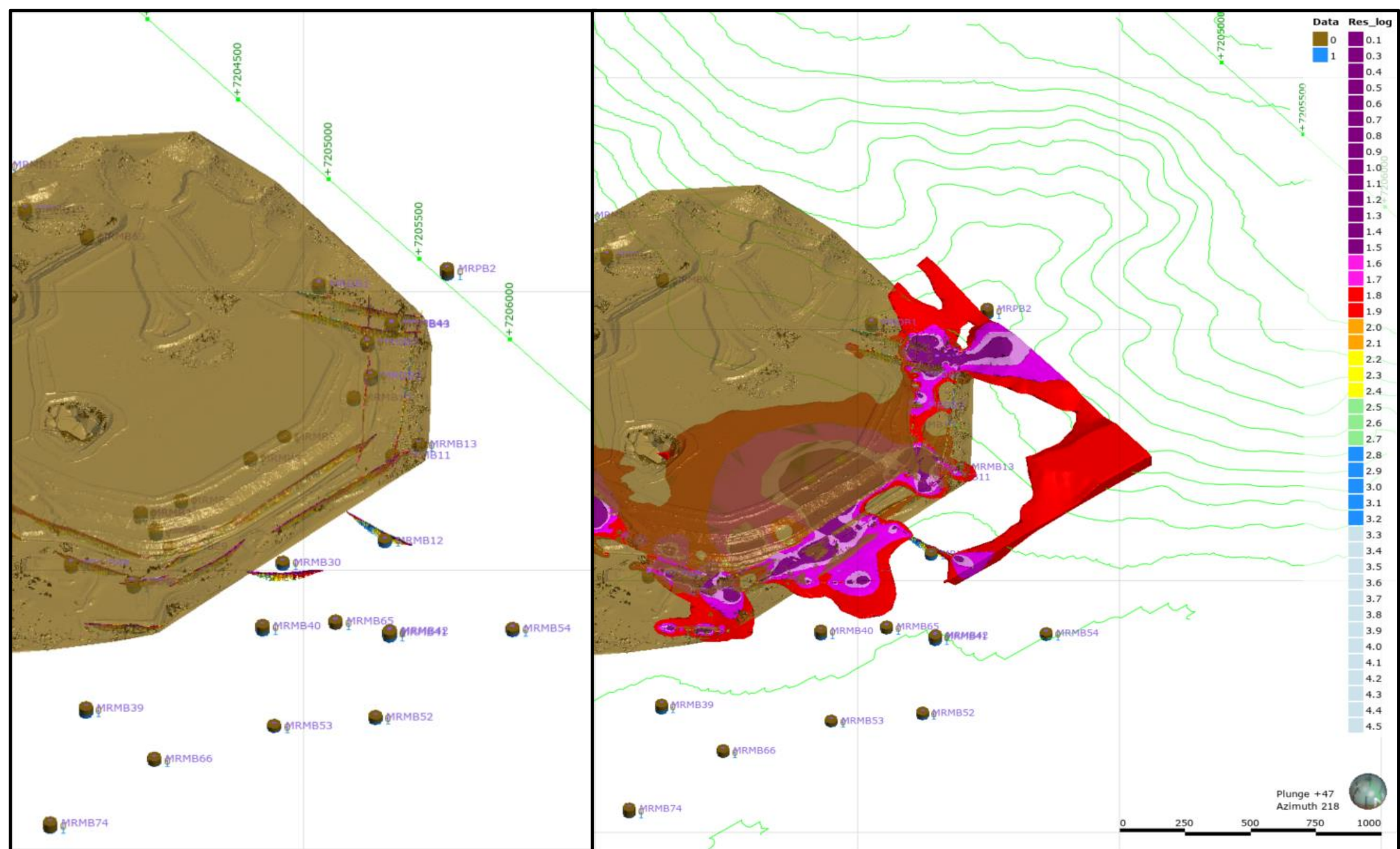






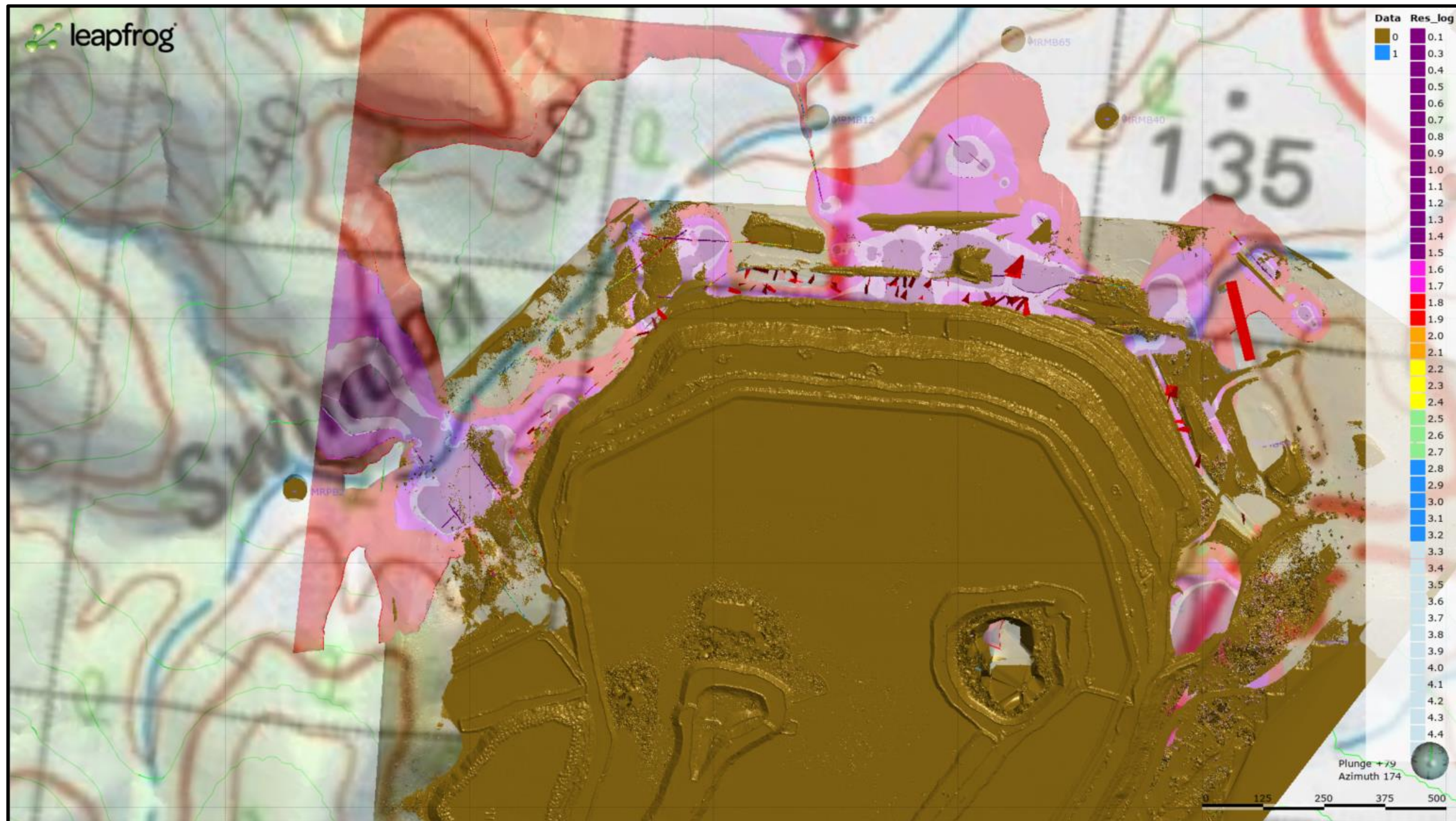
Supporting images for Figures 15 and 16 ³²

³² Birds eye view of the Swindon Creek catchment from the north. The left image shows the TSF topography (bronze image), groundwater bores featuring the PVC bore casing (brown) and screen (blue), contours of the groundwater surface in 10-metre intervals (green contour lines), and a heat map of the groundwater surface. The centre image shows the TSF topography, groundwater bores and mine-lease scale geology including the inferred West Dam Fault, Aranbanga Volcanics (green), Curtis Island Group Metasediments (grey), granite/granodiorite (white cross on pink background). Refer Figure 11 of the Stage 1 report for legend. The right image shows TSF topography, groundwater bores and the mine-lease scale topography with timbered hillslopes (green), landscape contours (brown lines), the 135 m AHD survey point and 160 m AHD topographic contour, creeks (blue dashed lines), road (solid red line) tracks (dashed red lines).



Supporting images for Figures 15 and 16 ³³

³³ Birds eye view of the Swindon Creek catchment from the north. The left image shows the TSF topography (bronze surface), 2-dimensional ERI transects, northings (green numbers) and groundwater bores featuring the PVC bore casing (brown) and screen (blue). The right image shows TSF topography, groundwater bores, northings, 3-dimensional ERI contours with legend featuring Ohm.m logarithmic intervals, and the groundwater surface at 10 m intervals sloping towards the viewer (green contour lines).



Supporting image for Figures 15 and 16 ³⁴

³⁴ Planview of the Swindon Creek catchment. The image shows the TSF topography (bronze surface), groundwater bores (brown circles), 2-dimensional ERI transects (lines in planview), 3-dimensional ERI contours with legend featuring Ohm.m logarithmic intervals, the mine-lease scale topographic map with timbered hillslopes (green), landscape contours (brown lines with black labels for the 135 m AHD survey point and topographic contours for 160m AHD and 240 m AHD), creeks (blue dashed lines), road (solid red line), tracks (dashed red lines) and the groundwater surface at 10 m intervals (green contour lines) sloping concordantly with the landscape contours.

Sample Point	Statistic	pH	EC (µS/cm)	Cyanide Total (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Sulphate (mg/L)	Alk Tot as CaCO3 (mg/L)	SO4/Cl (M/M)	Fluoride (mg/L)	Nitrate as N (mg/L)	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)
MRPB2 22/08/2012 - 20/02/2019	Count	64	64	66	66	65	66	66	65	66	65	66	66	66	66	66	66
	Min	6.37	2425	0.001	308	480	177	394	0.12	0.9	0.005	0.001	0.001	0.013	0.00005	0.0005	0.0005
	5th %ile	6.47	2518	0.002	311	513	193	455	0.13	1.0	0.005	0.005	0.002	0.025	0.00005	0.0005	0.0005
	20th %ile	6.55	2645	0.002	324	529	204	485	0.14	1.1	0.005	0.005	0.002	0.025	0.00005	0.0005	0.0005
	Mean	6.75	2700	0.002	341	542	219	501	0.15	1.2	0.007	0.006	0.002	0.025	0.00005	0.0008	0.0007
	Median	6.69	2705	0.002	335	544	220	505	0.15	1.2	0.005	0.005	0.002	0.025	0.00005	0.0005	0.0005
	80th %ile	6.98	2780	0.002	356	555	230	522	0.16	1.3	0.005	0.005	0.003	0.025	0.00005	0.0005	0.0005
	95th %ile	7.13	2820	0.002	381	567	243	539	0.17	1.5	0.020	0.005	0.003	0.025	0.00005	0.0005	0.0010
	Max	7.20	2840	0.012	398	592	251	556	0.17	2.0	0.020	0.070	0.005	0.025	0.00010	0.0120	0.0090
MRMB43 13/07/2012 - 12/02/2020	Count	73	74	63	71	70	72	71	70	71	70	71	63	63	63	62	63
	Min	6.70	2135	0.002	370	290	28	776	0.03	1.5	0.005	0.001	0.001	0.004	0.00005	0.0005	0.0005
	5th %ile	6.95	2288	0.002	402	314	38	808	0.04	1.6	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	20th %ile	7.04	2458	0.002	436	368	42	848	0.04	1.7	0.005	0.005	0.002	0.025	0.00005	0.0005	0.0005
	Mean	7.23	2719	0.003	466	412	85	891	0.07	1.9	0.021	0.006	0.002	0.025	0.00006	0.0009	0.0007
	Median	7.19	2775	0.002	469	420	66	896	0.06	1.9	0.005	0.005	0.002	0.025	0.00005	0.0005	0.0005
	80th %ile	7.38	2925	0.004	502	450	131	930	0.10	2.0	0.030	0.005	0.003	0.025	0.00005	0.0005	0.0005
	95th %ile	7.67	3144	0.006	519	484	195	969	0.15	2.5	0.071	0.005	0.004	0.025	0.00008	0.0018	0.0020
	Max	7.88	3230	0.012	544	512	241	983	0.19	3.2	0.180	0.050	0.004	0.025	0.00040	0.0160	0.0030
MRMB44 13/07/2012 - 12/02/2020	Count	74	75	72	72	71	73	72	71	71	71	72	72	72	72	72	75
	Min	7.01	2710	0.002	624	360	75	993	0.06	2.3	0.005	0.001	0.001	0.004	0.00005	0.0005	0.0005
	5th %ile	7.21	3224	0.002	649	381	95	1066	0.06	2.4	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0037
	20th %ile	7.32	3388	0.002	675	425	127	1110	0.08	2.7	0.005	0.005	0.002	0.025	0.00005	0.0005	0.0070
	Mean	7.46	3691	0.003	740	494	281	1197	0.21	3.1	0.076	0.006	0.002	0.025	0.00011	0.0010	0.0111
	Median	7.46	3550	0.002	740	470	216	1160	0.17	3.1	0.020	0.005	0.002	0.025	0.00005	0.0005	0.0100
	80th %ile	7.59	3992	0.002	804	572	411	1332	0.36	3.5	0.090	0.005	0.002	0.025	0.00005	0.0005	0.0130
	95th %ile	7.80	4707	0.005	852	669	692	1435	0.45	3.8	0.370	0.007	0.003	0.025	0.00045	0.0025	0.0203
	Max	7.86	4930	0.012	929	790	799	1500	0.49	5.8	0.830	0.040	0.004	0.025	0.00100	0.0290	0.0500
MRMB09 29/01/2002 - 01/10/2014	Count	148	149	150	58	58	148	48	58	48	50	148	147	53	148	52	148
	Min	6.02	795	0.002	757	397	39	675	0.03	0.8	0.005	0.003	0.001	0.004	0.00005	0.0005	0.0005
	5th %ile	6.44	4913	0.002	1100	435	134	793	0.08	1.8	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	20th %ile	6.74	5313	0.002	1174	460	545	837	0.45	2.9	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	Mean	7.01	6920	0.107	1292	820	1034	952	0.81	3.1	0.127	0.022	0.002	0.024	0.01603	0.0020	0.0522
	Median	7.02	6430	0.018	1250	613	1240	894	0.80	3.2	0.005	0.005	0.001	0.025	0.00020	0.0005	0.0020
	80th %ile	7.28	8462	0.173	1350	947	1400	994	1.23	3.4	0.066	0.008	0.002	0.025	0.00110	0.0020	0.0200
	95th %ile	7.54	10286	0.485	1744	2114	1557	1445	1.34	3.6	0.680	0.140	0.003	0.025	0.10510	0.0065	0.2786
	Max	8.18	10719	0.563	1940	2790	1830	1600	1.55	4.8	1.370	0.500	0.040	0.025	0.50000	0.0150	2.0400
MRMB10 20/11/2001 - 14/05/2015	Count	143	144	144	64	63	144	58	63	56	55	144	144	58	144	57	144
	Min	5.80	5530	0.002	1050	991	210	93	0.03	0.1	0.005	0.001	0.001	0.004	0.00005	0.0005	0.0005
	5th %ile	6.15	7197	0.002	1150	1131	277	624	0.04	0.4	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	20th %ile	6.41	8038	0.002	1356	1244	479	1230	0.08	0.5	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	Mean	6.72	11004	0.005	1630	2258	991	1318	0.24	0.6	0.057	0.029	0.002	0.024	0.00079	0.0022	0.0090
	Median	6.71	11020	0.002	1570	2050	1070	1350	0.20	0.6	0.005	0.005	0.002	0.025	0.00005	0.0005	0.0020
	80th %ile	7.01	14068	0.006	1916	3084	1358	1540	0.42	0.7	0.020	0.005	0.003	0.025	0.00074	0.0020	0.0100
	95th %ile	7.35	15454	0.013	2307	4543	1509	1663	0.47	0.8	0.242	0.048	0.007	0.025	0.00491	0.0082	0.0249
	Max	7.72	16060	0.134	2470	5540	1790	1750	0.52	1.1	1.370	1.730	0.020	0.025	0.01630	0.0290	0.3700
MRMB11 02/09/2001 - 10/12/2014	Count	62	63	62	24	23	63	15	23	23	24	63	63	14	63	18	62
	Min	6.25	1144	0.002	221	190	38	394	0.07	0.4	0.005	0.005	0.003	0.025	0.00005	0.0005	0.0005
	5th %ile	6.62	1692	0.002	274	209	62	499	0.08	0.6	0.005	0.005	0.004	0.025	0.00005	0.0005	0.0005
	20th %ile	6.85	2104	0.002	333	265	71	630	0.09	0.7	0.005	0.005	0.005	0.025	0.00005	0.0005	0.0005
	Mean	7.00	2250	0.003	391	333	90	723	0.11	1.0	0.019	0.049	0.007	0.025	0.00018	0.0014	0.0040
	Median	6.98	2300	0.002	399	331	87	732	0.11	1.0	0.005	0.005	0.005	0.025	0.00005	0.0005	0.0005
	80th %ile	7.14	2410	0.002	446	382	106	848	0.12	1.2	0.020	0.020	0.008	0.025	0.00005	0.0032	0.0005
	95th %ile	7.52	2692	0.005	467	475	129	893	0.16	1.5	0.074	0.390	0.010	0.025	0.00040	0.0040	0.0020
	Max	8.13	2840	0.018	512	605	145	905	0.20	1.6	0.150	0.500	0.020	0.025	0.00600	0.0040	0.2000

Statistic	Statistic	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Lead Dissolved (mg/L)	Zinc Dissolved (mg/L)	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Molybdenum Dissolved (mg/L)	Se Diss (mg/L)
MRPB2 22/08/2012 - 20/02/2019	Count	66	66	66	66	66	66	66	66	26
	Min	0.58	0.220	0.0005	0.0025	129	3	70	0.0200	0.0050
	5th %ile	0.69	0.230	0.0005	0.0025	139	3	71	0.0210	0.0050
	20th %ile	0.72	0.242	0.0005	0.0025	146	4	73	0.0230	0.0050
	Mean	0.79	0.265	0.0007	0.0055	151	4	76	0.0241	0.0050
	Median	0.76	0.258	0.0005	0.0025	151	4	77	0.0240	0.0050
	80th %ile	0.82	0.279	0.0005	0.0100	156	4	79	0.0260	0.0050
	95th %ile	0.90	0.328	0.0005	0.0148	163	4	82	0.0260	0.0050
	Max	2.20	0.410	0.0060	0.0260	165	4	83	0.0300	0.0050
MRMB43 13/07/2012 - 12/02/2020	Count	72	71	63	63	71	71	71	63	30
	Min	0.03	0.001	0.0005	0.0010	33	4	57	0.0150	0.0050
	5th %ile	0.03	0.004	0.0005	0.0025	48	6	61	0.0190	0.0050
	20th %ile	0.03	0.021	0.0005	0.0025	53	6	67	0.0210	0.0050
	Mean	0.33	0.079	0.0007	0.0051	63	7	78	0.0235	0.0050
	Median	0.20	0.068	0.0005	0.0025	62	7	75	0.0230	0.0050
	80th %ile	0.50	0.118	0.0005	0.0070	72	7	90	0.0270	0.0050
	95th %ile	1.04	0.251	0.0005	0.0160	87	8	101	0.0285	0.0050
	Max	2.70	0.292	0.0120	0.0380	92	10	107	0.0310	0.0050
MRMB44 13/07/2012 - 12/02/2020	Count	72	72	72	72	72	72	72	72	31
	Min	0.03	0.003	0.0005	0.0025	25	4	72	0.0240	0.0050
	5th %ile	0.03	0.005	0.0005	0.0025	28	4	74	0.0286	0.0050
	20th %ile	0.03	0.008	0.0005	0.0025	30	4	79	0.0400	0.0050
	Mean	0.06	0.030	0.0008	0.0057	37	5	97	0.0491	0.0050
	Median	0.03	0.019	0.0005	0.0025	35	5	88	0.0515	0.0050
	80th %ile	0.06	0.045	0.0005	0.0098	43	5	110	0.0588	0.0050
	95th %ile	0.29	0.087	0.0020	0.0178	56	6	152	0.0645	0.0050
	Max	0.63	0.275	0.0140	0.0280	70	9	166	0.0690	0.0050
MRMB09 29/01/2002 - 01/10/2014	Count	148	122	148	147	54	54	54	79	
	Min	0.00	0.001	0.0005	0.0010	26	4	51	0.0110	
	5th %ile	0.01	0.001	0.0005	0.0025	32	5	76	0.0168	
	20th %ile	0.01	0.014	0.0005	0.0102	33	6	81	0.0286	
	Mean	0.03	0.858	0.0014	0.6245	41	7	106	0.0325	
	Median	0.03	0.020	0.0005	0.0250	35	7	86	0.0330	
	80th %ile	0.03	0.030	0.0005	0.0880	42	8	105	0.0384	
	95th %ile	0.10	3.864	0.0033	3.9070	76	13	209	0.0421	
	Max	0.38	32.200	0.0520	19.6000	92	17	284	0.0470	
MRMB10 20/11/2001 - 14/05/2015	Count	143	121	143	144	60	60	60	84	
	Min	0.00	0.010	0.0005	0.0025	77	9	216	0.0040	
	5th %ile	0.02	0.055	0.0005	0.0025	85	10	241	0.0200	
	20th %ile	0.03	0.086	0.0005	0.0126	96	11	300	0.0230	
	Mean	0.20	0.134	0.0015	0.0496	137	15	398	0.0410	
	Median	0.06	0.120	0.0005	0.0300	117	12	364	0.0360	
	80th %ile	0.38	0.170	0.0010	0.0694	177	19	477	0.0604	
	95th %ile	0.69	0.256	0.0030	0.1143	226	24	660	0.0846	
	Max	1.50	0.950	0.0320	0.7020	286	28	855	0.1310	
MRMB11 02/09/2001 - 10/12/2014	Count	63	43	63	63	16	16	17	28	
	Min	0.01	0.034	0.0005	0.0025	30	2	0	0.0005	
	5th %ile	0.03	0.074	0.0005	0.0025	39	2	27	0.0024	
	20th %ile	0.05	0.127	0.0005	0.0025	44	2	54	0.0030	
	Mean	0.44	0.215	0.0005	0.0147	57	3	60	0.0052	
	Median	0.39	0.211	0.0005	0.0060	52	2	61	0.0060	
	80th %ile	0.72	0.296	0.0005	0.0200	69	3	72	0.0070	
	95th %ile	0.99	0.355	0.0005	0.0299	88	4	85	0.0083	
	Max	1.49	0.520	0.0020	0.2900	91	7	89	0.0100	

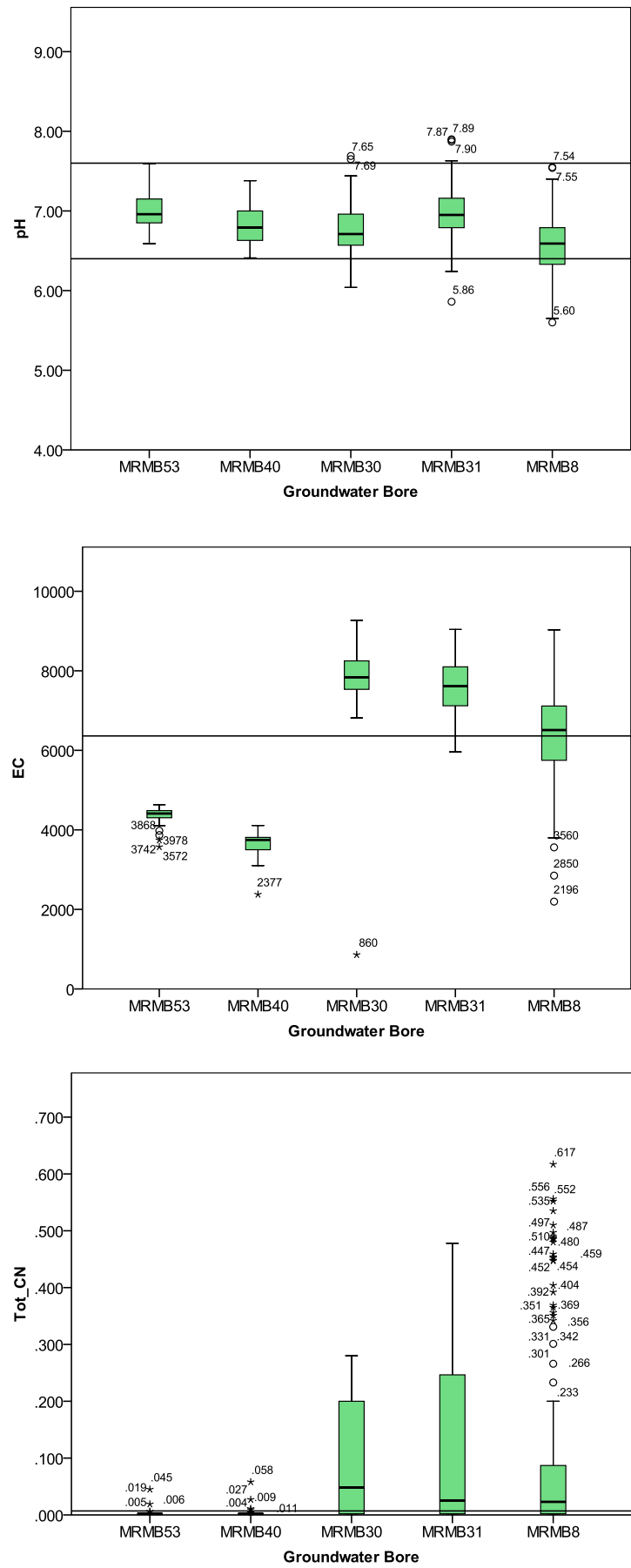
Sample Point	Statistic	pH	EC (µS/cm)	Cyanide Total (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Sulphate (mg/L)	Alk Tot as CaCO3 (mg/L)	SO4/Cl (M/M)	Fluoride (mg/L)	Nitrate as N (mg/L)	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)
MRMB12 02/09/2001 - 15/11/2019	Count	165	166	166	102	101	166	96	100	93	94	166	166	97	166	98	166
	Min	5.65	134	0.002	22	1	2	1	0.01	0.1	0.005	0.005	0.001	0.008	0.00005	0.0005	0.0005
	5th %ile	5.92	471	0.002	52	106	16	57	0.04	0.1	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	20th %ile	6.08	1580	0.002	114	337	62	142	0.05	0.1	0.020	0.005	0.001	0.025	0.00005	0.0005	0.0005
	Mean	6.38	2467	0.024	158	678	123	250	0.07	0.2	0.338	0.011	0.001	0.025	0.00029	0.0007	0.0021
	Median	6.34	2455	0.006	152	676	119	236	0.07	0.2	0.100	0.005	0.001	0.025	0.00005	0.0005	0.0005
	80th %ile	6.65	3480	0.051	209	1010	185	354	0.09	0.3	0.470	0.005	0.001	0.025	0.00020	0.0005	0.0010
	95th %ile	6.91	4433	0.094	270	1230	242	440	0.12	0.7	1.159	0.020	0.001	0.025	0.00068	0.0011	0.0028
	Max	7.46	4990	0.159	320	1410	378	490	0.16	0.9	5.440	0.300	0.002	0.025	0.00900	0.0091	0.1100
MRMB13 02/09/2001 - 06/02/2019	Count	160	161	161	97	97	161	90	97	90	90	161	161	92	0	93	161
	Min	5.76	270	0.002	188	464	15	1	0.04	0.5	0.005	0.002	0.001	0.022	0.00000	0.0005	0.0005
	5th %ile	6.29	2460	0.002	462	901	127	457	0.07	0.9	0.005	0.005	0.001	0.025	N.A	0.0005	0.0005
	20th %ile	6.51	4010	0.002	519	995	228	540	0.08	1.1	0.005	0.005	0.001	0.025	N.A	0.0005	0.0005
	Mean	6.74	4164	0.003	540	1064	243	566	0.09	1.2	0.102	0.025	0.003	0.026	N.A	0.0009	0.0025
	Median	6.71	4374	0.002	539	1060	252	583	0.09	1.2	0.012	0.005	0.003	0.025	N.A	0.0005	0.0005
	80th %ile	6.98	4580	0.002	576	1140	272	614	0.10	1.3	0.070	0.005	0.004	0.025	N.A	0.0005	0.0010
	95th %ile	7.26	4770	0.005	613	1210	296	640	0.11	1.5	0.304	0.120	0.005	0.025	N.A	0.0030	0.0120
	Max	7.74	5180	0.047	654	1740	344	649	0.12	2.1	3.000	0.890	0.020	0.050	N.A	0.0140	0.0650
MRMB41 12/07/2012 - 11/02/2020	Count	72	73	70	70	70	71	70	70	69	69	70	70	70	70	70	70
	Min	6.29	1320	0.002	119	326	28	158	0.03	0.4	0.005	0.001	0.001	0.010	0.00005	0.0005	0.0005
	5th %ile	6.42	1595	0.002	141	391	44	184	0.04	0.5	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	20th %ile	6.51	1781	0.002	160	469	50	199	0.04	0.5	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	Mean	6.74	2013	0.002	179	534	65	223	0.04	0.6	0.009	0.007	0.001	0.025	0.00005	0.0006	0.0006
	Median	6.68	2023	0.002	181	546	67	225	0.05	0.6	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	80th %ile	7.00	2268	0.002	198	596	76	243	0.05	0.6	0.010	0.005	0.001	0.025	0.00005	0.0005	0.0005
	95th %ile	7.20	2369	0.003	210	630	82	257	0.05	0.7	0.020	0.005	0.001	0.025	0.00005	0.0005	0.0005
	Max	7.35	2409	0.012	225	684	88	277	0.05	0.8	0.090	0.170	0.001	0.050	0.00020	0.0046	0.0040
MRMB42 12/07/2012 - 11/02/2020	Count	72	73	71	71	71	72	71	71	69	70	71	71	70	71	71	71
	Min	5.82	575	0.002	52	130	13	68	0.03	0.3	0.005	0.001	0.001	0.025	0.00005	0.0005	0.0005
	5th %ile	5.95	655	0.002	58	150	16	72	0.04	0.4	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	20th %ile	6.09	691	0.002	62	166	18	74	0.04	0.4	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	Mean	6.31	784	0.002	68	195	22	82	0.04	0.4	0.018	0.005	0.001	0.025	0.00006	0.0006	0.0020
	Median	6.29	765	0.002	69	187	22	81	0.04	0.4	0.008	0.005	0.001	0.025	0.00005	0.0005	0.0005
	80th %ile	6.57	876	0.002	73	224	26	89	0.05	0.4	0.030	0.005	0.001	0.025	0.00005	0.0005	0.0005
	95th %ile	6.77	952	0.002	77	248	30	96	0.05	0.5	0.060	0.005	0.001	0.025	0.00010	0.0005	0.0015
	Max	6.85	1059	0.011	85	294	33	101	0.05	0.7	0.120	0.030	0.001	0.025	0.00020	0.0029	0.1000
MRMB65 11/12/2013 - 15/01/2020	Count	53	56	53	53	52	53	53	52	53	52	53	53	53	53	52	53
	Min	6.33	5713	0.002	880	1300	104	542	0.02	1.1	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	5th %ile	6.45	6088	0.002	954	1396	110	612	0.02	1.5	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	20th %ile	6.50	6300	0.002	975	1552	112	810	0.02	1.6	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	Mean	6.67	6352	0.004	1019	1621	117	836	0.03	1.8	0.008	0.005	0.001	0.026	0.00005	0.0005	0.0005
	Median	6.60	6375	0.002	1020	1635	117	862	0.03	1.8	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	80th %ile	6.82	6490	0.005	1066	1718	121	891	0.03	2.0	0.010	0.005	0.001	0.025	0.00005	0.0005	0.0005
	95th %ile	7.13	6529	0.008	1102	1769	126	916	0.03	2.2	0.020	0.005	0.001	0.025	0.00005	0.0005	0.0007
	Max	7.29	6570	0.025	1150	1790	148	934	0.04	2.9	0.050	0.010	0.001	0.060	0.00005	0.0020	0.0010
MRMB52 16/05/2012 - 05/02/2019	Count	69	69	69	69	69	69	69	69	69	68	69	69	69	69	67	69
	Min	6.49	2167	0.002	353	534	50	316	0.02	1.2	0.005	0.001	0.001	0.023	0.00005	0.0005	0.0005
	5th %ile	6.61	2781	0.002	386	669	60	404	0.03	1.3	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	20th %ile	6.70	2868	0.002	405	703	65	416	0.03	1.4	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	Mean	6.89	2934	0.002	432	727	67	430	0.03	1.5	0.008	0.006	0.001	0.025	0.00005	0.0007	0.0006
	Median	6.80	2948	0.002	431	730	67	428	0.03	1.5	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	80th %ile	7.10	3020	0.002	457	755	69	445	0.04	1.6	0.010	0.005	0.001	0.025	0.00005	0.0005	0.0005
	95th %ile	7.32	3082	0.002	490	789	76	457	0.04	1.7	0.020	0.005	0.001	0.025	0.00005	0.0005	0.0010
	Max	7.41	3139	0.010	521	814	83	470	0.05	2.1	0.040	0.040	0.002	0.050	0.00005	0.0098	0.0060

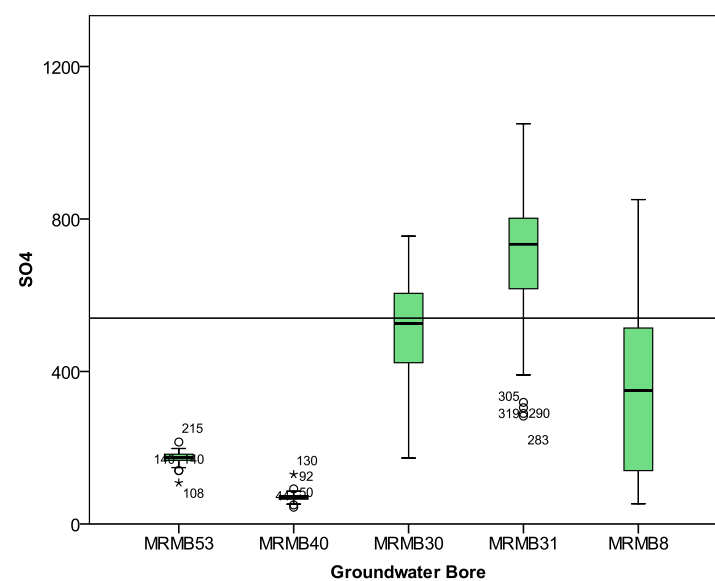
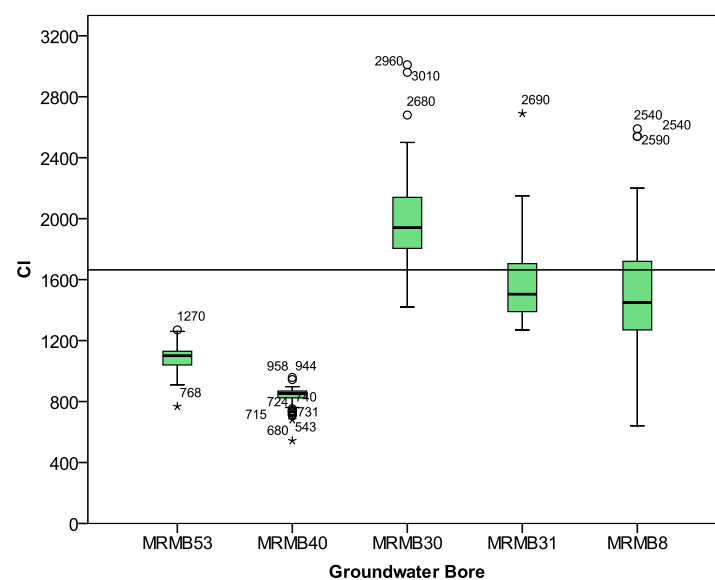
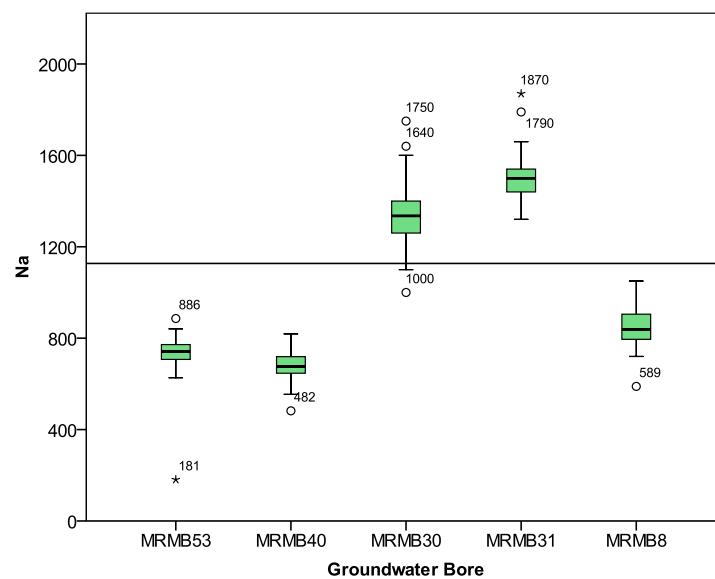
Statistic	Statistic	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Lead Dissolved (mg/L)	Zinc Dissolved (mg/L)	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Molybdenum Dissolved (mg/L)	Se Diss (mg/L)
MRMB12 02/09/2001 - 15/11/2019	Count	166	142	166	166	96	96	97	116	37
	Min	0.01	0.003	0.0005	0.0020	1	1	1	0.0005	0.0050
	5th %ile	0.03	0.024	0.0005	0.0025	25	1	14	0.0005	0.0050
	20th %ile	0.03	0.110	0.0005	0.0025	94	2	54	0.0005	0.0050
	Mean	0.26	0.244	0.0006	0.0213	204	3	111	0.0005	0.0050
	Median	0.15	0.214	0.0005	0.0155	192	3	103	0.0005	0.0050
	80th %ile	0.38	0.372	0.0005	0.0300	311	3	172	0.0005	0.0050
	95th %ile	0.90	0.529	0.0005	0.0653	392	4	210	0.0005	0.0050
	Max	2.50	1.110	0.0060	0.2900	466	4	244	0.0020	0.0050
MRMB13 02/09/2001 - 06/02/2019	Count	161	136	161	160	91	91	91	110	32
	Min	0.00	0.001	0.0005	0.0025	1	1	1	0.0005	0.0050
	5th %ile	0.03	0.363	0.0005	0.0025	155	4	144	0.0020	0.0050
	20th %ile	0.20	0.520	0.0005	0.0025	175	4	155	0.0030	0.0050
	Mean	0.47	0.611	0.0011	0.0248	184	5	163	0.0030	0.0050
	Median	0.45	0.625	0.0005	0.0130	188	5	166	0.0030	0.0050
	80th %ile	0.64	0.708	0.0005	0.0300	201	6	174	0.0030	0.0050
	95th %ile	0.84	0.817	0.0030	0.0900	207	6	181	0.0040	0.0050
	Max	2.70	1.100	0.0270	0.4400	211	8	187	0.0040	0.0050
MRMB41 12/07/2012 - 11/02/2020	Count	75	70	70	70	70	70	70	70	30
	Min	0.03	0.604	0.0005	0.0010	54	2	55	0.0005	0.0050
	5th %ile	0.62	0.626	0.0005	0.0025	68	3	67	0.0010	0.0050
	20th %ile	1.75	0.656	0.0005	0.0025	78	4	79	0.0020	0.0050
	Mean	2.00	0.708	0.0011	0.0044	89	4	89	0.0020	0.0050
	Median	2.05	0.694	0.0005	0.0025	91	4	91	0.0020	0.0050
	80th %ile	2.41	0.751	0.0005	0.0052	100	4	99	0.0020	0.0050
	95th %ile	2.76	0.807	0.0005	0.0107	106	5	107	0.0020	0.0050
	Max	3.65	1.370	0.0380	0.0340	118	5	114	0.0040	0.0050
MRMB42 12/07/2012 - 11/02/2020	Count	68	74	71	71	71	71	71	71	31
	Min	0.05	1.130	0.0005	0.0025	24	2	21	0.0005	0.0050
	5th %ile	0.07	1.863	0.0005	0.0025	28	2	22	0.0005	0.0050
	20th %ile	0.10	2.106	0.0005	0.0025	30	2	24	0.0005	0.0050
	Mean	0.43	2.616	0.0010	0.0057	35	2	28	0.0007	0.0050
	Median	0.30	2.620	0.0005	0.0025	34	2	27	0.0005	0.0050
	80th %ile	0.69	3.038	0.0005	0.0070	39	3	32	0.0010	0.0050
	95th %ile	1.25	3.587	0.0005	0.0155	44	3	39	0.0010	0.0050
	Max	1.98	4.110	0.0330	0.0740	51	3	45	0.0010	0.0050
MRMB65 11/12/2013 - 15/01/2020	Count	53	53	53	53	53	53	53	53	29
	Min	1.08	0.679	0.0005	0.0025	124	6	137	0.0025	0.0050
	5th %ile	1.10	0.703	0.0005	0.0025	132	7	153	0.0050	0.0050
	20th %ile	1.17	0.754	0.0005	0.0025	141	7	162	0.0050	0.0050
	Mean	1.25	0.773	0.0005	0.0046	146	8	167	0.0057	0.0050
	Median	1.25	0.776	0.0005	0.0025	147	8	170	0.0060	0.0050
	80th %ile	1.31	0.796	0.0005	0.0056	154	9	174	0.0060	0.0050
	95th %ile	1.43	0.826	0.0005	0.0172	158	10	178	0.0060	0.0050
	Max	1.56	0.925	0.0005	0.0200	161	10	187	0.0070	0.0050
MRMB52 16/05/2012 - 05/02/2019	Count	69	69	69	69	69	69	69	69	27
	Min	0.03	0.077	0.0005	0.0010	70	3	57	0.0005	0.0050
	5th %ile	0.96	0.082	0.0005	0.0025	81	3	66	0.0020	0.0050
	20th %ile	1.07	0.091	0.0005	0.0025	88	4	70	0.0020	0.0050
	Mean	1.16	0.108	0.0030	0.0054	94	4	73	0.0027	0.0050
	Median	1.14	0.107	0.0005	0.0025	95	4	73	0.0030	0.0050
	80th %ile	1.27	0.117	0.0005	0.0060	99	4	77	0.0030	0.0050
	95th %ile	1.51	0.156	0.0005	0.0142	102	5	80	0.0036	0.0050
	Max	1.85	0.230	0.1640	0.0760	104	5	83	0.0040	0.0050

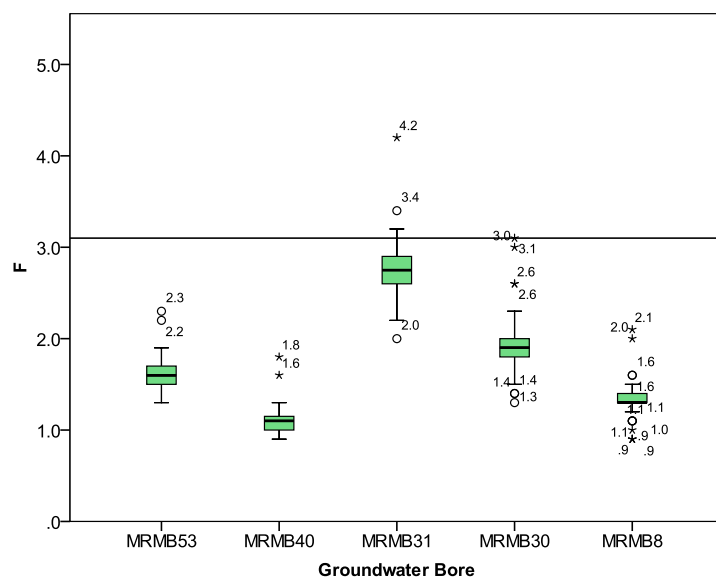
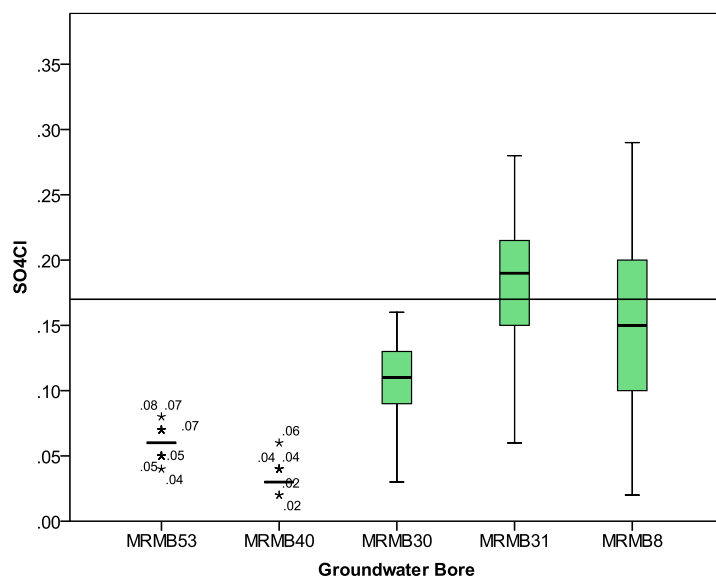
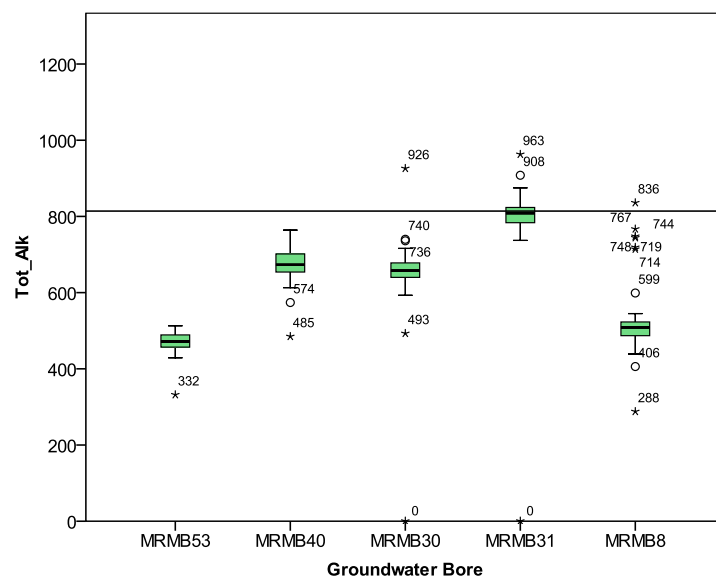
Sample Point	Statistic	pH	EC (µS/cm)	Cyanide Total (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Sulphate (mg/L)	Alk Tot as CaCO3 (mg/L)	SO4/Cl (M/M)	Fluoride (mg/L)	Nitrate as N (mg/L)	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)
MRMB54 16/05/2012 - 05/02/2019	Count	18	18	17	18	18	18	17	18	17	17	17	17	17	17	17	17
	Min	6.53	2094	0.002	394	380	84	539	0.08	2.8	0.005	0.005	0.002	0.025	0.00005	0.0005	0.0005
	5th %ile	6.59	2101	0.002	401	384	93	551	0.08	2.8	0.005	0.005	0.002	0.025	0.00005	0.0005	0.0005
	20th %ile	6.80	2213	0.002	411	389	99	562	0.09	2.9	0.005	0.005	0.002	0.025	0.00005	0.0005	0.0005
	Mean	6.91	2278	0.002	431	398	105	588	0.10	3.1	0.005	0.005	0.003	0.025	0.00005	0.0005	0.0006
	Median	6.84	2299	0.002	433	396	103	580	0.10	3.1	0.005	0.005	0.003	0.025	0.00005	0.0005	0.0005
	80th %ile	7.12	2315	0.002	450	404	107	617	0.10	3.1	0.005	0.005	0.004	0.025	0.00005	0.0005	0.0005
	95th %ile	7.22	2419	0.003	452	414	121	635	0.11	3.5	0.005	0.005	0.004	0.025	0.00005	0.0005	0.0010
	Max	7.29	2479	0.005	454	450	142	649	0.13	3.5	0.005	0.005	0.005	0.025	0.00005	0.0005	0.0010

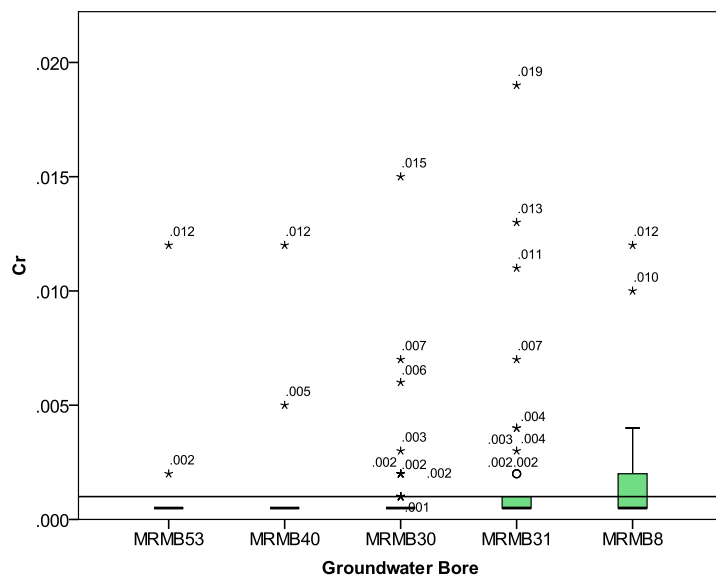
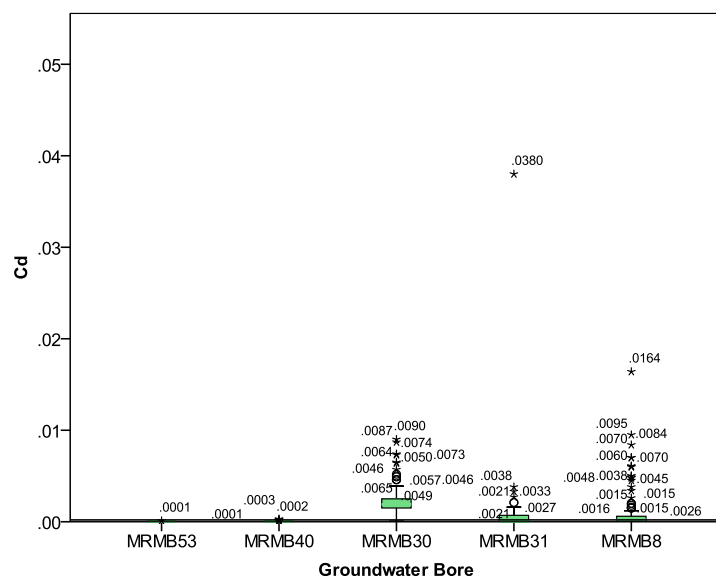
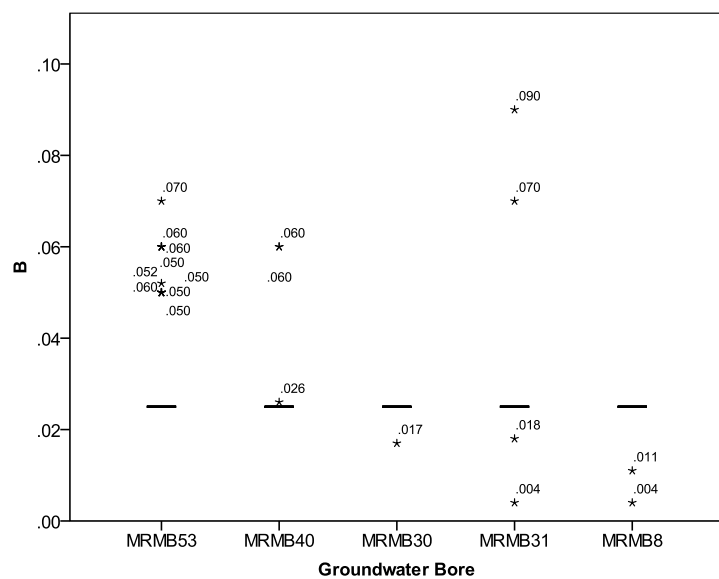
Statistic	Statistic	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Lead Dissolved (mg/L)	Zinc Dissolved (mg/L)	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Molybdenum Dissolved (mg/L)	Se Diss (mg/L)
MRMB54 16/05/2012 - 05/02/2019	Count	18	18	17	17	18	18	18	17	10
	Min	0.30	0.109	0.0005	0.0025	30	3	34	0.0080	0.0050
	5th %ile	0.52	0.111	0.0005	0.0025	32	4	35	0.0080	0.0050
	20th %ile	0.62	0.119	0.0005	0.0025	33	4	35	0.0080	0.0050
	Mean	0.67	0.137	0.0008	0.0058	54	4	37	0.0090	0.0050
	Median	0.65	0.124	0.0005	0.0025	35	4	37	0.0090	0.0050
	80th %ile	0.73	0.165	0.0005	0.0074	36	4	38	0.0098	0.0050
	95th %ile	0.81	0.182	0.0016	0.0156	89	4	38	0.0106	0.0050
	Max	1.10	0.213	0.0060	0.0380	380	5	39	0.0130	0.0050

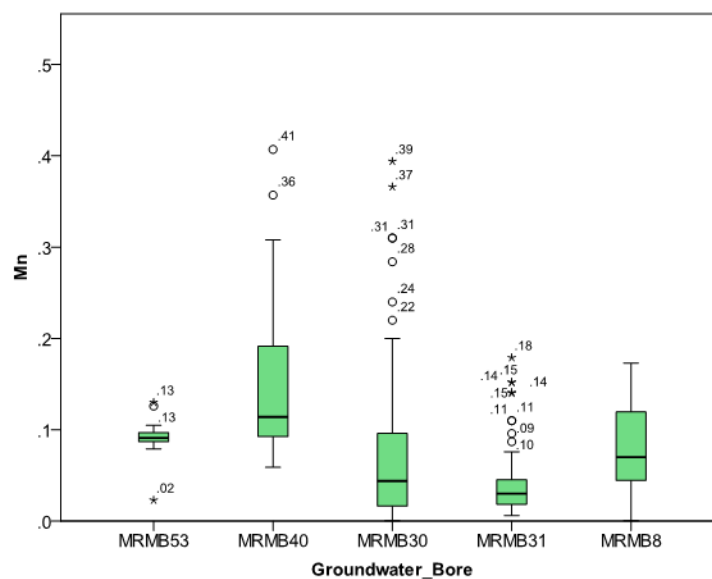
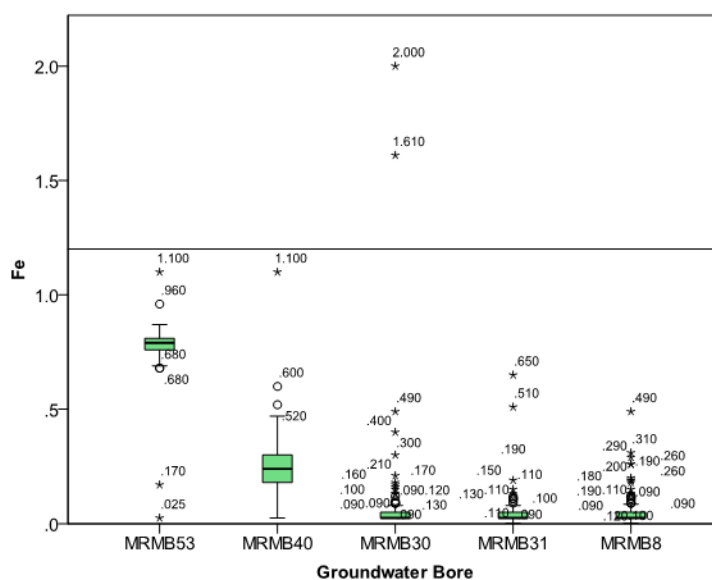
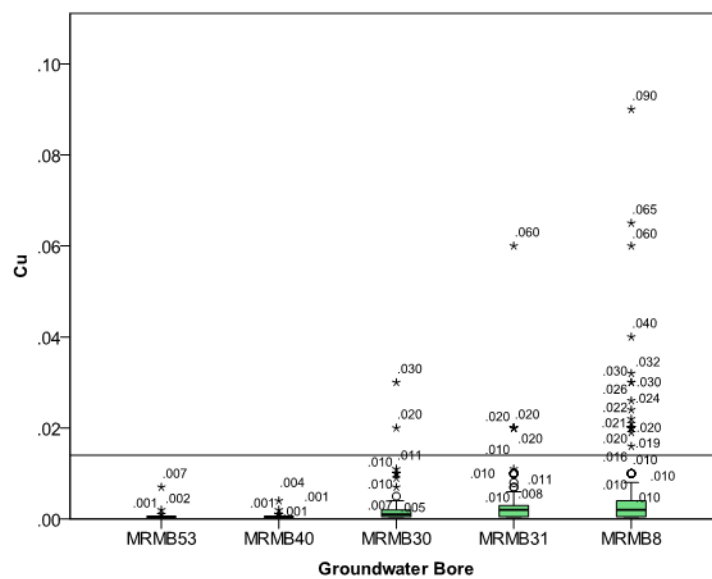
Appendix 14: Data Summaries for the Unnamed Creek between Swindon Creek and Rawdon Creek

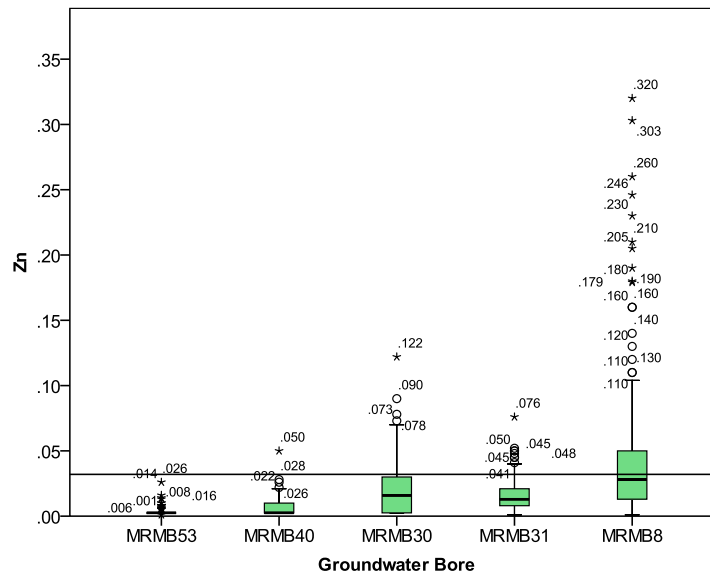
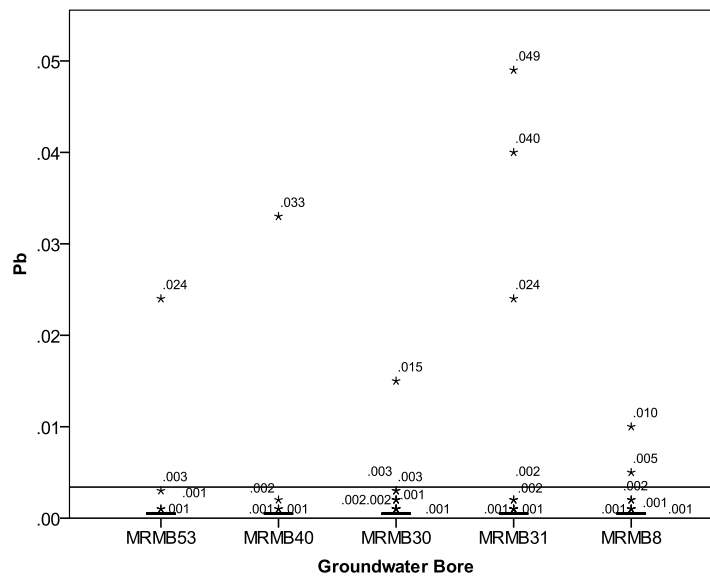






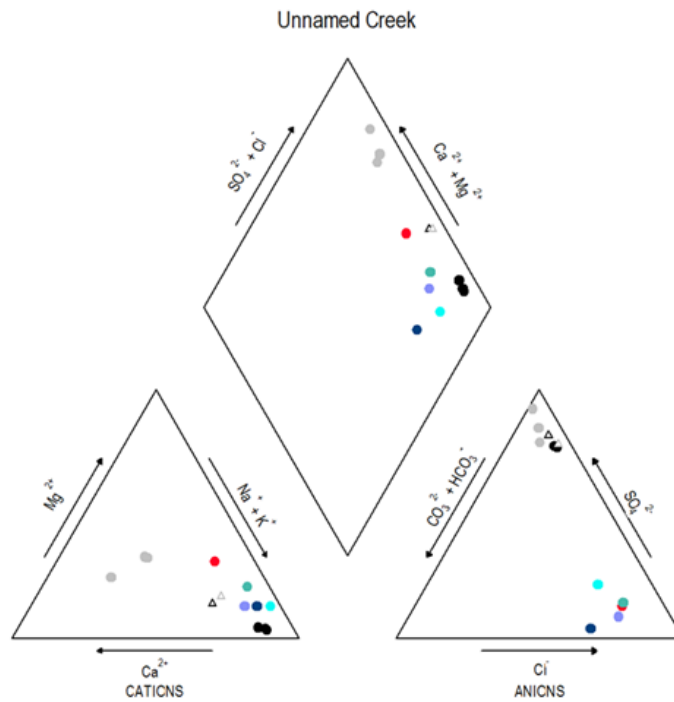






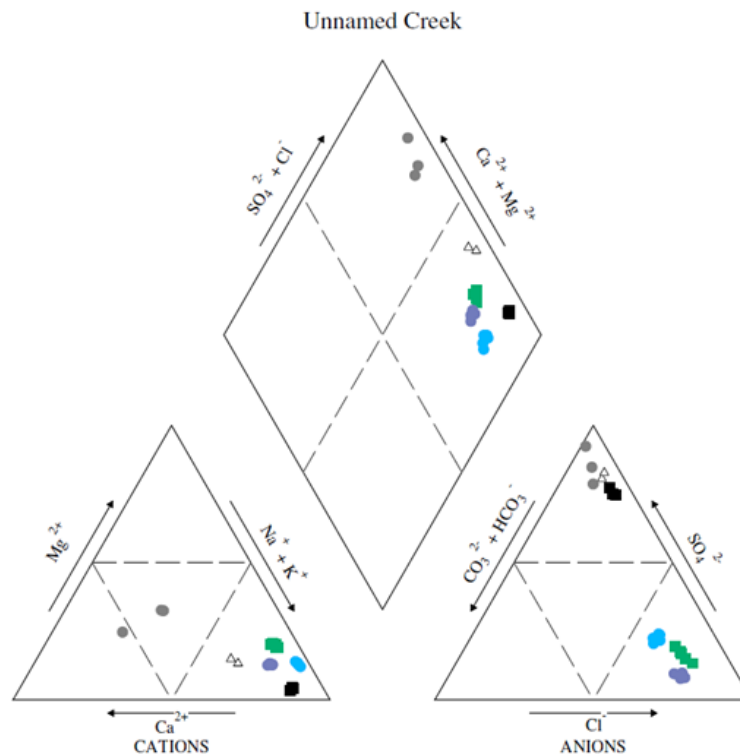
A

EXPLANATION
 ● Waste Rock
 ● Waste Rock
 ● Waste Rock
 ● Decant
 ● Decant
 ● Decant
 △ Seep 26
 △ Sediment Dam 1
 ● MRMB08
 ● MRMB31
 ● MRMB30
 ● MRMB40
 ● MRMB53



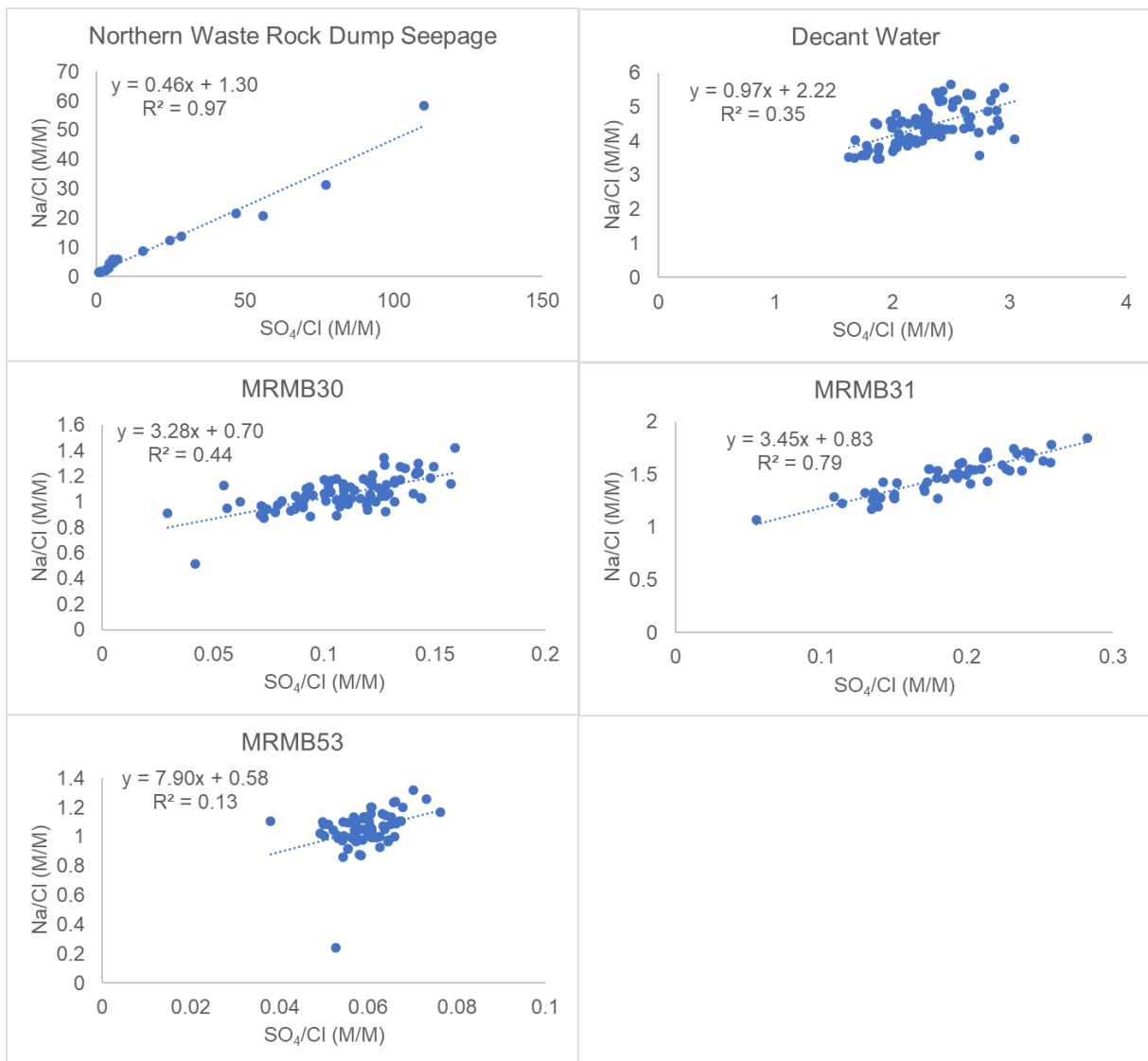
B

EXPLANATION
 △ Seep 26
 ● Waste Rock
 ● Decant
 ● MRMB30
 ● MRMB31
 ● MRMB53



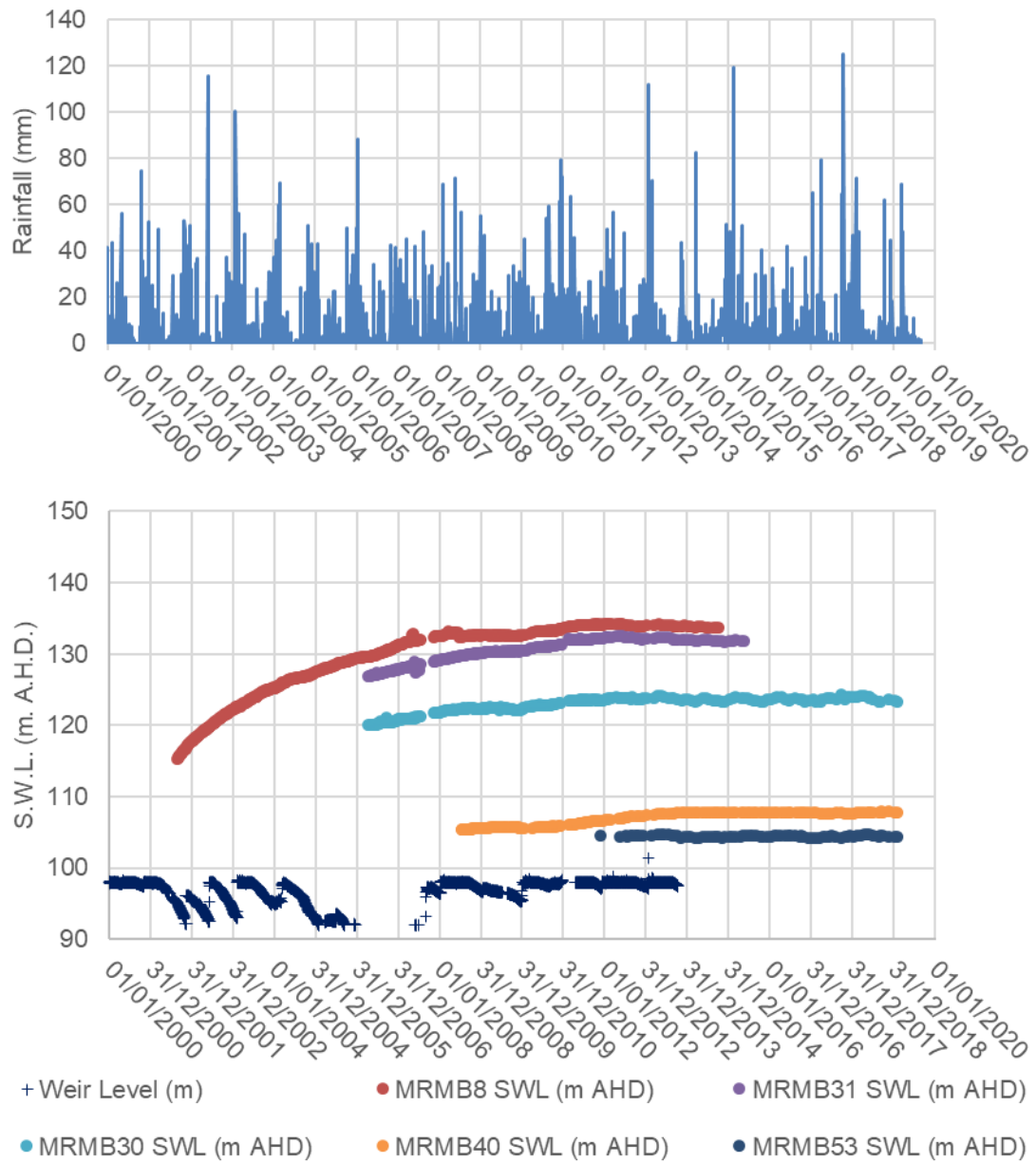
³⁵ Footnote

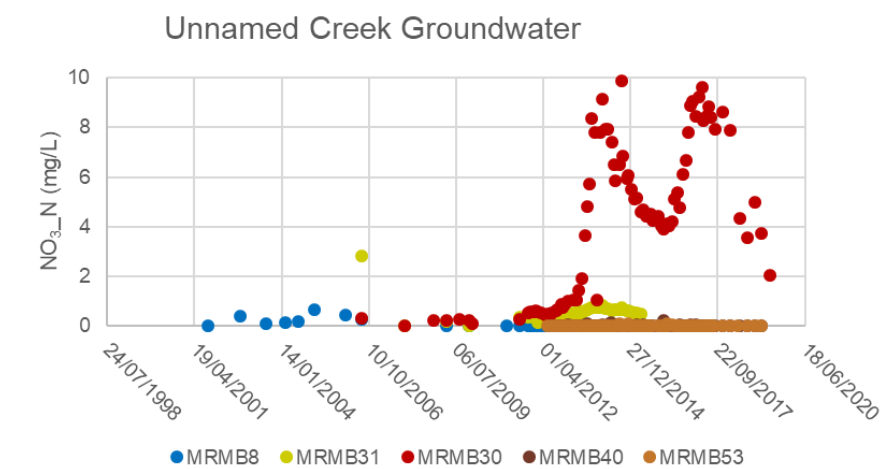
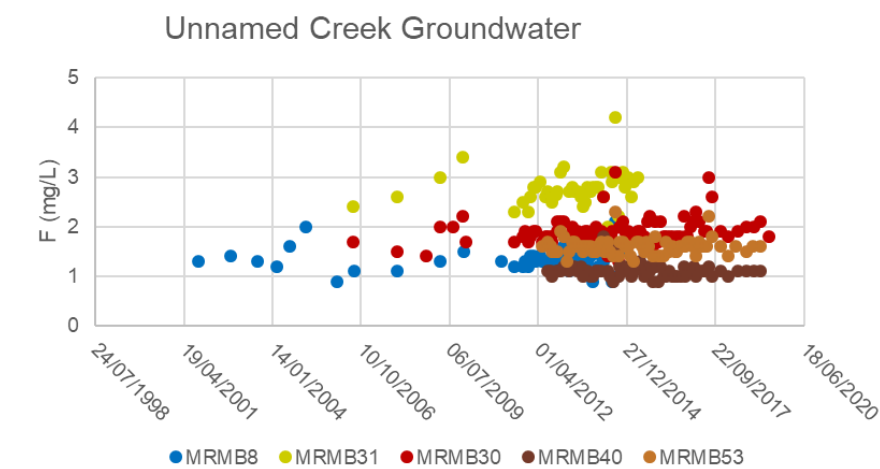
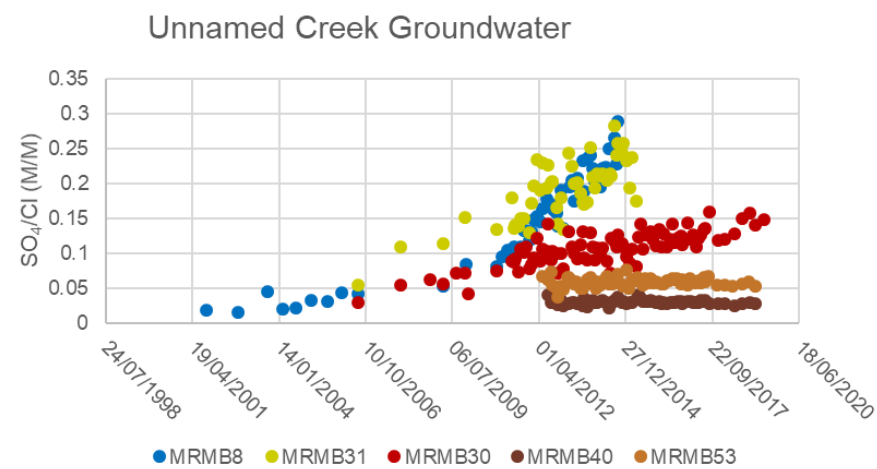
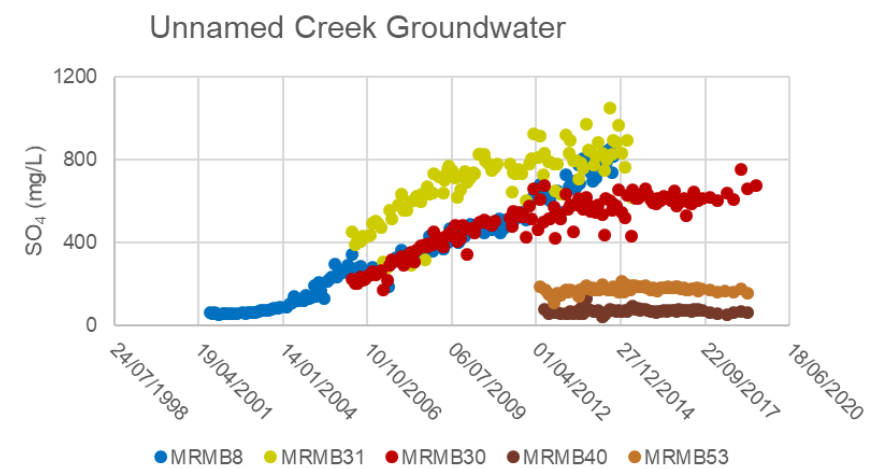
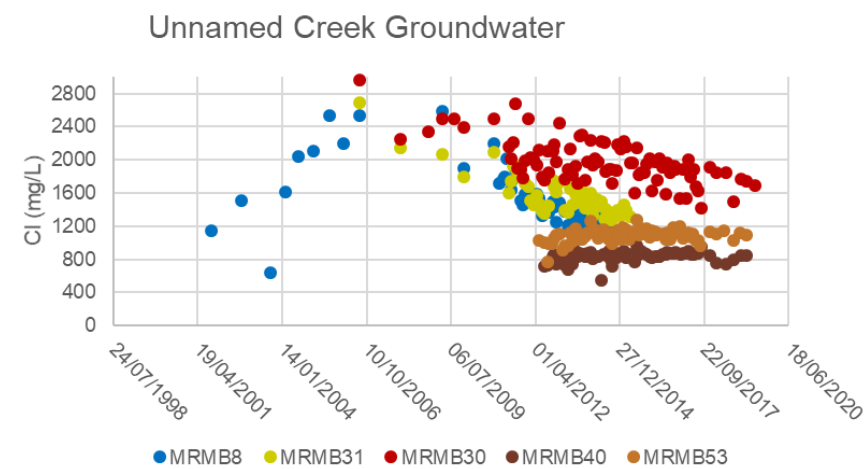
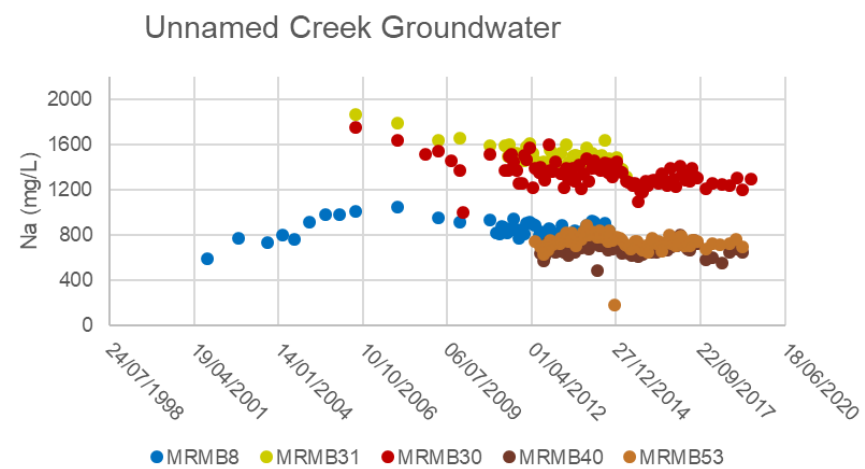
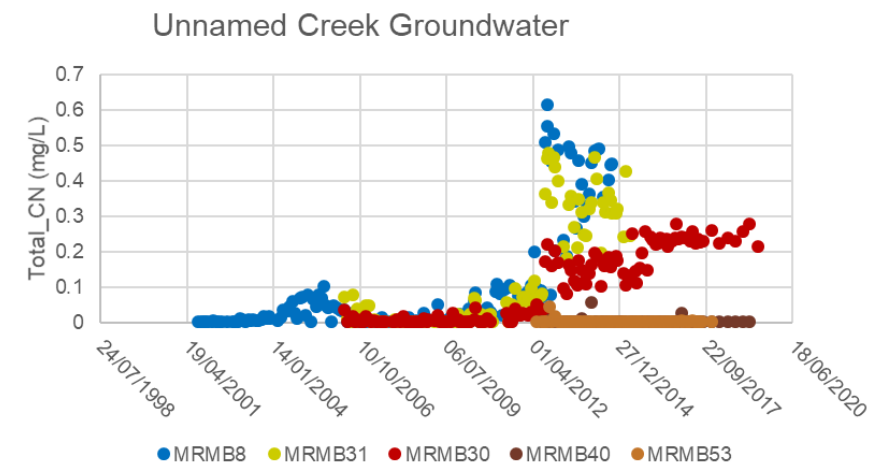
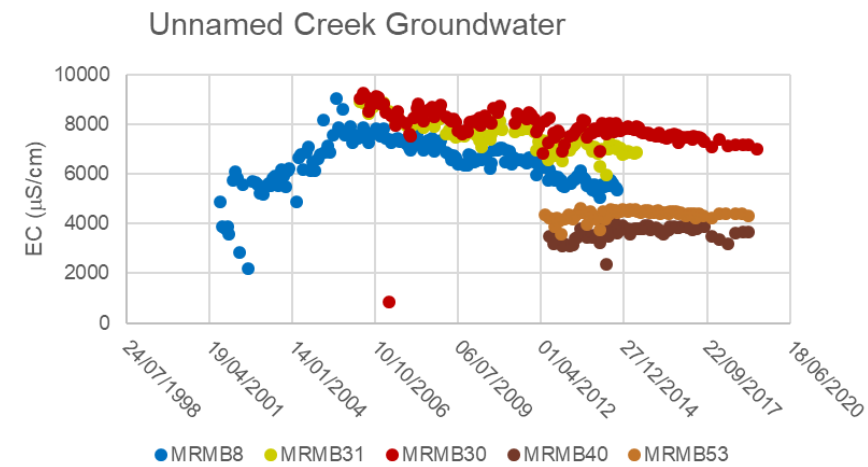
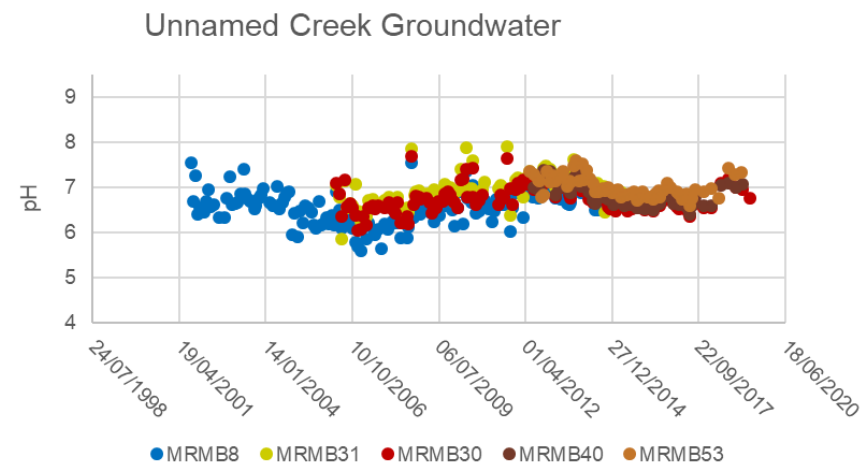
³⁵ A represents median cation and anion concentrations in groundwater monitoring bores, and representative cation and anion concentrations in waste - rock seepage and decant water. B shows representative cation and anion concentrations in selected groundwater monitoring bores, waste – rock seepage and decant water.

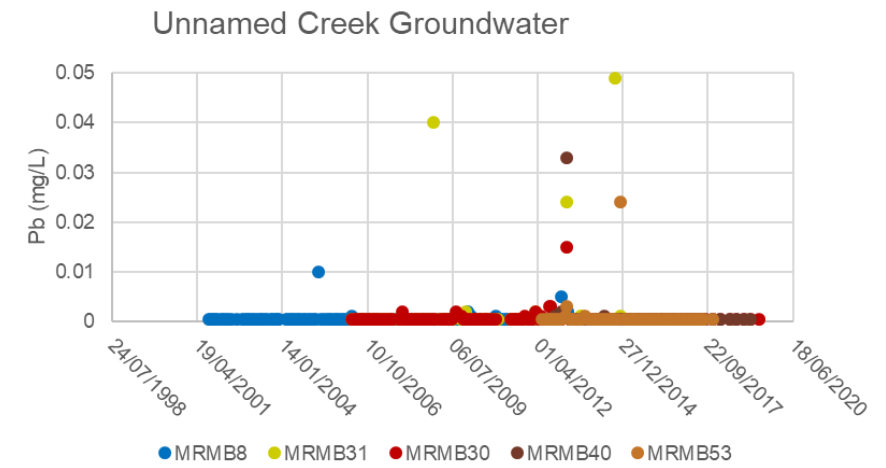
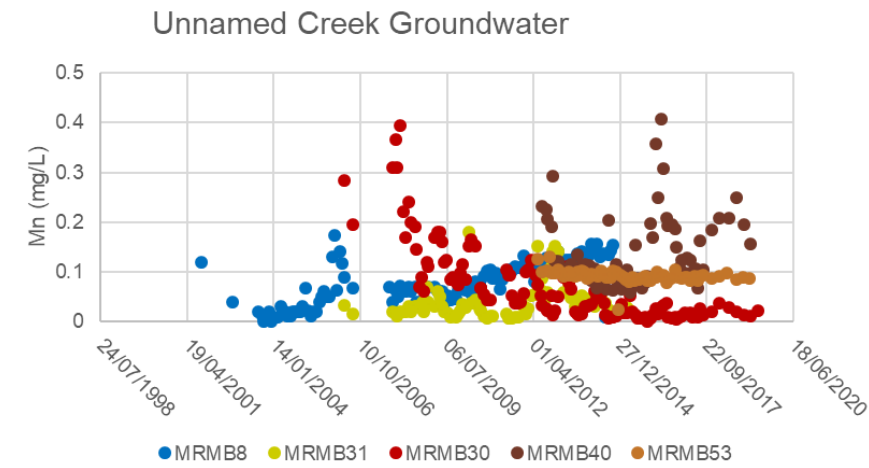
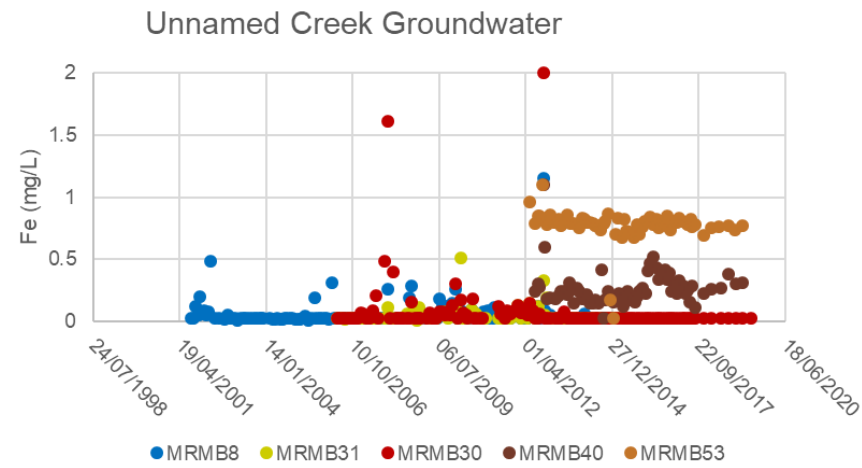
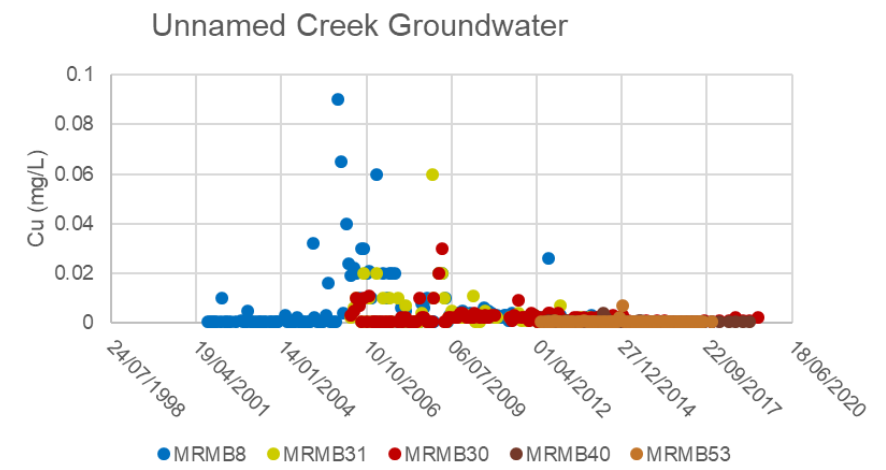
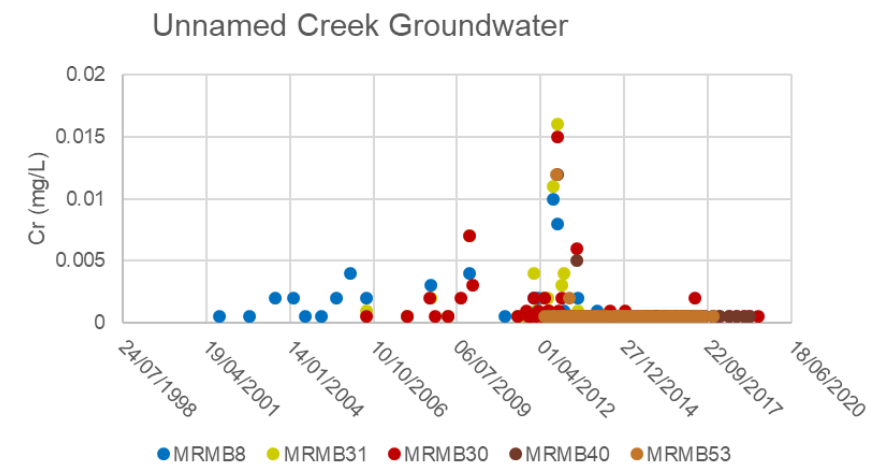
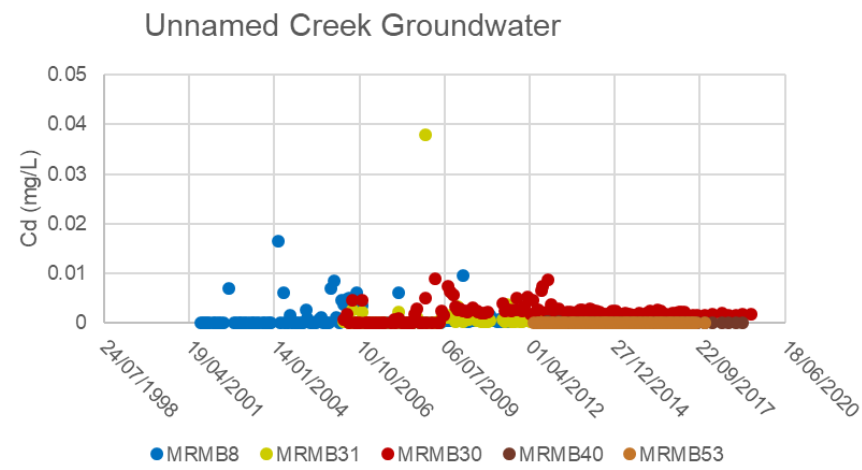
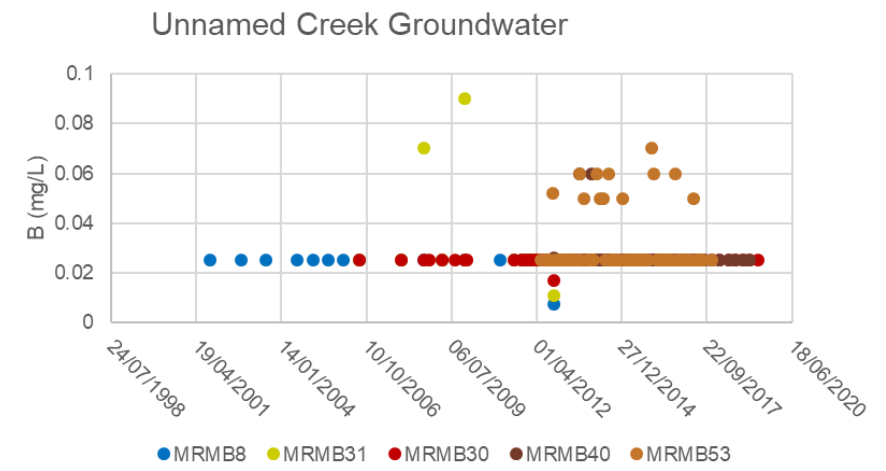
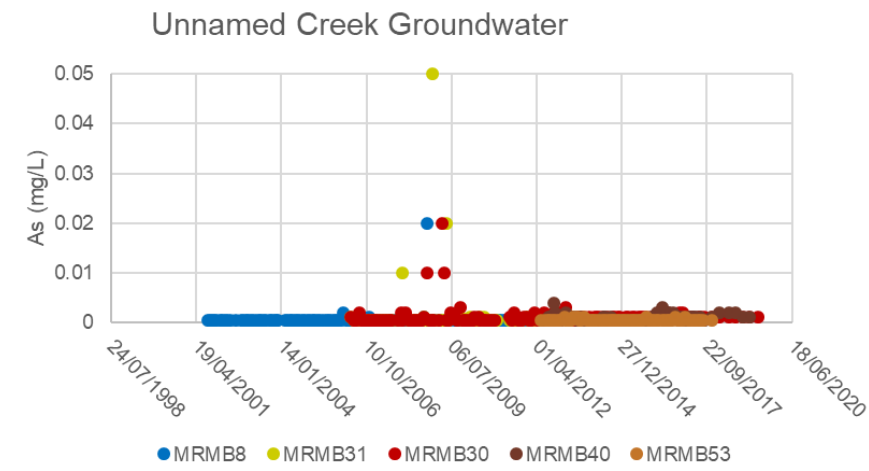
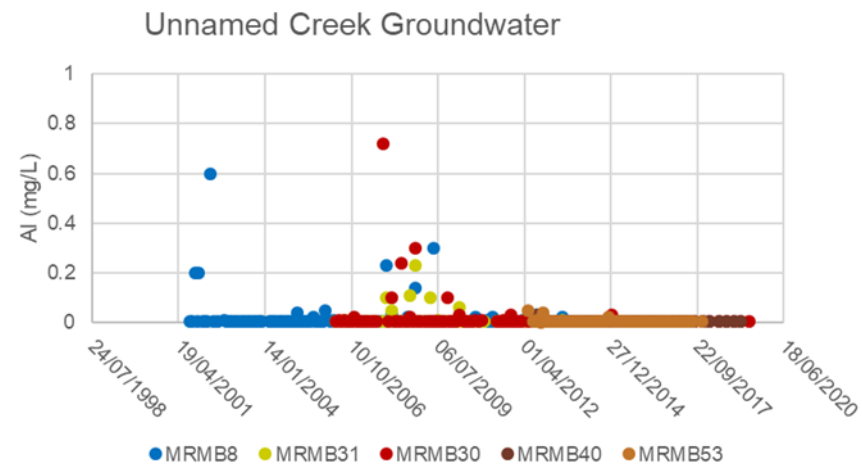


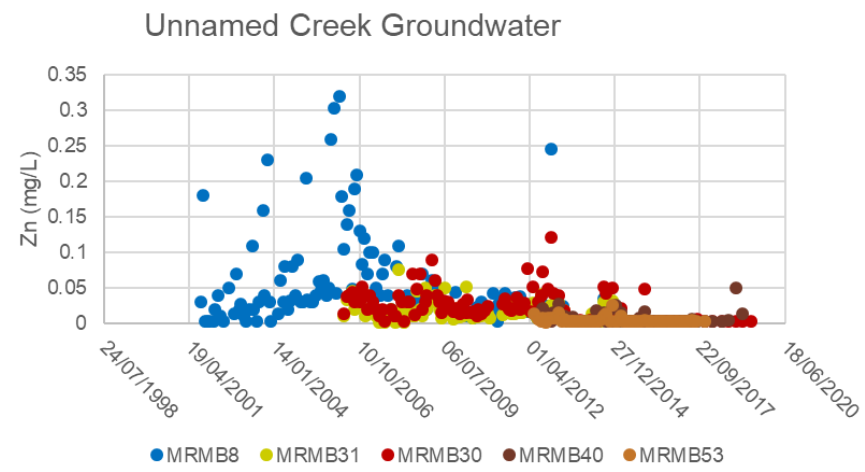
³⁶ Footnote

³⁶ Na/Cl (M/M) vs SO₄/Cl (M/M) concentration ratios in the source term (waste rock seepage, decant water) and in selected groundwater samples from the unnamed creek showing correlations associated with neutral mine drainage in mining affected water (MRMB31, MRMB30).





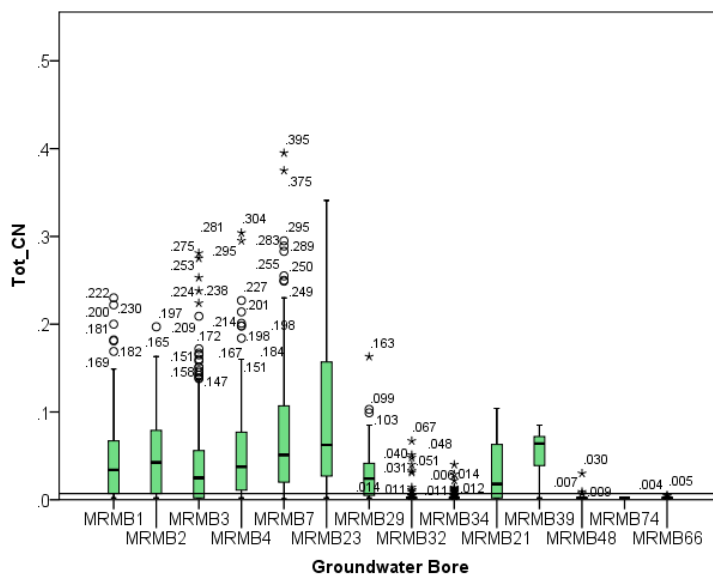
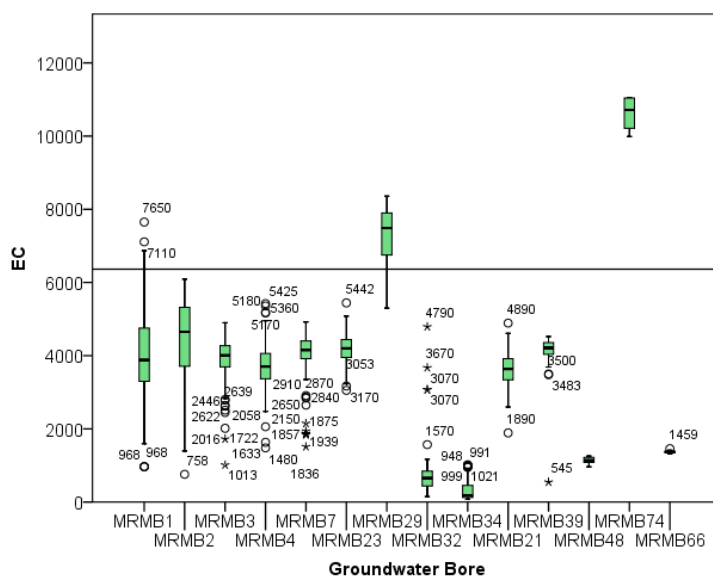
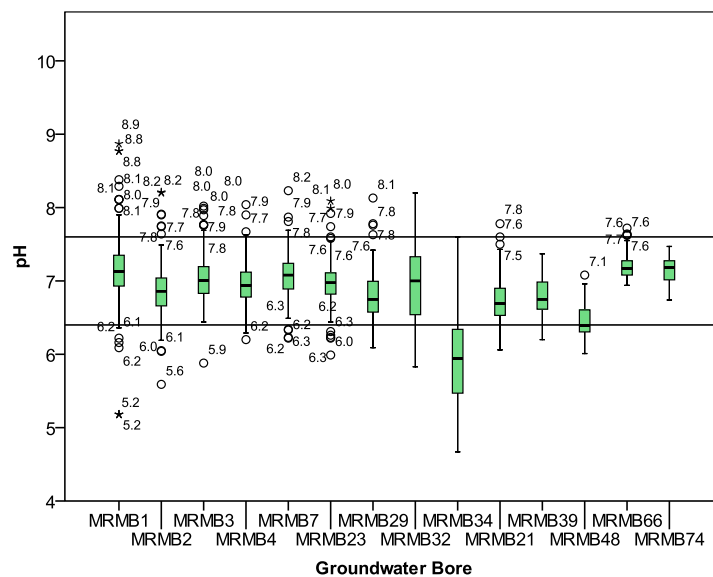


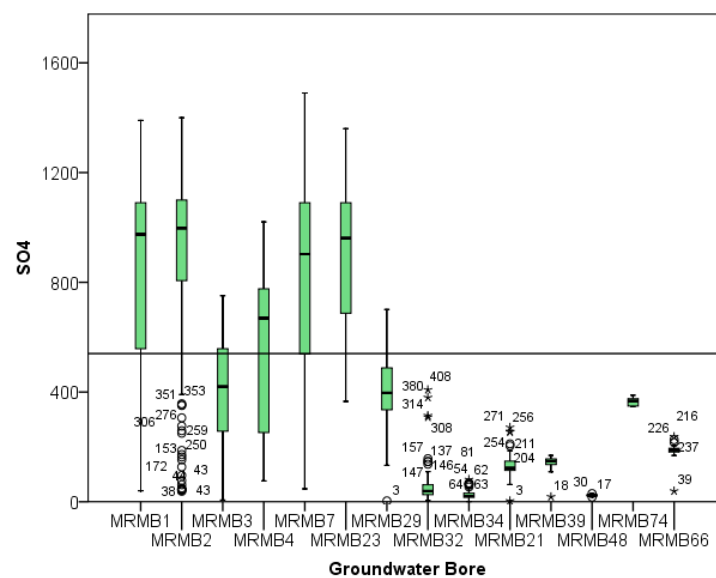
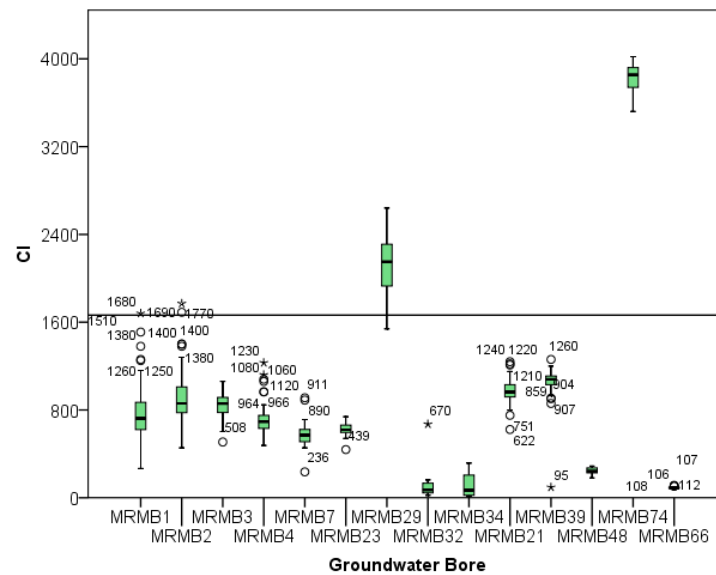
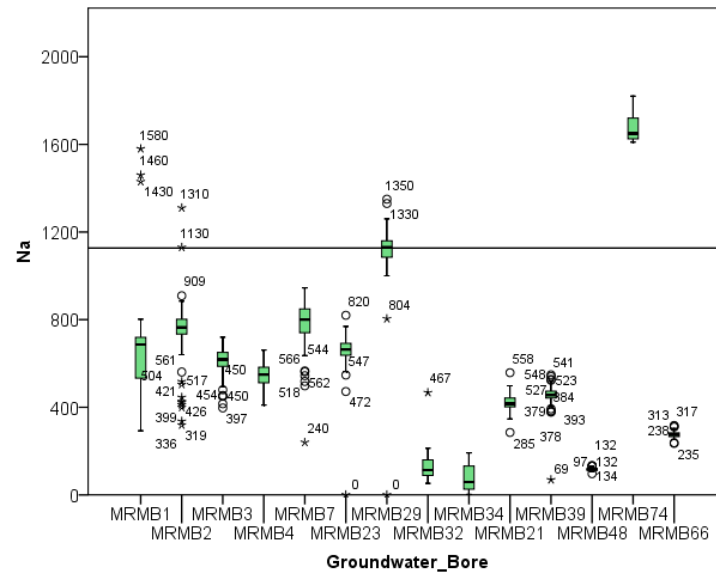


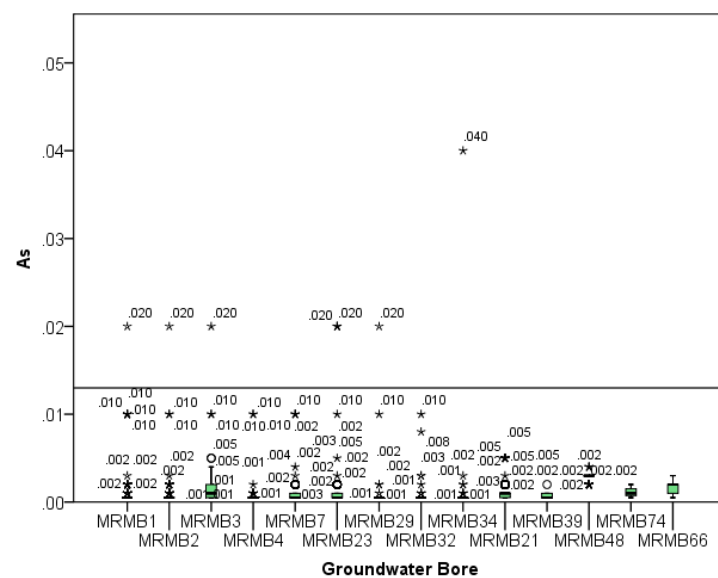
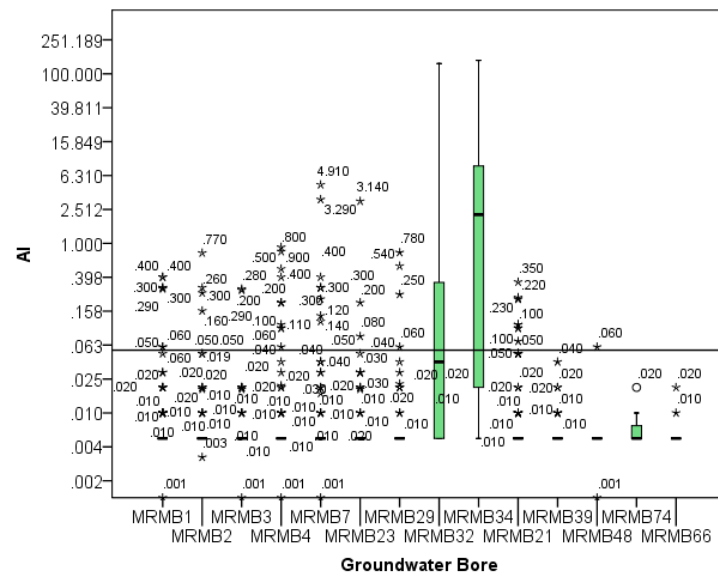
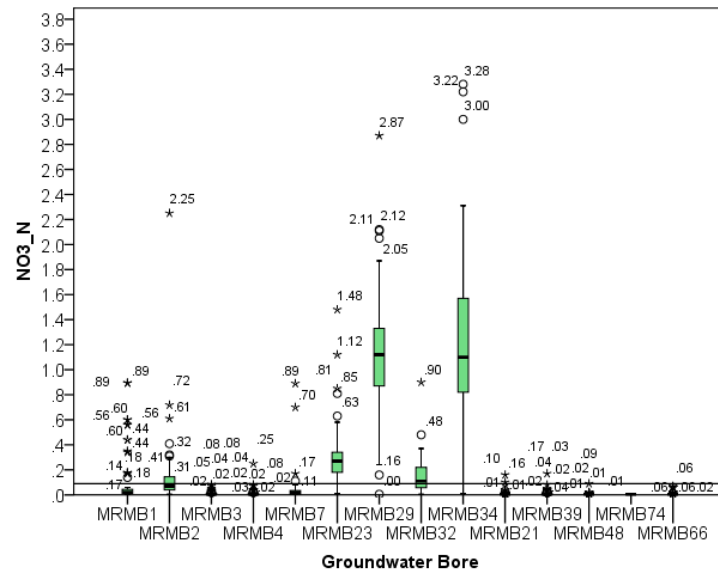
Sample Point	Statistic	pH	EC (µS/cm)	Cyanide Total (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Sulphate (mg/L)	Alk Tot as CaCO3 (mg/L)	SO4/Cl (M/M)	Fluoride (mg/L)	Nitrate as N (mg/L)	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)
MRMB08 30/08/2001 - 01/10/2014	Count	154	155	158	58	57	154	53	57	50	49	154	154	51	154	51	154
	Min	5.60	2196	0.002	589.00	641.00	53.00	288.00	0.02	0.9	0.005	0.001	0.0005	0.004	0.0001	0.0005	0.0005
	5th %ile	5.94	4982	0.002	743	1166	60	443	0.02	0.9	0.005	0.005	0.0005	0.025	0.0001	0.0005	0.0005
	20th %ile	6.22	5617	0.002	788	1242	119	475	0.09	1.2	0.005	0.005	0.0005	0.025	0.0001	0.0005	0.0005
	Mean	6.57	6414	0.099	847	1534	367	526	0.15	1.3	0.054	0.017	0.0007	0.024	0.0009	0.0014	0.0059
	Median	6.59	6510	0.023	839	1450	351	509	0.15	1.3	0.005	0.005	0.0005	0.025	0.0002	0.0005	0.0020
	80th %ile	6.88	7282	0.105	914	1786	593	538	0.22	1.4	0.020	0.005	0.0005	0.025	0.0008	0.0020	0.0054
	95th %ile	7.18	7758	0.487	986	2268	776	746	0.25	1.6	0.340	0.033	0.0010	0.025	0.0053	0.0040	0.0247
	Max	7.55	9030	0.617	1050	2590	851	836	0.29	2.1	0.660	0.600	0.0200	0.025	0.0164	0.0120	0.0900
MRMB31 11/04/2006 - 20/05/2015	Count	102	103	103	52	52	101	48	52	46	46	101	101	48	101	48	101
	Min	5.86	5960	0.002	1320	1270	283	1	0.06	2.0	0.01	0.001	0.0005	0.004	0.00005	0.0005	0.0005
	5th %ile	6.45	6802	0.002	1371	1301	404	760	0.12	2.3	0.15	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	20th %ile	6.71	7024	0.002	1430	1382	583	779	0.15	2.5	0.37	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	Mean	6.96	7647	0.120	1505	1588	697	795	0.19	2.8	0.56	0.012	0.0014	0.027	0.00083	0.0018	0.0059
	Median	6.95	7610	0.025	1500	1505	734	809	0.19	2.8	0.53	0.005	0.0005	0.025	0.00005	0.0005	0.0020
	80th %ile	7.21	8226	0.311	1578	1738	827	834	0.23	3.0	0.70	0.005	0.0005	0.025	0.00080	0.0016	0.0040
	95th %ile	7.49	8874	0.426	1649	2079	913	870	0.25	3.2	0.74	0.050	0.0010	0.025	0.00210	0.0096	0.0200
	Max	7.90	9040	0.478	1870	2690	1050	963	0.28	4.2	2.82	0.230	0.0500	0.090	0.03800	0.0190	0.2250
MRMB30 12/04/2006 - 15/11/2019	Count	137	137	136	92	91	137	86	91	85	86	137	137	88	137	88	137
	Min	6.04	860	0.002	1000	1420	173	1	0.03	1.3	0.01	0.005	0.001	0.017	0.0001	0.0005	0.0005
	5th %ile	6.37	7130	0.002	1186	1595	234	614	0.07	1.6	0.23	0.005	0.001	0.025	0.0001	0.0005	0.0005
	20th %ile	6.55	7480	0.002	1260	1770	382	635	0.09	1.8	0.59	0.005	0.001	0.025	0.0009	0.0005	0.0005
	Mean	6.76	7870	0.101	1342	1985	497	653	0.11	1.9	4.29	0.041	0.001	0.025	0.0021	0.0010	0.0022
	Median	6.71	7840	0.048	1335	1940	526	658	0.11	1.9	4.44	0.005	0.001	0.025	0.0019	0.0005	0.0010
	80th %ile	7.07	8356	0.224	1428	2190	612	683	0.13	2.1	7.82	0.005	0.001	0.025	0.0026	0.0005	0.0030
	95th %ile	7.21	8814	0.246	1529	2500	658	708	0.14	2.3	9.02	0.030	0.002	0.025	0.0053	0.0020	0.0092
	Max	7.69	9270	0.280	1750	3010	755	926	0.16	3.1	9.88	3.320	0.020	0.025	0.0090	0.0150	0.0300
MRMB40 12/07/2012 - 06/02/2019	Count	67	67	67	67	66	67	67	66	67	66	67	67	67	67	66	67
	Min	6.41	2377	0.002	482	543	44	485	0.02	0.9	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	5th %ile	6.54	3156	0.002	588	717	56	620	0.03	1.0	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	20th %ile	6.62	3470	0.002	642	793	63	646	0.03	1.0	0.010	0.005	0.001	0.025	0.00005	0.0005	0.0005
	Mean	6.83	3642	0.003	680	832	70	672	0.03	1.1	0.023	0.006	0.001	0.026	0.00006	0.0007	0.0006
	Median	6.79	3750	0.002	676	852	70	673	0.03	1.1	0.020	0.005	0.001	0.025	0.00005	0.0005	0.0005
	80th %ile	7.03	3830	0.002	726	872	76	706	0.03	1.2	0.020	0.005	0.001	0.025	0.00005	0.0005	0.0005
	95th %ile	7.25	3917	0.007	769	895	82	724	0.04	1.2	0.050	0.005	0.002	0.025	0.00010	0.0005	0.0010
	Max	7.38	4110	0.058	819	958	130	764	0.06	1.8	0.200	0.030	0.004	0.060	0.00030	0.0120	0.0040
MRMB53 16/05/2012 - 05/02/2019	Count	69	69	69	69	69	69	69	69	69	68	69	69	69	69	67	69
	Min	6.59	3572	0.002	181	768	108	332	0.04	1.3	0.005	0.001	0.0005	0.025	0.00005	0.0005	0.0005
	5th %ile	6.75	4030	0.002	662	962	148	433	0.05	1.4	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	20th %ile	6.83	4226	0.002	705	1036	164	450	0.06	1.5	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	Mean	7.01	4364	0.003	736	1086	174	469	0.06	1.6	0.010	0.006	0.0006	0.031	0.00005	0.0007	0.0006
	Median	6.96	4410	0.002	741	1100	174	472	0.06	1.6	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	80th %ile	7.20	4494	0.002	779	1140	186	490	0.06	1.7	0.005	0.005	0.0005	0.035	0.00005	0.0005	0.0005
	95th %ile	7.41	4566	0.004	828	1180	195	499	0.07	1.8	0.046	0.010	0.0010	0.060	0.00005	0.0005	0.0008
	Max	7.59	4633	0.045	886	1270	215	513	0.08	2.3	0.110	0.050	0.0010	0.070	0.00010	0.0120	0.0070

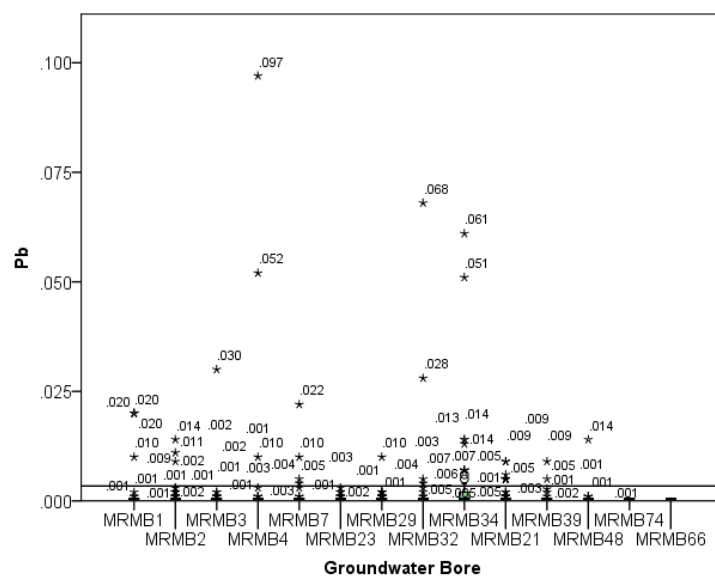
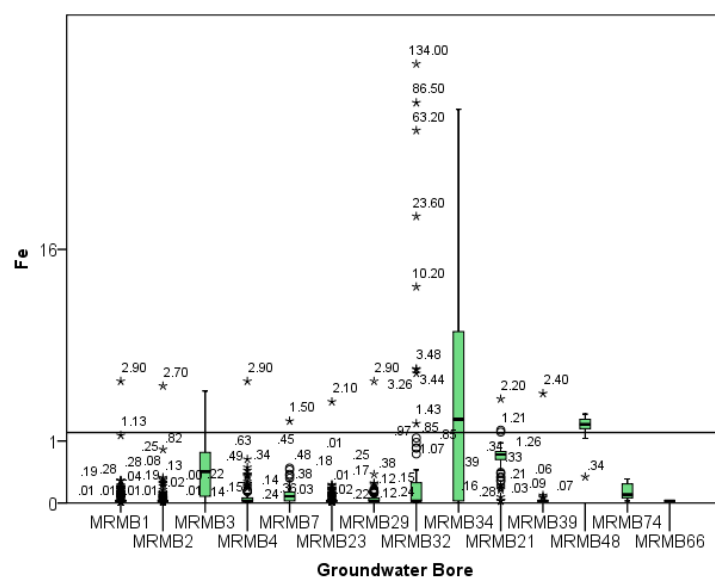
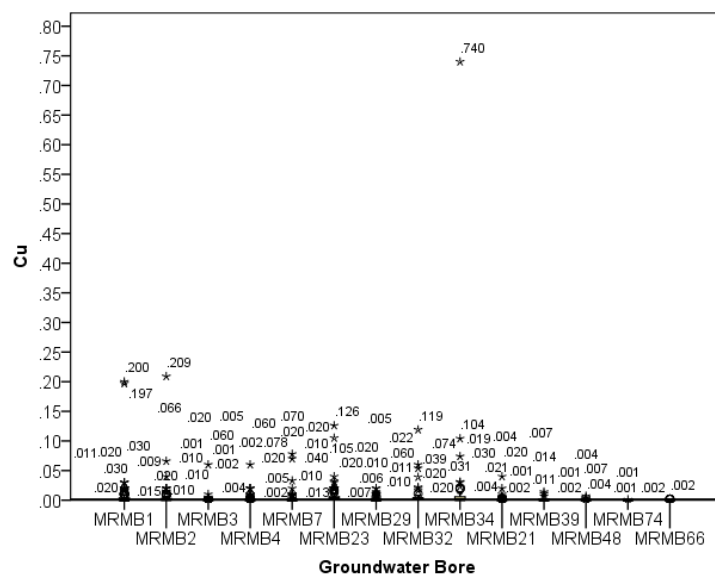
Sample Point	Statistic	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Lead Dissolved (mg/L)	Zinc Dissolved (mg/L)	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Molybdenum Dissolved (mg/L)
MRMB08 30/08/2001 - 01/10/2014	Count	154	120	154	154	54	54	55	75
	Min	0.003	0.001	0.0005	0.0010	140	4	0	0.002
	5th %ile	0.020	0.010	0.0005	0.0025	154	5	204	0.008
	20th %ile	0.025	0.040	0.0005	0.0100	166	6	227	0.010
	Mean	0.066	0.079	0.0006	0.0467	185	6	251	0.014
	Median	0.025	0.070	0.0005	0.0280	180	6	248	0.014
	80th %ile	0.070	0.123	0.0005	0.0600	202	7	277	0.017
	95th %ile	0.190	0.140	0.0007	0.1835	236	9	333	0.018
	Max	2.300	0.173	0.0100	0.3200	269	9	399	0.021
MRMB31 11/04/2006 - 20/05/2015	Count	101	87	101	101	50	50	50	70
	Min	0.003	0.006	0.0005	0.0010	1	1	1	0.016
	5th %ile	0.025	0.008	0.0005	0.0025	44	7	109	0.018
	20th %ile	0.025	0.016	0.0005	0.0060	50	8	117	0.019
	Mean	0.050	0.040	0.0017	0.0171	52	10	125	0.022
	Median	0.025	0.030	0.0005	0.0130	55	10	126	0.021
	80th %ile	0.060	0.052	0.0005	0.0260	57	12	140	0.023
	95th %ile	0.120	0.131	0.0010	0.0450	59	14	145	0.024
	Max	0.650	0.179	0.0490	0.0760	66	18	175	0.108
MRMB30 12/04/2006 - 15/11/2019	Count	137	123	137	137	87	87	87	106
	Min	0.025	0.001	0.0005	0.0025	0.50	0.50	0.37	0.008
	5th %ile	0.025	0.007	0.0005	0.0025	89	10	174	0.008
	20th %ile	0.025	0.014	0.0005	0.0025	107	12	183	0.009
	Mean	0.075	0.071	0.0007	0.0204	122	14	200	0.011
	Median	0.025	0.044	0.0005	0.0160	124	14	203	0.010
	80th %ile	0.060	0.114	0.0005	0.0358	138	17	218	0.011
	95th %ile	0.172	0.218	0.0010	0.0536	156	18	229	0.012
	Max	2.000	0.394	0.0150	0.1220	190	25	280	0.110
MRMB40 12/07/2012 - 06/02/2019	Count	67	67	67	67	67	67	67	67
	Min	0.03	0.059	0.0005	0.0025	29	4	41	0.004
	5th %ile	0.15	0.066	0.0005	0.0025	51	4	50	0.005
	20th %ile	0.17	0.083	0.0005	0.0025	57	5	54	0.006
	Mean	0.27	0.142	0.0010	0.0071	72	5	59	0.006
	Median	0.24	0.114	0.0005	0.0025	62	5	59	0.006
	80th %ile	0.33	0.197	0.0005	0.0120	65	6	64	0.007
	95th %ile	0.46	0.279	0.0008	0.0217	71	6	67	0.008
	Max	1.10	0.407	0.0330	0.0500	853	9	69	0.009
MRMB53 16/05/2012 - 05/02/2019	Count	69	69	69	69	69	69	69	69
	Min	0.03	0.023	0.0005	0.0010	26	1	17	0.001
	5th %ile	0.68	0.082	0.0005	0.0025	93	4	64	0.002
	20th %ile	0.75	0.086	0.0005	0.0025	102	4	67	0.003
	Mean	0.77	0.092	0.0009	0.0042	106	4	69	0.003
	Median	0.79	0.091	0.0005	0.0025	107	4	69	0.003
	80th %ile	0.82	0.099	0.0005	0.0060	113	5	73	0.003
	95th %ile	0.86	0.104	0.0008	0.0118	116	5	76	0.004
	Max	1.10	0.130	0.0240	0.0260	120	6	80	0.004

Appendix 15: Data Summaries for Rawdon Creek

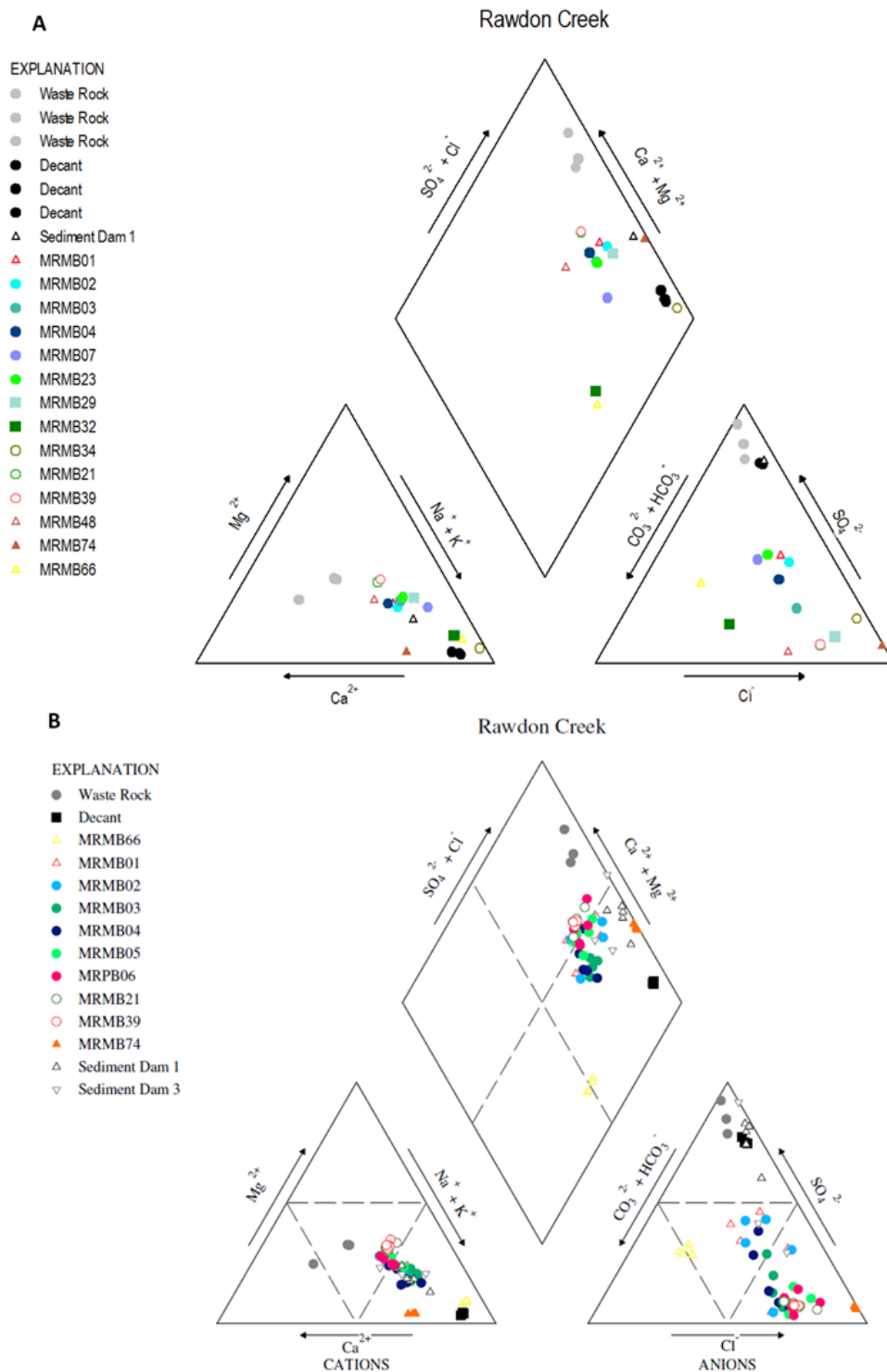






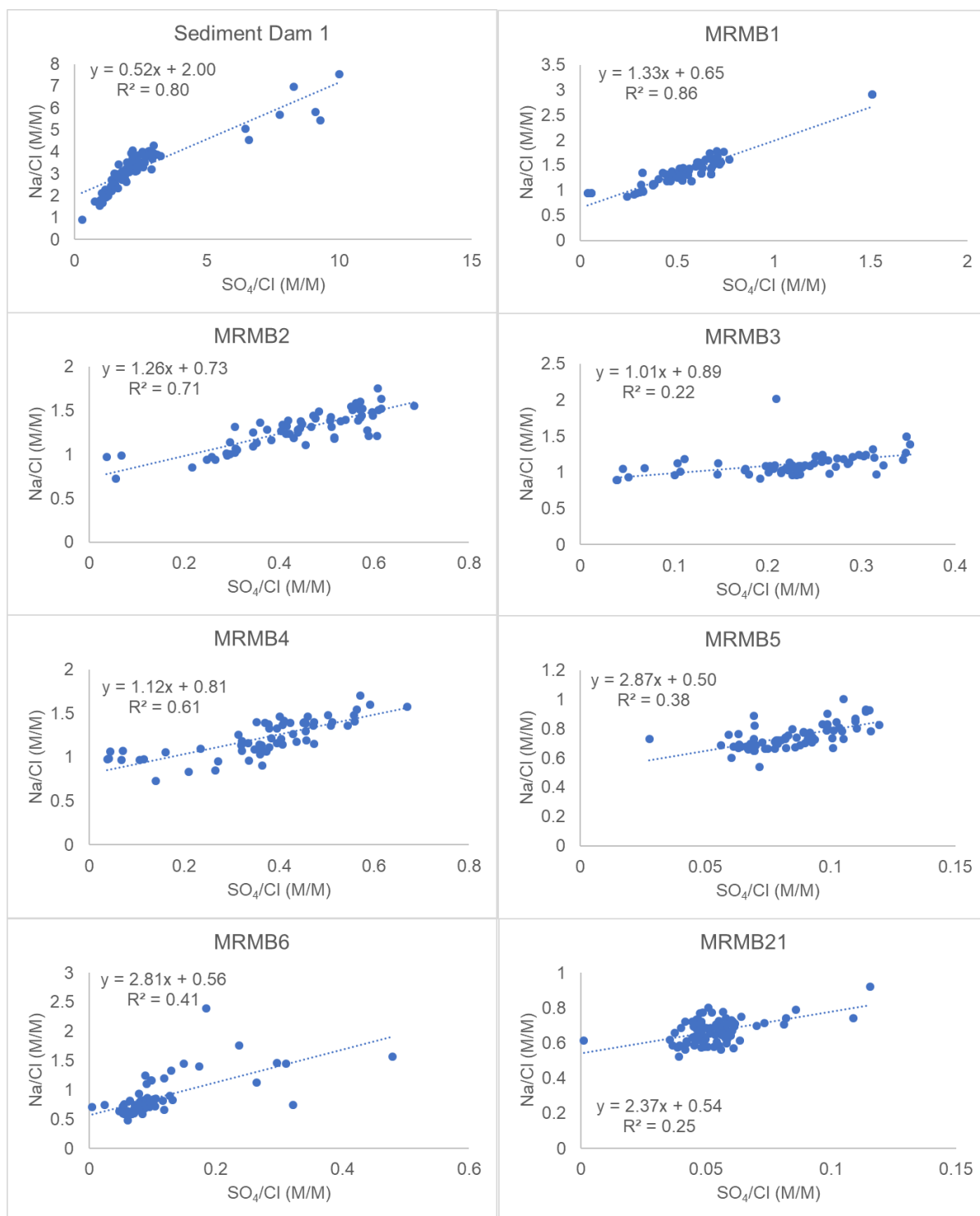






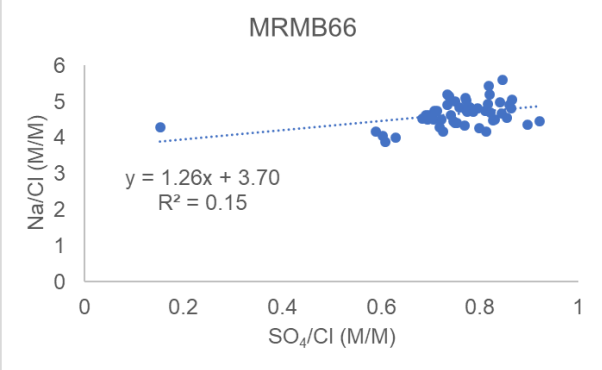
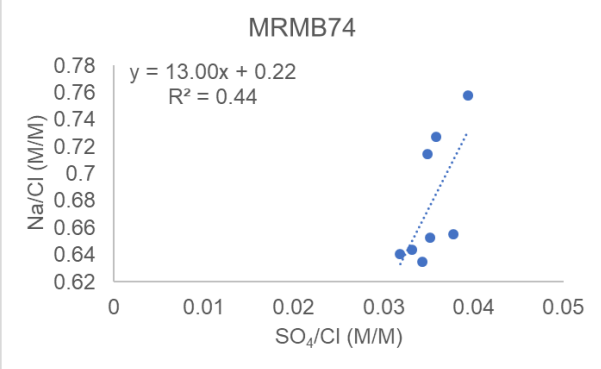
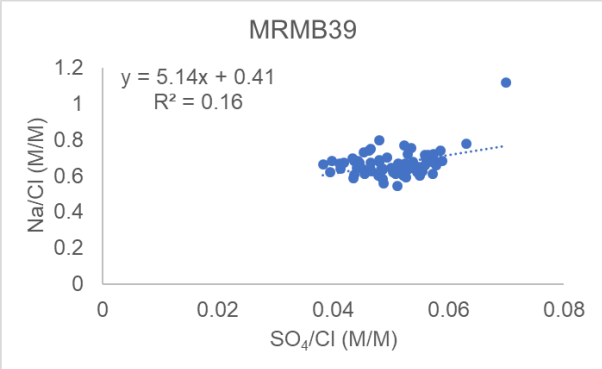
³⁷ Footnote

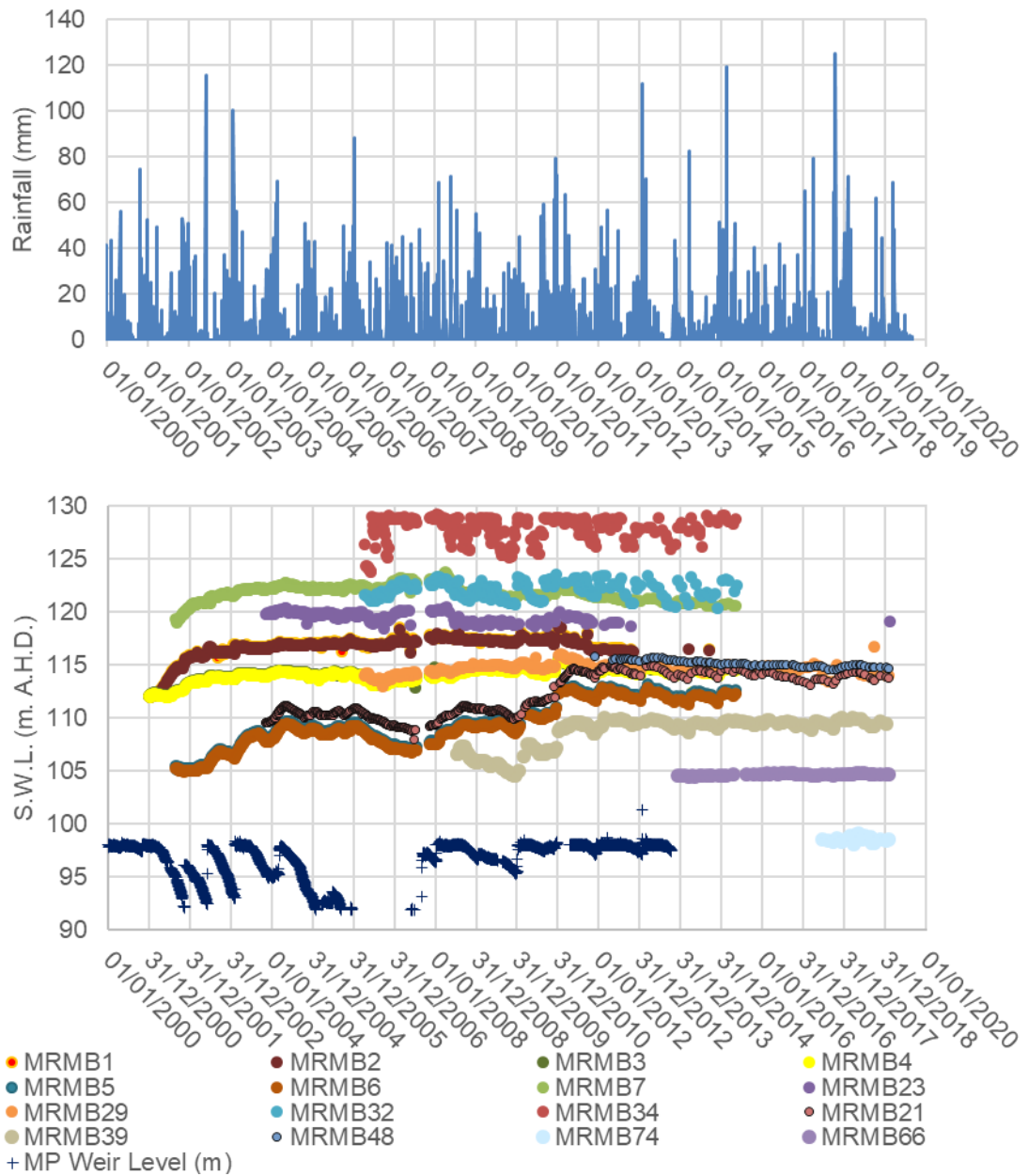
³⁷ A represents median cation and anion concentrations in groundwater monitoring bores, and representative cation and anion concentrations in waste - rock seepage and decant water. B shows representative cation and anion concentrations in selected groundwater monitoring bores, waste – rock seepage and decant water.

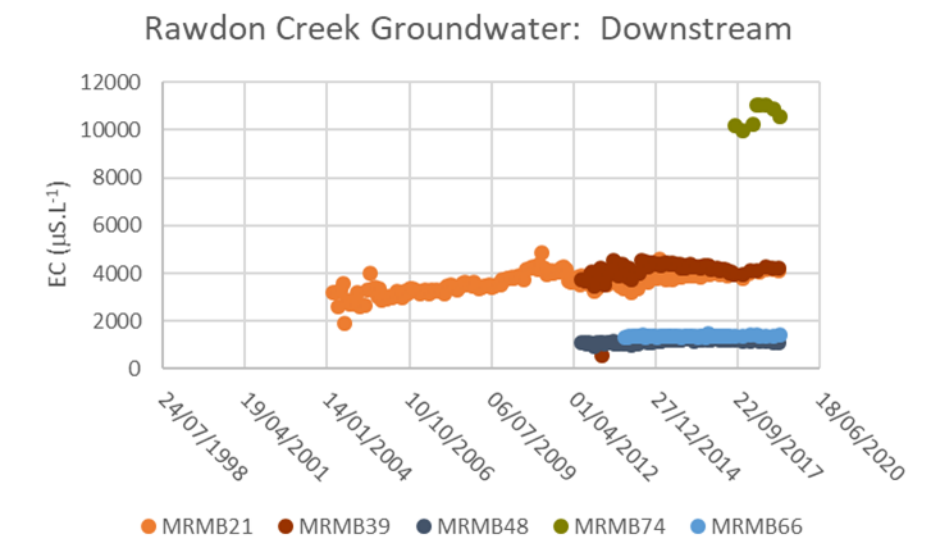
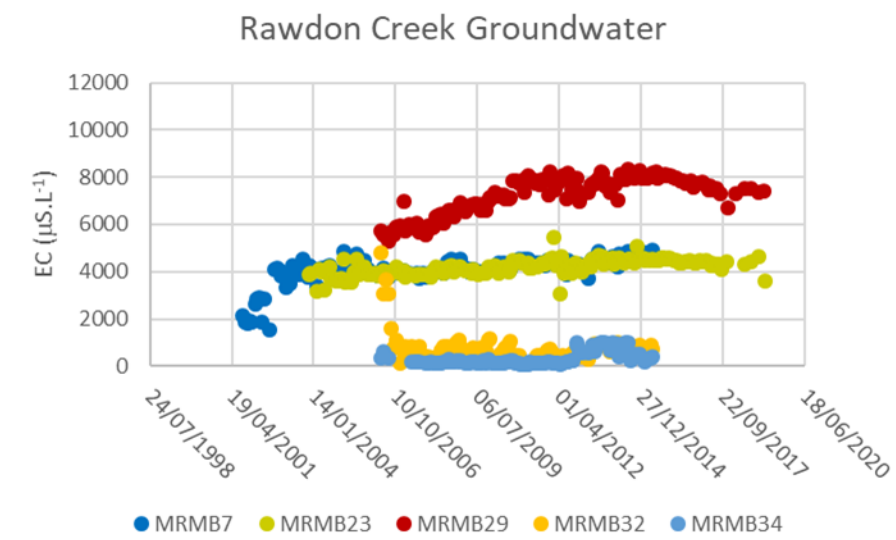
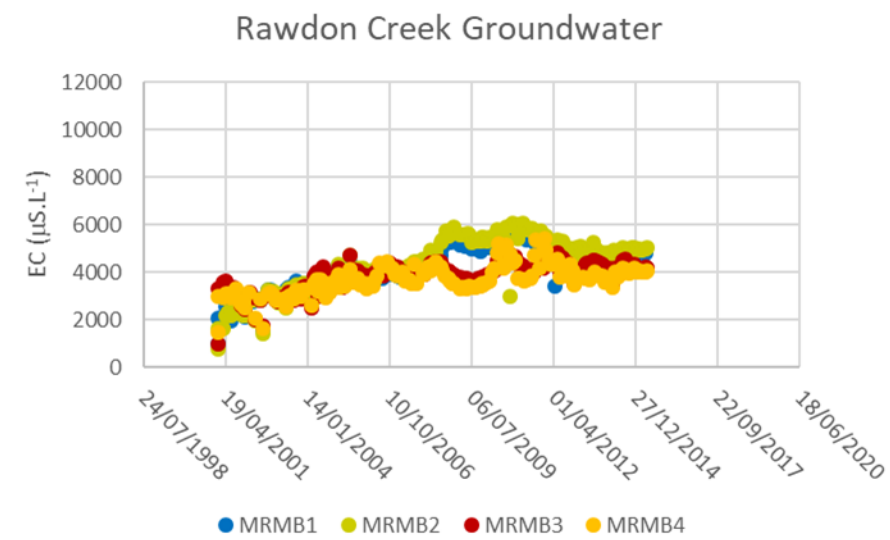
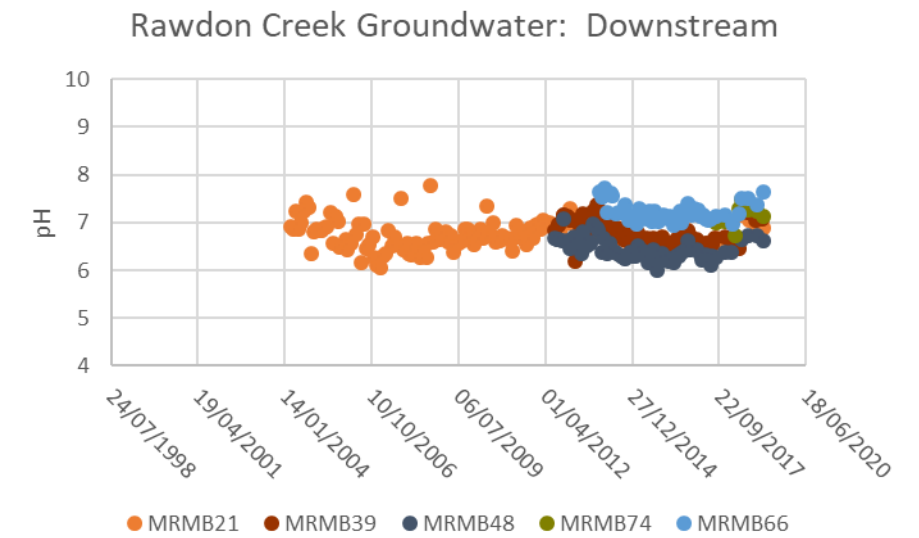
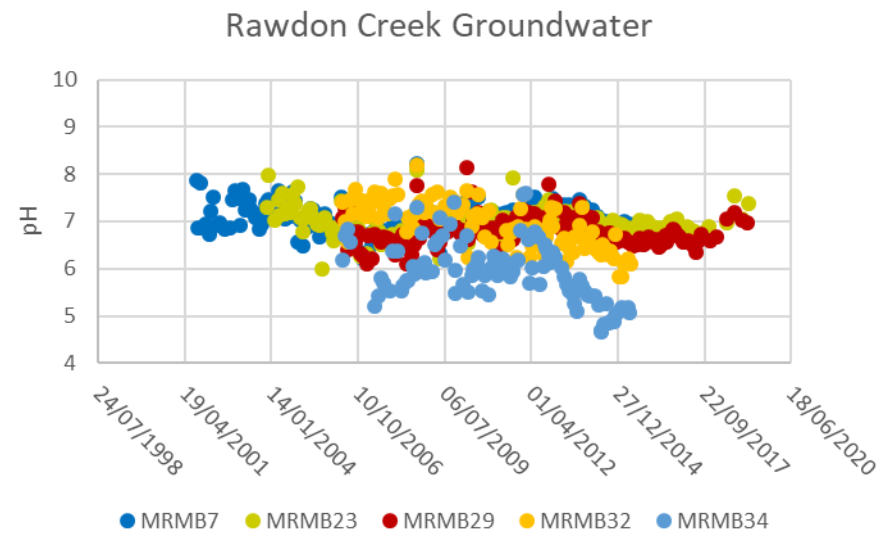
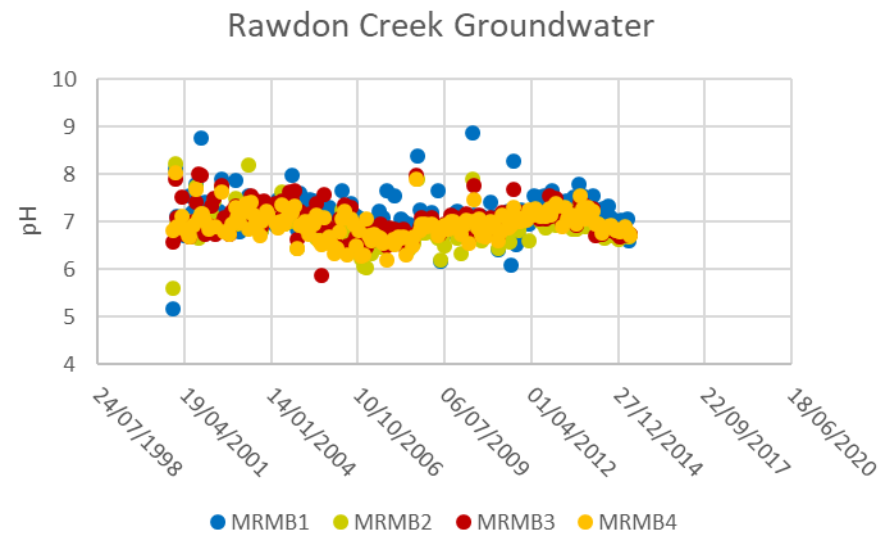
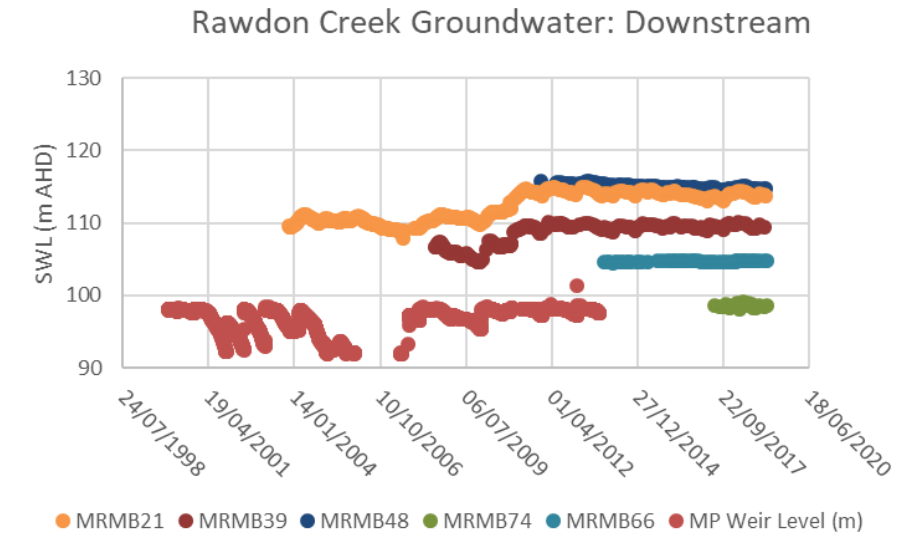
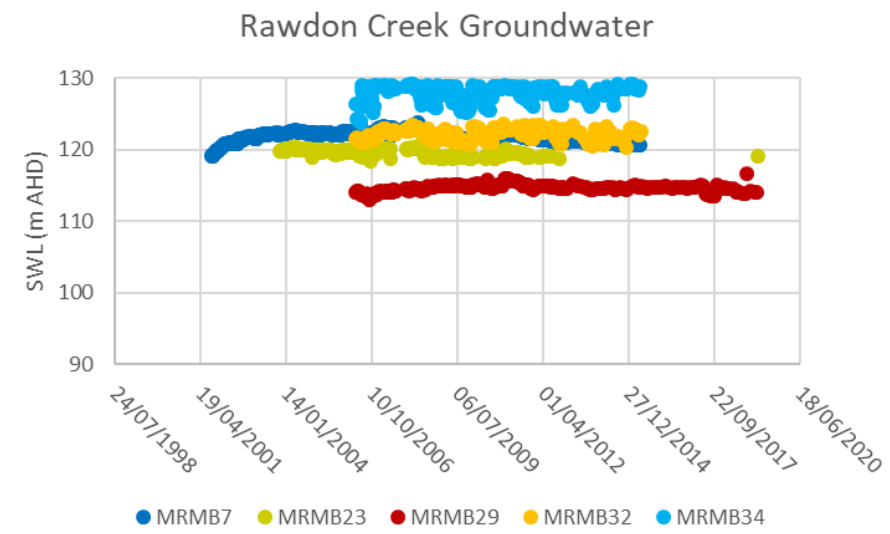
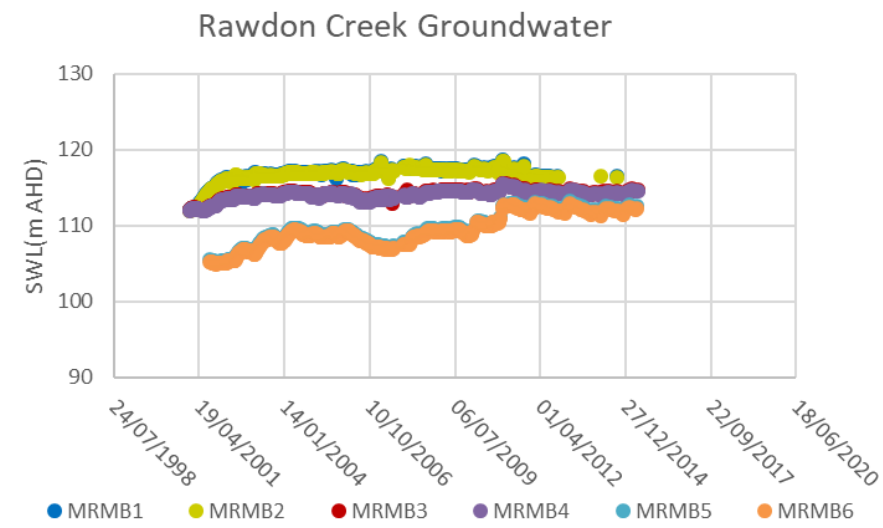


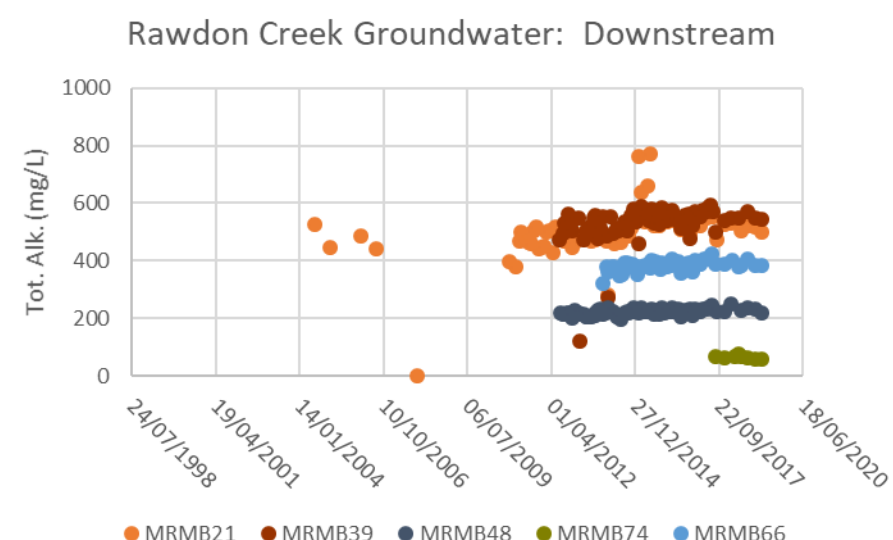
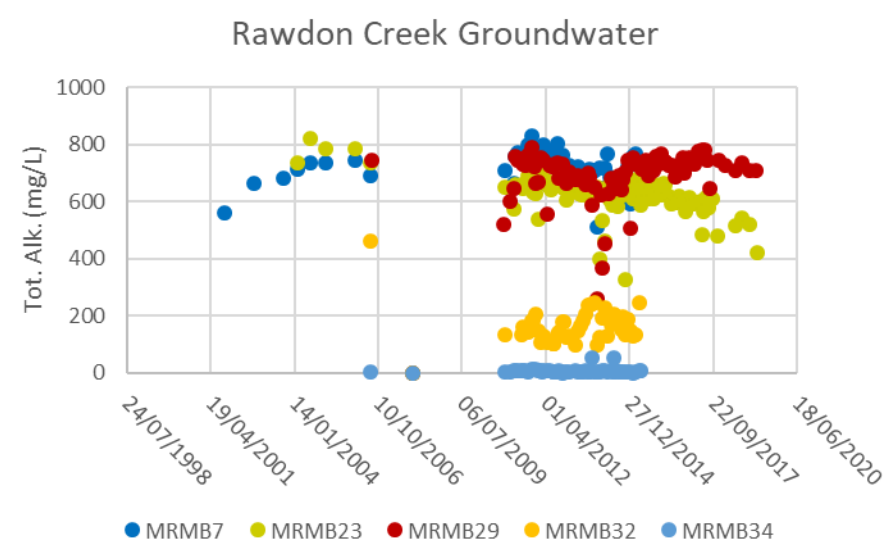
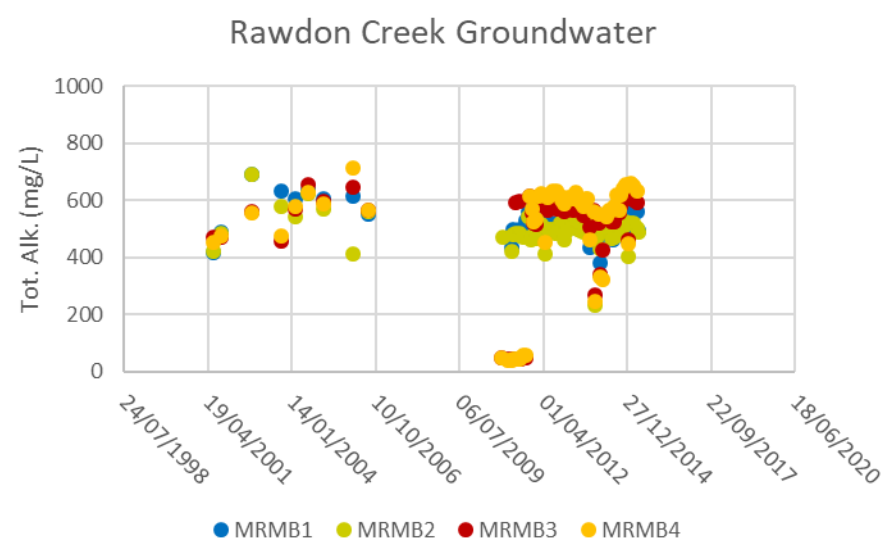
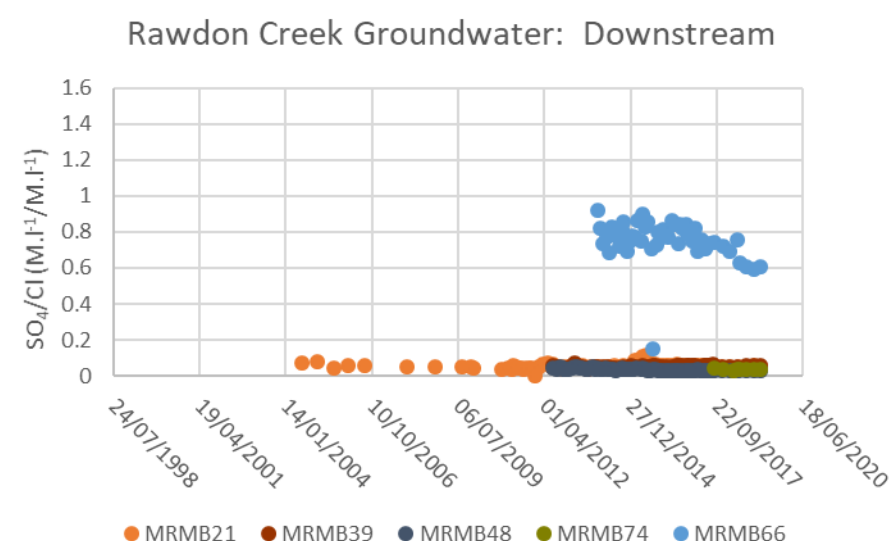
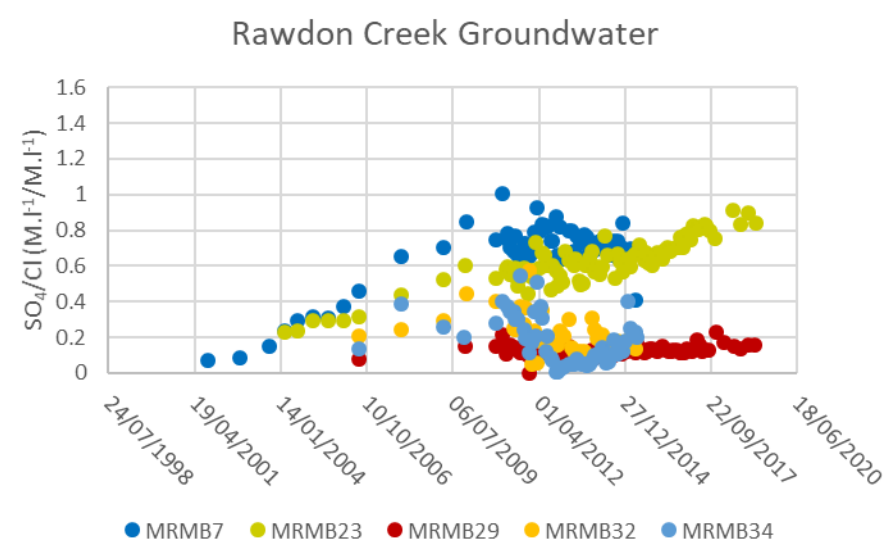
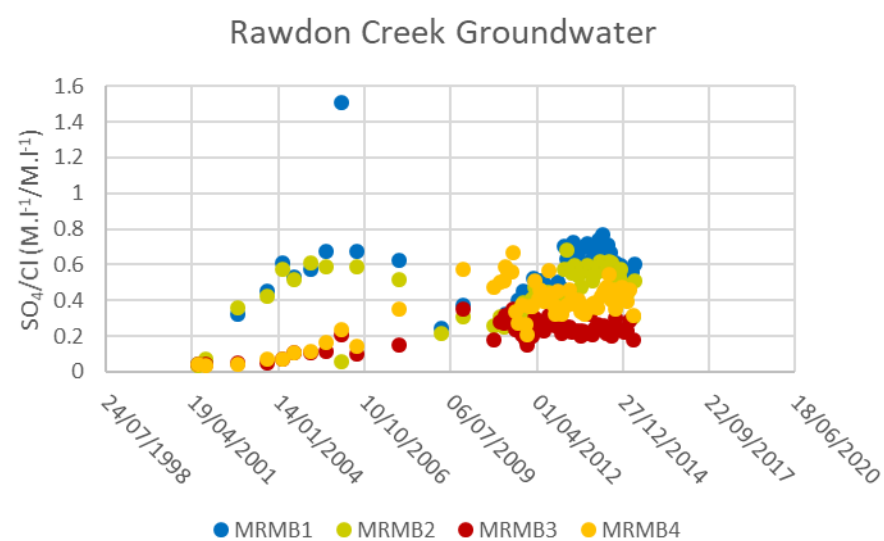
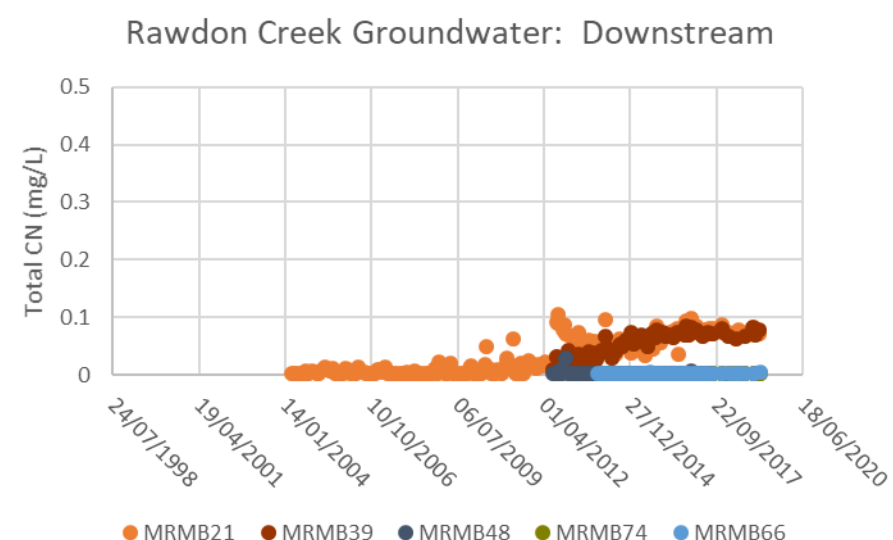
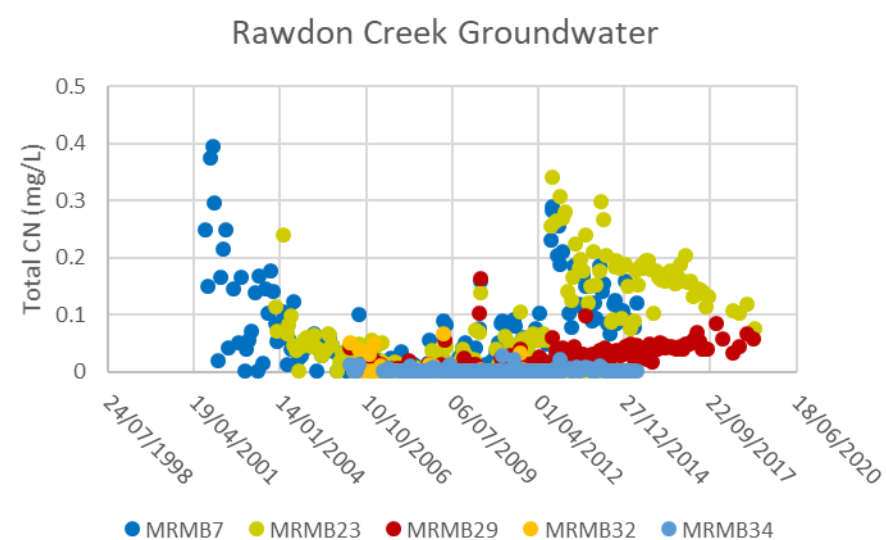
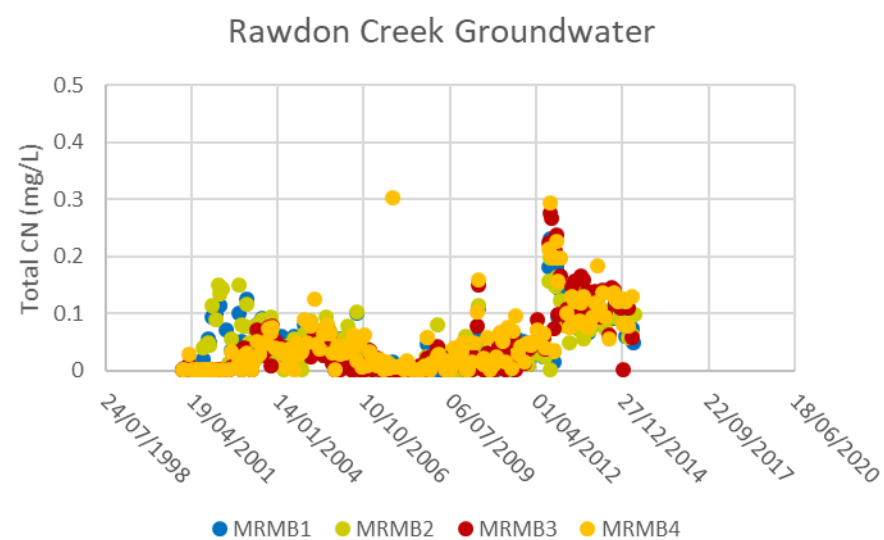
³⁸ Footnote

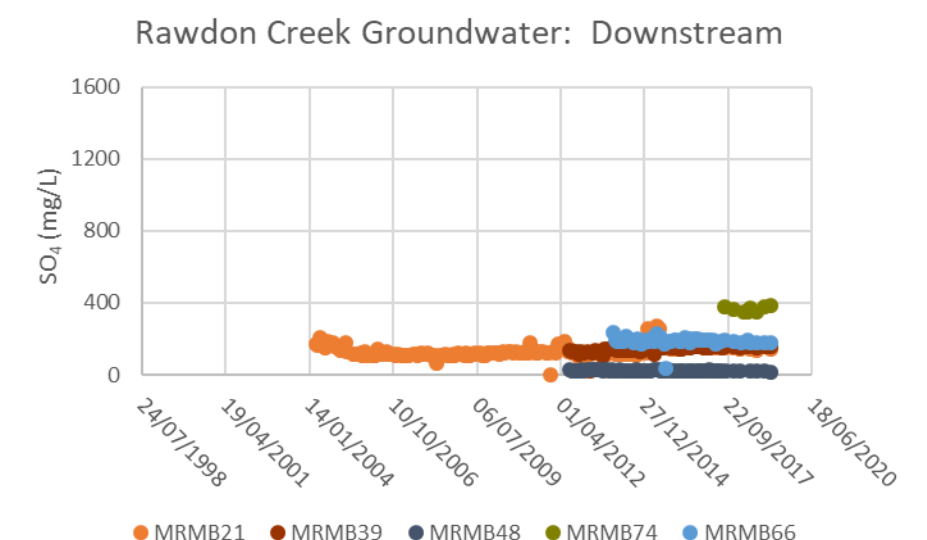
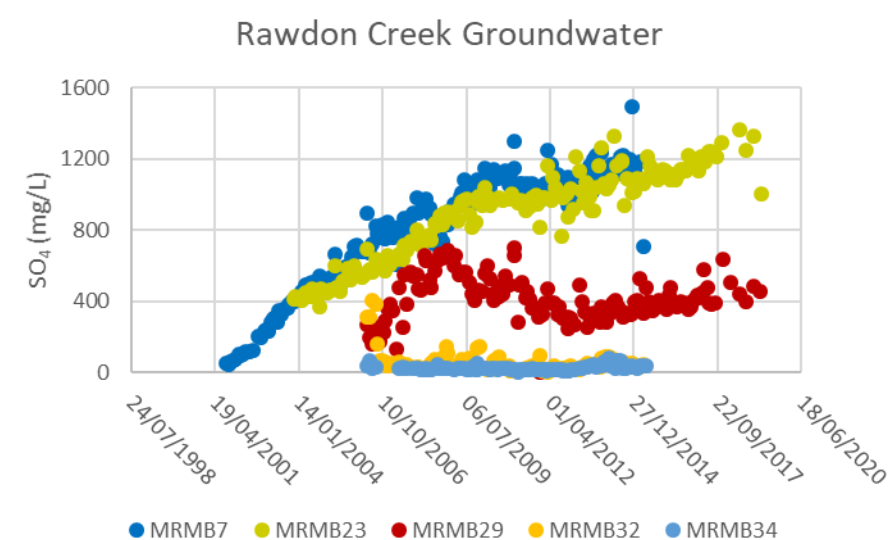
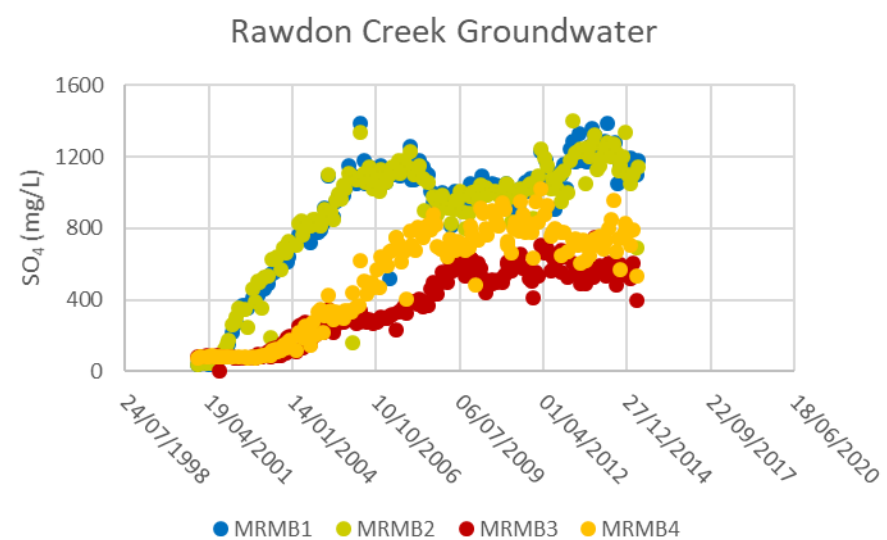
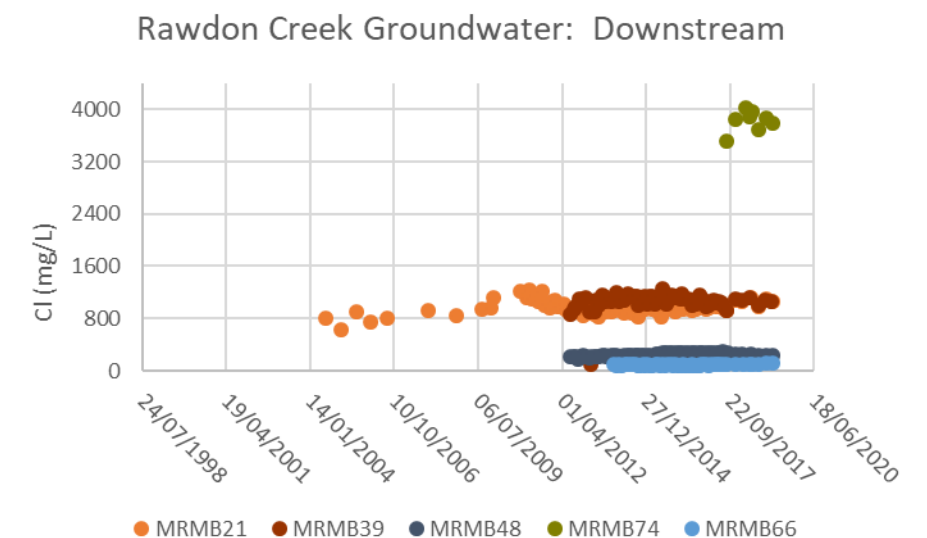
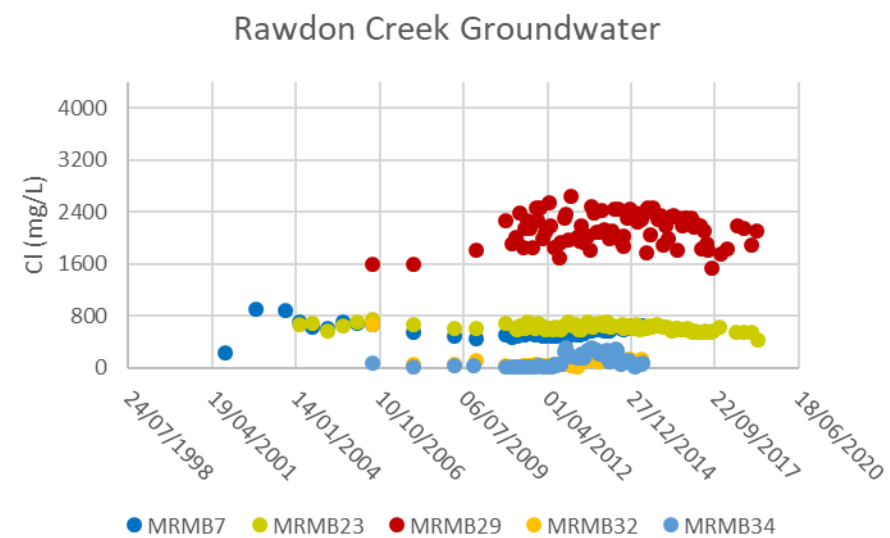
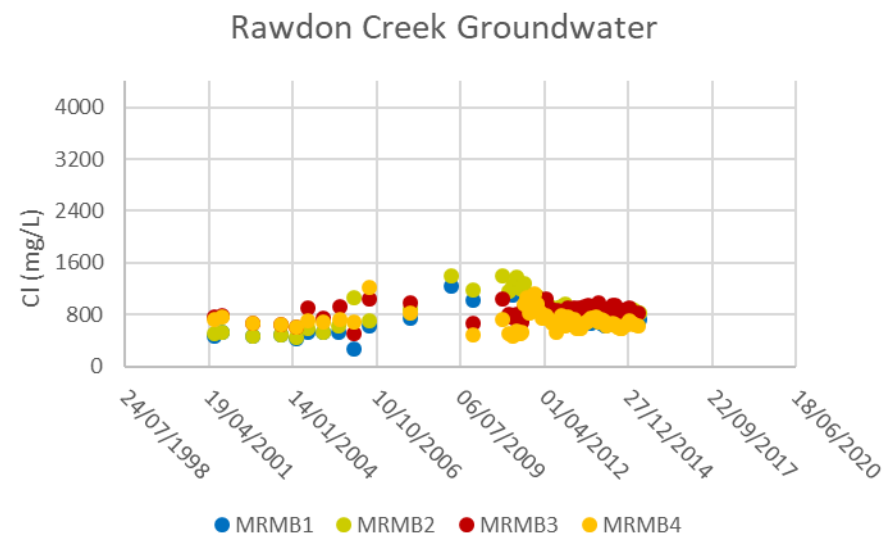
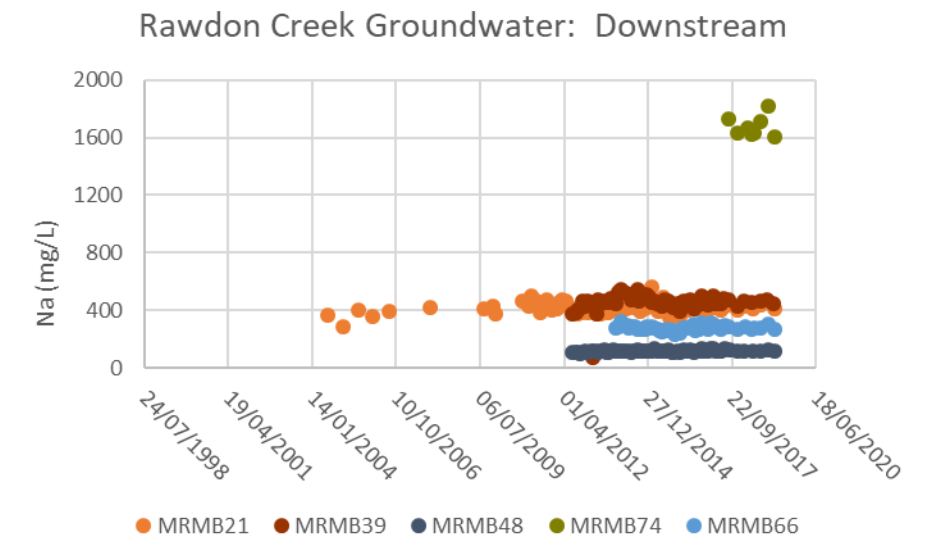
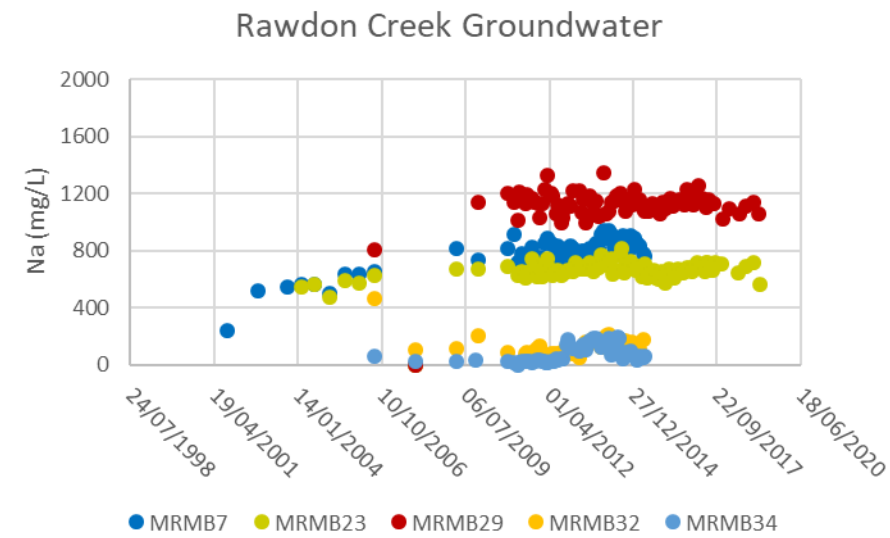
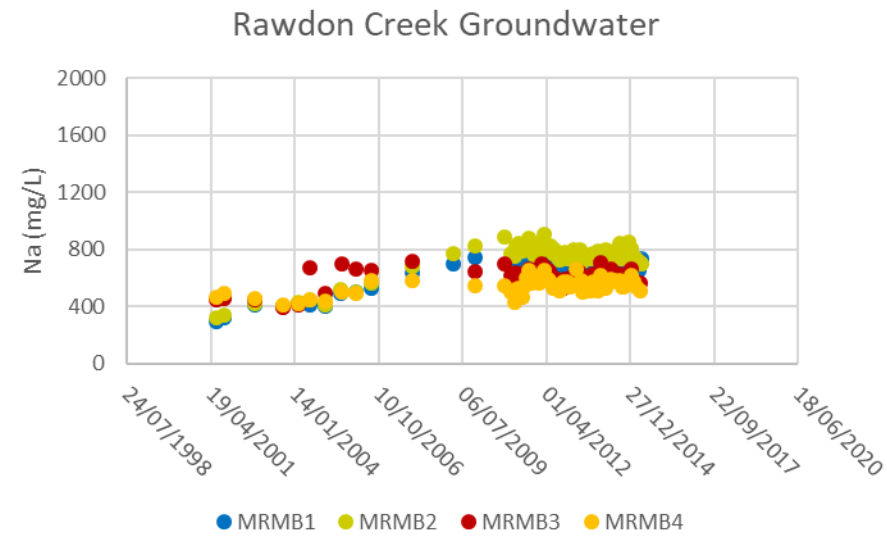
³⁸ Na/Cl (M/M) vs SO₄/Cl (M/M) concentration ratios in the source term (Sediment Dam 1) and in selected groundwater samples from Rawdon Creek showing correlations associated with neutral mine drainage in mining affected water (MRMB1, MRMB2, MRMB3, MRMB4, MRMB5, MRMB6 and MRMB21). Outliers are excluded in MRMB5 - Na/Cl 1.39 M/M, SO₄/Cl 0.69 M/M and in MRMB21 Na/Cl 7.33 M/M, SO₄/Cl (M/M) 0.48.

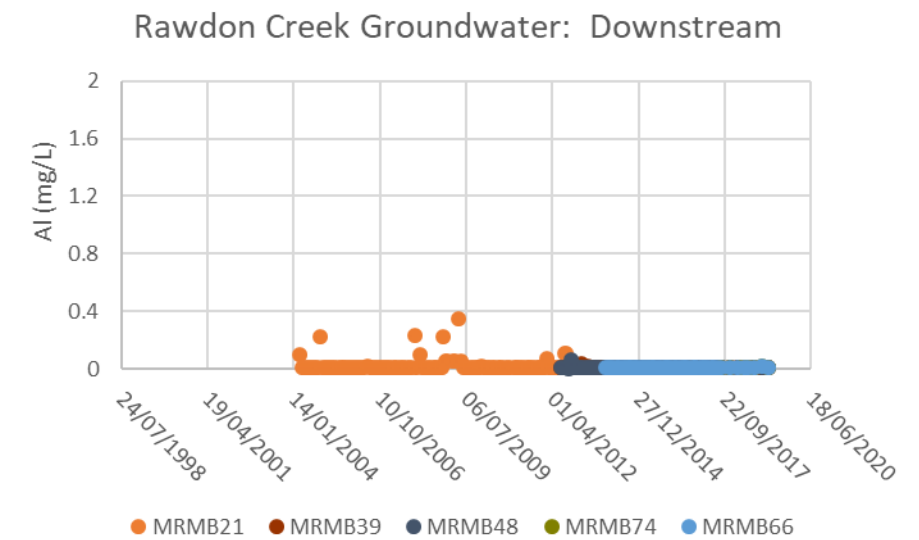
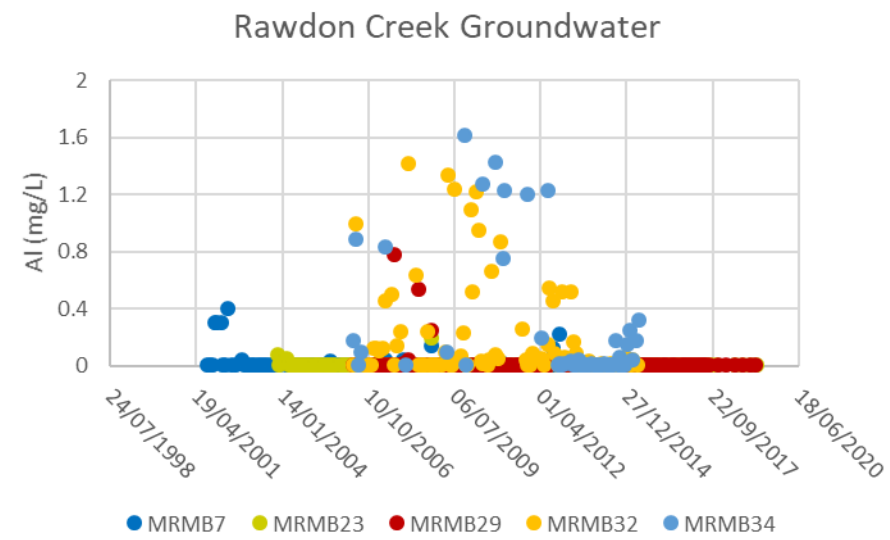
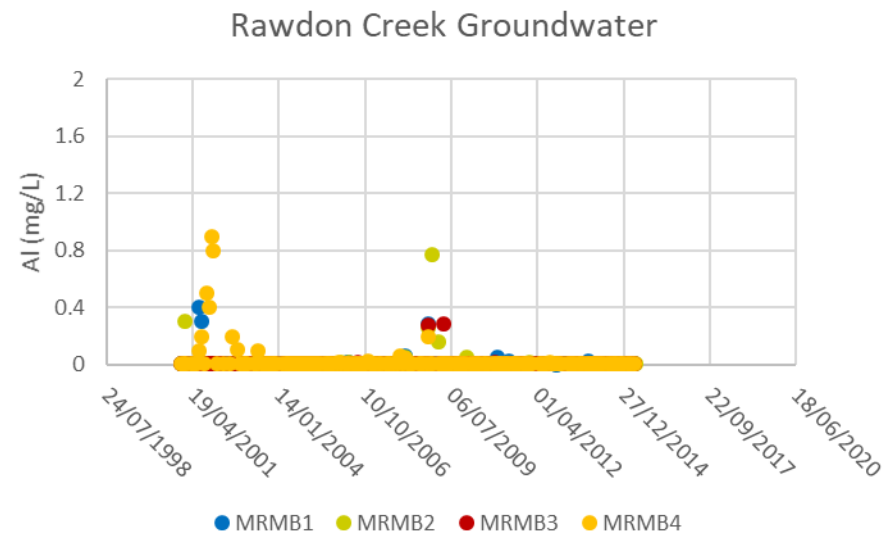
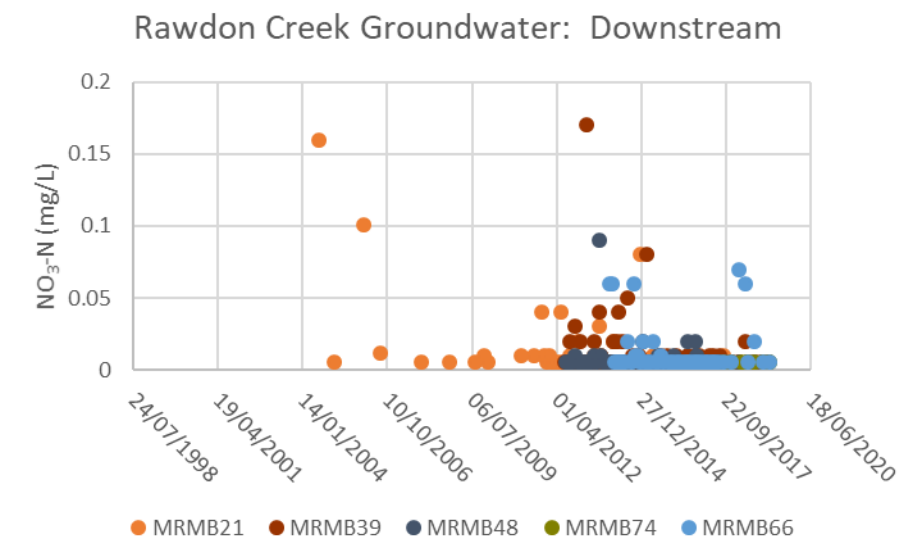
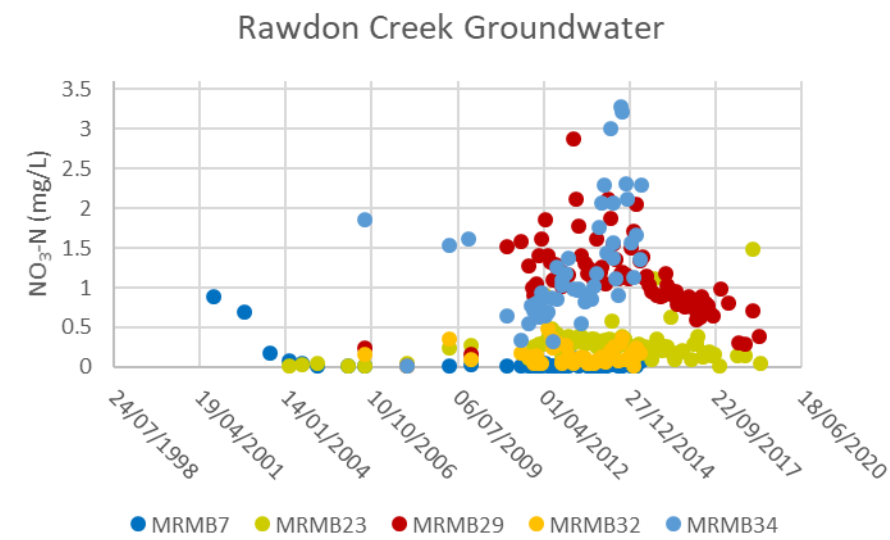
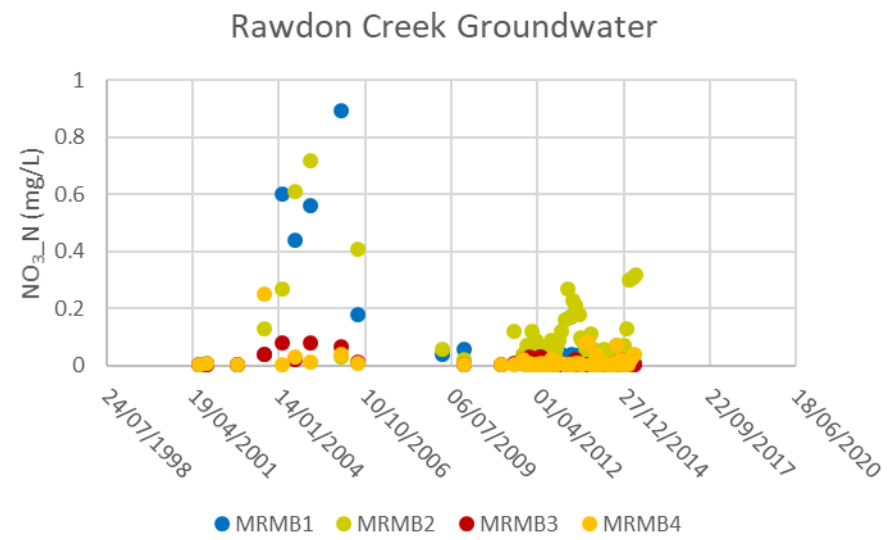
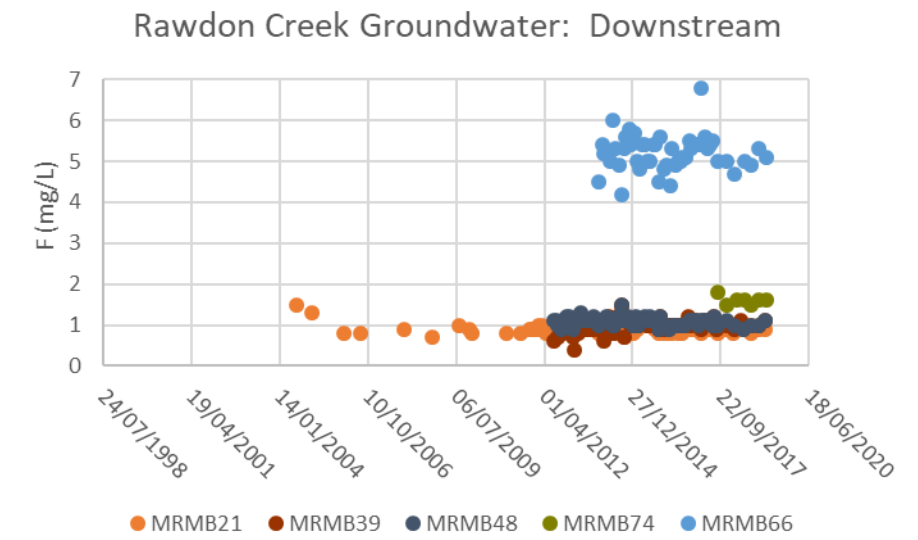
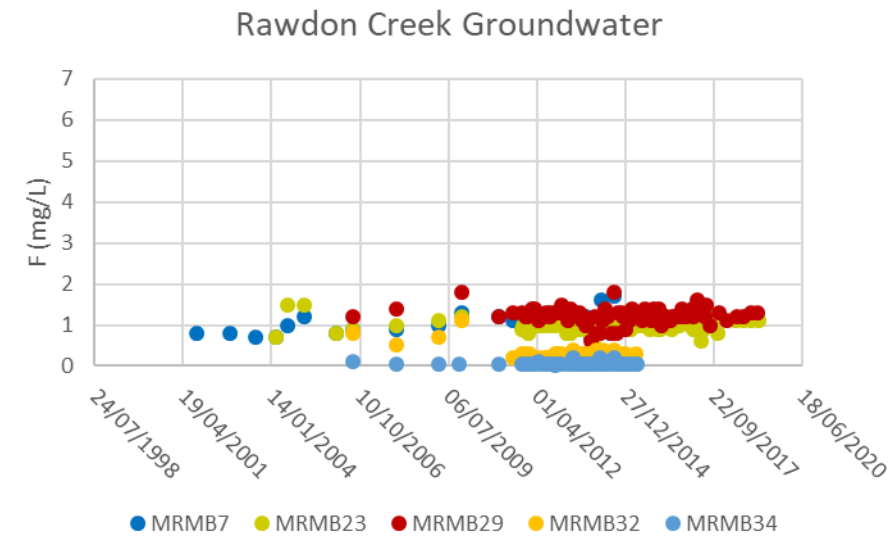
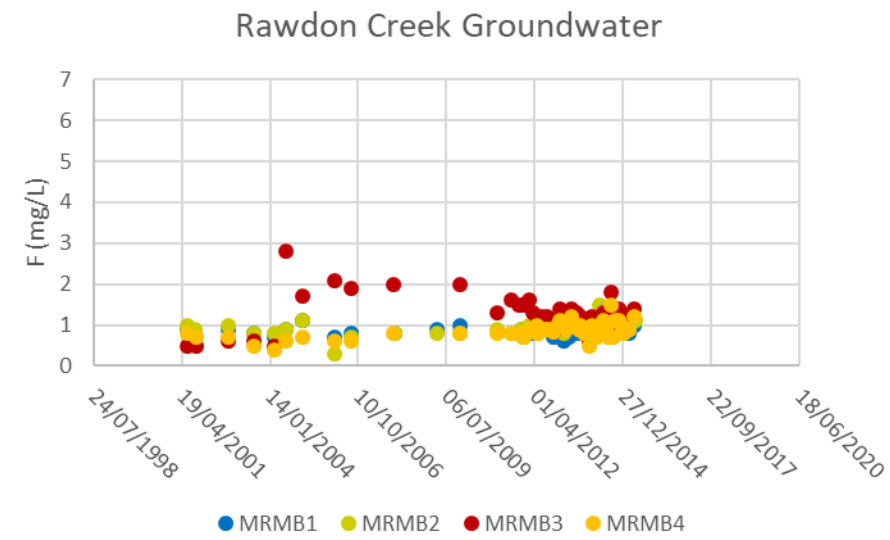


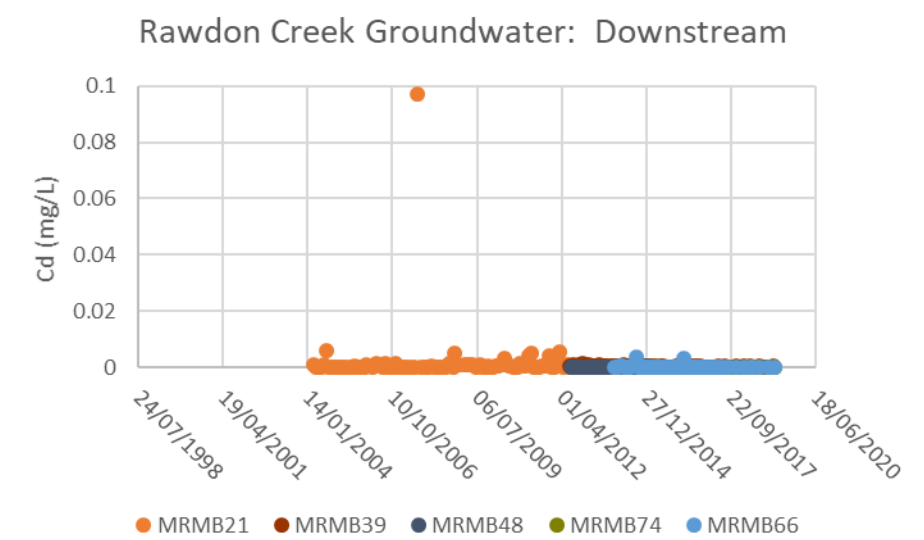
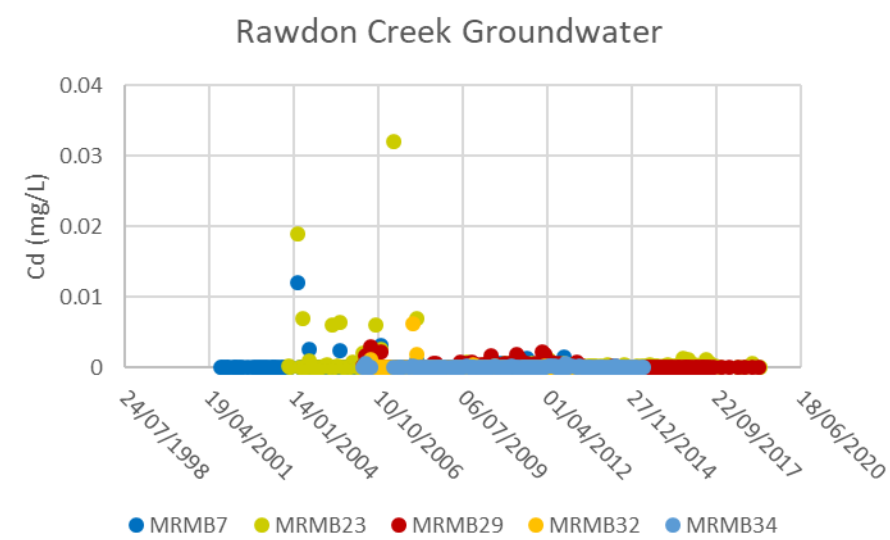
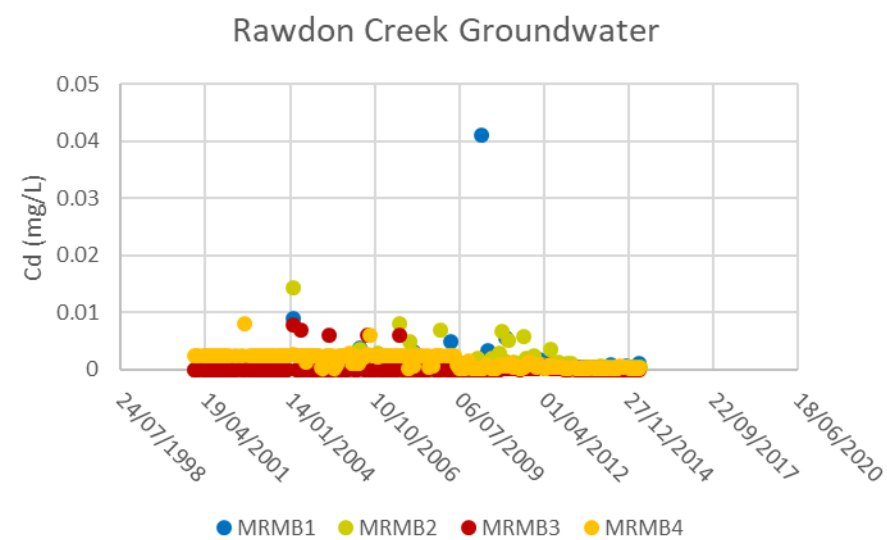
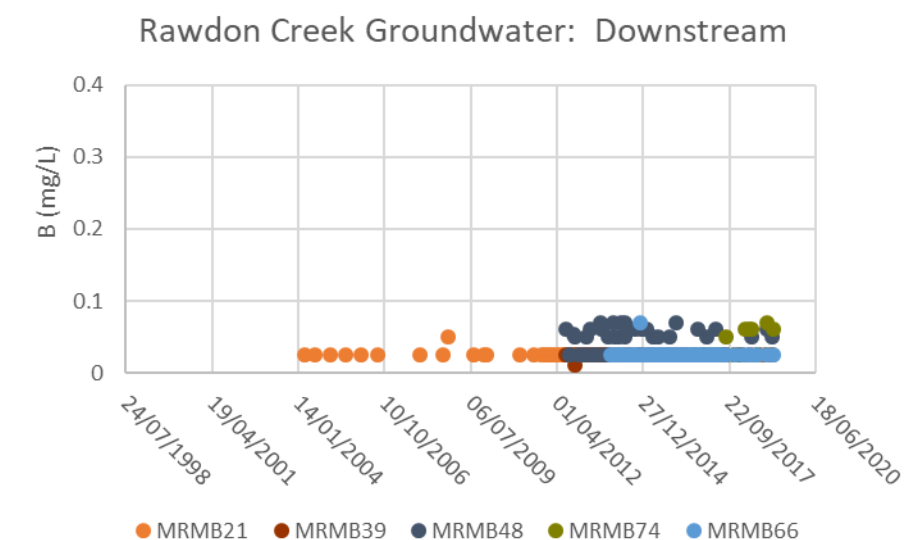
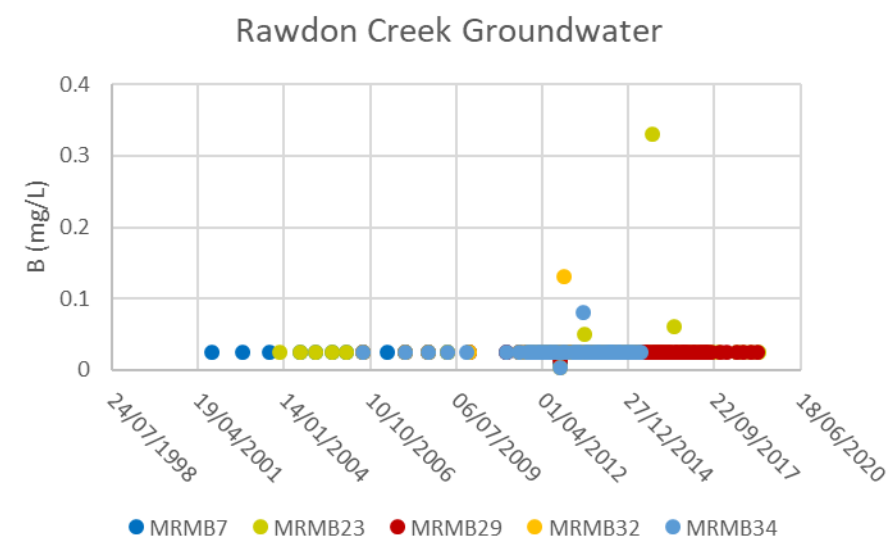
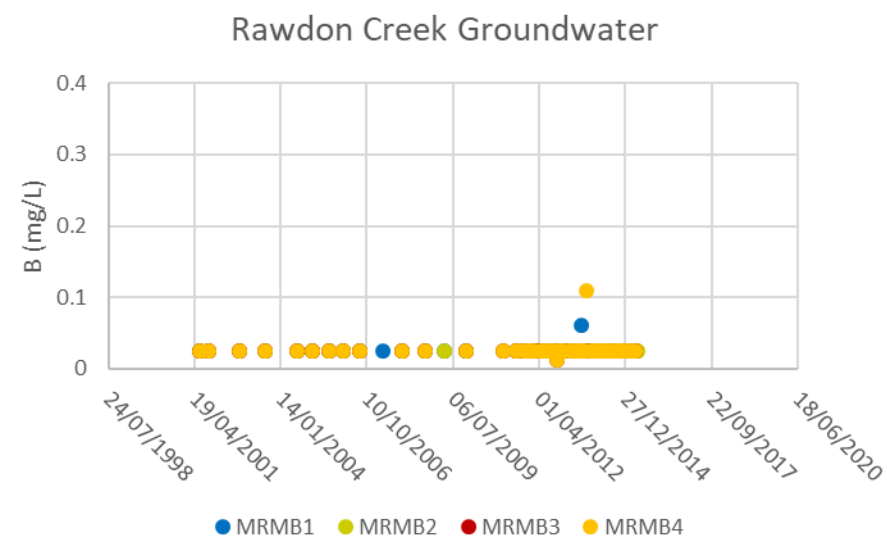
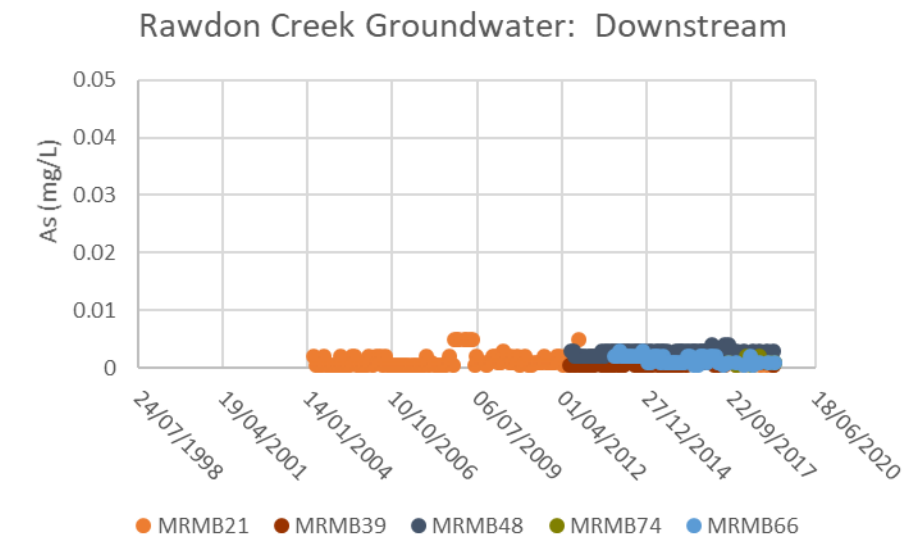
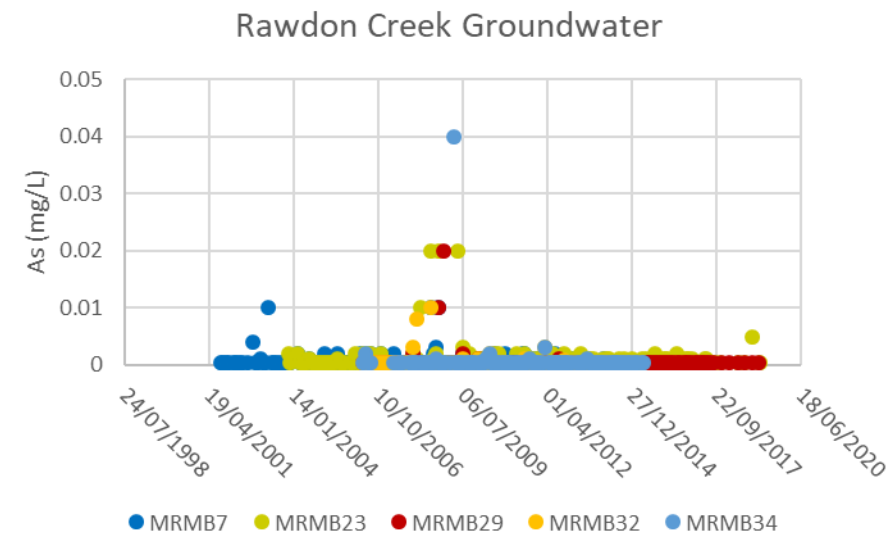
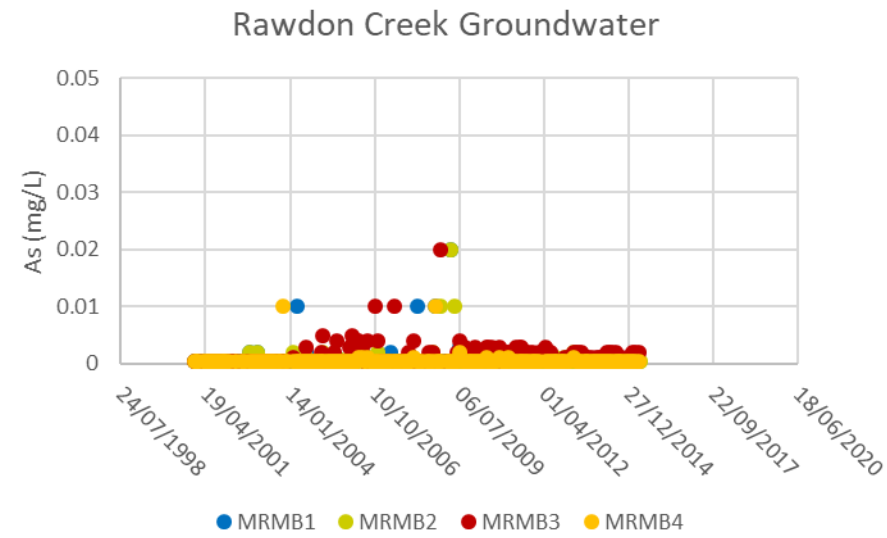


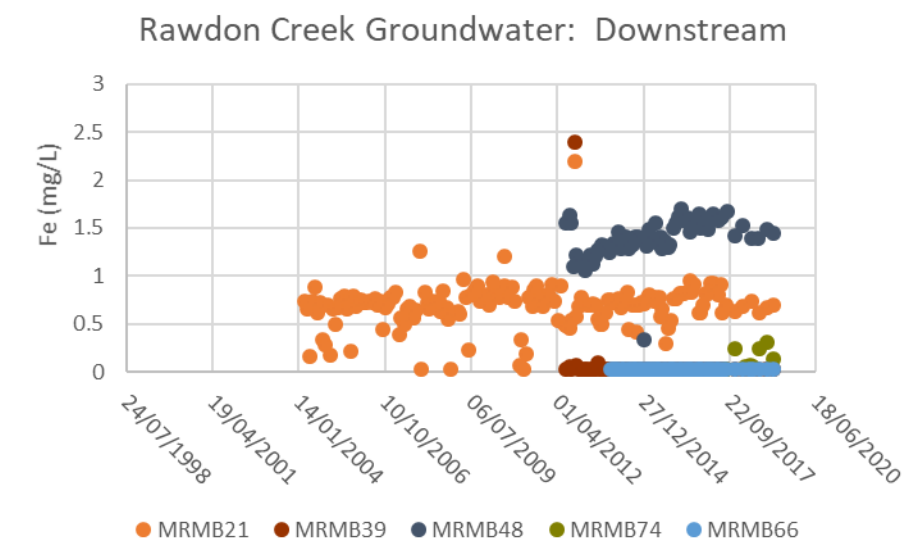
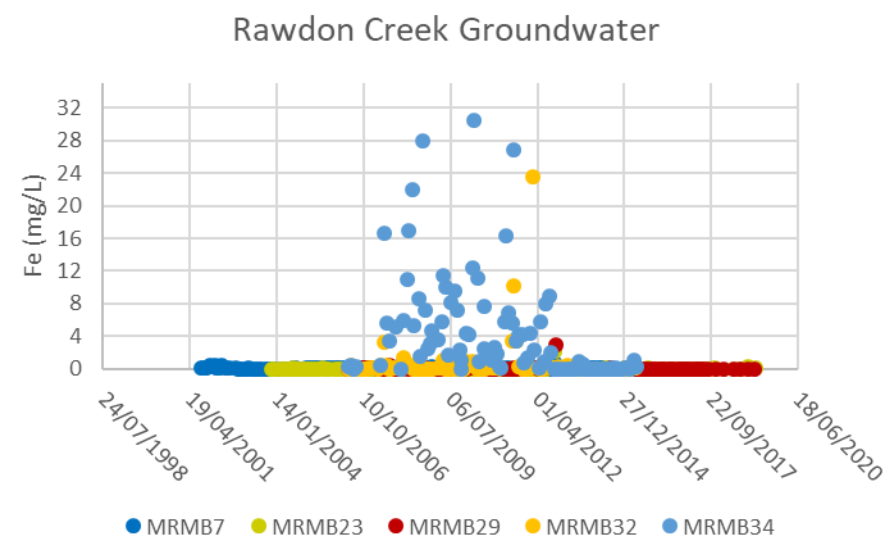
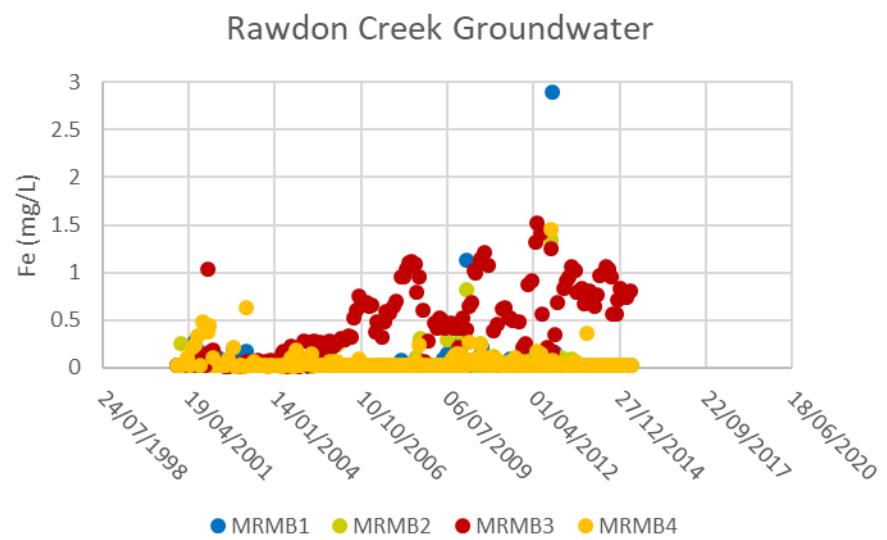
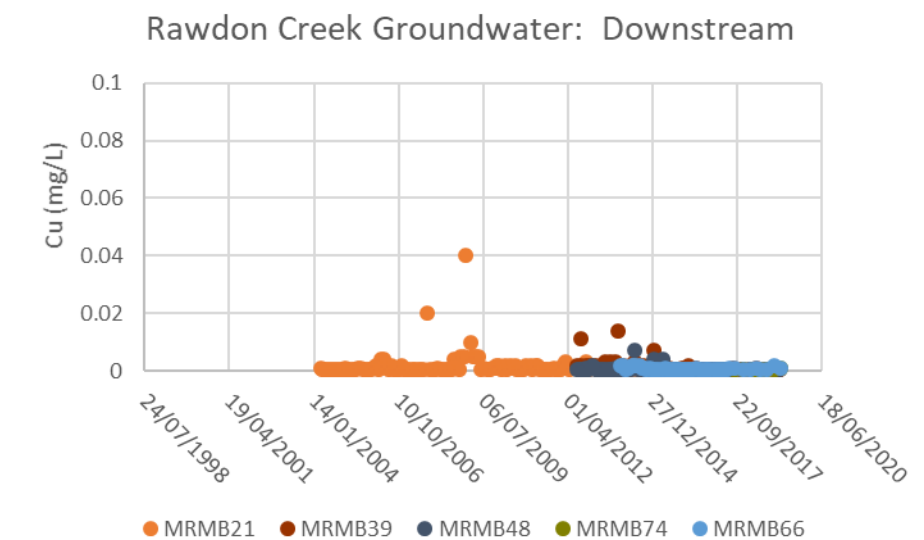
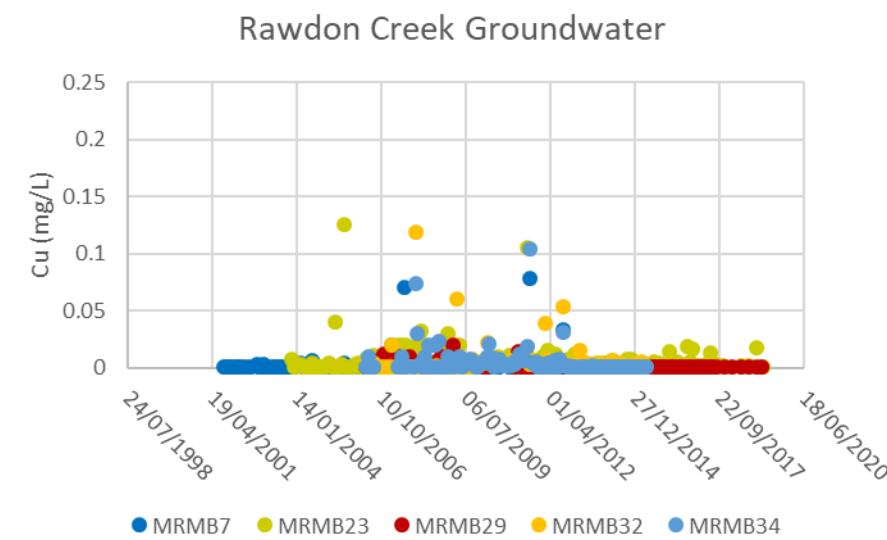
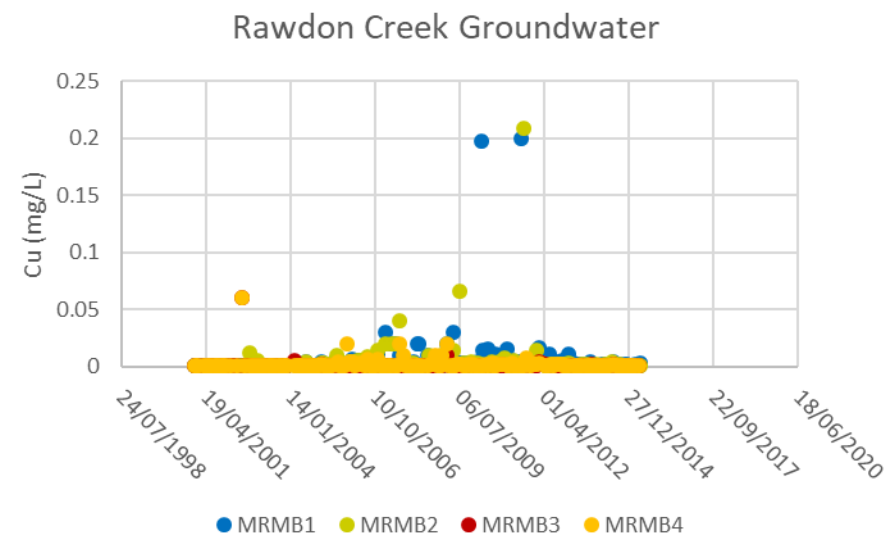
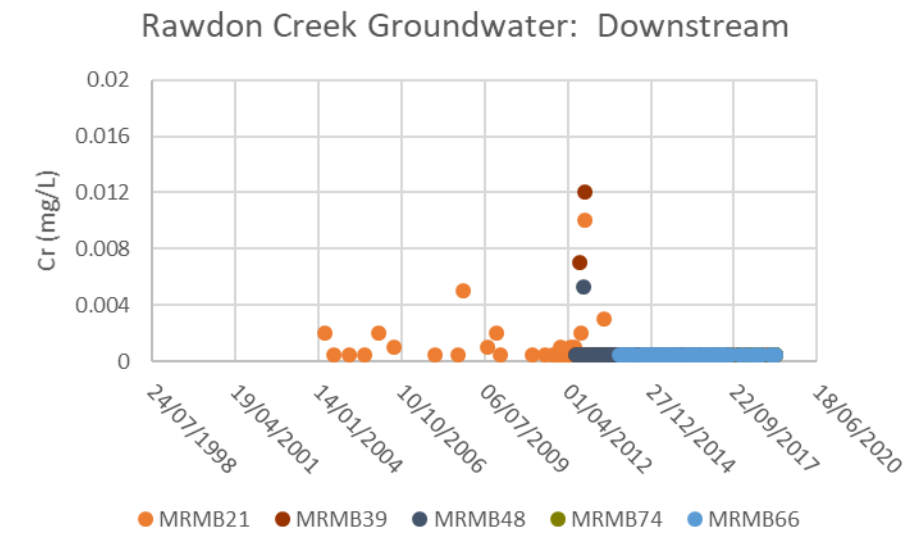
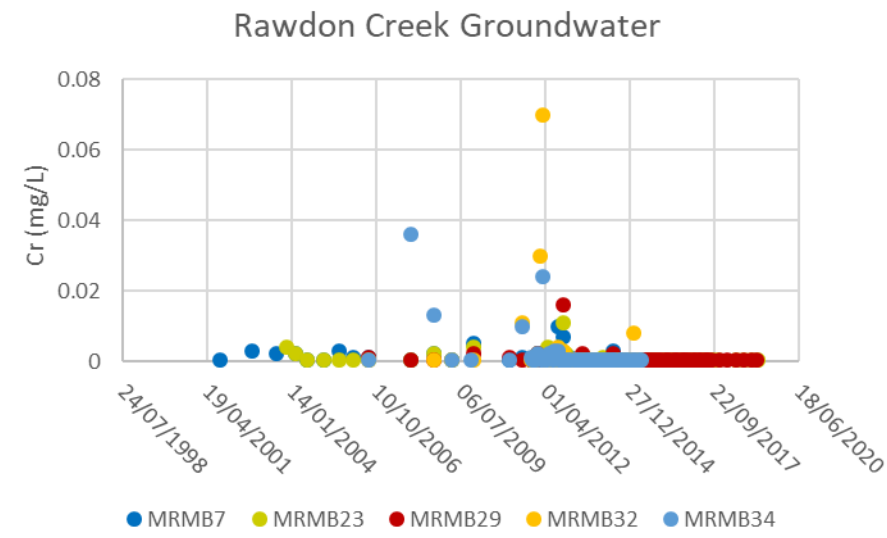
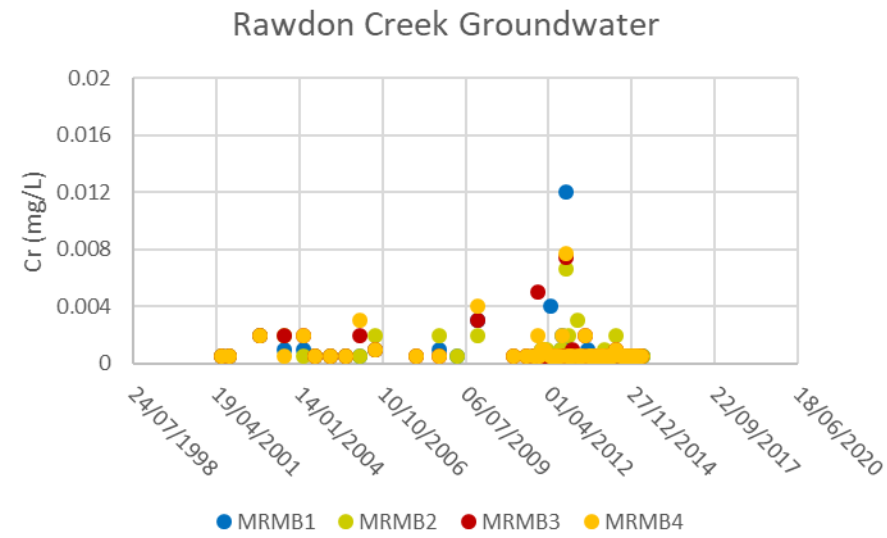


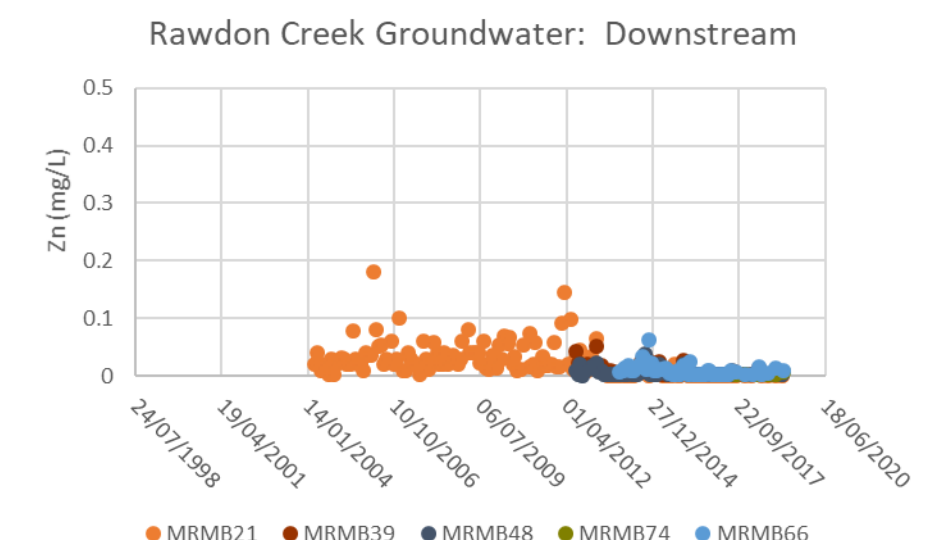
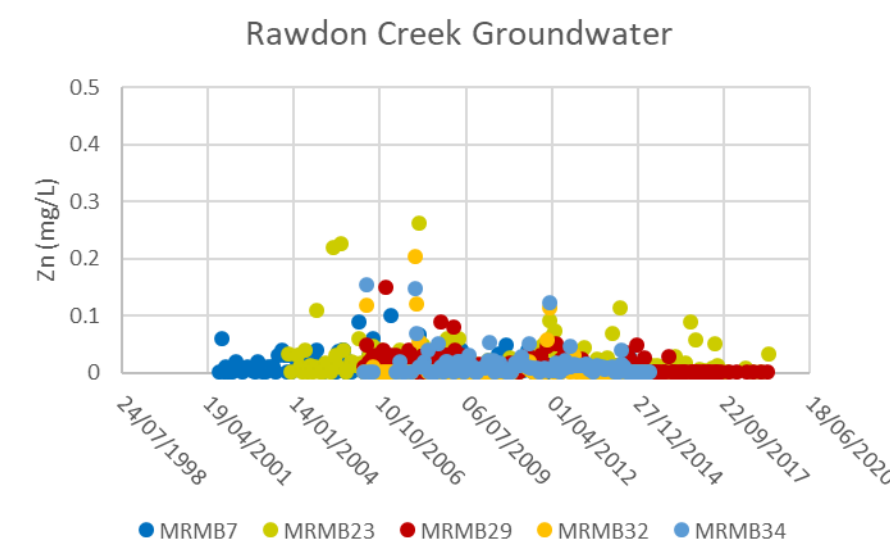
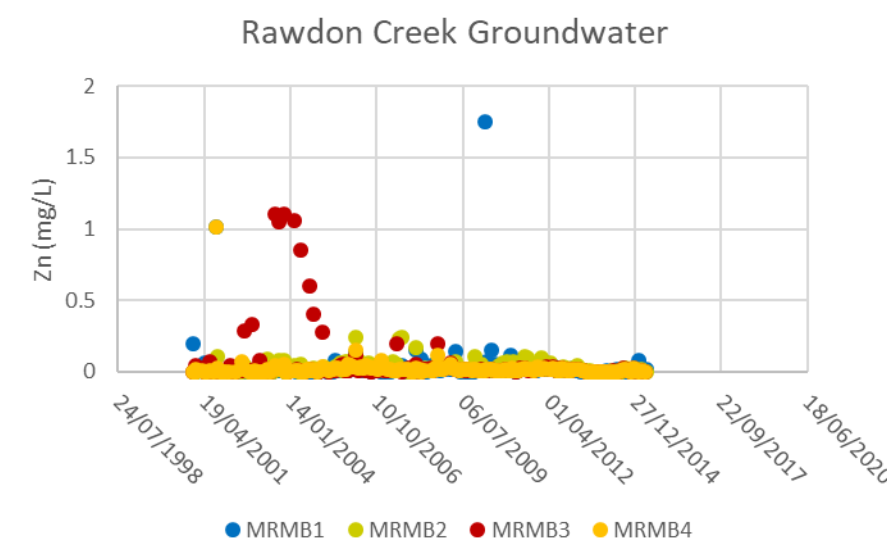
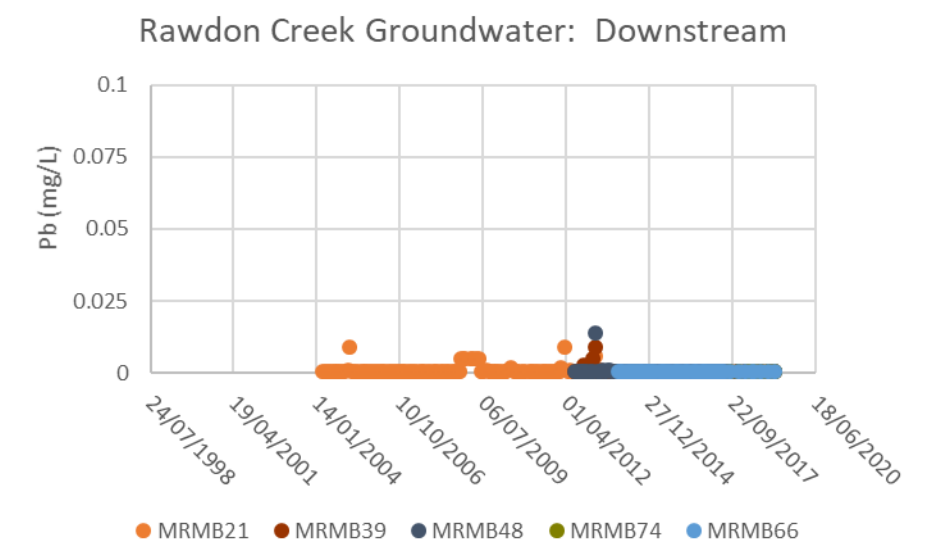
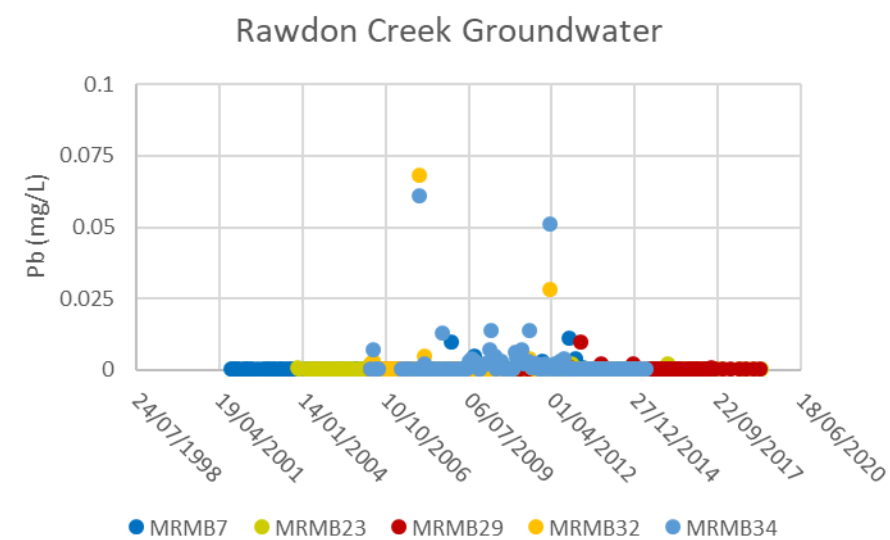
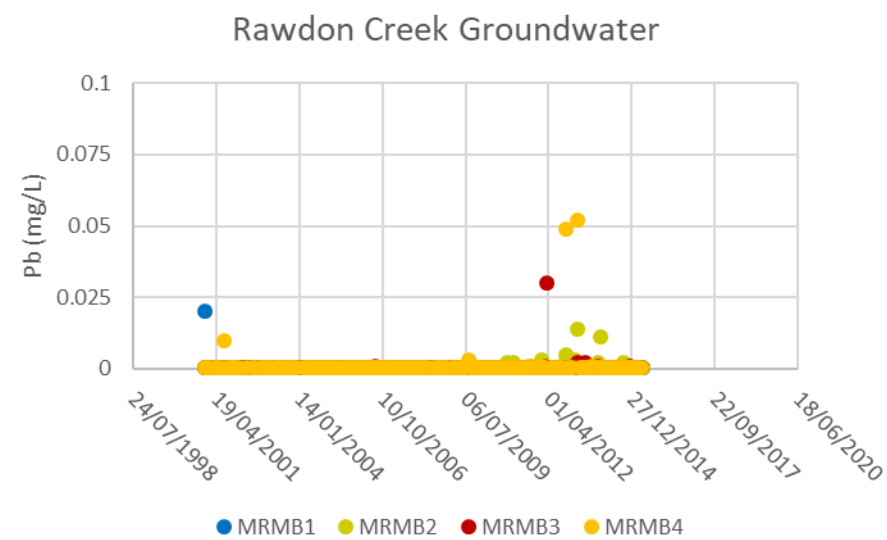
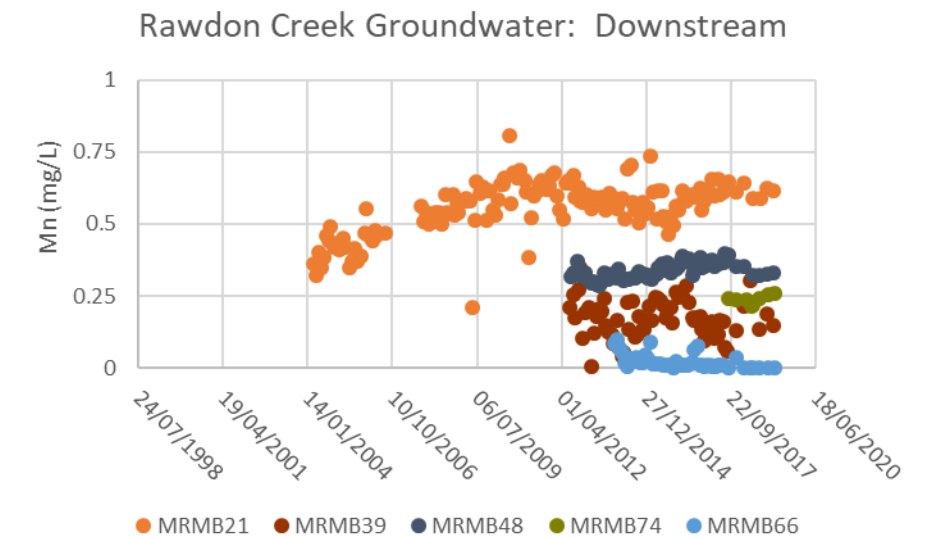
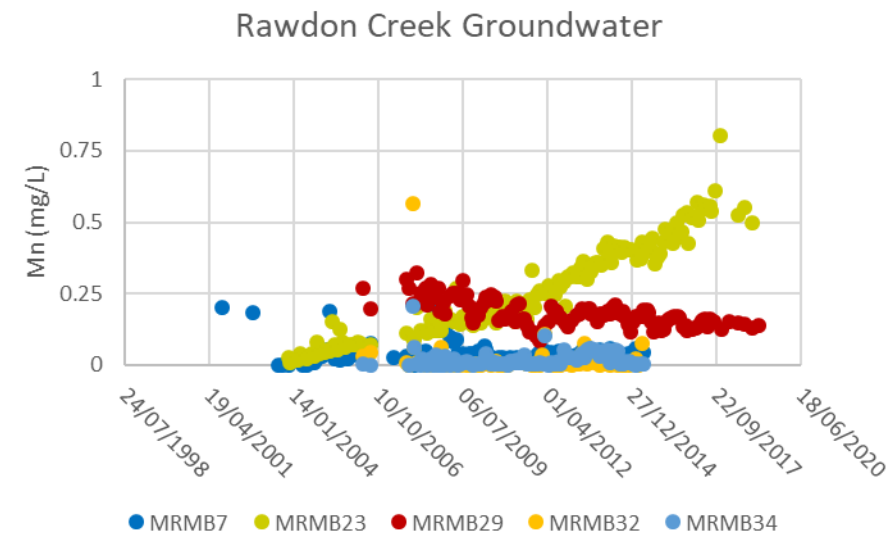
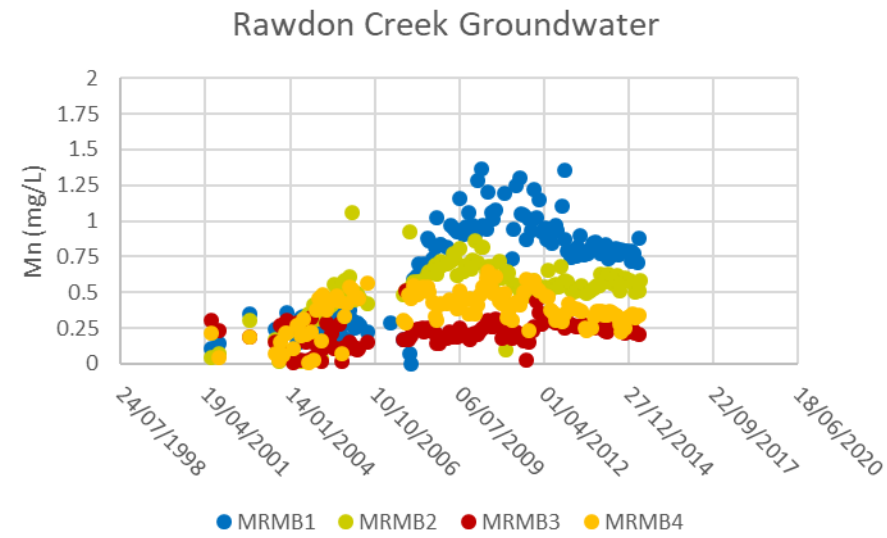












Sample Point	Statistic	pH	EC (µS/cm)	Cyanide Total (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Sulphate (mg/L)	Alk Tot as CaCO3 (mg/L)	SO4/Cl (M/M)	Fluoride (mg/L)	Nitrate as N (mg/L)	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)
MRMB01 07/12/2000 - 05/05/2015	Count	251	249	251	75	75	251	69	75	66	64	251	251	69	251	67	251
	Min	5.18	968	0.002	293	267	40	381	0.039	0.6	0.005	0.001	0.0005	0.025	0.00005	0.0005	0.0005
	5th %ile	6.59	2130	0.002	377	459	50	435	0.186	0.7	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	20th %ile	6.89	3160	0.004	497	536	461	489	0.376	0.8	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	Mean	7.16	3898	0.044	629	737	824	526	0.535	0.9	0.103	0.013	0.0009	0.026	0.00067	0.0009	0.0048
	Median	7.14	3870	0.034	685	719	986	511	0.531	0.9	0.020	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	80th %ile	7.46	4838	0.074	719	873	1130	563	0.677	1.0	0.050	0.005	0.0005	0.025	0.00070	0.0010	0.0040
	95th %ile	7.87	5309	0.123	756	1153	1260	634	0.731	1.1	0.594	0.020	0.0020	0.025	0.00195	0.0020	0.0200
	Max	8.87	5650	0.230	802	1260	1390	691	1.507	1.1	0.894	0.400	0.0200	0.060	0.04100	0.0120	0.2000
MRMB02 07/12/2000 - 14/05/2015	Count	173	173	174	67	67	173	61	67	59	58	173	173	60	172	60	173
	Min	5.59	758	0.002	319	455	38	233	0.037	0.3	0.005	0.003	0.0005	0.004	0.00005	0.0005	0.0005
	5th %ile	6.43	2214	0.002	414	510	88	414	0.227	0.7	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	20th %ile	6.64	3426	0.003	712	761	699	472	0.310	0.8	0.040	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	Mean	6.88	4395	0.049	727	889	888	494	0.444	0.9	0.116	0.014	0.0009	0.025	0.00084	0.0010	0.0042
	Median	6.86	4650	0.043	763	854	1000	496	0.456	0.9	0.065	0.005	0.0005	0.025	0.00040	0.0005	0.0010
	80th %ile	7.10	5382	0.089	811	1068	1126	520	0.571	1.0	0.166	0.005	0.0005	0.025	0.00118	0.0010	0.0030
	95th %ile	7.45	5792	0.138	866	1274	1240	570	0.609	1.1	0.333	0.019	0.0020	0.025	0.00322	0.0021	0.0132
	Max	8.21	6090	0.197	909	1400	1400	691	0.685	1.5	0.718	0.770	0.0200	0.026	0.01430	0.0092	0.2090
MRMB03 07/12/2000 - 20/05/2015	Count	183	181	183	65	65	180	60	65	56	56	180	180	58	180	58	180
	Min	5.88	1013	0.002	397	508	6	44	0.039	0.5	0.005	0.001	0.0005	0.004	0.00005	0.0005	0.0005
	5th %ile	6.58	2830	0.002	451	661	79	46	0.055	0.6	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	20th %ile	6.81	3400	0.002	572	753	181	469	0.179	1.0	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	Mean	7.04	3885	0.046	605	845	391	494	0.226	1.2	0.012	0.009	0.0016	0.025	0.00030	0.0011	0.0011
	Median	7.01	4020	0.025	613	856	434	566	0.232	1.2	0.005	0.005	0.0010	0.025	0.00005	0.0005	0.0005
	80th %ile	7.24	4350	0.078	655	926	578	591	0.288	1.5	0.011	0.005	0.0020	0.025	0.00020	0.0010	0.0010
	95th %ile	7.62	4630	0.160	703	1040	637	620	0.347	2.0	0.047	0.010	0.0040	0.025	0.00070	0.0030	0.0020
	Max	8.02	4900	0.281	720	1060	751	657	0.352	2.8	0.082	0.290	0.0200	0.025	0.00790	0.0120	0.0600
MRMB04 07/12/2000 - 20/05/2015	Count	166	165	166	64	64	165	61	64	56	55	163	164	56	164	56	164
	Min	6.20	1480	0.002	410	476	76	38	0.000	0.4	0.005	0.001	0.0005	0.004	0.00010	0.0005	0.0005
	5th %ile	6.49	2821	0.002	442	517	80	43	0.000	0.6	0.005	0.005	0.0005	0.025	0.00020	0.0005	0.0005
	20th %ile	6.71	3276	0.006	507	610	159	450	0.000	0.7	0.005	0.005	0.0005	0.025	0.00030	0.0005	0.0005
	Mean	6.95	3691	0.053	546	709	535	492	0.000	0.9	0.018	0.027	0.0006	0.026	0.00155	0.0010	0.0019
	Median	6.94	3701	0.038	550	694	669	581	0.000	0.9	0.005	0.005	0.0005	0.025	0.00180	0.0005	0.0005
	80th %ile	7.15	4150	0.084	585	765	784	622	0.000	1.0	0.020	0.005	0.0005	0.025	0.00250	0.0010	0.0020
	95th %ile	7.37	4704	0.159	622	1046	897	651	0.000	1.1	0.073	0.100	0.0010	0.025	0.00250	0.0031	0.0070
	Max	8.04	5425	0.304	661	1230	1020	712	0.000	1.5	0.250	0.900	0.0100	0.110	0.00800	0.0120	0.0600
MRMB07 30/08/2001 - 14/05/2015	Count	161	162	162	64	65	161	60	65	57	56	161	161	59	161	58	160
	Min	6.22	1513	0.001	240	236	47	513	0.074	0.7	0.005	0.001	0.0005	0.004	0.00005	0.0005	0.0005
	5th %ile	6.61	2842	0.002	547	472	117	630	0.247	0.8	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	20th %ile	6.86	3890	0.014	720	500	497	676	0.644	0.9	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	Mean	7.07	4074	0.075	776	572	806	713	0.669	1.1	0.053	0.068	0.0010	0.024	0.00024	0.0013	0.0025
	Median	7.08	4155	0.051	801	571	903	718	0.715	1.1	0.020	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	80th %ile	7.31	4480	0.122	856	627	1100	765	0.789	1.2	0.040	0.005	0.0010	0.025	0.00005	0.0010	0.0020
	95th %ile	7.52	4769	0.229	914	708	1200	799	0.860	1.3	0.125	0.120	0.0020	0.025	0.00060	0.0033	0.0081
	Max	8.23	4920	0.395	945	911	1490	832	1.002	1.7	0.890	4.910	0.0100	0.025	0.01210	0.0110	0.0780
MRMB23 20/11/2003 - 20/02/2019	Count	162	163	162	94	92	163	91	92	85	85	163	163	87	163	87	163
	Min	5.99	3053	0.002	1	439	366	1	0.226	0.5	0.010	0.005	0.0005	0.018	0.00005	0.0005	0.0005
	5th %ile	6.53	3641	0.002	570	549	446	470	0.308	0.8	0.034	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	20th %ile	6.79	3915	0.017	624	586	610	587	0.537	0.9	0.140	0.005	0.0005	0.025	0.00005	0.0005	0.0020
	Mean	6.98	4188	0.091	656	623	897	614	0.621	1.0	0.289	0.027	0.0013	0.029	0.00072	0.0009	0.0069
	Median	6.98	4200	0.063	664	620	961	629	0.627	1.0	0.270	0.005	0.0005	0.025	0.00010	0.0005	0.0030
	80th %ile	7.16	4466	0.166	705	668	1126	660	0.713	1.1	0.360	0.005	0.0010	0.025	0.00030	0.0005	0.0080
	95th %ile	7.46	4590	0.241	745	699	1229	733	0.829	1.2	0.620	0.020	0.0020	0.025	0.00254	0.0020	0.0200
	Max	8.09	5442	0.341	820	739	1360	823	0.909	1.5	1.480	3.140	0.0200	0.330	0.03200	0.0110	0.1260

Sample Point	Statistic	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Lead Dissolved (mg/L)	Zinc Dissolved (mg/L)	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Molybdenum Dissolved (mg/L)
MRMB01 07/12/2000 - 05/05/2015	Count	251	170	251	251	75	71	71	89
	Min	0.010	0.001	0.0005	0.001	1	4	67	0.0005
	5th %ile	0.020	0.140	0.0005	0.003	64	4	96	0.0050
	20th %ile	0.025	0.251	0.0005	0.003	209	5	144	0.0060
	Mean	0.064	0.597	0.0007	0.035	225	5	153	0.0069
	Median	0.025	0.680	0.0005	0.008	250	5	157	0.0070
	80th %ile	0.070	0.922	0.0005	0.030	264	6	169	0.0080
	95th %ile	0.185	1.177	0.0005	0.102	297	7	183	0.0090
	Max	2.900	2.060	0.0200	1.748	305	7	188	0.0090
MRMB02 07/12/2000 - 14/05/2015	Count	173	133	173	173	63	63	64	84
	Min	0.003	0.020	0.0005	0.001	99	2	1	0.0030
	5th %ile	0.020	0.092	0.0005	0.003	182	3	110	0.0050
	20th %ile	0.025	0.422	0.0005	0.003	224	3	142	0.0060
	Mean	0.064	0.524	0.0008	0.030	241	4	151	0.0069
	Median	0.025	0.550	0.0005	0.020	246	4	155	0.0070
	80th %ile	0.050	0.644	0.0005	0.041	271	4	170	0.0080
	95th %ile	0.180	0.768	0.0014	0.098	290	5	182	0.0080
	Max	2.700	1.060	0.0140	0.240	309	8	186	0.0090
MRMB03 07/12/2000 - 20/05/2015	Count	180	140	179	179	62	62	62	93
	Min	0.003	0.012	0.0005	0.001	85	2	63	0.0005
	5th %ile	0.025	0.088	0.0005	0.003	103	3	70	0.0020
	20th %ile	0.060	0.166	0.0005	0.003	149	4	114	0.0020
	Mean	0.482	0.220	0.0007	0.055	176	4	131	0.0024
	Median	0.420	0.230	0.0005	0.011	185	4	138	0.0020
	80th %ile	0.840	0.273	0.0005	0.024	200	5	152	0.0030
	95th %ile	1.101	0.310	0.0005	0.277	210	5	166	0.0030
	Max	2.500	0.510	0.0300	1.100	220	6	172	0.0030
MRMB04 07/12/2000 - 20/05/2015	Count	164	126	164	164	63	62	62	80
	Min	0.003	0.010	0.0005	0.001	0	1	52	0.0005
	5th %ile	0.020	0.080	0.0005	0.003	119	2	63	0.0020
	20th %ile	0.025	0.270	0.0005	0.003	194	3	111	0.0030
	Mean	0.080	0.370	0.0015	0.023	220	3	128	0.0036
	Median	0.025	0.379	0.0005	0.013	220	4	130	0.0040
	80th %ile	0.074	0.480	0.0005	0.023	251	4	150	0.0040
	95th %ile	0.266	0.545	0.0005	0.046	307	5	179	0.0050
	Max	2.900	0.649	0.0970	1.010	348	6	197	0.0050
MRMB07 30/08/2001 - 14/05/2015	Count	161	127	161	161	61	61	61	83
	Min	0.003	0.001	0.0005	0.001	61	5	64	0.0005
	5th %ile	0.020	0.002	0.0005	0.003	86	6	121	0.0040
	20th %ile	0.025	0.020	0.0005	0.003	108	7	131	0.0060
	Mean	0.102	0.044	0.0008	0.014	116	8	138	0.0084
	Median	0.080	0.034	0.0005	0.010	117	8	138	0.0090
	80th %ile	0.140	0.048	0.0005	0.020	129	9	145	0.0106
	95th %ile	0.260	0.154	0.0005	0.040	137	11	155	0.0129
	Max	1.500	0.220	0.0220	0.100	139	14	178	0.0180
MRMB23 20/11/2003 - 20/02/2019	Count	163	149	163	163	90	90	92	111
	Min	0.010	0.010	0.0005	0.003	1	1	1	0.0100
	5th %ile	0.020	0.034	0.0005	0.003	131	4	134	0.0125
	20th %ile	0.025	0.110	0.0005	0.003	167	5	149	0.0150
	Mean	0.054	0.288	0.0006	0.023	173	5	154	0.0157
	Median	0.025	0.247	0.0005	0.012	180	5	158	0.0160
	80th %ile	0.025	0.415	0.0005	0.030	187	6	164	0.0170
	95th %ile	0.159	0.548	0.0005	0.069	195	7	169	0.0185
	Max	2.100	3.720	0.0030	0.262	203	8	176	0.0220

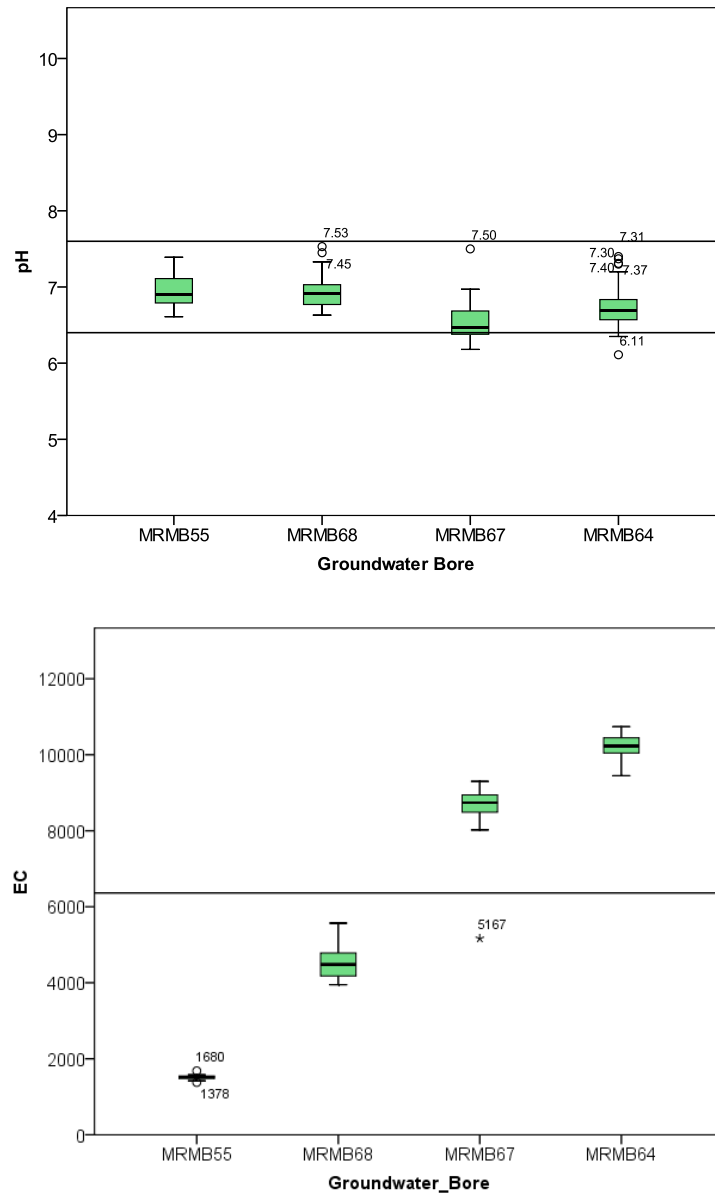
Sample Point	Statistic	pH	EC (µS/cm)	Cyanide Total (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Sulphate (mg/L)	Alk Tot as CaCO3 (mg/L)	SO4/Cl (M/M)	Fluoride (mg/L)	Nitrate as N (mg/L)	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)
MRMB29 12/04/2006 - 06/02/2019	Count	139	139	139	88	87	139	87	87	80	80	139	139	82	139	81	139
	Min	6.09	5300	0.002	1	1540	3	1	0.001	0.6	0.005	0.005	0.0005	0.014	0.00005	0.0005	0.0005
	5th %ile	6.34	5699	0.002	1014	1756	241	510	0.087	0.8	0.309	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	20th %ile	6.55	6586	0.002	1080	1892	324	661	0.107	1.1	0.800	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	Mean	6.79	7262	0.026	1117	2123	416	685	0.124	1.2	1.119	0.018	0.0007	0.025	0.00027	0.0008	0.0018
	Median	6.75	7489	0.024	1130	2150	397	717	0.122	1.2	1.120	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	80th %ile	7.02	7940	0.043	1176	2348	523	746	0.140	1.4	1.402	0.005	0.0005	0.025	0.00040	0.0005	0.0020
	95th %ile	7.28	8180	0.057	1230	2460	650	765	0.166	1.5	1.879	0.020	0.0005	0.025	0.00124	0.0020	0.0100
	Max	8.13	8360	0.163	1350	2640	701	790	0.230	1.8	2.870	0.780	0.0200	0.025	0.00300	0.0160	0.0200
MRMB32 12/04/2006 - 20/05/2015	Count	101	102	101	52	52	100	49	52	47	48	100	100	49	100	49	100
	Min	5.83	150	0.002	53	22	4	1	0.050	0.1	0.005	0.005	0.0005	0.003	0.00005	0.0005	0.0005
	5th %ile	6.20	330	0.002	62	30	17	102	0.086	0.2	0.040	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	20th %ile	6.43	422	0.002	80	38	24	128	0.122	0.2	0.050	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	Mean	6.94	770	0.005	128	96	59	167	0.203	0.3	0.160	4.380	0.0008	0.026	0.00015	0.0059	0.0056
	Median	7.00	654	0.002	114	72	39	156	0.180	0.3	0.110	0.040	0.0005	0.025	0.00005	0.0005	0.0030
	80th %ile	7.40	901	0.002	164	136	70	203	0.270	0.3	0.246	0.520	0.0005	0.025	0.00005	0.0005	0.0040
	95th %ile	7.62	1168	0.031	204	158	148	245	0.384	0.6	0.370	5.658	0.0011	0.025	0.00021	0.0224	0.0201
	Max	8.20	4790	0.067	467	670	408	460	0.571	1.1	0.900	132.000	0.0100	0.130	0.00610	0.1380	0.1190
MRMB34 11/04/2006 - 14/05/2015	Count	102	103	104	60	60	102	58	59	53	53	101	101	53	101	52	101
	Min	4.67	80	0.002	2	11	1	1	0.007	0.0	0.010	0.005	0.0005	0.003	0.00005	0.0005	0.0005
	5th %ile	4.87	100	0.002	19	14	11	1	0.022	0.1	0.460	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	20th %ile	5.42	120	0.002	23	19	15	4	0.052	0.1	0.792	0.010	0.0005	0.025	0.00005	0.0005	0.0005
	Mean	5.93	334	0.004	81	116	25	7	0.173	0.6	1.271	7.909	0.0010	0.025	0.00007	0.0022	0.0130
	Median	5.94	184	0.002	59	69	21	5	0.124	0.1	1.100	2.180	0.0005	0.025	0.00005	0.0005	0.0010
	80th %ile	6.47	572	0.004	145	240	34	9	0.301	0.1	1.724	9.420	0.0005	0.025	0.00005	0.0005	0.0080
	95th %ile	7.08	971	0.012	188	284	62	12	0.401	0.2	2.586	34.500	0.0010	0.025	0.00020	0.0114	0.0230
	Max	7.60	1021	0.040	192	316	81	53	0.543	27.0	3.280	144.000	0.0400	0.080	0.00050	0.0360	0.7400
MRMB21 31/03/2004 - 06/02/2020	Count	170	170	169	98	97	166	93	97	90	89	167	167	93	167	92	167
	Min	6.06	1890	0.002	285	622	3	1	0.001	0.7	0.005	0.005	0.0005	0.021	0.00001	0.0005	0.0005
	5th %ile	6.33	2895	0.002	372	826	108	414	0.039	0.8	0.005	0.005	0.0005	0.025	0.00001	0.0005	0.0005
	20th %ile	6.51	3288	0.002	394	906	112	468	0.046	0.8	0.005	0.005	0.0005	0.025	0.00001	0.0005	0.0005
	Mean	6.73	3614	0.033	455	970	132	500	0.053	0.9	0.011	0.016	0.0012	0.025	0.00101	0.0008	0.0013
	Median	6.69	3637	0.018	417	964	123	502	0.051	0.9	0.005	0.005	0.0010	0.025	0.00005	0.0005	0.0005
	80th %ile	6.95	4000	0.071	449	1050	152	540	0.059	1.0	0.010	0.005	0.0020	0.025	0.00060	0.0005	0.0010
	95th %ile	7.24	4207	0.085	474	1120	175	568	0.075	1.1	0.036	0.064	0.0027	0.025	0.00210	0.0020	0.0040
	Max	7.78	4890	0.104	3969	1240	271	770	0.116	1.5	0.160	0.350	0.0050	0.050	0.09700	0.0100	0.0400
MRMB39 12/07/2012 - 05/02/2020	Count	71	71	73	71	71	72	71	71	71	70	71	71	71	71	70	71
	Min	6.20	545	0.002	69	95	18	122	0.038	0.4	0.005	0.005	0.0005	0.010	0.00005	0.0005	0.0005
	5th %ile	6.47	3694	0.017	389	919	119	472	0.041	0.7	0.005	0.005	0.0005	0.025	0.00020	0.0005	0.0005
	20th %ile	6.58	3970	0.033	432	1020	133	506	0.045	0.9	0.005	0.005	0.0005	0.025	0.00020	0.0005	0.0005
	Mean	6.79	4118	0.056	453	1058	144	529	0.051	1.0	0.013	0.006	0.0007	0.025	0.00039	0.0008	0.0015
	Median	6.75	4210	0.064	456	1080	148	542	0.051	1.0	0.005	0.005	0.0005	0.025	0.00030	0.0005	0.0005
	80th %ile	7.04	4390	0.073	482	1130	157	563	0.056	1.1	0.010	0.005	0.0010	0.025	0.00060	0.0005	0.0020
	95th %ile	7.23	4435	0.080	521	1165	164	582	0.058	1.2	0.040	0.010	0.0010	0.025	0.00070	0.0005	0.0030
	Max	7.37	4520	0.085	548	1260	169	592	0.070	1.5	0.170	0.040	0.0020	0.025	0.00130	0.0120	0.0140
MRMB48 13/07/2012 - 06/02/2019	Count	67	67	68	68	68	68	68	68	68	68	68	68	68	68	67	68
	Min	6.01	963	0.002	97	180	17	198	0.026	0.9	0.005	0.001	0.0020	0.025	0.00005	0.0005	0.0005
	5th %ile	6.18	1039	0.002	107	209	19	205	0.027	0.9	0.005	0.005	0.0020	0.025	0.00005	0.0005	0.0005
	20th %ile	6.29	1079	0.002	111	223	21	212	0.030	1.0	0.005	0.005	0.0020	0.025	0.00005	0.0005	0.0005
	Mean	6.44	1148	0.003	117	246	23	222	0.035	1.1	0.007	0.006	0.0028	0.039	0.00007	0.0006	0.0007
	Median	6.39	1142	0.002	117	242	23	222	0.035	1.1	0.005	0.005	0.0030	0.025	0.00005	0.0005	0.0005
	80th %ile	6.63	1227	0.002	121	274	25	232	0.040	1.2	0.005	0.005	0.0030	0.060	0.00005	0.0005	0.0005
	95th %ile	6.83	1242	0.002	131	279	27	237	0.047	1.2	0.017	0.005	0.0030	0.070	0.00010	0.0005	0.0017
	Max	7.08	1259	0.030	134	288	30	252	0.049	1.5	0.090	0.060	0.0040	0.070	0.00050	0.0053	0.0070

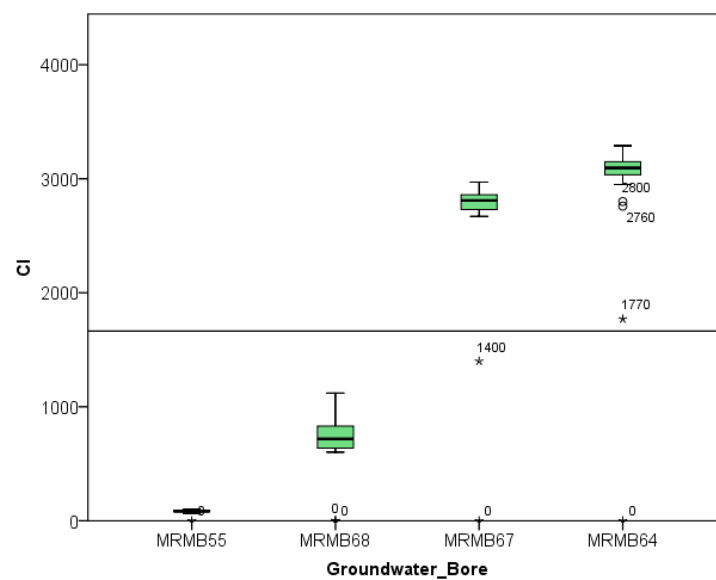
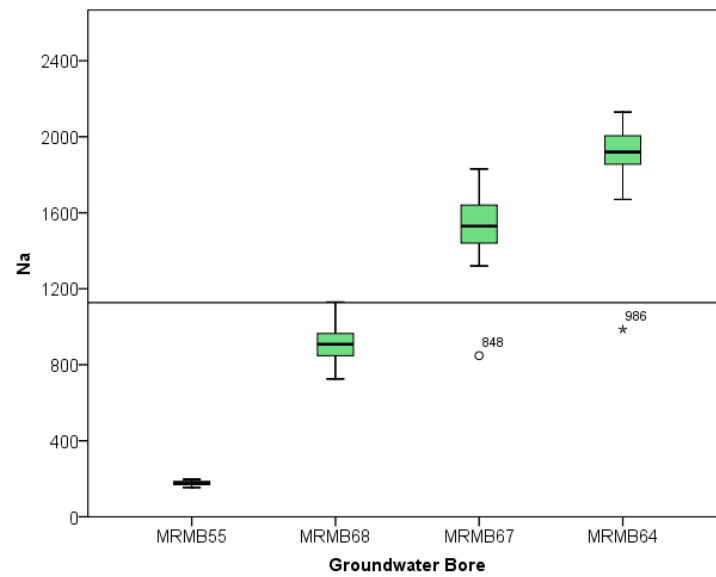
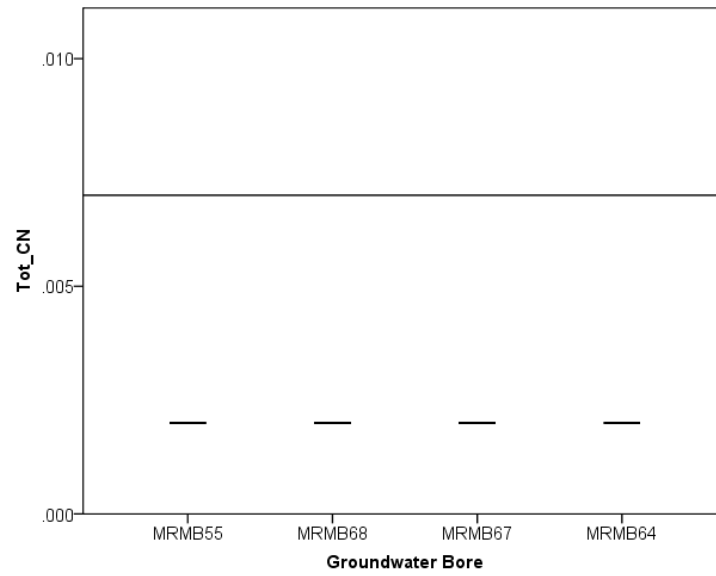
Sample Point	Statistic	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Lead Dissolved (mg/L)	Zinc Dissolved (mg/L)	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Molybdenum Dissolved (mg/L)
MRMB29 12/04/2006 - 06/02/2019	Count	139	125	139	139	87	87	87	107
	Min	0.020	0.085	0.0005	0.003	1	6	1	0.0070
	5th %ile	0.025	0.118	0.0005	0.003	184	7	216	0.0080
	20th %ile	0.025	0.142	0.0005	0.003	217	8	241	0.0090
	Mean	0.071	0.180	0.0007	0.016	249	20	248	0.0105
	Median	0.025	0.173	0.0005	0.010	230	8	250	0.0100
	80th %ile	0.080	0.217	0.0005	0.026	243	10	264	0.0128
	95th %ile	0.141	0.270	0.0010	0.047	261	10	276	0.0140
MRMB32 12/04/2006 - 20/05/2015	Max	2.900	0.324	0.0100	0.150	2300	992	288	0.0170
	Count	100	86	100	100	50	50	50	70
	Min	0.003	0.001	0.0005	0.001	1	1	1	0.0005
	5th %ile	0.025	0.001	0.0005	0.003	3	1	4	0.0005
	20th %ile	0.025	0.001	0.0005	0.003	5	2	5	0.0005
	Mean	3.417	0.017	0.0016	0.010	12	2	10	0.0037
	Median	0.025	0.002	0.0005	0.003	10	2	8	0.0020
	80th %ile	0.372	0.014	0.0005	0.003	15	3	12	0.0032
MRMB34 11/04/2006 - 14/05/2015	95th %ile	3.816	0.060	0.0021	0.056	21	4	15	0.0170
	Max	134.000	0.563	0.0680	0.204	100	12	99	0.0230
	Count	101	95	101	101	58	58	58	78
	Min	0.003	0.001	0.0005	0.003	0	1	1	0.0005
	5th %ile	0.025	0.001	0.0005	0.003	1	1	1	0.0005
	20th %ile	0.025	0.002	0.0005	0.003	1	1	1	0.0005
	Mean	5.425	0.019	0.0027	0.016	1	1	5	0.0008
	Median	1.550	0.009	0.0005	0.009	1	1	2	0.0005
MRMB21 31/03/2004 - 06/02/2020	80th %ile	7.260	0.036	0.0020	0.020	2	1	11	0.0005
	95th %ile	22.000	0.057	0.0070	0.051	3	1	14	0.0020
	Max	80.300	0.204	0.0610	0.155	3	1	15	0.0180
	Count	167	153	167	166	94	94	94	115
	Min	0.025	0.210	0.0005	0.001	1	1	1	0.0005
	5th %ile	0.245	0.383	0.0005	0.001	129	3	129	0.0030
	20th %ile	0.584	0.500	0.0005	0.001	175	3	140	0.0030
	Mean	0.689	0.558	0.0009	0.024	182	3	149	0.0034
MRMB39 12/07/2012 - 05/02/2020	Median	0.720	0.579	0.0005	0.020	185	3	152	0.0030
	80th %ile	0.800	0.627	0.0005	0.040	201	4	162	0.0040
	95th %ile	0.910	0.675	0.0050	0.072	210	4	167	0.0040
	Max	2.200	0.806	0.0090	0.180	218	5	195	0.0070
	Count	71	71	71	71	71	71	71	71
	Min	0.025	0.005	0.0005	0.003	21	1	16	0.0010
	5th %ile	0.025	0.057	0.0005	0.003	165	1	155	0.0040
	20th %ile	0.025	0.114	0.0005	0.003	180	1	162	0.0040
MRMB48 13/07/2012 - 06/02/2019	Mean	0.060	0.169	0.0007	0.008	188	2	168	0.0041
	Median	0.025	0.167	0.0005	0.005	191	2	171	0.0040
	80th %ile	0.025	0.228	0.0005	0.013	200	2	176	0.0040
	95th %ile	0.043	0.268	0.0015	0.025	209	2	185	0.0050
	Max	2.400	0.350	0.0090	0.051	214	3	192	0.0060
	Count	68	68	68	68	68	68	68	68
	Min	0.340	0.284	0.0005	0.001	50	3	28	0.0005
	5th %ile	1.130	0.300	0.0005	0.003	55	3	30	0.0005
	20th %ile	1.280	0.312	0.0005	0.003	58	4	31	0.0005
	Mean	1.398	0.336	0.0007	0.006	61	4	33	0.0005
	Median	1.410	0.328	0.0005	0.003	61	4	33	0.0005
	80th %ile	1.568	0.365	0.0005	0.009	66	4	36	0.0005
	95th %ile	1.637	0.382	0.0008	0.019	68	4	38	0.0005
	Max	1.700	0.398	0.0140	0.037	69	5	40	0.0010

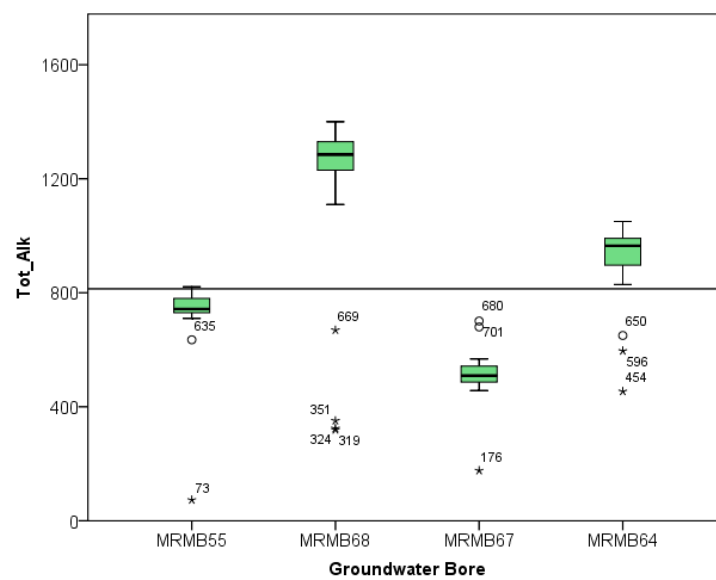
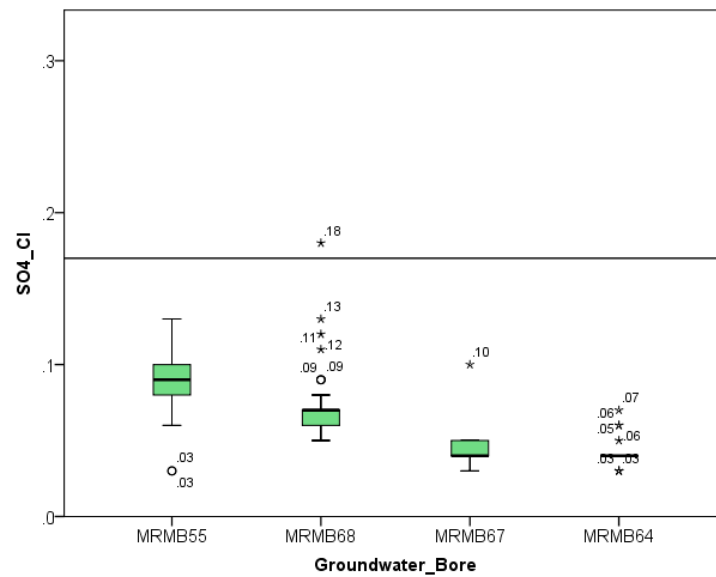
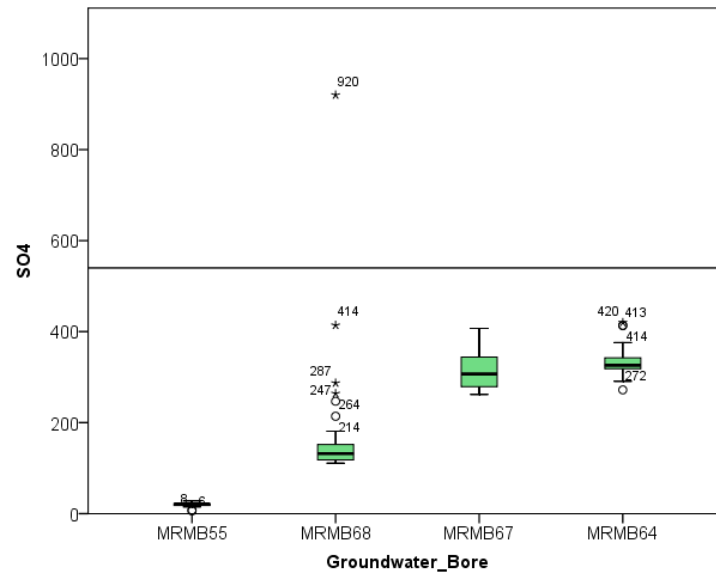
Sample Point	Statistic	pH	EC (µS/cm)	Cyanide Total (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Sulphate (mg/L)	Alk Tot as CaCO3 (mg/L)	SO4/Cl (M/M)	Fluoride (mg/L)	Nitrate as N (mg/L)	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)
MRMB74 16/08/2017 - 12/02/2019	Count	8	8	8	8	8	8	8	8	7	8	8	8	8	8	8	8
	Min	6.74	9990	0.002	1610	3520	347	59	0.032	1.5	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	5th %ile	6.83	10064	0.002	1614	3580	348	59	0.032	1.5	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	20th %ile	7.01	10212	0.002	1624	3730	349	61	0.034	1.5	0.005	0.005	0.0007	0.035	0.00005	0.0005	0.0005
	Mean	7.15	10623	0.002	1678	3821	365	65	0.035	1.6	0.005	0.008	0.0011	0.051	0.00005	0.0005	0.0006
	Median	7.19	10715	0.002	1650	3855	368	64	0.035	1.6	0.005	0.005	0.0010	0.060	0.00005	0.0005	0.0005
	80th %ile	7.28	11040	0.002	1722	3928	376	67	0.037	1.6	0.005	0.008	0.0016	0.060	0.00005	0.0005	0.0005
	95th %ile	7.40	11047	0.002	1789	3999	384	74	0.039	1.7	0.005	0.017	0.0020	0.067	0.00005	0.0005	0.0008
	Max	7.47	11050	0.002	1820	4020	388	77	0.039	1.8	0.005	0.020	0.0020	0.070	0.00005	0.0005	0.0010
MRMB66 12/02/2013 - 12/02/2019	Count	51	51	51	51	51	51	51	51	50	50	51	51	51	51	49	51
	Min	6.94	1317	0.002	235	84	39	320	0.153	4.2	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	5th %ile	6.99	1337	0.002	255	85	173	352	0.606	4.5	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	20th %ile	7.08	1350	0.002	265	87	179	376	0.709	4.9	0.005	0.005	0.0010	0.025	0.00005	0.0005	0.0005
	Mean	7.22	1372	0.002	277	92	187	383	0.755	5.2	0.012	0.005	0.0015	0.026	0.00022	0.0005	0.0008
	Median	7.17	1369	0.002	275	90	189	384	0.771	5.3	0.005	0.005	0.0020	0.025	0.00005	0.0005	0.0005
	80th %ile	7.37	1392	0.002	286	95	197	395	0.827	5.4	0.010	0.005	0.0020	0.025	0.00020	0.0005	0.0010
	95th %ile	7.63	1412	0.002	307	107	211	406	0.865	5.8	0.060	0.005	0.0020	0.025	0.00035	0.0005	0.0020
	Max	7.72	1459	0.005	317	112	237	422	0.921	6.8	0.070	0.020	0.0030	0.070	0.00360	0.0005	0.0020

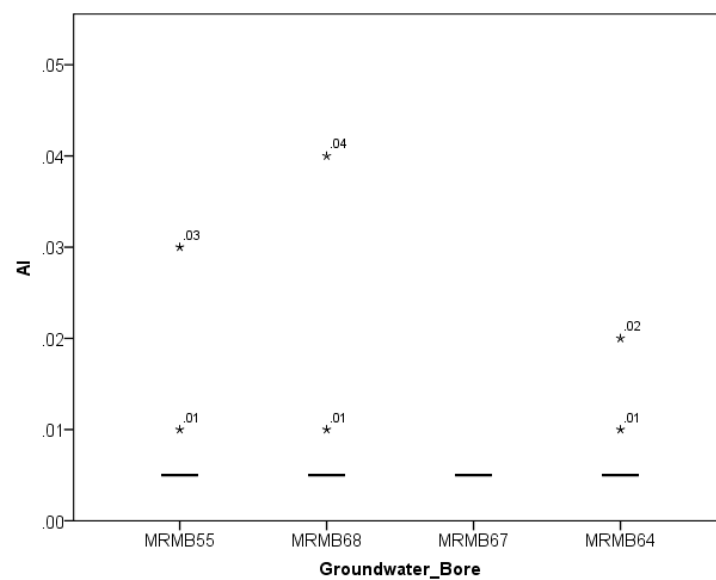
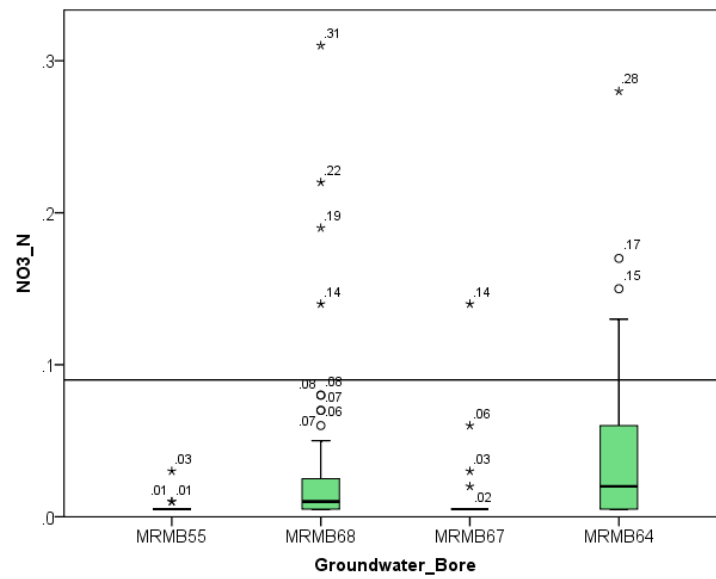
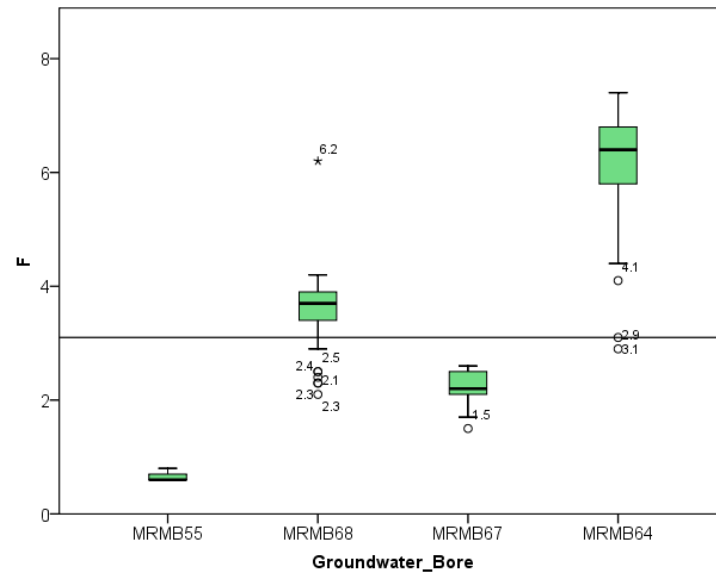
Sample Point	Statistic	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Lead Dissolved (mg/L)	Zinc Dissolved (mg/L)	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Molybdenum Dissolved (mg/L)
MRMB74 16/08/2017 - 12/02/2019	Count	8	8	8	8	8	8	8	8
	Min	0.025	0.216	0.0005	0.003	543	3	51	0.0005
	5th %ile	0.037	0.217	0.0005	0.003	549	3	51	0.0007
	20th %ile	0.060	0.226	0.0005	0.003	562	4	51	0.0014
	Mean	0.142	0.238	0.0005	0.003	589	4	53	0.0019
	Median	0.100	0.238	0.0005	0.003	579	4	53	0.0020
	80th %ile	0.240	0.249	0.0005	0.003	608	4	56	0.0026
	95th %ile	0.286	0.256	0.0005	0.005	650	4	57	0.0030
	Max	0.310	0.257	0.0005	0.006	669	4	57	0.0030
	Count	51	51	51	51	51	51	51	51
MRMB66 12/02/2013 - 12/02/2019	Min	0.025	0.001	0.0005	0.003	16	1	13	0.0050
	5th %ile	0.025	0.001	0.0005	0.003	16	1	15	0.0050
	20th %ile	0.025	0.006	0.0005	0.003	17	1	15	0.0060
	Mean	0.025	0.021	0.0005	0.010	20	3	16	0.0066
	Median	0.025	0.011	0.0005	0.008	18	2	16	0.0060
	80th %ile	0.025	0.032	0.0005	0.013	20	4	17	0.0070
	95th %ile	0.025	0.080	0.0005	0.026	25	5	18	0.0080
	Max	0.025	0.096	0.0005	0.062	94	8	20	0.0190

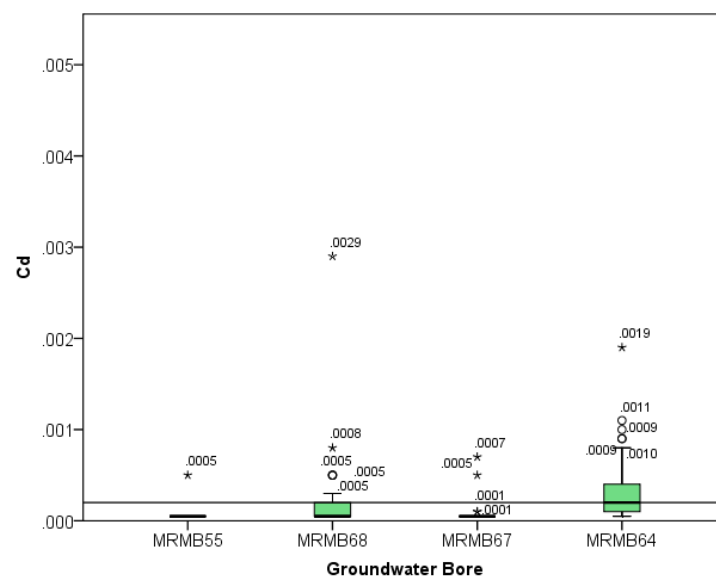
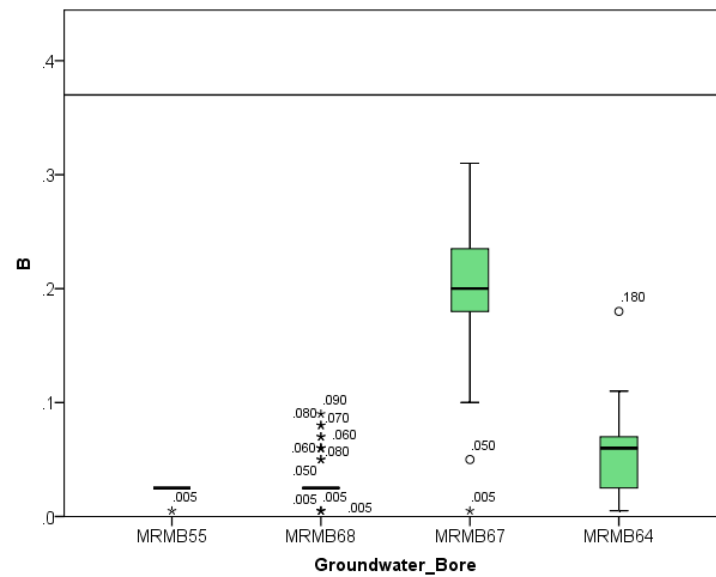
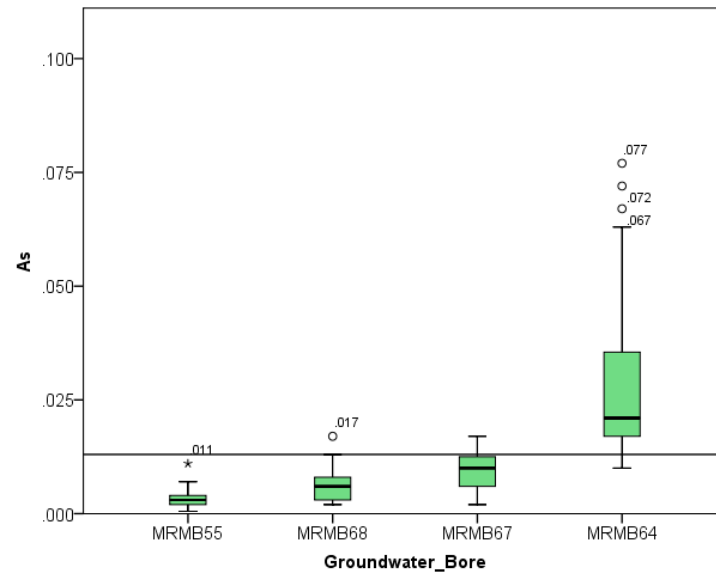
Appendix 16: Data Summaries for the Landscape Spur between Rawdon Creek and Twelve Mile Creek

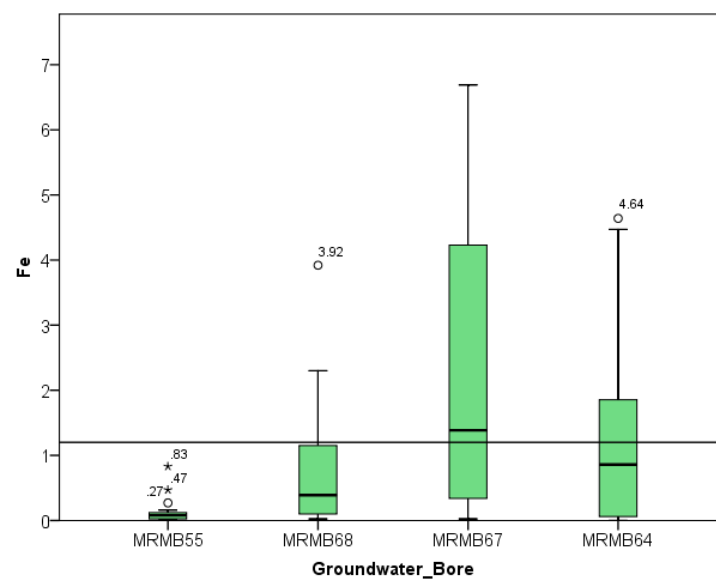
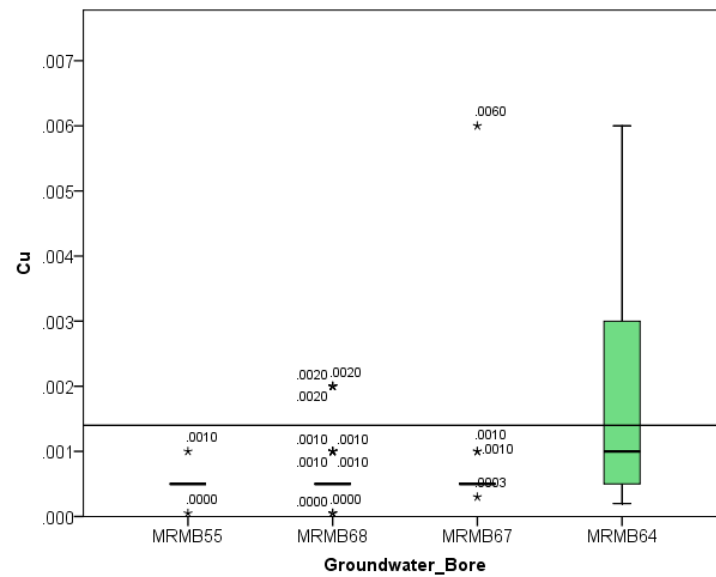
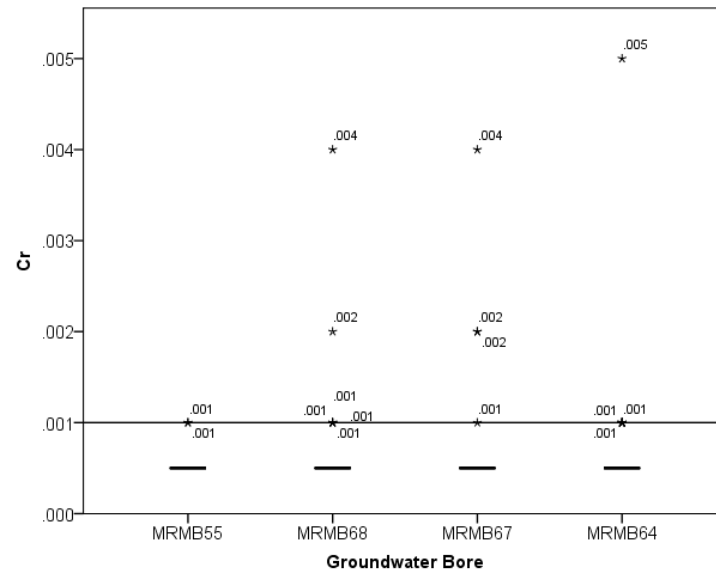


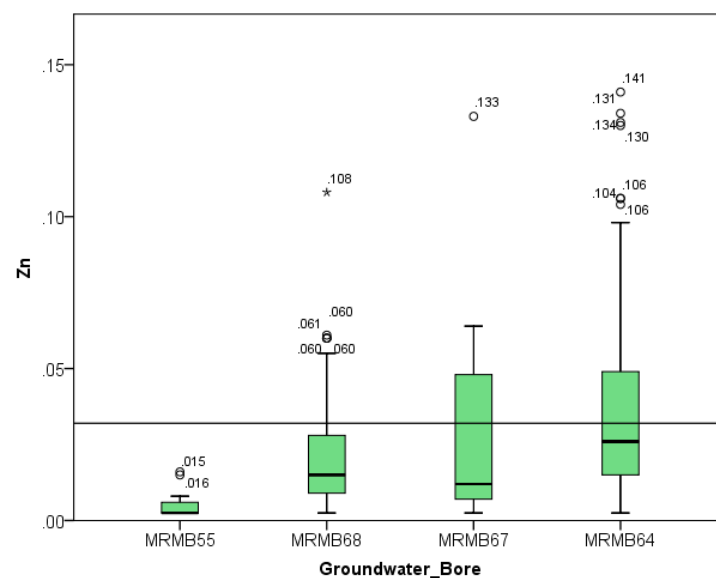
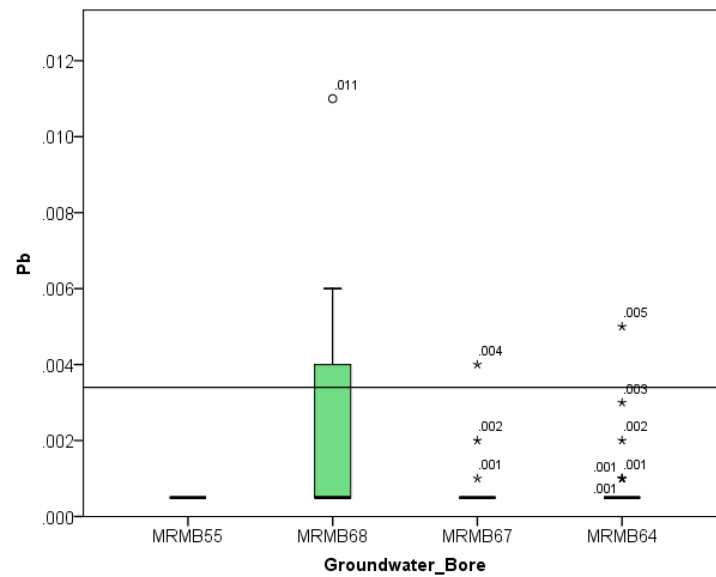
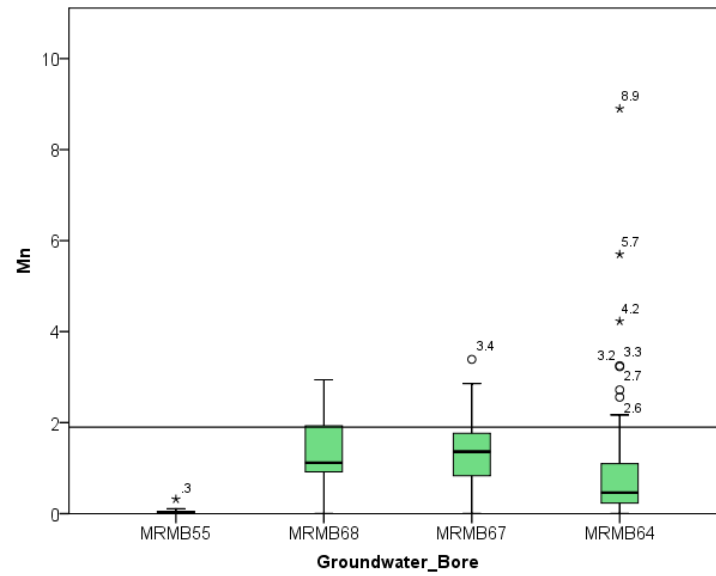








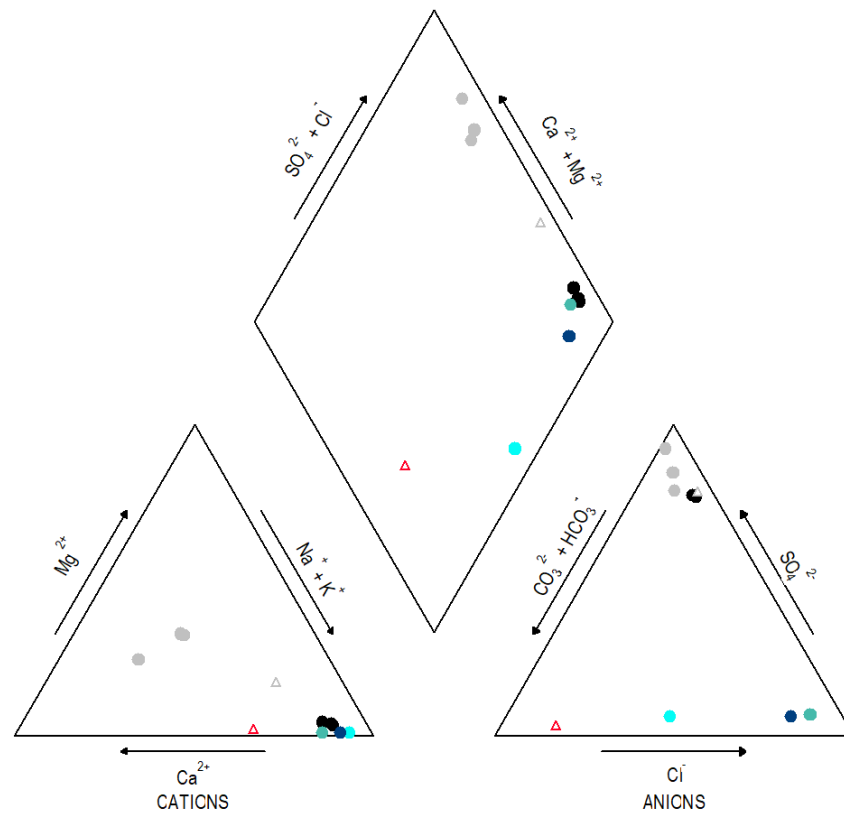


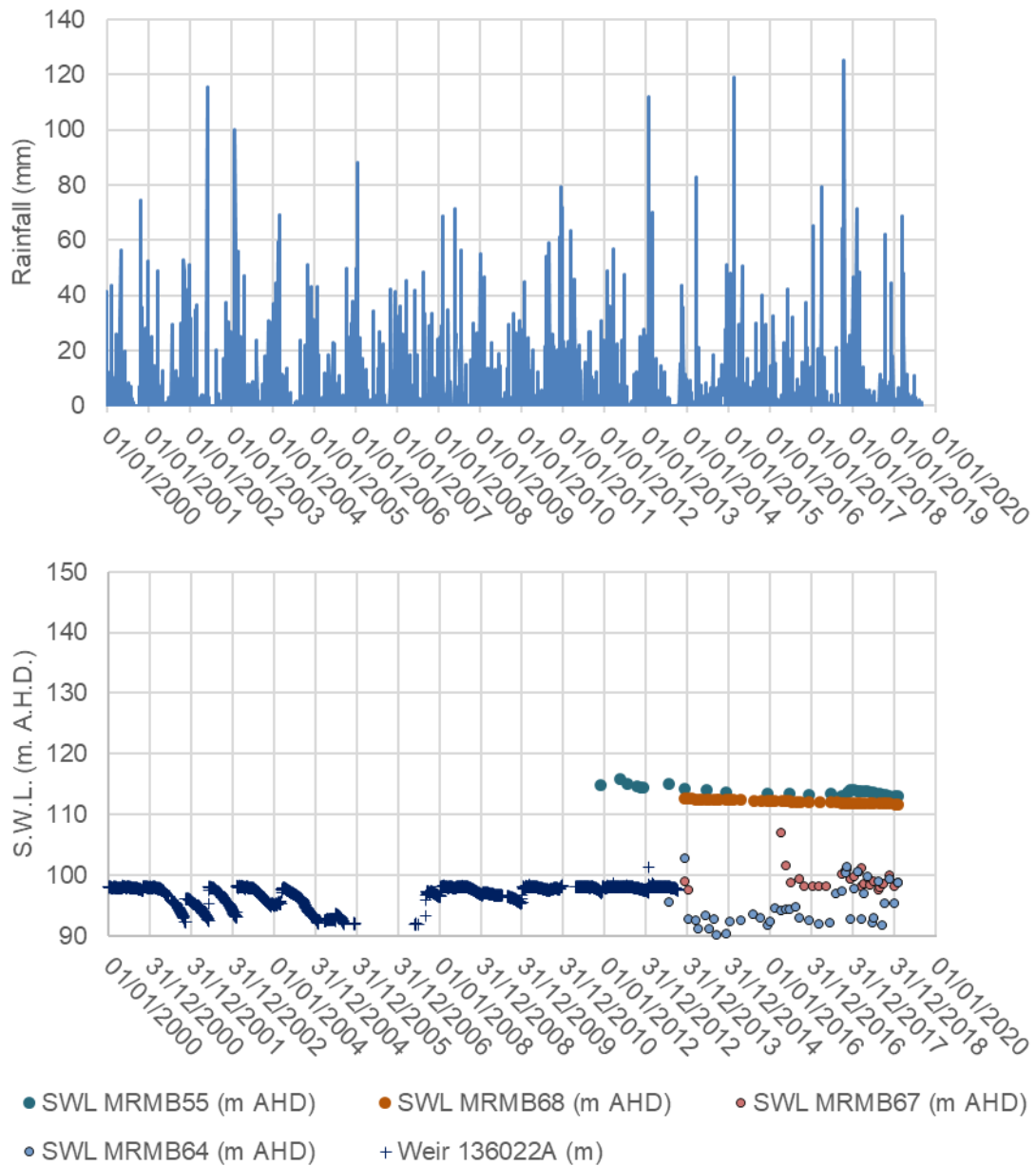


Landscape Spur

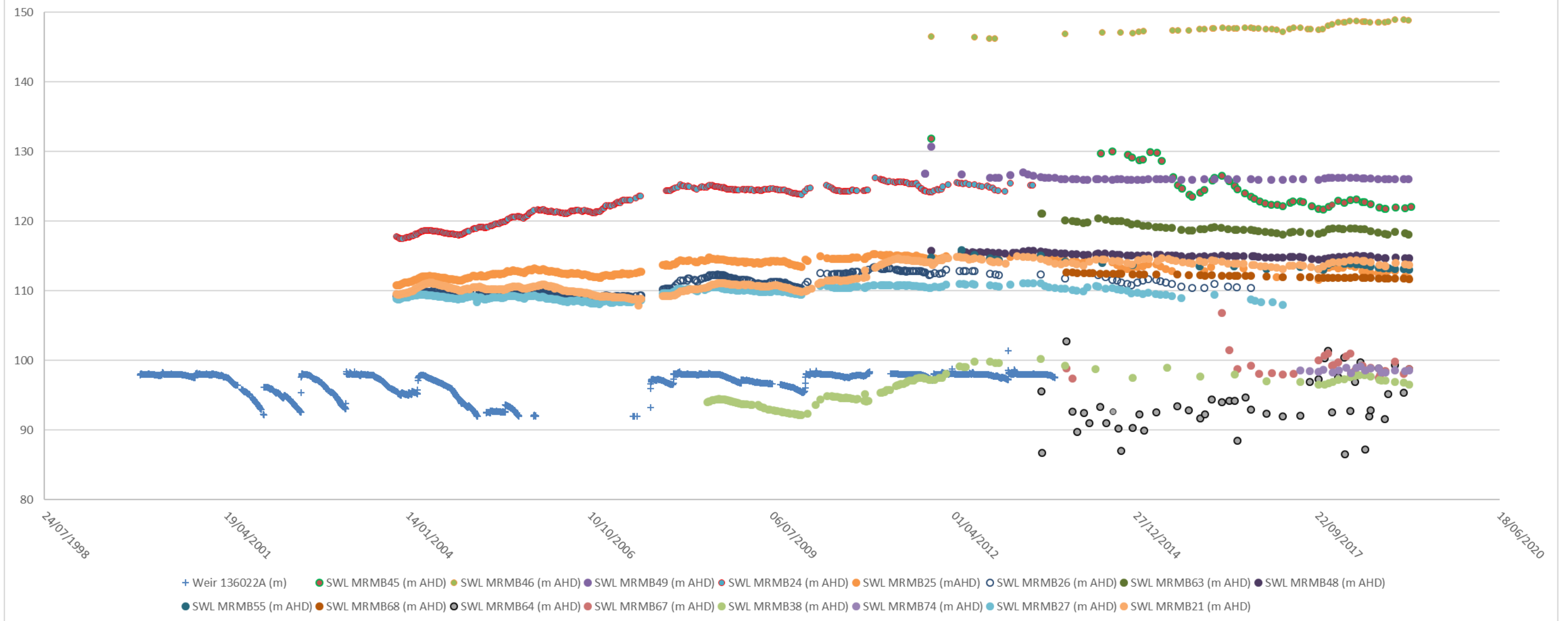
EXPLANATION

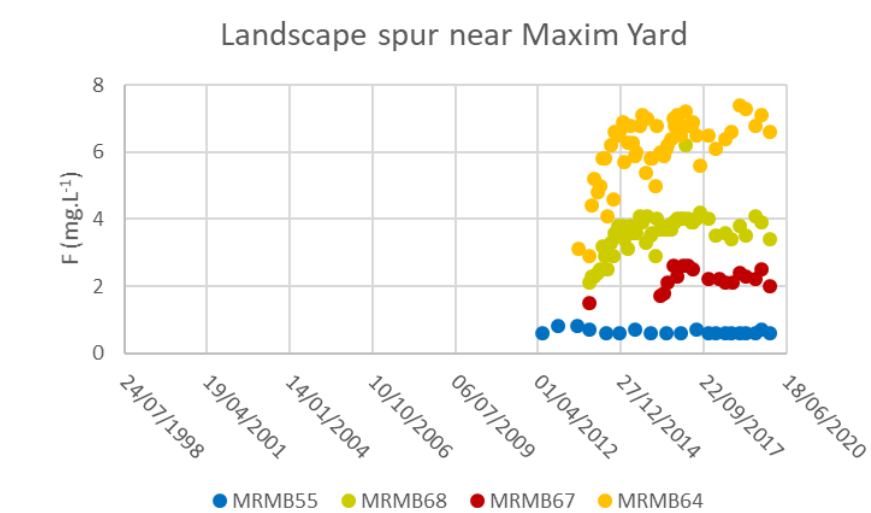
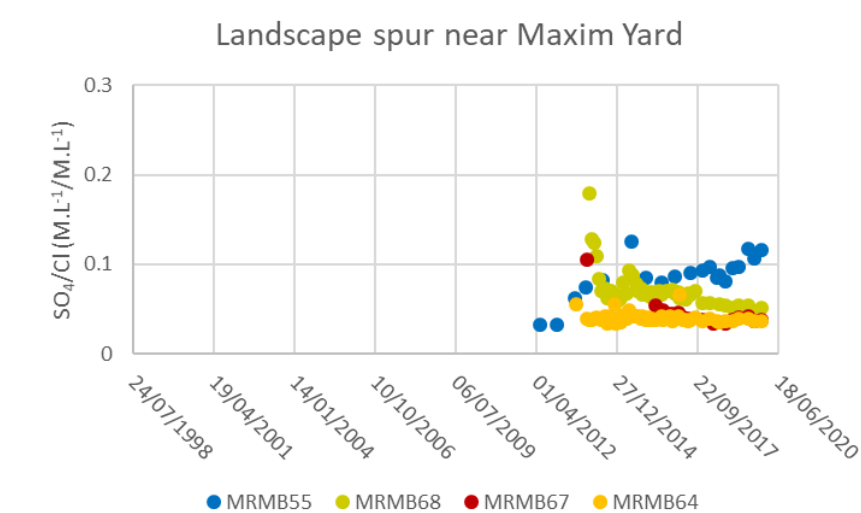
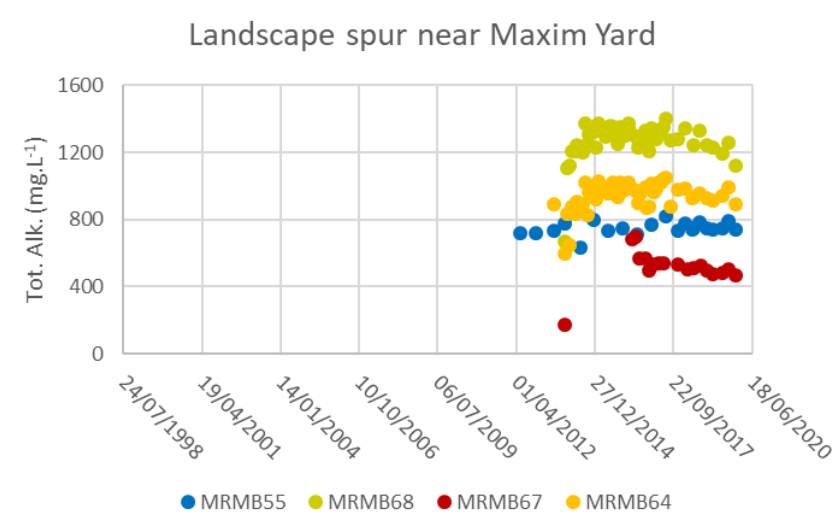
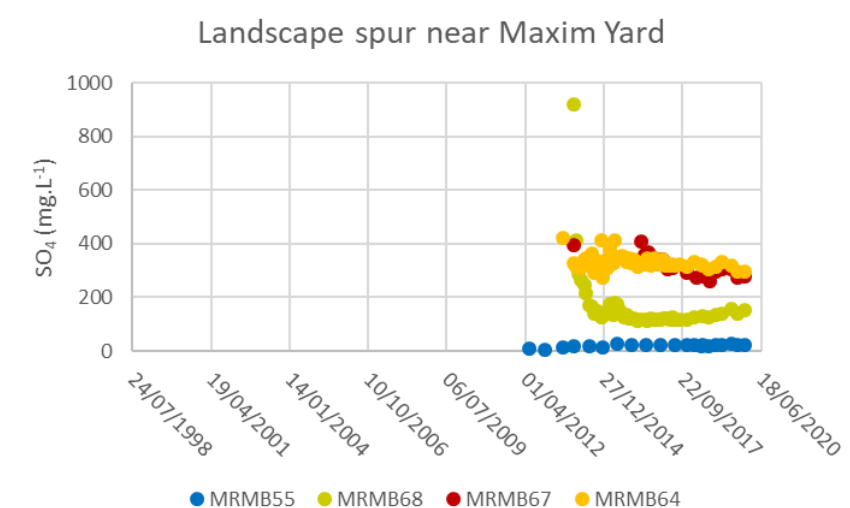
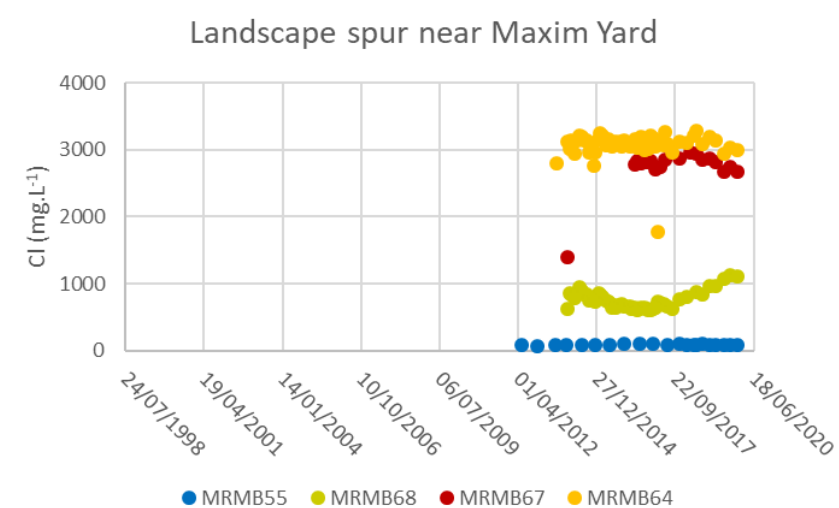
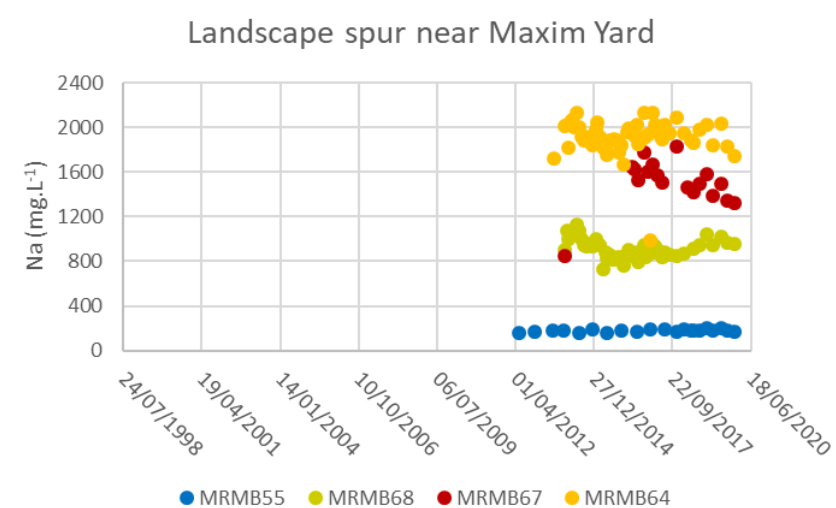
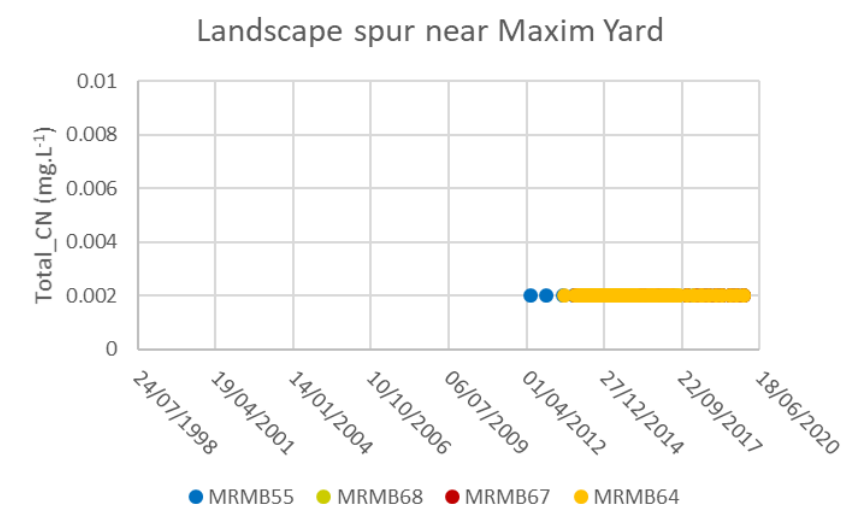
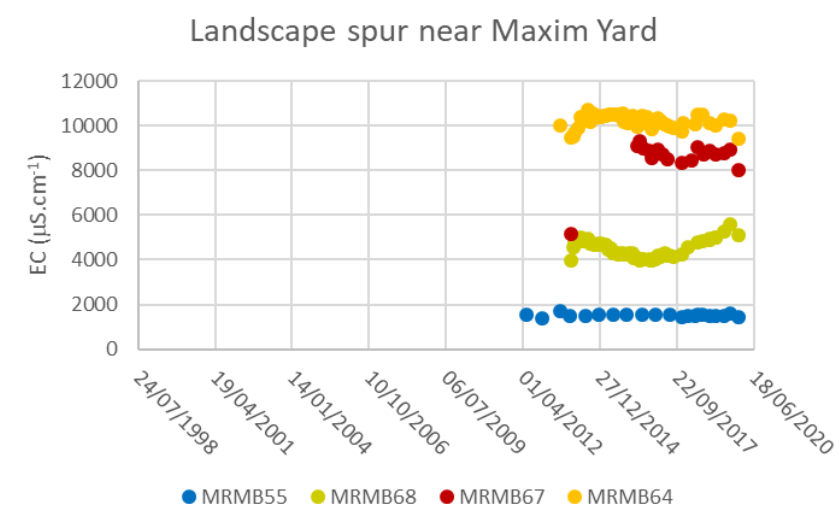
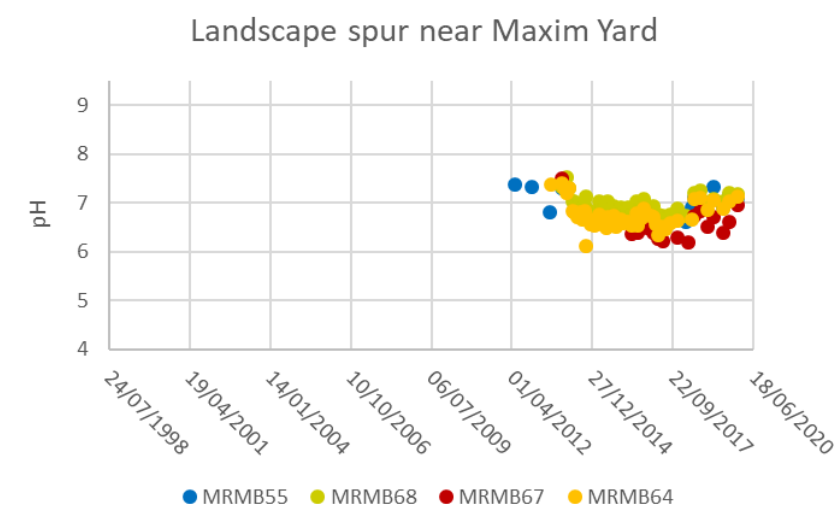
- Waste Rock
- Waste Rock
- Waste Rock
- Decant
- Decant
- Decant
- △ Sediment Dam 1
- △ MRMB55
- MRMB68
- MRMB67
- MRMB64

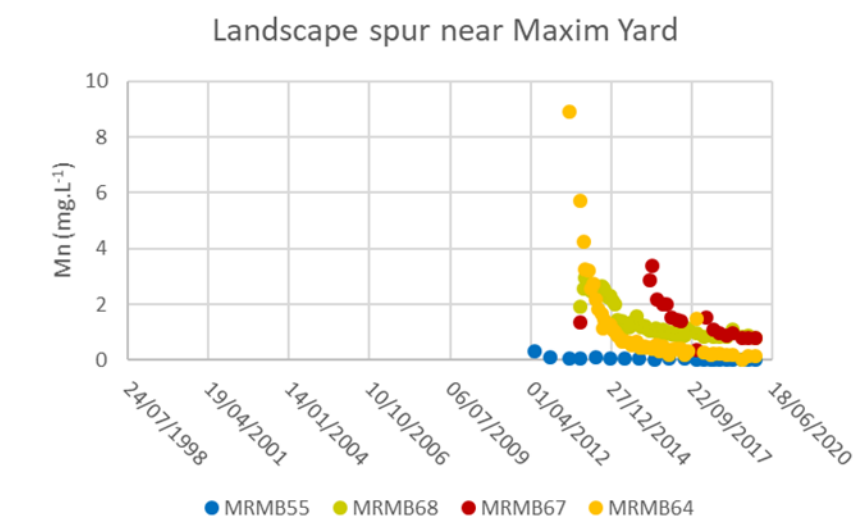
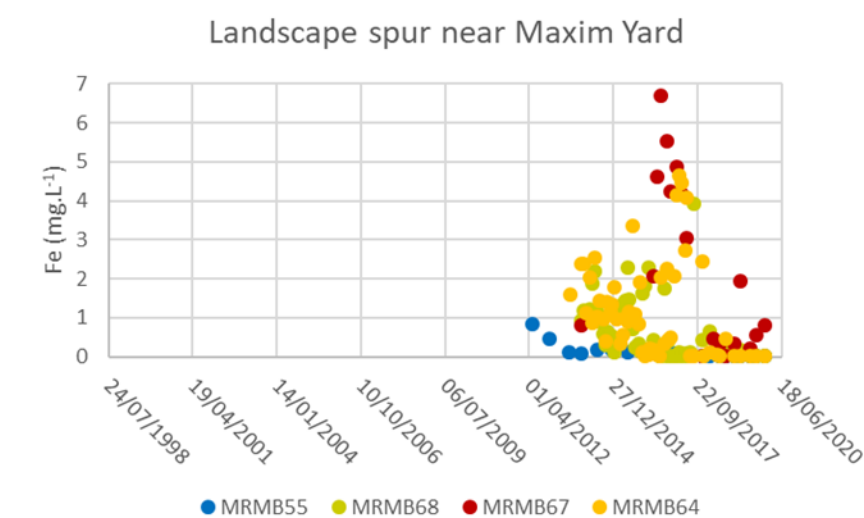
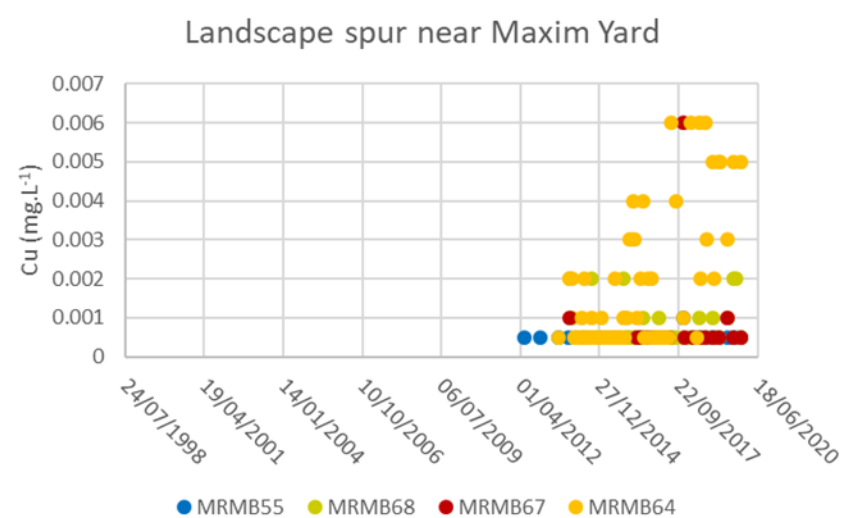
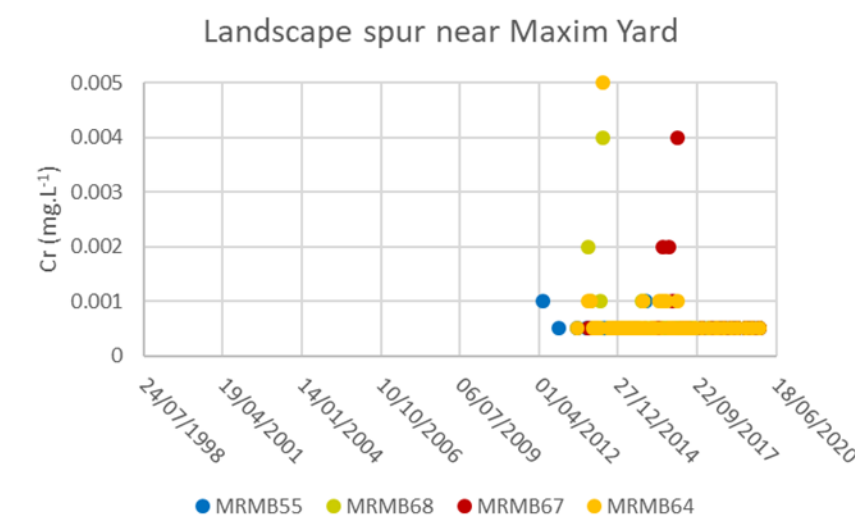
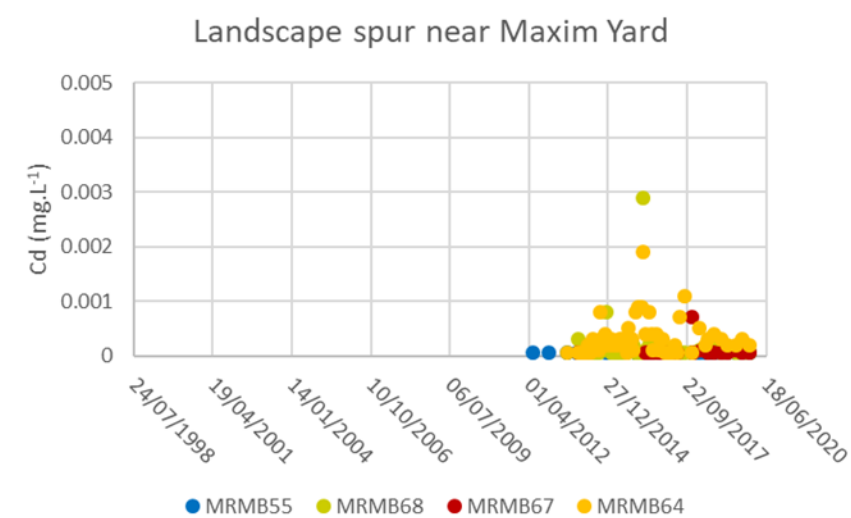
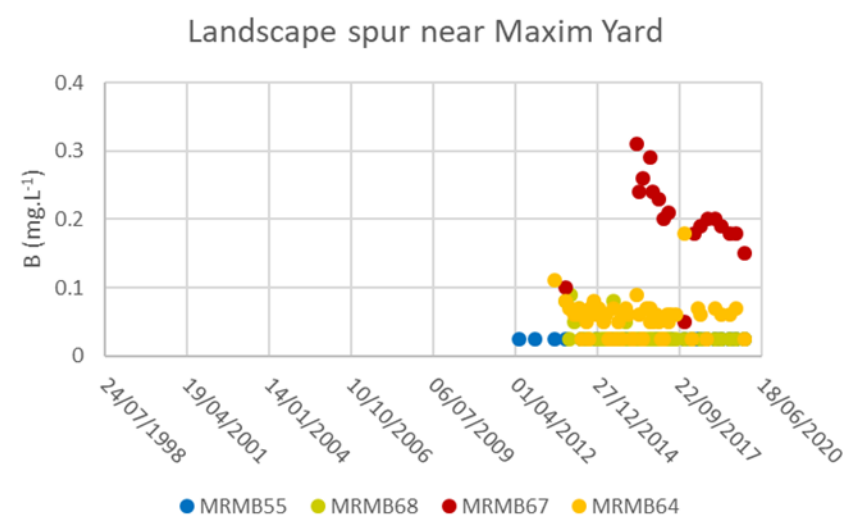
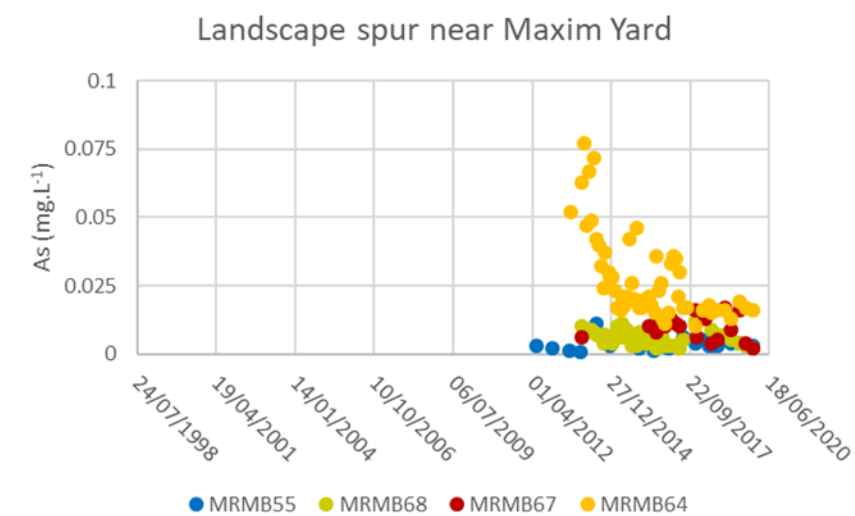
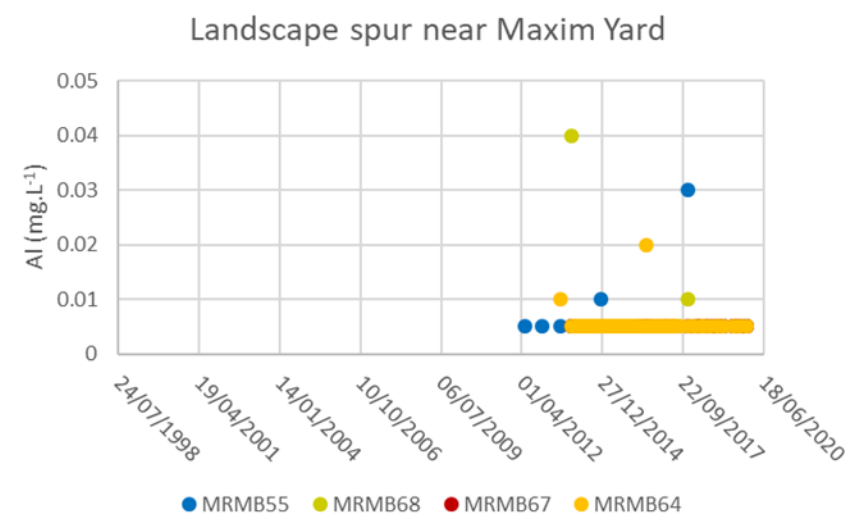
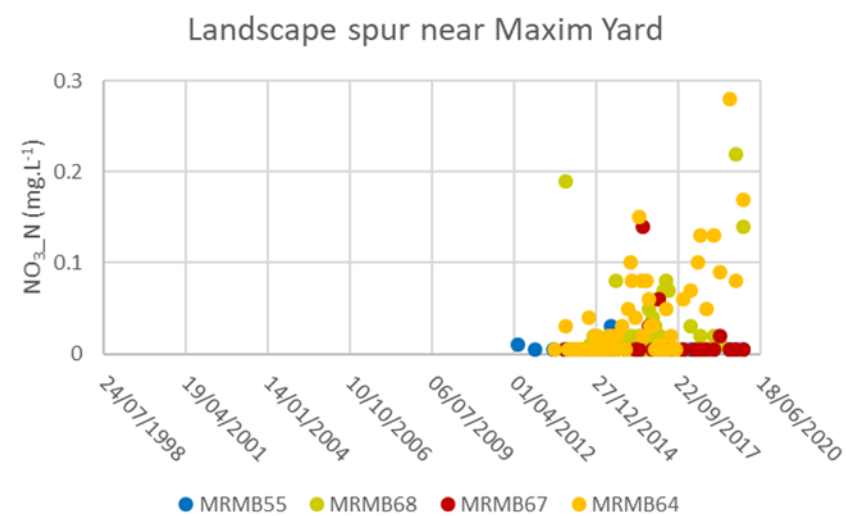


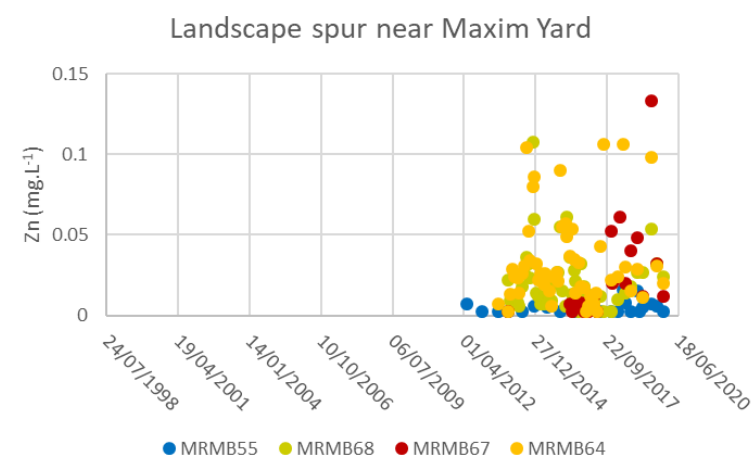
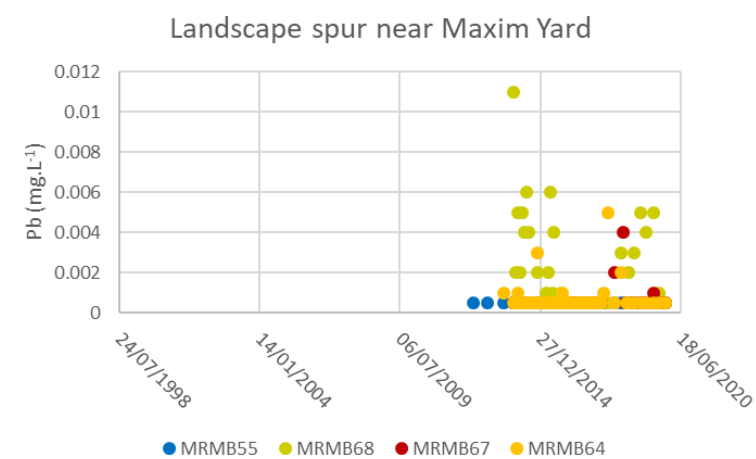


Groundwater Standing Water Levels in and around the Landscape Spur





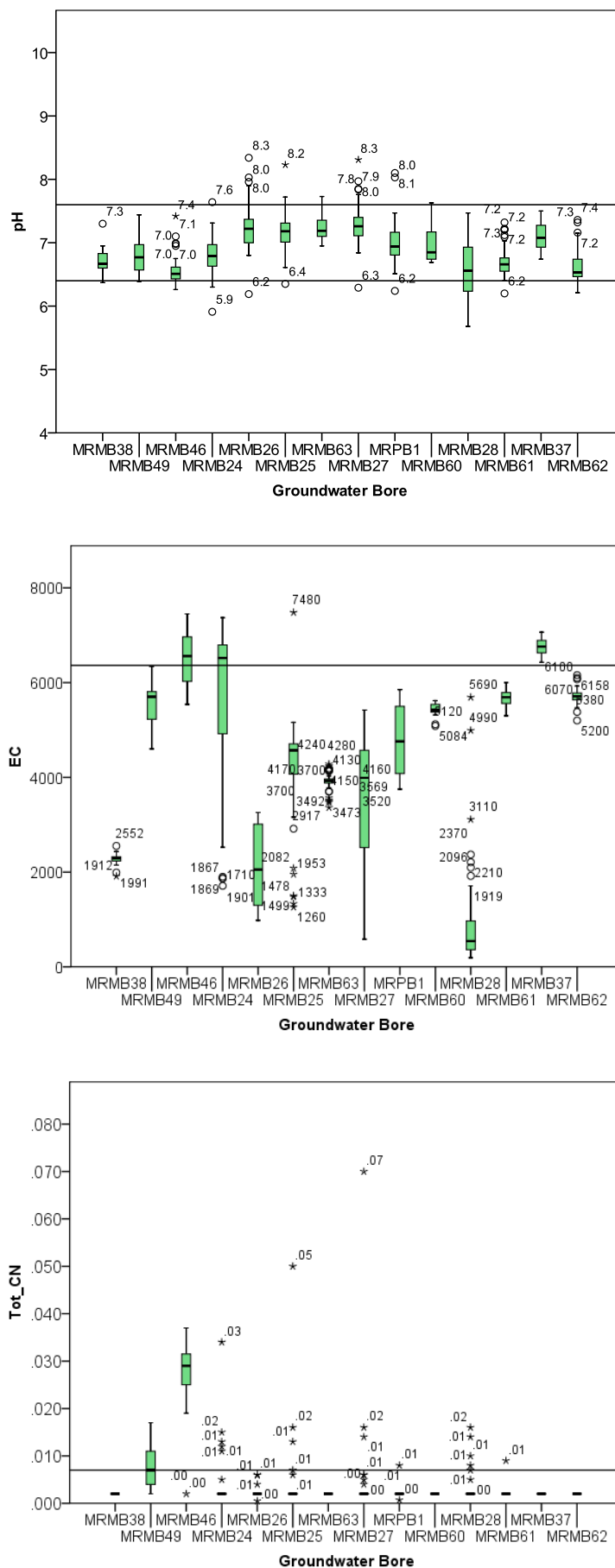


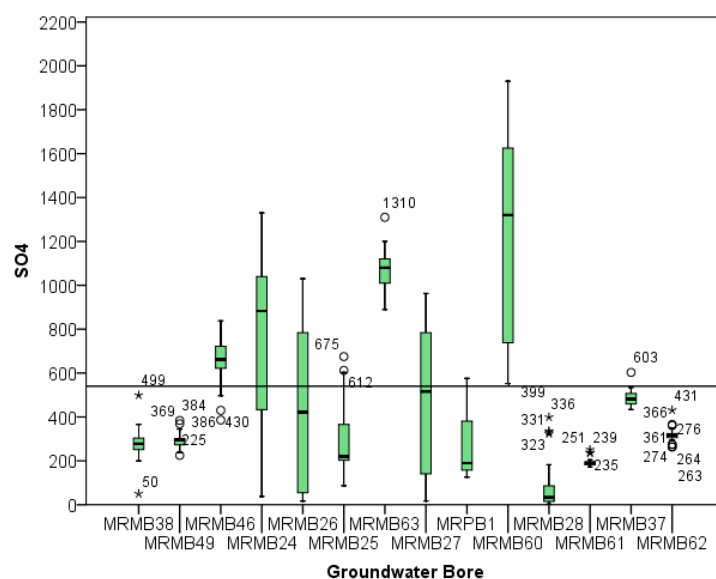
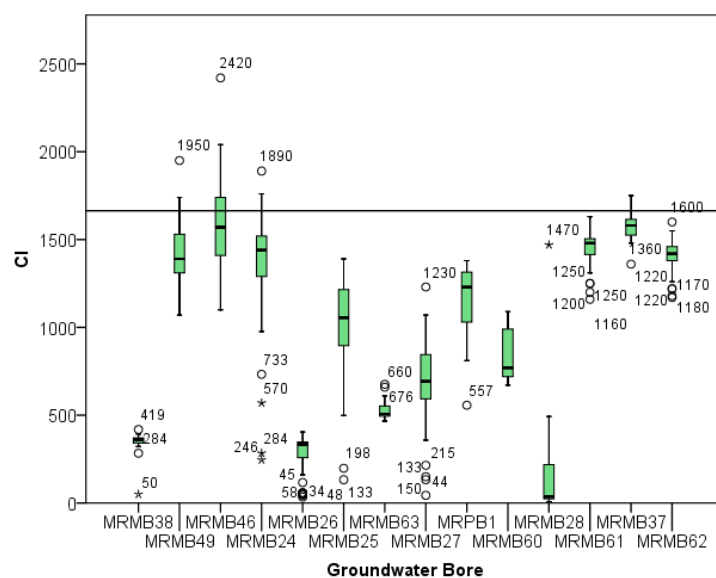
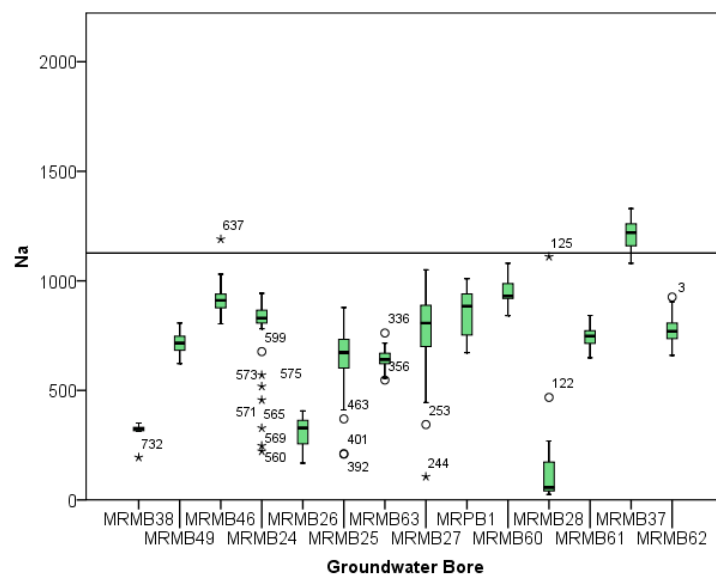


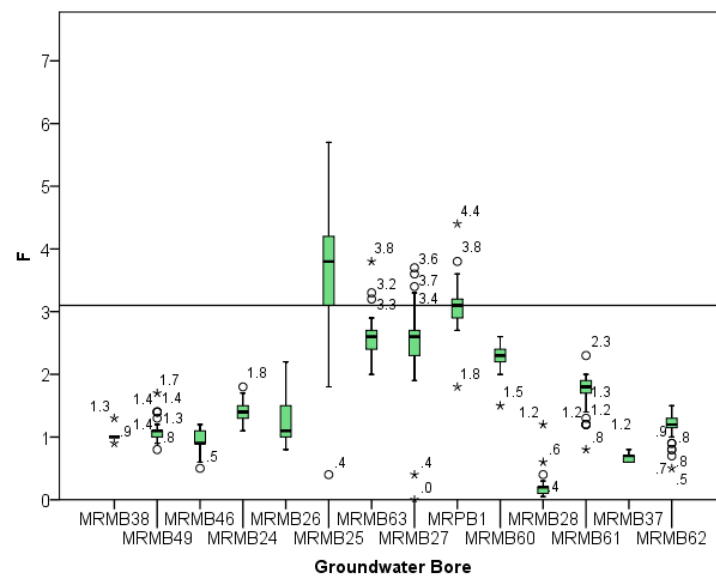
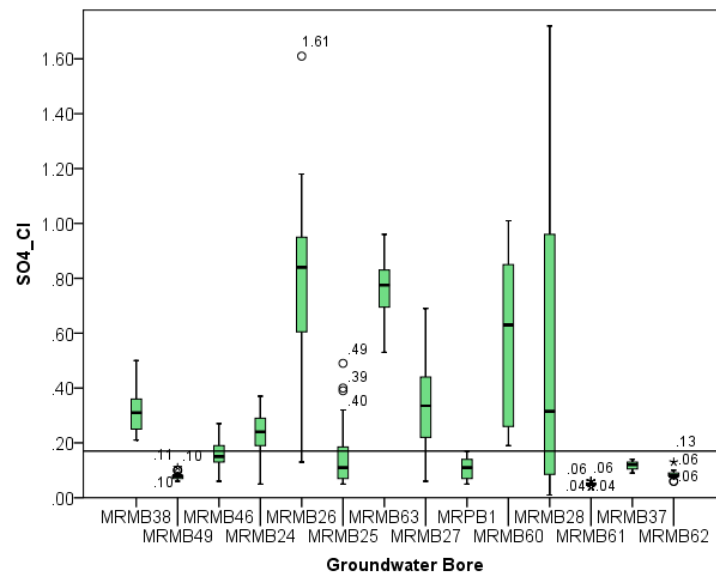
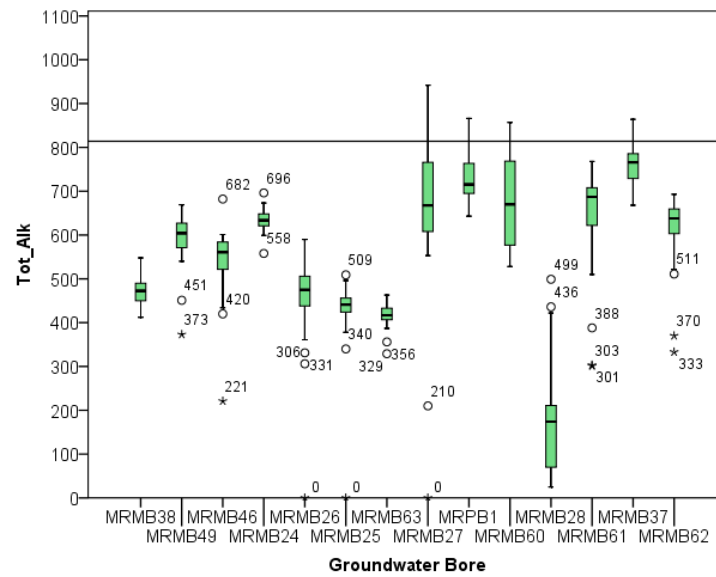
Sample Point	Statistic	pH	EC (µS/cm)	Cyanide Total (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Sulphate (mg/L)	Alk Tot as CaCO3 (mg/L)	SO4/Cl (M/M)	Fluoride (mg/L)	Nitrate as N (mg/L)	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)
MRMB55 16/05/2012 - 26/02/2020	Count	22	22	21	21	21	21	21	21	20	21	21	21	21	21	21	21
	Min	6.61	1378	0.002	154	67	6	635	0.03	0.6	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	5th %ile	6.64	1422	0.002	155	73	8	710	0.03	0.6	0.005	0.005	0.0010	0.025	0.00005	0.0005	0.0005
	20th %ile	6.75	1481	0.002	168	80	17	730	0.07	0.6	0.005	0.005	0.0020	0.025	0.00005	0.0005	0.0005
	Mean	6.95	1514	0.002	177	85	20	748	0.09	0.6	0.007	0.006	0.0036	0.025	0.00005	0.0005	0.0005
	Median	6.90	1520	0.002	176	85	21	746	0.09	0.6	0.005	0.005	0.0030	0.025	0.00005	0.0005	0.0005
	80th %ile	7.14	1552	0.002	186	91	23	780	0.10	0.7	0.005	0.005	0.0050	0.025	0.00005	0.0005	0.0005
	95th %ile	7.34	1577	0.002	196	94	25	796	0.12	0.8	0.010	0.010	0.0070	0.025	0.00005	0.0010	0.0005
	Max	7.39	1680	0.002	197	102	28	821	0.13	0.8	0.030	0.030	0.0110	0.025	0.00005	0.0010	0.0010
MRMB68 12/12/2013 - 26/02/2020	Count	54	55	53	53	53	53	53	53	53	52	53	53	53	53	51	54
	Min	6.63	3950	0.002	725	602	111	669	0.05	2.1	0.005	0.005	0.0020	0.025	0.00005	0.0005	0.0005
	5th %ile	6.72	3990	0.002	810	612	116	1120	0.05	2.4	0.005	0.005	0.0026	0.025	0.00005	0.0005	0.0005
	20th %ile	6.77	4110	0.002	842	637	118	1230	0.06	3.2	0.005	0.005	0.0030	0.025	0.00005	0.0005	0.0005
	Mean	6.94	4507	0.002	912	752	162	1270	0.08	3.6	0.033	0.006	0.0062	0.034	0.00016	0.0006	0.0007
	Median	6.92	4480	0.002	902	722	132	1290	0.07	3.7	0.010	0.005	0.0060	0.025	0.00005	0.0005	0.0005
	80th %ile	7.05	4849	0.002	965	842	162	1340	0.08	4.0	0.038	0.005	0.0090	0.040	0.00020	0.0005	0.0010
	95th %ile	7.32	5150	0.002	1080	1006	273	1370	0.13	4.1	0.163	0.005	0.0114	0.074	0.00024	0.0010	0.0020
	Max	7.53	5570	0.002	1130	1120	920	1400	0.54	6.2	0.310	0.040	0.0170	0.090	0.00290	0.0040	0.0020
MRMB67 12/12/2013 - 26/02/2020	Count	19	19	18	18	18	18	18	18	18	18	18	19	18	19	18	19
	Min	6.18	5167	0.002	848	1400	262	176	0.03	1.5	0.005	0.005	0.0020	0.050	0.00005	0.0005	0.0005
	5th %ile	6.22	7735	0.002	1249	2480	271	425	0.03	1.7	0.005	0.005	0.0038	0.093	0.00005	0.0005	0.0005
	20th %ile	6.33	8408	0.002	1402	2726	278	485	0.04	2.0	0.005	0.005	0.0056	0.180	0.00005	0.0005	0.0005
	Mean	6.55	8545	0.002	1507	2736	319	516	0.04	2.2	0.018	0.005	0.0096	0.200	0.00009	0.0009	0.0008
	Median	6.47	8740	0.002	1520	2810	307	518	0.04	2.2	0.005	0.005	0.0100	0.200	0.00005	0.0005	0.0005
	80th %ile	6.71	8968	0.002	1642	2866	353	557	0.05	2.5	0.014	0.005	0.0130	0.240	0.00005	0.0008	0.0005
	95th %ile	7.02	9129	0.002	1788	2953	399	683	0.06	2.6	0.072	0.005	0.0161	0.293	0.00016	0.0023	0.0015
	Max	7.50	9300	0.002	1830	2970	407	701	0.10	2.6	0.140	0.005	0.0170	0.310	0.00070	0.0040	0.0060
MRMB64 29/07/2013 - 26/02/2020	Count	55	56	55	55	55	55	55	55	54	54	55	55	55	55	53	59
	Min	6.11	9450	0.002	986	1770	272	596	0.03	2.9	0.005	0.005	0.0100	0.025	0.00005	0.0005	0.0005
	5th %ile	6.49	9666	0.002	1734	2905	297	831	0.04	4.3	0.005	0.005	0.0130	0.025	0.00005	0.0005	0.0005
	20th %ile	6.56	10000	0.002	1840	3020	317	890	0.04	5.7	0.005	0.005	0.0160	0.025	0.00005	0.0005	0.0005
	Mean	6.74	10206	0.002	1909	3069	332	943	0.04	6.1	0.042	0.005	0.0279	0.056	0.00032	0.0007	0.0019
	Median	6.69	10230	0.002	1920	3100	326	969	0.04	6.4	0.020	0.005	0.0210	0.060	0.00020	0.0005	0.0010
	80th %ile	6.88	10470	0.002	2020	3164	345	995	0.04	6.8	0.080	0.005	0.0376	0.070	0.00040	0.0005	0.0034
	95th %ile	7.30	10528	0.002	2102	3229	387	1023	0.05	7.1	0.137	0.005	0.0642	0.083	0.00090	0.0010	0.0060
	Max	7.40	10740	0.002	2130	3290	420	1050	0.07	7.4	0.280	0.020	0.0770	0.180	0.00190	0.0050	0.0060

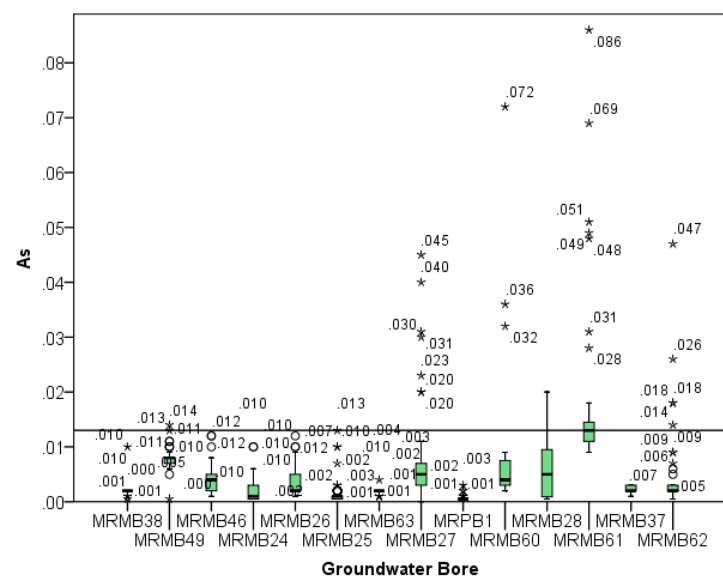
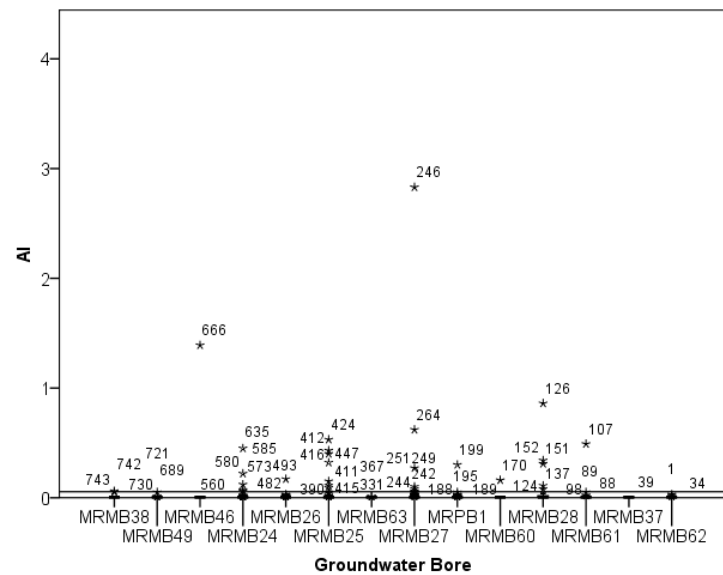
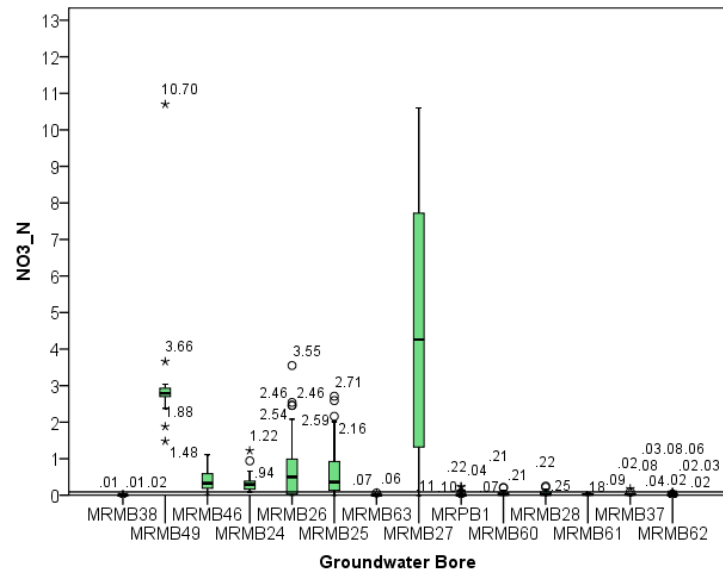
Sample Point	Statistic	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Lead Dissolved (mg/L)	Zinc Dissolved (mg/L)	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Molybdenum Dissolved (mg/L)	Selenium Dissolved (mg/L)	Ammonia Dissolved (mg/L)
MRMB55 16/05/2012 - 26/02/2020	Count	21	21	21	22	21	21	21	21	14	11
	Min	0.025	0.002	0.0005	0.0025	69	3	62	0.002	0.005	0.005
	5th %ile	0.025	0.003	0.0005	0.0025	70	3	63	0.002	0.005	0.005
	20th %ile	0.025	0.012	0.0005	0.0025	72	3	65	0.005	0.005	0.005
	Mean	0.132	0.050	0.0005	0.0049	76	3	70	0.008	0.005	0.022
	Median	0.080	0.035	0.0005	0.0025	76	3	69	0.008	0.005	0.030
	80th %ile	0.160	0.053	0.0005	0.0068	79	3	73	0.013	0.005	0.030
	95th %ile	0.470	0.106	0.0005	0.0147	81	4	76	0.014	0.005	0.040
	Max	0.830	0.317	0.0005	0.0160	94	4	77	0.016	0.005	0.040
MRMB68 12/12/2013 - 26/02/2020	Count	53	53	53	53	53	53	53	53	29	14
	Min	0.025	0.799	0.0005	0.0025	38	4	50	0.044	0.005	0.050
	5th %ile	0.025	0.835	0.0005	0.0025	41	4	55	0.050	0.005	0.057
	20th %ile	0.080	0.920	0.0005	0.0084	45	4	60	0.060	0.005	0.070
	Mean	0.713	1.457	0.0018	0.0207	64	5	70	0.080	0.005	0.121
	Median	0.390	1.150	0.0005	0.0140	50	5	68	0.075	0.005	0.105
	80th %ile	1.276	2.282	0.0036	0.0276	63	6	76	0.097	0.005	0.170
	95th %ile	2.232	2.620	0.0054	0.0570	76	7	95	0.123	0.005	0.225
	Max	3.920	2.940	0.0110	0.1080	624	8	106	0.159	0.005	0.270
MRMB67 12/12/2013 - 26/02/2020	Count	18	18	19	19	18	18	18	18	17	11
	Min	0.025	0.344	0.0005	0.0025	149	4	117	0.003	0.005	0.050
	5th %ile	0.025	0.712	0.0005	0.0025	162	5	142	0.003	0.005	0.055
	20th %ile	0.328	0.825	0.0005	0.0025	205	6	149	0.003	0.005	0.080
	Mean	2.262	1.458	0.0008	0.0251	214	7	162	0.006	0.005	0.117
	Median	1.385	1.375	0.0005	0.0120	218	7	166	0.005	0.005	0.110
	80th %ile	4.470	2.006	0.0005	0.0432	235	8	176	0.008	0.005	0.160
	95th %ile	5.696	2.940	0.0022	0.0682	249	10	183	0.013	0.005	0.195
	Max	6.690	3.390	0.0040	0.1330	250	13	186	0.016	0.005	0.200
MRMB64 29/07/2013 - 26/02/2020	Count	56	55	55	55	55	55	55	55	30	15
	Min	0.025	0.016	0.0005	0.0025	141	3	82	0.003	0.005	0.010
	5th %ile	0.025	0.169	0.0005	0.0050	152	7	140	0.003	0.005	0.017
	20th %ile	0.060	0.304	0.0005	0.0140	158	7	155	0.005	0.005	0.028
	Mean	1.180	1.100	0.0007	0.0331	224	10	159	0.008	0.005	0.070
	Median	0.925	0.513	0.0005	0.0240	168	9	162	0.006	0.005	0.060
	80th %ile	2.070	1.452	0.0005	0.0496	175	12	168	0.009	0.005	0.108
	95th %ile	4.093	3.544	0.0013	0.0998	201	16	174	0.019	0.005	0.170
	Max	4.640	8.900	0.0050	0.1060	3180	22	182	0.029	0.005	0.170

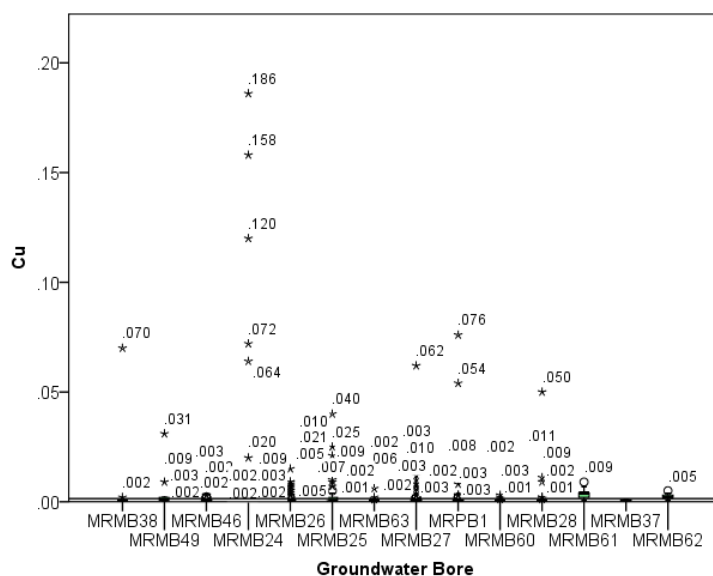
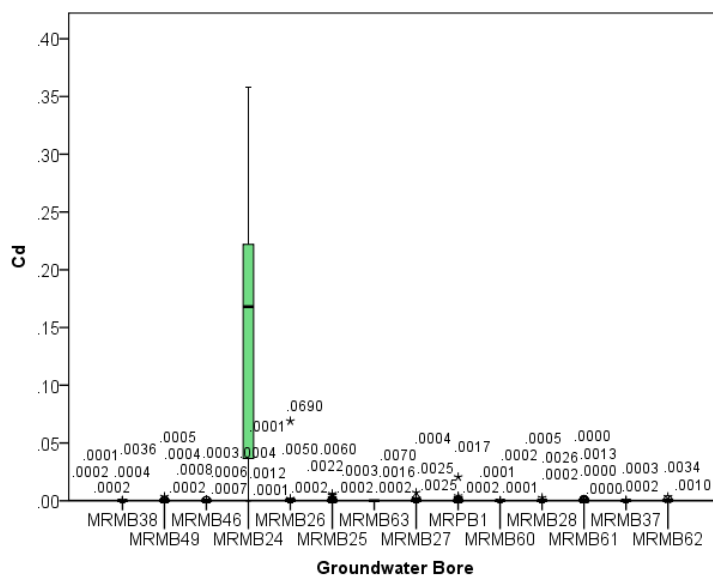
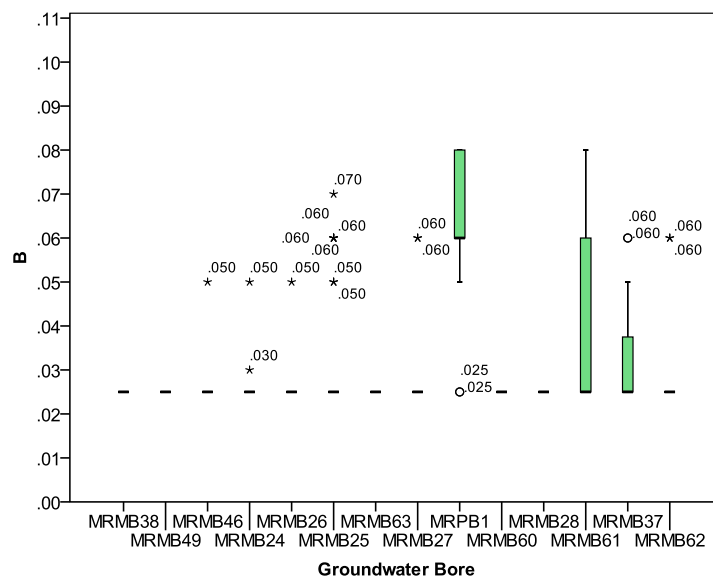
Appendix 17: Data Summaries for Twelve Mile Creek

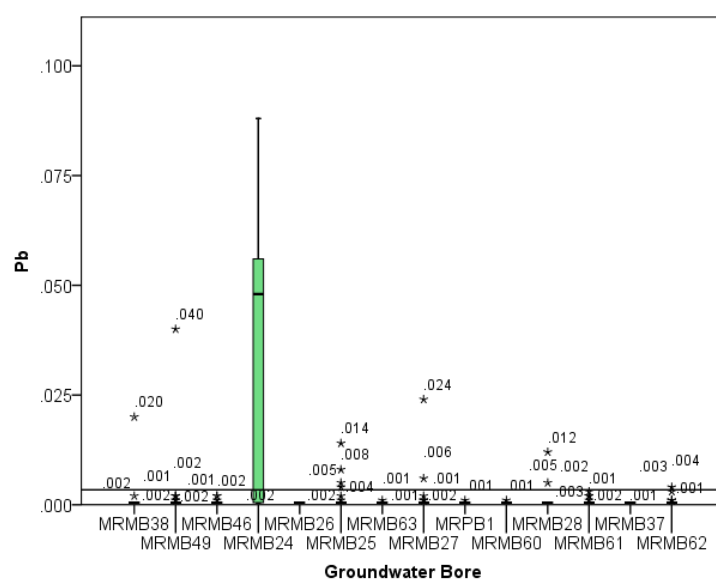
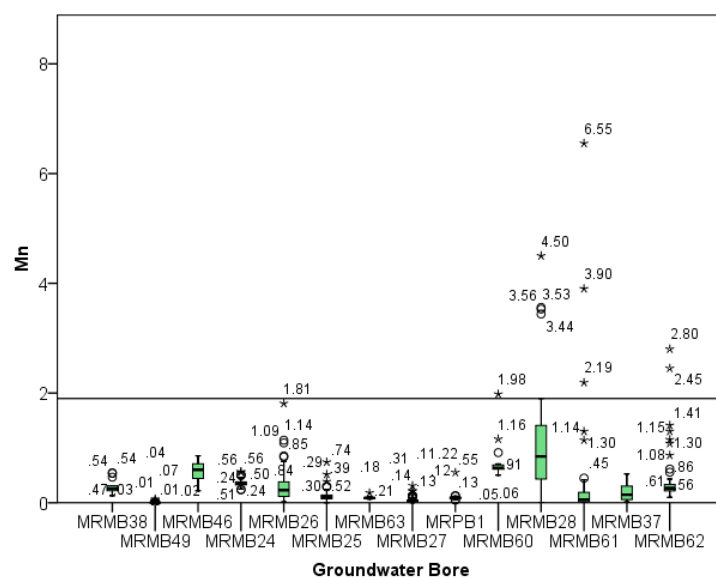
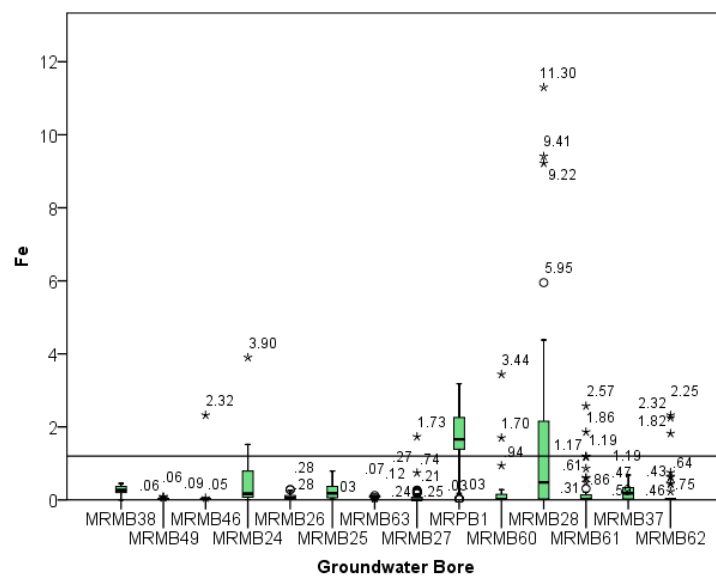




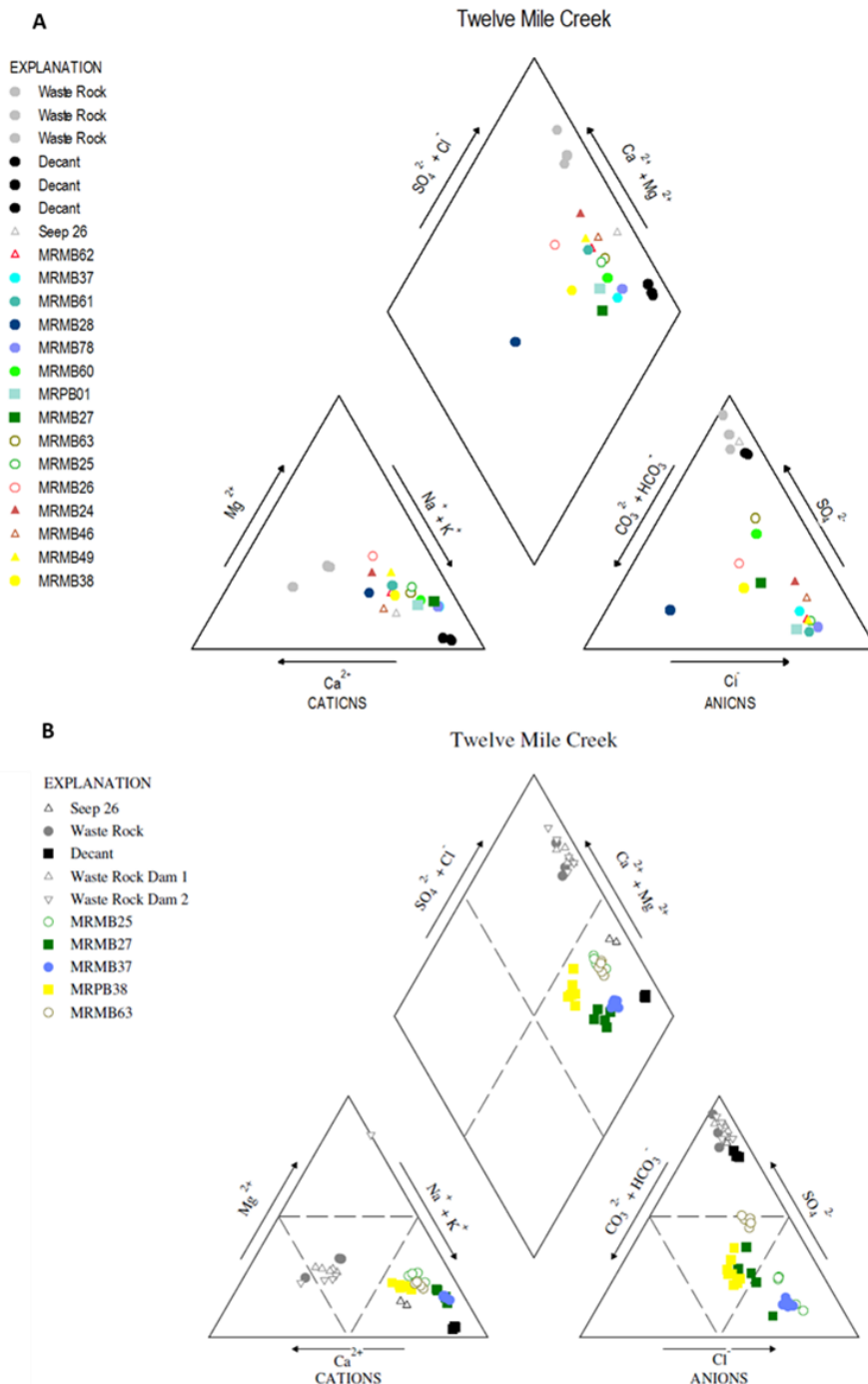






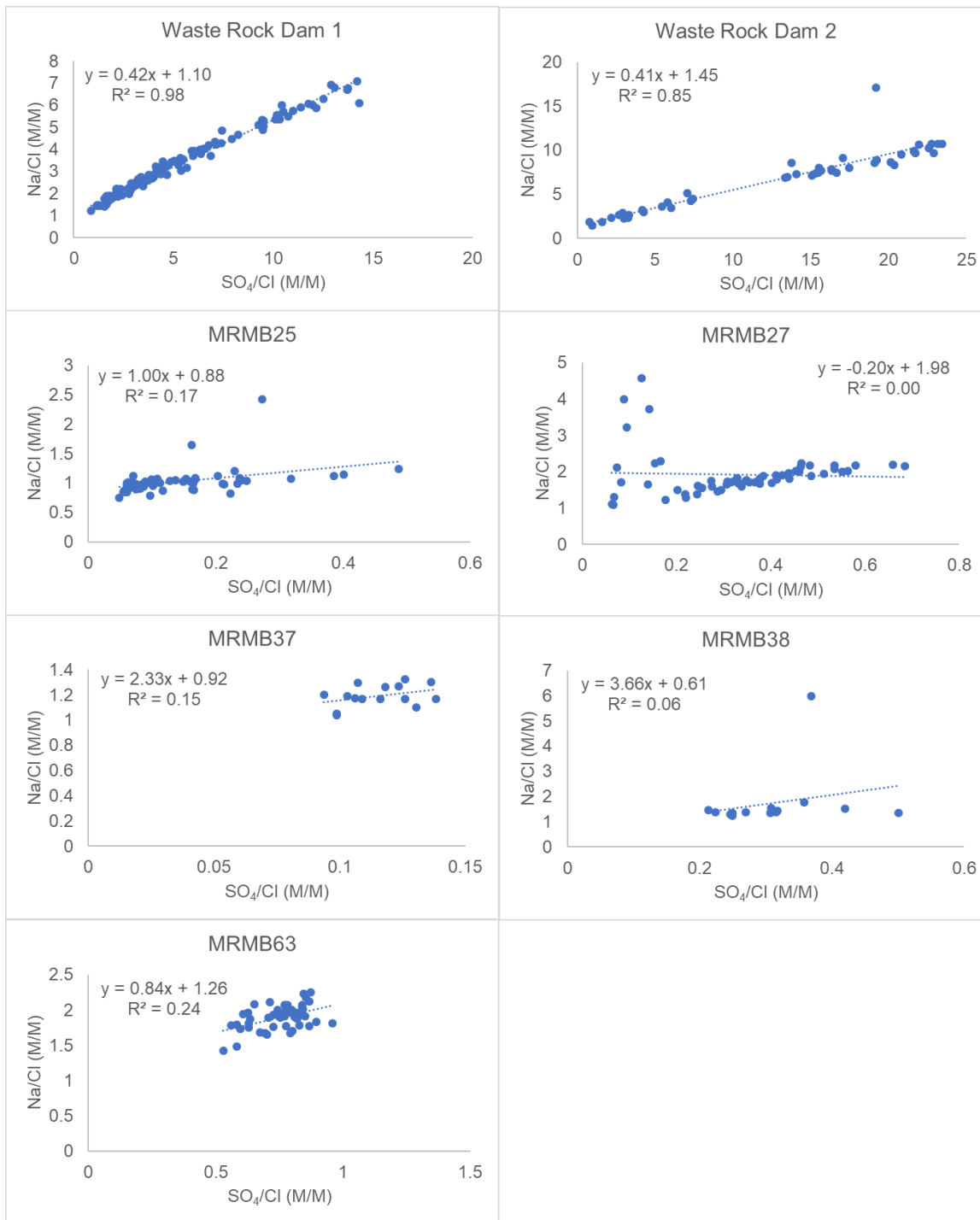






³⁹Footnote

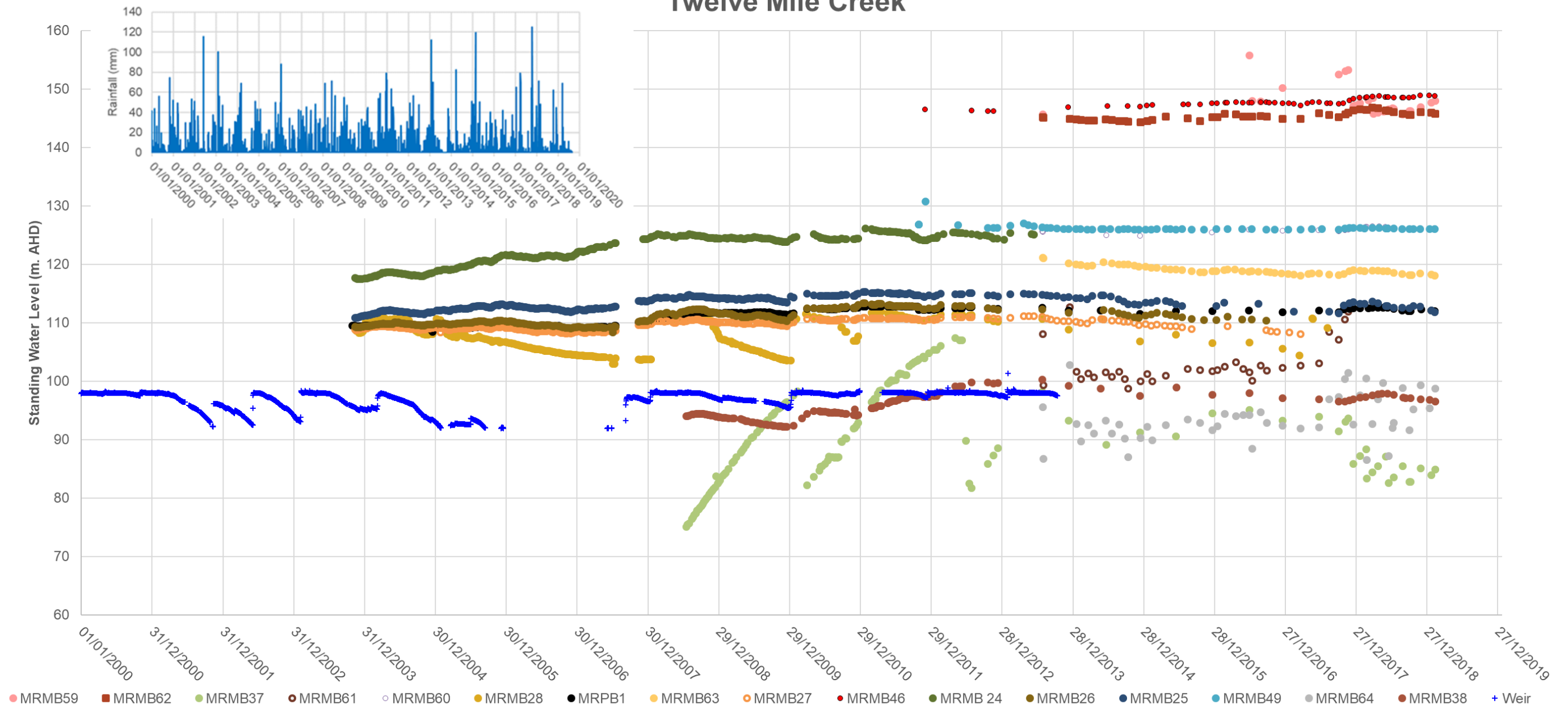
³⁹ A represents median cation and anion concentrations in groundwater bores, and representative cation and anion concentrations in waste - rock seepage and decant water. B shows representative cation and anion concentrations in selected groundwater monitoring bores, waste – rock seepage and decant water.



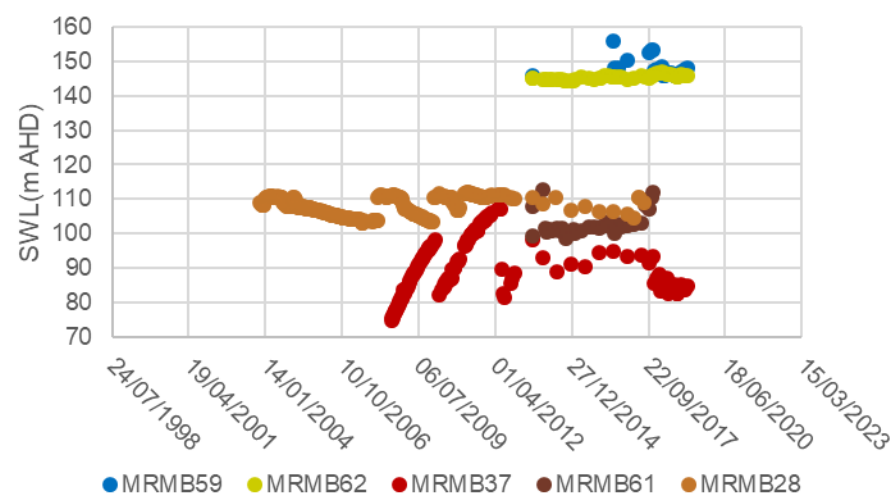
⁴⁰ Footnote

⁴⁰ Na/Cl (M/M) vs SO₄/Cl (M/M) concentration ratios in the source term (Waste Rock Dam 1, Waste Rock Dam 2) and in selected groundwater samples from Twelve Mile Creek showing correlations associated with neutral mine drainage in mining affected water (MRMB25, MRMB27). Outliers are excluded in MRMB5 - Na/Cl 1.39 M/M, SO₄/Cl 0.69 M/M and in MRMB21 Na/Cl 7.33 M/M, SO₄/Cl (M/M) 0.48.

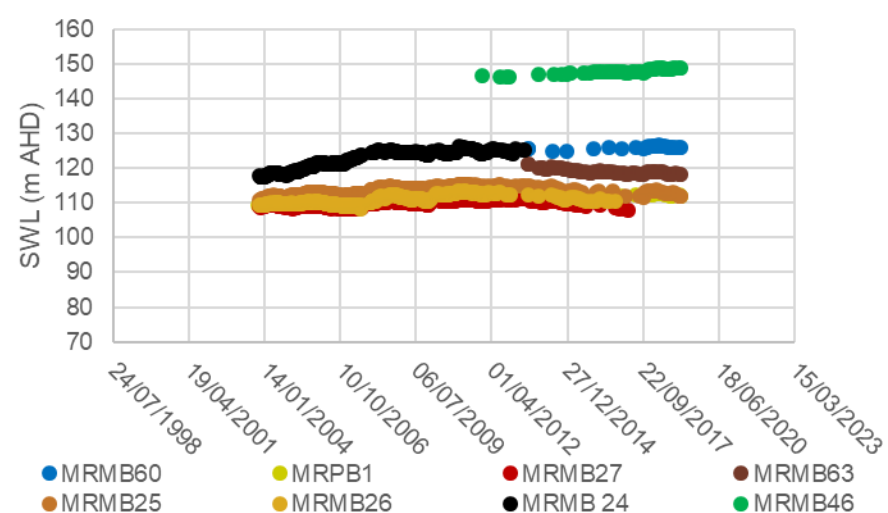
Twelve Mile Creek



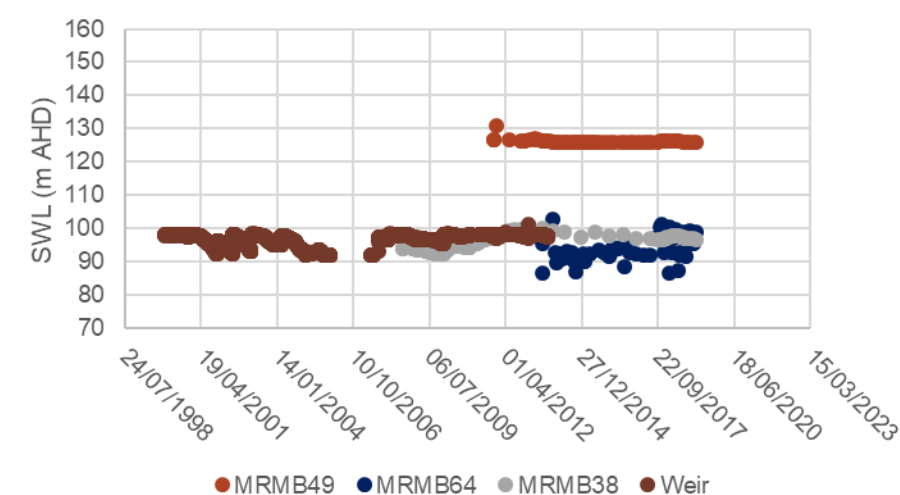
12 Mile Creek Groundwater: Upstream



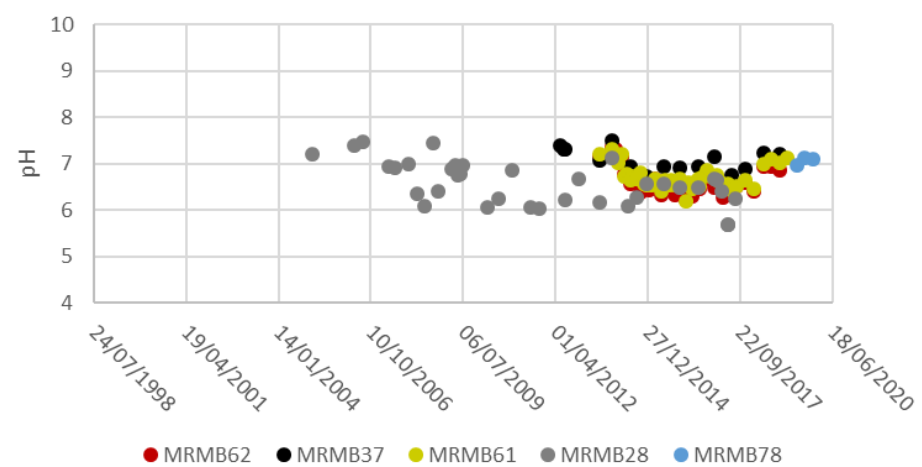
12 Mile Creek Groundwater



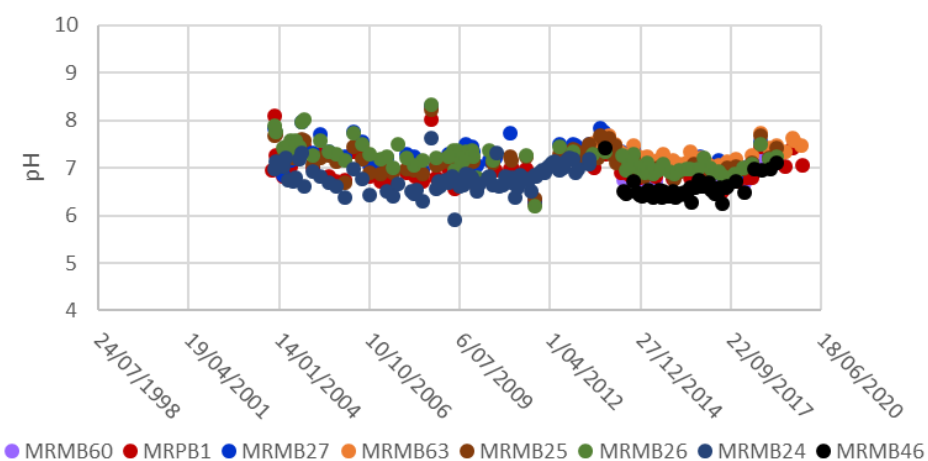
12 Mile Creek Groundwater: Downstream



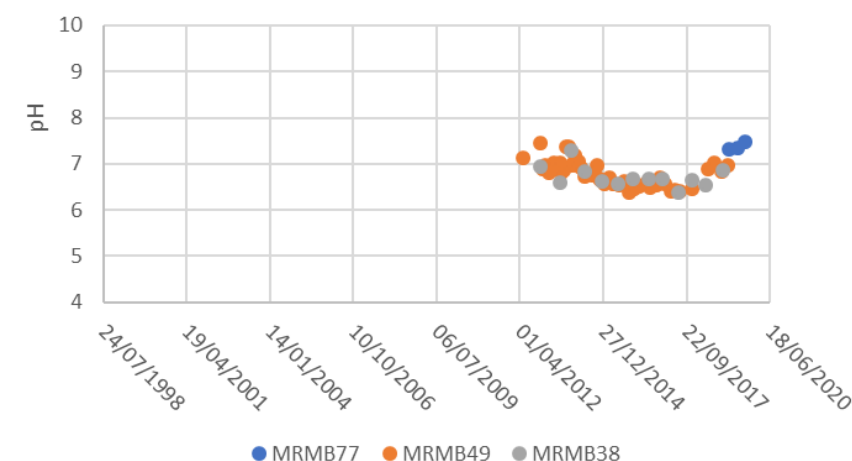
12 Mile Creek Groundwater: Upstream



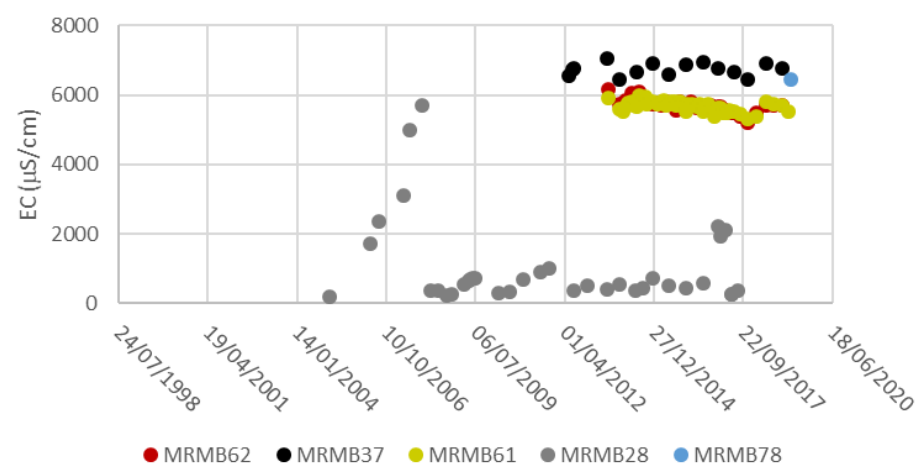
12 Mile Creek Groundwater



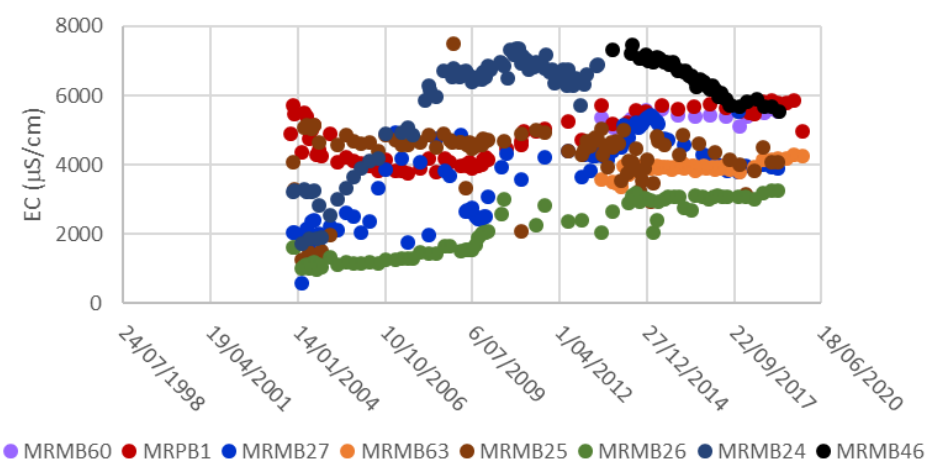
12 Mile Creek Groundwater: Downstream



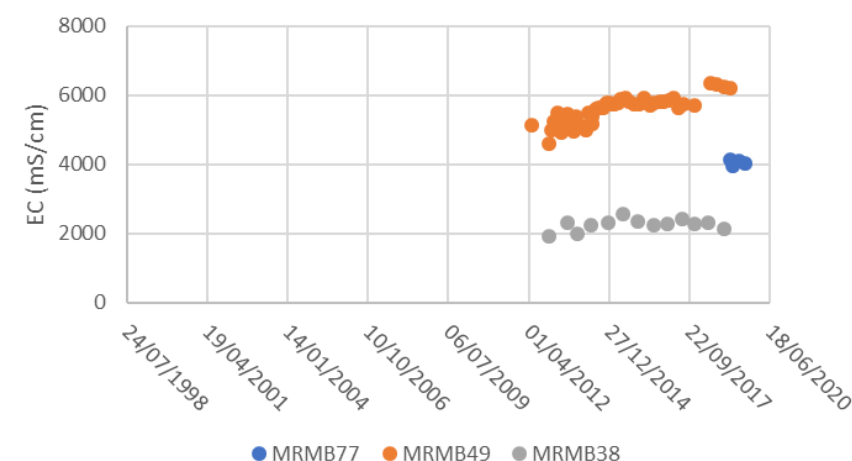
12 Mile Creek Groundwater: Upstream

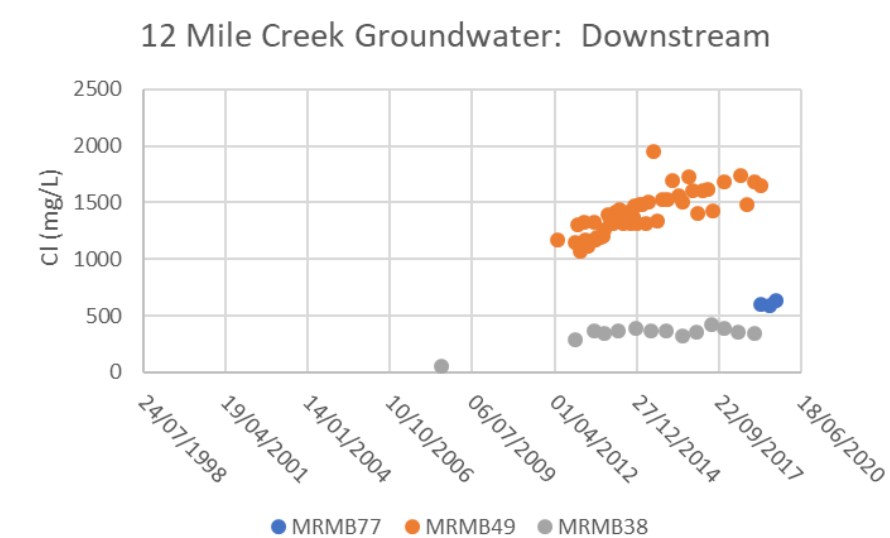
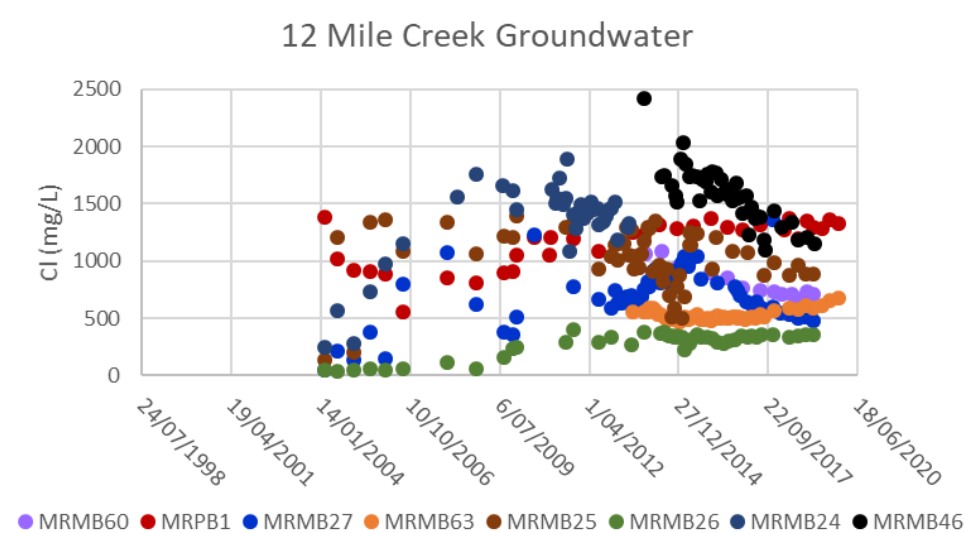
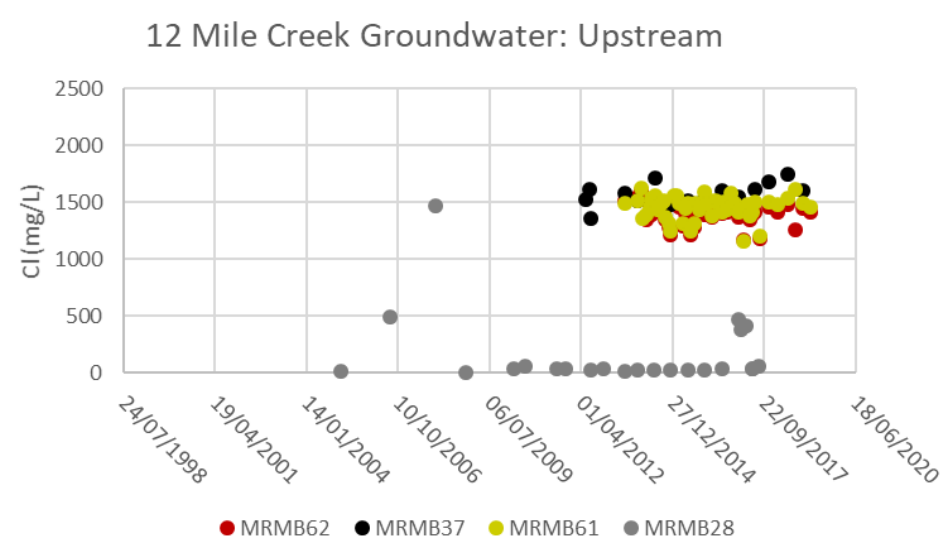
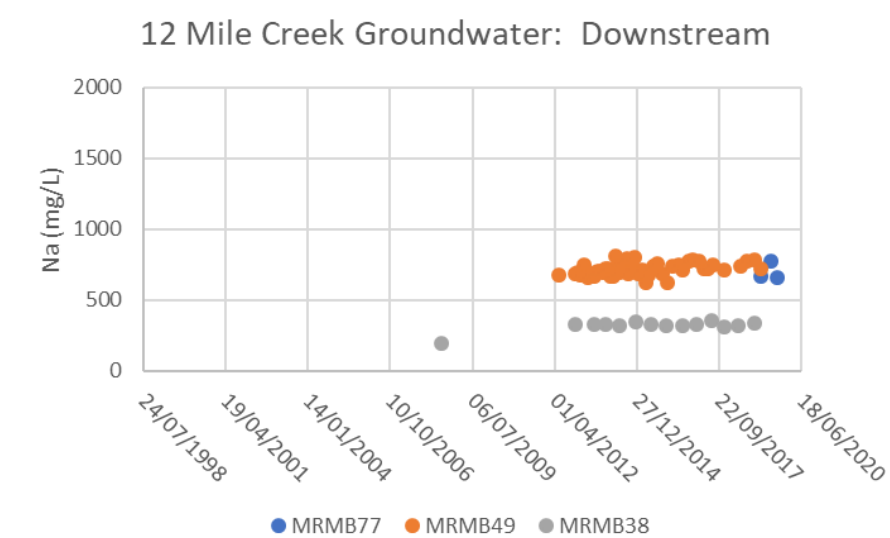
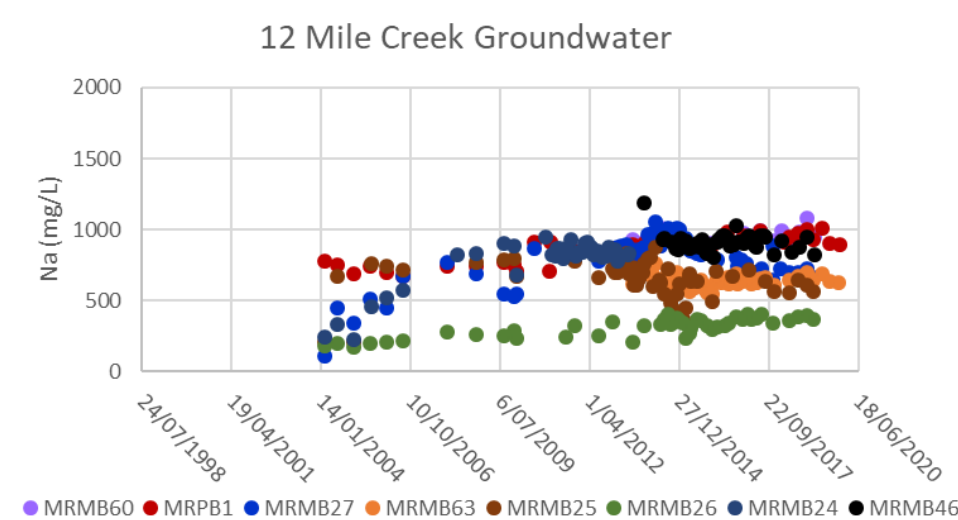
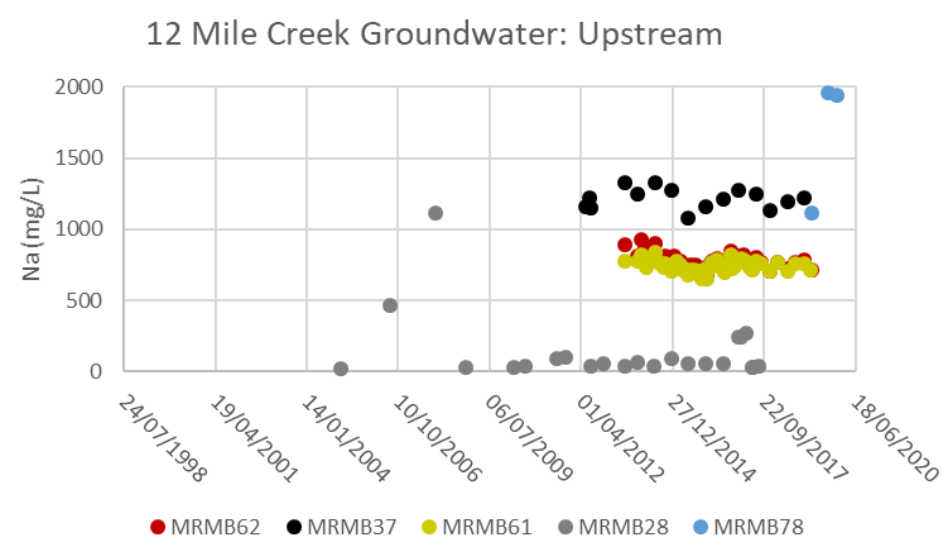
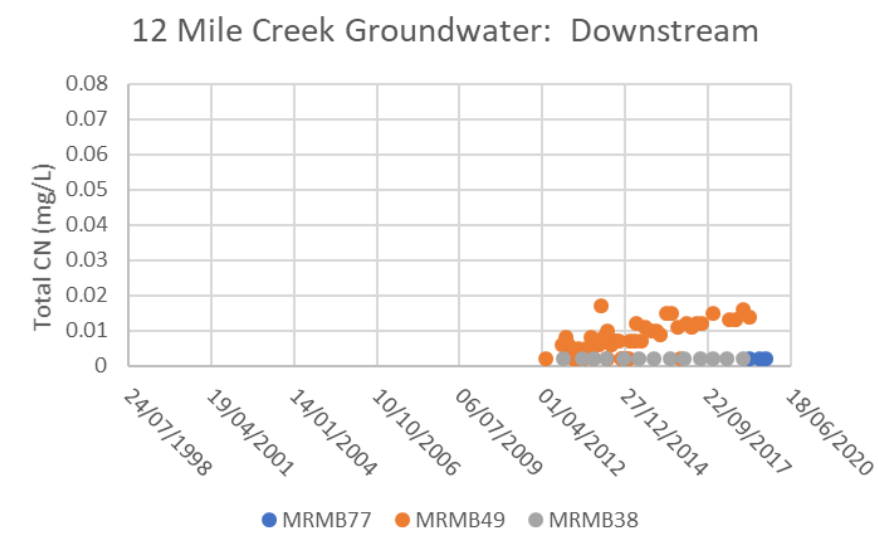
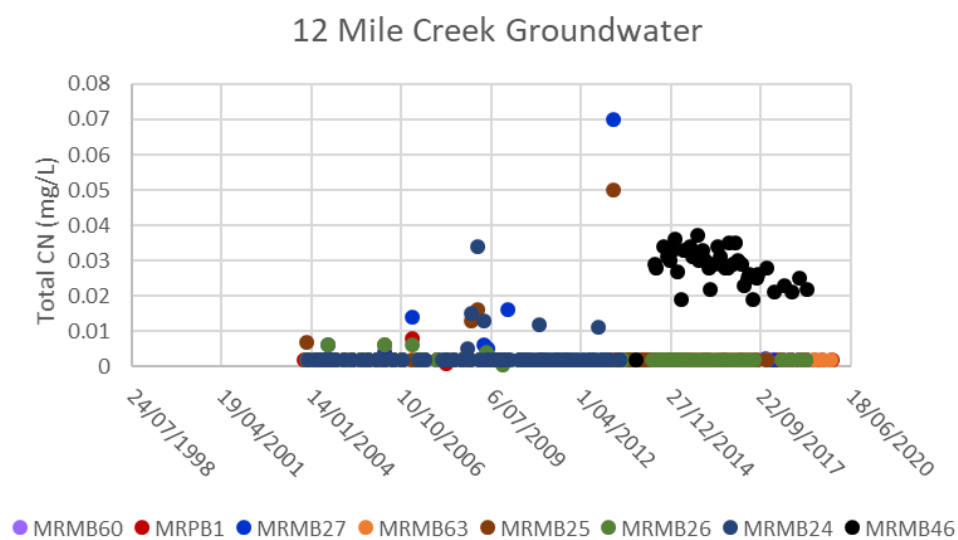
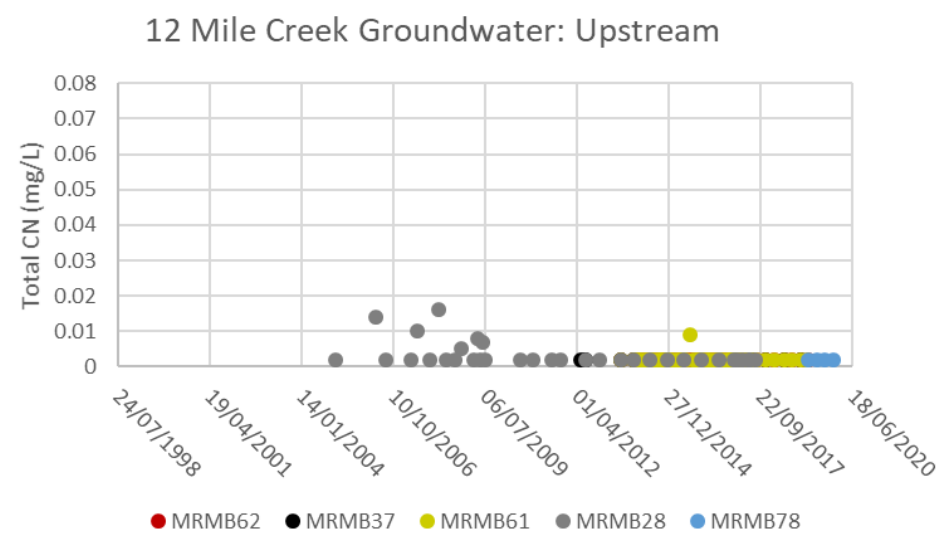


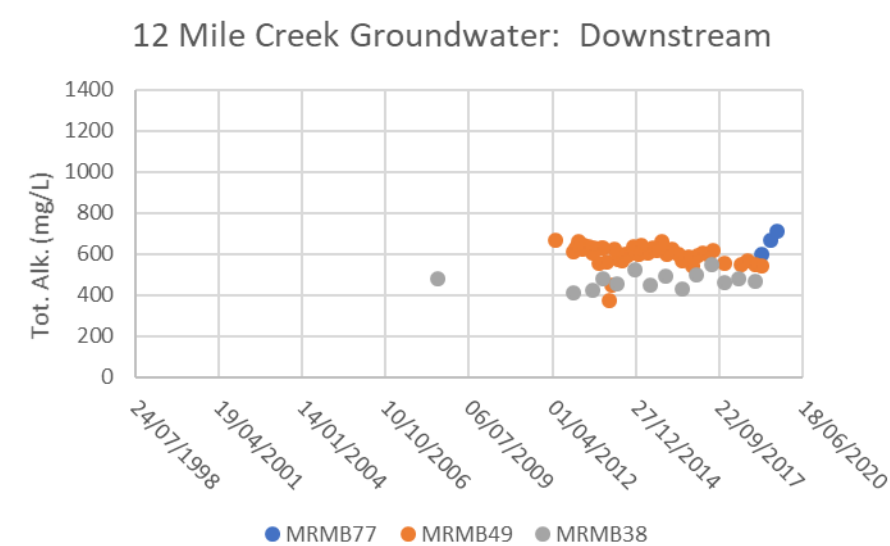
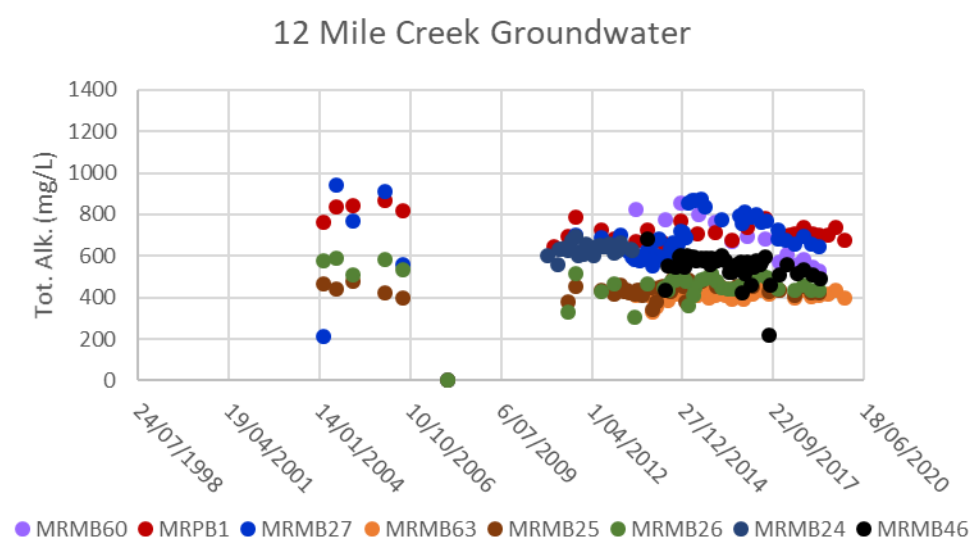
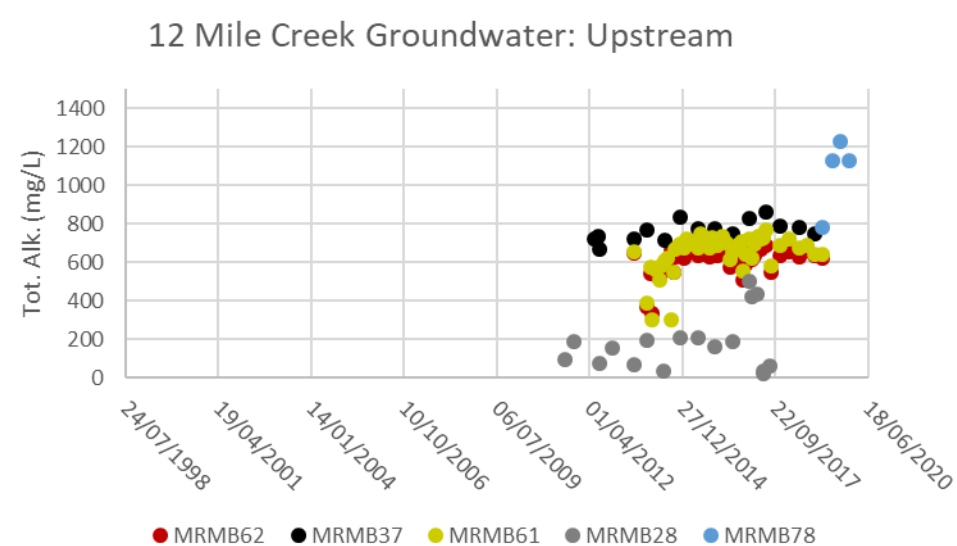
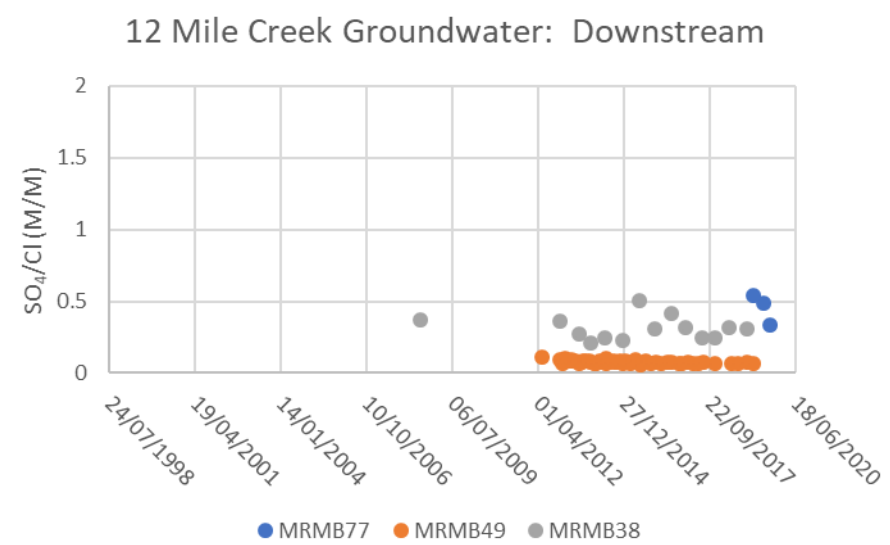
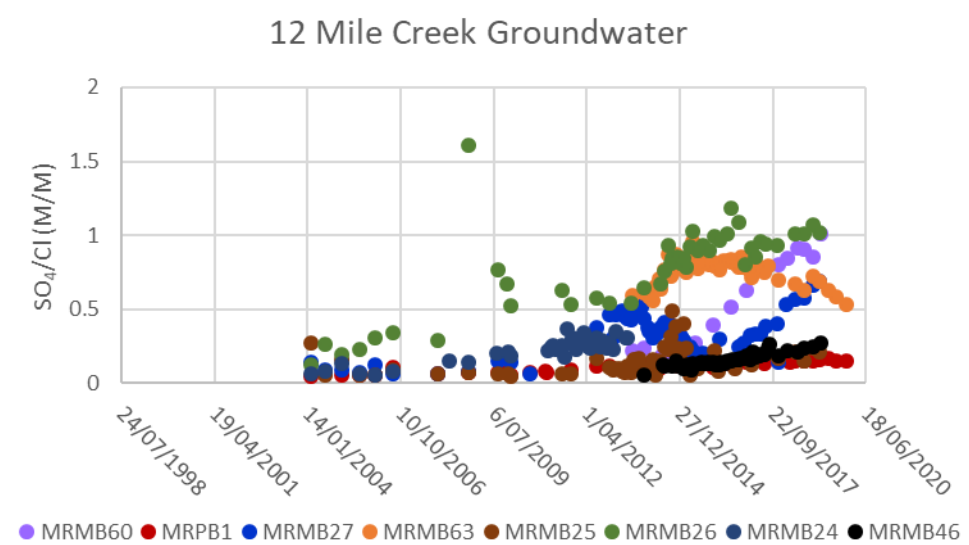
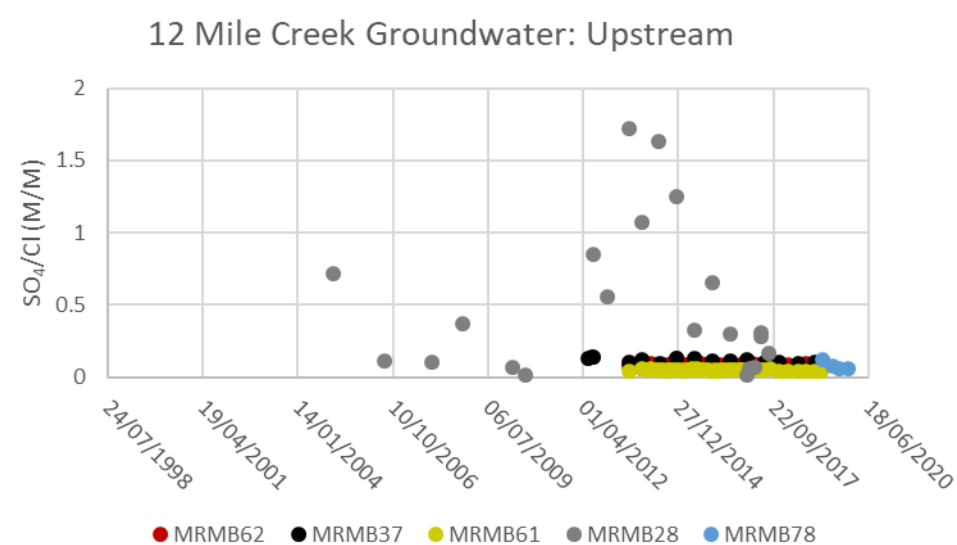
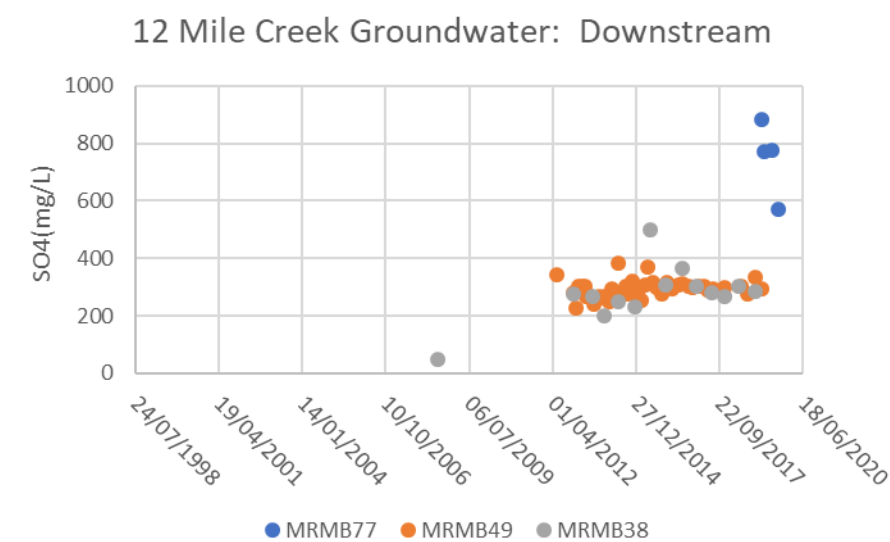
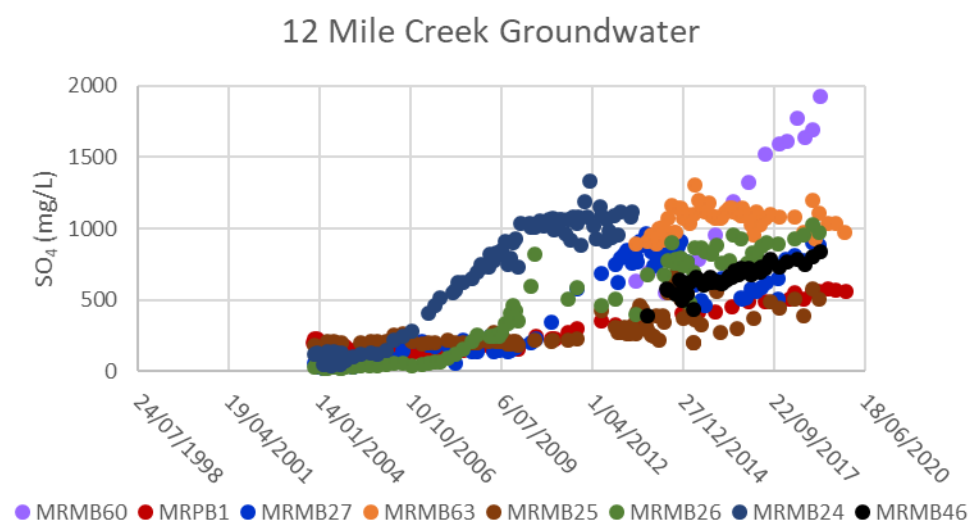
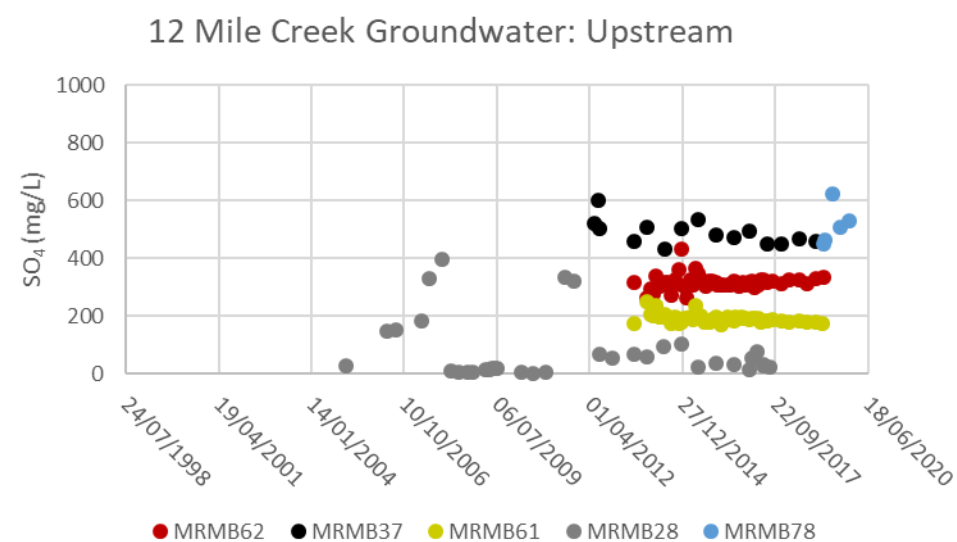
12 Mile Creek Groundwater

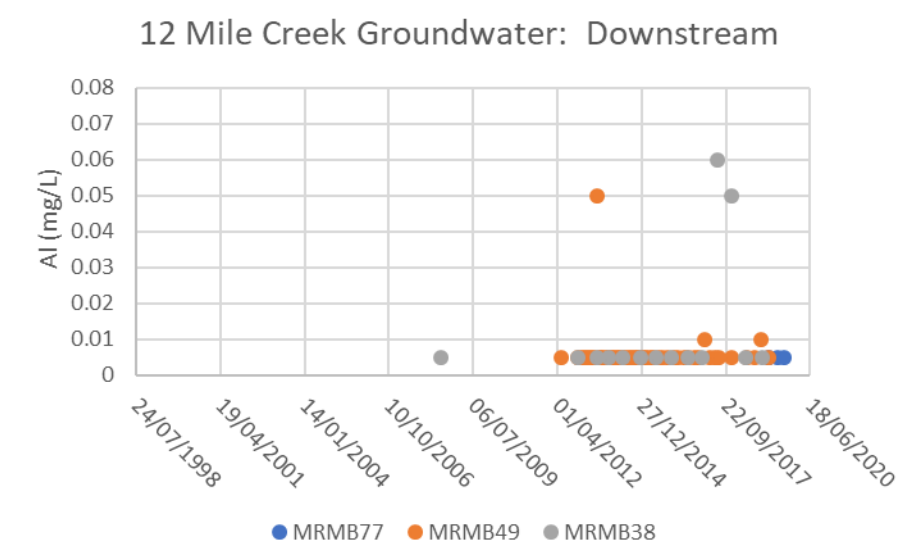
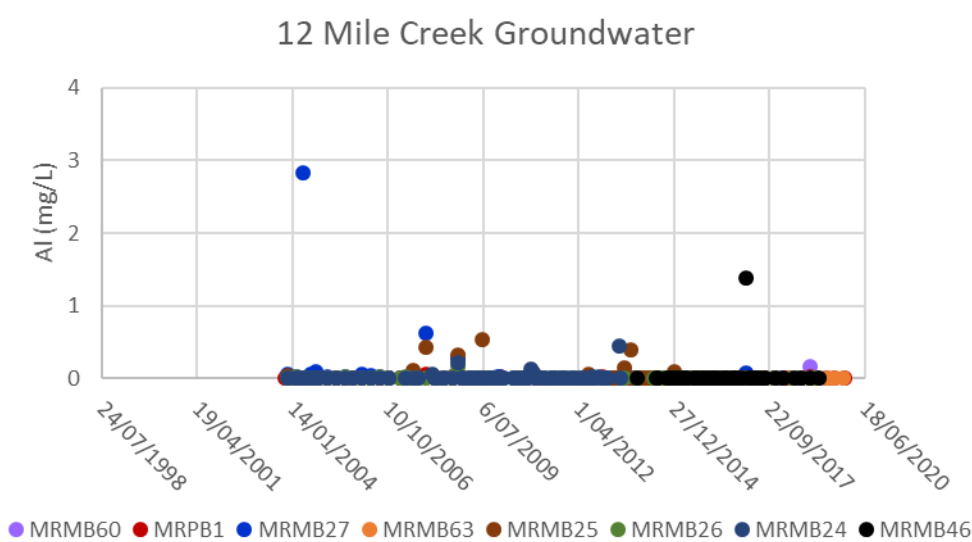
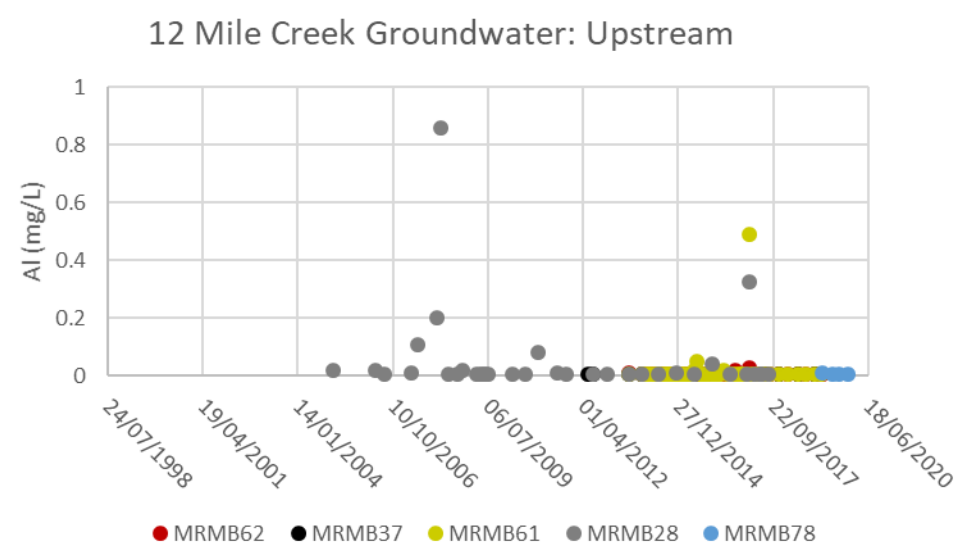
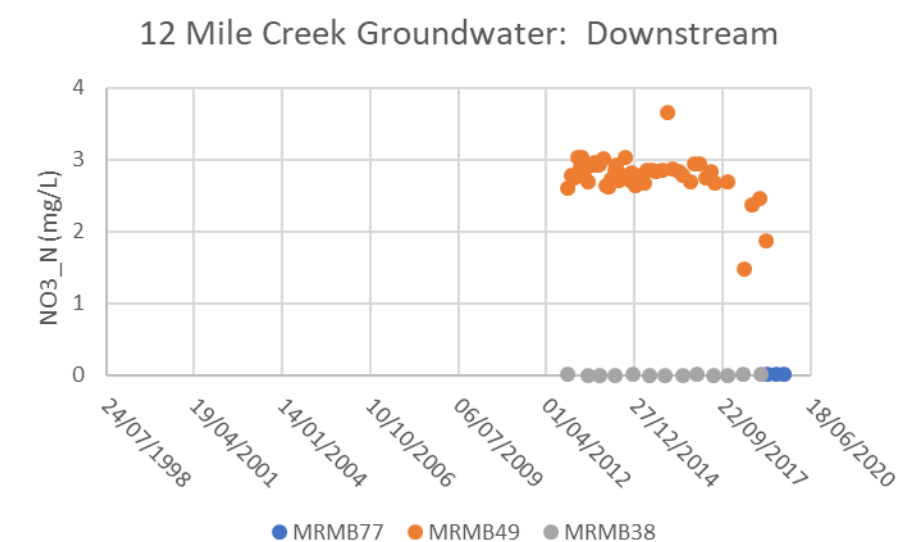
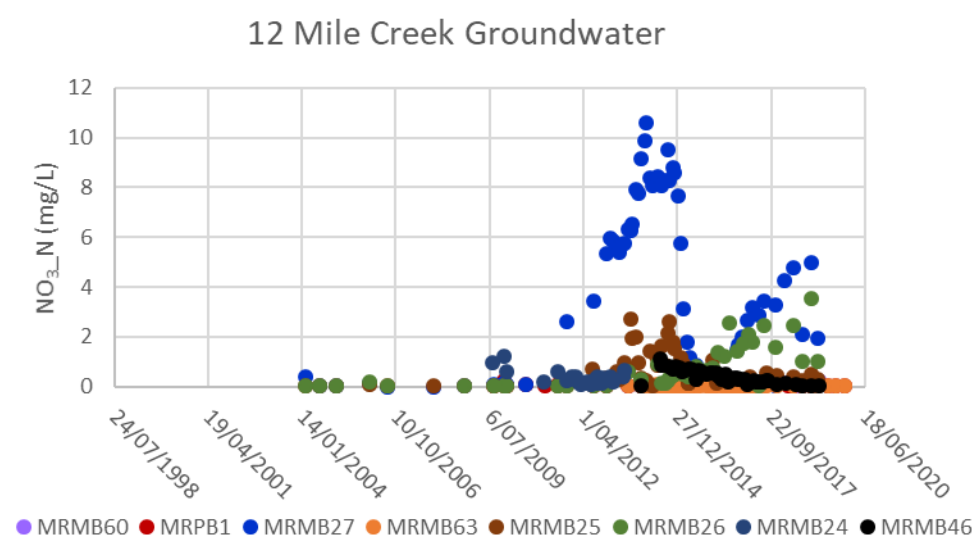
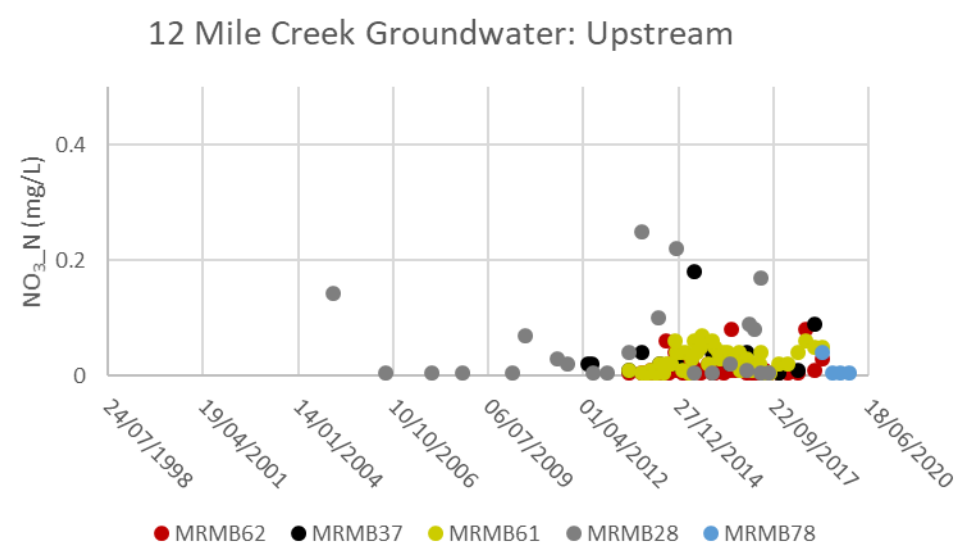
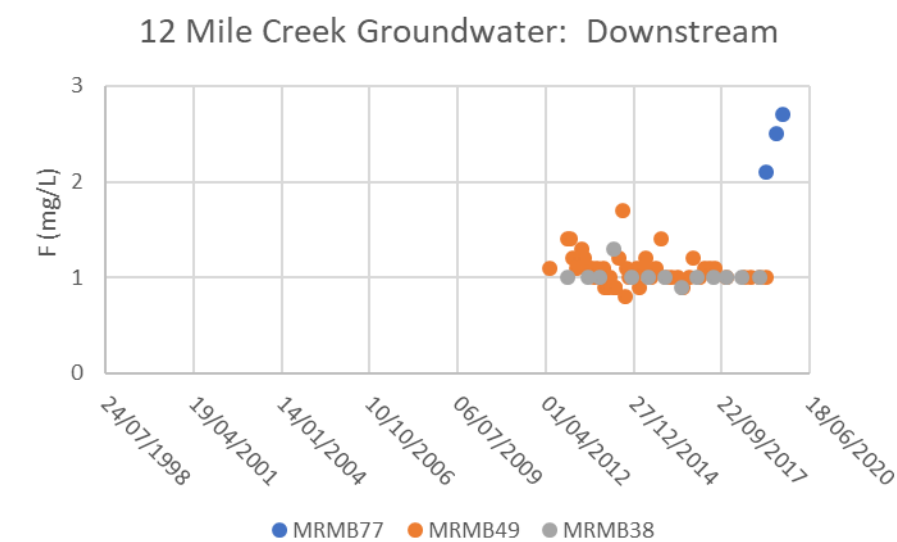
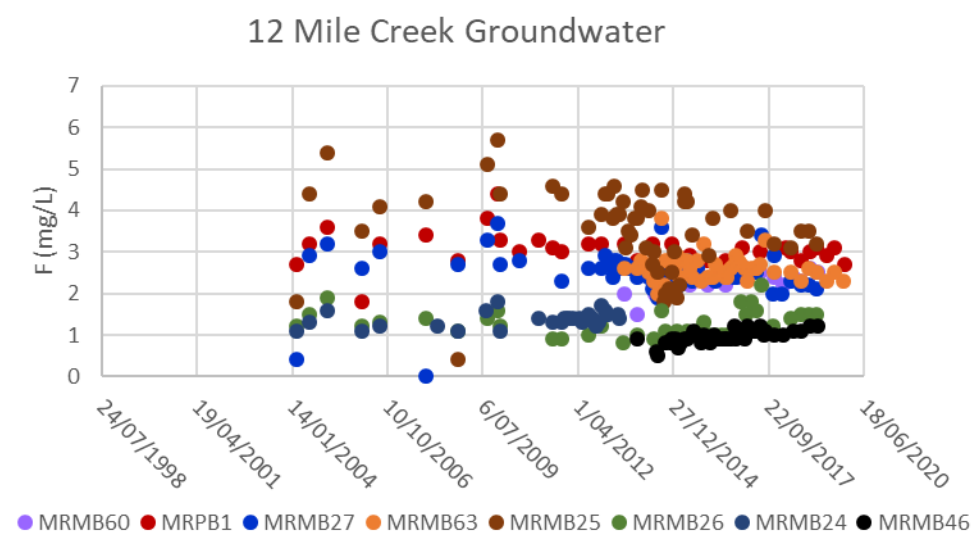
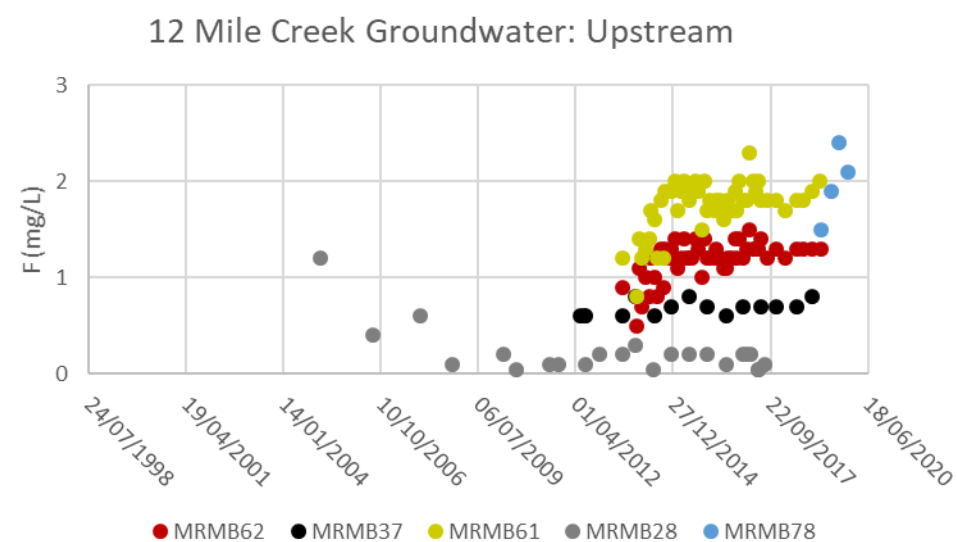


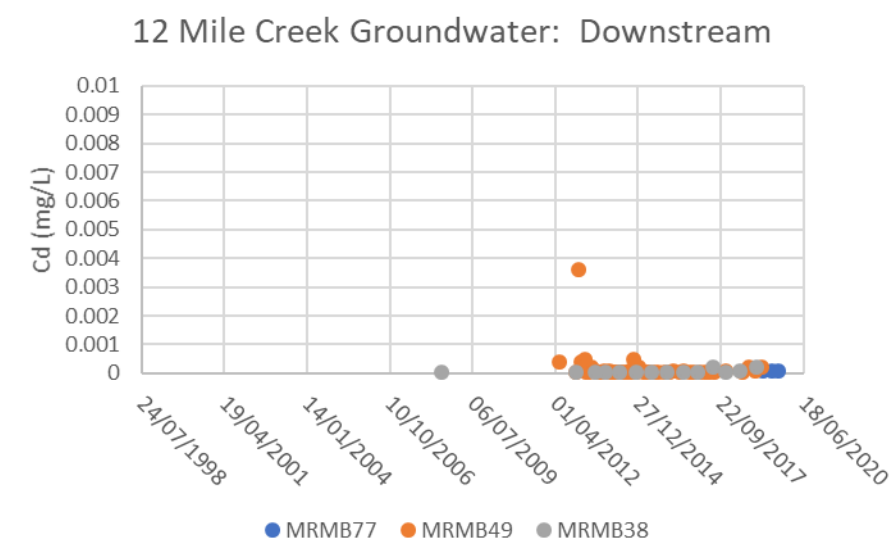
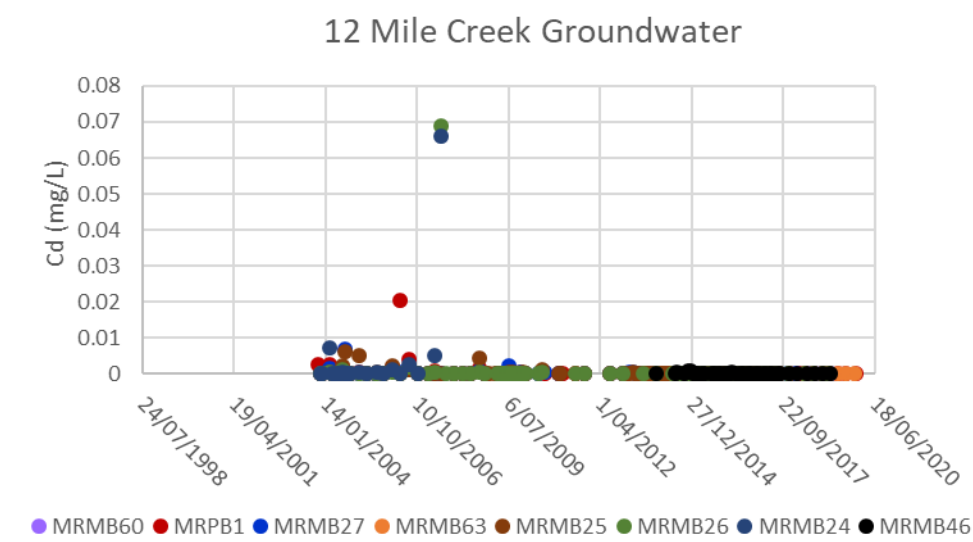
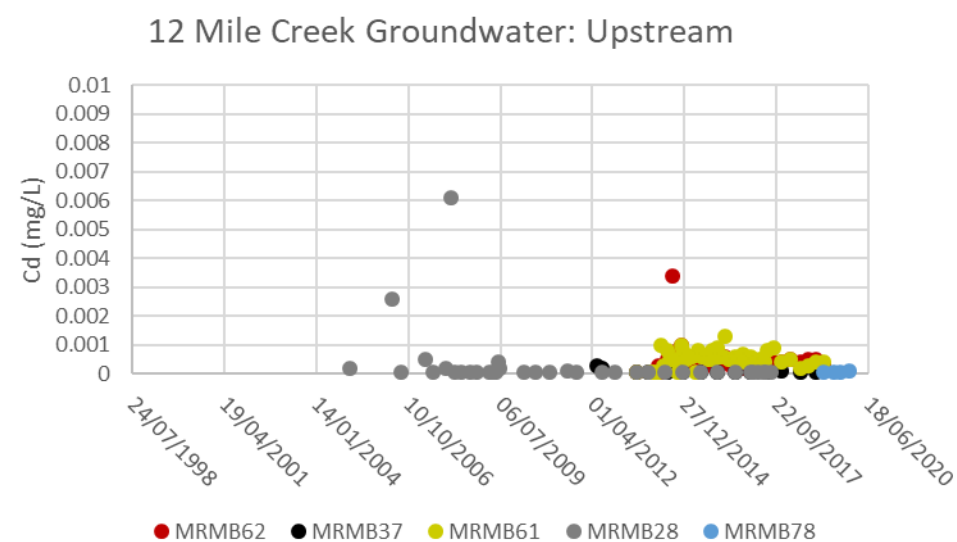
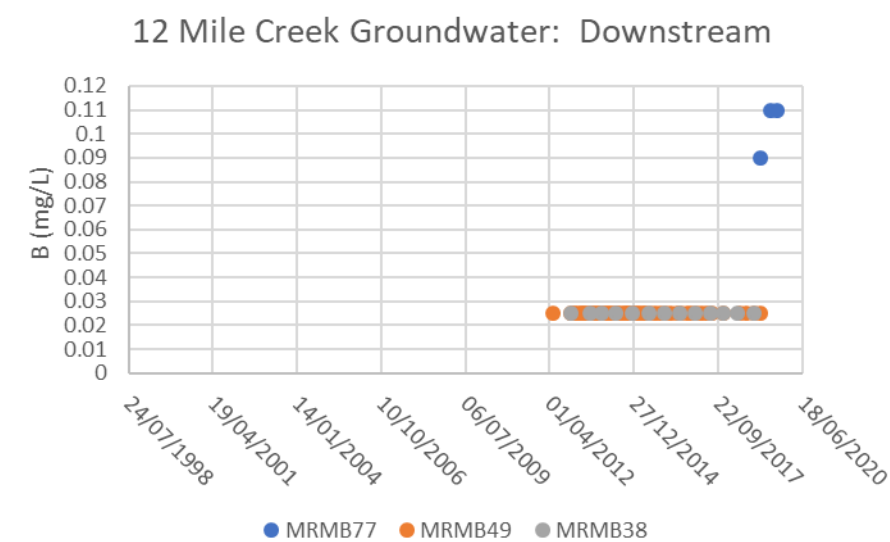
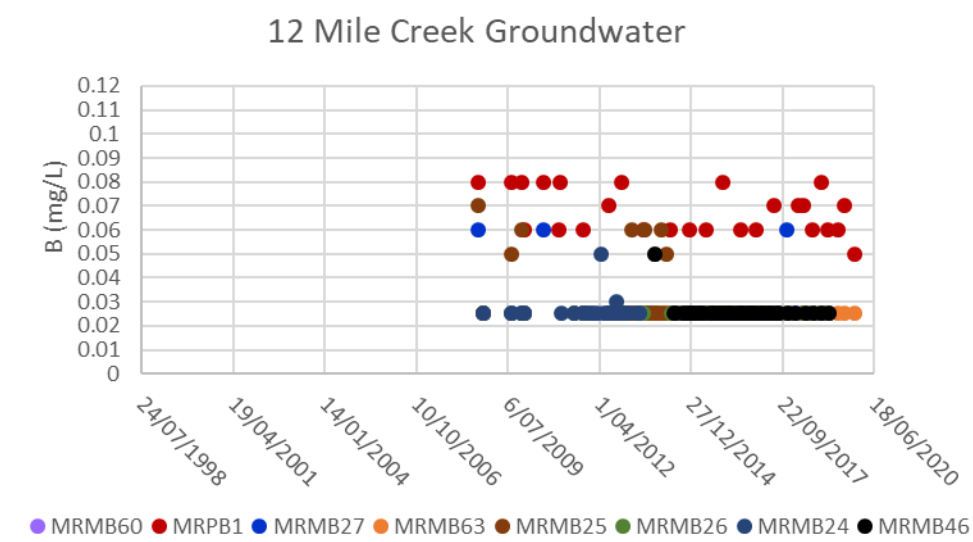
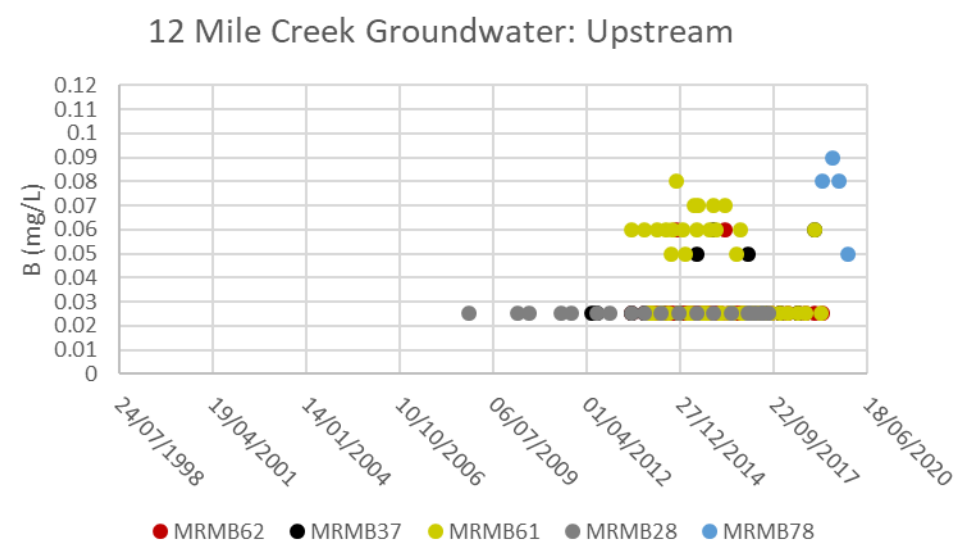
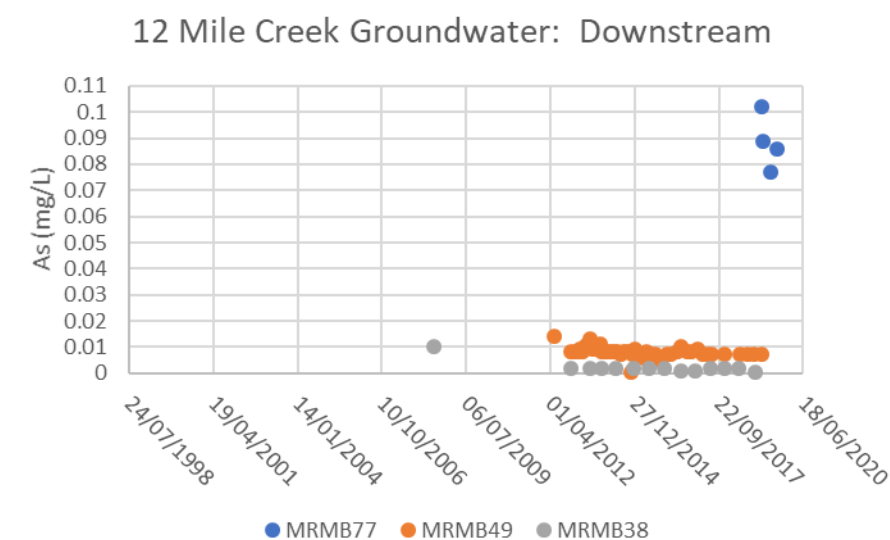
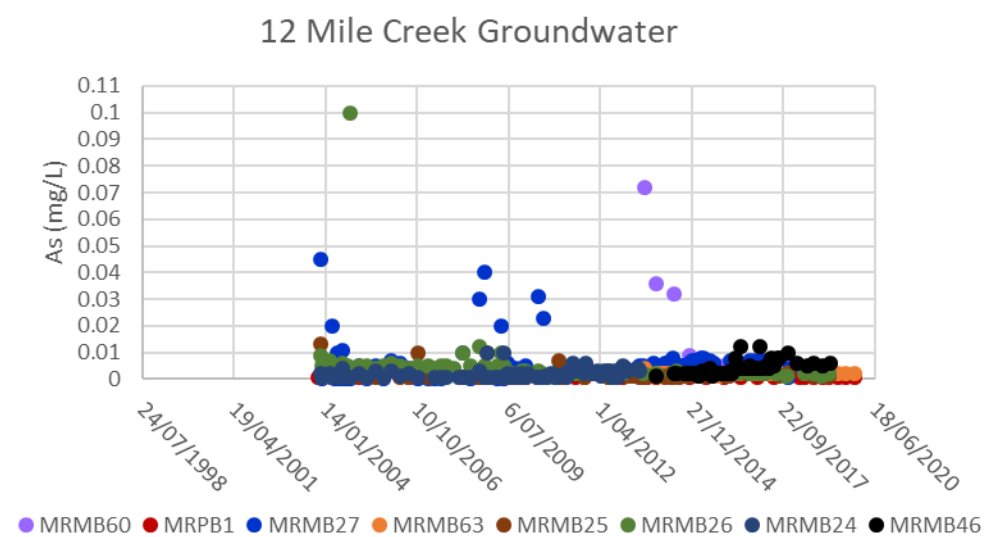
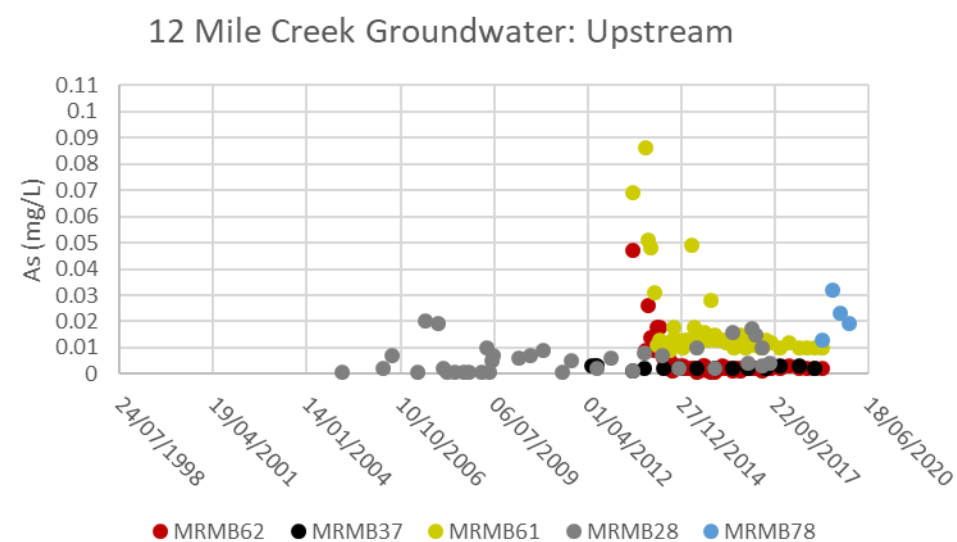
12 Mile Creek Groundwater: Downstream

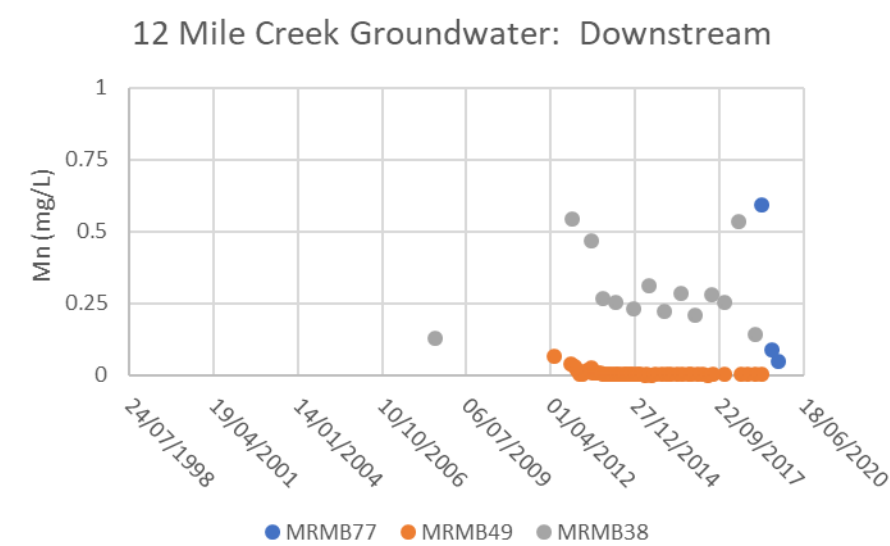
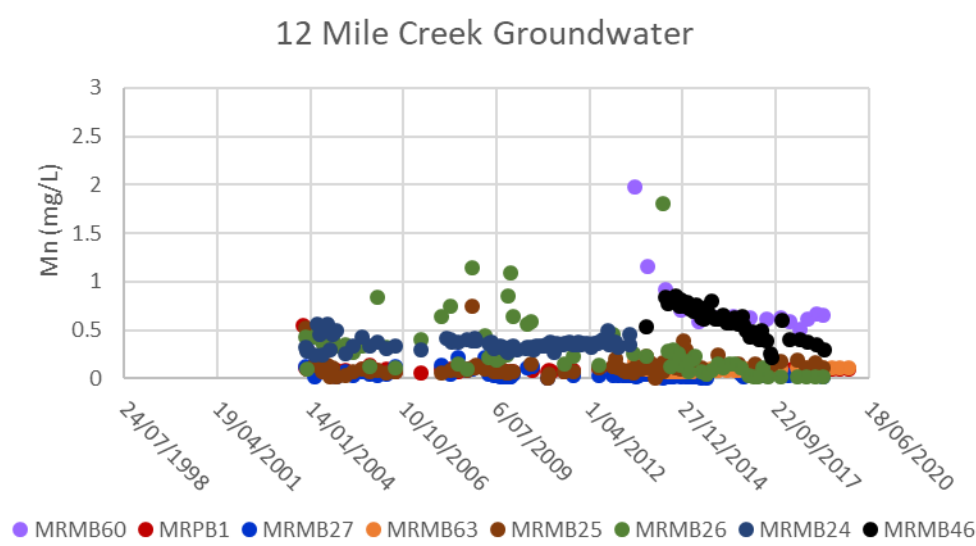
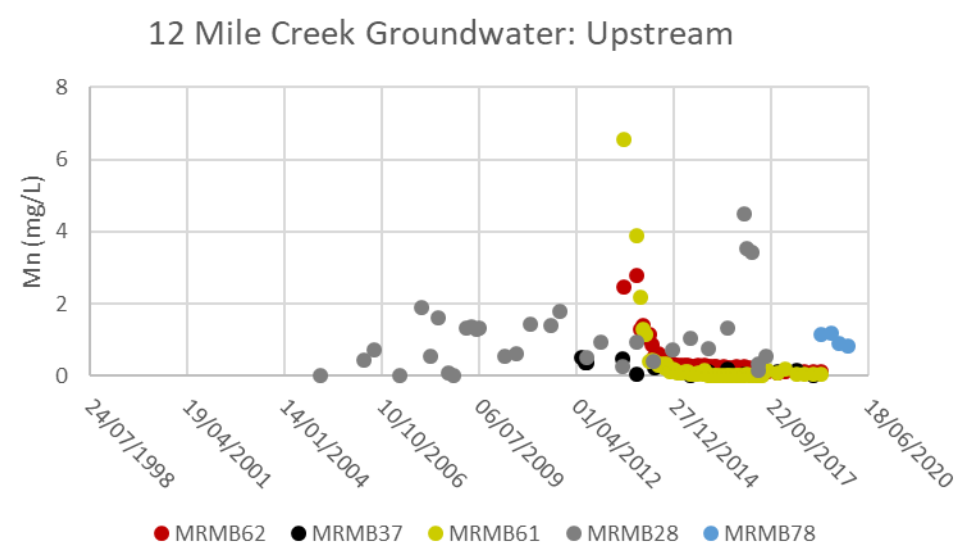
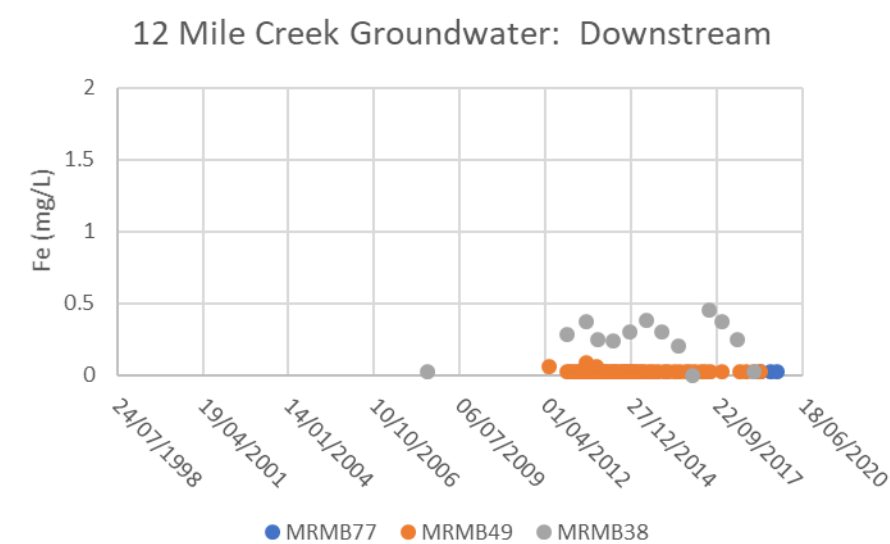
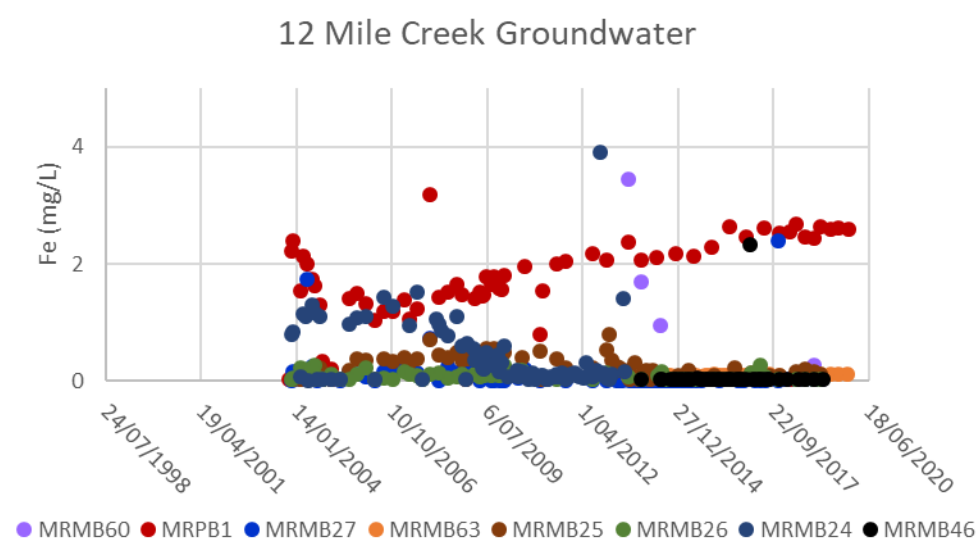
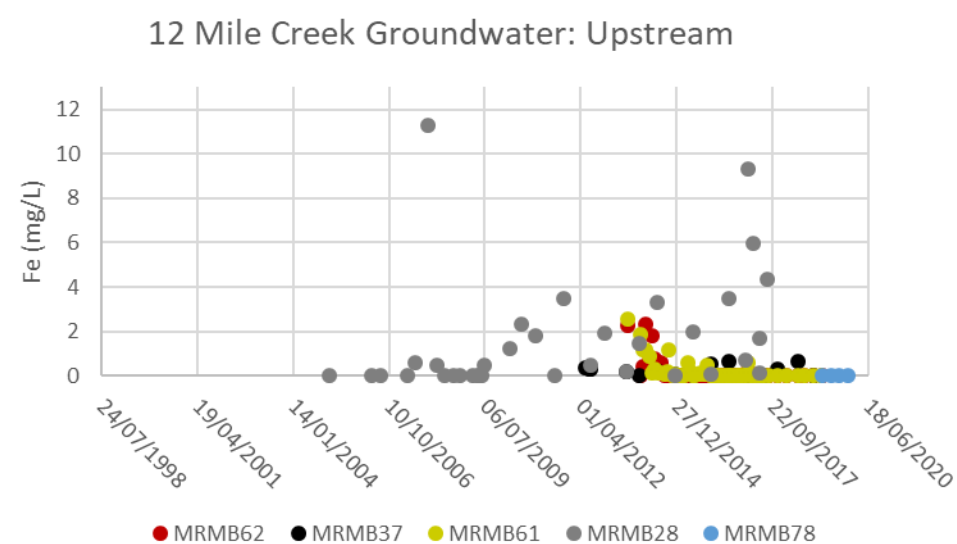
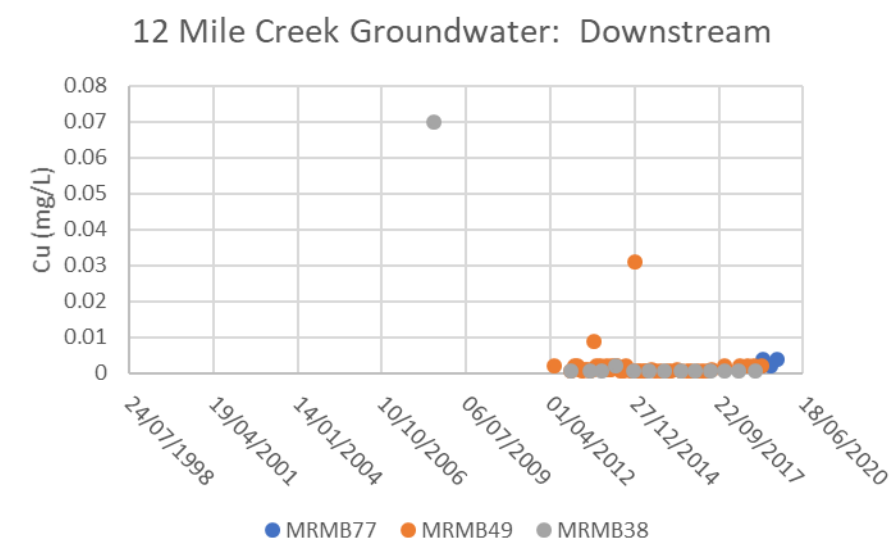
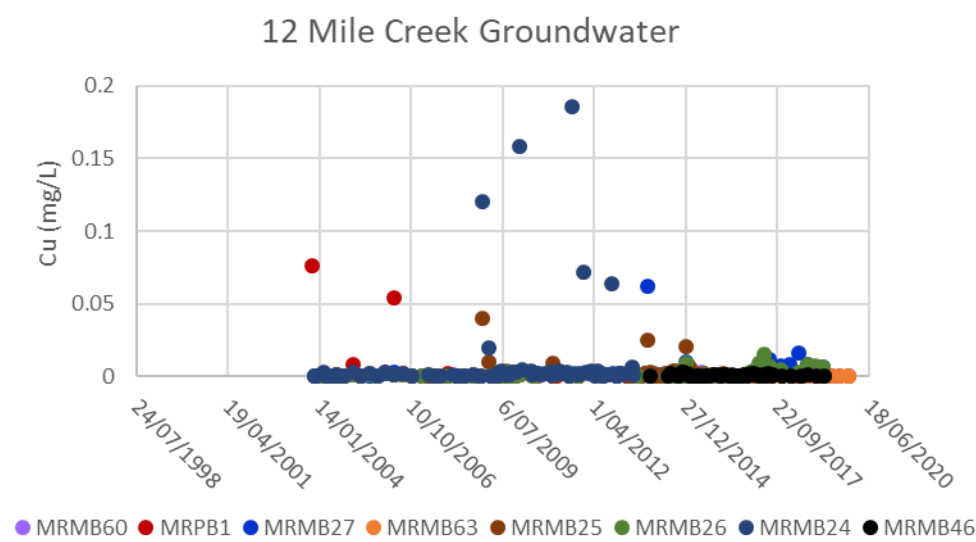
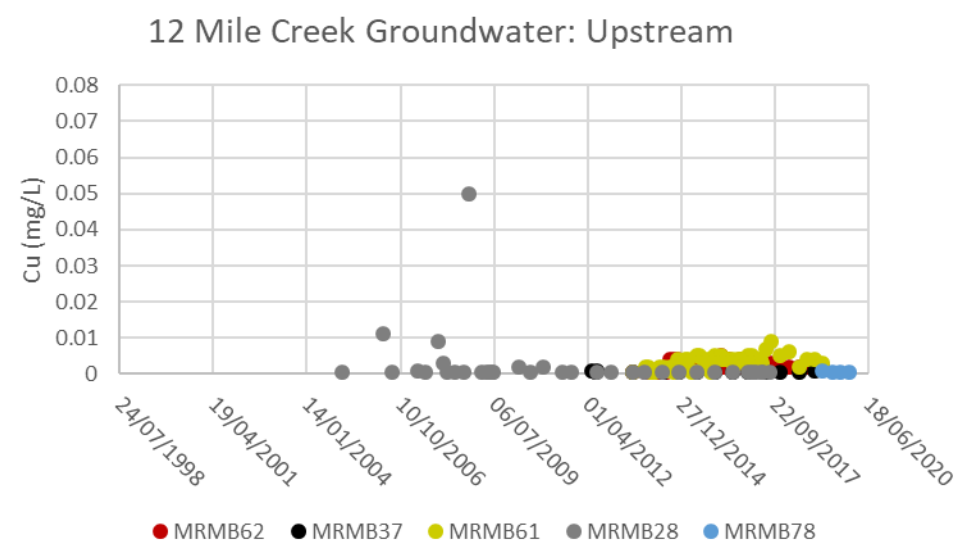


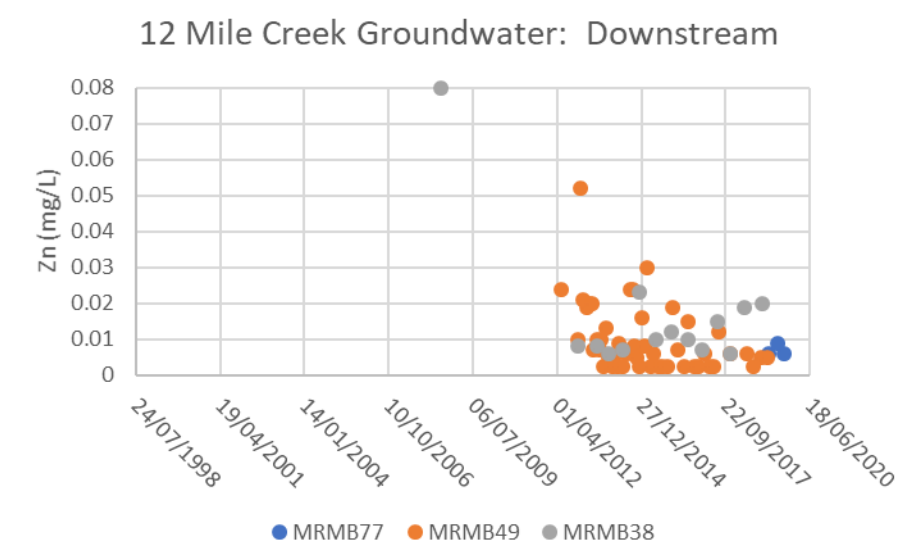
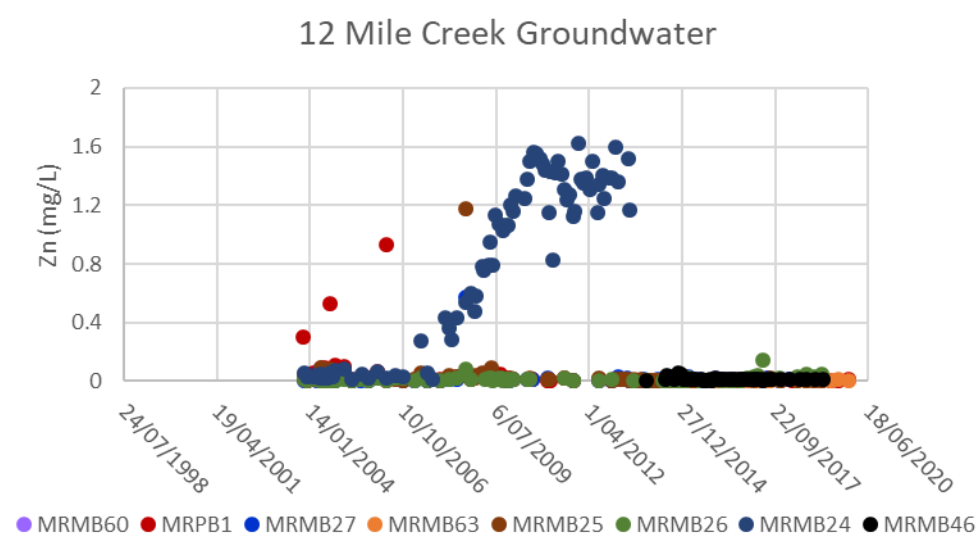
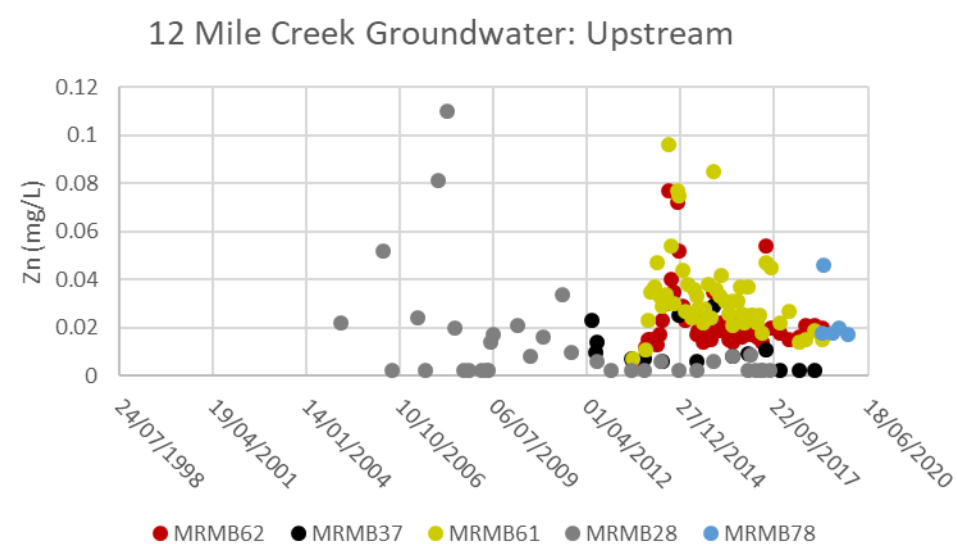
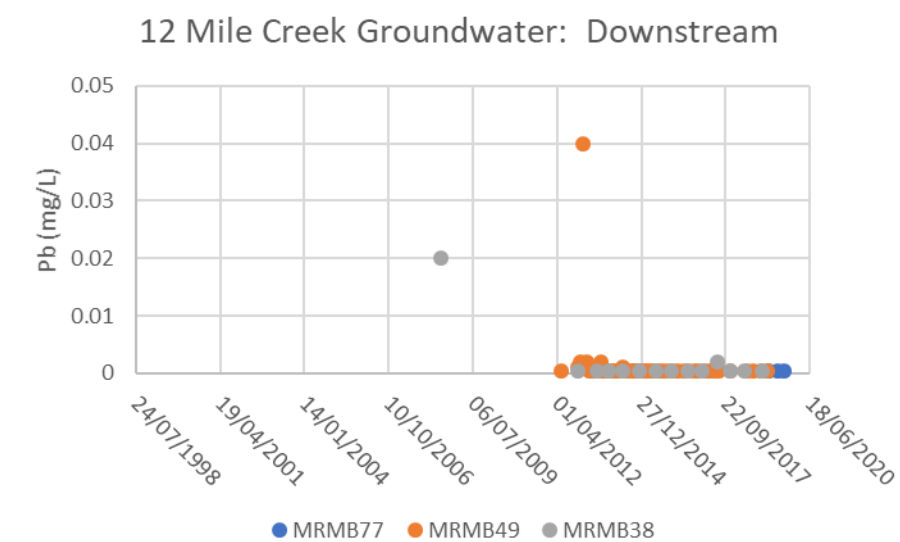
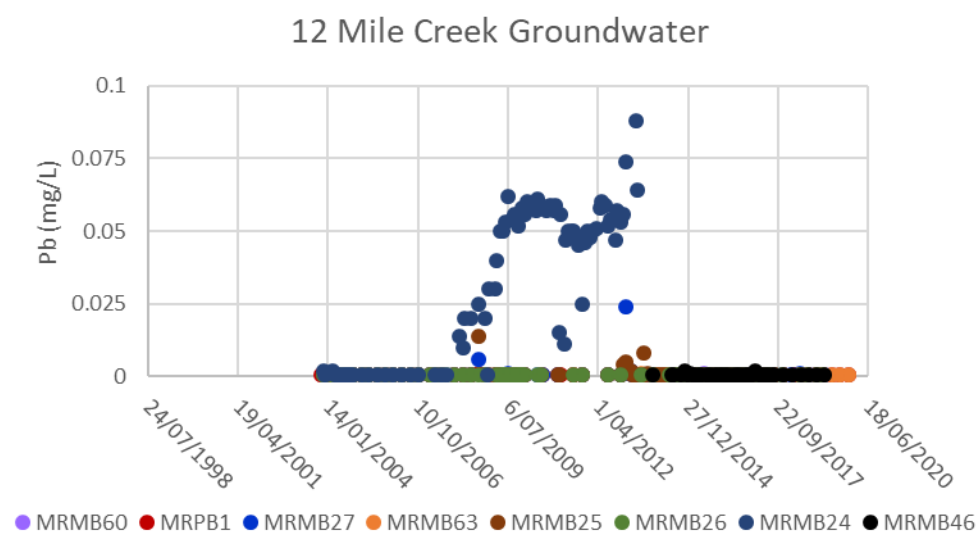
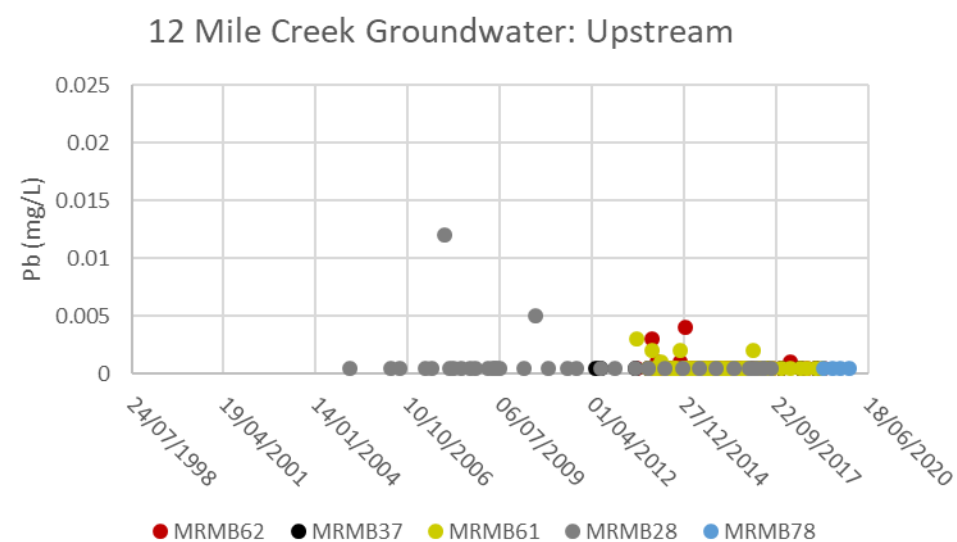












Sample Point	Statistic	pH	EC (µS/cm)	Cyanide Total (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Sulphate (mg/L)	Alk Tot as CaCO3 (mg/L)	SO4/Cl (M/M)	Fluoride (mg/L)	Nitrate as N (mg/L)	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)
MRMB62 29/07/2013 - 20/02/2019	Count	52	52	51	51	51	51	51	51	51	50	51	51	51	51	49	51
	Min	6.21	5200	0.002	660	1170	263	333	0.06	0.5	0.005	0.005	0.001	0.025	0.0001	0.0005	0.001
	5th %ile	6.32	5487	0.002	699	1220	275	517	0.07	0.8	0.005	0.005	0.001	0.025	0.0001	0.0005	0.001
	20th %ile	6.44	5592	0.002	727	1350	306	590	0.08	1.1	0.005	0.005	0.002	0.025	0.0003	0.0005	0.001
	Mean	6.62	5702	0.002	775	1410	317	619	0.08	1.2	0.014	0.006	0.005	0.026	0.0004	0.0005	0.002
	Median	6.53	5710	0.002	770	1420	317	638	0.08	1.2	0.010	0.005	0.002	0.025	0.0003	0.0005	0.002
	80th %ile	6.77	5790	0.002	813	1480	326	667	0.09	1.3	0.020	0.005	0.003	0.025	0.0005	0.0005	0.003
	95th %ile	7.15	5993	0.002	886	1530	355	675	0.10	1.4	0.051	0.008	0.018	0.025	0.0008	0.0005	0.004
	Max	7.36	6158	0.002	926	1600	431	693	0.13	1.5	0.080	0.030	0.047	0.060	0.0034	0.0010	0.005
MRMB37 18/05/2012 - 29/11/2018	Count	15	15	15	15	15	15	15	15	15	14	15	15	15	15	15	15
	Min	6.74	6430	0	1080	1360	434	668	0.09	0.6	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	5th %ile	6.75	6432	0	1115	1444	445	700	0.10	0.6	0.005	0.005	0.002	0.025	0.00005	0.0005	0.0005
	20th %ile	6.92	6593	0	1158	1518	458	722	0.10	0.6	0.010	0.005	0.002	0.025	0.00005	0.0005	0.0005
	Mean	7.09	6740	0	1215	1575	490	765	0.12	0.7	0.037	0.005	0.002	0.033	0.00009	0.0008	0.0006
	Median	7.08	6760	0	1220	1580	482	766	0.12	0.7	0.020	0.005	0.002	0.025	0.00005	0.0005	0.0005
	80th %ile	7.32	6920	0	1270	1632	512	796	0.13	0.7	0.040	0.005	0.003	0.050	0.00012	0.0006	0.0010
	95th %ile	7.43	6992	0	1330	1722	555	842	0.14	0.8	0.122	0.005	0.003	0.060	0.00023	0.0022	0.0010
	Max	7.50	7066	0	1330	1750	603	864	0.14	0.8	0.180	0.005	0.003	0.060	0.00030	0.0025	0.0010
MRMB61 29/07/2013 - 12/02/2019	Count	50	50	51	51	51	51	51	51	51	50	51	51	51	51	49	51
	Min	6.20	5300	0.002	649	1160	172	301	0.04	0.8	0.01	0.005	0.009	0.025	0.0001	0.0005	0.001
	5th %ile	6.45	5402	0.002	686	1250	176	449	0.04	1.2	0.01	0.005	0.010	0.025	0.0001	0.0005	0.001
	20th %ile	6.54	5520	0.002	712	1380	181	611	0.05	1.6	0.01	0.005	0.010	0.025	0.0004	0.0005	0.002
	Mean	6.70	5673	0.002	745	1453	192	650	0.05	1.7	0.03	0.016	0.018	0.039	0.0005	0.0006	0.003
	Median	6.66	5690	0.002	748	1480	191	687	0.05	1.8	0.02	0.005	0.013	0.025	0.0005	0.0005	0.004
	80th %ile	6.81	5800	0.002	779	1520	198	713	0.05	1.9	0.04	0.005	0.015	0.060	0.0007	0.0005	0.004
	95th %ile	7.21	5877	0.002	811	1585	220	736	0.06	2.0	0.06	0.020	0.050	0.070	0.0010	0.0010	0.006
	Max	7.32	6000	0.009	842	1630	251	768	0.06	2.3	0.07	0.490	0.086	0.080	0.0013	0.0020	0.009
MRMB28 19/01/2005 - 31/07/2017	Count	36	36	36	24	24	36	18	24	24	24	36	36	21	36	22	36
	Min	5.68	193	0.002	25	8	3	25	0.01	0.05	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	5th %ile	5.95	245	0.002	30	15	6	33	0.02	0.05	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	20th %ile	6.16	360	0.002	37	21	13	67	0.07	0.10	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	Mean	6.58	1053	0.022	147	173	80	194	0.74	0.22	0.058	0.268	0.006	0.025	0.00016	0.0008	0.0025
	Median	6.56	543	0.002	57	36	34	174	0.32	0.20	0.020	0.005	0.005	0.025	0.00005	0.0005	0.0005
	80th %ile	6.96	1710	0.002	243	378	105	335	1.14	0.20	0.094	0.020	0.010	0.025	0.00005	0.0005	0.0005
	95th %ile	7.41	3580	0.015	438	490	332	445	3.19	0.57	0.213	0.470	0.018	0.025	0.00043	0.0010	0.0095
	Max	7.47	5690	0.660	1110	1470	399	499	3.61	1.20	0.250	7.700	0.020	0.025	0.00260	0.0070	0.0500
MRMB78 13/02/2019 - 26/02/2020	Count	5	6	4	4	4	5	4	4	4	4	4	4	4	4	4	4
	Min	7.0	6190	0.002	1110	1420	449	783	0.06	1.5	0.005	0.005	0.013	0.05	0.00005	0.0005	0.0005
	5th %ile	7.0	6258	0.002	1235	1675	452	835	0.06	1.6	0.005	0.005	0.014	0.05	0.00005	0.0005	0.0005
	20th %ile	7.0	6460	0.002	1608	2440	461	991	0.06	1.7	0.005	0.005	0.017	0.07	0.00005	0.0005	0.0005
	Mean	7.1	9380	0.002	1790	2763	516	1068	0.08	2.0	0.014	0.006	0.022	0.08	0.00006	0.0005	0.0006
	Median	7.1	10710	0.002	1950	3180	510	1130	0.07	2.0	0.005	0.005	0.021	0.08	0.00005	0.0005	0.0005
	80th %ile	7.1	10900	0.002	2036	3252	550	1170	0.09	2.2	0.019	0.007	0.027	0.08	0.00007	0.0005	0.0007
	95th %ile	7.2	11208	0.002	2122	3266	605	1215	0.11	2.4	0.035	0.009	0.031	0.09	0.00009	0.0005	0.0009
	Max	7.2	11310	0.002	2150	3270	623	1230	0.12	2.4	0.040	0.010	0.032	0.09	0.00010	0.0005	0.0010
MRMB60 29/07/2013 - 12/02/2019	Count	15	15	15.000	15	15	15	15	15	15	15	15	15	15	15	15	15
	Min	6.69	5084	0.002	841	671	552	528	0.19	1.5	0.01	0.005	0.002	0.025	0.00005	0.0005	0.0005
	5th %ile	6.69	5109	0.002	887	696	576	539	0.21	1.9	0.01	0.005	0.003	0.025	0.00005	0.0005	0.0005
	20th %ile	6.73	5357	0.002	918	710	682	567	0.24	2.2	0.01	0.005	0.003	0.025	0.00005	0.0005	0.0005
	Mean	6.96	5420	0.002	950	845	1231	670	0.59	2.2	0.05	0.015	0.013	0.025	0.00006	0.0006	0.0008
	Median	6.85	5420	0.002	931	770	1320	670	0.63	2.3	0.02	0.005	0.004	0.025	0.00005	0.0005	0.0005
	80th %ile	7.22	5554	0.002	990	1040	1650	779	0.87	2.4	0.09	0.005	0.014	0.025	0.00006	0.0005	0.0006
	95th %ile	7.39	5613	0.002	1031	1069	1818	835	0.95	2.5	0.21	0.051	0.047	0.025	0.00010	0.0009	0.0023
	Max	7.63	5620	0.002	1080	1090	1930	857	1.01	2.6	0.21	0.160	0.072	0.025	0.00010	0.0020	0.0030

Sample Point	Statistic	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Lead Dissolved (mg/L)	Zinc Dissolved (mg/L)	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Molybdenum Dissolved (mg/L)
MRMB62 29/07/2013 - 20/02/2019	Count	51	51	51	51	51	51	51	51
	Min	0.025	0.099	0	0	209	6	128	0.001
	5th %ile	0.025	0.107	0.0005	0.014	216	7	142	0.001
	20th %ile	0.025	0.176	0.0005	0.015	230	7	152	0.001
	Mean	0.207	0.435	0.0006	0.023	263	10	157	0.004
	Median	0.025	0.264	0.0005	0.019	244	8	159	0.002
	80th %ile	0.025	0.363	0.0005	0.026	254	11	165	0.004
	95th %ile	1.285	1.355	0.0010	0.053	263	23	169	0.012
	Max	2.320	2.800	0.0040	0.077	1370	32	175	0.057
MRMB37 18/05/2012 - 29/11/2018	Count	15	15	15	15	15	15	15	15
	Min	0.025	0.014	0.0005	0.003	70	6	124	0.006
	5th %ile	0.025	0.015	0.0005	0.003	82	6	130	0.007
	20th %ile	0.025	0.052	0.0005	0.005	94	6	141	0.009
	Mean	0.248	0.195	0.0005	0.011	194	7	143	0.010
	Median	0.180	0.146	0.0005	0.008	101	7	144	0.010
	80th %ile	0.384	0.384	0.0005	0.016	104	8	147	0.011
	95th %ile	0.659	0.499	0.0005	0.026	538	9	150	0.014
	Max	0.680	0.525	0.0005	0.029	1550	10	151	0.016
MRMB61 29/07/2013 - 12/02/2019	Count	51	51	51	51	51	51	51	51
	Min	0.025	0.006	0.0005	0.007	189	9	148	0.005
	5th %ile	0.025	0.012	0.0005	0.015	196	11	163	0.006
	20th %ile	0.025	0.019	0.0005	0.022	209	12	172	0.009
	Mean	0.250	0.388	0.0006	0.033	246	14	178	0.013
	Median	0.025	0.057	0.0005	0.030	220	13	179	0.012
	80th %ile	0.210	0.296	0.0005	0.038	235	18	186	0.016
	95th %ile	1.190	1.745	0.0020	0.076	255	23	193	0.029
	Max	2.570	6.550	0.0030	0.096	1410	24	198	0.035
MRMB28 19/01/2005 - 31/07/2017	Count	36	34	36	36	21	21	21	25
	Min	0.01	0.01	0.0005	0.0025	0	0	0	0.0005
	5th %ile	0.01	0.01	0.0005	0.0025	3	2	4	0.0005
	20th %ile	0.03	0.39	0.0005	0.0025	11	2	8	0.0005
	Mean	1.85	1.16	0.0009	0.0143	58	4	23	0.0026
	Median	0.48	0.84	0.0005	0.0060	29	3	14	0.0010
	80th %ile	3.31	1.51	0.0005	0.0200	66	6	48	0.0040
	95th %ile	9.27	3.54	0.0016	0.0593	109	6	52	0.0070
	Max	11.30	4.50	0.0120	0.1100	470	7	61	0.0140
MRMB78 13/02/2019 - 26/02/2020	Count	4	4	4	5	4	4	4	4
	Min	0.025	0.814	0.0005	0.017	94	16	100	0.038
	5th %ile	0.025	0.825	0.0005	0.017	104	16	120	0.040
	20th %ile	0.025	0.859	0.0005	0.018	134	16	179	0.044
	Mean	0.025	1.006	0.0005	0.024	154	17	202	0.088
	Median	0.025	1.015	0.0005	0.018	167	16	233	0.076
	80th %ile	0.025	1.156	0.0005	0.025	179	18	238	0.128
	95th %ile	0.025	1.174	0.0005	0.041	187	19	242	0.154
	Max	0.025	1.180	0.0005	0.046	190	20	243	0.163
MRMB60 29/07/2013 - 12/02/2019	Count	15	15	15	15	15	15	15	15
	Min	0.025	0.503	0.0005	0.003	131	10	110	0.010
	5th %ile	0.025	0.559	0.0005	0.003	132	10	117	0.011
	20th %ile	0.025	0.607	0.0005	0.008	135	11	132	0.016
	Mean	0.442	0.767	0.0005	0.014	187	12	142	0.022
	Median	0.025	0.633	0.0005	0.014	145	11	140	0.023
	80th %ile	0.412	0.748	0.0005	0.017	155	12	156	0.028
	95th %ile	2.222	1.406	0.0007	0.027	349	15	161	0.033
	Max	3.440	1.980	0.0010	0.034	770	17	169	0.035

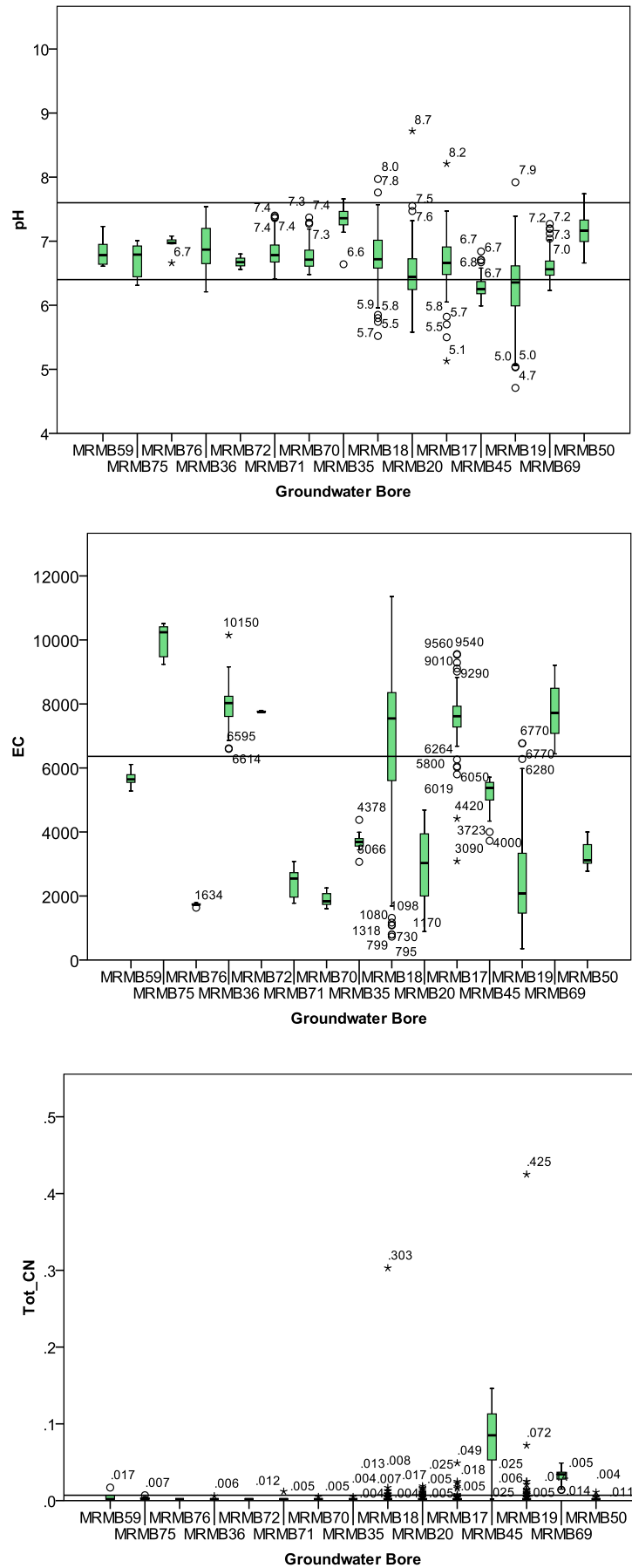
Sample Point	Statistic	pH	EC (µS/cm)	Cyanide Total (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Sulphate (mg/L)	Alk Tot as CaCO3 (mg/L)	SO4/Cl (M/M)	Fluoride (mg/L)	Nitrate as N (mg/L)	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)
MRPB01 29/10/2003 - 12/02/2020	Count	68	69	65	35	35	66	28	35	34	27	65	65	29	65	30	65
	Min	6.24	3750	0.001	672	557	126	643	0.05	1.8	0.005	0.005	0.0005	0.03	0.00005	0.0005	0.0005
	5th %ile	6.66	3830	0.002	697	844	137	667	0.06	2.7	0.005	0.005	0.0005	0.04	0.00005	0.0005	0.0005
	20th %ile	6.79	4022	0.002	745	918	149	685	0.07	2.8	0.005	0.005	0.0005	0.06	0.00005	0.0005	0.0005
	Mean	7.00	4779	0.002	856	1156	269	731	0.11	3.1	0.034	0.011	0.0006	0.06	0.00063	0.0010	0.0028
	Median	6.94	4760	0.002	884	1230	190	716	0.11	3.1	0.005	0.005	0.0005	0.06	0.00005	0.0005	0.0005
	80th %ile	7.28	5558	0.002	954	1322	414	776	0.15	3.2	0.036	0.005	0.0005	0.08	0.00024	0.0012	0.0010
	95th %ile	7.45	5788	0.002	1000	1370	557	839	0.16	3.7	0.187	0.020	0.0010	0.08	0.00236	0.0036	0.0030
	Max	8.10	5850	0.008	1010	1380	576	866	0.17	4.4	0.240	0.300	0.0030	0.08	0.02050	0.0050	0.0760
MRMB27 19/11/2003 - 05/02/2019	Count	89	89	88	60	60	89	54	60	59	59	88	89	54	89	56	89
	Min	6.29	581	0.002	106	44	17	0	0.06	0.0	0.00	0.005	0.000	0.025	0.00005	0.0005	0.001
	5th %ile	6.95	1857	0.002	449	212	46	558	0.07	2.0	0.04	0.005	0.000	0.025	0.00005	0.0005	0.001
	20th %ile	7.06	2436	0.002	685	538	115	597	0.17	2.3	0.53	0.005	0.003	0.025	0.00005	0.0005	0.001
	Mean	7.28	3700	0.003	783	693	457	674	0.33	2.5	4.33	0.053	0.006	0.026	0.00024	0.0007	0.002
	Median	7.26	3990	0.002	807	694	516	668	0.34	2.6	4.26	0.005	0.005	0.025	0.00005	0.0005	0.001
	80th %ile	7.47	4720	0.002	923	879	814	781	0.46	2.7	8.07	0.008	0.007	0.025	0.00007	0.0005	0.002
	95th %ile	7.76	5234	0.006	1001	1040	905	871	0.56	3.3	9.21	0.073	0.022	0.025	0.00112	0.0013	0.008
	Max	8.31	5420	0.070	1050	1230	963	942	0.69	3.7	10.60	2.830	0.045	0.060	0.00700	0.0070	0.062
MRMB63 29/07/2013 - 05/02/2020	Count	55	55	52	52	52	53	52	52	52	51	52	52	52	52	50	52
	Min	6.95	3363	0.002	547	467	890	329	0.53	2.0	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	5th %ile	6.98	3512	0.002	573	484	915	389	0.58	2.3	0.005	0.005	0.001	0.025	0.00005	0.0005	0.0005
	20th %ile	7.07	3850	0.002	616	494	975	405	0.66	2.4	0.005	0.005	0.002	0.025	0.00005	0.0005	0.0005
	Mean	7.24	3912	0.002	643	526	1065	416	0.76	2.6	0.013	0.005	0.002	0.025	0.00005	0.0005	0.0007
	Median	7.19	3930	0.002	641	508	1080	417	0.77	2.6	0.005	0.005	0.002	0.025	0.00005	0.0005	0.0005
	80th %ile	7.44	3990	0.002	678	563	1126	435	0.84	2.8	0.020	0.005	0.002	0.025	0.00005	0.0005	0.0005
	95th %ile	7.62	4176	0.002	704	609	1188	444	0.87	3.0	0.040	0.005	0.002	0.025	0.00005	0.0005	0.0010
	Max	7.73	4280	0.002	762	676	1310	463	0.96	3.8	0.070	0.010	0.004	0.025	0.00005	0.0005	0.0060
MRMB25 19/11/2003 - 05/02/2019	Count	89	89	89	55	56	89	51	56	55	55	89	89	50	89	52	88
	Min	6.35	1260	0.002	209	133	87	0	0.05	0.4	0.01	0.005	0.001	0.025	0.00005	0.0005	0.0005
	5th %ile	6.83	2005	0.002	399	508	123	379	0.06	1.9	0.01	0.005	0.001	0.025	0.00005	0.0005	0.0005
	20th %ile	6.98	3915	0.002	563	881	201	420	0.07	3.0	0.05	0.005	0.001	0.025	0.00005	0.0005	0.0005
	Mean	7.19	4275	0.003	645	1019	290	432	0.15	3.6	0.63	0.029	0.001	0.030	0.00033	0.0007	0.0022
	Median	7.18	4570	0.002	673	1055	220	441	0.11	3.8	0.36	0.005	0.001	0.025	0.00005	0.0005	0.0005
	80th %ile	7.37	4738	0.002	757	1250	402	458	0.21	4.4	1.07	0.005	0.002	0.025	0.00020	0.0005	0.0020
	95th %ile	7.65	5021	0.004	803	1343	571	490	0.34	4.8	2.06	0.134	0.003	0.060	0.00184	0.0020	0.0083
	Max	8.23	7480	0.050	878	1390	675	509	0.49	5.7	2.71	0.530	0.013	0.070	0.00600	0.0030	0.0400
MRMB26 19/11/2003 - 05/02/2019	Count	78	78	75	47	47	77	42	47	46	45	77	77	40	77	41	77
	Min	6.19	979	0.001	168	34	16	0	0.13	0.8	0.01	0.005	0.001	0.025	0.00005	0.0005	0.0005
	5th %ile	6.88	1073	0.002	196	49	24	333	0.24	0.8	0.01	0.005	0.002	0.025	0.00005	0.0005	0.0005
	20th %ile	6.99	1264	0.002	248	225	43	434	0.54	1.0	0.02	0.005	0.002	0.025	0.00005	0.0005	0.0005
	Mean	7.23	2145	0.002	312	278	449	460	0.77	1.2	0.74	0.008	0.005	0.026	0.00102	0.0007	0.0016
	Median	7.22	2054	0.002	328	334	422	475	0.84	1.1	0.50	0.005	0.002	0.025	0.00005	0.0005	0.0005
	80th %ile	7.43	3056	0.002	366	353	821	511	0.99	1.5	1.37	0.005	0.005	0.025	0.00009	0.0005	0.0010
	95th %ile	7.77	3128	0.003	399	375	935	575	1.08	1.8	2.46	0.020	0.009	0.025	0.00052	0.0020	0.0072
	Max	8.34	3260	0.006	406	405	1030	590	1.61	2.2	3.55	0.170	0.100	0.050	0.06900	0.0030	0.0150
MRMB24 19/11/2003 - 11/06/2013	Count	79	79	78	39	38	79	26	38	30	24	79	79	25	79	29	79
	Min	5.91	1710	0.002	222	246	38	558	0.05	1.1	0.09	0.001	0.001	0.025	0.000	0.0005	0.001
	5th %ile	6.41	2462	0.002	320	527	97	600	0.06	1.1	0.09	0.005	0.001	0.025	0.000	0.0005	0.001
	20th %ile	6.62	4012	0.002	789	1220	186	611	0.16	1.2	0.15	0.005	0.001	0.025	0.001	0.0005	0.001
	Mean	6.80	5747	0.005	773	1339	727	634	0.23	1.4	0.35	0.017	0.002	0.026	0.146	0.0016	0.009
	Median	6.79	6520	0.002	830	1440	883	634	0.24	1.4	0.30	0.005	0.001	0.025	0.168	0.0005	0.001
	80th %ile	7.01	6856	0.002	870	1550	1060	649	0.29	1.5	0.46	0.005	0.003	0.025	0.227	0.0020	0.003
	95th %ile	7.22	7163	0.012	910	1735	1120	671	0.35	1.7	0.90	0.061	0.005	0.029	0.258	0.0048	0.065
	Max	7.64	7370	0.149	943	1890	1330	696	0.37	1.8	1.22	0.450	0.010	0.050	0.358	0.0160	0.186

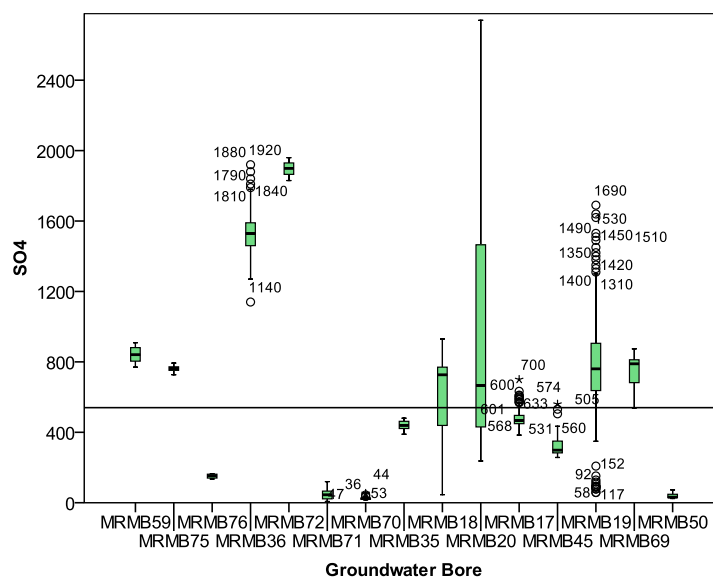
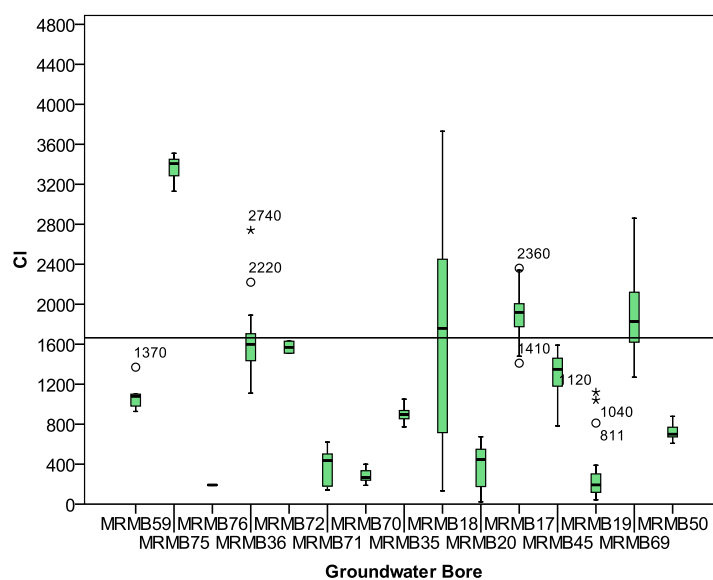
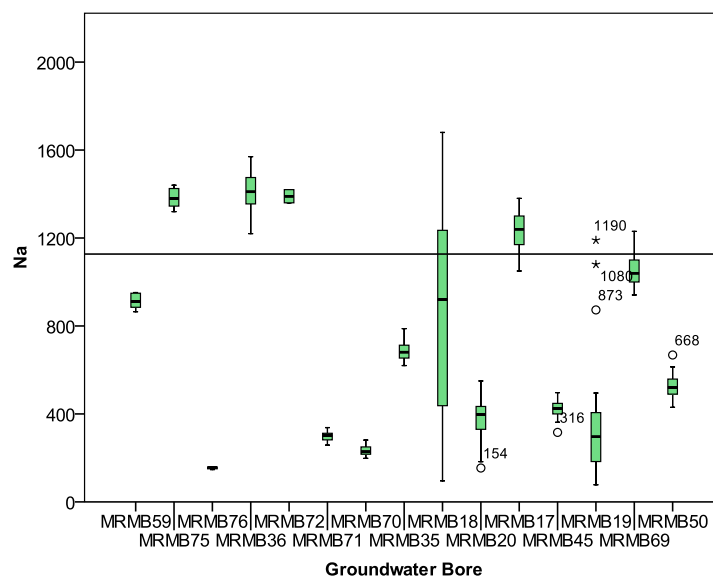
Sample Point	Statistic	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Lead Dissolved (mg/L)	Zinc Dissolved (mg/L)	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Molybdenum Dissolved (mg/L)
MRPB01 29/10/2003 - 12/02/2020	Count	67	62	65	65	27	27	27	43
	Min	0.03	0.050	0.0005	0.0025	64	5	72	0.001
	5th %ile	0.03	0.065	0.0005	0.0025	98	6	78	0.002
	20th %ile	1.25	0.076	0.0005	0.0025	133	6	102	0.003
	Mean	1.69	0.095	0.0005	0.0474	191	7	115	0.003
	Median	1.66	0.090	0.0005	0.0110	161	7	121	0.003
	80th %ile	2.39	0.096	0.0005	0.0400	177	7	133	0.003
	95th %ile	2.63	0.110	0.0005	0.1072	184	8	137	0.005
	Max	3.18	0.551	0.0010	0.9320	1270	10	138	0.005
MRMB27 19/11/2003 - 05/02/2019	Count	89	85	89	89	55	55	55	69
	Min	0.000	0.001	0.0005	0.000	0	0	0	0.001
	5th %ile	0.000	0.011	0.0005	0.001	21	2	26	0.013
	20th %ile	0.000	0.020	0.0005	0.002	63	2	92	0.016
	Mean	0.073	0.050	0.0009	0.018	70	2	101	0.019
	Median	0.000	0.035	0.0005	0.008	75	2	110	0.018
	80th %ile	0.102	0.067	0.0005	0.018	86	3	123	0.020
	95th %ile	0.246	0.128	0.0010	0.038	90	4	134	0.027
	Max	1.730	0.310	0.0240	0.569	97	4	142	0.028
MRMB63 29/07/2013 - 05/02/2020	Count	52	52	52	52	52	52	52	52
	Min	0.03	0.07	0.0005	0.0025	101	4	100	0.007
	5th %ile	0.08	0.07	0.0005	0.0025	105	5	109	0.009
	20th %ile	0.09	0.08	0.0005	0.0025	115	6	114	0.009
	Mean	0.10	0.09	0.0005	0.0036	121	6	121	0.010
	Median	0.10	0.09	0.0005	0.0025	122	6	120	0.010
	80th %ile	0.11	0.10	0.0005	0.0025	128	6	128	0.012
	95th %ile	0.11	0.11	0.0005	0.0115	133	7	132	0.012
	Max	0.12	0.18	0.0010	0.0130	135	7	134	0.015
MRMB25 19/11/2003 - 05/02/2019	Count	89	84	89	89	52	52	52	66
	Min	0.02	0.001	0.0005	0.0025	0	0	0	0.001
	5th %ile	0.03	0.036	0.0005	0.0025	74	2	85	0.001
	20th %ile	0.03	0.070	0.0005	0.0025	102	3	129	0.001
	Mean	0.22	0.126	0.0008	0.0286	114	3	133	0.004
	Median	0.18	0.110	0.0005	0.0100	115	3	139	0.003
	80th %ile	0.39	0.146	0.0005	0.0200	133	4	147	0.005
	95th %ile	0.54	0.284	0.0016	0.0612	144	4	153	0.010
	Max	0.79	0.740	0.0140	1.1800	154	5	160	0.015
MRMB26 19/11/2003 - 05/02/2019	Count	77	73	77	77	43	43	43	57
	Min	0.020	0.015	0.0005	0.003	0	0	0	0.007
	5th %ile	0.025	0.018	0.0005	0.003	26	1	29	0.008
	20th %ile	0.025	0.102	0.0005	0.003	84	2	101	0.008
	Mean	0.083	0.301	0.0005	0.014	112	2	127	0.012
	Median	0.060	0.231	0.0005	0.009	128	2	146	0.010
	80th %ile	0.148	0.426	0.0005	0.020	143	2	158	0.014
	95th %ile	0.222	0.842	0.0005	0.040	152	3	173	0.019
	Max	0.280	1.810	0.0005	0.139	154	4	174	0.039
MRMB24 19/11/2003 - 11/06/2013	Count	79	74	79	79	33	33	33	55
	Min	0.010	0.238	0.001	0.010	91	6	66	0.003
	5th %ile	0.025	0.272	0.001	0.020	129	6	92	0.005
	20th %ile	0.066	0.319	0.001	0.057	329	6	269	0.012
	Mean	0.445	0.359	0.034	0.855	325	8	251	0.013
	Median	0.170	0.353	0.048	1.070	364	8	280	0.014
	80th %ile	0.958	0.390	0.057	1.394	375	9	287	0.015
	95th %ile	1.301	0.500	0.061	1.551	388	10	294	0.017
	Max	3.900	0.562	0.088	2.100	394	11	296	0.020

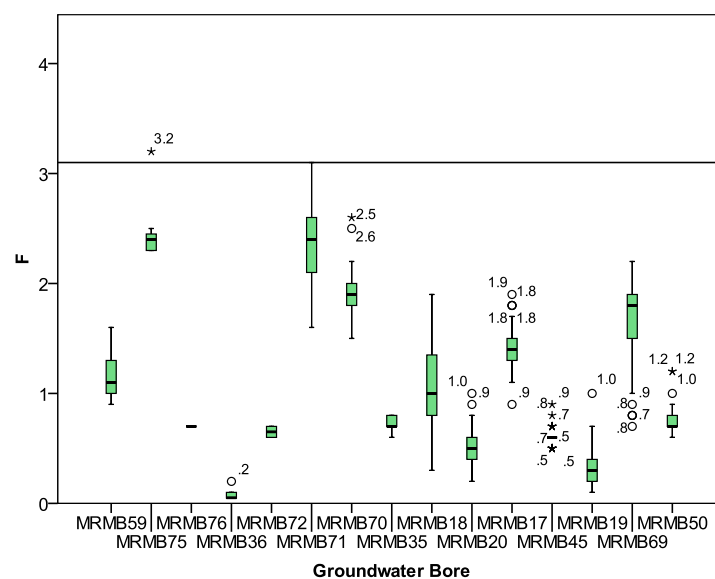
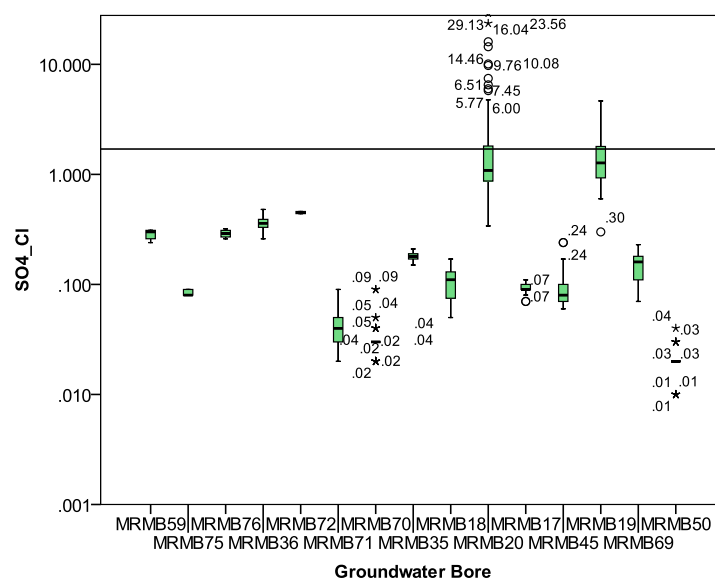
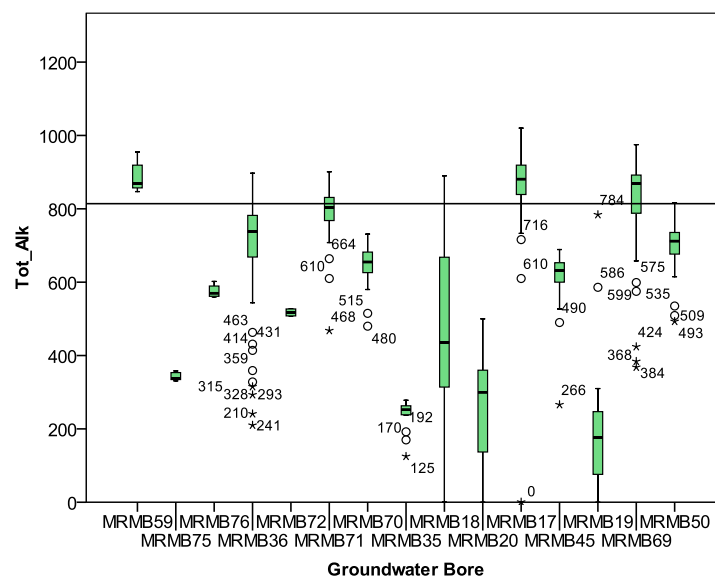
Sample Point	Statistic	pH	EC (µS/cm)	Cyanide Total (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Sulphate (mg/L)	Alk Tot as CaCO3 (mg/L)	SO4/Cl (M/M)	Fluoride (mg/L)	Nitrate as N (mg/L)	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)
MRMB46 05/12/2013 - 20/02/2019	Count	43	43	43	43	43	43	43	43	43	42	43	43	43	43	41	43
	Min	6.26	5540	0.002	804	1100	386	221	0.06	0.5	0.01	0.005	0.001	0.025	0.00005	0.0005	0.0005
	5th %ile	6.39	5690	0.019	825	1181	501	436	0.10	0.7	0.03	0.005	0.001	0.025	0.00005	0.0005	0.0005
	20th %ile	6.42	5912	0.024	871	1374	609	513	0.13	0.9	0.18	0.005	0.002	0.025	0.00005	0.0005	0.0005
	Mean	6.57	6499	0.028	911	1574	659	545	0.16	1.0	0.39	0.037	0.004	0.026	0.00012	0.0006	0.0009
	Median	6.51	6560	0.029	911	1570	662	561	0.15	0.9	0.33	0.005	0.004	0.025	0.00005	0.0005	0.0005
	80th %ile	6.66	7040	0.033	943	1746	727	591	0.19	1.1	0.67	0.005	0.006	0.025	0.00010	0.0005	0.0010
	95th %ile	6.99	7214	0.035	959	1886	783	600	0.24	1.2	0.82	0.005	0.010	0.025	0.00057	0.0005	0.0020
	Max	7.42	7450	0.037	1190	2420	838	682	0.27	1.2	1.11	1.390	0.012	0.050	0.00080	0.0040	0.0030
MRMB49 16/05/2012 - 05/02/2019	Count	49	51	49	49	49	49	49	49	49	49	49	49	49	49	48	49
	Min	6.39	4602	0.002	622	1070	225	373	0.06	0.8	1.48	0.005	0.001	0.025	0.00005	0.0005	0.001
	5th %ile	6.41	4970	0.002	663	1154	252	541	0.06	0.9	2.41	0.005	0.006	0.025	0.00005	0.0005	0.001
	20th %ile	6.55	5170	0.002	683	1236	267	566	0.07	1.0	2.69	0.005	0.007	0.025	0.00005	0.0005	0.001
	Mean	6.78	5580	0.008	717	1410	290	596	0.08	1.1	2.93	0.006	0.008	0.025	0.00018	0.0006	0.002
	Median	6.77	5700	0.007	716	1390	295	604	0.08	1.1	2.79	0.005	0.008	0.025	0.00005	0.0005	0.001
	80th %ile	6.97	5850	0.012	760	1576	304	630	0.08	1.2	2.93	0.005	0.009	0.025	0.00010	0.0005	0.002
	95th %ile	7.28	6230	0.015	789	1714	340	655	0.10	1.4	3.04	0.008	0.011	0.025	0.00046	0.0008	0.002
	Max	7.44	6340	0.017	807	1950	384	669	0.11	1.7	10.70	0.050	0.014	0.025	0.00360	0.0025	0.031
MRMB38 23/06/2008 - 28/11/2018	Count	13	13	13	14	14	14	14	14	13	13	14	14	13	14	13	14
	Min	6.37	1912	0.002	194	50	50	412	0.21	0.9	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	5th %ile	6.47	1959	0.002	272	202	148	421	0.22	1.0	0.005	0.005	0.0008	0.025	0.00005	0.0005	0.0005
	20th %ile	6.58	2182	0.002	316	334	244	442	0.25	1.0	0.005	0.005	0.0016	0.025	0.00005	0.0005	0.0005
	Mean	6.72	2262	0.002	318	337	278	471	0.31	1.0	0.007	0.012	0.0023	0.025	0.00008	0.0005	0.0056
	Median	6.67	2289	0.002	325	362	278	473	0.31	1.0	0.005	0.005	0.0020	0.025	0.00005	0.0005	0.0005
	80th %ile	6.85	2346	0.002	335	376	305	494	0.36	1.0	0.008	0.005	0.0020	0.025	0.00007	0.0005	0.0005
	95th %ile	7.09	2481	0.002	345	402	413	530	0.45	1.1	0.014	0.054	0.0048	0.025	0.00020	0.0005	0.0258
	Max	7.30	2552	0.002	351	419	499	548	0.50	1.3	0.020	0.060	0.0100	0.025	0.00020	0.0005	0.0700

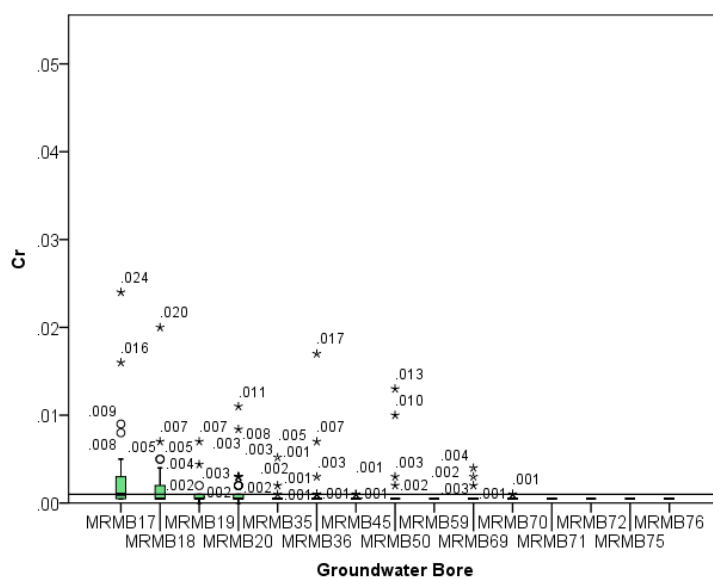
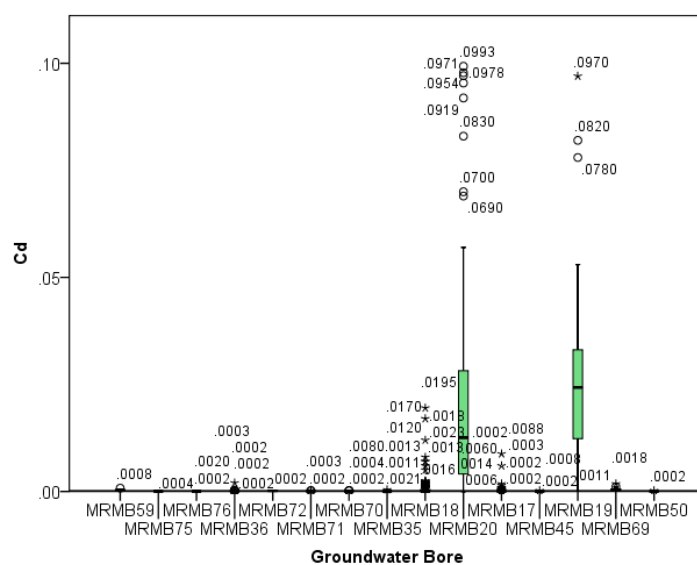
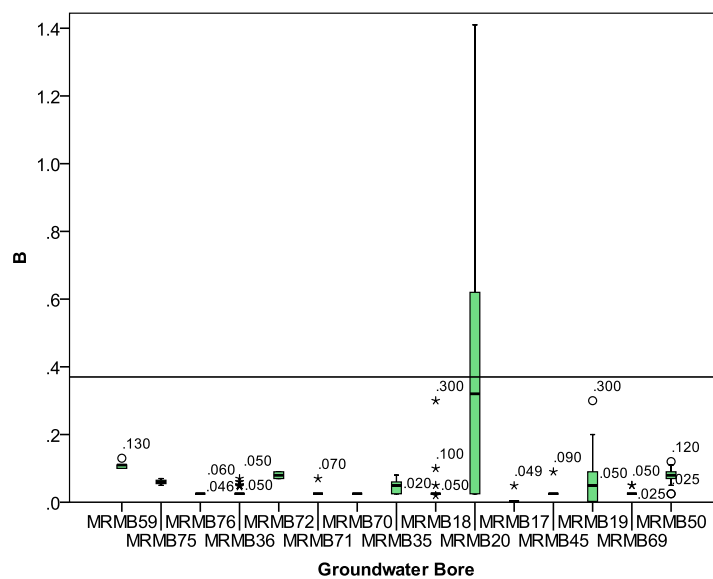
Sample Point	Statistic	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Lead Dissolved (mg/L)	Zinc Dissolved (mg/L)	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Molybdenum Dissolved (mg/L)
MRMB46 05/12/2013 - 20/02/2019	Count	43	43	43	43	43	43	43	43
	Min	0.025	0.218	0.0005	0.0025	221	5	97	0.003
	5th %ile	0.025	0.305	0.0005	0.0029	252	7	108	0.004
	20th %ile	0.025	0.406	0.0005	0.0080	304	8	115	0.004
	Mean	0.079	0.577	0.0006	0.0130	376	9	132	0.005
	Median	0.025	0.602	0.0005	0.0100	364	8	134	0.005
	80th %ile	0.025	0.746	0.0005	0.0140	402	10	149	0.005
	95th %ile	0.025	0.811	0.0009	0.0357	440	12	158	0.006
	Max	2.320	0.855	0.0020	0.0600	1420	14	166	0.007
MRMB49 16/05/2012 - 05/02/2019	Count	49	49	49	49	49	49	49	49
	Min	0.025	0.001	0.0005	0.0025	154	4	171	0.001
	5th %ile	0.025	0.001	0.0005	0.0025	164	4	179	0.004
	20th %ile	0.025	0.002	0.0005	0.0025	171	5	189	0.005
	Mean	0.028	0.007	0.0014	0.0099	192	5	210	0.005
	Median	0.025	0.003	0.0005	0.0060	197	5	212	0.005
	80th %ile	0.025	0.006	0.0005	0.0172	209	6	227	0.006
	95th %ile	0.046	0.028	0.0020	0.0240	224	6	243	0.007
	Max	0.090	0.066	0.0400	0.0520	235	7	246	0.015
MRMB38 23/06/2008 - 28/11/2018	Count	14	14	14	14	14	14	14	13
	Min	0.000	0.130	0.0005	0.006	41	1	23	0.003
	5th %ile	0.016	0.137	0.0005	0.006	66	1	43	0.004
	20th %ile	0.130	0.216	0.0005	0.007	90	1	58	0.004
	Mean	0.246	0.295	0.0020	0.017	112	1	60	0.004
	Median	0.265	0.261	0.0005	0.010	96	1	62	0.004
	80th %ile	0.370	0.372	0.0005	0.019	109	2	65	0.004
	95th %ile	0.405	0.539	0.0083	0.043	202	2	69	0.004
	Max	0.450	0.544	0.0200	0.080	351	2	72	0.005

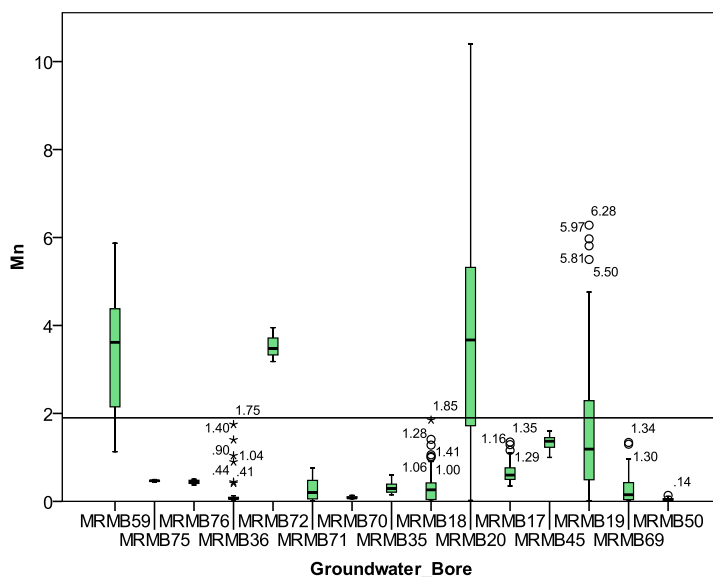
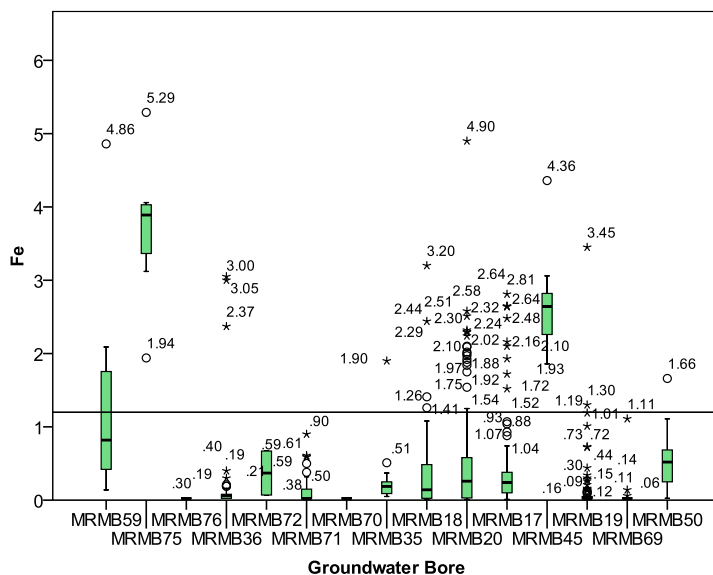
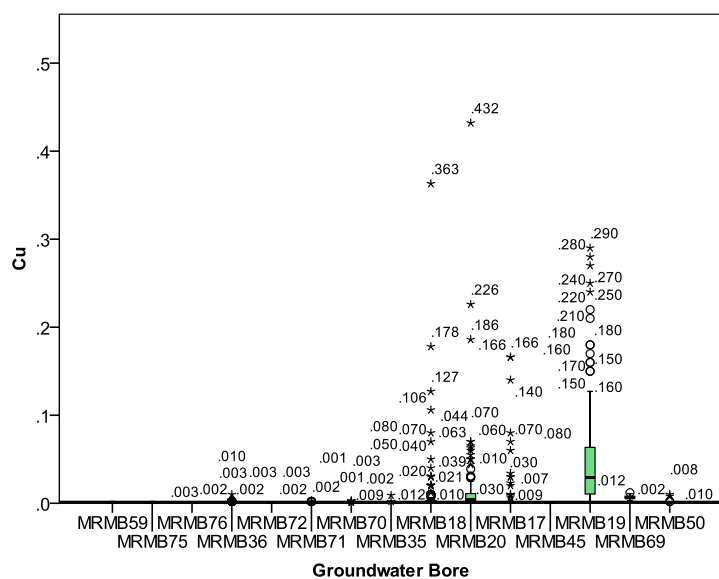
Appendix 18: Data Summaries for the Southern Drainage to Mingham Creek

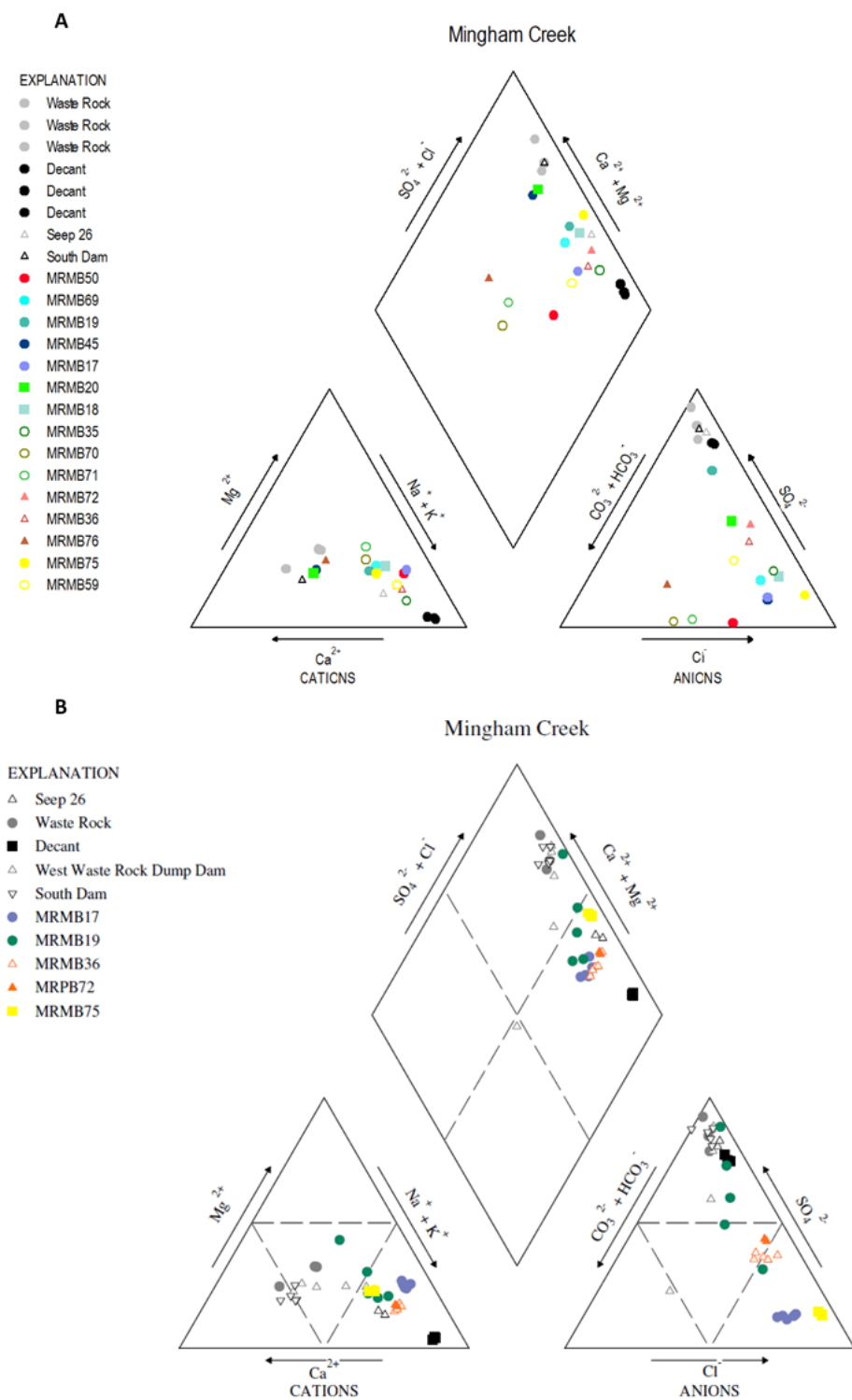






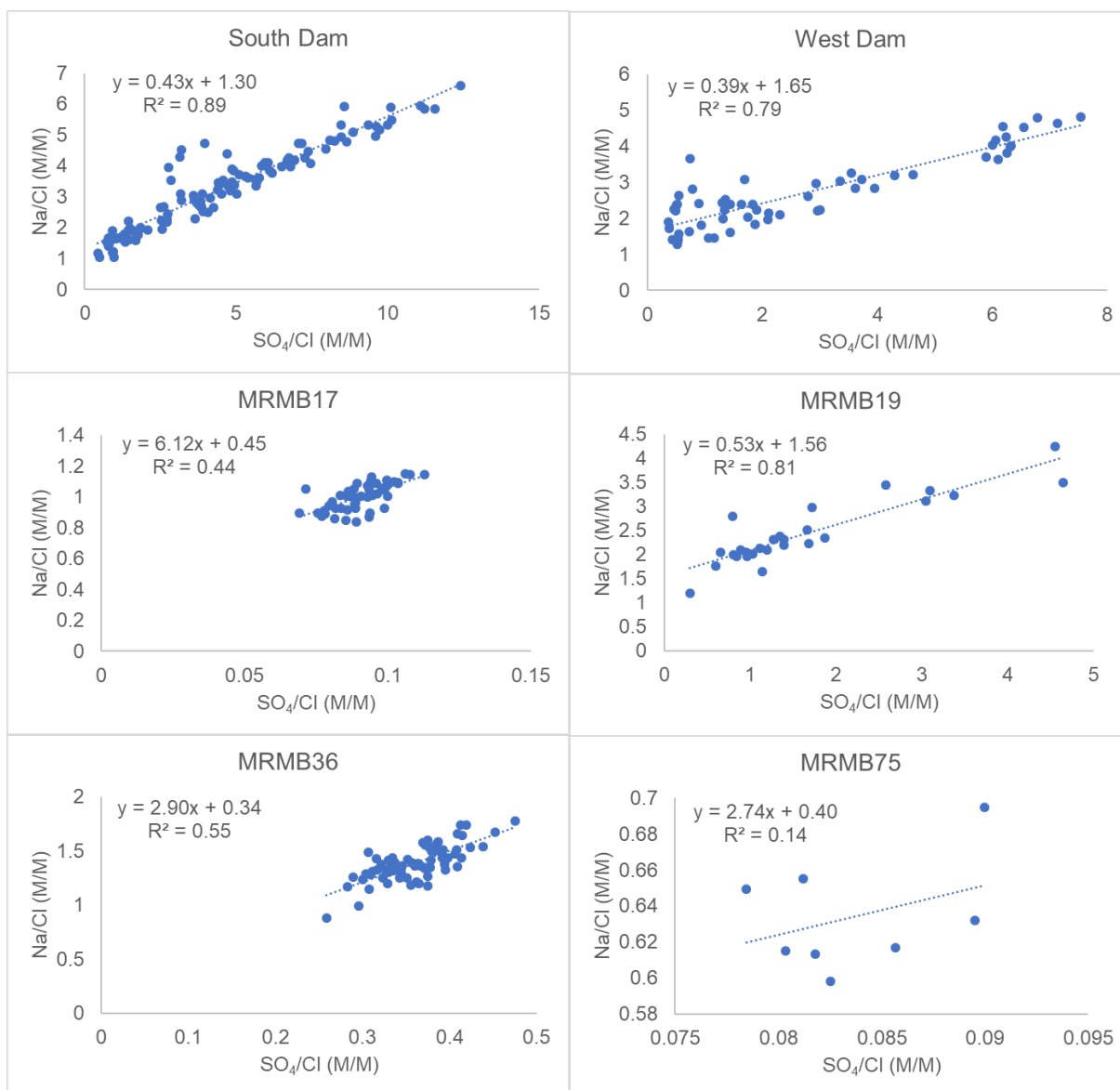






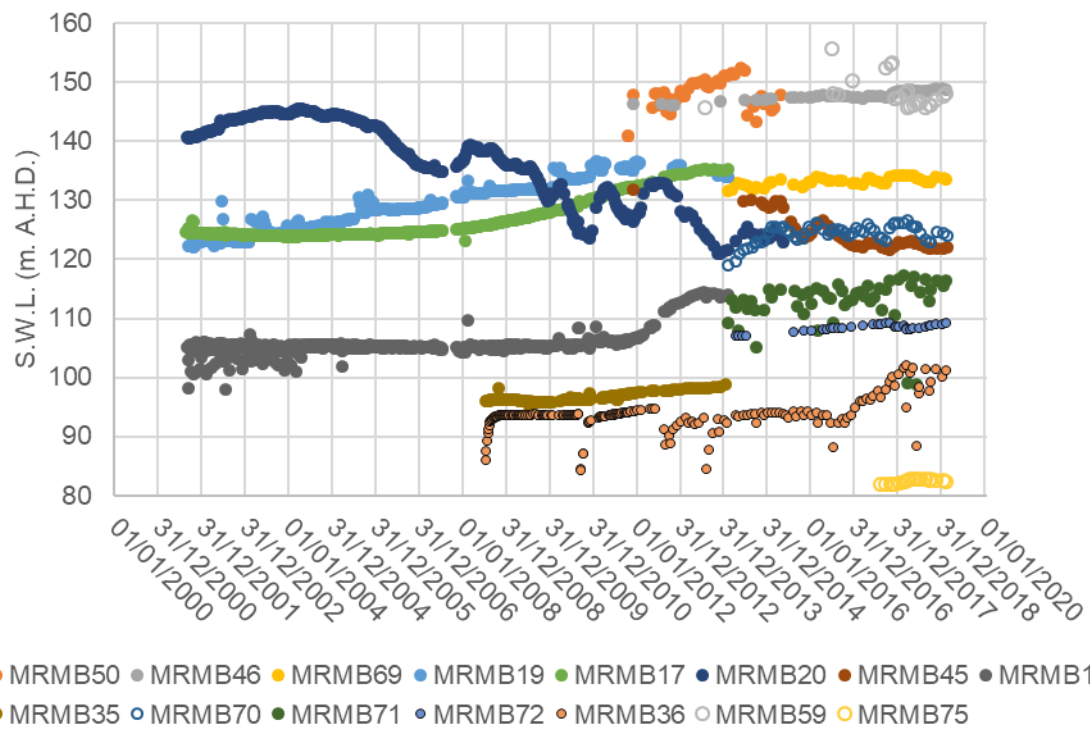
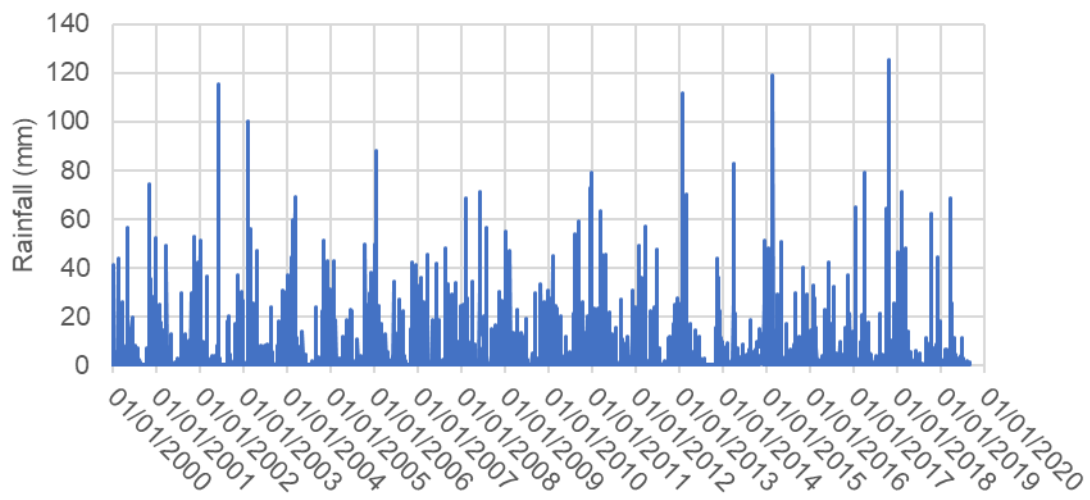
⁴¹ Footnote

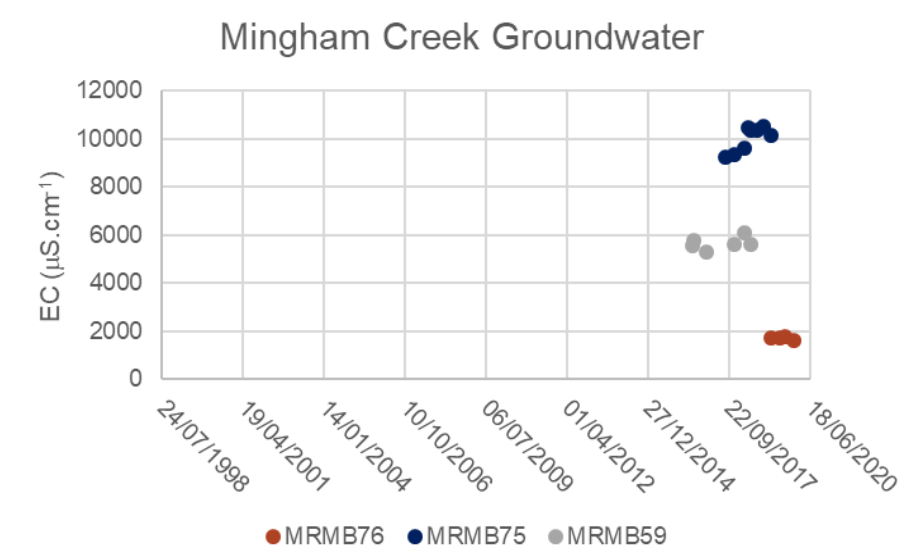
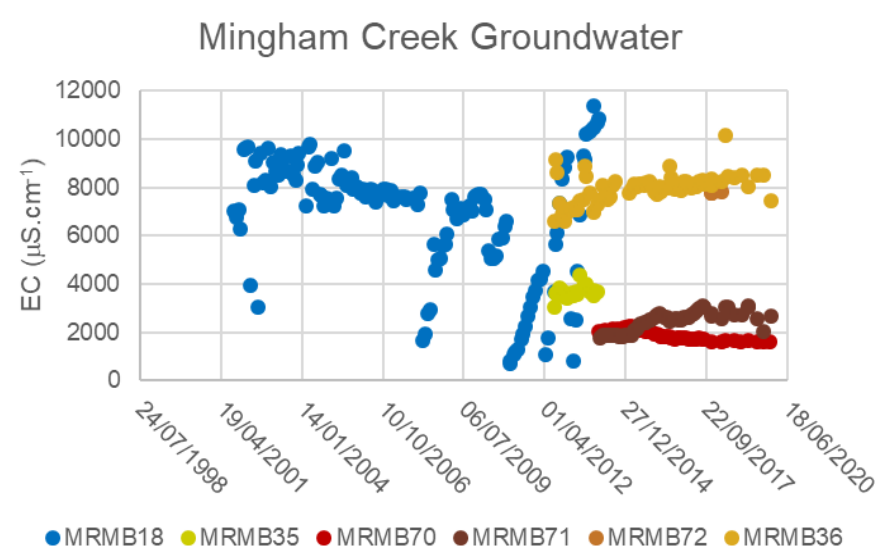
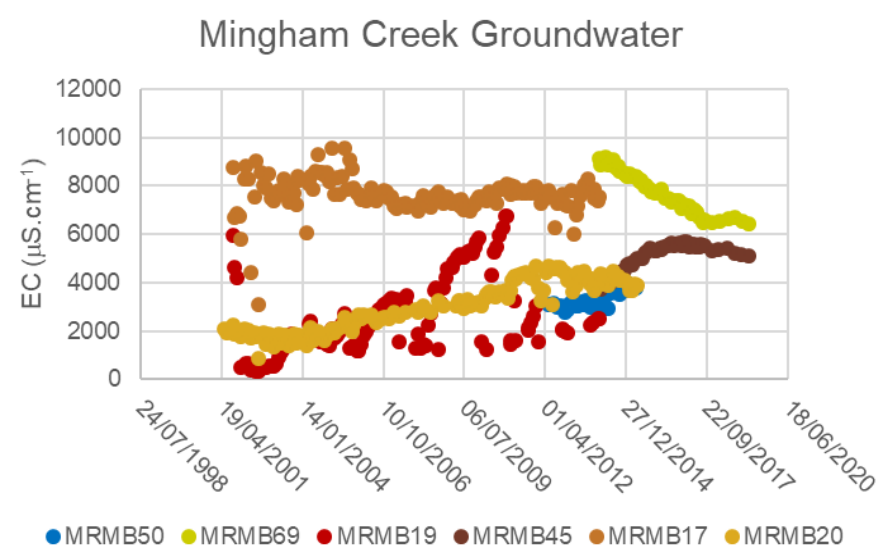
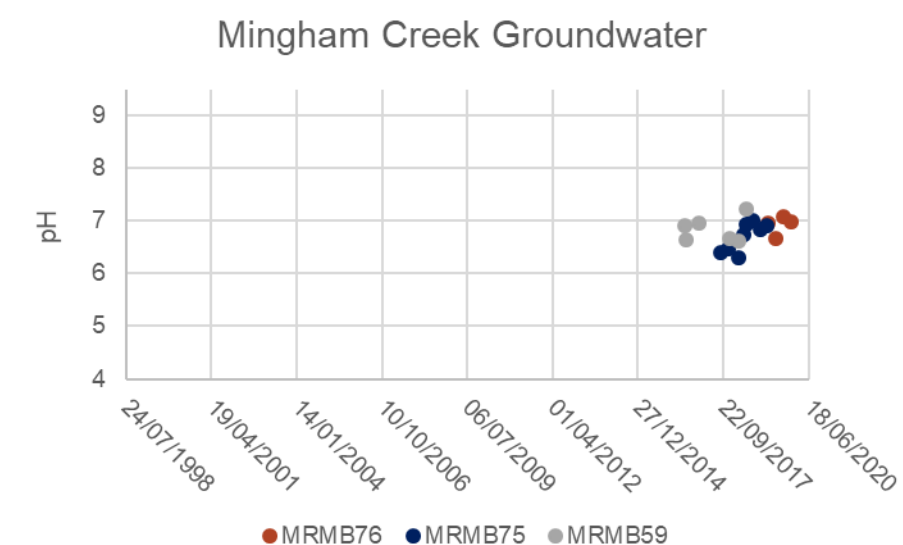
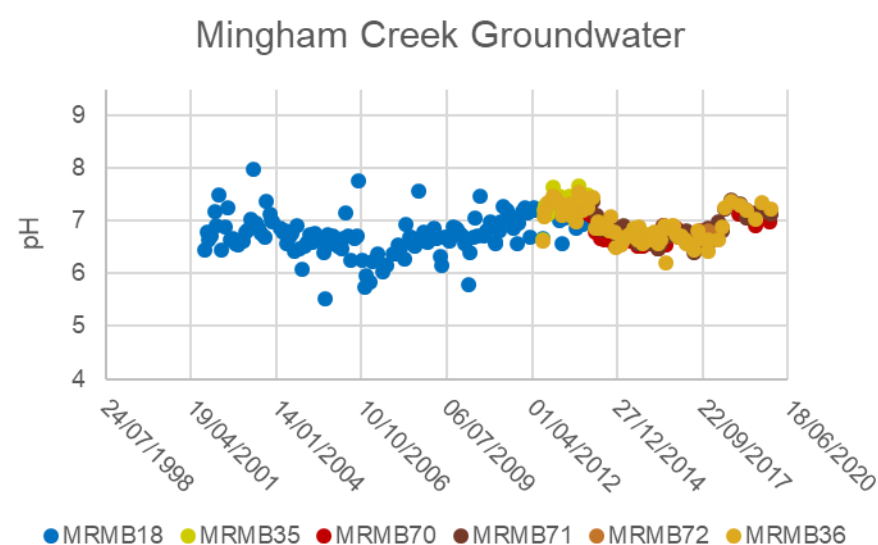
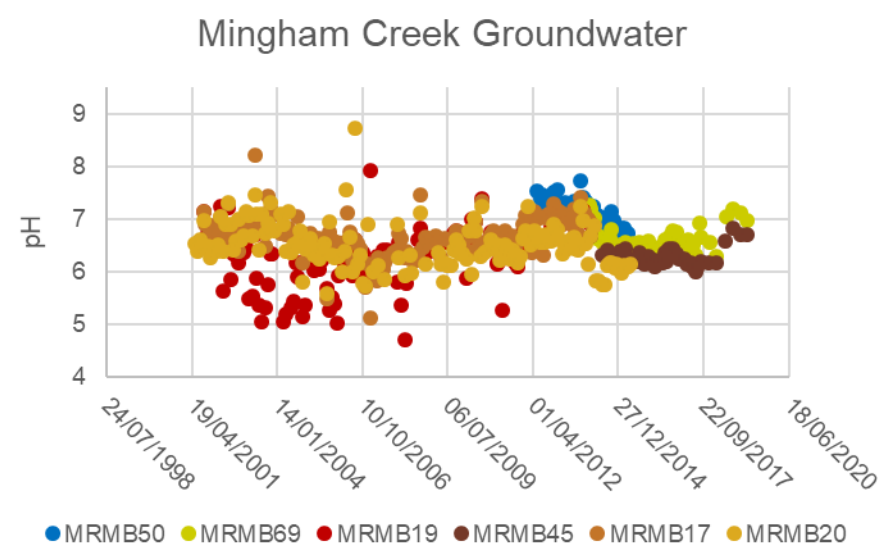
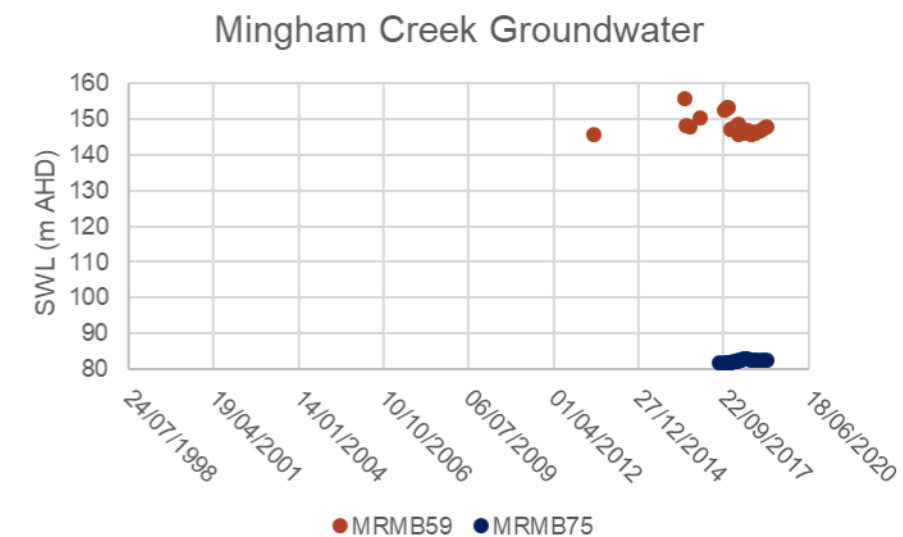
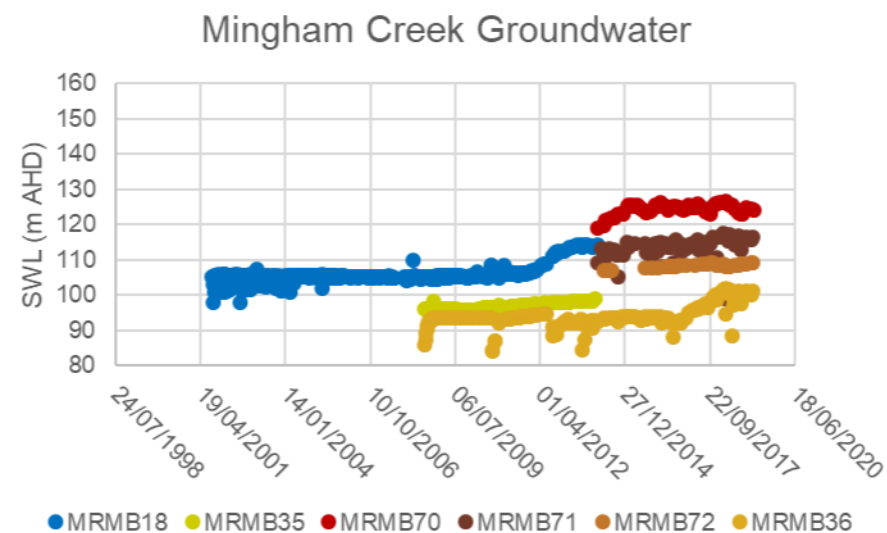
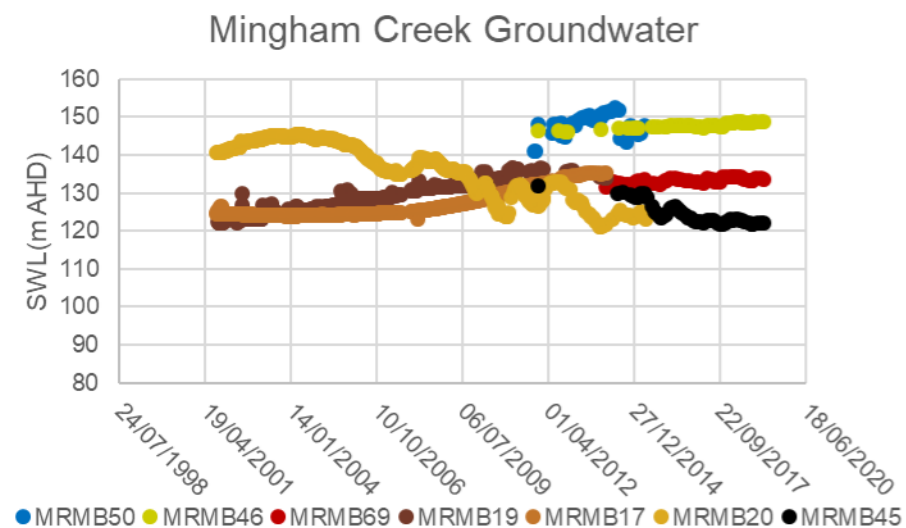
⁴¹ A represents median cation and anion concentrations in groundwater monitoring bores, and representative cation and anion concentrations in waste - rock seepage and decant water. B shows representative cation and anion concentrations in selected groundwater monitoring bores, waste – rock seepage and decant water.

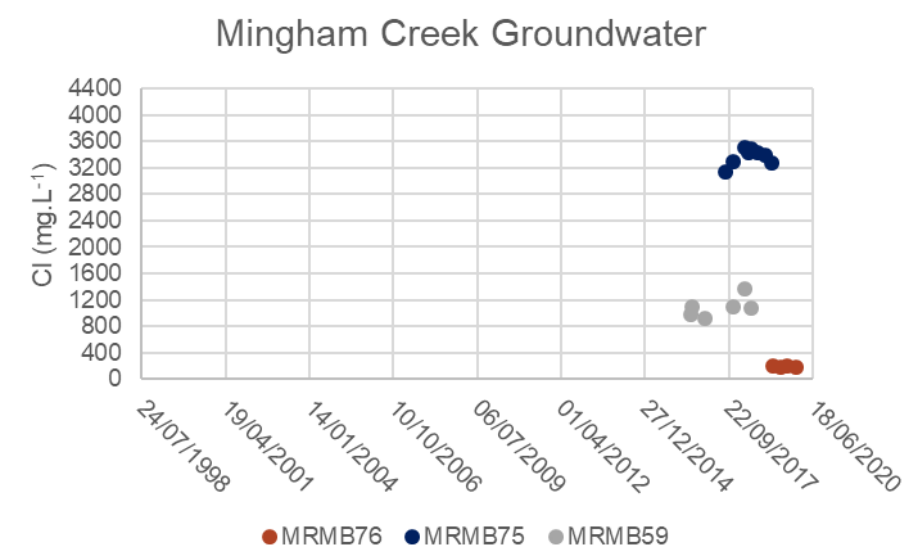
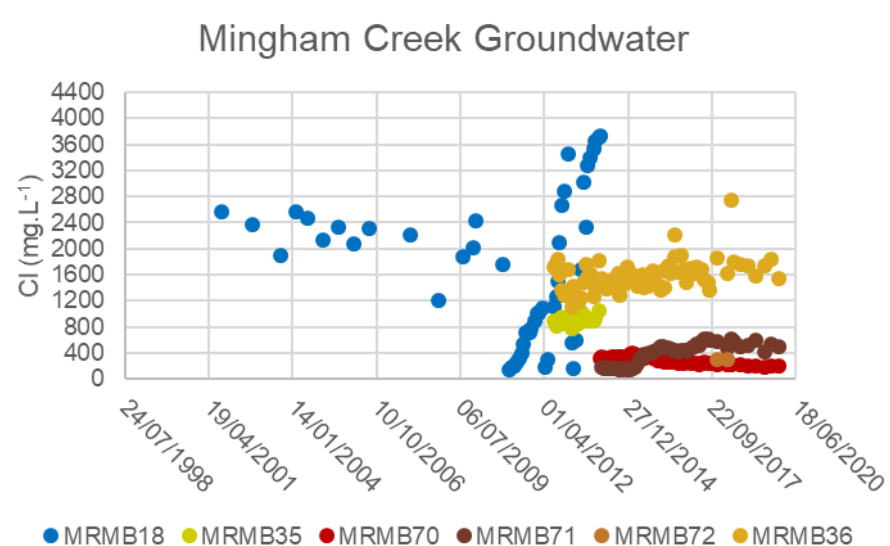
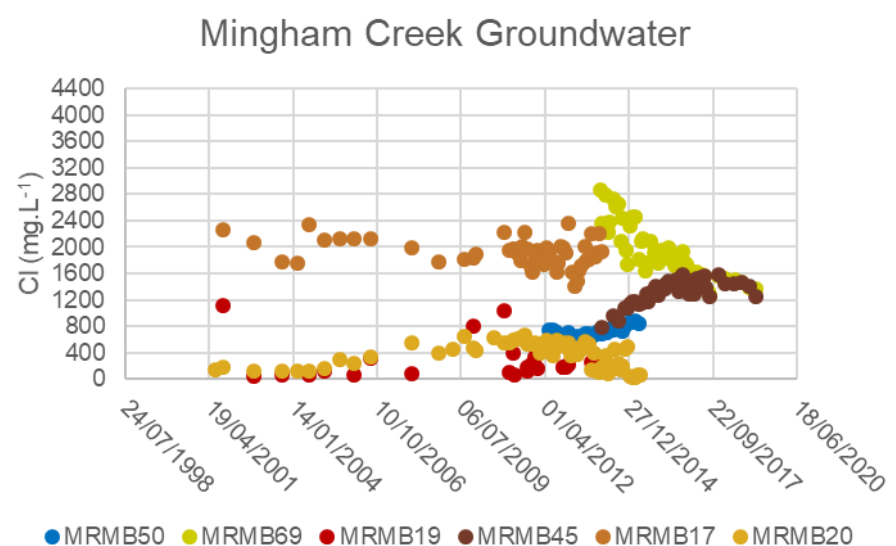
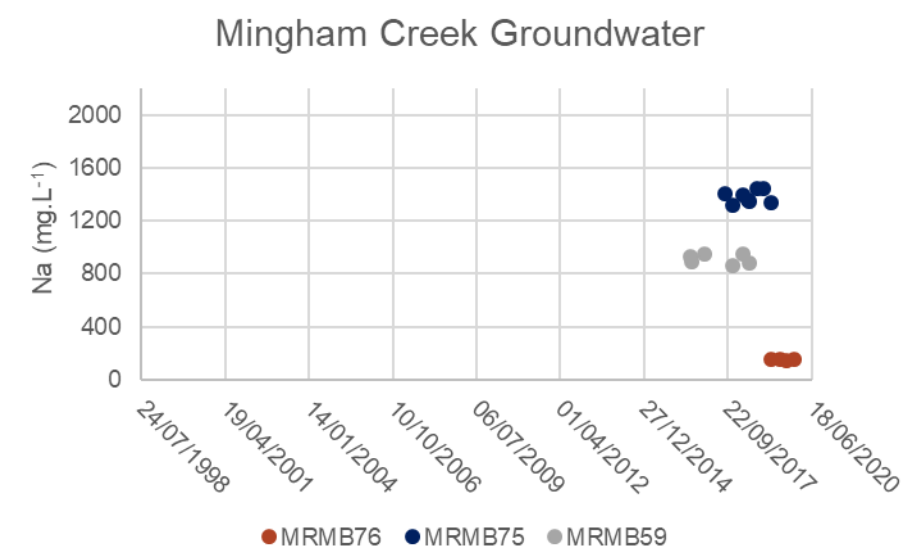
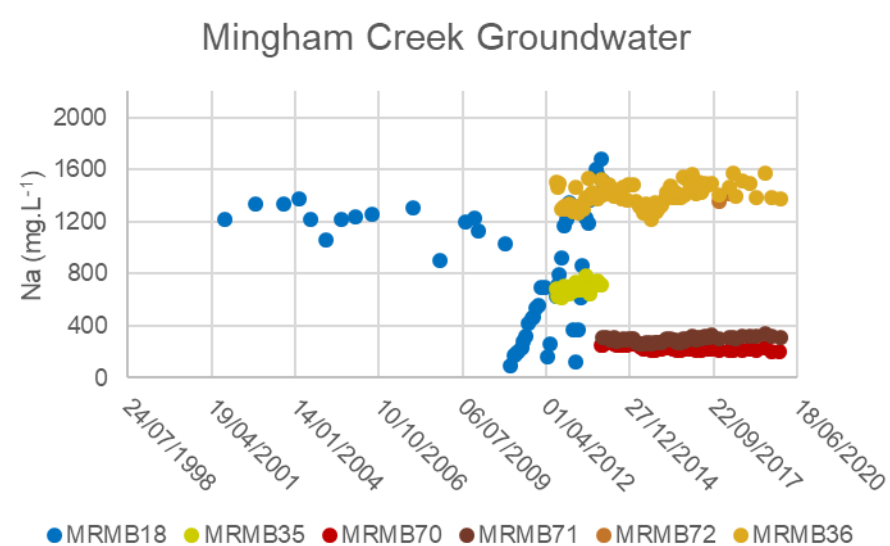
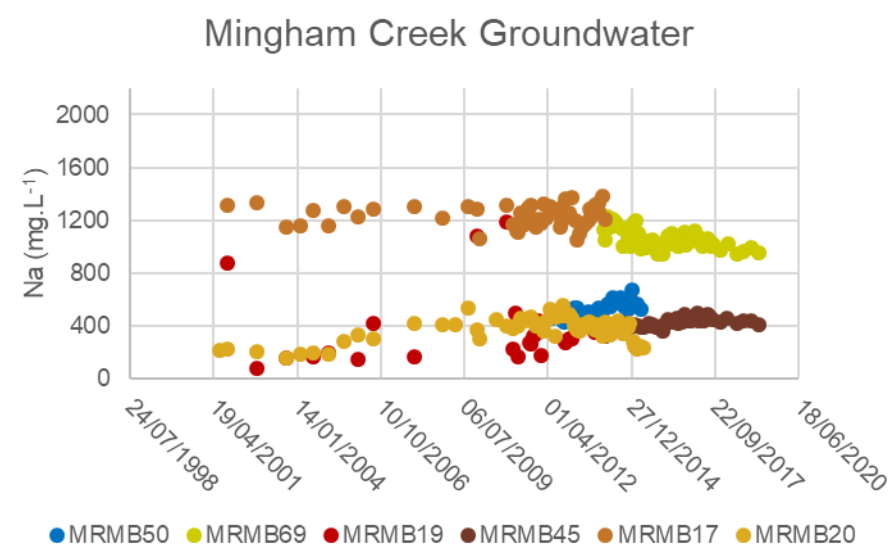
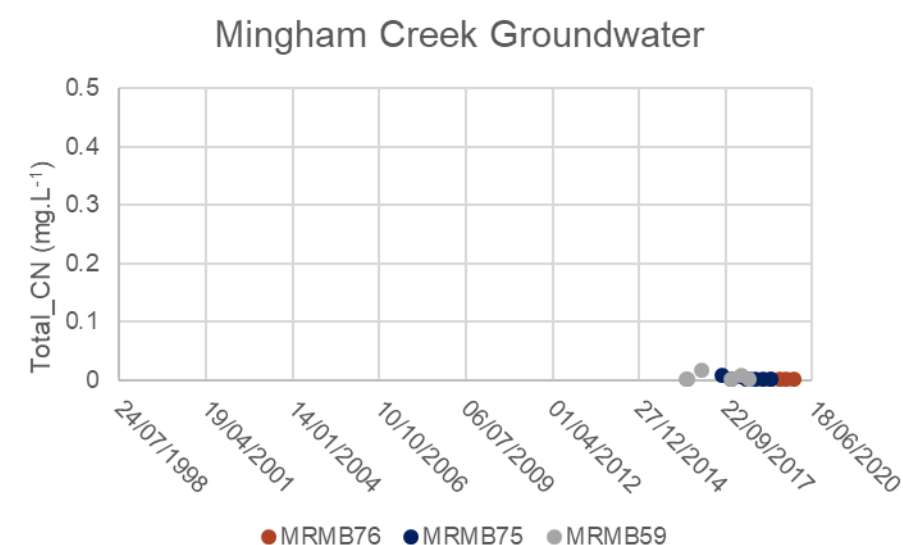
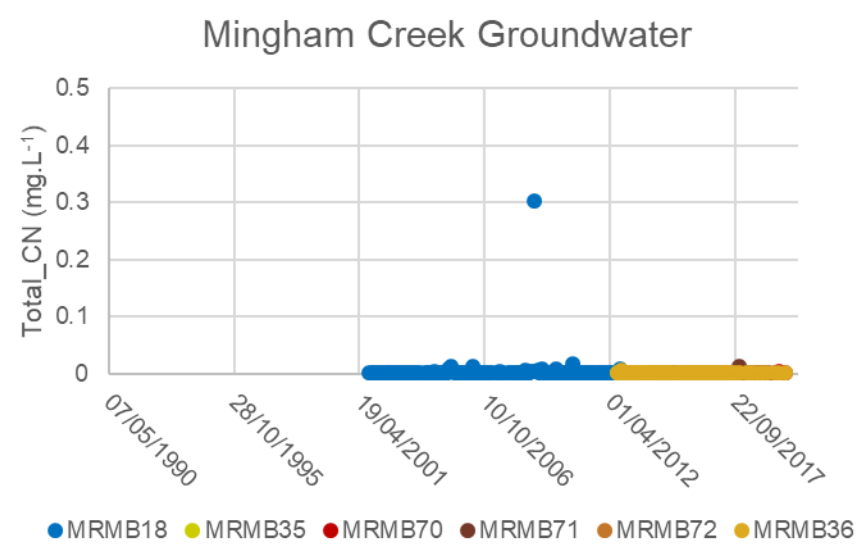
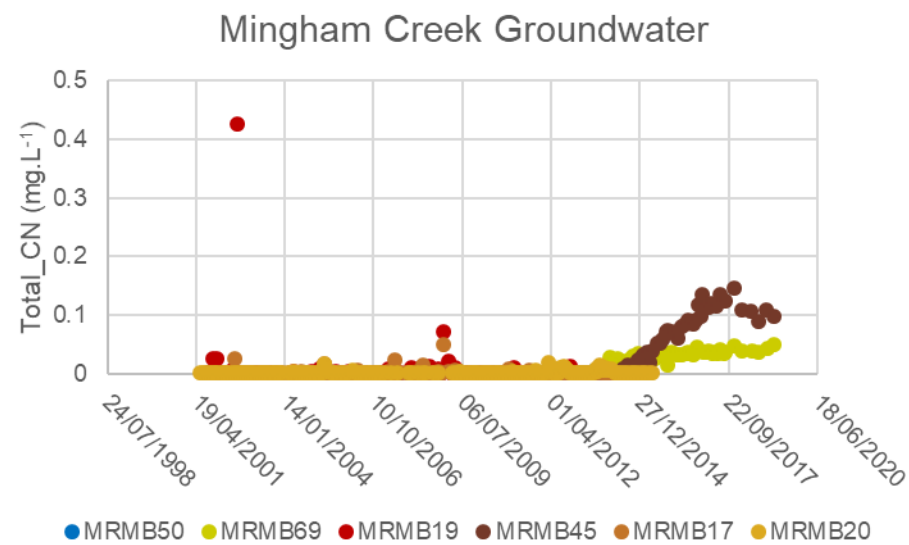


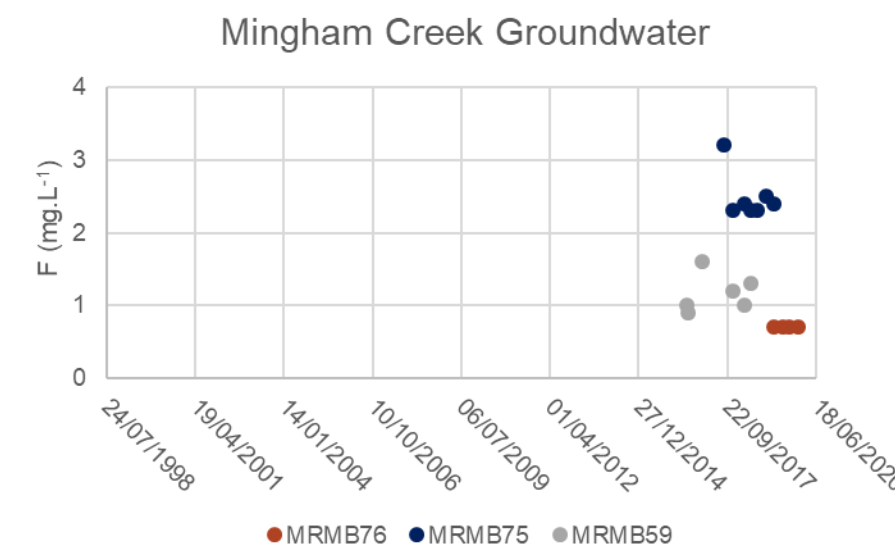
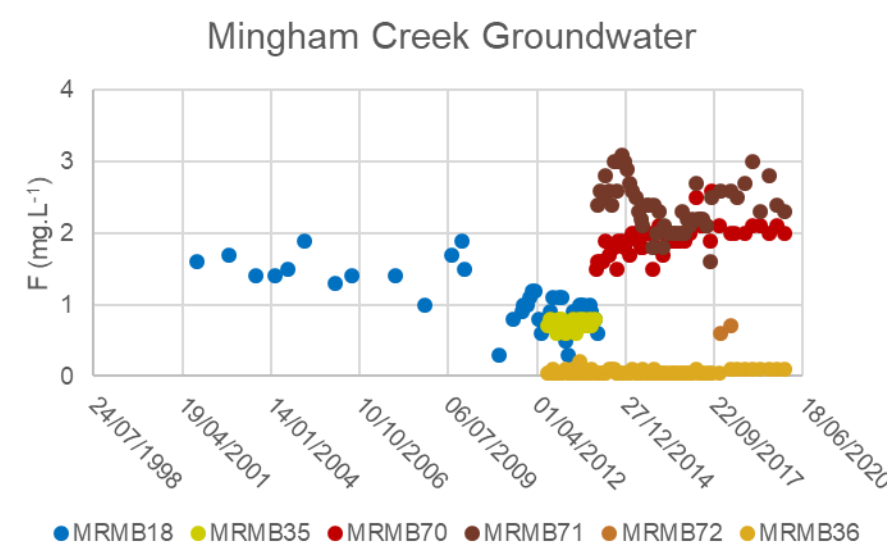
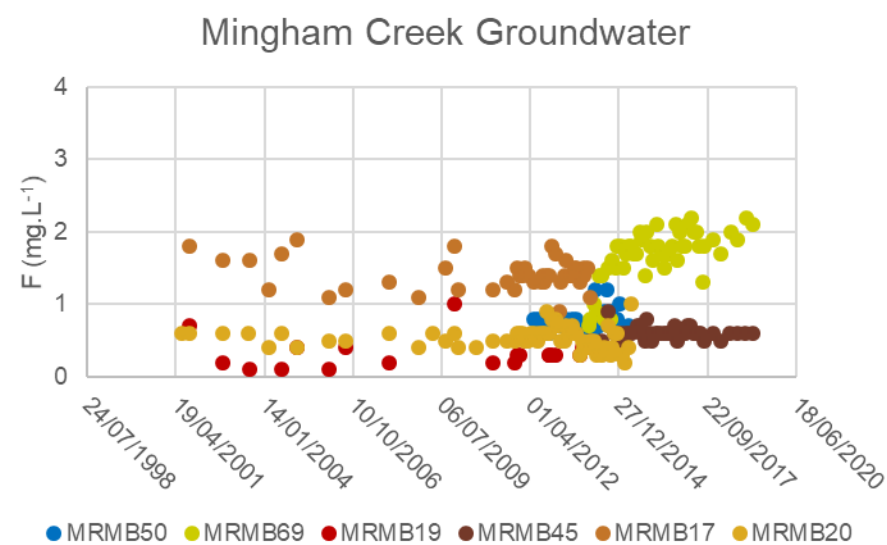
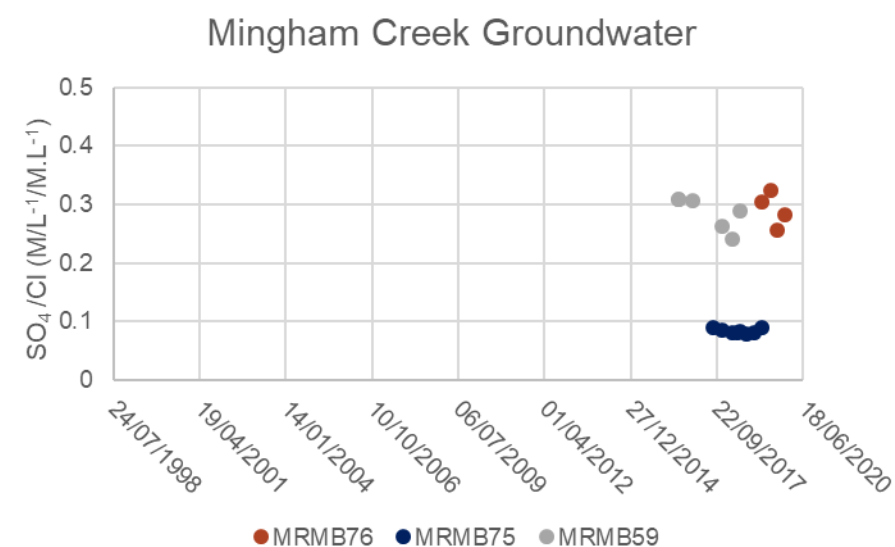
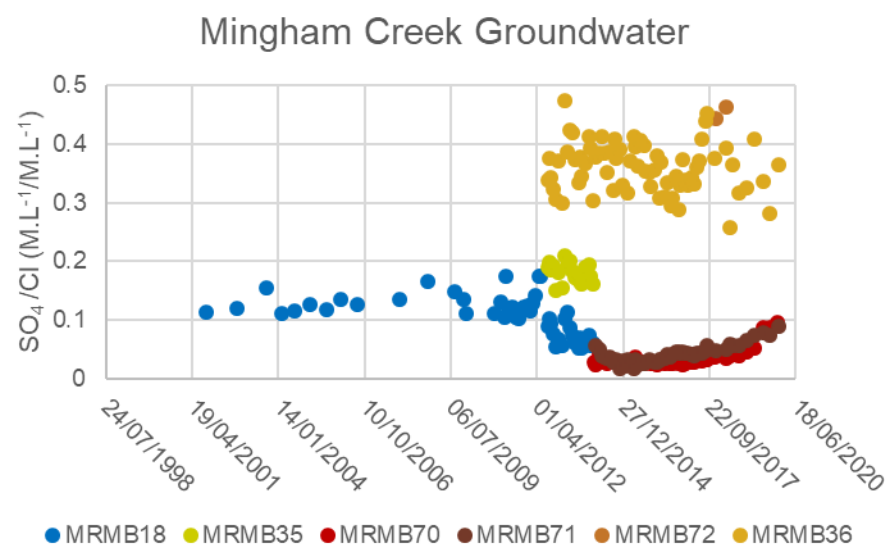
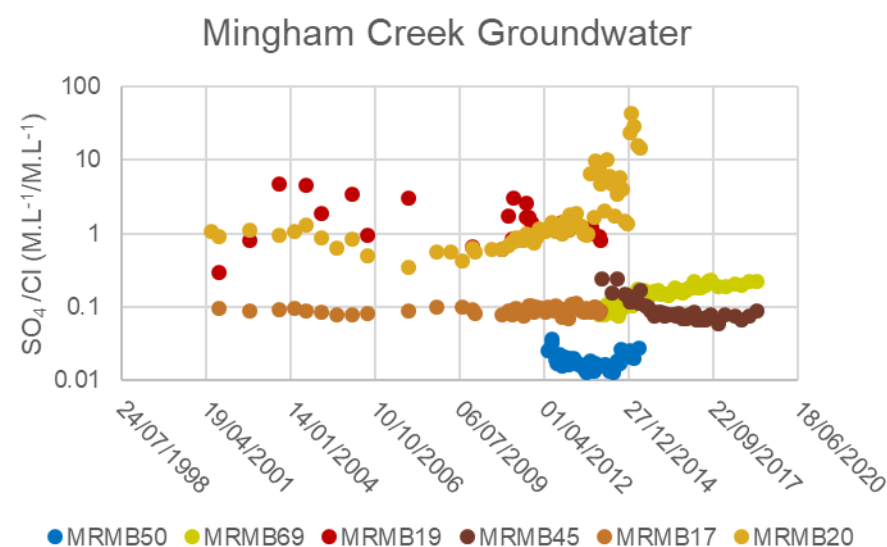
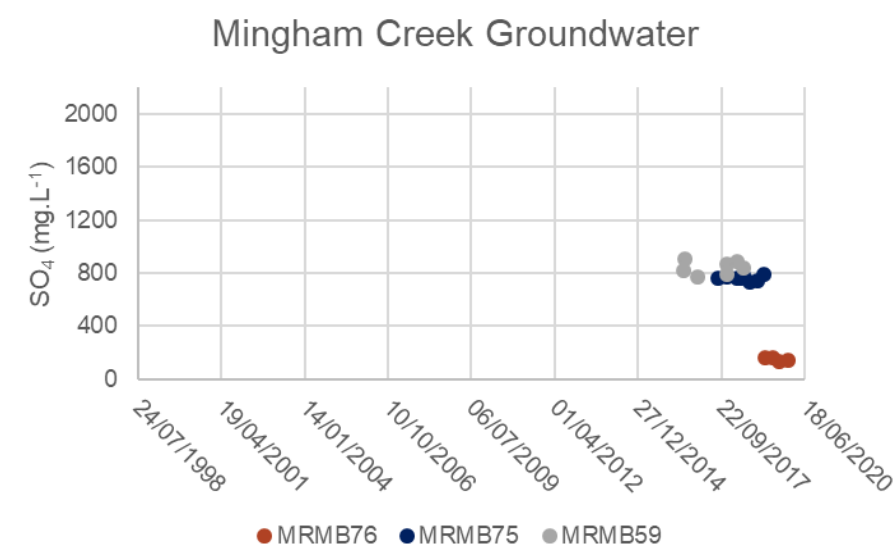
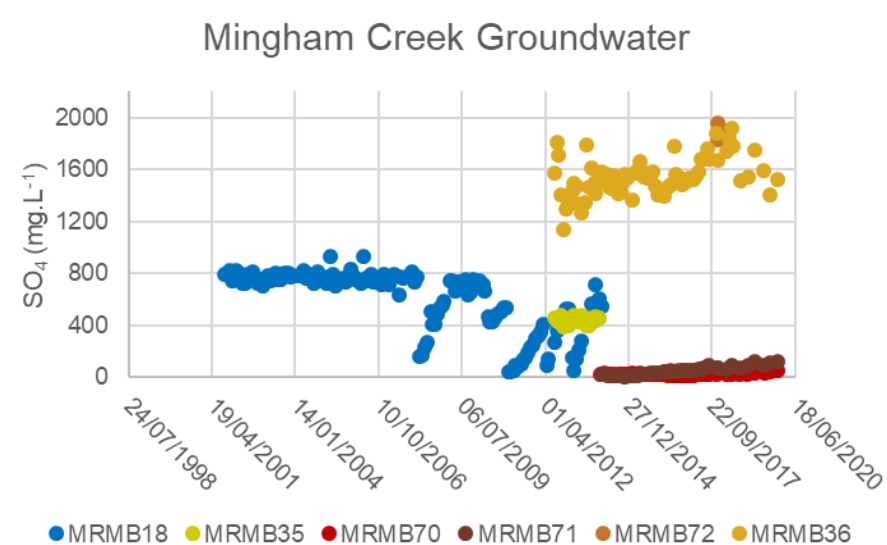
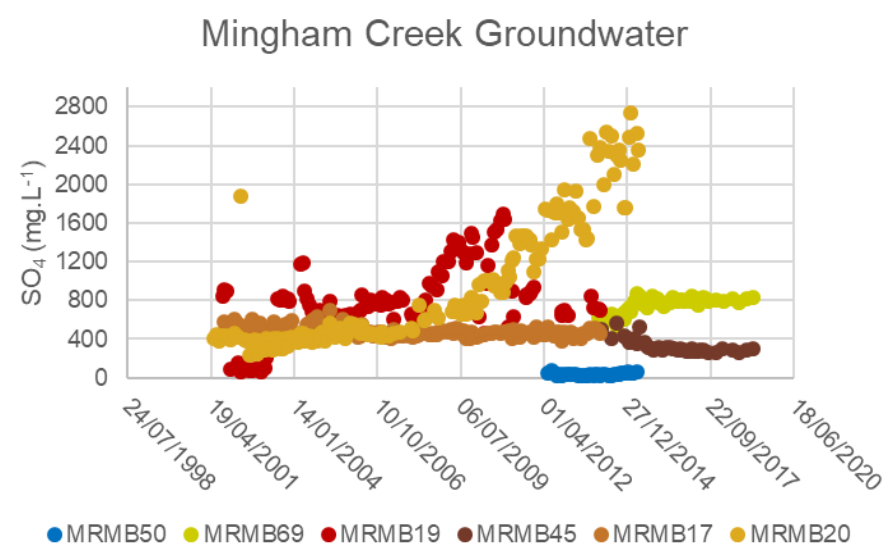
⁴² Footnote

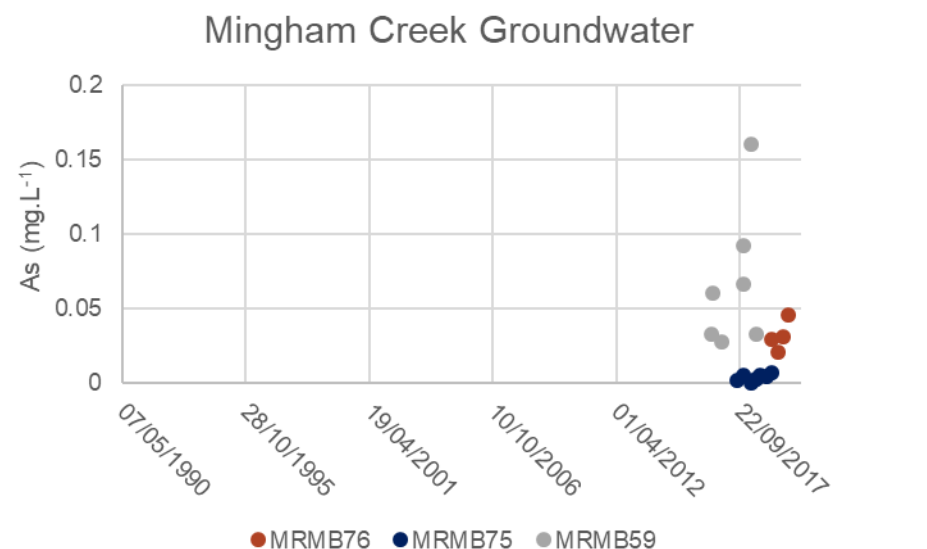
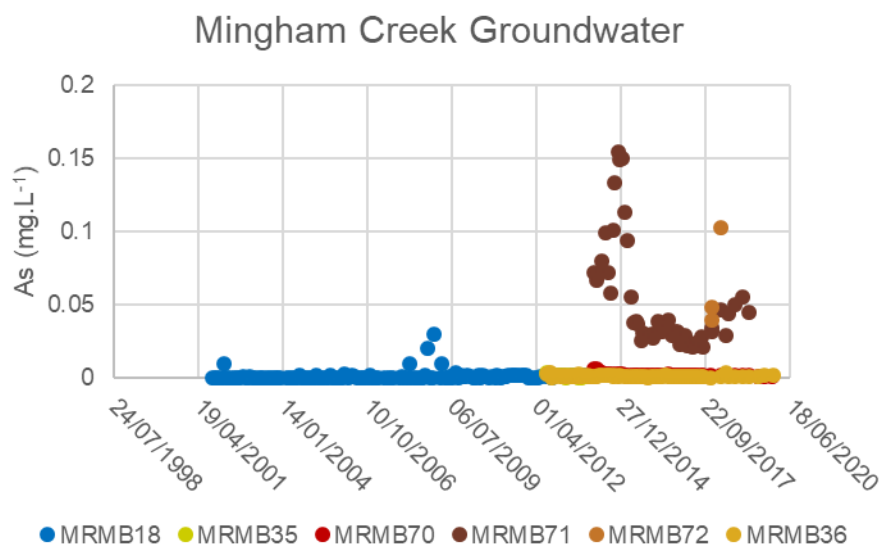
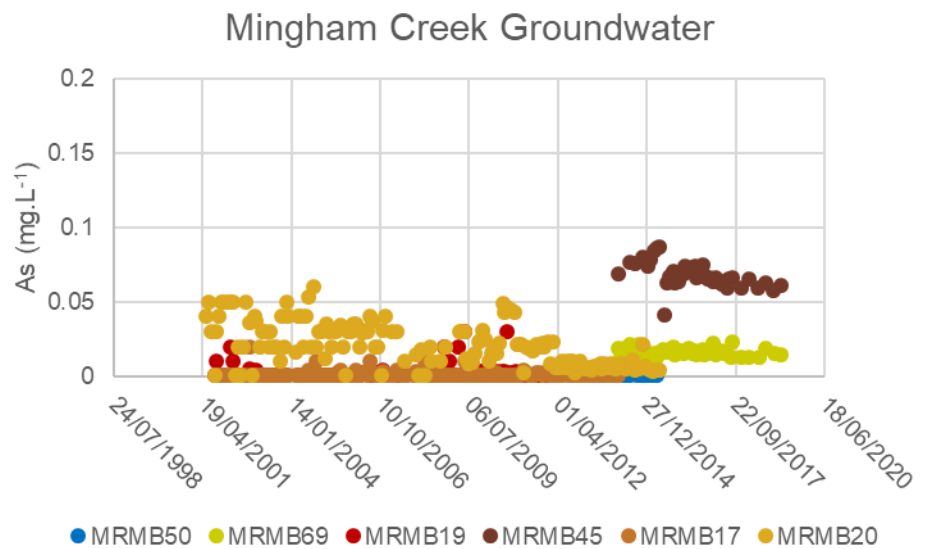
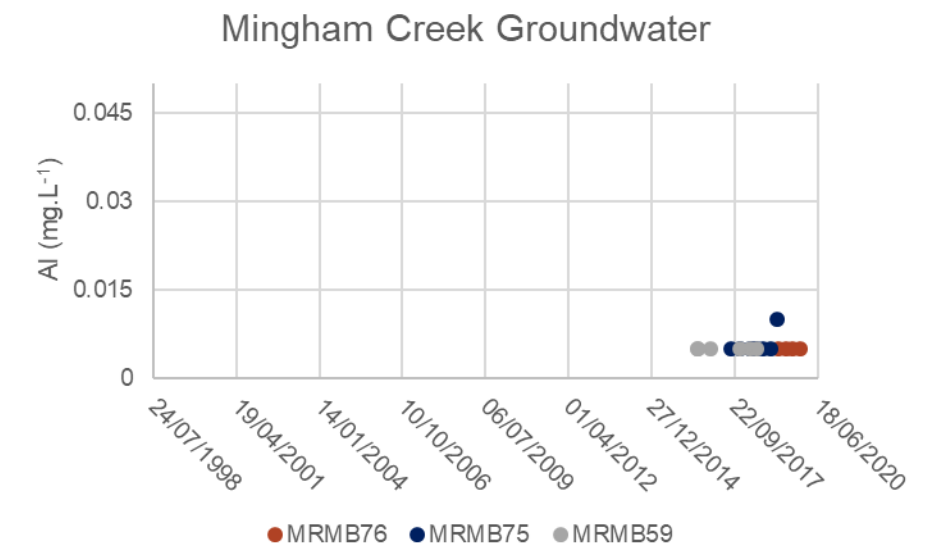
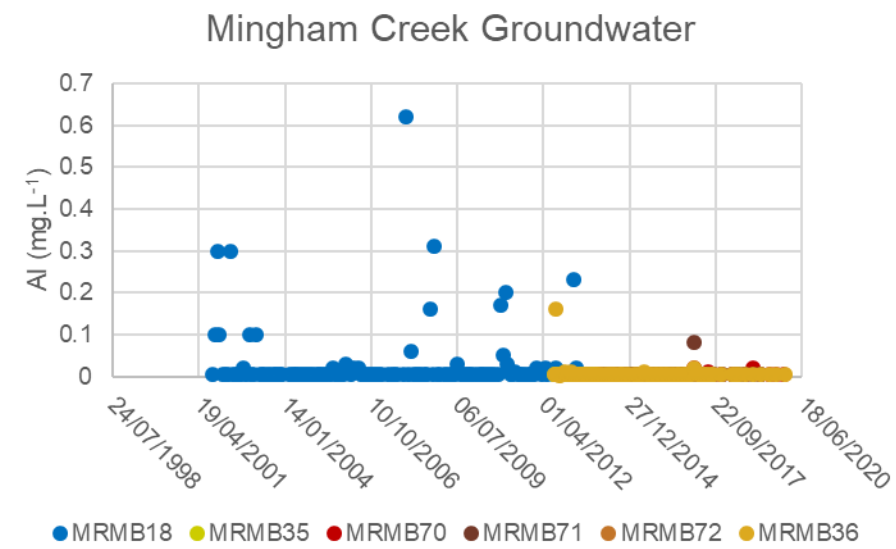
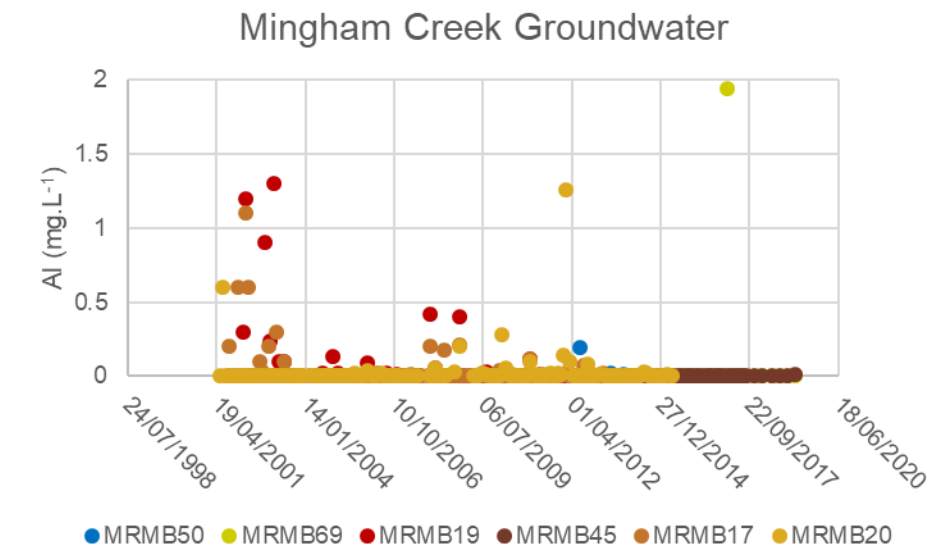
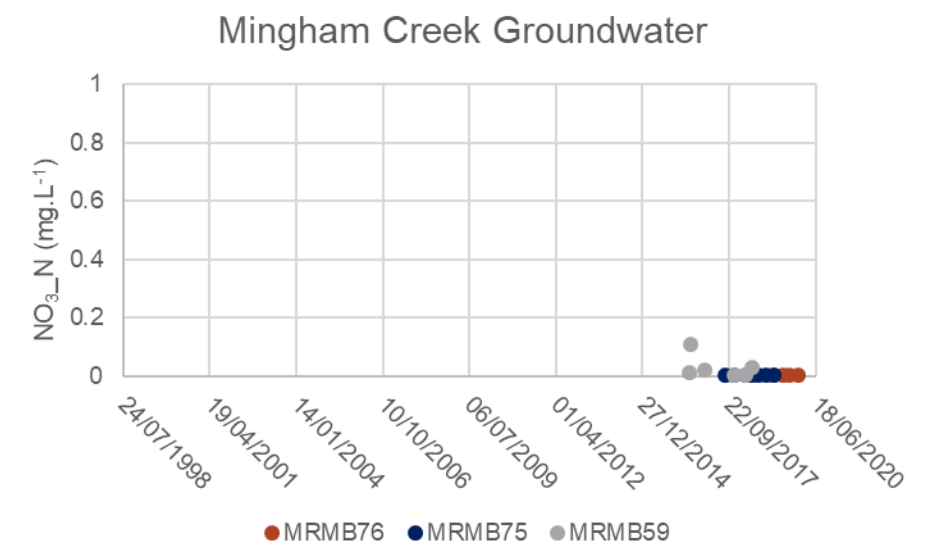
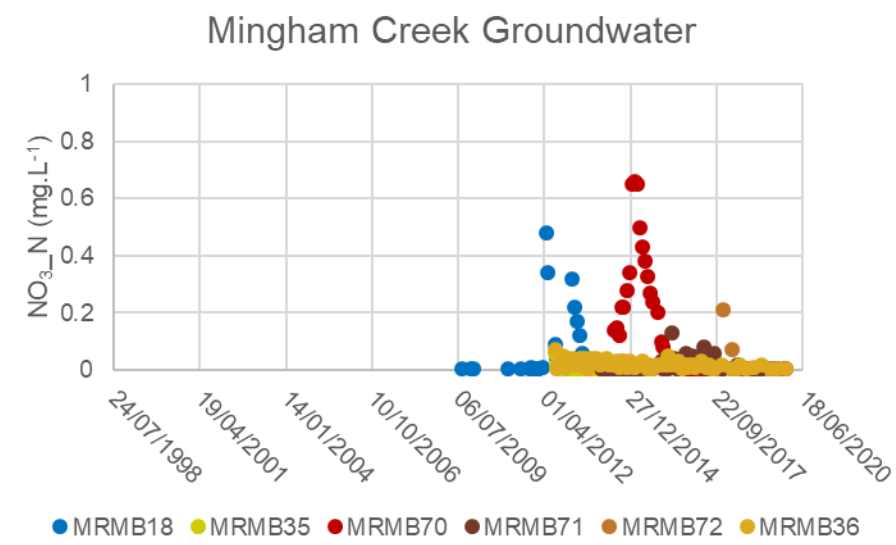
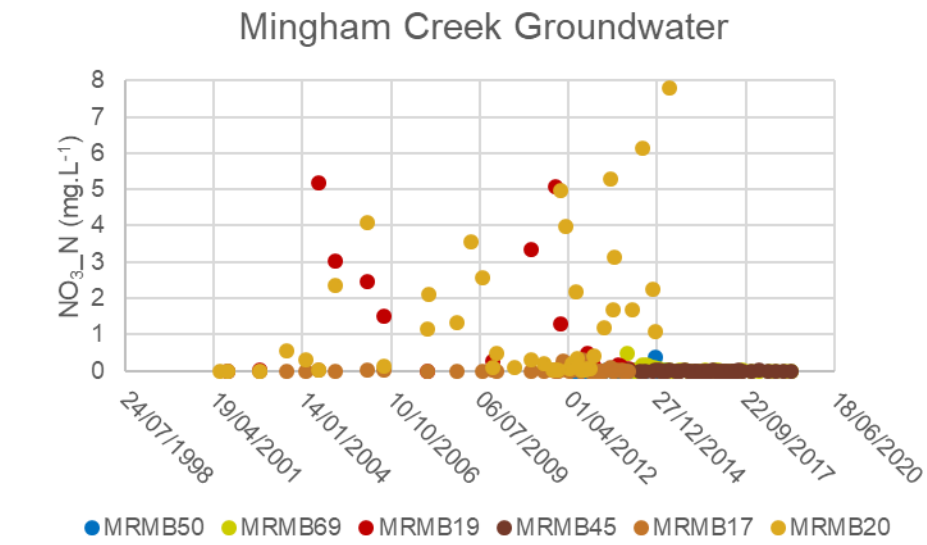
⁴² Na/Cl (M/M) vs SO₄/Cl (M/M) concentration ratios in the source term (South Dam, West Waste Rock Dam) and in selected groundwater samples from the Southern Drainage to Mingham Creek showing correlations associated with neutral mine drainage in mining affected water (MRMB19).

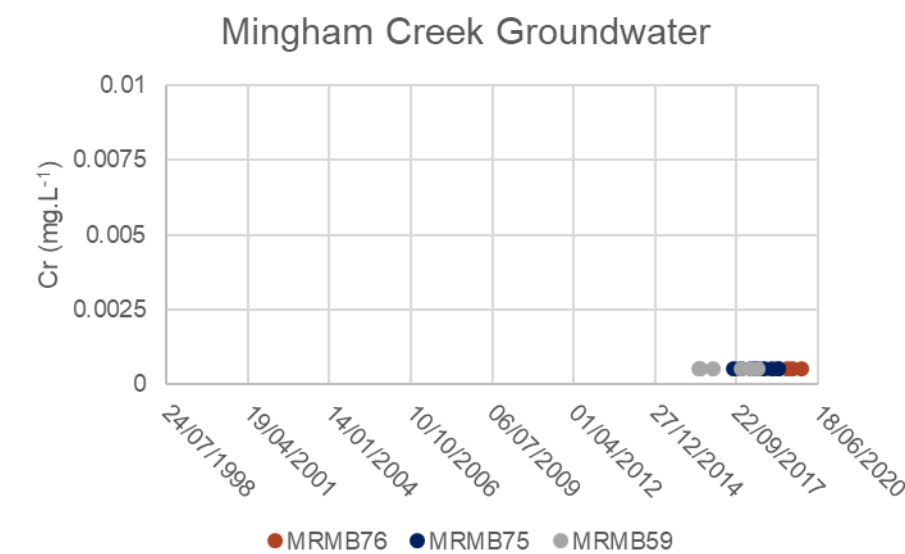
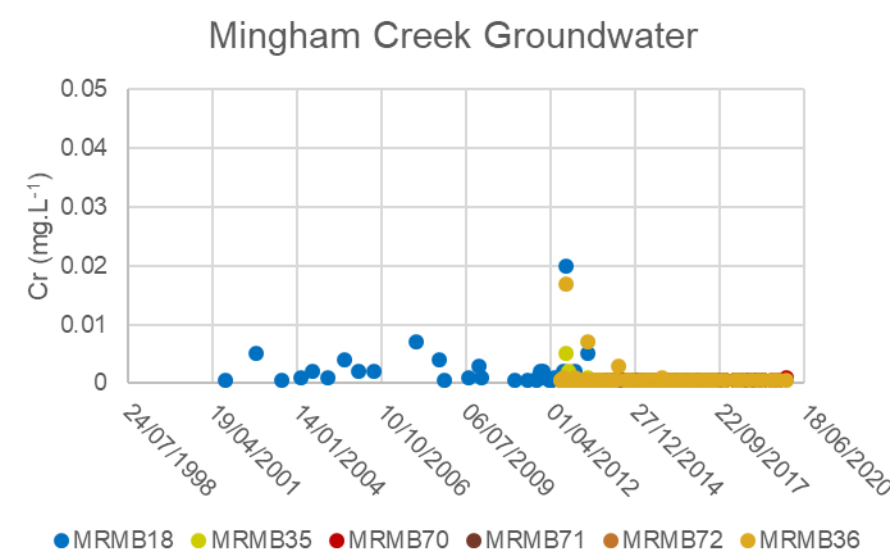
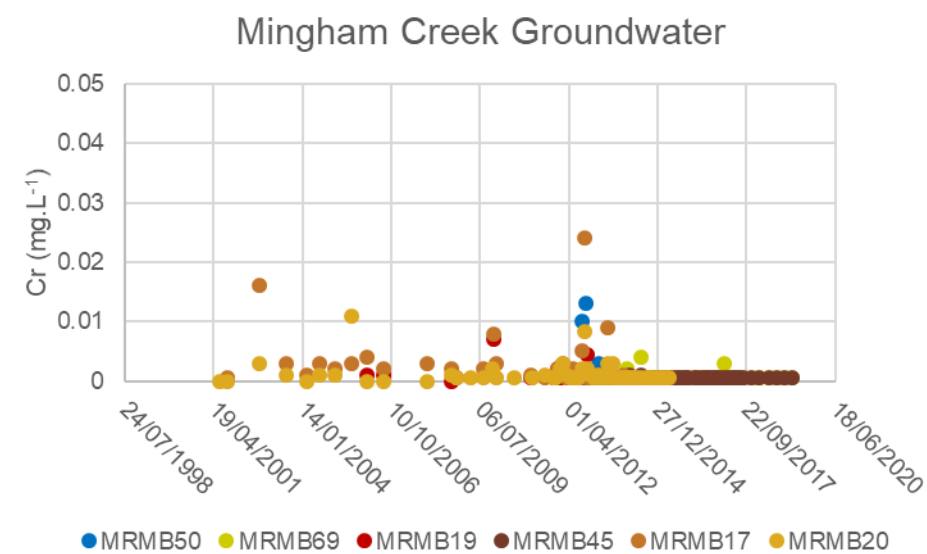
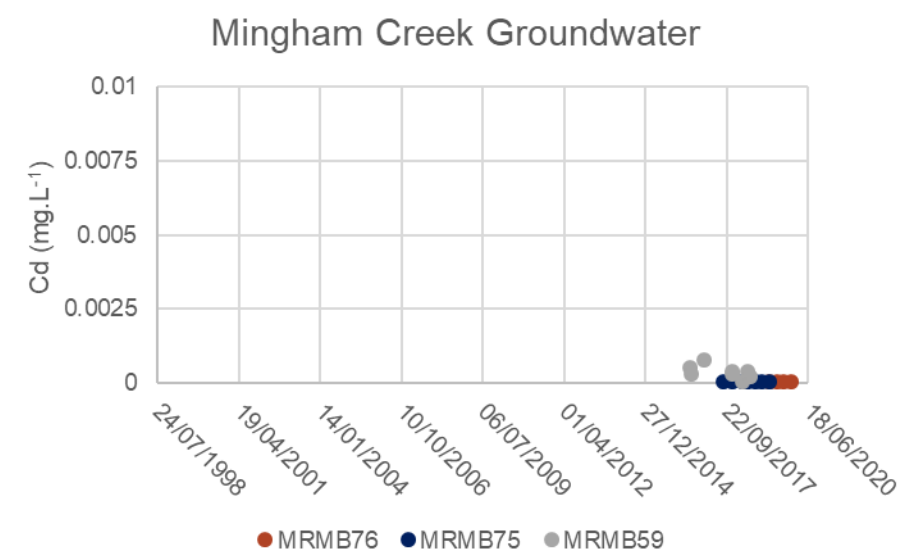
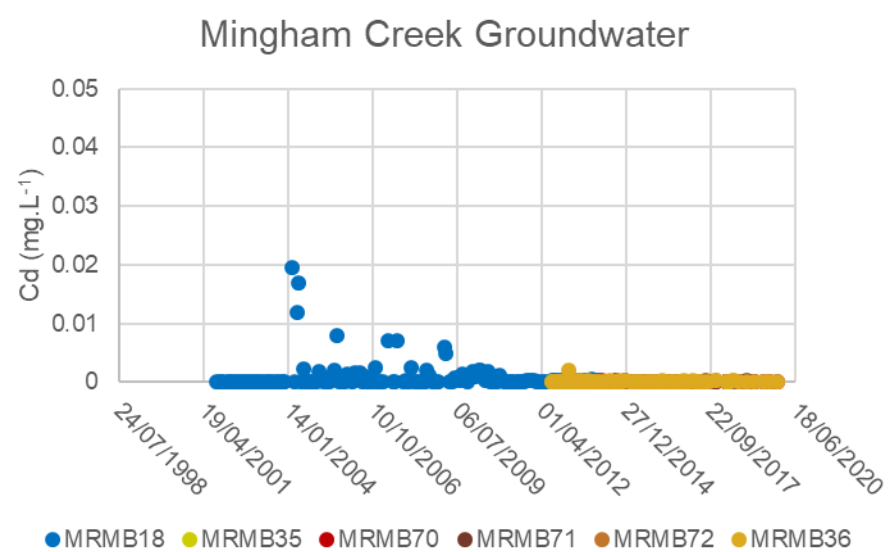
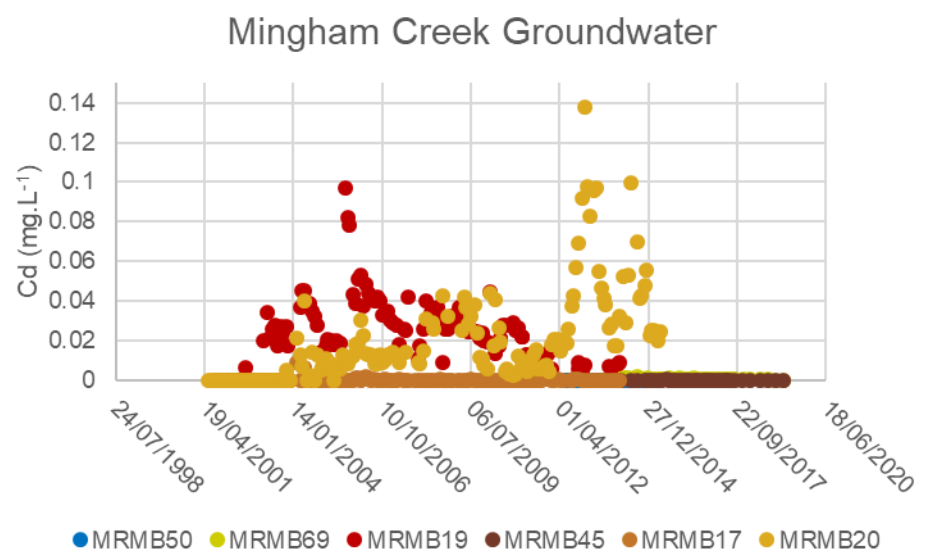
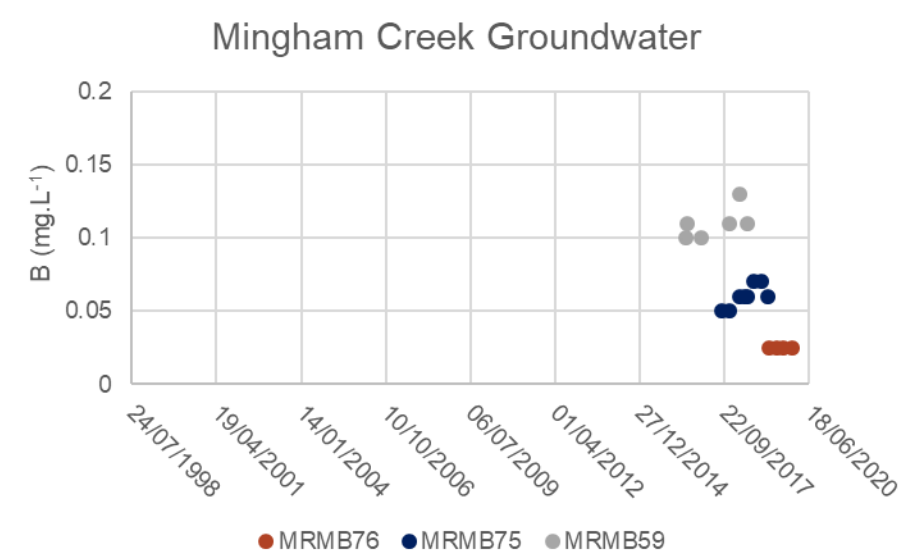
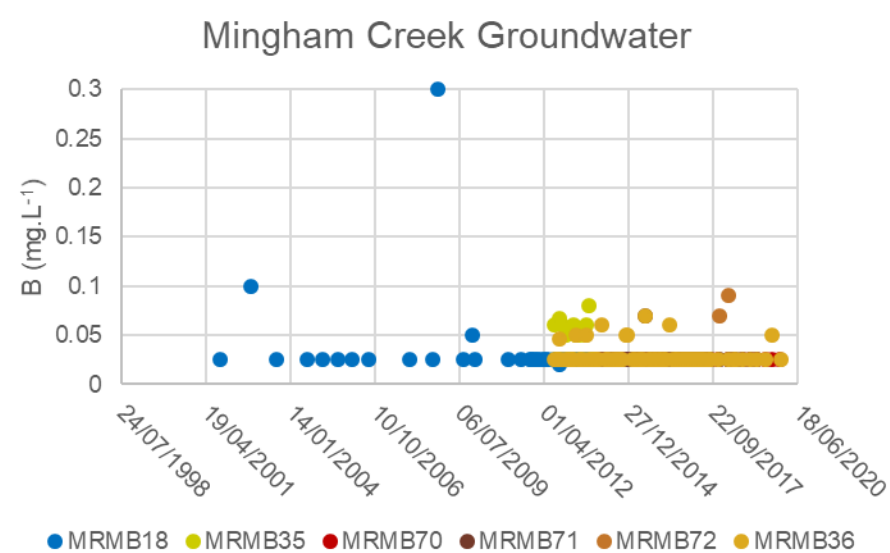
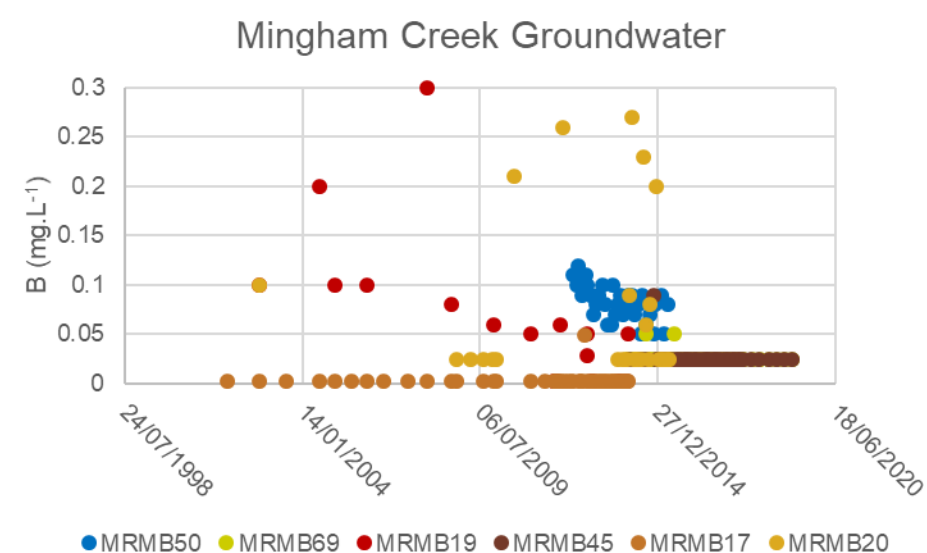


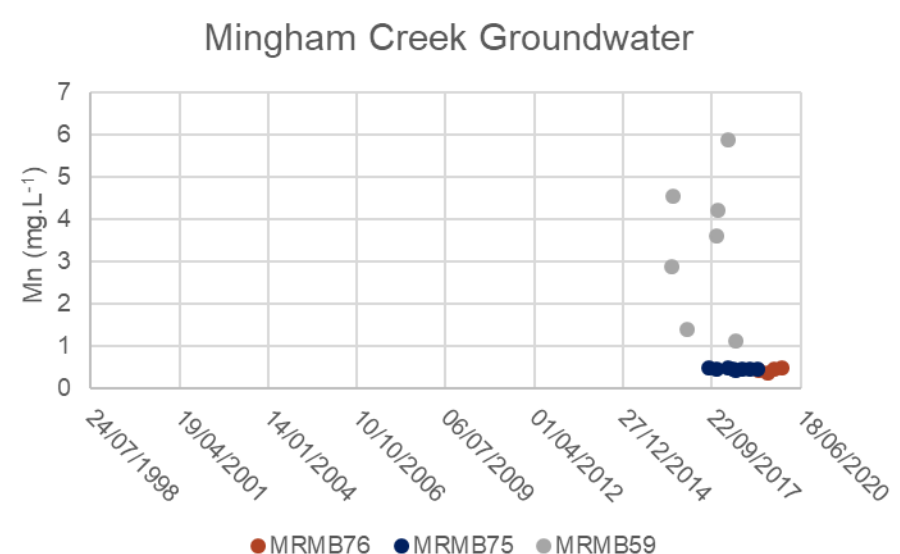
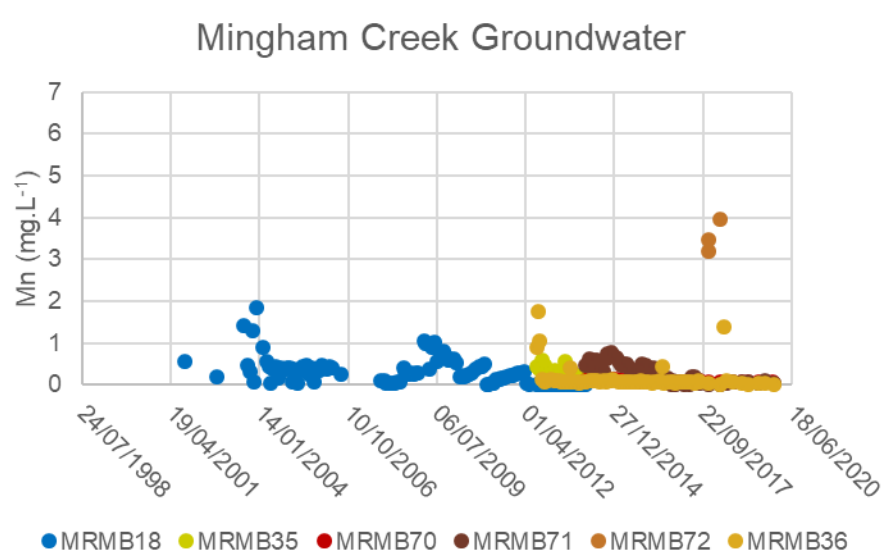
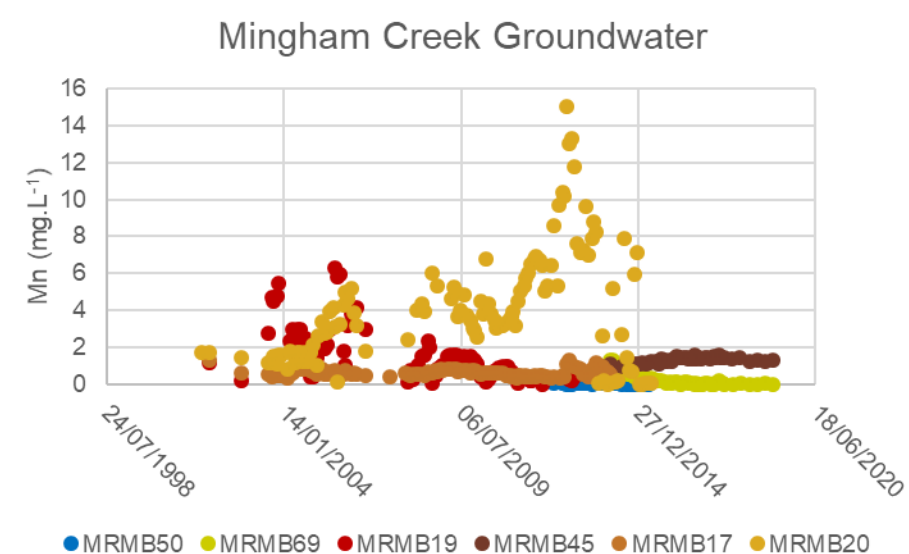
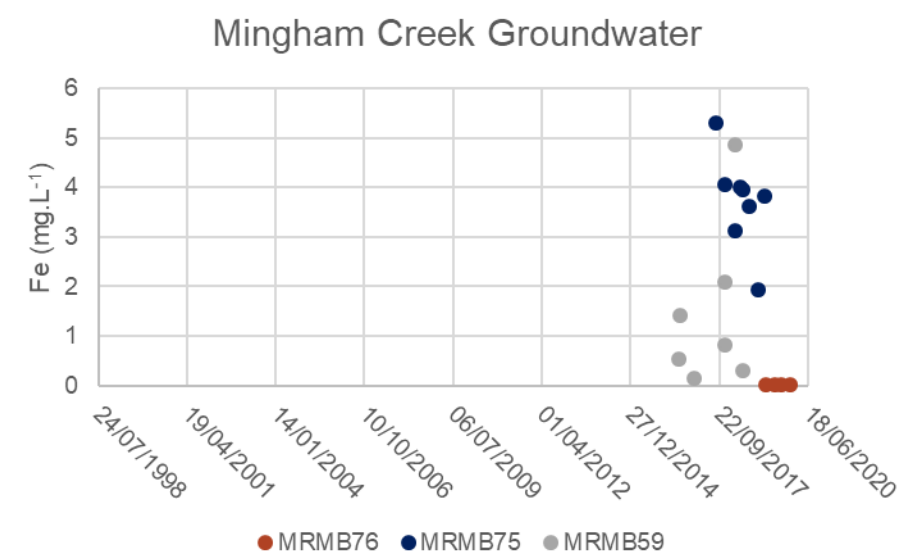
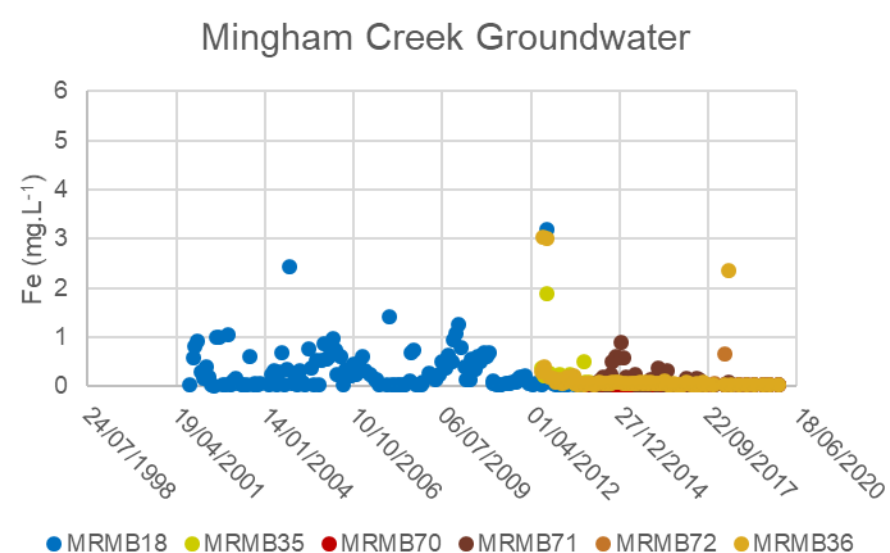
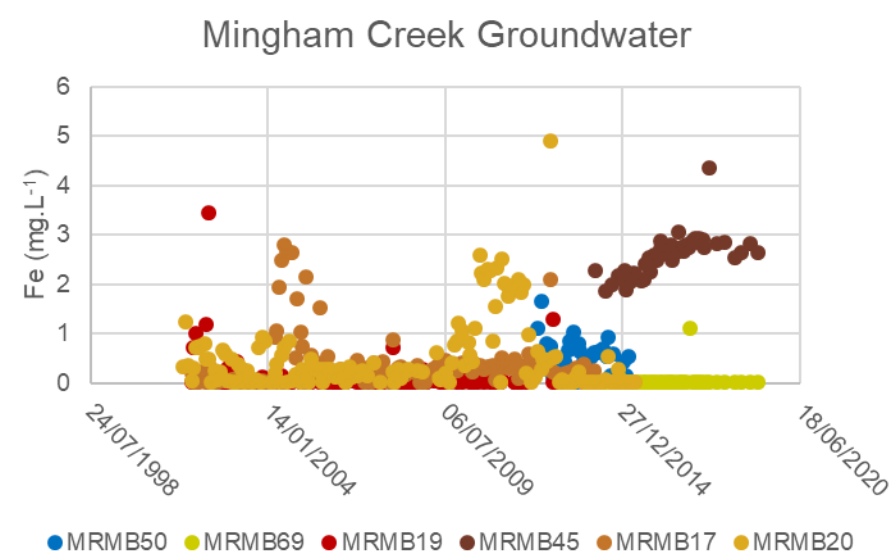
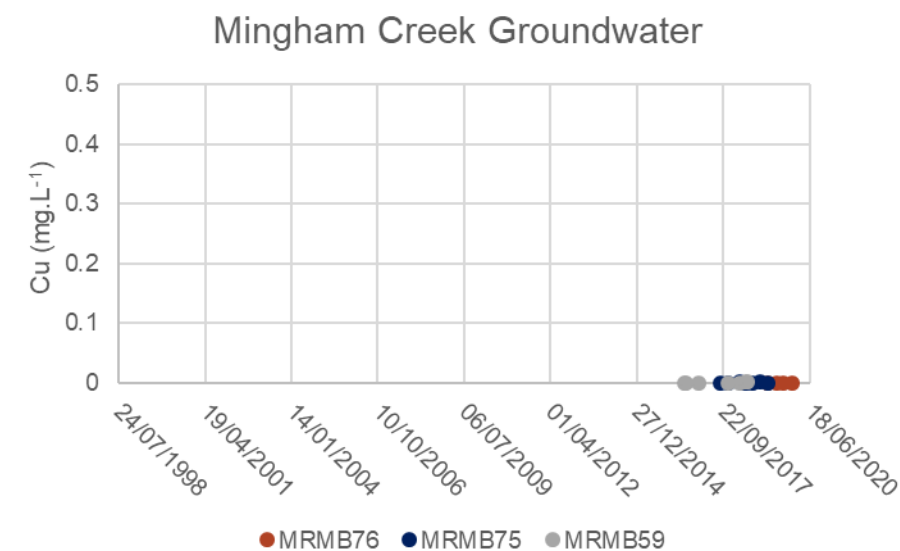
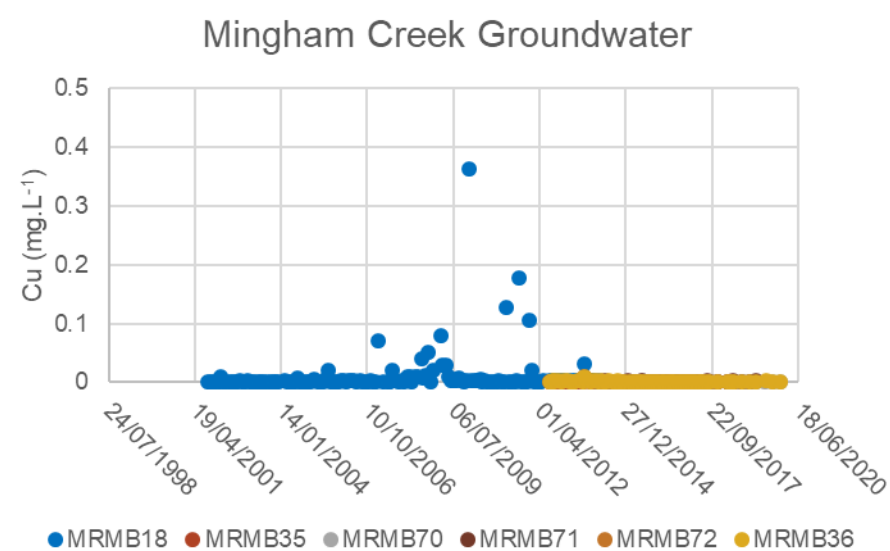
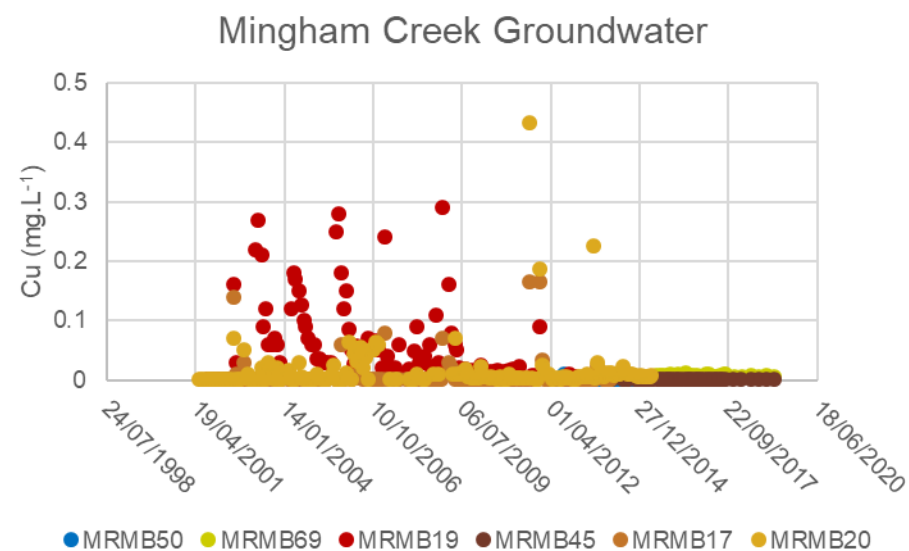


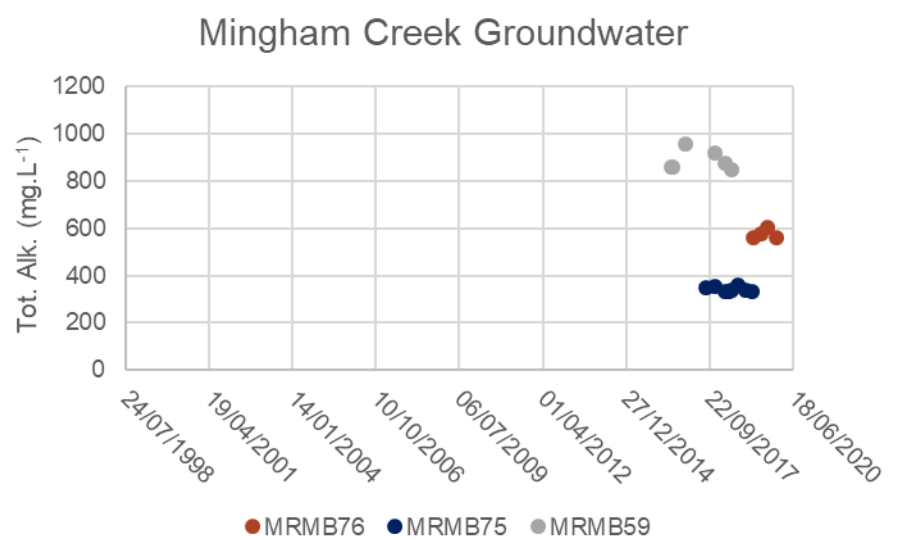
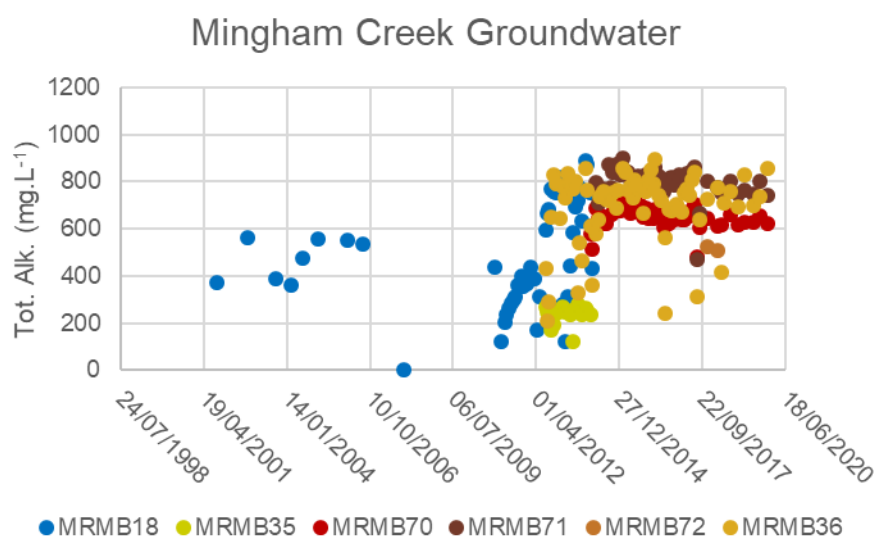
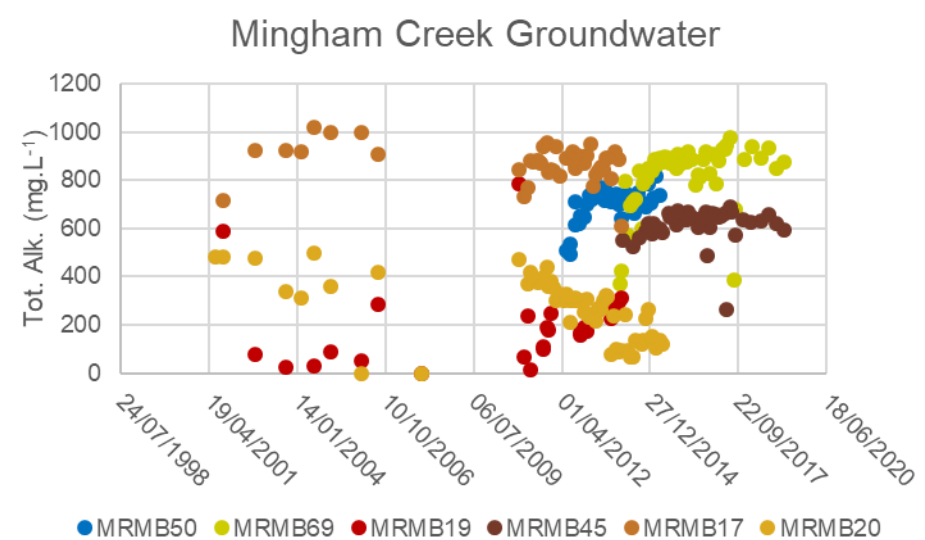
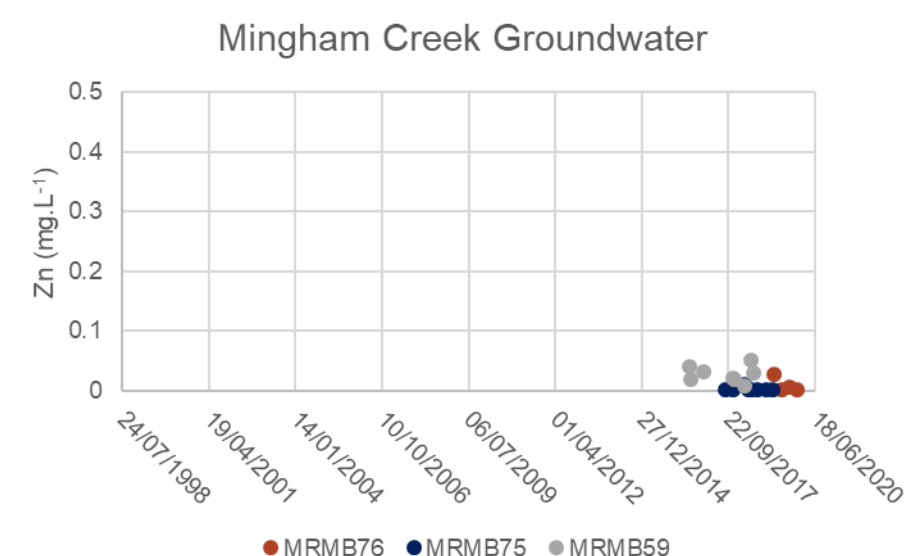
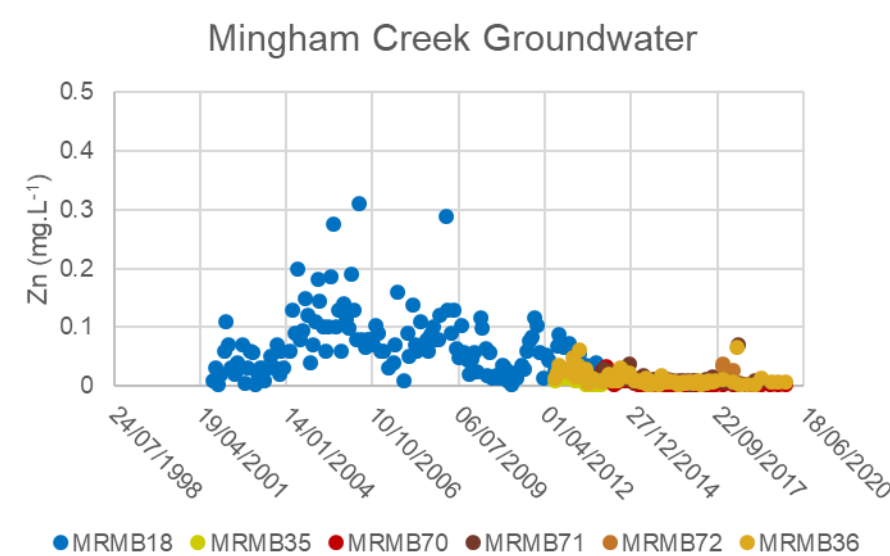
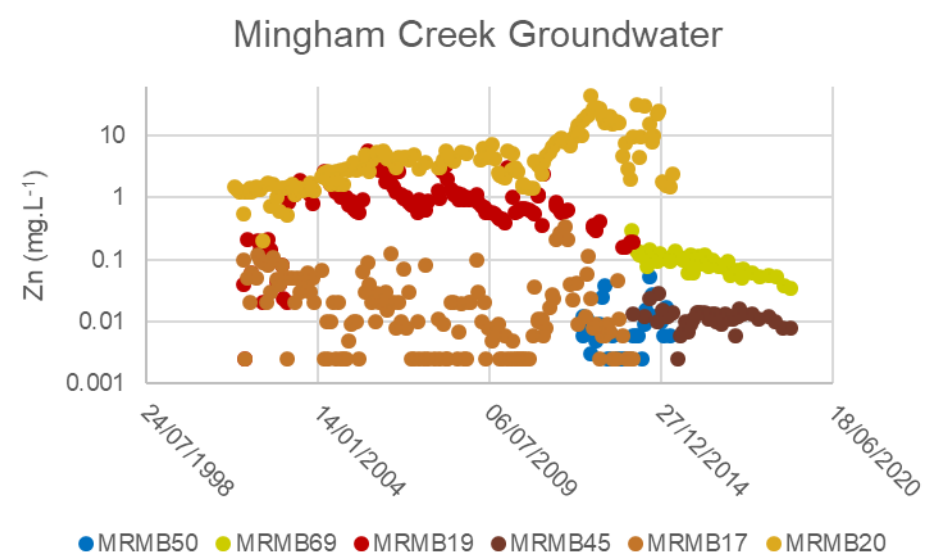
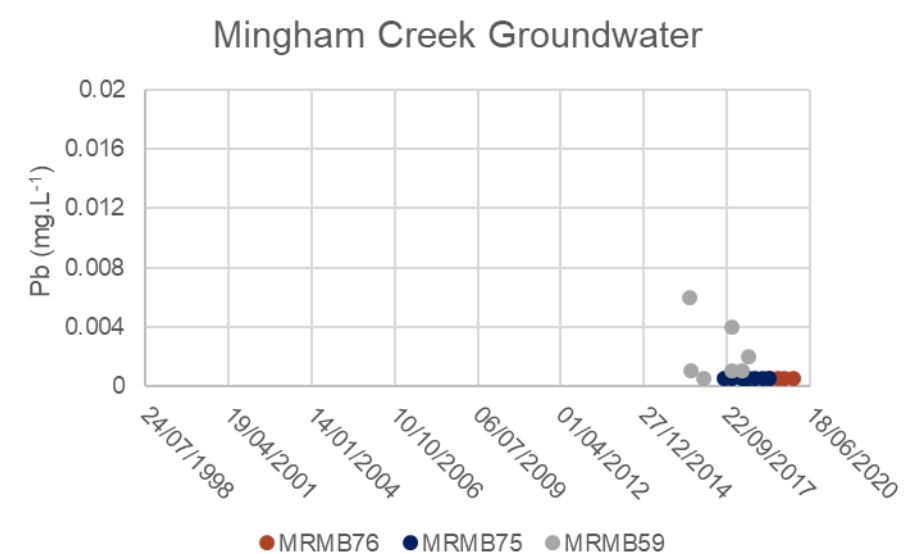
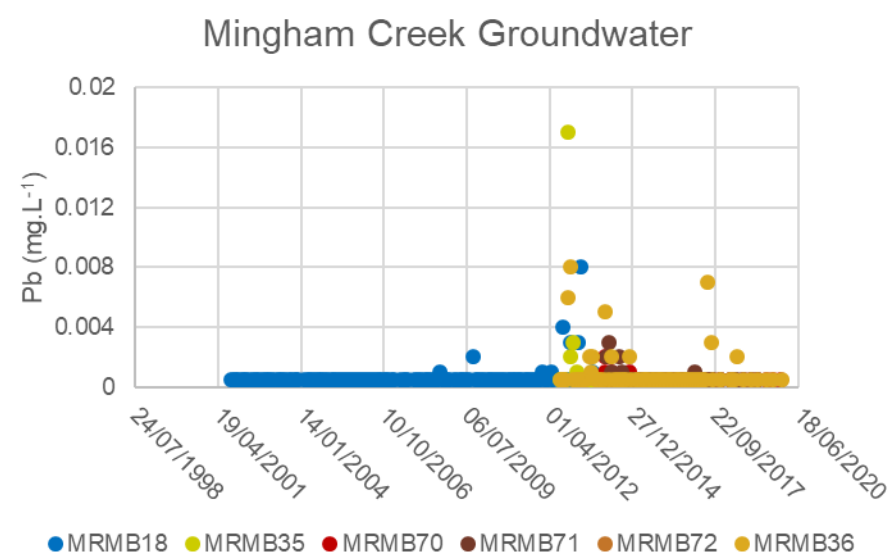
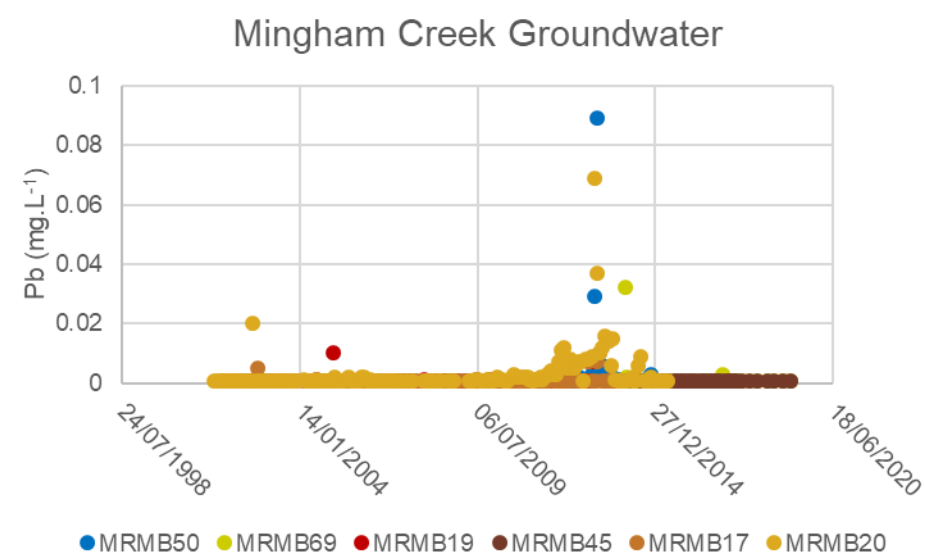












Sample Point	Statistic	pH	EC (µS/cm)	Cyanide Total (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Sulphate (mg/L)	Alk Tot as CaCO3 (mg/L)	SO4/Cl (M/M)	Fluoride (mg/L)	Nitrate as N (mg/L)	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)
MRMB50 17/05/2012 - 23/04/2015	Count	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	Min	6.7	2774	0.002	430	608	24	493	0.01	0.6	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	5th %ile	6.7	2900	0.002	455	628	26	529	0.01	0.6	0.005	0.005	0.0005	0.044	0.00005	0.0005	0.0005
	20th %ile	6.9	2990	0.002	485	653	29	653	0.02	0.7	0.005	0.005	0.0005	0.060	0.00005	0.0005	0.0005
	Mean	7.2	3266	0.002	525	724	38	695	0.02	0.8	0.023	0.012	0.0010	0.079	0.00005	0.0012	0.0012
	Median	7.2	3121	0.002	521	701	32	712	0.02	0.7	0.005	0.005	0.0005	0.080	0.00005	0.0005	0.0005
	80th %ile	7.4	3670	0.002	564	801	51	739	0.02	0.8	0.020	0.005	0.0020	0.100	0.00005	0.0005	0.0010
	95th %ile	7.5	3823	0.004	612	859	61	776	0.03	1.1	0.058	0.025	0.0023	0.110	0.00005	0.0048	0.0035
	Max	7.7	4000	0.011	668	878	73	816	0.04	1.2	0.390	0.190	0.0030	0.120	0.00020	0.0130	0.0100
MRMB69 23/01/2014 - 20/12/2019	Count	50	50	50	50	50	50	50	50	50	49	50	50	50	50	48	50
	Min	6.2	6440	0.014	941	1270	538	368	0.07	0.7	0.005	0.005	0.0090	0.025	0.00005	0.0005	0.0030
	5th %ile	6.3	6524	0.015	951	1369	591	492	0.08	0.8	0.005	0.005	0.0130	0.025	0.00020	0.0005	0.0040
	20th %ile	6.5	6892	0.026	1000	1568	652	766	0.11	1.5	0.005	0.005	0.0140	0.025	0.00028	0.0005	0.0058
	Mean	6.6	7761	0.032	1054	1914	752	815	0.15	1.7	0.032	0.044	0.0164	0.026	0.00045	0.0007	0.0068
	Median	6.6	7720	0.034	1040	1825	789	869	0.16	1.8	0.005	0.005	0.0160	0.025	0.00030	0.0005	0.0060
	80th %ile	6.8	8578	0.038	1122	2334	814	898	0.19	2.0	0.030	0.005	0.0190	0.025	0.00060	0.0005	0.0080
	95th %ile	7.2	9031	0.045	1196	2689	840	938	0.22	2.1	0.138	0.005	0.0210	0.025	0.00096	0.0015	0.0100
	Max	7.3	9210	0.049	1230	2860	874	975	0.23	2.2	0.500	1.940	0.0230	0.050	0.00180	0.0040	0.0120
MRMB19 03/09/2001 - 04/02/2014	Count	120	120	120	27	27	120	25	27	21	22	120	120	20	120	17	120
	Min	4.7	354	0.002	78	43	58	0	0.30	0.1	0.005	0.001	0.0005	0.003	0.00005	0.0000	0.0005
	5th %ile	5.3	510	0.002	149	63	92	15	0.62	0.1	0.006	0.005	0.0005	0.003	0.00005	0.0004	0.0005
	20th %ile	5.9	1348	0.002	169	86	579	62	0.86	0.2	0.038	0.005	0.0005	0.003	0.00850	0.0005	0.0080
	Mean	6.3	2583	0.008	363	276	775	195	1.67	0.3	2.126	0.050	0.0026	0.060	0.02371	0.0013	0.0535
	Median	6.4	2085	0.002	296	192	760	176	1.27	0.3	0.280	0.005	0.0005	0.050	0.02430	0.0005	0.0295
	80th %ile	6.7	3868	0.004	414	317	992	277	2.44	0.4	3.290	0.010	0.0020	0.100	0.03540	0.0010	0.0866
	95th %ile	7.1	5707	0.014	1018	971	1452	531	4.20	0.7	9.949	0.243	0.0105	0.205	0.04518	0.0049	0.2105
	Max	7.9	6770	0.425	1190	1120	1690	784	4.65	1.0	12.900	1.300	0.0300	0.300	0.09700	0.0070	0.2900
MRMB45 13/02/2014 - 20/12/2019	Count	42	42	42	42	42	42	42	42	42	41	42	42	42	42	41	42
	Min	6.0	3723	0.002	316	783	257	266	0.06	0.5	0.005	0.005	0.0410	0.025	0.00005	0.0005	0.0005
	5th %ile	6.1	4348	0.016	366	958	267	528	0.07	0.5	0.005	0.005	0.0590	0.025	0.00005	0.0005	0.0005
	20th %ile	6.2	4974	0.037	397	1172	281	590	0.07	0.6	0.005	0.005	0.0630	0.025	0.00005	0.0005	0.0005
	Mean	6.3	5220	0.079	423	1323	326	615	0.10	0.6	0.007	0.005	0.0683	0.027	0.00005	0.0005	0.0005
	Median	6.3	5375	0.085	425	1350	299	632	0.08	0.6	0.005	0.005	0.0665	0.025	0.00005	0.0005	0.0005
	80th %ile	6.4	5566	0.117	449	1476	366	658	0.12	0.6	0.005	0.005	0.0748	0.025	0.00005	0.0005	0.0005
	95th %ile	6.7	5650	0.135	481	1559	501	668	0.17	0.7	0.020	0.005	0.0838	0.025	0.00005	0.0005	0.0005
	Max	6.8	5710	0.146	497	1590	560	689	0.24	0.9	0.030	0.010	0.0870	0.090	0.00020	0.0010	0.0005
MRMB17 02/09/2001 - 06/02/2014	Count	146	146	145	51	51	146	45	51	42	43	146	146	45	146	45	146
	Min	5.1	3090	0.002	1050	1410	384	1	0.07	0.9	0.005	0.005	0.0005	0.003	0.00005	0.0005	0.0005
	5th %ile	6.2	6773	0.002	1105	1620	415	719	0.08	1.1	0.005	0.005	0.0005	0.003	0.00005	0.0005	0.0005
	20th %ile	6.4	7240	0.002	1160	1750	445	830	0.08	1.2	0.005	0.005	0.0005	0.003	0.00005	0.0005	0.0005
	Mean	6.7	7623	0.003	1234	1913	479	854	0.09	1.4	0.028	0.034	0.0013	0.004	0.00023	0.0025	0.0068
	Median	6.7	7620	0.002	1240	1920	467	881	0.09	1.4	0.005	0.005	0.0005	0.003	0.00005	0.0010	0.0005
	80th %ile	7.0	8050	0.002	1300	2110	512	922	0.10	1.6	0.020	0.005	0.0010	0.003	0.00005	0.0030	0.0020
	95th %ile	7.2	8665	0.006	1345	2240	587	987	0.10	1.8	0.107	0.195	0.0040	0.003	0.00080	0.0088	0.0300
	Max	8.2	9560	0.049	1380	2360	700	1020	0.11	1.9	0.300	1.100	0.0200	0.049	0.00880	0.0240	0.1660
MRMB20 29/05/2001 - 14/05/2015	Count	152	152	149	70	69	152	62	69	62	63	153	153	53	153	63	153
	Min	5.6	889	0.002	154	23	237	0	0.34	0.2	0.005	0.005	0.0005	0.025	0.00001	0.0000	0.0005
	5th %ile	5.8	1615	0.002	201	59	368	69	0.56	0.3	0.020	0.005	0.0014	0.025	0.00001	0.0000	0.0005
	20th %ile	6.2	1918	0.002	302	148	416	131	0.79	0.4	0.074	0.005	0.0060	0.025	0.00001	0.0005	0.0005
	Mean	6.5	3001	0.003	376	381	983	267	3.56	0.5	9.981	0.025	0.0211	0.437	0.02164	0.0011	0.0206
	Median	6.4	3025	0.002	398	446	667	300	1.09	0.5	2.170	0.005	0.0200	0.320	0.01260	0.0005	0.0040
	80th %ile	6.8	4126	0.002	450	555	1690	379	3.63	0.6	14.240	0.010	0.0346	0.740	0.03222	0.0010	0.0130
	95th %ile	7.2	4462	0.009	484	621	2369	479	15.40	0.8	47.820	0.068	0.0500	1.302	0.07520	0.0030	0.0612
	Max	8.7	4685	0.019	550	674	3120	500	43.97	1.0	101.000	1.260	0.0600	2.400	0.28700	0.0110	0.8500

Sample Point	Statistic	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Lead Dissolved (mg/L)	Zinc Dissolved (mg/L)	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Molybdenum Dissolved (mg/L)
MRMB50 17/05/2012 - 23/04/2015	Count	36	36	36	36	36	36	36	36
	Min	0.025	0.006	0.0005	0.0025	42	4	86	0.011
	5th %ile	0.025	0.014	0.0005	0.0025	60	5	88	0.013
	20th %ile	0.200	0.023	0.0005	0.0025	72	5	91	0.018
	Mean	0.522	0.049	0.0043	0.0100	78	6	98	0.022
	Median	0.520	0.046	0.0005	0.0060	78	6	95	0.019
	80th %ile	0.750	0.067	0.0020	0.0120	89	6	107	0.025
	95th %ile	1.058	0.103	0.0118	0.0298	93	7	115	0.044
	Max	1.660	0.136	0.0890	0.0530	95	8	118	0.046
MRMB69 23/01/2014 - 20/12/2019	Count	50	50	50	50	50	50	50	50
	Min	0.025	0.005	0.0005	0.0340	241	9	207	0.016
	5th %ile	0.025	0.010	0.0005	0.0519	252	12	210	0.020
	20th %ile	0.025	0.036	0.0005	0.0618	283	13	242	0.023
	Mean	0.050	0.273	0.0013	0.0952	357	15	271	0.028
	Median	0.025	0.149	0.0005	0.0920	322	14	265	0.028
	80th %ile	0.025	0.529	0.0005	0.1160	378	17	315	0.032
	95th %ile	0.044	0.925	0.0016	0.1403	436	19	336	0.042
	Max	1.110	1.340	0.0320	0.2980	1660	27	346	0.047
MRMB19 03/09/2001 - 04/02/2014	Count	120	87	120	120	26	26	28	44
	Min	0.010	0.016	0.0005	0.0025	0	0	0	0.001
	5th %ile	0.020	0.182	0.0005	0.0429	28	4	0	0.001
	20th %ile	0.025	0.429	0.0005	0.3804	87	6	48	0.001
	Mean	0.119	1.639	0.0007	1.0530	112	7	69	0.003
	Median	0.025	1.190	0.0005	0.8450	114	7	71	0.003
	80th %ile	0.070	2.738	0.0005	1.4080	136	8	82	0.006
	95th %ile	0.454	4.739	0.0010	3.0120	200	10	140	0.008
	Max	3.450	6.280	0.0100	5.5700	219	21	194	0.009
MRMB45 13/02/2014 - 20/12/2019	Count	42	42	42	42	42	42	42	42
	Min	1.860	0.999	0.0005	0.0025	353	4	107	0.003
	5th %ile	1.993	1.081	0.0005	0.0061	399	4	136	0.005
	20th %ile	2.216	1.152	0.0005	0.0092	425	5	147	0.005
	Mean	2.580	1.332	0.0005	0.0119	471	5	164	0.005
	Median	2.640	1.370	0.0005	0.0120	473	5	165	0.005
	80th %ile	2.852	1.470	0.0005	0.0138	511	5	183	0.006
	95th %ile	2.939	1.539	0.0005	0.0160	541	6	194	0.006
	Max	4.360	1.600	0.0005	0.0290	590	6	202	0.008
MRMB17 02/09/2001 - 06/02/2014	Count	146	112	146	146	47	47	47	67
	Min	0.010	0.350	0.0005	0.0025	1	1	1	0.012
	5th %ile	0.025	0.399	0.0005	0.0025	136	4	210	0.017
	20th %ile	0.050	0.481	0.0005	0.0025	156	6	234	0.030
	Mean	0.386	0.646	0.0007	0.0323	159	7	240	0.047
	Median	0.240	0.599	0.0005	0.0110	162	7	243	0.044
	80th %ile	0.400	0.797	0.0005	0.0500	173	8	258	0.058
	95th %ile	1.878	1.016	0.0005	0.1138	177	9	273	0.080
	Max	2.810	1.350	0.0100	0.3430	191	13	296	0.173
MRMB20 29/05/2001 - 14/05/2015	Count	153	118	153	153	62	63	65	81
	Min	0.010	0.022	0.0005	0.2000	0	0	0	0.003
	5th %ile	0.025	0.081	0.0005	1.1960	130	7	41	0.005
	20th %ile	0.025	1.518	0.0005	1.4840	364	9	103	0.010
	Mean	0.505	4.083	0.0027	6.6269	423	11	130	0.014
	Median	0.260	3.670	0.0005	3.6300	456	11	144	0.015
	80th %ile	0.742	6.410	0.0020	7.8520	531	12	166	0.019
	95th %ile	2.094	9.741	0.0114	22.9200	582	14	185	0.024
	Max	4.900	15.000	0.0690	97.2000	674	17	200	0.027

Sample Point	Statistic	pH	EC (µS/cm)	Cyanide Total (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Sulphate (mg/L)	Alk Tot as CaCO3 (mg/L)	SO4/Cl (M/M)	Fluoride (mg/L)	Nitrate as N (mg/L)	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)
MRMB18 24/09/2001 - 06/02/2014	Count	144	144	143	51	51	144	46	51	43	33	144	144	44	144	45	144
	Min	5.5	730	0.002	96	133	46	1	0.05	0.3	0.005	0.005	0.0005	0.020	0.00005	0.0005	0.0005
	5th %ile	6.2	1692	0.002	168	187	109	136	0.05	0.5	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	20th %ile	6.5	4854	0.002	365	563	402	300	0.07	0.8	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	Mean	6.8	6792	0.005	873	1698	598	472	0.11	1.1	0.067	0.026	0.0015	0.033	0.00093	0.0018	0.0191
	Median	6.7	7545	0.002	920	1760	726	436	0.11	1.0	0.020	0.005	0.0005	0.025	0.00005	0.0005	0.0010
	80th %ile	7.1	8678	0.002	1310	2570	778	693	0.13	1.4	0.078	0.010	0.0020	0.025	0.00090	0.0020	0.0044
	95th %ile	7.3	9696	0.008	1535	3595	811	810	0.17	1.7	0.328	0.151	0.0020	0.046	0.00462	0.0050	0.0485
	Max	8.0	11360	0.303	1680	3730	930	890	0.17	1.9	0.480	0.620	0.0300	0.300	0.01950	0.0200	1.3100
MRMB35 31/07/2012 - 14/01/2014	Count	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
	Min	6.6	3066	0.002	620	773	389	125	0.15	0.6	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	5th %ile	7.1	3404	0.002	630	811	397	166	0.15	0.6	0.005	0.005	0.0005	0.025	0.00005	0.0005	0.0005
	20th %ile	7.2	3534	0.002	651	853	411	238	0.16	0.7	0.005	0.005	0.0010	0.025	0.00005	0.0005	0.0005
	Mean	7.3	3689	0.002	686	904	440	240	0.18	0.7	0.012	0.005	0.0017	0.043	0.00007	0.0009	0.0011
	Median	7.4	3683	0.002	681	895	440	252	0.18	0.7	0.005	0.005	0.0020	0.050	0.00005	0.0005	0.0005
	80th %ile	7.5	3860	0.002	714	952	463	267	0.19	0.8	0.014	0.005	0.0020	0.060	0.00005	0.0005	0.0010
	95th %ile	7.6	4029	0.002	753	1023	476	271	0.20	0.8	0.033	0.005	0.0031	0.068	0.00008	0.0023	0.0027
	Max	7.7	4378	0.005	788	1050	480	278	0.21	0.8	0.060	0.005	0.0040	0.080	0.00040	0.0052	0.0090
MRMB70 23/01/2014 - 27/02/2020	Count	54	54	53	53	53	54	53	53	53	52	53	53	53	53	52	53
	Min	6.5	1604	0.002	198	188	17	480	0.02	1.5	0.005	0.005	0.0010	0.025	0.00005	0.0005	0.0005
	5th %ile	6.5	1613	0.002	208	204	18	596	0.02	1.6	0.005	0.005	0.0016	0.025	0.00005	0.0005	0.0005
	20th %ile	6.6	1720	0.002	214	232	19	623	0.03	1.8	0.005	0.005	0.0020	0.025	0.00005	0.0005	0.0005
	Mean	6.8	1898	0.002	233	283	24	653	0.03	1.9	0.120	0.006	0.0024	0.025	0.00007	0.0005	0.0006
	Median	6.7	1839	0.002	228	267	23	655	0.03	1.9	0.010	0.005	0.0020	0.025	0.00005	0.0005	0.0005
	80th %ile	6.9	2094	0.002	253	338	26	688	0.03	2.1	0.236	0.005	0.0030	0.025	0.00010	0.0005	0.0005
	95th %ile	7.2	2208	0.002	267	372	39	727	0.07	2.1	0.567	0.007	0.0044	0.025	0.00014	0.0005	0.0010
	Max	7.4	2250	0.005	281	399	53	731	0.09	2.6	0.660	0.020	0.0060	0.025	0.00020	0.0010	0.0030
MRMB71 10/02/2014 - 27/02/2020	Count	55	56	53	53	53	54	53	53	52	52	53	54	53	53	52	53
	Min	6.4	1776	0.002	258	141	7	468	0.02	1.6	0.005	0.005	0.0210	0.025	0.00005	0.0005	0.0005
	5th %ile	6.6	1849	0.002	264	148	12	690	0.02	1.9	0.005	0.005	0.0220	0.025	0.00005	0.0005	0.0005
	20th %ile	6.6	1873	0.002	275	168	16	758	0.03	2.1	0.005	0.005	0.0286	0.025	0.00005	0.0005	0.0005
	Mean	6.8	2450	0.002	297	390	48	793	0.04	2.4	0.018	0.006	0.0514	0.026	0.00007	0.0005	0.0009
	Median	6.8	2551	0.002	301	434	45	804	0.04	2.4	0.005	0.005	0.0360	0.025	0.00005	0.0005	0.0005
	80th %ile	7.0	2768	0.002	313	517	74	837	0.05	2.7	0.030	0.005	0.0720	0.025	0.00010	0.0005	0.0010
	95th %ile	7.3	3060	0.002	324	603	100	872	0.07	3.0	0.060	0.005	0.1386	0.025	0.00014	0.0005	0.0020
	Max	7.4	3080	0.012	338	620	120	901	0.09	3.1	0.130	0.080	0.1540	0.070	0.00030	0.0005	0.0030
MRMB72 28/11/2017 - 26/03/2018	Count	3	3	2	2	2	3	2	2	2	2	2	3	2	2	2	2
	Min	6.6	7750	0.002	1360	1510	1830	508	0.44	0.6	0.070	0.005	0.0400	0.070	0.00010	0.0005	0.0005
	5th %ile	6.6	7750	0.002	1363	1516	1837	509	0.44	0.6	0.077	0.005	0.0408	0.071	0.00011	0.0005	0.0005
	20th %ile	6.6	7750	0.002	1372	1534	1858	512	0.45	0.6	0.098	0.005	0.0432	0.074	0.00012	0.0005	0.0006
	Mean	6.7	7767	0.002	1390	1570	1897	518	0.45	0.7	0.140	0.005	0.0637	0.080	0.00015	0.0005	0.0008
	Median	6.7	7750	0.002	1390	1570	1900	518	0.45	0.7	0.140	0.005	0.0480	0.080	0.00015	0.0005	0.0008
	80th %ile	6.7	7780	0.002	1408	1606	1936	523	0.46	0.7	0.182	0.005	0.0810	0.086	0.00018	0.0005	0.0009
	95th %ile	6.8	7795	0.002	1417	1624	1954	526	0.46	0.7	0.203	0.005	0.0975	0.089	0.00020	0.0005	0.0010
	Max	6.8	7800	0.002	1420	1630	1960	527	0.46	0.7	0.210	0.005	0.1030	0.090	0.00020	0.0005	0.0010
MRMB36 31/07/2012 - 27/02/2020	Count	73	69	71	71	71	73	71	71	70	70	71	71	71	72	70	71
	Min	6.2	6595	0.002	1220	1110	1140	210	0.26	0.1	0.005	0.001	0.0005	0.025	0.00005	0.0005	0.0005
	5th %ile	6.5	6983	0.002	1280	1270	1346	322	0.30	0.1	0.005	0.005	0.0010	0.025	0.00005	0.0005	0.0005
	20th %ile	6.7	7472	0.002	1330	1410	1414	639	0.33	0.1	0.010	0.005	0.0010	0.025	0.00005	0.0005	0.0005
	Mean	6.9	7946	0.002	1412	1590	1540	692	0.36	0.1	0.021	0.008	0.0014	0.029	0.00013	0.0009	0.0011
	Median	6.9	8030	0.002	1410	1600	1530	738	0.36	0.1	0.020	0.005	0.0010	0.025	0.00010	0.0005	0.0005
	80th %ile	7.2	8284	0.002	1480	1730	1666	798	0.39	0.1	0.030	0.005	0.0020	0.025	0.00010	0.0005	0.0020
	95th %ile	7.4	8765	0.002	1535	1860	1798	853	0.42	0.1	0.040	0.010	0.0030	0.050	0.00020	0.0010	0.0030
	Max	7.5	10150	0.006	1570	2740	1920	897	0.48	0.2	0.070	0.160	0.0040	0.070	0.00200	0.0170	0.0100

Sample Point	Statistic	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Lead Dissolved (mg/L)	Zinc Dissolved (mg/L)	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Molybdenum Dissolved (mg/L)
MRMB18 24/09/2001 - 06/02/2014	Count	143	111	144	144	47	47	47	66
	Min	0.010	0.003	0.0005	0.0025	1	1	1	0.001
	5th %ile	0.025	0.005	0.0005	0.0103	30	3	20	0.003
	20th %ile	0.025	0.020	0.0005	0.0290	69	4	44	0.003
	Mean	0.310	0.306	0.0006	0.0692	202	10	212	0.009
	Median	0.140	0.261	0.0005	0.0600	229	12	215	0.004
	80th %ile	0.568	0.450	0.0005	0.1000	322	15	358	0.019
	95th %ile	1.006	0.953	0.0010	0.1585	374	18	457	0.023
	Max	3.200	1.850	0.0080	0.3110	391	22	508	0.028
MRMB35 31/07/2012 - 14/01/2014	Count	19	19	19	19	19	19	19	19
	Min	0.050	0.151	0.0005	0.0025	111	2	47	0.009
	5th %ile	0.059	0.170	0.0005	0.0025	121	3	48	0.011
	20th %ile	0.086	0.207	0.0005	0.0025	124	3	52	0.012
	Mean	0.278	0.315	0.0016	0.0108	131	3	55	0.012
	Median	0.190	0.289	0.0005	0.0090	130	3	56	0.012
	80th %ile	0.276	0.422	0.0007	0.0180	137	4	59	0.013
	95th %ile	0.649	0.566	0.0044	0.0216	142	4	61	0.015
	Max	1.900	0.600	0.0170	0.0270	162	4	61	0.015
MRMB70 23/01/2014 - 27/02/2020	Count	53	53	53	53	53	53	53	53
	Min	0.025	0.060	0.0005	0.0025	72	3	58	0.007
	5th %ile	0.025	0.065	0.0005	0.0025	76	4	62	0.008
	20th %ile	0.025	0.070	0.0005	0.0025	80	4	63	0.008
	Mean	0.025	0.086	0.0006	0.0052	93	4	71	0.010
	Median	0.025	0.078	0.0005	0.0025	90	4	70	0.010
	80th %ile	0.025	0.107	0.0005	0.0080	101	5	78	0.012
	95th %ile	0.025	0.123	0.0010	0.0152	109	6	84	0.012
	Max	0.025	0.137	0.0020	0.0340	252	6	93	0.014
MRMB71 10/02/2014 - 27/02/2020	Count	53	53	53	53	53	53	53	53
	Min	0.025	0.011	0.0005	0.0025	58	6	54	0.008
	5th %ile	0.025	0.019	0.0005	0.0040	63	6	58	0.009
	20th %ile	0.025	0.052	0.0005	0.0070	72	6	64	0.010
	Mean	0.128	0.275	0.0006	0.0123	108	7	106	0.014
	Median	0.025	0.198	0.0005	0.0090	111	7	116	0.013
	80th %ile	0.184	0.493	0.0005	0.0142	125	8	131	0.017
	95th %ile	0.590	0.664	0.0014	0.0272	133	9	147	0.022
	Max	0.900	0.762	0.0030	0.0700	445	11	159	0.028
MRMB72 28/11/2017 - 26/03/2018	Count	2	3	2	3	2	2	2	2
	Min	0.070	3.180	0.0005	0.0260	304	16	191	0.166
	5th %ile	0.100	3.210	0.0005	0.0267	304	16	191	0.166
	20th %ile	0.190	3.300	0.0005	0.0288	305	16	191	0.166
	Mean	0.370	3.537	0.0005	0.0323	306	17	192	0.167
	Median	0.370	3.480	0.0005	0.0330	306	17	192	0.167
	80th %ile	0.550	3.762	0.0005	0.0360	307	17	192	0.167
	95th %ile	0.640	3.903	0.0005	0.0375	308	17	192	0.167
	Max	0.670	3.950	0.0005	0.0380	308	17	192	0.167
MRMB36 31/07/2012 - 27/02/2020	Count	71	71	71	71	71	71	71	71
	Min	0.025	0.006	0.0005	0.0025	217	5	139	0.003
	5th %ile	0.025	0.034	0.0005	0.0025	234	8	157	0.004
	20th %ile	0.025	0.056	0.0005	0.0060	257	9	167	0.006
	Mean	0.188	0.147	0.0010	0.0134	309	10	179	0.008
	Median	0.060	0.069	0.0005	0.0080	278	9	176	0.008
	80th %ile	0.090	0.095	0.0005	0.0220	302	11	191	0.010
	95th %ile	0.350	0.669	0.0040	0.0360	446	12	217	0.014
	Max	3.050	1.750	0.0080	0.0660	1670	13	226	0.021

Sample Point	Statistic	pH	EC (µS/cm)	Cyanide Total (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Sulphate (mg/L)	Alk Tot as CaCO3 (mg/L)	SO4/Cl (M/M)	Fluoride (mg/L)	Nitrate as N (mg/L)	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)
MRMB76 28/02/2019 - 27/02/2020	Count	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Min	6.7	1634	0.002	147	187	135	560	0.26	0.7	0.005	0.005	0.0210	0.025	0.00005	0.0005	0.0005
	5th %ile	6.7	1651	0.002	148	187	137	560	0.26	0.7	0.005	0.005	0.0222	0.025	0.00005	0.0005	0.0005
	20th %ile	6.9	1702	0.002	151	188	141	562	0.27	0.7	0.005	0.005	0.0258	0.025	0.00005	0.0005	0.0005
	Mean	6.9	1726	0.002	155	191	151	576	0.29	0.7	0.005	0.005	0.0318	0.025	0.00005	0.0005	0.0005
	Median	7.0	1732	0.002	156	192	153	570	0.29	0.7	0.005	0.005	0.0300	0.025	0.00005	0.0005	0.0005
	80th %ile	7.0	1763	0.002	158	194	162	587	0.31	0.7	0.005	0.005	0.0370	0.025	0.00005	0.0005	0.0005
	95th %ile	7.1	1782	0.002	160	195	163	598	0.32	0.7	0.005	0.005	0.0438	0.025	0.00005	0.0005	0.0005
	Max	7.1	1789	0.002	160	195	164	602	0.32	0.7	0.005	0.005	0.0460	0.025	0.00005	0.0005	0.0005
MRMB75 16/08/2017 - 20/02/2019	Count	8	8	8	8	8	8	8	8	7	8	8	8	8	8	8	8
	Min	6.3	9240	0.002	1320	3130	727	331	0.08	2.3	0.005	0.005	0.0005	0.050	0.00005	0.0005	0.0005
	5th %ile	6.3	9275	0.002	1327	3179	734	332	0.08	2.3	0.005	0.005	0.0010	0.050	0.00005	0.0005	0.0005
	20th %ile	6.4	9448	0.002	1344	3282	751	334	0.08	2.3	0.005	0.005	0.0020	0.054	0.00005	0.0005	0.0005
	Mean	6.7	10000	0.003	1383	3365	762	343	0.08	2.5	0.005	0.006	0.0036	0.060	0.00005	0.0005	0.0009
	Median	6.8	10240	0.002	1380	3405	764	338	0.08	2.4	0.005	0.005	0.0035	0.060	0.00005	0.0005	0.0005
	80th %ile	6.9	10416	0.004	1428	3456	773	354	0.09	2.5	0.005	0.005	0.0050	0.066	0.00005	0.0005	0.0016
	95th %ile	7.0	10486	0.006	1440	3500	788	357	0.09	3.0	0.005	0.008	0.0063	0.070	0.00005	0.0005	0.0020
	Max	7.0	10510	0.007	1440	3510	793	358	0.09	3.2	0.005	0.010	0.0070	0.070	0.00005	0.0005	0.0020
MRMB59 28/06/2016 - 03/07/2018	Count	6	6	6	6	6	7	6	6	6	6	6	7	6	8	6	7
	Min	6.6	5280	0.002	865	927	770	847	0.24	0.9	0.005	0.005	0.0280	0.100	0.00005	0.0005	0.0005
	5th %ile	6.6	5348	0.002	870	941	775	850	0.25	0.9	0.005	0.005	0.0295	0.100	0.00010	0.0005	0.0005
	20th %ile	6.6	5550	0.002	885	981	793	857	0.26	1.0	0.005	0.005	0.0330	0.100	0.00024	0.0005	0.0005
	Mean	6.8	5668	0.005	912	1090	841	886	0.29	1.2	0.030	0.005	0.0674	0.110	0.00037	0.0005	0.0011
	Median	6.8	5640	0.002	911	1080	840	870	0.30	1.1	0.015	0.005	0.0600	0.110	0.00035	0.0005	0.0010
	80th %ile	7.0	5790	0.007	949	1100	887	919	0.31	1.3	0.030	0.005	0.0868	0.110	0.00046	0.0005	0.0018
	95th %ile	7.2	6030	0.015	951	1303	904	946	0.31	1.5	0.090	0.005	0.1396	0.125	0.00070	0.0005	0.0020
	Max	7.2	6110	0.017	952	1370	909	955	0.31	1.6	0.110	0.005	0.1600	0.130	0.00080	0.0005	0.0020

Sample Point	Statistic	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Lead Dissolved (mg/L)	Zinc Dissolved (mg/L)	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Molybdenum Dissolved (mg/L)
MRMB76 28/02/2019 - 27/02/2020	Count	4	4	4	4	4	4	4	4
	Min	0.025	0.374	0.0005	0.0025	139	4	59	0.004
	5th %ile	0.025	0.384	0.0005	0.0025	140	4	60	0.004
	20th %ile	0.025	0.415	0.0005	0.0025	143	4	63	0.004
	Mean	0.025	0.444	0.0005	0.0098	148	5	65	0.006
	Median	0.025	0.449	0.0005	0.0048	148	5	67	0.005
	80th %ile	0.025	0.476	0.0005	0.0150	153	5	68	0.008
	95th %ile	0.025	0.498	0.0005	0.0240	156	5	68	0.010
	Max	0.025	0.505	0.0005	0.0270	157	5	68	0.011
MRMB75 16/08/2017 - 20/02/2019	Count	8	8	8	8	8	8	8	8
	Min	1.940	0.439	0.0005	0.0025	431	8	274	0.001
	5th %ile	2.353	0.443	0.0005	0.0025	434	9	280	0.001
	20th %ile	3.316	0.453	0.0005	0.0025	444	10	294	0.001
	Mean	3.725	0.466	0.0005	0.0034	466	10	300	0.001
	Median	3.890	0.467	0.0005	0.0025	462	10	301	0.001
	80th %ile	4.036	0.478	0.0005	0.0025	484	10	309	0.001
	95th %ile	4.860	0.492	0.0005	0.0074	511	11	316	0.001
	Max	5.290	0.497	0.0005	0.0100	522	11	317	0.001
MRMB59 28/06/2016 - 03/07/2018	Count	7	7	7	8	6	6	6	6
	Min	0.140	1.130	0.0005	0.0080	176	20	127	0.026
	5th %ile	0.191	1.214	0.0007	0.0122	177	20	128	0.027
	20th %ile	0.354	1.706	0.0010	0.0200	181	20	130	0.028
	Mean	1.453	3.383	0.0022	0.0281	329	21	142	0.032
	Median	0.820	3.620	0.0010	0.0260	194	21	134	0.030
	80th %ile	1.956	4.476	0.0036	0.0372	305	22	138	0.035
	95th %ile	4.029	5.471	0.0054	0.0478	772	22	176	0.042
	Max	4.860	5.870	0.0060	0.0520	927	22	189	0.044